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Final WINNER II System Requirements

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Abstract:

This document summarizes the Final WINNER II System Requirements. Starting from the user-oriented service requirements, lower-layer performance requirements are derived. The system capabilities and terminal requirements are addressed. The spectrum technologies targeted by WINNER are then characterized. Furthermore, an illustration of the dependency of lower-layer requirements on the higher-layer requirements is given.

Keyword list:

WINNER requirements, services, system capabilities, radio interface, performance, terminal, spectrum, regulation.

Disclaimer:

Executive Summary

This document provides the final set of WINNER system requirements which have been partly derived from previous requirements described in earlier documents [WIN2D6111] [WIN1D71], and newly identified and formulated, considering the latest advancements within the project, as well as developments in research, regulation, standardisation, wireless market, and industry. The focus is on system requirements with impact on the development of a new radio interface concept and design, which is the primary goal of WINNER.

The set of requirements defined in this document take their user-centric origin in the service requirements. First, a set of service classes together with target performance figures is defined which should be supported by the WINNER system. Exemplary services in the real-time domain (virtual reality and VoIP) which motivate specific requirements are further characterised. Broadcast and multicast support, as well as emergency call services, are then covered. Finally, requirements and recommendations for service provisioning (e.g., physical context information) are given.

The system capabilities requirements focus largely on the mobility support, i.e., handover within WINNER, between different WINNER deployments, and with legacy systems. This is an essential feature of the ubiquitous mobile communication system, and the cooperation with legacy systems sets the path for migration towards WINNER. The corresponding measurements which are necessary for these network functions are described. Furthermore, requirements on QoS mechanisms and prioritisation are addressed. Regarding security and privacy protection, recommendations are given. For location based services, the requirements on location determination accuracy are determined by critical applications like emergency calls.

Given the broad scope of the WINNER system, it is clear that in the terminal requirements chapter, the re-configurability and adaptability of the network to a wide range of terminals plays a prominent role. Furthermore, requirements on maximum transmit power, reduction of power consumption, and antenna configuration are given.

The key requirements for the WINNER RAN address the lower-layer system performance. Here, a separation is made between the theoretically achievable performance values (e.g., in the form of peak data rates and achievable delay) which characterize the fundamental performance limits due to system design, and the achievable performance under realistic conditions and following some satisfied user criteria. The spectral efficiency requirements address the latter case. The satisfied user criterion of WINNER phase II is defined as 95% of the users having an average active session throughput greater or equal than 2 Mbit/s.

Spectrum is a scarce resource and recent developments in regulation make it even more important for WINNER to provide solutions for different spectrum scenarios, including limited bandwidth and fragmented spectrum. Therefore the corresponding spectrum requirements have been further elaborated regarding, e.g., spectrum sharing between WINNER cell layers, WINNER RANS and with other systems. Also requirements considering the cooperation with legacy RATS, between WINNER RATS, and WINNER modes have been reviewed accordingly.

This document provides a framework for the challenging goals of WINNER, in particular to ensure that WINNER will support all service classes identified in the project, including interactive ultra high multimedia services, i.e., services which require concurrently high data rates (up to 50Mbps) and low delays (less than 20ms-100ms). Therefore, while 2G wireless systems provided support for voice services, and 3G added support for basic multimedia, the ambition of WINNER is to provide the technical solutions to support advanced applications such as virtual reality over wireless.

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List of Acronyms and Abbreviations

3G	3rd Generation (Cellular System)
3GPP	3G Partnership Program
ACS	Admission Control Server
ADC	Analog-Digital Converter
AGC	Automatic Gain Controller
AN	Ambient Networks Integrated Project
AoA	Angle of Arrival
AP	Access Point
ARQ	Automatic Repeat Request
BAN	Body Area Network
BER	Bit Error Rate
BLER	Block Error Rate
BSIC	Base Station Identity Code
DDB	Download Data Burst
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
FDD	Frequency Division Duplex
FSU	Flexible Spectrum Use
FTP	File Transfer Protocol
GoP	Group of Pictures
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
HO	Handover
HSDPA	High-Speed Downlink Packet Access
IMHO	Intra Mobile Handover
ICNIRP	International Commission on Non-Ionising Radio Protection
IP	Internet Protocol
ISHO	Inter System Handover
ITU	International Telecommunications Union
KPI	Key Parameters Indicators
LA	Local Area
LTE	Long Term Evolution
MA	Metropolitan Area
MBMS	Multimedia Broadcast Multicast Service
MIMO	Multiple Input Multiple Output
MTU	Maximum Transmit Unit
NLoS	Near Line of Sight or Non Line of Sight
PAN	Personal Area Network

PHY	Physical Layer
QoS	Quality of Service
RAN	Radio Access Network
RAP	Radio Access Point
RAT	Radio Access Technology
RN	Relay Node
RRM	Radio Resource Management
RSS	or Received Signal Strength
RT	Real Time
SAR	Specific Absorption Rate
SI	International System of Units
SIB	System Information Block
SRRM	Serving Radio Resource Management
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TDoA	Time Difference of Arrival
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access
ToA	Time of Arrival
UMTS	Universal Mobile Telecommunications System
UT	User Terminal
WA	Wide Area

Table of Contents

1 Introduction

This document captures the essential characteristics describing the concept, applications and technology of WINNER as a new ubiquitous radio access network, and translates them into a set of system requirements. These requirements are based on both the outcome of the research performed during the project and the latest developments in the wireless market and industry.

The goal of this document is to provide a framework for the challenges of WINNER, in particular to ensure that WINNER will support all service classes including interactive ultra high multimedia services, i.e., services which require concurrently high data rates (up to 50 Mbps) and low delays (less than 20 ms – 100 ms). Therefore, while 2G wireless system provided support for voice services, and 3G added support for basic multimedia, the ambition for WINNER is to provide the technical solutions to support highly demanding services like virtual reality over wireless.

A significant attribute of WINNER is the user-centric approach that was followed from the beginning of the project. The identification of the main system features was performed by an iterative methodology based on the aggregation of as many as possible needs and demands of the current and futuristic wireless services users, which have also been grouped into user types according to their activities in terms of service usage. This has been the basis of the formation of an extensive number of scenarios that were targeting both contemporary and future applications. This process was followed by further application grouping, in terms of common technical requirements and thus generic applications and service classes were created.

However, while the design of the WINNER concept is based on user demands and services, the key requirements of the WINNER RAN affect the lower layers which are the subject of the research within the project. Service requirements can ultimately only be fulfilled if subordinate requirements on the system capabilities, the terminal characteristics, the lower layers' performance and on spectrum technologies are met. From a system engineering point of view, the hard and quantitative lower-layer requirements, e.g., regarding spectral efficiency or delay, are the most challenging ones and will also serve as a foundation for comparison with other systems.

The description of the requirements in this document adopts a top-down approach based on the user and services perspective. Within WINNER, these higher-layer requirements have been elaborated into assessment criteria that include detailed definitions suitable for evaluation by the available simulation tools.

This refinement of assessment criteria definitions has been inspired by related definition in standardisation, in order to align with existing definitions and facilitate comparisons. Additionally these definitions have been adapted to ensure consistency throughout the set of WINNER requirements and stress even more the user-centric approach. E.g., the updated spectral efficiency requirements include a definition of an associated satisfied user criterion under which the spectral efficiency has to be measured. This satisfied user criterion is consistent with the required data rates of most WINNER service classes. With respect to a definition used in phase I evaluations, the satisfied user criterion is considerably more stringent: 95% of the users must receive an average active session throughput of 2 Mbit/s or more.

This document finalises the WINNER system requirements that have been partly updated from earlier versions of the requirements set, and also some new elements that must be provided for a complete overall description of the requirements for the envisioned WINNER system. Whenever possible, the requirements descriptions will provide links to the description of the respective service classes and applications, so as to highlight the work performed in early stages of the WINNER project and to emphasise the user-centric approach.

Following the structuring motivated above, Chapter 2 provides the user-motivated service requirements. In Chapter 3, the requirements on system capabilities are described, while Chapter 4 contains requirements on the user terminals. The core performance requirements, derived from the service characteristics, are presented in Chapter 5. Requirements on spectrum technologies then follow in Chapter 6.

Last but not least, the deliverable provides and overview of requirements by presenting a list of them in Chapter 7. Furthermore the listed requirements are grouped and mapped based on the layer they address.

The Appendix contains some additional recommendations that might affect the overall system design but are out of scope for WINNER, e.g., EMF exposure aspects.

2 Service Requirements

In this chapter, an overview of the RAN-related target performance figures of all relevant WINNER service classes [WIN2D6112] is provided. Subsequently, some services which have particular impact on system design are discussed in dedicated sections, like services related to physical context (e.g., location-based services), real time applications, virtual reality, voice over IP (VoIP), multicast, and broadcast. The service requirements follow a high-level description. The performance requirements associated and derived from the service requirements then follow in a later chapter.

2.1 Service Classes

The WINNER system concept and its associated technologies shall allow a cost-efficient baseline deployment, to provide at least minimum requirements for some basic services and to meet minimum regulatory requirements. However, some of the envisioned services in Table 2.1, go beyond a basic functionality. The table represents a list of services classes targeted by the WINNER platform. It also indicates a mapping between these classes and typical applications falling in the scope of the respective classes.

Table 2.1: Service classes and associated applications

Service Class	Applications
1. Real Time Collaboration and Gaming	Telepresence – Videoconference – Collaborative Work – Navigation Systems – Real Time Gaming
2. Geographic Real Time Datacast	Real Time Video Streaming – Collaborative Work
3. Short Control Messages & Signalling	Alarms – Remote Control – Sensors – Presence Driven Transfer (Lightweight Content)
4. Simple Interactive Applications	Presence Driven Transfer (heavy content) – Interactive Geographical Maps (remote processing)
5. Interactive High Quality Multimedia	Rich Data Call – Control – Video Broadcasting / Streaming
6. Geographic Interactive Multimedia Broadcast	Video Broadcasting – Streaming Localized Map Download
7. Interactive Ultra High Quality Multimedia	High Quality Video Conference – Collaborative Work
8. Simple Telephony & Messaging	Voice Telephony – Instant Messaging – Lightweight Multiplayer Games
9. Data & Media Telephony	Audio Streaming – Video Telephony (Medium Quality) – Multiplayer Games (High Quality)
10. Geographic Datacast	Localized Datacast / Beacons – Audio Streaming
11. Rich Data & Media Telephony	High Quality Video Telephony – Collaborative Work – Standard Data Call
12. LAN Access & File Services	Access to Databases – Filesystems
13. Multimedia Messaging	Messaging (Data / Voice / Media) – Web Browsing (lightweight)
14. Lightweight Browsing	Messaging (Data / Voice / Media) (medium weight) - Access to Corporate Database – Audio on Demand – Web Browsing – Internet Radio
15. File Exchange	Access To Databases (heavy weight) – Filesystems – Video Download / Upload – Peer-to-peer File Sharing
16. Video Streaming	Video Streaming (normal)
17. High Quality Video Streaming	Video Streaming (archival)
18. Large Files Exchange	

2.1.1 Target Performance Figures

Table 2.2 lists for each service class typical target data rates, end-to-end delays, and bit error rates. These values have been derived from a user perspective and describe the desired performance at application layer. Because the higher-layer functions influencing these performance figures are out of scope for the definition of a radio access network, these values can only be regarded as guidelines for the derivation of requirements on lower layers.

Table 2.2: Service classes, data and error rates, interactivity levels

Service Class	Data Rate	Delay (Interactivity)	Bit Error Rate
1. Real Time Collaboration and Gaming	1 – 20Mbps	highly interactive (<20ms)	$10^{-6} – 10^{-9}$
2. Geographic Real Time Datacast	2 – 5 Mbps	highly interactive (<20ms)	10^{-6}
3. Short Control Messages & Signalling	8 – 64Kbps	interactive / control (20 – 100 ms)	10^{-9}
4. Simple Interactive Applications	64 – 512Kbps	interactive / control (20 – 100 ms)	10^{-6}
5. Interactive High Quality Multimedia	2 – 5Mbps	interactive / control (20 – 100 ms)	10^{-6}
6. Geographic Interactive Multimedia Broadcast	2 – 5Mbps	interactive / control (20 – 100 ms)	10^{-6}
7. Interactive Ultra High Quality Multimedia	10 – 50Mbps	interactive / control (20 – 100 ms)	$10^{-3} – 10^{-6}$
8. Simple Telephony & Messaging	8 – 64Kbps	conversational (100 – 200ms)	$10^{-3} – 10^{-6}$
9. Data & Media Telephony	64 – 512Kbps	conversational (100 – 200ms)	$10^{-3} – 10^{-6}$
10. Geographic Datacast	64 – 512Kbps	conversational (100 – 200ms)	$10^{-3} – 10^{-6}$
11. Rich Data & Media Telephony	2 – 5Mbps	conversational (100 – 200ms)	$10^{-3} – 10^{-6}$
12. LAN Access & File Services	Up to 50Mbps	conversational (100 – 200ms)	10^{-6}
13. Multimedia Messaging	8 – 64Kbps	few seconds (> 200ms)	$10^{-6} – 10^{-9}$
14. Lightweight Browsing	64 – 512Kbps	few seconds (> 200ms)	10^{-6}
15. File Exchange	Up to 5Mbps	few seconds (> 200ms)	10^{-6}
16. Video Streaming	5Mbps	few seconds (> 200ms)	10^{-6}
17. High Quality Video Streaming	Up to 30Mbps	few seconds (> 200ms)	10^{-9}
18. Large Files Exchange	Up to 50Mbps	few seconds (> 200ms)	10^{-6}

In the following sections, some characteristic applications envisioned for the WINNER system are described in more detail with respect to their requirements on the transmission system.

2.1.2 Requirements for Real-Time Applications

WINNER will support provisioning for real-time applications. This is a direct consequence of the requirement for support the list of service classes (Section 2.1), which incorporates real time services: real time collaboration & gaming, geographical real time datacast, and the respective applications: telepresence, video conference, collaborative work, real time video streaming, navigation systems, real-time gaming.

R1: The WINNER system shall provide the appropriate QoS guarantees to sustain the real-time applications listed in Table 2.1.

For details on generalised QoS support within WINNER, see Section 3.4.

2.1.3 Virtual Reality

Virtual reality is an environment simulated by a computer through integration of multiple sensorial perceptions. By transmitting 3D images and sound, it becomes possible to create a virtual space reproducing a sense as if the person is actually located at a real place. Applications based on virtual reality are manifold, spanning from advanced gaming, to enhancement of communication, like telepresence, videoconferencing, etc.

Related to the air interface, it is important to note that virtual reality includes a combination of high-end video and audio with ultra-fast response times for controlling the virtual reality based on user interaction. It can therefore be classified as a high-end service within the class of interactive ultra high multimedia services, and supporting virtual reality is a major challenge due to the combination of high data rates and short delay times tolerated. Furthermore it is expected that the amount of data to be transferred, i.e., the packet sizes, are highly variable: They might span from ultra large size during a set-up or complete update of the virtual reality data to very small packet calls just requesting updates of the user and sensor status, or transmitting status, tracking, or manipulation information on the uplink. A high asymmetry of the amount of data in the two link direction further adds to the problem.

Therefore, supporting virtual reality services constitutes the utmost challenge to the WINNER air interface and is therefore adopted as a cornerstone in the requirements.

While 2G wireless cellular systems support voice, 3G includes additional support for multimedia services. WINNER, however, has the ambition to enhance supported data rates and delay requirements even more and therefore will be able to support mobile virtual reality applications.

R2: WINNER shall support the QoS requirements for interactive ultra high data rate, low delay multimedia services.

2.1.4 Voice over IP

As an example of real-time applications, the voice over IP (VoIP) service has obtained considerable publicity in research, and standardisation, e.g., for HSDPA and LTE. Internet VoIP applications (e.g., SKYPE) are being used increasingly. For WINNER, supporting VoIP is indispensable in order to realise a fully packet-oriented air interface since voice telephony will continue to be one of the most important mobile services. Furthermore VoIP offers the opportunity to integrate voice services closely with other concurrent services in a multi-flow transmission for one user. Voice services are summarised in the WINNER service classes 8 and 9, depending whether or not multimedia content is associated to voice, see Section 2.1.

During talk spurts, in regular intervals (normally every 20 ms or 30 ms) a voice packet in the order of 300 bits is generated. Moreover, many VoIP users need to be supported in parallel, which means that efficient addressing and careful design of connection states is mandatory to efficiently support this service. This is a particular challenge to be considered in the air interface design. LTE currently targets to hold up to 200 users in a connection state that would support VoIP.

R3: A WINNER site shall support a large number of parallel VoIP users.

2.1.5 Broadcast and Multicast Support

In communication networks, broadcast is a unidirectional point-to-multipoint service in which data is transmitted from a single source point to all users in a certain geographical area or multiple areas. Broadcast transmissions are unacknowledged. Acknowledgement of broadcast transmissions may be required by specific applications but this is not within the scope of this service.

Multicast allows the unidirectional point-to-multipoint transmission of data from a single source point to a subgroup of users in a certain geographical area or multiple areas. The user should be able to select and/or join different multicast services and groups. The operator should have admission control for each service in order to be able to provide a particular service for closed groups only, such as companies.

The time-aligned distribution of data to a group of users includes a wide range of applications: localised area information, news, advertisement, software updates, server and database synchronisation, cell broadcast, etc. From a technical point of view, broadcasting typically works without any CQI (Channel Quality Information) in the transmitter and contains push services without user interaction. CQI knowledge can be feasible for multicast, however, link adaptation and spatial processing needs to consider the constraints set by the whole group and cannot be tailored to a particular user.

2.1.5.1 Broadcast / Multicast Applications

In Table 2.3, some applications that can be offered within the broadcast / multicast (BM) environment are presented. These applications are also mapped to the WINNER service classes that can be found in Section 2.1 and in [WIN2D6111][WIN2D6112].

Table 2.3: Example of broadcast and multicast applications

Application	Media type	Broadcast / Multicast	Service class
Emergency services	Text, Voice	B	Multimedia messaging; geographic interactive multimedia broadcast
Local news	Text, Audio	M	Lightweight browsing
Weather report	Text, Static images	M	Geographic datacast
Traffic information	Audio, Static images, Low quality video	M	Geographic real time datacast
Tourist information	Text, Audio, Low quality video	M	Geographic datacast
Audio, average quality	Audio (stereo)	BM	Data and media telephony
Audio CD quality	Audio (stereo)	BM	Data and media telephony
Video	Video	BM	Video streaming

Another possible BM application is software updates, which can be illustrated by the following example (see Figure 2-1): The terminal manufacturer develops a security update for its X series terminals. The network operator is notified and the software update is scheduled during a quiet network period. The update is multicast to the users during the night. The network operator also requests the acknowledgement of users that have received and installed successfully the updates. These users are then removed from the multicast group.

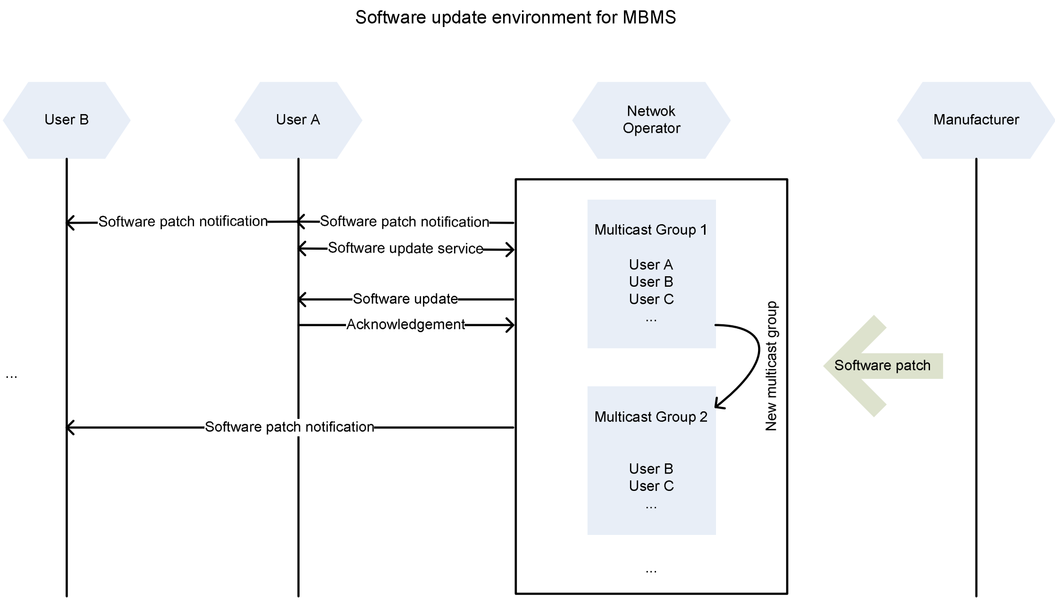


Figure 2-1: Software update message sequence chart

2.1.5.2 BM Recommendations and Requirements

Most of the following recommendations are based on [BBD14].

- Services should be delivered with the required/agreed QoS level and user should be able to subscribe to the most appropriate QoS level for a single BM service.
- The subscriber should be able to define service preference for reception with a priority procedure during simultaneous/concurrent BM services.
- Services should fetch in the network for the user settings (user's profile).
- The BM service architecture should enable the efficient usage of radio network and core-network resources, with the main focus on the radio interface efficiency, so the service architecture should reuse the existing network components and protocol elements thus, minimizing necessary changes to existing infrastructure and service notifications should maximise the reuse of existing channels.
- BM service centre should be considered in WINNER architecture.

R4: WINNER shall support efficient and reliable multicasting and broadcasting.

R5: It shall be possible for a terminal to receive concurrently multicast / broadcast services and other services.

2.1.6 Background Services

In current and future networks, apart from the signalling messages, there are applications running in the background and may influence the "behaviour" of foreground applications (e.g., if there is a "service discovery" running in the background, the way that services are presented to user depends on the ones that were found). Depending on the nature of each background service, user may access and interact with these services (e.g., e-mail download) or be blocked to do so (e.g., software/firmware service update).

The background services have bursty data (in general) and do not require permanent allocation of resources. These services have the lowest priority in any QoS classification, thus background applications only use the transmission resources when interactive applications do not need them. In fact there are no reserved resources for background applications. For this reason, the destination is not expecting the data within a certain time.

In this class of services, the scheduling is very important because it is used to exploit service burstiness to accommodate more users and maximise resources utilisation.

Background services are, at principle, relatively insensitive to delay. The transmission/retransmission of packets should be transparent (i.e., with zero error rate). For this reason background services are also used in machine-to-machine communications, which are not delay sensitive.

Examples of background applications are: SMS, e-mail, telnet, FTP and news.

R6: WINNER shall handle background services in an efficient way, exploiting the burstiness of transmitted data to accommodate a large number of users.

2.1.7 Support for Emergency Services

Mobile communications can be very useful in times of emergency mainly because of the potentially high penetration of user terminals, and their mobility: cellular phones are cheap, so almost everyone has one, and because of its dimensions, people can carry cellular phones in their pockets. However, there are some aspects that have been proven critical in the use of mobile phones in this kind of situations, namely the limited connectivity when the network is overloaded, which happens very often in emergency situations. Cases like having too many users for limited resources (e.g., in the surroundings the BS were destroyed) are common situations and sometimes the terminal may not have enough power to reach the nearest BS or relay node.

WINNER is not a design target to replace professional mobile radio systems which are used by emergency authorities (fire-fighters, police, ambulances, etc.). Professional systems like TETRA provide an extremely high coverage and reliabilities that are needed for emergency situations and may not be offered by WINNER in all situations.

R7: The WINNER System shall aim at achieving user emergency call requirements.

2.1.7.1 Applications in Emergency Situations

The Mobile IT Forum proposed a table with typical applications usage in emergency situations [MITF]. This table is presented here (Table 2.4) and updated according to WINNER's services [WIN2D6112].

Table 2.4: Typical used applications for disaster and emergency cases and estimated bandwidth required for each application when used in ambulance, etc.

Application	Data rate	Disaster prevention operation	Emergency situation
Chat	8 – 64 kbps	X	X
E-mail	8 – 64 kbps	X	X
Web browsing	64 – 512 kbps	X	X
Location Information	8 – 64 kbps	X	X
IP telephony	64 – 512 kbps	X	X
IP camera	64 – 512 kbps	X	X
IP video conference	1 – 20 Mbps	(X)	X
IP broadcast	2 – 5 Mbps	–	X
Medical information	8 – 64 kbps	–	X

2.1.7.2 Emergency Call Number and Initiation

In European Union the emergency call number is 112, in United States of America and Canada this number is 911 and in Japan it is 110.

In the 3GPP2 a "global emergency call" function [MITF] – which does not depend on the telephone number – is defined, because there are different numbers used for emergency calls per country. The connections to the emergency service authorities can be handled preferentially by linking the individual telephone numbers of emergency service authorities with the general emergency call function in the mobile system. In addition, the local emergency call numbers can be coded into the phone.

It is essential that in the WINNER system, users will be able to initiate emergency calls worldwide without knowledge of the local emergency number.

In future networks, as nowadays, the emergency calls must be prioritised and the users shall be able to perform those calls even if congestion occurs. The emergency calls should have the ability to override any service in order to complete the call. Emergency calls should be free of charge from any telephone, including public pay telephones.

When an emergency call is performed, a location service shall also be performed, finding from where the call is originated.

2.1.7.3 Transmission of Medical Data

Emergency lifesaving treatments need to be provided properly and early as possible. The requirements imposed on emergency medical systems are the realisation of "medical control" and "proper conveyance".

Currently the communications between ambulances and hospitals are based on voice communications over emergency radio channels or cellular phones. Professional Mobile Radio solutions sometimes offer only a limited data rate for data channels. In these cases, the WINNER system might be used for the transmission of high-resolution images and monitoring of body data, like temperature, blood pressure, etc. Hence, it would be possible to increase life-saving rate. Doctors may give adequate instructions concerning the required treatments and prepare adequately the hospital to receive the patient.

To provide proper treatment when there are serious injuries or during a transport of patients under critical situation to the hospitals, it is very important to confirm the identity and check their medical history. To obtain this, a wide-area electronic patient chart system can be used (inside moving ambulances or in hospitals) [MITF]. In this situation, the mobile networks should automatically switch over to the internal hospital's local area wireless network from the vehicle's information network once the emergency vehicles arrive to the hospital. Here, speed and security are the requirements.

Telemedicine has a great future, in the scope of sharing experiences of surgical operations to provide operations of higher quality or promote operations in remote areas can be implemented, without the need of the patients to move to a central hospital.

2.1.7.4 Large-Scale Disasters

Cellular mobile systems become predictably overloaded in regions that suffer natural/human large-scale disasters. Small data transmitters such as pagers can work as limited alternatives.

However, in this kind of situations it is very important to provide anyone the opportunity to contact their families and friends, or to be connected to a central disaster management entity. These communications can help saving lives, because authorities or individual people outside the disaster can give helpful information such as instructions on how to escape danger. The "I am alive" (or IAA communication) function can also be extremely important, and shall be prioritised.

To promptly and adequately implement countermeasures in events of large-scale disasters, it is indispensable to collect and transmit a wide variety of information. This way, the network should handle the transmission of information, not only via voice but also using a wider variety of applications, with the aim to create an advanced information/communication system to users.

The information that should be transmitted in disaster situations depends on the intended audience: emergency service workers would want to access to both detailed forms of static information, such as building plants or technical data about building structures, and dynamic data, such has the location of people, the status of fire, data provided by personal status devices (e.g., location), data provided by sensors (e.g., heat, smoke, water, movement), etc. People lost in the forest, mountains etc., or trapped in large buildings, industrial structures like refineries, power plants, oil fields, etc., would want instant information about escape routes, emergency procedures, neighbourhood layout, etc. [Groe06]

Although these data and information sources must be authenticated and managed to ensure that materials are relevant and updated. Some of this information is sensible and violates the common norms of what is inappropriate to share, such as office layouts.

Emergencies situations have demanding requirements, especially when visibility is poor, hands are busy, or when stress and distractions provoked by the surrounding chaos create severe psychological strain. This must be taken into account when designing such emergency services.

2.2 Requirements for Service Provisioning

2.2.1 Network Reconfigurability, Content Adaptation, and Context Awareness

Services are in principle heterogeneous in nature (e.g., different contents, QoS, delay, data rates, etc.). In fact, because of the heterogeneity of the network, the same service can be provided with different parameters according to a specific location. For example, a user outside the shopping local area wireless network coverage range may still receive pop-ups from stores and advertisements, exploiting the relay nodes coverage or the RAN from other operator (multiple routing).

When the circumstances (environment and context) change, the behaviour of service or application and the network should adapt to the user's desires. In some cases it may be necessary to dynamically change, e.g., the number of users, topology and the billing platform – dynamic reconfigurability.

When travelling between different networks, ensuring the same level of QoS for a certain service may not be possible. Although, depending on the service, different QoS levels must be guaranteed (see Section 2.1.1). If the network cannot provide that level, the user shall be informed and the service cancelled.

Content adaptation consists of tailoring the multimedia services to specific transmission capabilities, according to different factors:

- Network characteristics (e.g., delay, data rates, BER).
- User terminal capabilities (e.g., memory, display size, type of codec, processor speed).
- User preferences (e.g., personalisation, interactivity with the content).
- User's actual environment (e.g., location, time).
- Content representations (e.g., syntax formats, encoded at various bit/frame rates).

In fact, the success of WINNER may rely on its: network and terminal heterogeneity. As stated before, terminal will play an important role because it will be the "service filter", according to the user's profile. In other words, user defines his profile in the terminal; the terminal shall deliver the user's profile to the service provider; and, finally, the service provider shall toiler the services to that user according to his user's profile. However, the network operator will have millions of subscribers and the network has to be capable to handle many services as users' needs.

Because of service and user personalisation, the service provisioning strictly depends on terminal characteristics, user preferences and context awareness. Therefore appropriate signalling mechanisms and service discovery technologies must be implemented in order to make sure that the right information is consumed at right place at right time by the right user.

Context awareness is not only related with location awareness, but also with the timely relevance for user, his actual activities and mobility. The GALILEO/GPS systems can provide the user location in an outdoor environment, which is important to provide services based on location-awareness, such as maps or directions to reach one place. Inside buildings, the location services may be provided by the wireless local area network, which may be important to provide, for example, information about a picture in a museum.

2.2.2 Personalisation

User personalisation refers to the way the user can configure the operational mode of his device and preselect the content of the services according to his profile [Frat]. Each user is unique thus he has exclusive needs. Therefore, in order to satisfy the user needs, a high level of personalisation has to be provided and terminals will filter the huge amount of information delivered according to the user's preferences.

In designing the system, the user-centric approach demonstrates that it is mandatory to focus attentions on the upper layers (maximum user-sensitivity), before improving or developing the lower ones. Without user friendliness, the user cannot exploit his device and personalise it.

User friendliness exemplifies and minimises the interaction between applications and user thanks to well designed and transparent mechanism that allows user and the machine to naturally interact (e.g., integration of speech interfaces); therefore, the terminal should be user-intuitive. For instance, personalised software applications may be downloaded by users, based on their personal preferences or current environments.

2.2.3 Physical Context Information

Physical context includes information such as location, speed and direction of movement. The information can be obtained by using built-in features of the radio interface or by using "external" location measurement techniques. The relevance of both techniques for WINNER is discussed with their specific advantages and disadvantages and related requirements are deduced.

The determination of the UT location by exploiting the already available internal resources of a cellular network provided by the WINNER RAN is generally based on measurements in terms of Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), and/or Received Signal Strength (RSS), processed by the network or UT. The accuracy depends on specific deployment parameters, e.g., cell size and bandwidth. The possible higher bandwidth of the WINNER compared to existing systems transfers into potentially better location accuracy. Location information could be obtained in situations where external sources are not available or do not work.

External solutions are based on external Global Navigation Satellite Systems (GNSSs) such as the available Global Positioning System (GPS) or the future European Galileo system that deliver very accurate position information for good environmental conditions. For direct Line of Sight (LoS) access to several satellites the achievable accuracy can be very high. Nevertheless, the performance loss in urban area scenarios can be dramatic due to certain limiting factors (multipath, NLoS). Therefore, the accuracy of such systems can vary between a few metres and up to hundred metres. For indoor scenarios usually no GNSS based positioning is possible due to weak satellite signals.

For WINNER, internal localisation is considered relevant because it can be applied in situations where no external localisation is available and does not require an additional satellite receiver. Although the accuracy is likely to be worse than GNSS, it may be sufficient for the most important localisation applications, (e.g., emergency calls or internal applications). The GNSS based solution is further considered as well, because of higher potential accuracy and ongoing price-reduction of receiver chipsets. This means to include specific functions in the protocols for GNSS. Even a hybrid approach is suitable depending on the UT position and the environmental conditions.

Localization classifications are differentiated as follows:

- *Network based* positioning requires measurements which are performed by the network or the BSs. No changes at the handsets are necessary; on the other side a higher traffic load due to signalling operations is generated.
- *UT based* positioning processes the measurements directly at the UT. All UTs can use the same signals from the BSs without increasing the network load. Nevertheless, computational complexity at the UT is increased.
- *UT assisted* processing combines the network based and UT based positioning. The terminal measures the available signals itself and afterwards, the measured data is retransmitted to the network. Finally, this data is post-processed in the network for location determination.

For location determination by cellular networks using WINNER RAN each of the aforementioned procedures can be used. If Global Navigation Satellite Systems (GNSS) are included, a pure network based solution is not possible because the measured satellite signals have to be pre-processed directly at the UT.

For example, location based services can be, vehicle navigation, fraud detection or automated billing. Besides for these user specific service-on-demand applications, also for system side implementations accurate knowledge about the UT position becomes desirable. Especially for location based handover, the location based vertical handover, or radio resource management that estimates of the UT location can be an input to improve the system performance. Furthermore, it is necessary that all wireless service providers have to deliver the location of all emergency callers with specified accuracy.

The requirements of the system specific applications depend mainly on the considered scenario (WA, MA, LA), especially on the cell size and the number of users in each cell. In a WA scenarios, the requirements regarding accuracy will be weak due to the large cell size and the usually uniformly distribution of the users over the cell, and hence, the handover or radio resource management can work properly for a location determination accuracy within about 100 metres. Certainly, this value should be reduced for LA scenarios with much lower cell size, increased number of users, and very high network traffic.

R8: The WINNER System will provide stand-alone location information that can be used as input for user and system-side applications, e.g., emergency services.

R9: The WINNER System will maintain compatibility with existing location information mechanisms (GPS, Galileo).

The WINNER system and UT should follow the developments in the area of prevention and warning in the case of natural disasters. Suitable functionalities, which allow high-priority multicasting in particular geographical regions, should be implemented.

2.2.4 Service Discovery

The terminal software should contain a search engine to allow the user to search for the best network services (service discovery). Alternatively, this search engine can run in the background.

While walking in streets, driving a car, or inside a shopping centre, etc. the UT maybe in the range of more than one RAP. At this point, the UT may need to discover some service information before it can make an intelligent network selection. The most critical is roaming information; while information about security policies, price/billing, RAP workload may also be useful. At minimum the UT has to know whether the RAP will offer its desired service.

2.3 Mapping of Service Requirements to RAN Requirements

As mentioned before, the service-level requirements represent the user perspective towards a mobile communication system. Because the respective protocol layers that are responsible for user interaction are out of scope for WINNER, most of these requirements can only be formulated qualitatively. Of course, there is a dependency of service-level requirements to the lower-layer requirements presented in the next chapters. This dependency is further illustrated in Section 7.2.

3 System Capabilities

The WINNER system concept will offer significantly enhanced capabilities to its stakeholders. Additionally, basic capabilities already fulfilled by legacy systems and relevant for the stakeholders have to be maintained.

3.1 System Autonomy

R10: The WINNER system shall be self-contained, allowing to target the chosen requirements without the need for inter-working with other systems.

3.2 Generalised Mobility Support within WINNER

A mobile radio system should be able to provide the user continuous connection regardless the user's location, as he is moving inside the system's network coverage from one cell to another. This mobility support is one of the key features of a mobile system. In the WINNER system, where different deployment modes will be operating together, it can support users moving from one operational mode to another or even to a different network, without losing their connection, by performing handovers. In WINNER there will be different types of handover, depending on whether the user is changing frequency, cell, mode, network etc. In order to initiate a handover there are also many types of triggers defined.

The handover process is necessary in order to provide the end user the best QoS, but sometimes involves a time-consuming amount of overhead signalling, especially when the network is congested or when there are many candidate target cells and there should be measurements performed for all the cells. The handover process should be quick enough related to the application the user is receiving, so he will not notice the handover.

In the WINNER system, a user terminal may be in the coverage area of several cells of the different WINNER modes, so the number of cells which the terminal will use to perform measurements for could be very large and cause limitations to the handover process. For the intra-mode handover the number of cells for the user terminal to measure will be lower, but the use of neighbouring cell lists could improve very much the handover process. In order to restrict the number of cells to measure, the mobile terminal can be supplied with a list of the neighbouring cells, that are the most likely to fulfil the signal strength or quality requirements at the mobile terminal location.

In the WINNER network there exists the concept of pool of gateways which means that many GWs are sharing the same pool of resources so a user moving between base stations that belong to that pool will not have to change gateways, performing only radio handovers. On the other hand, since gateways are entities that can process limited load, load balancing will be needed between GWs to avoid congestions. The load balancing between gateways will be performed by handing over users and since these users will change GW they will change IP address and this type of handover will be an IP handover. The IP handover will also take place when there is a need for inter-system handover, so the user will be then connected to a whole new network with a different IP address.

R11: The handover process shall respect and take into account the user's service requirements especially in terms of delay, so the handover will not be noticeable from the user's point of view on the application level.

R12: WINNER shall be able to provide the user terminal a list of neighbouring cells for which the terminal should perform measurements in order to improve the handover process. These cells could be operating in a different mode or in another network.

R13: WINNER shall be able to support not only radio but also IP handover for the users. Both radio and IP handovers shall be seamless and not noticeable by the end user.

3.2.1 Intra-Deployment Handover

As mentioned before, in the WINNER network there will be different deployment modes. When a user is connected to only one deployment mode and he is moving from cell to cell inside the WINNER network he is performing inter-cell intra-deployment handovers. Intra-deployment handover is the handover between Radio Access Points (BSs and RNs) operating in the same deployment mode (intra BSs, intra RNs and between RN and BSs of the same mode). This type of handover includes the intra-cell handover where the user remains in the same mode (an example, the change of frequency in the same cell) and the inter-cell handover between cells of the same mode. The basic trigger for inter-cell handover is the received signal strength (as it is already used in currently deployed systems), but also the location of the user, the load of the neighbour cells, increased interference, congestion situations etc.

R14: WINNER shall be able to support seamless intra-deployment handover of user sessions (or flows) inside the same Radio Access Point (RAP) or between different Radio Access Points of one deployment mode (either LA or MA or WA).

3.2.2 Inter-Deployment Handover

Inter-deployment handover is defined as the switching process between two cells of different WINNER operational modes. The typical WINNER scenario is expected to be the one where the cells of the different modes are overlapping either completely or partially. The triggers for inter-deployment handover are bad signal strength or signal quality, terminal location, user mobility, other physical layer based triggers and algorithm based triggers (presented in Section 3.3.2). Many other triggers can also initiate an inter-deployment handover, such as user's location, user's received service requirements (i.e., data rate), congestion in one mode, etc.

If one operator runs multiple instances of WINNER in the same geographical area operating at different PHY parameterizations, e.g., in different bands or with different duplex schemes, then, a resource management between these would be needed for terminals which can use both. The WINNER system should make effective use of both instances, e.g., by enabling dynamic routing of flows of one terminal over radio links from both instances. If a UT leaves the coverage area of one deployment (a hot-spot, for example), all flows of that UT have to be transferred to the overlay deployment. That constitutes an inter-deployment handover due to leaving the coverage area. If both deployments are available simultaneously, the possibility to select the deployment for each flow arises, and WINNER system may transfer a flow to another deployment for other reasons, e.g., load-balancing between the cells, congestion situations, etc.

R15: WINNER shall be able to route each flow individually through the available deployments. This must be done taking into account the flow's QoS requirements, the user's preferences, together with the capabilities and advantages/disadvantages of each deployment.

R16: WINNER shall support seamless handover of any individual flow between cells of different deployments.

R17: WINNER shall support resource management amongst different deployments, including handover, load balancing between base stations of different deployments that controls the load of the cells and supports handover of individual flows from one cell to another.

3.3 Generalised Mobility Support between WINNER and Legacy Networks

3.3.1 Cooperation with Legacy Systems

The WINNER network will not be a standalone network in the future. Most likely, it will operate together with other legacy or other future wireless networks in the same area. This cooperation can be done in different ways i.e., by performing inter-system handovers or by sharing spectrum. WINNER will be able to cooperate with these legacy systems in order to maximize the efficiency of the system, to serve the users with best QoS and to ease the migration from the existing systems to the WINNER system. Depending on the level of integration that is necessary, different approaches can be taken to combine different RATs. When the integration between different technologies is close, service provisioning is more efficient and the system change will be more seamless, especially with real-time flows. On the other hand, a higher level of integration means providing a greater effort in the definition of interfaces and mechanisms that are able to support the necessary exchange of data and signalling between RATs, and in general it means more network complexity. Signalling between RATs is necessary to archive required network capabilities. The cooperation of arbitrary radio and wireless systems is in the scope of the AN project. WINNER concentrates on the provision of required measurements in order to enable efficient cooperation and on the cooperation between WINNER deployments. WINNER should provide the necessary interface to enable a seamless change of radio access systems. In order to offer a good quality to the user, handover management should minimise any degradation of the provided QoS (e.g., packet loss and delay) during a handover.

R18: The WINNER system shall provide an interface that supports the cooperation with legacy systems in order to support an efficient interworking between WINNER RAT and legacy RATs. These RATs could belong to the same or different operators. This interface shall also support the seamless handover between WINNER and legacy networks.

The WINNER inter-system handover should be consistent with the inter-system handover already defined in legacy systems. In particular, the inter-system handover procedure between UMTS and another RAT is already specified by the 3GPP. Some of the specifications are applicable to any RAT while others are RAT specific (e.g., specified measurements on GSM are applicable to GSM only). Therefore, the WINNER design must fulfil all the requirements that are mentioned in the 3GPP specifications for every RAT and the 3GPP will need to do some specifications dedicated to the WINNER system.

Also, WINNER has identified intra-system handover (intra-deployment and inter-deployment). These types of handover should coexist with the inter-system handover in order to initiate an inter-system handover when the other two types cannot be executed, or are rejected.

3.3.2 Measurement Requirements for the WINNER System

Measurements are essential inputs for RRM algorithms and therefore mechanisms to configure, perform and report measurements must be defined for the WINNER system. Measurements affect the design of the WINNER PHY, MAC and RLC (or RRC) from the physical procurement of these measurements, to the transport of these measurements to the logical entities that need this information, including the definition of the protocols for the transport of this information.

R19: The WINNER system shall provide at least to the RRM (and/or cooperative RRM) entity a set of measurements for handover and other RRM functionalities.

These measurements may include:

- *Received signal strength, interference level and C/I ratio.* These must allow concluding on the reception quality of the current flows and the possibility (or the necessity) of doing a handover to other cell or radio access technology. In WINNER these measurements will be based on the UL and DL synchronization pilots (performed by terminals, base stations and the relay nodes), not only in the WINNER RAN, but also on legacy RANs, when necessary. Three different types of measurements should be available intra-frequency, inter-frequency and inter-system, the last one should be performed by the WINNER multi-system terminals.
- *Transmitted power*. This is a report of the transmitted power setting in a precise instant. Path loss measurements can also be measured as the difference between the transmitted power and the received signal strength. For WINNER, it should be performed by UT, BS and RN.
- *Quality measurements*. These must allow concluding on the quality perceived by the UT and RAN and to compare it with the required quality. So it is necessary to do some measurements based on users' flows in order to determine QoS levels and compare them with thresholds. QoS indicators could be: BLER (block error rate), retransmitted block rate or bit rate at different layers
- *Cell load*. The cell load corresponds to the amount of currently used resources in comparison with the available amount, cell load can be measured at different levels, e.g., transmitted radio power (PHY layer), or, number of used chunks (MAC user plane), etc.
- *Terminal velocity and location*. As minimum requirement the system should know to which serving BS the UT is attached. To estimate the coverage area of the serving BS, a more detailed position determination should be performed, using received signal strength measurements or satellite measurements (GPS).
- *List of neighbouring base stations and relay nodes.*

The split of measurements between the BS/RN, UT and WINNER RAN could be the following:

- BS/RN measurements:
  - Received Total Signal Strength (UL)
  - C/I (UL)
  - Synchronization and time measurements (UL): Observed time difference
  - Total Transmitted Power (DL): Total TX power compared with the total available
  - Transmitted Power per chunk (DL): Report
  - Traffic quality measurements (DL): BLER, PER
- UT measurements:
  - Intramode – intra-frequency and inter-frequency (DL): RSSI, C/I
  - Intermode – intra-frequency and inter-frequency (DL): RSSI, C/I
  - Inter-RAT (DL): RSSI, C/I
  - Rx-Tx time difference (DL/UL)
  - Quality measurements (DL): BLER, PER (transport channel)

  - Synchronization and time measurements (DL): observed time difference (ToA, TDoA, AoA)
  - Transmitted power per chunk (UL): Report
  - Traffic measurements (UL, internal measurement): total, average, variance buffer occupancy
  - Positioning measurements (UL): UT GPS or Galileo timing
- RAN measurements:
  - SLC and RS buffer load

During the inter-system handover from a legacy system to a WINNER cell, the target WINNER deployment mode and cell for the user performing the handover should be found. The selection should be based on the previous parameters that the current deployment mode or RAT and possible target deployment mode or RATs can offer to the terminal, and also other information elements will be taken into account:

- *Network capabilities*. The legacy RANs cannot support many of the services that can be offered by B3G networks, but also B3G networks with limited bandwidth can provide a limited subset of services. The information on network capabilities should be available (data rate, delay, etc)
- *Terminal capabilities*. The B3G terminals will be classified by performance (e.g., delay, data-rates, etc.). It is expected that some terminals will have limited performance to achieve reduced size, longer battery duration, lower cost, etc.
- *User preferences*. The user could select some characteristics, e.g., pre-selecting the network that will offer lower cost per transmitted bit.
- *Operator classification of users*. The operator could offer different classes of subscription, bronze, silver and premium users, with different levels of performance
- *Other high level parameters*. The architecture should be enough flexible to accommodate other information elements.

The WINNER UT, BS and RN should perform measurements, and also the mechanisms to report these measurements to the UT/RN/ACS should be established. The measurements should be triggered periodically and on demand.

3.3.2.1 Measurement of Legacy RANs

The WINNER multi-system terminal should have the possibility to measure the received signal strength of base stations/access points of legacy systems. Moreover, the RRM entity in WINNER, associated to the BS, should have the possibility to know (through signalling) to what possible cells of legacy systems to have a fast intersystem handover, when necessary. Most of the measurements described in the previous section are required not only for WINNER but also for the legacy networks.

The possible measurements and signalling parameters include:

- *Received signal strength, Interference level and C/I ratio.*
- *Transmitted power.*
- *Cell load.*
- *Terminal locations and velocities (if possible).*

These figures will be either signalled directly from the legacy network or reported to the WINNER RAN by the terminals.

3.3.2.2 Handover from WINNER to Legacy RANs

The handover from WINNER to a legacy system shall be defined in order to provide mobility support to users that are moving outside an area that has coverage by WINNER. This handover can also be initiated due to congestion in WINNER or by the user if he has a preference to be connected to a legacy network (if he does not receive a service that can only be offered via WINNER). The possibility for a terminal in WINNER to measure the received signal strength of base stations or access points of legacy systems should be foreseen when defining the WINNER system. The RRM entity in WINNER should have access to these measurements on legacy systems. Moreover the possibility to exchange load information between WINNER and legacy systems should also be anticipated (e.g., exchanged between cooperative RRM entities).

The WINNER system should broadcast information about the legacy RANs, like information about neighbouring cells (hence this requires some specific signalling within the WINNER system). Some signalling is also requested to configure and report the measurements performed on the WINNER and legacy systems. The multi-mode UT should clearly be able to detect the other RAT. Some information of the legacy systems to be supported should be carried inside the WINNER system: The RAN to which the UT is connected should send the connection information from the target RAN to the UT. Specifically, it should send an encapsulated message, specified in the other standard, including the candidate/target cell identifier(s) and the radio parameters relevant for the target radio access technology. UMTS considers two "System types": CDMA 2000 and GSM 900/1800/1900, a new type could be WINNER or LTE. Therefore, an inter-RAN information exchange between network elements of different RANs is necessary. Also, in the IST E2R project, there is a common pilot channel concept developed, whereas, one can support much faster frequency scanning.

3.3.2.3 Handover from Legacy RANs to WINNER

The handover from a legacy network to WINNER shall be supported by the WINNER system in order to provide mobility support for users that are moving outside a coverage area of the legacy network, for users that are requesting new services that can only be offered via the WINNER system, for resolving congestion situations in the legacy network, or for user's preference to the WINNER network.

Some information about the WINNER system should be broadcast in the legacy RANs, like the neighbouring WINNER cells, together with some information necessary to demodulate their signal: Some specific signalling should be added in legacy RANs. If short scanning times and efficient handover, load balance and other inter-RAN functionalities are considered desirable, there should be some inter-RAN information exchange. This concept has already proven to be viable in the current UMTS and GSM specifications. The inter-operator case will be different to the inter-RAT case, since so far there is no inter-operator interworking directly through the Radio Access, except RAN sharing. Besides, some information should be "broadcast" by the WINNER cells to allow their identification (cf. BSIC in GSM or synchronization codes in UMTS): This information should be defined so as to be quickly demodulated by terminals on legacy systems, particularly if compressed mode is used in UMTS. The time structure (or period) of this information should allow to avoid the problems related to the BSIC identification in the case of UMTS to GSM handover. WINNER should provide beacons to be measured by terminals on the legacy systems. The WINNER system should take into account the constraints related to the use of compressed mode in UMTS systems.

R20: The WINNER system concept shall provide an interface to legacy RATs that supports seamless handover to minimise degradation of communication quality and enables further cooperation mechanisms, e.g., RRM.

R21: A signalling channel to report measurements of other RANs shall be included in the WINNER concept.

R22: In order to enable measurements of other systems by a WINNER transceiver, the WINNER MAC frame design shall allow reserving time-frequency resources which are deliberately not used for transmission, but left free for measurements.

R23: A signalling channel to notify user terminals about other available RANs shall be included in the WINNER concept.

3.4 Support for QoS Mechanisms and Prioritisation of Flows

The different service classes introduced in Table 2.2 exhibit different target values of performance indicators. These targets are derived from general QoS requirements on the service level, which should be propagated through all layers of the WINNER protocol stack.

R24: Packet flows are classified by QoS requirements. QoS of each flow shall be controlled individually. QoS related to the delivery of a requested application shall be negotiable, including renegotiation during an active session.

To facilitate service-motivated QoS support mechanisms, a prioritisation of users' data flows is essential. Examples where prioritisation should be applied include:

- Services with tight delay constraints (e.g., voice and interactive multimedia services): Usually, some timestamp information is available for incoming data related to such services (for VoIP, the RTP could be used). WINNER should be able to evaluate such information, and to configure the prioritisation of the respective flows accordingly, so that the data is available at the receiver within delay bounds. On the other hand, if the timestamp indicates that the delay limit has been already exceeded, the packet can be discarded in the network without consuming radio resources. On the other hand, WINNER should be able to signal prioritisation information to external networks where its outgoing flows are routed to.

- Services with data rate constraints (e.g., real-time video streaming): Counters could be implemented at various protocol layers to ensure that the flow's data rate remains between certain limits. Activated at certain thresholds, prioritisation mechanisms may lead to a rate stabilisation even for an increasing network load.

Prioritisation mechanisms should be realised on different protocol layers

- PHY: Transmit power control, modulation and coding format for the subcarriers that carry a prioritised flow
- MAC: Prioritisation can be easily integrated in score-based resource scheduling
- RLC/RRC: Prioritisation should influence RRM mechanisms like admission control and load control

R25: WINNER shall support prioritisation of flows to facilitate QoS support. Prioritisation mechanisms shall be implemented at all necessary protocol layers.

3.5 Security/Privacy Protection

The term security lacks in meaning until the definition of what is to be secure and for whom. WINNER will have several security stakeholders for which the mobile platform must provide security services. Moreover, the potential threats may differ from stakeholder to stakeholder. There are different security aspects relevant for a radio interface. User security means safeguards to ensure that the personal data and privacy of the user and of the subscriber are protected. Network security means that the network is not harmed nor its resources are misused, thereby causing an unacceptable degradation of services.

There are three main classes concerning the stakeholders (users, operators and service providers) and what kind of security they want to find in the network as stated next [Gehr06]:

- Users expect that mobile terminal offers secure and reliable communication; this way the mobile terminal is trusted to handle sensitive tasks, such as e-commerce transactions or encrypted voice calls. The main threats to this class of stakeholders are malicious software or malware, such as viruses and worms, or weak or misbehaving security mechanisms.
- The concerns of the second stakeholder class, the mobile network operators, rely on network identification mechanisms (related with billing capability) and network-related software. Operators thus require that the integrity of software can be guaranteed when the terminal is in operation. They also want to be certain that users cannot break SIM lock mechanisms (used in 2G networks) and IMEI protection.
- The content providers want to be paid for the content that users consume (music, pictures, videos and software). They also aim to ensure that users cannot (mis)use their phones to illegally copy or re-distribute content. This is where digital rights management (DRM) functions play an important role. To provide a DRM solution that meets content provider requirements, the mobile phone platform must contain security functions that guarantee secure execution and code integrity.

The security mechanisms should exhibit the following characteristics [Gehr06]:

- "Intelligent", transparent to users and easy to use. They must be usable without difficulties to users, otherwise security may be compromised because users may be reluctant in using them.
- Security mechanisms should not interfere with or compromise QoS (at least apparently).
- Giving the responsibility to users to setup the security of their mobile terminal is, at principle, a bad idea, because inappropriate configurations may be exploited by attackers, leading into serious issues.

3.5.1 Security/Privacy Recommendations

Some of the following recommendations can also be found in [Dut04]:

- A mobile terminal can only be activated and used by an authorised user (apart from emergency calls, a valid SIM or USIM is required to access the 2G and 3G networks).
- Stolen terminals should be blocked to access to networks. Network operators can blacklist to prevent them from being used in their networks: The IMEI value can be used to bar a terminal. However, for this mechanism to be effective, users must not be able to modify IMEI value.

- Identity and integrity validation, using certificates or cryptography mechanisms, should be used not only for common tasks for human beings (e.g., user data) but also for software (e.g., software updates) [Gehr06].
- Prevention or mitigation of Denial of Service (DoS) and Distributed Denial of Service (DDoS) attacks [Swa06].
- E-commerce should be secure.
- During a handover, once the device moves from one network to another, maintaining the service level agreement may be of high importance, because there is also an agreement in security level and while the negotiation is made, an intruder may change the level.
- In general, the operator should implement security infrastructures to prevent tampering of the network and its elements. This can be done using cryptographic hash functions and electronic signatures. If possible, the network should be able to identify the tampering, give an alarm and heal automatically.
- Reconfiguration of the network should always be done in a secure way.
- Rogue BSs are a threat. To prevent this, the mobile network operator should have mechanisms that will identify such base stations and protect the users.
- Extension of network should not lead to weakness in security. Security should not compromise network extensibility. Security solutions are not limited to a place or a number of people. The security solutions should be scalable. Scalability also means that the security solution should be flexible enough to modify and fulfil the security needs as the network changes.
- If possible, the WINNER RAN shall provide security by its own. Providing security at lower layers implies security at higher layers, however standard secure communication protocols (e.g., TLS/SSL, IPsec) may also be used.
- Countermeasures against eavesdropping techniques shall be implied.

In general, the WINNER system should at least provide IMT-2000 functionality regarding security and privacy protection.

3.5.2 Other Security Aspects

Attaching/detaching securely to/from the network is a very important issue. When one first tries to attach to a network, important information is exchanged between the network and device. Normally information like username and password are communicated but besides issues to such well known items one of the major security issues for IP network is DHCP (Dynamic Host Configuration Protocol).

DHCP is used to make life of administrator easier by providing dynamic addresses to users. This obviously is the easiest way of providing IP addresses. Several security threats may arise from the use of DHCP, like man-in-the middle attacks through faked DHCP servers, incorrect configuration information or theft-of-service attack. Providing security at lower layers may reduce threats to DHCP.

For optimum performance of a security concept it is necessary that each protocol layer has the same understanding of the service and there should also be a possibility of the protocol layers to distribute tasks. It is therefore essential that the involved protocol layers communicate with each other.

Most protocols available for security and mobility require a lot of message exchange which uses valuable capacity and battery life, especially if the user is very mobile. This must not compromise QoS.

Infrastructure security means security of network, networks' elements like router, server etc. and any information available in the network. Attacking one of these elements can lead to outage of the whole network. Secure management of network elements, software deployment and timely upgrades are key issues for the infrastructure security.

However, even if dedicated security mechanisms have been implemented, security leaks can arise from factors such as careless human behaviour or software bugs.

3.6 Location-based Services Support

The WINNER system shall be able to provide physical context information for both location based user services and emergency services. Physical context information such as location, velocity and direction of movement can be obtained through external networks (i.e., GPS, Galileo) or by exploiting the available WINNER radio resources and location measurement techniques. The accuracy for location determination of the UT will depend upon the service requirements and radio environments. For the emergency situations the system shall be able to fulfil the minimum accuracy requirements for emergency situations to the public safety organisations (fire brigades, rescue teams, etc).

For this reason, the European Commission is currently considering recommendations for the implementation of an EU-wide emergency services system for emergency calls made from mobile phones, in which the location of the caller would be provided automatically by the system under the directive “Universal Service Directive 2002/22/EC”. Currently there is no common consensus on the precise value of location accuracy for E-112 emergency service. However E-112 accuracy guidelines state the location accuracy should be 50 meters or less in urban corridors/centres and this one decreases as the distance from the urban increases (i.e., not so stringent for rural areas).

The E-112 accuracy guidelines range from 50-100m for different radio environments (Urban, Suburban, Rural, Indoor and Crossroads).

The United States Federal Communications Commission (FCC) has defined the accuracy guidelines that wireless operators must comply with. These guidelines did not recognize a difference in accuracy requirements between urban, suburban, etc. locations as defined between 100m and 300m for network based systems and 50 to 150m for UT location based.

R26: Regarding LD accuracy, WINNER shall at least meet the requirements for the unified E-112 system agreed by the EU.

3.7 Power Minimisation

The transmit power at all RAPs (and certainly at the UTs, see Section 4.2) should be minimized through different mechanisms such as power control (uplink and downlink), DTX (discontinuous transmission), load control and load sharing between cells.

This is beneficial not only for the general target of energy minimisation and consequently a reduction of associated costs, but also for a reduction of intercell interference and a corresponding increase in the capacity of neighbouring cells. The traffic load between cells should be dynamically balanced trough the coordination across BSs, by adjusting dynamically the pilot cell coverage area (service area) and radio resource sharing among the neighbouring cells.

In unloaded traffic scenarios, the maximum radiated power by the RAPs should be reduced to the minimum required level provided by the link budget calculations according the service type and the maximum allowed transmit power at terminal side. This way WINNER aims to minimise the overall required power at RAPs, save energy with reduced operational costs and increase terminal battery life.

R27: WINNER shall aim at minimising transmit power at all RAPs in low cell load situations.

4 Terminal Requirements

Today, many different kinds of terminals for mobile communication systems are available. In the next generation networks, many more will exist with different sizes, shapes and functionalities. However, the mobile phone as we know it, is the most used terminal device; maybe because of its size, multimedia interface (MMI), functionalities, simplicity, etc. Due to these characteristics, in the upcoming wireless networks will be user centric enabling communications always on, anytime and anywhere. It is expected that users will pay more attention to dedicated content like news, event notifications, pop-up advertisements, etc. received on their mobile phones than on any other device. Thus next generation terminals will support multi-mode and multi-service transmission with different QoS requirements, mobility and reconfigurability.

A wide range of different applications and services implies terminal heterogeneity meaning support of different terminals in terms of display size, weight and dimensions, energy consumption, complexity, according the service area scenario etc. In contrast to future wireless networks, current wireless networks are characterised mostly by non configurable homogeneous terminals. Thus, the advantage for the costumer is to buy a device on which he has the potential to get the right presentation format for each service. The communication interface between human user and devices, if required, should be as natural as possible – like human talking or conversation, supporting audiovisual and other natural means of information exchange.

Furthermore high definition and quality video applications provided by broadcast/multicast (e.g., virtual sightseeing) will require at terminal side high performance on video processing (i.e. codecs) and display capabilities accompanied by extended autonomy and battery life.

In general, many system functionalities require the support from terminal side, including in particular the provision of the associated control measurements.

4.1 Reconfigurability and Scalability

Multi-mode user terminals are essential as they can adapt to different wireless networks by reconfiguring themselves. This way, users can access different wireless networks without the need of multiple terminals or multiple hardware in a terminal.

Furthermore, a large range of different terminals should suit the needs of different applications, use cases, and to generate manifold business opportunities for the stakeholders. Terminal classes should exist that are capable to dynamically reconfigure their software in order to use different spectrum bands or different communication schemes, i.e., download the software to use; adaptively switch the transmission; multi-mode operation, etc.

For example, the number of antennas will vary for different terminal types, i.e., a wide range of terminals ranging from low-cost single-antenna terminals to high-end multi-antenna terminals need to be supported. Since two physical layer modes of WINNER exist, namely TDD and FDD, apart from some specialised terminal classes, terminals should support both modes and for the evaluations it can be assumed that multi-mode terminals dominate in the field.

R28: WINNER shall support different terminal classes, in order to accommodate a wide range of terminals with different complexity, cost, capabilities and form factors.

4.2 Maximum Transmit Power

The peak transmit power is limited by technology constraints and radiation exposure aspects. In WINNER, the current reference design assumptions on the transmit power of the user terminal are 24 dBm for “base coverage urban” and “microcellular” scenarios whereas 21 dBm is assumed for “indoor” scenarios, [WIN2D6137].

The regulatory bodies provide regulations concerning radiation exposure limits and calculation methods for the corresponding frequency range. EIRP (effective isotropic radiated power) values have to be considered in the energy absorption calculations for comparison with the limits of SAR values presented in Section 9.1.2. Depending on the terminal type (handheld, laptop or mobile phone), service type (voice call or data session implies different typical mean holding times) and position in respect to the human body, the maximum transmit power can vary significantly. The peak transmit power is also limited by the maximum output of the PA (power amplifier) depending of the amplifier operating class, modulation scheme for the specific frequency range and link budget aspects to ensure the path balance in both directions (UL and DL). According to the EMC directives the maximum transmit power has to be limited when the systems are used close to the head especially for long time exposure periods.

R29: Maximum and average transmit power in the terminals must comply with the EMF regulations of the corresponding frequency range.

4.3 Battery and Power Consumption

Power consumption of the terminal is categorised into transmission or RF power and transceiver signal processing power. Power consumption has direct effect on battery life and thus on talk and standby times of the terminal. Talk and standby times should be at least as long as with current available terminals varying with different terminal types. This is a challenging requirement, considering that the use of higher data rates, as well as rich multimedia services (including audio, and higher resolution video) will result in considerably higher power consumption.

Nowadays, talk and standby times for cellular phones are in the range of several hundreds of minutes and several days, respectively. Furthermore, power consumption must be kept at the level that the surface temperature of the terminal does not feel too hot. Today, most batteries are based on NiMH and Li-ion technologies while in the future, solar battery, fuel cells and other power generating batteries could become available to the mass market which can increase several times the capacity of current batteries. In case of handheld type terminals, 400 hours or more for continuous standby time and 140 minutes or more for continuous talk time. In case of PDA type terminals, 60 hours or more for standby time and 50 minutes or more for continuous talk time.

The 2G terminals were shipped with one battery. Most of 3G terminals were already shipped with 2 batteries. Therefore, if this rule is followed the power consumption will increase proportionally to the more advanced services. However the next mobile wireless networks are expected to break this rule, by improving the power consumption.

For example, using multi-hop networks can permit the coverage extension to many areas, increasing the spectral efficiency of the system while minimising the power consumption [Frat].

R30: Talk and standby times shall be at least comparable to 2G and 3G systems and preferably better. Power consumption shall be minimized in order to improve battery life.

4.4 Antenna System Diversity

Antenna diversity and associated processing algorithms at terminal improve the network coverage, data rate and system capacity by increasing the received SNR values and intercell interference mitigation. Furthermore, improved data performance decreases the terminal power consumption for high data rate applications.

Antenna diversity schemes and/or multi antenna processing techniques are envisaged at terminal side with at least two receive and transmit antennas depending of the terminal type and antenna (array) size (handheld, PDA, etc.), correlation properties and propagation scenarios. Low complexity antenna system is assumed at terminal for cheap mass market devices.

However, certain terminal types may still only employ one transmit antenna due to cost and size constraints. Basic system operation, with reduced performance, shall be possible for such terminals.

R31: The WINNER system shall be able to make use of antenna diversity or multi antenna processing techniques at the terminal to improve SNR, data rates and system capacity.

R32: The WINNER system shall be able operate with basic functionality if only one transmit antenna is used at the terminal to save transmit power, complexity and cost.

5 Performance Requirements

From end-user’s point of view, performance requirements can be derived based on the supported services. Measuring the system performance has many aspects, and the measurement criteria have to be selected in a way that the “real” user experience will be reflected. The user experience may be, e.g., the time to transfer a file of a certain size, the time to download a whole web-page, the minimum response time for gaming applications, streaming services and also qualitative assessments and feelings, e.g., about the voice quality. Note that this end-users experience is regardless of the underlying transport protocol, e.g., the user doesn’t take care if it is FTP or HTTP or any other protocol.

On the other hand, the measures should not only reflect the end-user’s experience, but also measure the system performance, e.g., from operators’ point of view. For the operator, the commercial operation of a mobile radio network and the usage of spectrum bands is coupled to significant costs, thus the operator’s target is to exploit the frequency spectrum efficiently by providing a full range of services to a large number of users per radio cell, with appropriate quality of service. The resulting technical performance requirements complement the requirements motivated by the end-users experience.

This chapter focuses on the technical performance requirements of the WINNER radio access network, covering all protocol layers below IP level. The performance of higher layers elements and functions (which also influence the end-user’s experience) is out of scope of the technical work within WINNER. However, the WINNER RAN should be designed in a way at least not to prevent the fulfilment of service requirements (see Chapter 2). Therefore, certain higher-layer requirements have an influence on the lower-laver performance requirements addressed here.

5.1 Coverage

Coverage is of major concern for WINNER. Therefore coverage aspects are inherently included in various other performance figures. A simple way to include coverage aspects in performance targets in loaded network conditions that is viable for simulations is to define the target values for a definite point in the cumulative distribution function of the respective performance measure. Within WINNER the 95%-ile is used. Although no strict one-to-one mapping of the 95%-ile to coverage area is possible, it can be regarded as the target that will be exceeded in the main service area of a site, whereas the remaining 5% represent unfavourable situations, such as users in heavy shadowing at the cell edge.

In order to ensure coverage and user satisfaction, a so-called satisfied user criterion has to be adopted in the definition of certain performance requirements, like the spectral efficiency in typical, loaded conditions. The target spectral efficiency has then to be proven in an operational point that guarantees coverage and user satisfaction at the same time.

However it is necessary to keep in mind that the satisfied user criteria, and therefore the coverage, depend on the type of application. As examples, the throughput and delay figures given for the service classes in Table 2.2 might serve as individual satisfied user criteria.

5.2 Data Rates

5.2.1 Definition of User Throughput

User throughput is defined as the throughput of correctly received information bits at IP packet layer during packet calls (so-called active session throughput), for a specific link direction (uplink or downlink). The user throughput shall be measured considering all effects of packet loss and retransmissions, and taking the overhead due to guard bands, guard times, preambles, pilots, headers, and control signalling into account. Only the information bits in correctly received packets shall be counted. Packets are considered not correctly received if in error (e.g., failure of CRC check or equivalent measures) or if they arrive with excess delay compared to a service specific threshold. Impact of functions related to header compression, encryption, ciphering, and transport delays between base station and gateway shall not be considered, as these do not characterise the performance of the radio access technology itself.

5.2.2 Peak Data Rate

Peak data rate is the user throughput according to the definition in Section 5.2.1, measured in ideal transmission conditions in an otherwise unloaded system. A single user per cell is assumed, so as to describe the fundamental performance limits due to system design.

R33: A downlink Peak Data Rate of 100 Mbit/s shall be achievable in macro cell deployments due to the WINNER system design. This requirement assumes a 100 MHz system bandwidth allocation where half of the radio resources are assigned for uplink and downlink, respectively.

R34: A downlink Peak Data Rate of 1 Gbit/s shall be achievable in local area deployments due to the WINNER system design. This requirement assumes a 100 MHz system bandwidth allocation where half of the radio resources are assigned for uplink and downlink, respectively.

5.2.3 Sustainable Data Rates

Sustainable data rate offered by a system is typically defined as the average user throughput achieved over the typical period of activity of a service in a cellular environment. For that, the number of simultaneous users has to be defined which can be offered with the respective data rate under a service dependent satisfied user criterion. These figures are highly dependent on the deployment scenario, service and on the distribution of users. Assumptions include realistic load in neighbouring cells (i.e., inter-cell interference) and the distribution of resources between users in the serving cell. Instead of defining the sustainable date rate, the spectral efficiency is measured for a the maximum number of users that can be provided with a certain service fulfilling a specific satisfied user criterion (see Section 5.5).

5.3 Allowed Error Rates

As with most of the system requirements, the guarantees in terms of allowed residual error rates at application layer will also stem from the service classes table. The list of most demanding applications in terms of permissible error rates encompasses applications related to critical functions and security transactions, such as Remote Control, authentications for Remote Payment and financial transactions, etc.

In many packet-based transmissions, virtually error-free communication will be realized by means of reliable error detection and HARQ techniques, transforming transmission errors into additional delay. Therefore, no formal requirements regarding error rates are defined.

5.4 Delay

5.4.1 Definition of User Plane Packet Delay

The user plane (U-plane) packet delay is defined in terms of the one-way transit time between a packet being available at the IP layer in either the user terminal or base station and the availability of this packet at IP layer in the base station / user terminal. User plane packet delay includes delay introduced by associated protocols and control signalling assuming the user terminal is in the active state. Impact of functions related to header compression, encryption, ciphering, and transport delays between base station and gateway shall not be considered.

5.4.2 Achievable User Plane Packet Delay

The achievable user plane packet delay is the user plane packet delay as defined in Section 5.4.1 measured in ideal transmission condition in an unloaded system. Performance is to be evaluated for a single user per cell, so as to describe the performance limits due to system design. The achievable delay is defined for a single hop transmission of a minimum size IP packet.

R35: The WINNER system shall enable an achievable user plane packet delay of less than 1 ms in the downlink and 2 ms in the uplink of a single-hop transmission in unloaded conditions.

R36: The WINNER system shall enable an achievable user plane packet delay of less than 5 ms in a two-hop transmission in unloaded conditions.

These delay targets enable two more additional features that give the WINNER system unique properties:

1. Link retransmission (hybrid ARQ) can then be used also for flows from traffic classes with them most stringent delay requirements and delay jitter requirements. This results in an improved link quality, as seen from higher layers.
2. It enables channel-aware link adaptation and scheduling with respect to frequency selective fading channels, using channel quality information prediction and also feedback, at vehicular velocities. This improves performance by adaptation gains and multi-user scheduling gains and provides a unique feature of the WINNER system.

R37: The QoS framework will provide guarantees for services that require high interactivity (delay in the network level <20ms).

5.5 Spectral Efficiency

Spectral efficiency is a performance measure used in widely different contexts throughout literature, although being sensitive to a number of assumptions and parameters, including cell range, bandwidth, transmit power, sectorisation, antenna configuration, re-use factor, terminal capabilities, user mobility, number of users, and cell load. Furthermore, control overhead and real-world effects, like imperfect synchronisation, channel estimation, control signalling and link adaptation need to be considered.

Peak spectral efficiencies can be easily calculated by dividing the peak data rate that can be carried per cell (cf. Section 5.2.2) by the system bandwidth. However, these figures are purely the result of supported code rate, modulation, and spatial multiplexing. These are therefore simply upper limits supported without any indication whether and how frequently in practical deployments these values are reached. Corresponding figures can be found in [WIN1D71].

For realistic comparison of air interface performance and for support of realistic economical projections, spectral efficiency has to be measured in an operational point of the system that ensures sufficient user satisfaction. Therefore the so-called satisfied user criterion plays a crucial role for determination of spectral efficiency. In this document, the term spectral efficiency is used only with the definition including the satisfied user criterion. In other texts this is also referred to as "achievable spectral efficiency", or "average spectral efficiency". These definitions of spectral efficiency should not be confused with peak spectral efficiency.

The spectral efficiency is defined as the sum of user throughputs for all user terminals served by a certain radio cell, divided by the overall system bandwidth per link direction (uplink or downlink), calculated for the maximum load (number of users) that still allows fulfilling the satisfied user criterion of a selected service in terms of data rate and delay. Furthermore a sufficient statistic (averaging effect) is needed in order to avoid singularities and misinterpretation.

The satisfied user criterion for WINNER phase II has been motivated in [WIN2D6111]. It is defined as 95% of the users having an average active session throughput greater or equal than 2 Mbit/s.

It was decided to formulate the required spectral efficiency per cell and not per site as in [WIN2D6111]. The main motivation for this change is the fact that in most deployments, the spectral efficiency per site can be easily increased by installing more independent radio sectors per base station. Furthermore, the definition per cell is in line with most standardisation and requirement definition activities. Compared to a definition per site, the efficiency figures given below should be multiplied by the number of sectors per site, because in most deployments, each sector represents an independent radio cell.

Similarly to 3GPP [3GPP07], a cell is defined by its unique identification that is broadcast over a geographical area by a WINNER RAP. However, it is assumed that a relay note does not constitute an independent cell but adds to the capacity of its serving base station cell (this concept is also reflected in the widely used term ‘relay-enhanced cell’).

R38: WINNER shall provide spectral efficiency in connected sites of 2 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in wide area deployments in an operation point that fulfils the satisfied-user criteria.

R39: WINNER shall provide a spectral efficiency in connected sites of 3 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in metropolitan area deployments in an operation point that fulfils the satisfied-user criteria.

R40: WINNER shall provide a spectral efficiency of 10 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in isolated (non-contiguous) sites (i.e., local area) in an operation point that fulfils the satisfied-user criteria.

The above spectral efficiency figures are valid for typical WINNER deployments, i.e., a cellular deployment with a site-to-site distance of approximately 1 km and some moderate multi-antenna technology in wide area, a deployment covering the Manhattan street grid with the help of relay nodes in metropolitan area, and advanced MIMO deployment using remote radio heads in local area [WIN2D6137].

It is important to understand that a direct comparison of spectral efficiency values (e.g., between WINNER and other systems) is only possible if the same satisfied user criterion has been used. In particular, many results in research and standardisation use less challenging satisfied user criteria (or even none at all), which is the main reason for high spectral efficiency values.

5.6 Maximum Terminal Speed

The maximum user terminal speed is limited by the variability of the radio channel due to Doppler spread/shift related to the deployment scenarios and service type considered. Taking into account the wide area deployment scenarios and assumptions, the challenging speed limit is to allow reliable links to high-speed trains at velocities up to 350 km/h or even up to 500 km/h, depending on the carrier frequency band and deployment environment.

R41: WINNER shall support at least low-rate services with reduced cell capacity for terminal speeds of up to 350 km/h, or even up to 500 km/h, depending on Doppler shift related with carrier frequency band and deployment environment.

6 Spectrum Requirements

6.1 WINNER Spectrum Range

R42: The WINNER System shall be able to operate anywhere in range between 2.7-5.0 GHz, taking into account that WINNER target characteristics have to be met.

6.2 Utilisation of Bands already Available for Mobile Services

There may be situations where current mobile systems in current mobile bands need to be migrated into WINNER. Therefore the WINNER system concept needs to be able to utilise also currently available bands for cellular use (i.e., 800/900MHz, 1800/1900MHz, 2GHz and 2.6GHz frequency ranges or other frequency bands that may become available below 2.7GHz). Such a situation may arise from technical, commercial or regulatory reasons.

In this case, due to the limited bandwidth size, the foreseen highest bit rate services will not be possible and the performance of the networks might be limited.

R43: The WINNER system shall be able to utilise current bands for cellular communication.

6.3 Spectrum Fragmentation

From an implementation point of view, a channel bandwidth of 100 MHz is the currently agreed upper limit. This relatively broad channel bandwidth decreases the likelihood to achieve a sufficient spectrum assignment for a WINNER network or a number of WINNER networks in one single chunk. Available spectrum bandwidth may be fragmented due to practical geographical spectrum allocation. Indeed some of the bands are expected to be available on a global basis while some others might be available only in certain region or countries. In this case the WINNER system concept should be able to support fragmented spectrum.

R44: The WINNER system shall be able to handle fragmented spectrum assignments efficiently.

6.4 Coexistence with Other Systems

R45: The WINNER system shall be able to coexist with non-WINNER systems and to share resources with minimized mutual interference.

R46: Operation in unlicensed bands shall be possible. Performance requirements shall be met if the interference caused by other systems operating in the same band does not prevent this.

6.5 Spectrum Sharing between WINNER RANs

Significant advantages are expected, especially during the network deployment phase or if there is a severe lack of spectrum, when the spectrum can be shared between multiple parallel radio access networks (RAN) using the same WINNER RAT and providing similar services. Most of the advantages result from the enhanced spectral scalability of the system since it should allow:

- the deployment of multiple RANs at the launch of the system, even when the spectrum can be made available gradually according to increasing traffic demands,
- system flexibility towards geographical differences in regulatory spectrum assignments,
- more versatile operation of the networks, and
- adaptation of the spectrum available to a network to reflect the changes on the number of subscribers as well as on daily traffic patterns.

R47: The WINNER system shall be able to use spectrum shared between parallel network deployments (Flexible Spectrum Utilization).

6.6 Spectrum Sharing between Cell Layers of a WINNER System

Further advantages are expected, especially during the network deployment phase or if there is a severe lack of spectrum, when the spectrum can be shared between different cell types of a WINNER network.

R48: The WINNER system shall be able to use spectrum shared between different cell types, e.g., between macro cells and micro cells, or between micro cells and hotspots.

6.7 System Bandwidth

The maximum required physical data rate and other performance requirements determine the necessary system bandwidth. Due to implementation complexity and power consumption reasons, an upper bound for the maximum continuous bandwidth of one radio link is assumed. A radio link is here defined to include all physical connections in a continuous frequency range between a terminal and the radio access network. This is meant for both FDD and TDD cases.

R49: Maximum required bandwidth for one radio link is 100 MHz.

The upper bandwidth limit can be further explained by two aspects: the receiver channel selection filter / AGC integration, and ADC implementation. Regarding the filter, implementation issues arise for very high bandwidths with basic operational amplifier methods, and the power consumption of this filter starts to increase. In the ADC, the bit count (number of bits), bandwidth, and required maximum modulation order (depth) are dependent on each other: The required sampling rate is at least two times the bandwidth.

R50: The total system bandwidth needed to fulfil the requirements should be minimised.

Migration from 2G and 3G cellular systems to WINNER worldwide requires the ability to operate in the spectrum bands made available to these. Derived from this, a minimum required bandwidth is assumed for one duplex radio link. This applies to both FDD and TDD, which means that in the FDD case, this bandwidth is needed for uplink and downlink each and in total twice. Performance in the minimum bandwidth may not be the same as that possible in higher bandwidths.

R51: A minimum bandwidth of 1.25 MHz for TDD and 1.25 MHz per duplex FDD link, i.e., 1.25 MHz for uplink and 1.25 MHz for downlink, is required.

7 Overview of Requirements

7.1 List of Requirements

R1. The WINNER system shall provide the appropriate QoS guarantees to sustain the real-time applications listed in Table 2.1. *(Section 2.1.2)*

R2. WINNER shall support the QoS requirements for interactive ultra high data rate, low delay multimedia services. *(Section 2.1.3)*

R3. A WINNER site shall support a large number of parallel VoIP users. *(Section 2.1.4)*

R4. WINNER shall support efficient and reliable multicast and broadcasting. *(Section 2.1.5)*

R5. It shall be possible for a terminal to receive concurrently multicast / broadcast services and other services. *(Section 2.1.5)*

R6. WINNER shall handle background services in an efficient way, exploiting the burstiness of transmitted data to accommodate a large number of users. *(Section 2.1.6)*

R7. WINNER System shall aim at achieving user emergency call requirements. *(Section 2.1.7)*

R8. The WINNER System will provide stand-alone location information that can be used as input for user and system-side applications, e.g., emergency services. *(Section 2.2.3)*

R9. The WINNER System will maintain compatibility with existing location information mechanisms (GPS, Galileo). *(Section 2.2.3)*

R10. The WINNER system shall be self-contained, allowing to target the chosen requirements without the need for inter-working with other systems. *(Section 3.1)*

R11. The handover process shall respect and take into account the user's service requirements especially in terms of delay, so the handover will not be noticeable from the user's point of view on the application level. *(Section 3.2)*

R12. WINNER shall be able to provide the user terminal a list of neighbouring cells to which the terminal should perform measurements in order to improve the handover process. These cells could be from each mode or from another network. *(Section 3.2)*

R13. WINNER shall be able to support not only radio but also IP handover for the users. Both radio and IP handovers shall be seamless and not noticeable by the end user. *(Section 3.2)*

R14. WINNER shall be able to support seamless intra-deployment handover of user's sessions (or flows) inside the same Radio Access Point (RAP) or between different Radio Access Points of one deployment mode (either LA or MA or WA). *(Section 3.2.1)*

R15. WINNER shall be able to route each flow individually through the available deployments. This must be done taking into account the flows QoS requirements, the user's preferences, together with the capabilities and advantages/disadvantages of each deployment. *(Section 3.2.2)*

R16. WINNER shall support seamless handover of any individual flow between cells of different deployments. *(Section 3.2.2)*

R17. WINNER shall support resource management amongst different deployments, including handover, load balancing between base stations of different deployments that controls the load of the cells and supports handover of individual flows from one cell to another. *(Section 3.2.2)*

R18. The WINNER system shall provide an interface that supports the cooperation with legacy systems in order to support an efficient interworking between WINNER RAT and legacy RATs. These RATs could belong to the same or different operators. This interface shall also support the seamless handover between WINNER and legacy networks. *(Section 3.3.1)*

R19. The WINNER system shall provide at least to the RRM (and/or cooperative RRM) entity a set of measurements for handover and other RRM functionalities. *(Section 3.3.2)*

R20. The WINNER system concept shall provide an interface to legacy RATs that supports seamless handover to minimise degradation of communication quality and enables further cooperation mechanisms, e.g., RRM. *(Section 3.3.2.3)*

R21. A signalling channel to report measurements of other RANs shall be included in the WINNER concept. *(Section 3.3.2.3)*

R22. In order to enable measurements of other systems by a WINNER transceiver, the WINNER MAC frame design shall allow reserving time-frequency resources which are deliberately not used for transmission, but left free for measurements. *(Section 3.3.2.3)*

R23. A signalling channel to notify user terminals about other available RANs shall be included in the WINENR concept. *(Section 3.3.2.3)*

R24. Packet flows are classified by QoS requirements. QoS of each flow shall be controlled individually. QoS related to the delivery of a requested application shall be negotiable, including renegotiation during an active session. *(Section 3.4)*

R25. WINNER shall support prioritisation of flows to facilitate QoS support. Prioritisation mechanisms shall be implemented at all necessary protocol layers. *(Section 3.4)*

R26. Regarding LD accuracy, WINNER shall at least meet the requirements for the unified E-112 system agreed by the EU. *(Section 3.6)*

R27. WINNER shall aim at minimising transmit power at all RAPs in low cell load situations. *(Section 3.7)*

R28. WINNER shall support different terminal classes, in order to support a wide range of terminals with different complexity, cost, capabilities and form factors. *(Section 4.1)*

R29. Maximum and average transmit power in the terminals must comply with the EMC regulations of the corresponding frequency range. *(Section 4.2)*

R30. Talk and standby times shall be at least comparable to 2G and 3G systems and preferably better. Power consumption shall be minimized in order to improve battery life. *(Section 4.3)*

R31. The WINNER system shall be able to make use of antenna diversity or multi antenna processing techniques at the terminal to improve SNR, data rates and system capacity. *(Section 4.4)*

R32. The WINNER system shall be able operate with basic functionality if only one transmit antenna is used at the terminal to save transmit power, complexity and cost. *(Section 4.4)*

R33. A downlink Peak Data Rate of 100 Mbit/s shall be achievable in macro cell deployments due to the WINNER system design. This requirement assumes a 100 MHz system bandwidth allocation where half of the radio resources are assigned for uplink and downlink, respectively. *(Section 5.2.2)*

R34. A downlink Peak Data Rate of 1 Gbit/s shall be achievable in local area deployments due to the WINNER system design. This requirement assumes a 100 MHz system bandwidth allocation where half of the radio resources are assigned for uplink and downlink, respectively. *(Section 5.2.2)*

R35. The WINNER system shall enable an achievable user plane latency of less than 1 ms in the downlink and 2 ms in the uplink of a single-hop transmission in unloaded conditions. *(Section 5.4.2)*

R36. The WINNER system shall enable an achievable user plane latency of less than 5 ms in a two-hop transmission in unloaded conditions. *(Section 5.4.2)*

R37. The QoS framework will provide guarantees for services that require high interactivity (delay in the network level < 20 ms). *(Section 5.4.2)*

R38. WINNER shall provide spectral efficiency in connected sites of 2-3 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in wide area deployments in an operation point that fulfils the satisfied-user criteria. *(Section 5.5)*

R39. WINNER shall provide a spectral efficiency in connected sites of 2-5 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in metropolitan area deployments in an operation point that fulfils the satisfied-user criteria. *(Section 5.5)*

R40. WINNER shall provide a spectral efficiency of 10 bit/s/Hz/cell for the downlink and 1/2 thereof for the uplink in isolated (non-contiguous) sites (i.e., local area) in an operation point that fulfils the satisfied-user criteria. *(Section 5.5)*

R41. WINNER shall support at least low-rate services with reduced cell capacity for terminal speeds of up to 350 km/h, or even up to 500 km/h, depending on Doppler shift related with carrier frequency band and deployment environment. *(Section 5.6)*

R42. The WINNER System shall be able to operate anywhere in range between 2.7-5.0 GHz, taking into account that WINNER target characteristics have to be met. *(Section 6.1)*

R43. The WINNER system shall be able to utilise current bands for cellular communication. *(Section 6.2)*

R44. The WINNER system shall be able to handle fragmented spectrum assignments efficiently. *(Section 6.3)*

R45. The WINNER system shall be able to coexist with non-WINNER systems and to share resources with minimized mutual interference. *(Section 6.4)*

R46. Operation in unlicensed bands shall be possible. Performance requirements shall be met if the interference caused by other systems operating in the same band does not prevent this. *(Section 6.4)*

R47. The WINNER system shall be able to use spectrum shared between parallel network deployments (Flexible Spectrum Utilization). *(Section 6.5)*

R48. The WINNER system shall be able to use spectrum shared between different cell types, e.g., between macro cells and micro cells, or between micro cells and hotspots. *(Section 6.6)*

R49. Maximum required bandwidth for one radio link is 100 MHz. *(Section 6.7)*

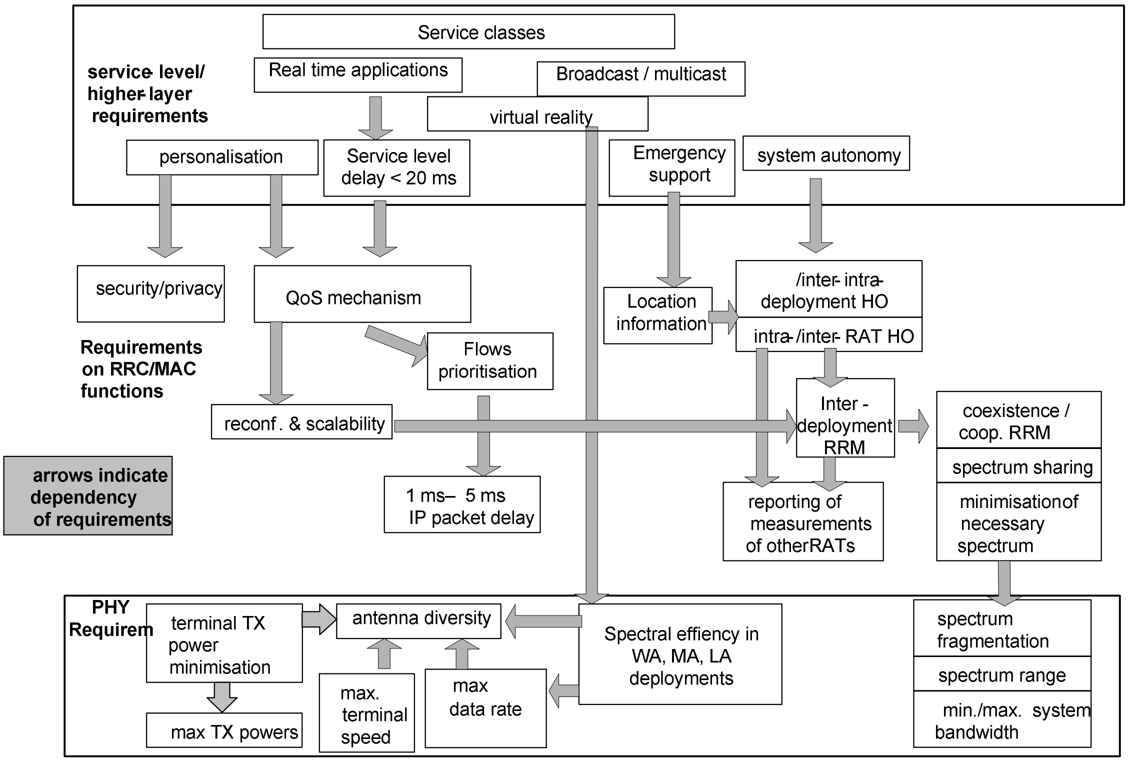
R50. The total system bandwidth needed to fulfil the requirements should be minimised. *(Section 6.7)*

R51. A minimum bandwidth of 1.25 MHz for TDD and 1.25 MHz per duplex FDD link, i.e., 1.25 MHz for uplink and 1.25 MHz for downlink, is required. *(Section 6.7)*

7.2 Mapping of Requirements

In Figure 7-1, an example of a mapping of higher-layer to lower-layer requirements is illustrated. The service-level requirements characterize some of the key functionalities of the WINNER system that are immediately visible to the user. All of these requirements rely on the RAN system capabilities and performance, which are in turn characterized by requirements on the RLC MAC and PHY layers. Most of these lower-layer requirements are expressed in quantitative figures and sometimes serve as targets for system-level or link-level simulations. The dependencies indicated in the figure should be regarded as examples and are not exhaustive.

Figure 7-1: Illustration of the inter-dependency of requirements



8 Conclusion

This document provides the final set of the WINNER system requirements, based on earlier work in WINNER phase I [WIN1D71], and subsequent refinements of the system requirements in phase II [WIN2D6111]. In the elaboration of the final system requirements, the latest status and assumptions about the WINNER system concept as well as the latest work results within WINNER, were considered along with recent developments in research, regulation, standardisation, wireless market, and industry.

The higher-layer requirements addressing supported service classes and services form the basis of all other requirements. Here, especially the support of ultra-high data rates and low delays for the virtual-reality service constitutes a challenge to the WINNER RAN.

Mobility support via handover within WINNER and with legacy systems constitutes an integral part of the system capabilities requirements. Measurements facilitating these and other network functions were addressed. Requirements regarding the terminal side include the support for a wide range of user terminals, e.g., with respect to different antenna configurations.

The performance requirements characterize both the fundamental system limits (peak data rate) and the system performance under realistic conditions, respecting the WINNER II satisfied user criterion. The spectral efficiency requirement was deliberately chosen not to describe the theoretical optimum but to characterise the 'real-world' system performance. It can only be compared to the corresponding figures of other systems if a similar satisfied user criterion is employed.

The spectrum requirements address the efficient use of the scarce spectrum resource by introducing a large amount of flexibility in spectrum assignment for WINNER, as well as spectrum sharing and coexistence with other systems.

The set of requirements defined in this document take their user-centric origin in the service requirements. First, a set of service classes together with target performance figures is defined which should be supported by the WINNER system. Exemplary services in the real-time domain (virtual reality and VoIP) which motivate specific requirements are further characterised. Broadcast and multicast support, as well as emergency call services, are then covered. Finally, requirements and recommendations for service provisioning (e.g., physical context information) are given.

The system capabilities requirements focus largely on the mobility support, i.e., handover within WINNER, between different WINNER deployments, and with legacy systems. This is an essential feature of the ubiquitous mobile communication system, and the cooperation with legacy systems sets the path for migration towards WINNER. The corresponding measurements which are necessary for these network functions are described. Furthermore, requirements on QoS mechanisms and prioritisation are addressed. Regarding security and privacy protection, recommendations are given. For location based services, the requirements on location determination accuracy are determined by critical applications like emergency calls.

Given the broad scope of the WINNER system, it is clear that in the terminal requirements chapter, the re-configurability and adaptability of the network to a wide range of terminals plays a prominent role. Furthermore, requirements on maximum transmit power, reduction of power consumption, and antenna configuration are given.

The key requirements for the WINNER RAN address the lower-layer system performance. Here, a separation is made between the theoretically achievable performance values (e.g., in the form of peak data rates and achievable delay) which characterize the fundamental performance limits due to system design, and the achievable performance under realistic conditions and following some satisfied user criteria. The spectral efficiency requirements address the latter case. The satisfied user criterion of WINNER phase II is defined as 95% of the users having an average active session throughput greater or equal than 2 Mbit/s.

Spectrum is a scarce resource and recent developments in regulation make it even more important for WINNER to provide solutions for different spectrum scenarios, including limited bandwidth and fragmented spectrum. Therefore the corresponding spectrum requirements have been further elaborated regarding, e.g., spectrum sharing between WINNER cell layers, WINNER RANS and with other systems. Also requirements considering the cooperation with legacy RATS, between WINNER RATS, and WINNER modes have been reviewed accordingly.

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9 Appendix

9.1 EMF Recommendations

The widespread use of Electromagnetic Field (EMF) sources has been accompanied by public concern about possible adverse effects on human health. As part of its charter to protect public health, the World Health Organisation (WHO) established the International EMF Project to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz (in WINNER scope, the relevant bandwidths are 900 MHz to 2.6 GHz and 3.4 GHz to 5 GHz). The EMF Project encourages focused research to fill important gaps in knowledge and to facilitate the development of internationally acceptable standards limiting the EMF exposure. The International Commission on Non-Ionising Radio Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) work with WHO in order to establish guidelines for Specific Energy Absorption Rate (SAR) and Maximum Permissible Exposure (MPE) limits and reference levels to prevent the risk of diseases.

The SAR is the unit that measures the amount of Radio Frequency (RF) energy absorbed by the body when using a mobile terminal. The closer the user is to the base station (BS) the lower is the SAR value, because the terminal needs less power to reach the BS. The SI unit for SAR is Watts per Kilogram (W/kg).

Regarding WINNER deployments, the aforementioned activities should be closely monitored and taken into account.

9.1.1 User Safety and Methods for Exposure Reduction

At RF, defined as 100 KHz to 300 GHz [Ahlbom], the fields only penetrate a short distance into the body. At 2.5 GHz the penetration depth in muscle tissue for plane model is about 1.7 cm. The energy of these fields is absorbed and transformed into the movement of molecules. Friction between rapidly moving molecules results in temperature rise. In the actual state of research, heating is the main known effect of the RF exposure. In addition to the absolute increase in temperature, duration of heating and thermoregulatory capacity of the body is important. Several studies found no convincing relation between human exposure to RF fields, such as those emitted by mobile terminal and BS, and the increase of some types of cancer and leukaemia. Additionally, there is no direct link between RF exposure and genotoxic effects, like DNA mutations, DNA strand breaks, or other genetic lesions.The actual exposure of user to RF fields depends on a large number of factors, such as terminal’s characteristics: the type and location of antenna; the way the terminal is handled; and most important, the adaptive power control, which may reduce the emitted power by orders of magnitude. The adaptive power control includes distance from the BS, frequency of handovers, and RF traffic conditions.

The RF absorption is maximal on the side of the head to which the phone is held, greatest close to the antenna and decreases to less than one-tenth on the opposite side of the head [Ahlbom].

Science-based simulation models of human physiological responses have predicted that after a body exposure of 5 W/kg SAR for indefinite time, a magnetic resonance imaging (MRI) scan of a 70 kg patient would not be sufficient to overcome the available heat loss mechanisms or raise core body temperature [SCC39].

Another study reported reduced fertility of sperm at SARs greater or equal to 50 W/kg. These are exposures that are much higher than the established adverse effects threshold of 4 W/kg [SCC39].

Regarding children’s safety there is no recommendation for limiting the use of mobile phones, because scientific evidence and knowledge does not show a danger in use of wireless devices, including children and teenagers.

9.1.2 EMF Regulation and Standards

There were no relevant changes in ICNIRP guidelines for the restrictions in RF exposure. Biological and health effects in WINNER’s frequency range are consistent to a body temperature rise of more than 1 ºC. This level of temperature increase results from exposure of individuals under moderate environmental conditions to a whole-body SAR of approximately 4 W/kg for about 30 minutes. To derive the basic restrictions for workers a safety factor of 10 is used, which gives a SAR of 0.4 W/kg. For general public 0.08 W/kg was chosen [ICNIRP98][Gabr].

In Table 9.1, the values proposed by ICNIRP for SAR are presented. All the SAR values are to be averaged over any period of 6 minutes and in a mass of 10 g of contiguous tissue.

Table 9.1: Basic restrictions in 10 MHz – 10 GHz range

	General public	Workers
Whole body average SAR	0.08 W/kg	0.4 W/kg
Localised SAR (human trunk, head, and most parts of body) – average over 10g tissue	2 W/kg	10 W/kg
Localised SAR (human body extremities and pinnae) – average over 10g tissue	4 W/kg	20 W/kg

The principal similarities between ICNIRP and IEEE guidelines are 2 W/kg SAR averaged over 10 g of tissues in head and trunk; however the IEEE values are to be averaged over periods of 2.5 to 30 minutes.

In the case of localised exposures, such as a mobile phone handset in use, different considerations have been used to develop partial body exposure limits.

For general public, in the frequency rage of 10 MHz – 10 GHz, different regions adopt different values for SAR, based on the actual standards. In the next table, these regions are summarised: Europe, Japan and Korea adopted the ICNIRP standard, expressed in Table 9.1; USA, Australia and Canada adopted the ICNIRP standard, but they limited the SAR value in human head and trunk to 1.6 W/kg (averaged over a period of 30 minutes in 1 g of tissue).

The EU/ICNIRP recommendation for RFs exposure is expressed in [ICNIRP98].

Table 9.2: Reference values for general public and workers in terms of E-field, H-field strength and Power Density (2 MHz to 300 GHz) [ICNIRP98]

	E-field	H-field	Power Density[1]
General public	61 V/m	0.16 A/m	10 Wm^{-2}
Workers	137 V/m	0.36 A/m	50 Wm^{-2}

Any system emitting less than 20 mW average power is compliant with the limits since the maximum absorbed power in 10 g in any condition is less than 2 W/kg, which is the EU recommended limits.

Dealing with BS the reference level for E-field applicable to general public is $1.37f^{1/2}$ (f in MHz) up to 2 GHz and 61 V/m above, which corresponds to a power level in the order of 1-10 W with typical antennas and mast heights. This is the situation in the vast majority of public cellular networks.

According to ICNIRP guidelines and IEEE standards, in the range of WINNER's frequencies, the MPE was defined to be 10 Wm^{-2}.for general public. In IEEE standards the maximum spatial power density is $18.56f^{0.699}$ Wm^{-2} (f in GHz) (for frequencies between 3 – 30 GHz).

9.2 Operational and Maintenance Requirements

9.2.1 System Resources Monitoring and Network Elements Fault Detection

The requirements for operation and management in WINNER are not significantly different from the legacy networks. System monitoring addresses the capability of surveying the current state of the system operation in terms of resources (e.g., spectrum, usage, traffic load and forecasts). Network monitoring data collected from the network elements comprises useful information for the sytem scalability maintaining the network resources optimised. In other way, fault elements detection via an OMC (operation & maintenance centre) allows minimising the system downtimes (outage) and recover from system faults.

O&M (Operations and Maintenance) functions are required to have a consistent set of monitoring functions, disasters recovery, resources monitoring, KPI collections, linked from the OMC to the different networks elements through standardised interfaces.

[1] Note:

1. Power densities are to be averaged over any 20 cm^2 of exposed area and any $68/f^{1.05}$-min period (where f is in GHz) to compensate for progressively shorter penetration depth as the frequency increases.
2. Spatial maximum power densities, averaged over 1 cm^2, should not exceed 20 times the values above.

Recommendations to be considered:

- Perform monitoring in terms of resources availability to support and control the load network increase.
- Provide flexible and friendly network configuration and management of network elements.
- Provide consistent and fully integrated failure management mechanisms in order to recover from accidental or systematic failures.
- Provide and support account, billing facilities, account management to handle billing procedures across different radio networks aiming at to introduce the concept of mobile virtual network operator (MVNO).

9.2.2 Network Management and Performance Metrics

Network management interface at the OMC allow the operator to have an overall status and control about the system performance. Different counters associated in terms of events will be collect from network elements and thus processed in terms of statistical performance indicators. This way the operators have the network under control. Configuration and setup of the network elements is provided through O&M links to the BS/RNs.

WINNER should provide relevant performance KPI indicators through the collection of O&M data counters from the network elements for network performance monitoring and analysis.

9.3 Charging and Billing Platform

Service providers and network operators should agree on a unified charging and billing platform.