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Revised WINNER II System Requirements

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Abstract:
This document provides an update of the WINNER system requirements described in WINNER phase I, considering the latest developments in research, regulation, standardisation, wireless market, and industry. The focus is only on system requirements with impact on the development of a new radio interface concept and design, which is the primary goal of WINNER.

Keyword list:

WINNER, requirements, services, radio interface, performance, terminal, spectrum, regulatory.

Disclaimer:

Executive Summary

This document provides an update of the WINNER system requirements based on deliverable D7.1 of WINNER phase I [1], considering the latest developments in research, regulation, standardisation, wireless market, and industry. The focus is only on system requirement with impact on the development of a new radio interface concept and design, which is the primary goal of WINNER.

Based on requirements for supported services, performance requirements are formulated. System capabilities, including mobility support, peer-to-peer communications, and QoS are considered as well as terminal requirements. Important impact from regulations is captured in the chapters on spectrum and EMF requirements.

Compared to the status of deliverable D7.1 of WINNER phase I many equally important requirements have been simply maintained, like the air interface delay of 1 ms, the EMF requirements, TCP/IP-based interface to the core network, terminal scalability, and requirements on talk and standby times.

However certain requirements have been newly introduced, adapted, and augmented with increased details in their definition. The following paragraphs focus on these changes due to recent developments, providing also brief background information.

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, e.g. regarding requirements on 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.

A so-called triple play strategy (that integrates voice, data, and broadcast) is today pursued by many wireless network operators. Services that became increasingly important during the last two years and which have impact on the air interface design include VoIP, video, multicasting, and broadcasting, as well as physical-context services (e.g. location-based services). Consequently these services will be considered in the service mix of the evaluation scenarios within the WINNER concept groups and the associated performance requirements regarding data rates, and delay will receive stronger focus.

The WINNER requirements originate from a user-centric approach, considering also the needs of all major stakeholders in the value chain. However, within WINNER these kind of high-level requirements need to be transformed into clearly defined assessment criteria suitable for evaluation by the available methodologies and simulation tools. This document also provides further work in the translation process from user-centric requirements to technical assessment criteria suited for evaluations. 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. Such more detailed definitions and explanations have been added, e.g., to the data rate requirements.

In contrast to D7.1 the new spectral efficiency requirements includes now a definition of an associated satisfied user criterion under which constraints the spectral efficiency has to be measured. With respect to a definition used in phase I evaluations the satisfied user criterion for phase I is considerably more stringent while maintaining the same target spectral efficiencies. This means that a tough new challenge has been adopted for WINNER phase II.

The requirements of this document provide a framework for the challenging goals 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 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 aspects comprising WINNER's vision of a new ubiquitous radio system and translates them into a set of system requirements, based on both the outcome of the research performed during project's first phase and the latest developments in the wireless market and industry.

A significant attribute of WINNER is the user-centric approach that was followed already in the first two years 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 [2].

The description of the requirements in this document adopts a top-down approach based on the system and user perspective. Within WINNER this formulation of the requirements will be further elaborated into assessment criteria that include detailed definitions suitable for evaluation by the available simulation tools. Such detailed assessment criteria definitions are given in [3] and [4]. Where possible and necessary, indications for the interpretation of the system-oriented requirements and possible transformation to assessment criteria are also given in this document to further assist this refinement process.

This document will recapitulate and update the relevant requirements that have been described in the previous system requirements [1], and also all the 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.

In the sequel service requirements, system capabilities, and terminal capabilities are given, followed by performance requirements derived thereof. Subsequently spectrum requirements, as well as EMF requirements are treated.

2 Service requirements

The service requirements in this chapter follow a high-level description. The performance requirements associated and derived from the service requirements then follow in a later chapter. First an overview of the air-interface related requirements of all relevant service classes is provided. Subsequently a few 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.

2.1 Service classes

The WINNER system concept and technologies shall allow deployment, at reasonable cost, to provide at least minimum service requirements (legacy cellular voice services, and minimum regulatory requirements). Other service requirements may be added from an analysis of WINNER service classes. Table 2-1 shows the mapping of typical applications to the different services classes according their QoS requirements. The mapping is based on work performed within WINNER I and reported in [2] [5] [6] [7]. Applications belong to service classes, thus each service class can be composed of several applications.

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 and 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 multimedia	Rich Data Call - Control - Video Broadcasting/Streaming - Robot security
6. Geographic interactive multimedia broadcast	Video Broadcasting Streaming - Localised Map Download
7. Interactive ultra high multimedia	High Quality Video Conference - Collaborative work
8. Simple telephony and messaging	Voice Telephony - Instant messaging - Lightweight multiplayers games - Bets and gambling
9. Data and media telephony	Audio streaming - Video Telephony (Medium Quality) - Multiplayer games (High Quality)
10. Geographic datacast	Localised Datacast/Beacons - Audio Streaming
11. Rich data and media telephony	High Quality Video Telephony - Collaborative work - Standard data call
12. LAN access and file services	Access to databases, filesystems
13. Multimedia messaging	Messaging (Data/Voice/Media) - Authentication (m-payment, m-wallet, m-ticket, m-key…) - Web browsing (light weight)
14. Lightweight browsing	Messaging (Data/Voice/Media - medium weight) - Access to corporate database (light weight) - audio and demand - web browsing (medium weight) - 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	

Table 2-2 summarizes the derived requirements related to rate, interactivity and required mobility for the WINNER service classes as defined in WINNER I and reported in [2] [5] [6] [7]. The applications are grouped according to their rate category and mobility requirements, thus forming service sets. Typically high demanding data rate services have limited mobility and coverage range mainly due to the service characteristics.

Table 2-2: Service classes' requirements and associated deployment scenario.

Service Class	Required Rate	Interactivity	Required Mobility/Range	Rate category
1. Real Time Collaboration and gaming	1-20 Mbps	Highly interactive	LM/SR	1-20 Mbps
2. Geographic real time datacast	2-5 Mbps		GM/SR	
3. Short Control messages and signalling	8-64 kbps	Interactive	Any	8-512 kbps
4. Simple interactive applications	64-512 kbps		Any	
5. Interactive high multimedia	2-5 Mbps	Interactive	LM/GR	1-50 Mbps
6. Geographic interactive multimedia broadcast	2-5 Mbps		GM/SR	
7. Interactive ultra high multimedia	1-50 Mbps		LM/SR	
8. Simple telephony and messaging	8-64 kbps	Conversational	Any	8-512 kbps
9. Data and media telephony	64-512 kbps		Any	
10. Geographic datacast	64-512 kbps		GM/SR	
11. Rich data and media telephony	2-5 Mbps	Conversational	Any	1-50 Mbps
12. LAN access and file services	0,5-50 Mbps		LM/SR	
13. Multimedia messaging	8-64 kbps	Few seconds delay tolerant	Any	8 kbps - 50 Mbps
14. Lightweight browsing	64-512 kbps		Any	
15. File exchange	Up to 5 Mbps		LM/GR	
16. Video streaming	5 Mbps		Any	
17. High quality video streaming	2-30 Mbps		LM/GR	
18. Large files exchange	1- 50 Mbps		LM/GR	

LM = low mobility
SR = short range
GM = global mobility
GR = global range

Table 2-3 gives the services classes and the degree of delivering the applications by legacy RANs. It is understood that the refereed legacy systems are in principal also able to support most of the service classes. However, since they are not optimised for these services classes, the support might be economically unattractive. In contrast to this, a WINNER system is targeted to provide efficient means to support these services in an economically successful manner [7].

Table 2-3: Service classes and RAN compatibility.

Service Class	GPRS	UMTS	WLAN	WINNER
1. Real Time Collaboration and gaming				x
2. Geographic real time datacast				x
3. Short Control messages and signalling		x		x
4. Simple interactive applications		x		x
5. Interactive high multimedia				x
6. Geographic interactive multimedia broadcast		x		x
7. Interactive ultra high multimedia			x	x
8. Simple telephony and messaging	x	x		x
9. Data and media telephony		x		x
10. Geographic datacast		x		x
11. Rich data and media telephony				x
12. LAN access and file services			x	x
13. Multimedia messaging	x	x		x
14. Lightweight browsing		x		x
15. File exchange		x	x	x
16. Video streaming		x	x	x
17. High quality video streaming				x
18. Large files exchange				x

2.2 Requirements for physical context information

Physical context includes information such as location, speed and direction of movement. The information can be obtained by using in-built feature 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 dramatically if the limiting factors (multipath, NLoS) occur. Therefore, the accuracy of such systems can vary between centimetres and up to hundred metres. For indoor scenarios usually no GNSS based positioning is possible due to too 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 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. GNSS based solution is further considered, too, 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 needed.
- *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 postprocessed in the network for location determination.

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

Location based services are, e.g., 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, location based vertical handover, or radio resource management the 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 scenario the requirements regarding accuracy can 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.

For emergency calls, accuracy assumptions are not yet well defined by a common European agreement. WINNER will monitor this process and ensure that these requirements are included once stable. Meanwhile, we make use of the requirements defined by the US Federal Communications Commission (FCC) that states that all wireless service providers have to deliver the location of all emergency callers with specified accuracy. The requirements are expressed in Circular Error Probability (CEP). It is differentiated between network and UT based positioning and – for instance – CEP67 = 100 m means, that at least 67% of the radial positioning errors should be smaller than 100 m.

Table 2-4: CEP specifications for location determination of emergency calls.

Specification	Network based	UT based
CEP67	100 m	50 m
CEP95	300 m	150 m

R2.2A: WINNER System will aim at achieving emergency call requirements.

R2.2B: WINNER System will provide stand-alone location information that can be used as input for user and system-side applications.

R2.2C: 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.

R2.2A and R2.2C were presented in D7.1 from phase I, however here we try to give a clear vision for the needs and the purpose to have location based measurements techniques in the WINNER network.

R2.2B is a new requirement.

2.3 Requirements for real time applications

Support for real time application will also be incorporated in the WINNER platform. As was the case with other kind of services, requirement for real time application support is also implied by the list of WINNER services depicted in Table 2-2, e.g., real time collaboration and gaming. Requirement for real time services support will be translated into appropriate technical terms in the generalized QoS framework that will be supported by WINNER applications. A first mapping of real time applications onto specific QoS requirements in terms of data / error rates, allowed delay values and traffic types is presented in Table 2-2.

Some examples of real time applications are telesurgery, telepresence, videoconferencing and internet multiple users gaming.

2.4 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. Exemplary usage scenarios and case studies including virtual reality services are contained in [7] and [8].

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 call 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 reverse link. 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, e.g. a supported high-end user data rate of 50 Mbps, see section 5.2 and delays that remain below 20 ms (section 5.4)
While 2G wireless cellular systems support voice, 3G includes additionally 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.

R2.4A: A WINNER shall support the QoS requirements for interactive ultra high multimedia services.

Support for this kind of services has been assumed already in phase I, however R2.4A is now an explicit formulation to stress the relevance.

2.5 Voice over IP

The voice over IP (VoIP) service has obtained considerable publicity in research, and standardisation, e.g. for HSDPA and LTE [9]. Internet VoIP application (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 is the most important service. Furthermore VoIP offers the opportunity to integrate voice service closely with other concurrent services in a multi-flow transmission to a 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.

VoIP traffic characteristics exhibit a sequence of talk spurts and silent periods; see also the traffic models available in [7] and [8]. 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.

R2.5A: A WINNER site shall support a large number of parallel VoIP users.

R2.5A is a new requirement and gives relevant information concerning VoIP technology. LTE currently targets to hold up to 200 users in a connection state that would support VoIP.

2.6 Broadcast and multicast support

Due to recent developments, like the triple play strategy, and field trials using solutions based on dedicated broadcast technologies for mobile users, e.g. DVB-H or DMB, broadcasting and multicasting to mobile users has attained increased interest. Broadcast and multicast services are expected to be an important part of an operator's service offering in the future and the requirements on broadcast and multicast support from phase I have even gained further relevance [1].

Time-aligned distribution of data to a group of users includes a wide range of applications, like localised area information, news, advertisement, software updates, server and database synchronisation, cell broadcast, etc. For requirements of these services see WINNER service classes 6 and 7 in section 2.1. With an increasing variety of services and increasingly localised broadcasting service areas, the clear difference between multicast and broadcast is blurring. From a technical point of view, broadcasting typically works without any channel quality information (CQI) at 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. Also if ARQ is used, dedicated protocols are required.

Efficient and reliable multicast is important and offers new opportunities for service providers. It is an enabler for increasing use of push services as compared to pull services. Efficient multicasting will allow increasing the number of concurrently active multicast groups, as well as the sizes of the individual multicast groups. It therefore allows supporting an increased variety of services and approaches broadcasting. While MBMS in UMTS imposes constraints on the applications, in particular that they need to be tolerant to packet loss or duplication, increased reliability of broadcast and multicast would be an enabler for a large class of additional services. Therefore reliability is in the major focus.

R2.6A: WINNER shall support efficient and reliable multicast and broadcasting.

R2.6B: It shall be possible for a terminal to receive concurrently multicast / broadcast services and other services.

These are new requirements.

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 stakeholder have to be maintained. These are described in this section.

3.1 System autonomy

R3.1A: The ubiquitous radio system will be self-contained, allowing WINNER to target the chosen requirements without the need for inter-working with other systems.

Requirement maintained from WINNER phase I.

3.2 Generalised Mobility support within WINNER

Mobility support means the ability of a mobile radio system to maintain the connection to a UT that is moving from one cell to another, commonly referred to as “handover”. For the WINNER system, different types of handover are foreseen. The WINNER system may be deployed using FDD or TDD physical layer mode with different parameterisation, e.g. using different bandwidths or carrier frequencies. Handover may occur within one deployment of WINNER (intra-deployment) or between different deployments of WINNER using different physical layer parameterisation (inter-deployment). Additionally, handover to legacy systems should be supported (inter-system).

3.2.1 Intra-deployment handover

R3.2.1A: WINNER shall support seamless handover of individual flows between cells of one WINNER deployment. The transfer of the flows to the new base station shall not be noticeable on the application layer.

This is a new requirement.

3.2.2 Inter-deployment handover

If one operator runs multiple instances of WINNER in the same geographical area operating at different PHY parameterisations, 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 means 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.

R3.2.2 A: The WINNER system shall be able to route each flow individually through the available deployments according to the restrictions and advantages of each deployment.

R3.2.2B: WINNER shall support seamless handover of any individual flow between cells of different deployments. The transfer of a flow to a new base station shall not be noticeable on the application layer.

R3.2.2C: WINNER shall support resource management of different deployments that controls the load of the cells and supports handover of individual flows from one cell to another.

All these requirements are new requirements.

3.3 Generalised Mobility support between WINNER and legacy Networks

3.3.1 Cooperation with legacy systems

The basic requirement is that the WINNER system concept shall cooperate with legacy systems. This cooperation feature opens up a migration path for operators that enable them to minimise their new investment and to allow an optimal use of the spectrum according to the user requirements and capabilities of different RATs. Examples of these cooperation mechanisms are joint RRM, concurrent RRM, and vertical handover.

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, the provisioning of the service is more efficient and the intersystem change will be more seamless, especially with real time flows. On the contrary, 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 Ambient Networks project [10]. 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 system. 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.

R3.3.1A: The WINNER system concept should provide an interface to legacy RATs that supports seamless handover to minimise degradation of communication quality and enables further cooperation mechanisms, e.g. RRM.

WINNER inter-system handover should be consistent with the inter-system HO already defined in legacy systems. In particular, the inter-system handover procedure between UMTS and another RAT is already specified by the 3GPP. Therefore, the WINNER inter-RAN handover protocol should be harmonized with 3GPP specifications on inter-RAN handover for specific cellular networks.

These requirements are updated providing relevant requirements concerning cooperation with legacy networks from phase I of WINNER project.

3.3.2 Measurements requirements for the WINNER system

As pointed out in the previous sections, measurements are essential inputs for RRM algorithms and therefore mechanisms to configure, perform and report measurements must be defined for the WINNER system. In particular, the WINNER system should at least provide to the RRM signal strength measurements, performed either by the terminals or by the base stations, not only on the WINNER RAN, but also on legacy RANs. Like current UMTS -GSM terminals, dual system WINNER transceivers are foreseen. In order to enable measurements of other systems by the WINNER transceiver, the WINNER MAC frame design should allow reserving time-frequency resources which are deliberately not used for transmission, but left free for measurements. For the alternative to have a terminal with two receivers (with increased battery consumption, size and cost of the UT) only an anyway needed signalling channel is required.

3.3.2.1 Requirements for measurement of legacy RANs

R3.3.2A: A signalling channel to report measurements of other RANs should be included in the WINNER concept

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R3.3.2B: In order to enable measurements of other systems by a WINNER transceiver, the WINNER MAC frame design should allow reserving time-frequency resources which are deliberately not used for transmission, but left free for measurements

These requirements are new.

3.3.2.2 Requirements for handover from WINNER system to legacy RANs

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). To improve efficiency and in order to avoid prohibitive scanning times of a diversity of systems, WINNER RAN should provide to the UT indication on what measurements should be performed. This can be obtained sending to the UT a neighbouring cell list with information on the candidate/target cell identifier (s) and the radio parameters relevant for the target radio access technology (synchronisation for measurements, identification of the measured cell, measurement configuration parameters, and other system depending information).

To enable fast frequency scanning and cell registrations to the proper RATs for the Multi-mode UTs, the WINNER system should be able to broadcast the selected system information from the legacy systems according to the operators' policy. Such system information can be the frequency allocation to the specific legacy RATs.

A step further is the interworking between WINNER system and a global spectrum coordination system when applicable. The global spectrum coordination system operates on a set of out-band signalling carrying the spectrum coordination w.r.t. the operators. Such interworking enables the advanced spectrum management by WINNER system.

R3.3.2C: A signalling channel to notify user terminals about other available RANs should be included in the WINENR concept.

This is a new requirement.

3.3.2.3 Requirements for handover from legacy RANs to WINNER system

Some information about WINNER system should be broadcasted in the legacy RANs, like the neighbouring WINNER cells, together with some information necessary to demodulate their signal: specific signalling must be added in legacy RANs. Inter-RAN information exchange is required to provide short scanning times and efficient handover, load balance and other inter-RAN functionalities. It is not something new, this is gathered in the current UMTS-GSM specifications aforementioned. The inter-operator case will be different to the inter-RAT case, since so far there is no inter-operator inter-working directly through the Radio Access, except RAN-Sharing.

Besides, some information must be "broadcasted" by the WINNER cells to allow their identification (this could be similar to Base Station Identity Code (BSIC) in GSM or to 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 hand-over: the identification of a WINNER "cell" should be easy, even with compressed mode (for example, it is better if the broadcasted WINNER information corresponds to a gap of compressed mode). WINNER should provide beacons to be measured by terminals on the legacy systems. As already mentioned, the WINNER system should take into account the constraints related to the use of compressed mode in UMTS systems and facilitate its use and parameter setting.

To enable fast frequency scanning and cell registrations to the proper RATs for the multi-mode UTs, the WINNER system should be able to interwork with the legacy systems in order to allow the legacy system broadcast the WINNER mode and carrier frequency in the evolved broadcasting message structure, for instance the SIB (System Information Block) of WCDMA system. Such system information can be the frequency allocation to the specific legacy RATs, and is determined by the operator's policy on inter-RAT interworking.

To enable the HO from legacy system to WINNER, cooperation between WINNER system and the global spectrum coordination system is needed when applicable. The global spectrum coordination system operates on a set of out-band signalling carrying the spectrum coordination w.r.t. the operators. Such interworking enables the advanced spectrum management by WINNER system.

This topic is identified as important for the WINNER system concept, but at this point no formal requirements have yet been defined. This is for further study.

3.4 Peer-to-peer communication

Peer-to-peer communications should be incorporated within the contexts of WINNER, both in terms of infrastructure equipments as also between user terminals. Within this scope, the platform should provide algorithms and mechanisms in terms of peer discovery protocols, physical layer provisioning, and radio resource management.

This is an important for the WINNER system concept, but at this time no formal requirements have yet been defined. This is for further study

3.5 QoS mechanism support

In a beyond 3G scenario, networks of different characteristics need to be interconnected in an optimum manner and with the objective to provide the end user with the requested services and corresponding QoS. QoS refers to a collective effect of service performance that determines the degree of satisfaction of the end user. The QoS requirements that are imposed are strongly linked to the performance and the load of the WINNER radio access network.

As it is clearly depicted the in the table 2-1 presenting the service classes list, all current and envisioned QoS demanding applications like real time streaming, interactive gaming, teleconference, etc. are within WINNER's scope. High interactivity and low delay are very stringent demands and can only be accomplished with a unified and consistent QoS approach that will be followed within the context of WINNER.

The WINNER system shall support controllable QoS provisioning. That means that specific constraints imposed by the services in terms of delay, jitter and data rates, are considered by the WINNER system in an adjustable way. Depending on operator policy and service level agreement, the QoS of each service and user is controlled in a particular load situation. In a low load situation, the QoS of all users may be maintained, whereas in heavy load situation particular services may be prioritised against others. Users may receive degraded QoS in congestion situations.

The necessary QoS support will be defined in a generic way that allows designing interfaces to specific approaches in this area, e.g. upcoming standardisation approaches and services and QoS offered by legacy RANs.

R3.5A: Packet streams are classified by QoS requirements, source and destination are mapped to flows. 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.

R3.5A is maintained from phase I [1].

3.6 Security / Privacy protection

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.

End-to-end security will be provided. Necessary security at L1 – L3 will depend on the overall security concept of the Wireless World Initiative.

Security aspects, however, will not be treated in detail within WINNER II.

3.7 Connection to core network

The WINNER interface with other networks, and the core network is through the TCP/IP protocol. RRM messages with other networks and with the core use TCP/IP as transport protocol. IP-based mobility is supported.

4 Terminal requirements

The next generation mobile systems are user-oriented, which enables communication anytime, anywhere with anyone or anything. Many terminal requirements can easily be deduced from the system requirements in chapter 3, in particular requirements related to:

- mobility,
- interworking, network and mode selection,
- peer-to-peer transmission, and
- multi-service transmission.

These requirements need the associated support on terminal side, including in particular the provision of the associated 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 need to 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 the software in order to use different spectrum bands or different communication schemes, this is: download the software to use; adaptively switch the transmission; multi-mode operation.

R4.1A: WINNER shall support different terminal classes, in order to support a wide range of terminals with different complexity, cost, capabilities and form factors.

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.

This is an update requirement from [1].

4.2 Maximum transmit power

The peak transmit power is limited by different aspects ranging from the terminal type and position in respect to the human body, (handheld, laptop or mobile phone) due to energy absorption, link budget, bandwidth, and technology constrains for the specific frequency band (terminal power consumption regarding maximum output power of amplifiers for the specific frequency range). Depending of the service types (voice or data sessions) the exposure to the radiation can vary significantly due to the distance from the UT and the human body and the duration of session/call. Thus more restrictions due to radiation exposure are typically applied for voice services. In contrast high demanding data sessions UT needs higher output power but the UT (handheld, laptop) is quite apart of the human body.

Taking into account EMC directives if the systems are used close to the head the power has to be limited (cf. also chapter 7). At 900 MHz and 2 GHz the maximum average output power is 250 mW and 125 mW in order to comply with the SAR values averaged over 6 minutes period. For higher frequency bands the extrapolation is complex since the exposed tissues depend on the frequency, oxygen and water vapour absorption [11].

R4.2A: Maximum and average transmit power in the terminals must comply with the EMC regulations of the corresponding frequency range.

The corresponding regulations will be monitored. The current working assumption on the maximum transmit power for base stations, relay nodes, and user terminals are given in [12]. In the "base coverage urban" and "microcellular" evaluation scenario 24 dBm have been adopted for the user terminal, whereas in the "indoor" evaluation scenario 21 dBm is assumed.

This requirement is maintained from phase I.

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 must 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 considerable higher power consumption.

As an example, talk and standby times for cellular phones are in the range of several hundreds of minutes and several days, even couple of tens of days, respectively, Furthermore, power consumption must be kept at the level that the surface temperature of the terminal does not feel too hot. As an example related to this thermal requirement, the average signal processing power consumption of a small (handheld) terminal should not be larger than 3 W (of which even about 2 W can be for a power amplifier (PA)).

R4.3A: Power consumption need to be minimised in order to ensure that the end user requirements for talk and standby times are met. Battery life will allow at least one day of use without charging.

R4.3B: Talk and standby times must be at least as long as with current available terminals.

These are reformulated requirements from [1].

5 Performance requirements

Based on the supported services, performance requirements can be derived. Measuring the system performance has many aspects. From end-users point of view, the criterion has to be in the way that the "real" user experience will be reflected. The user experience may be 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-users experience, but also measure the system performance from operators' point of view. For the operator the spectrum band is coupled to costs, thus the operator's point of view is to best exploit the frequency spectrum by giving each user its appropriate quality of service. These requirements complement the end-users experience in the way that users don't get blocked, and a lower bound of quality of service (QoS) may be kept. Stringent QoS requirements (e.g. minimum delay at the air interface) go at the expense of system performance. This view mainly focuses on the air interface aspect.

5.1 Coverage

Coverage is of major concern for WINNER. Therefore coverage aspects are inherently built-in in various other performance requirements. A simple way to include coverage aspects in performance targets 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 disfavoured 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 been adopted in the definition of spectral efficiency, see section 5.5. This satisfied user criterion has been designed in a way, that users in the main service area are able to use all WINNER service classes. Therefore the target spectral efficiency has 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 coverage depends on a large number of factors, for example, data rate or the type of application.

Furthermore in the following section data rates are mentioned that need to be supported in the whole coverage area.

5.2 Data rates

In the ITU Recommendation "Framework and Overall Objectives of the Future Development of IMT-2000 and Systems Beyond IMT-2000" [13] assumptions were made on the needed data rates of systems beyond IMT-2000. In particular, 100 Mbps peak aggregate useful data rate over 100 MHz bandwidth for new mobile access and 1 Gbps for new local area wireless access were assumed for systems beyond IMT-2000. While these targets are acknowledged it should noted that a requirement for peak data rate does not give any indication on the quality of service experienced by one user. For that, requirements specifying e.g. sustainable data rates and delay performance need to be defined.

When considering relevant requirements for sustainable data rate we must consider the types of services that support the list of applications targeted by WINNER. The "Data Rates" column in Table 2-2 indicates that the heaviest (in terms of data rate requirements) among the proposed services (i.e. Interactive Ultra High Multimedia, Large Files Exchange and LAN Access and File Service) require a rate of maximum 50 Mbps, see section 2.1.

In the following the required data rate refers to the useful data to the user above layer 2, i.e. the MAC layer in WINNER. Overhead due to guard bands, guard times, pilots, and control overhead should to be taken into account. These are minimum requirements. Aspects of measuring user throughput in different kind of simulators are discussed in [3].

R5.2A: A sustainable "high end" downlink data rate per link of 50 Mb/s.

This requirement refers not to an instantaneous data rate but to the average data rate achieved over the period of activity of a service. Averaging with respect to the user population should include only terminals with advanced terminal capabilities supporting 50 Mb/s downlink or more, services generating the required load, and low mobility. Assumption for evaluation should assume an deployment having 100 MHz bandwidth, include realistic load in neighbouring cells (i.e., creating realistic intercell interference) and might assume a single user in the serving cell excluding disadvantageous positions within the cell, like the cell fringe.

R5.2B: A consistent and ubiquitous data rate per link of 5 Mb/s in the downlink.

In contrast to R5.2A, the averaging shall be based on all terminals supporting 5 Mb/s or more, having services generating a load of greater than 5 Mb/s, and including up to medium mobility. The average includes the complete coverage area. Realistic requirements for the uplink are for further study.

R5.2A and R5.2B are requirements from phase I [1] with some additional recommendation for technical interpretation.

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, etc.

This topic is identified as important for the WINNER system concept, but at this point no formal requirements have yet been defined. This is for further study.

5.4 Delay

Delay can be distinguish between the service response time (e.g., in gaming) from the application point-of-view and the Round Trip Time for ACKs. The RTT requirement of 1 ms is chosen to support 1Gbps at 100 MHz BW.

The WINNER system design should enable to achieve lower bounds on delay over the air interface to ensure the delay constrains to the most sensitive services. This minimum value is required e.g. for framing, interleaving as well as for channel coding. This includes error control mechanisms and scheduling.

This is a flexible target requirement for WINNER research. It is set rather low in order to enable flexible and fast resource allocation in all targeted scenarios and mobility, whereby these impacts are difficult to predict; they may depend on system performance as well as on requirements defined at user service level. In terms of network layer, values for allowed delays are also dictated by the targeted services. It is evident that these guarantees will be offered in the QoS framework that will support the deployment of delay - sensitive applications, the most demanding of which are the ones classified as “highly interactive” (i.e. the ones corresponding to the services classes “Real Time Collaboration and Gaming” and “Geographic Real Time Datacast”), requiring a delay that does not surpass the value of 20 ms.

R5.4A: The radio interface shall support that the delay from arrival of a packet to the MAC layer to the earliest instance the packet can be received and decoded in a single hop transmission is 1ms or less.

The 1 ms target delay over the air interface enables 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.

R5.4B: The QoS framework will provide guarantees for services that require high interactivity (delay in the network level < 20 ms).

R5.4A and R5.4B are updates from [1] with numerical values. A requirement based on the cumulative distribution function of delay is for further study.

5.5 Spectral efficiency

Spectral efficiency is a performance measure used in widely different context throughput literature (e.g. in the respective requirements documents of 3GPP LTE and 3GPP2 [14], [15]) 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 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 [1].

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[1]. Satisfied user criteria can be found in [8] and [16]. In general a satisfied user has certain requirements regarding blocking, dropping, and active session throughput.

Such a satisfied user criteria, however, is not applicable to all classes of simulators used within WINNER since it requires simulation of admission control and complete user sessions [12]. In particular simulators, using uncorrelated drops of user positions with only short-term evolution and / or simulations based on full queue assumptions without dedicated packet modelling cannot evaluate the corresponding satisfied user criterion. In these cases, alternative approaches based on the cumulative distribution function of the

[1] In this document and in accordance with [16] and [8] 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.

average user throughput as presented in [3] and [4] shall be used. During WINNER I the spectral efficiency has been obtained based on the load for which 90% of users have an average active session throughput greater or equal than 500 kbps. The corresponding average cell throughput is normalised by the bandwidth and further to the number of cells per site or to the area, depending on whether site spectral efficiency or area spectral efficiency is presented.

In phase II the satisfied user criterion will be updated in order to provide a consistent set of requirements. The definition of the satisfied user criterion enables the users in the main service area to use all service classes defined within WINNER:

- As the main service area is defined as the 95%-ile of the user throughput cumulative distribution function, this will also be used as the target percentile for the satisfied users.
- As 2 Mbps is the minimum data rate that would allow to use services from all important service classes (cf. Table 2-2) this will be the target rate for user satisfaction.
- The throughput used for calculating the spectral efficiency is the data rate on top of layer 2 of successfully received packets excluding PHY and MAC layer overhead.
- The bandwidth for calculating the spectral efficiency is the system bandwidth which is allocated to a specific deployment (equivalent to 20 MHz in 802.11a/g or 5 MHz in 3GPP).
- A site is defined as the physical co-location of base station hardware serving a set of antennas. Users may be connected to a site either directly or through relay nodes.

The satisfied user criterion for phase II is thus defined as 95% of the users have an average active session throughput greater or equal than 2 Mbps. A session is considered active from the time the first packet of a packet call enters the transmit buffer until the last packet of a packet call has been successfully received.

R5.5A: WINNER shall provide spectral efficiency in connected sites of 2-3 b/s/Hz/site for the downlink and 2/3 thereof for the uplink in wide area deployments in an operation point that fulfils the satisfied-user criterion.

R5.5B: WINNER shall provide a spectral efficiency in connected sites of 2-5 b/s/Hz/site for the downlink and 2/3 thereof for the uplink in metropolitan area deployments in an operation point that fulfils the satisfied-user criterion.

R5.5C: WINNER shall provide a spectral efficiency of 10 b/s/Hz/site for the downlink and 2/3 thereof for the uplink in isolated (non-contiguous) sites (i.e. local area) in an operation point that fulfils the satisfied-user criterion.

The spectral efficiency values are calculated for the maximum load (number of users) that still allows fulfilling the satisfied user criterion. Furthermore a sufficient statistic (averaging effect) is needed in order to avoid singularities and misinterpretation.

Simulations related to spectral efficiency are available in [4] and have been evaluated for a satisfied user criterion of 90% of users having an average active session throughput greater than 500 kbps in [17]. For example, for the downlink values obtained for wide area deployments range between 2.2 b/s/Hz/site and 10.5 b/s/Hz/site, dependent on the spatial processing scheme, the availability of channel state information at the transmitter, and the number of antennas (which ranged from 2 to 4 BS antennas and assumed 2 UT antennas in the cited values). It needs to be mentioned, that these simulations produce optimistic results, since many effects important in real-world deployments are neglected or ideal assumptions were adopted, including

- no consideration of outdoor-to-indoor coverage,
- no consideration of point-to-multipoint or broadcasting services,
- low user mobility,
- rough estimation of control and pilot overhead (20%),
- perfect synchronization, channel estimation, and link adaptation,
- ideal control feedback without errors and delay, and
- full buffer traffic model,

Furthermore the results were obtained for a significantly less demanding satisfied user criterion and it is unclear whether the assumption (e.g. on cell range and number of antennas) would allow economically sensible deployment and business cases.

Therefore a conservative implementation margin for operational and successful real-world deployments had to be assumed, leading to the above requirements. With increasingly realistic simulation tools and knowledge on the remaining implementation margin, it is expected that the target spectral efficiency values will be revised and most likely even can be increased.

Note that the satisfied user criterion puts high requirements on user satisfaction and therefore might dictate to operate the system in a way that cannot benefit from many opportunities in e.g. opportunistic scheduling and spatial link adaptation. Therefore, and due to the assumed implementation margin, the resulting effective average spectral efficiency values are lower than found elsewhere.

It is important to understand, that a direct comparison of spectral efficiency values (e.g. between WINNER and legacy 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. Currently, e.g., in 3GPP LTE standardisation no clear and consistently used definition of the satisfied user criterion is available. Once such satisfied user criteria are available, this requirement will be re-considered. Furthermore exact definitions of the evaluation assumptions will be developed in the concept groups and technical work packages. This detailed technical work will be a further source for future updates of this requirement.

R5.5A, B, and C replace the peak spectral efficiency requirements of phase I [1]. It must be noted that, due to the stringent satisfied user criterion, these requirements provide a new challenge adopted for WINNER phase II even compared to the working assumptions adopted in WP2 and WP6 of phase I.

5.6 Packet flow establishment time

In WINNER, packet streams classified by QoS requirements, source and destination(s), are denoted as flows. Flows are identified at the interface of WINNER and transmitted individually according to their specific QoS requirements. For example, a real time service and a file transfer service may be mapped to different flows, thus allowing the scheduler (Service level controller) to privilege the real time service and to stay within the delay constraints of that service.

Therefore, each flow requires an individual ID and separate queue. When the first packet of a new flow arrives, the flow parameter have to generated, passed, and the flow has to be established at BS, UT and each relay node between them. The time from arrival of the first packet of a new flow at the upper layer interface of WINNER until the flow is established in WINNER and the packet is received and passed to the layer above WINNER on the peer side is denoted as packet flow establishment time. This time includes the transition of the UT from idle state (UT monitors broadcast channel and receives resource allocation information) to the active state (UT receives and / or transmits data) in the case that no other flow is transmitted.

R3.6:The packet flow establishment time shall be below 5ms.

This is a reformulated requirement from [1].

5.7 Maximum user / terminal speed

The maximum user terminal speed depends highly on the deployment scenario, service type and the radio interface constrains due to Doppler spread and shift. Regarding WINNER I and taking into account the evaluation scenarios in particular for wide area deployment scenarios and assumptions, terminal speed limit is defined as 220 Km/h. However the challenging speed limit is to allow reliable links to high-speed trains at higher velocities up to 350 Km/h also [8].

R5.7A: The terminal speed limit for evaluation assumption should be up to 350 Km/h.

This is an updated requirement from [1].

6 Spectrum requirements

6.1 WINNER spectrum range

R6.1A: The WINNER System Concept should be able to operate anywhere in range between 2.7 – 5.0 GHz. Separate bands in other spectrum ranges can be requested based on specific technical or regulatory reasons, taking into account that WINNER target characteristics have to be met.

This is a requirement maintained from phase I.

6.2 Capability to utilise current bands for cellular communication

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 / 900 MHz, 1800 / 1900 MHz, 2 GHz and 2.6 GHz frequency ranges or other frequency bands that may become available below 2.7 GHz). Such 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 will be limited.

R6.2A: The WINNER system concept has to be able to utilise current bands for cellular communication with limited performance operation.

This requirement is reformulated from phase I.

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.

R6.3A: The WINNER system concept has to be able to handle fragmented spectrum assignments efficiently.

This requirement is maintained from phase I.

6.4 Spectrum sharing between WINNER RANs

Significant advantages are expected to be obtained, especially during the network deployment phase or if there is a severe lack of spectrum, when the spectrum can be shared between multiple parallel networks, multiple 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.

R6.4A: WINNER system concept has to be able to use spectrum shared between parallel network deployments.

This is an implicit requirement updated from WINNER I.

6.5 Spectrum sharing between cell layers of a WINNER systems

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

R6.5A: WINNER system concept has to be able to use spectrum shared between cell types, e.g. between macro cells and micro cells, or between micro cells and hot spots.

R6.5A is an explicit requirement of previous WINNER phase I implicit requirement.

6.6 Spectrum sharing between WINNER and Non-WINNER systems

The frequency range below 6 GHz is currently in full use and many of the current usages cannot be re-farmed to other frequencies. Therefore WINNER system concept has to be able to share spectrum with other usage.

First, this means that no harmful interference is generated towards the Non-WINNER systems due to the deployment of a WINNER based radio access system in frequency bands adjacent or nearby to the band(s) occupied by the Non-WINNER system(s). This will require control of the emissions into the band(s) occupied by the respective Non-WINNER system(s).

Secondly, this means that a WINNER radio access system can be operated in the same frequency band(s) as a selected Non-WINNER system without causing harmful interference towards these Non-WINNER systems. This will require control of the emissions into the band(s) shared between the respective Non-WINNER system(s) and a WINNER based radio access system.

R6.6A: WINNER system must be able to share spectrum and coexist with other usage.

R6.7B: The total system bandwidth needed to fulfil the requirements should be minimised.

Requirement R6.6A is reformulated from phase I. Requirement R6.7B is maintained from phase I

6.7 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, whereby one link corresponds to uplink or downlink.

R6.7A: Maximum required bandwidth for one radio link is 100 MHz.

Reasoning behind the requirement R6.7A is further explained here. Two aspects are: the receiver channel selection filter / AGC integration, and ADC implementation. In the filter side -3 db filter bandwidth starts to be difficult to implement with basic operational amplifier methods, and the power consumption of this filter starts to increase. In the ADC side, the bit count (number of bits), bandwidth, and required maximum modulation order (depth) are dependent on each other: the larger the bandwidth, the smaller the number of bits can be with reasonable power consumption, and thus the smaller the modulation order can be. For base station this is not a problem. The required sampling rate is at least two times the bandwidth.

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 for both FDD and TDD, which means that in 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.

R6.7B: 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.

The R6.7A is maintained from phase I. In the R6.7B requirement, the bandwidth for TDD and FDD modes are presented, including the bandwidth for downlink and uplink.

7 EMF requirements

The widespread use of 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 the WINNER scope, the relevant bandwidth is 3.5 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 EMF exposure. EMF requirements have already been in the focus of WINNER I requirements [1] and permanently new regulations will be monitored.

The Specific Energy Absorption Rate (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 typically the value of SAR, because the terminal needs less power to reach the BS. The SI unit for SAR is watt per kilogram (W/Kg).

7.1 User safety

The International Commission on Non-Ionising Radio Protection (ICNIRP) works with WHO in order to establish guidelines for SAR limits and reference levels to prevent the risk of diseases, for instance, cancer, heart diseases, adverse outcomes of pregnancy, etc.

At RF, defined as 100 KHz to 300 GHz [18], the fields only penetrate a short distance into the body. 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 thermo-regulatory 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 RFs 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 [18].

As an example, an study reported reduced fertility of sperm at SARs greater or equal to 50 W/Kg, this is exposures that are much higher than the established adverse effects threshold of 4 W/Kg (see section 7.2) [20].

7.2 EMF regulation and standards

Since [1] was published, there were no relevant changes in the ICNIRP guidelines for the restrictions in RF range. The threshold for effects that are considered detrimental to health is observed at SAR of 4 W/Kg, averaged over a 6 minute time interval and over the whole body. This corresponds to a systemic temperature increase of less than 1º C at normal conditions. 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 (see [19] and [20]).

Table 7-1: Basic restrictions in RF range [1].

	General public	Workers
Whole body average SAR	0.08 W/Kg	0.4 W/Kg
Localised SAR (head and trunk) – average over 10g tissue	2 W/Kg	10 W/Kg
Localised SAR (limbs) – average over 10g tissue	4 W/Kg	20 W/Kg

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. By considering the non-uniform nature of RF energy deposition and practical measure volumes the US standards committee established a limit of 1.6 W/Kg in a 1 g cube of tissue. Based on the ability of small volumes of tissue to dissipate thermal loads the ICNIRP recommends a limit of 2 W/kg in a 10 g cube of tissue.

The EU/ICNIRP recommendation for RFs exposure is expressed in Table 7-2.

Table 7-2: Reference values for general public and workers in terms of E-field and H-field strength (2 MHz to 300 GHz) [11].

	E-field	H-field
General public	61 V/m	0.16 A/m
Workers	137 V/m	0.36 A/m

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

If the systems are used close to the head the power has to be limited. Further analysis must be done with the physical design and the frequency band of the system. As an example, at 900 MHz and 2 GHz the maximum average output power is 250 mW and 125 mW. Extrapolation is complex since the exposed tissues depend on the frequency but at higher frequency the maximum power will be below 0.1 W.

Dealing with BS the reference level 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.

In [1] and [11], some methods to reduce the exposure to EMF are presented.

All the EMF requirements are maintained from phase I, because there were no changes since [1] was delivered.

8 Conclusion

This document provides an update of the WINNER system requirements based on deliverable D7.1 of WINNER phase I [1], considering the latest developments in research, regulation, standardisation, wireless market, and industry.

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.

A so-called triple play strategy (that integrates voice, data, and broadcast) is today pursued by many wireless network operators. Services that became increasingly important during the last two years and which have impact on the air interface design include physical-context services (e.g. location-based services), VoIP, multicasting, and broadcasting. Consequently these services will be considered in the service mix of the evaluation scenarios within the WINNER concept groups and the associated performance requirements regarding data rates, and delay will receive stronger focus.

This document also provides further work in the translation process from user-centric requirements to technical assessment criteria suited for evaluations. 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., in contrast to D7.1 the new spectral efficiency requirements includes now a definition of an associated satisfied user criterion under which constraints the spectral efficiency has to be measured. This satisfied user criterion is consistent with the required data rates of the WINNER service classes. With respect to a definition used in phase I evaluations the satisfied user criterion is considerably more stringent while maintaining the same target spectral efficiencies: 95% of the users must receive an average active session throughput of 2 Mbps or more (compared to 90% of users having an average active session throughput of 500 kbps). This means that a though new challenge has been adopted for WINNER phase II.

The requirements of this document provide a framework for the challenging goals 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 – 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 virtual reality over wireless[2].

[2] It should be noted, that virtual reality services are not promoted as a candidate for future killer applications. Such evaluations and business cases are not within the scope of WINNER. Virtual reality is simply seen as an interactive ultra high multimedia service which serves as a cornerstone to be supported by the technical solution for the WINNER air interface.

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