D2.4

Requirements specification for the key enabling components

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Abstract:

This Deliverable contains the outcome of Task 2.5 "Requirements Specification for the Key Enabling Components". It specifies the requirements for the main components of SANSA such as the smart antennas, the intelligent backhaul node and the hybrid network manager by considering as underlying documents papers and reports beyond the SoTA.

Document History

Version	Date	Editor	Modification
v0.1	10/09/2015	OTE	Initial ToC, assignment of responsibilities.
V0.2	28/03/2016	OTE	Updated requirements, document
V0.3	06/04/2016	CTTC	Requirements on the antenna element.
V0.4	11/04/2016	AVA	Requirements of the antenna key enabling component
V0.5	20/4/2016	OTE, AVA	E2E architecture general requirements
V1.0	26/4/2016	OTE	Updated requirements section
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Contributors		
Name	**Company**	**Contributions include**
Dimitris Ntaikos	AIT	Executive summary, sections update
Kostas Voulgaris	AIT	Executive summary, sections update
Georgios Ziaragkas	AVA	Chapters 2, 3, 4
Georgia Poziopoulou	AVA	Chapters 2, 3, 4
Simon Watts	AVA	Quality Assurance
George Agapiou	OTE	Executive summary, chapters 1-3, Conclusions
Pantelis Argyrokastritis	OTE	Executive summary, chapters 1-3, Conclusions
Miguel Ángel Vázquez	CTTC	Chapter 4
Jose Núñez Martínez	CTTC	Chapter 5, 6
Xavier Artiga	CTTC	Chapters 4, QA
Christos Tsinos	ULUX	Chapter 4
Isaac Moreno	TASE	Chapters 5, 6
Rudolf Zetik	FRA	Chapter 4
Daniel Llorens	VIA	Chapter 4

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List of Acronyms

BN	Backhaul Node
BS	Base Station
BSS	Business Support System
eICIC	Enhanced Inter cell interference cancellation
EIRP	Effective Isotropic Radiated Power
eNB	eNodeB
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplex
FSS	Fixed Satellite Service
HNM	Hybrid Network Manager
HTS	High Throughput Satellite
IA	Interference Alignment
iBN	Intelligent Backhaul Node
KPI	Key Performance Indicator
LoS	Line of Sight
LSAS	Large Scale Antenna Systems
LTE	Long Term Evolution
MNO	Mobile Network Operator
PtMP	Point-to-MultiPoint
PtP	Point-to-Point
PTP	Precision Time Protocol
QoS	Quality of Service
R&D	Research & Development
RAN	Radio Access Network
RF	Radio Frequency
RTN	Return (channel)
SA	Smart Antenna
SINR	Signal to Interference plus Noise Ratio
SMS	Short Messaging Service
SNR	Signal to Noise Ratio
SoTA	State-of-the-Art
TDD	Time Division Duplex
UL	Uplink
WP	Work Package
XPIC	Cross Polar Interference Cancellation

Executive Summary

This deliverable D2.4 of the SANSA "Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas" project documents the outcome of Task 2.5 "Requirements Specification for the Key Enabling Components".

In particular, this deliverable describes the requirements that are driven by the scenarios, use cases and architecture design which have been presented in previous SANSA deliverables D2.2 [1] & D2.3 [2]. For this purpose, a table format is used to describe and provide a weight for each requirement.

Firstly, the end-to-end system architecture of the SANSA system is introduced; consisting of the Radio Access Network (RAN), the Core Network and the Transport Network. Then the key components of the SANSA Transport Network are also presented, including the intelligent Backhaul Node (iBN), the Hybrid Network Management (HNM) and the Satellite. This is followed by the definition of end to end architectural general requirements that are those imposed to the whole SANSA architecture. These requirements are derived from the objectives of the project SANSA but also from current and future perspectives of the mobile and satellite technologies in terms of their capabilities.

In the next section, the requirements for Smart Antennas are presented, since they are an integral part of the intelligent backhaul nodes (iBNs) and their design plays a major factor in the quality of a wireless link. The requirements that are listed in this section indicate idealistic antenna parameters for smart antennas in the envisaged SANSA system. Two lists of antenna requirements are presented. The first list is for smart antennas at nodes in dense or urban areas and the second list of requirements is related to end nodes in rural topologies.

In the following section, the requirements for the Hybrid Network Manager (HNM) are presented, since it is a crucial component of the SANSA architecture. The general requirements for the HNM are presented, followed by the specifications for the HNM.

This is followed by the presentation of the requirements for the intelligent Backhaul Node (iBN). In this section the components that have to be incorporated within the iBN are presented as a requirements list.

Finally, the conclusion section summarizes the main and significant parts of the document.

1 Introduction

The objective of this document is to describe in detail the technical requirements of the SANSA system architecture and of its key enabling components: Smart Antennas, Hybrid Network Manager and Intelligent Backhaul Node.

1.1 Organization of the deliverable

The document is structured as follows:

Chapter 2 describes the overall SANSA system architecture. This architecture has been well presented in previous documents D2.3 [2], but it is provided again for clearness purposes.

Chapter 3 describes the end to end state-of-the-art general system requirements in order to show what should be achieved by the integrated SANSA architecture.

Chapter 4 describes the requirements for the Smart Antennas.

Chapter 5 describes the requirements for the Hybrid Network Manager.

Chapter 6 describes the requirements for the Intelligent Backhaul Node.

Finally, chapter 7 concludes the document by presenting the main outcomes of the document.

1.2 Methodology followed for writing this deliverable

In this document, we have considered the SANSA architecture and its component elements from which the **general and technical** end to end requirements are derived by considering the project objectives and the requirements of current state-of-the-art mobile networks. Firstly general aspects and considerations are examined for a wireless backhaul link, for a satellite link and lastly for a hybrid terrestrial-satellite link. From this, it can be clear what currently key parameters of a network like capacity, latency, etc. can provide, in order to make it clear what advancement of SANSA key components can provide to a network. The above aspects can be used so that there can be a smooth follow up of the parameters and techniques that SANSA needs to improve. Also by considering the SANSA architecture, the requirements and specifications for the developed components in the project like HNM, iBN and smart antennas are detailed. An overview of the steps followed to derive the requirements is shown in Figure 1-1.

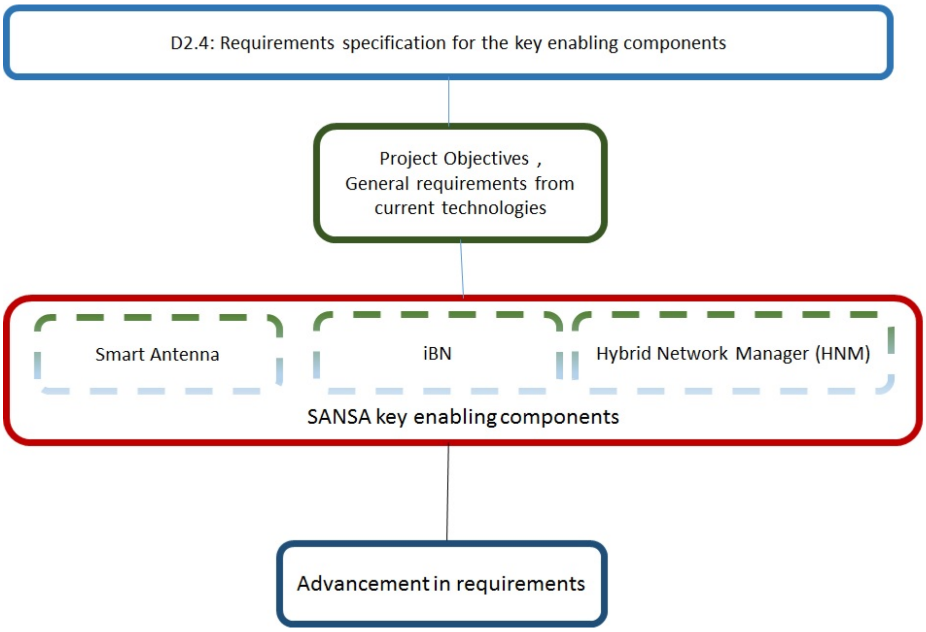

Figure 1-1: Steps followed for the advancement of requirements

The template of the table used to describe and provide a weight for each requirement is provided in the following Table 1-1.

Table 1-1: Template used for requirements definition

ID	Description
Rx.y	
Coordinates	
Weight: ***Category:*** ***Applicable To:***	

The ID Section: R refers to requirement and x.y refer to x=1, 2, 3 depending on the chapter and y=1, 2, ..., n is an index increase.

The definition of how strong the requirements may be requested, follows the wording of IETF RFC 2119 [3]:

1. **MUST:** this word in the deliverable means that the definition is an absolute requirement of the specification.
2. **MUST NOT:** this word means that the definition is not an absolute requirement of the specification.

3. **SHOULD:** this word means that it is a rather preferable that the requirement is implemented.
4. **SHOULD NOT:** this word is the negative result of bullet 3.
5. **MAY:** this word gives the option to the implementer of the requirement either to obey or nor obey the requirement.

2 End-to-End system architecture

The SANSA end-to-end system architecture has been introduced in WP2 at the deliverable D2.3 and is revisited here for clarity reasons. The goal is to highlight the key enabling components of the SANSA system for which this deliverable derives the technical requirements. The SANSA system architecture (Figure 2-1) consists of three main parts:

- **Radio Access Network:** Includes the Users Equipment (UE), the Backhaul Node(BN), and the Mobile Base Station (MBS).
- **Core Network:** The 3GPP Evolved Packet Core (EPC) is assumed with all its building blocks and signalling procedures.
- **Transport Network:** Connects the Radio Access Network with the Core Network and is the main focus of the SANSA project.

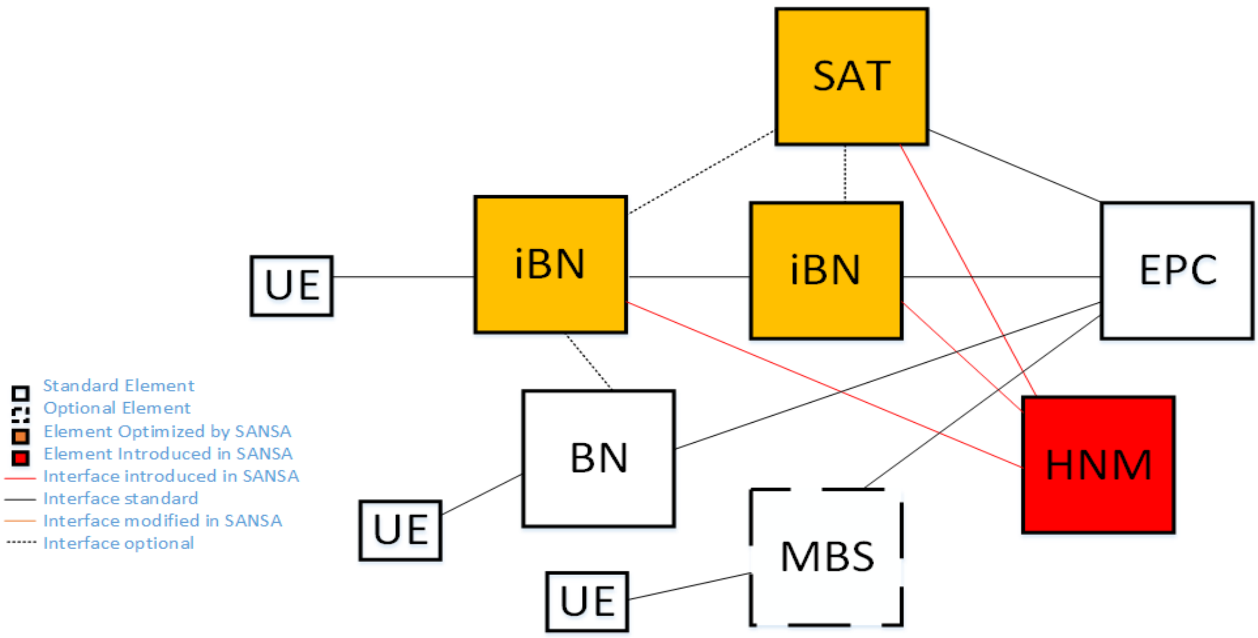

Figure 2-1: SANSA System Architecture [D2.3]

In particular, the SANSA key innovations are introduced in the transport network with the key enabling components that are illustrated in Figure 2-1; the Intelligent Backhaul Node, the Hybrid Network Management and the Satellite:

- **Intelligent Backhaul Node (iBN):** The iBN is an optimised BN that can manage backhaul satellite and terrestrial resources and embed routing, traffic classification, and energy management functions. The iBN can be connected to other iBNs and/or the EPC through radio or satellite link. The iBN is also responsible for driving the **Smart Antennas (SA)** that enable the reconfiguration of the terrestrial network topology.
- **Hybrid Network Manager (HNM):** The HNM is a new element that manages the network resources in long and medium timescales. Its main functions include configuration, events and topology management.
- **Satellite (SAT):** The SAT is an important element for the SANSA network providing improved coverage and data offloading and resilience. It connects the iBNs with the EPC and is smoothly integrated with the reconfigurable SANSA transport network.

3 General aspects/considerations

3.1 General considerations

SANSA project aims to improve the capacity, resilience and coverage of mobile backhaul networks while maximizing at the same time, their spectral and energy efficiency. Thus, the first set of requirements as mentioned before are derived from the project objectives, state-of-the-art requirements and projected requirements.

Project objectives:

1. To increase the mobile backhaul networks capacity in order to avoid the so-called "capacity crunch"
2. To drastically improve backhaul network resilience against link failures and congestion
3. To facilitate the deployment of mobile networks both in low and highly populated areas
4. To improve the spectrum efficiency in the extended Ka band for backhaul operations
5. To reduce the energy consumption of mobile backhaul networks
6. To strengthen European terrestrial and satellite operators market and their related industries

State of the Art requirements:

The requirements are basically placed on the capacity and the spectral efficiency

- Backhaul capacity
- Spectral efficiency

The relation of the above parameters to key enabling SANSA components is shown in Figure 3-1:

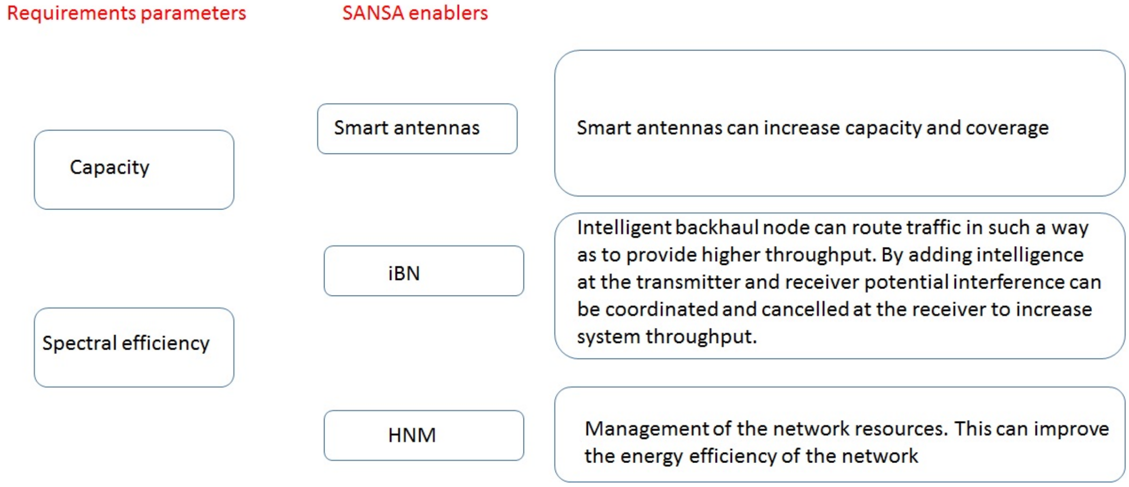

Figure 3-1: Consideration Parameters and SANSA key enablers

In order to understand the backhaul needs that the hybrid SANSA system should satisfy in terms of capacity, values that today an LTE access link can support is provided in Table 3-1 for a single access LTE link.

Table 3-1: Typical data rate values for an access LTE link today consisting of three nodes

Channel BW	Dense urban	Suburban	Rural
20 MHz	140 Mbps	80 Mbps	55 Mbps

The above values are theoretical peak values when the user terminal is very close to the access node. If the user is in the middle distance from the node, then the above data rate values fall to 50%-60%, whereas if it is close to the edge then the values fall to 20%-5% respectively for each geographical area. To backhaul these values an overbooking factor of 3-5 is used for urban to rural areas respectively for a three sector node.

3.2 End to end operator/general considerations

It has been reported in many reports that traffic levels are increasing very rapidly driven by the use of applications like video, HDTV and access to social media. Standardisation bodies like 3GPP which is the basic standardization body for 4G and even for future 5G systems, detail requirements for the access and the core domains but do not discuss requirements for packet backhaul network. The technical high level requirements are derived here from the objectives of the SANSA and also for the completeness we present general requirements that an operator would request when implementing a wireless or satellite network. From this, the advancement brought by the hybrid terrestrial-satellite SANSA architecture and the algorithms, techniques proposed to be implemented will be more obvious. Key parameters for a backhaul wireless link and a satellite link are presented in Table 3-2 and Table 3-3 respectively.

Table 3-2: Key parameters for a wireless backhaul node

Capacity	>150 Mbps	Channel size to be greater than 4x7=28 MHz, or 56 MHz and higher. Also modulation of 256 QAM should be supported. 150 Mbps is the minimum capacity that the link should support for backhauling a single access three sector link.
Coverage	At least 1 km	
Availability	99.999% - 99.99%	

Regarding the satellite technology of the hybrid SANSA architecture, it has been presented in a survey that 37% of operators consider that it is essential to provide remote broadband connectivity to rural areas [5]. This can result to the provision of new services to remote users, the economy can be flourished and the operator can gain new subscribers.

Table 3-3: Key parameters the backhaul expansion via satellite

Capacity	>150 Mbps
Latency	≤ 300 ms one way. This value has shown not to present negative impact to voice. Also no problem has presented to data browsing and video streaming.
Availability	99.9%

At last we present key parameters of a hybrid satellite-wireless backhaul network in Table 3-4.

Table 3-4: Key parameters for hybrid satellite-terrestrial architectures

		Propositions
Capacity	>500 Mbps	WBN: The link capacity (Mbps) = channel size (MHz) x spectral efficiency (bps). Use of XPIC to increase the spectral efficiency. In addition spectrally separated antennas can improve the spectral efficiency. Sat: New generation of ultra-high throughput satellites that provide greater throughput.
Latency	< current SoTA	Sat: Payload compression using LZ4 data compression algorithm or similar. Header compression using RoHCv8.1 algorithm or similar as proposed in 3GPP. TCP acceleration to be used if possible to reduce the impact of latency.

So far the current and projected short term traffic demands have been presented. The next section proposes a set of requirements to deal with those demands. Additionally, projected long term traffic demands are considered as a worst case approach for some of them.

4 Requirements for Smart Antennas

The smart antennas are an integral part of the Intelligent Backhaul Nodes (iBNs). The quality of a link is highly dependent upon their design and installation in the network of an operator.

Requirements listed in this chapter indicate idealistic antenna parameters for smart antennas in the envisaged SANSA system. These requirements do not represent hard selection criteria that must be fulfilled by antenna technologies that will be analysed in WP3. We anticipate that a realistic antenna technology can be excellent in some parameters but can fail to completely fulfil all the requirements. It is the aim of WP3 deliverables D3.3 and D3.5 to describe, analyse and select the most promising antenna technology that more or less fulfils the requirements indicated in this chapter and, at the same time, minimize the costs and complexity of the beamforming and precoding network.

There are two lists of antenna requirements. The first list is for smart antennas at nodes in dense or urban areas. These antennas have to support multiple simultaneous beams to neighbouring base stations. The distances to the neighbouring base stations are usually between 200 meters to 1400 meters in such topologies. The second set of requirements is related to end nodes in rural topologies. These nodes require usually only single beam antennas that need to cope with stronger path loss between base station that are 1 km to 20 km apart.
From the SANSA KPIs, a group of more general requirements is generated as presented in Table 4-1. These requirements are followed by more detailed specifications with regards to the antenna design and installation that is given in Table 4-2 and Table 4-3 for the end node antenna of dense areas.

4.1 General requirements of smart antennas

General requirements for the smart antennas are presented in the following Table 4-1.

Table 4-1: General requirements for the smart antennas

ID	Description
R4.1	The smart antennas must be capable of electronically steering multiple simultaneous beams (with different data streams not the multicast) in order to enable self-organization of the hybrid terrestrial network which must be able to reconfigure its topology according to the instantaneous network status.
Coordinates	
Weight: *Must* ***Category:*** *Performance* ***Applicable To:*** *Antenna Architecture*	

ID	Description

R4.2	The smart antennas must be capable to electronically steer nulls in order to mitigate potential interference to/from other terrestrial links and to/from satellite terminals.
Coordinates	
Weight: *Must* ***Category:*** *Performance* ***Applicable To:*** *Antenna Architecture*	

4.2 Smart antenna specifications

The description of each antenna specification contains a range of values for a specific design parameter as well as an explanation how these values were estimated or why they were proposed. Firstly, there is a list of requirements that are common for the dense area node as well as the end node antenna. These common specifications are followed by antenna specific requirements.

Table 4-2: Common specifications of smart antennas

ID	Description
R4.3	Operational frequencies: 17.7-19.7 GHz or 27.8-29.5 GHz These operational frequencies reflect the regulatory environment described in D2.1.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.4	Bandwidth: 500MHz - 2GHz The lower limit is the usual number for phased array instantaneous bandwidth requirement. The upper limit covers all downlink or uplink operational frequencies from R4.3
Coordinates	

Weight: *Should*
Category: *Design Parameters*
Applicable To: *Antenna Architecture*

ID	Description
R4.5	Polarization: linear or dual linear polarization The polarization reflects technical specifications of available modems.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.6	Scanning range in azimuth: 360° The scanning range in azimuth comes from the fact that the SANSA system shall be reconfigurable and shall seamlessly integrate new base stations. Therefore the scanning throughout the whole azimuth plane is necessary.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.7	Beamwidth (HPBW) is gain dependent according to: • for directive gain > 40 dBi, HPBW < 2°. • for directive gain > 35 dBi, HPBW < 3.5°. • for directive gain > 30 dBi, HPBW < 6°. • for directive gain > 25 dBi, HPBW < 11°. • for directive gain > 20 dBi, HPBW < 19°.

	The beamwidths listed above are the broadside beamwidths of uniform circular apertures of the stated gain in intervals of 5 dB. The weight of R4.7 is "Should" for two reasons. First, beamwidth is not a direct performance parameter. Beamwidth may vary when beamforming with actual performance objectives and there should not be a requirement that limits the capabilities of the beamforming. Second, minimum beamwidth at maximum gain is a physically limited parameter (an antenna of 20 dBi of equivalent aperture cannot have a beam narrower than 18°).
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.8	Pointing precision is gain dependent as follows: • For directive gain > 45 dBi, pointing precision shall be < 0.2 ° • For directive gain > 40 dBi, pointing precision shall be < 0.35 ° • For directive gain > 35 dBi, pointing precision shall be < 0.7 ° • For directive gain > 30 dBi, pointing precision shall be < 1.1 ° • For directive gain > 25 dBi, pointing precision shall be < 2 ° • For directive gain > 20 dBi, pointing precision shall be < 3.5 ° The pointing errors are selected in a way to limit the gain loss on the main beam to 0.1 dB for unshaped beams of the specified gain.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

4.2.1 Smart antenna specifications beyond the-state-of-the-art for a node in dense area

Specifications of the smart antennas installed in future dense areas where the capacity demands are considered to be very high are presented in the following Table 4-3.

Table 4-3: Specifications of smart antennas for the dense or urban area node

ID	Description
R4.9a	Number of simultaneous beams: 2 – 4 This requirement is related to the throughput that an iBN shall support on the terrestrial link. For computing this requirement we will shall consider the traffic forecasts [6] which reports that in urban areas 750 Gbps DL and 125 Gbps UL shall be supported per Km^2. Such huge data rates will be strongly supported by fiber connections and we will assume that the wireless backhaul part will only support a 10% of the aggregated traffic. Bearing this in mind, SANSA system will require to support 10 Gbps in an urban area. This number is inline with InterDigital forecast in [7] where they predict an 8.8 $Gbps/Km^2$ for wireless backhaul links. Considering an available bandwidth of 500 MHz for the terrestrial links and range of spectral efficiencies between 7 and 12 bits/Hz, the terrestrial links shall make use of 2-4 simultaneous beams for meeting the requirement. Remarkably, in short term timeline, this requirement can be reduced as the traffic demands will be exponentially lower compared to the ones described above.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.10a	Antenna gain: 19dB - 31dB The antenna gain was computed according to Gant=0.5*(SNR+Pnoise-Lpath-Ptx-2*Lcable+Lmarg), where Ptx is the transmitted power, SNR is the SNR required by 1024 QAM, Lpath is the free space path loss, Pnoise is the receiver

	sensitivity, Lcable represents losses in the cables and Lmarg is the link margin. According to the terrestrial link budget description from D2.3 [2] the following values were used: Ptx=30dBm and Pnoise=-90dBm. The SNR required for 1024QAM was set to 36dB which is an estimate (scaled) according to Huawei RTN905 modems that were identified within WP6 for the use in demonstration scenarios. The path loss used in this equation reflects usual distances in urban scenario from 200m up to 1400m for operational frequency from 17.7GHZ to 29.5GHz. The 19dB antenna gain corresponds to the link distance of 200m and operational frequencies of 17.7.GHz. The 31dB antenna gain corresponds to the link distance of 1400m and operational frequencies of 29.5.GHz. The link margin was set to 10dB
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	
ID	**Description**
R4.11a	Scanning range in elevation: 4°-26° The scanning range in elevation for the central node antenna reflects the topology of the Helsinki benchmark scenario with the lower limit of 4°. The upper limit is related to the more general case for a dense area scenario with shorter distances and antennas positioned at different heights. The scanning range of 26° allows 100m antenna height difference for the 200m link distance.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	
ID	**Description**
R4.12a	Number of nulls: 5-8 The number of nulls is proposed according to the interference analysis provided in D2.3 [2] for Vienna benchmark scenario. This analysis indicates that it is necessary to mitigate interference in the following

	cases: terrestrial link to other terrestrial links, terrestrial link to a satellite terminal and satellite terminal to a terrestrial link. The number of nulls is related to the neighbouring number of nodes. Assuming 50 nodes per km^2 and only the 10% will be connected through a wireless backhaul link, the total number of nulls will be 5. If we consider the presence of additional satellite user terminals, these can be increased up to 8.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.13a	Depth of nulls: -22dB to -55dB The depth of nulls depends on the number of interferences, the distances between the different nodes and the interference scenario. In further considerations we assume that a receiver shall maintain SINR of 27 dB for the terrestrial link and 6 dB for the satellite forward link. It was assumed that a satellite dish does not directly point the terrestrial receiver and that the side lobes of the satellite antenna pattern are at least 25dB below its main lobe. This is realistic for commercially available VSAT antennas. In what follows 3 different interference cases are described. *Case 1:* Satellite user terminal interferes with a terrestrial node. Considering the case described in Section 3.7.2.3.4 of D2.3 [2] and a single interference. In this case the received signal level (RSL) at the terrestrial receiver is -45dBm from the satellite user terminal and -68dBm from a terrestrial transmitter. Both transmitters are at 1km distance from the terrestrial receiver. In order to achieve SINR of 27dB it is necessary to mitigate the satellite signal for 50dB. Since the satellite dish does not directly point at the terrestrial receiver and its side lobe level is assumed to be at least 25dB the null depth of the terrestrial antenna pattern must be -25dB at the direction of the satellite transmitter.

	Similarly it is possible to compute the necessary interference mitigation for the satellite user terminal at the 200m distance from the terrestrial receiver. In this case the interference must be mitigated by 64dB. This refers to the null depth of -39dB. In case of 1400m the null depth must be -22dB. *Case 2: Terrestrial node interferes with a satellite user terminal.* Considering the case described in Section 3.7.2.3.6 of D2.3 [2] and a single interference. In this case the interference must be reduced for 80dB in case of the 200 m and for 64dB in case of the 1400m distance between the terrestrial transmitter and the satellite receiver. This results in null depth of -55dB and -39dB. *Case 3. Terrestrial node interferes with a terrestrial node.* Considering the case described in Section 3.7.2.3.3 of D2.3 [2], the terrestrial links feature SINR=0dB. These links require interference mitigation. In order to achieve SINR=27dB the interference must be mitigated for 27dB. In the case if only the receiver protects itself by placing a null at a corresponding angle the null depth must be -27dB. It should be taken into account that if the number of interference signals increases in all aforementioned cases, the null depth must be further increased for 10log10(Number of interferers).
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

Smart antenna specifications beyond the-state-of-the-Art for an end node at a rural environment

Specifications for the smart antenna of an end node at a rural environment are presented in Table 4-4.

Table 4-4: Specifications of smart antennas for an end node in a rural scenario

ID	Description
R4.9b	Number of simultaneous beams: 1-2 It is assumed that the end nodes usually support just one link or they can help in case of a link failure with two beams.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.10b	Antenna gain: 26dB - 42dB The antenna gain was computed according to Gant=0.5*(SNR+Pnoise-Lpath-Ptx-2*Lcable+Lmarg), where Ptx is the transmitted power, SNR is the SNR required by 1024 QAM, Lpath is the free space path loss, Pnoise is the receiver sensitivity, Lcable represents losses in the cables and Lmarg is the link margin. According to the terrestrial link budget description from D2.3 [2] the following values were used: Ptx=30dBm and Pnoise=-90dBm. The SNR required for 1024QAM was set to 36dB which is an estimate (scaled) according to Huawei RTN905 modems that were identified within WP6 for the use in demonstration scenarios. The path loss used in this equation reflects usual distances in rural scenario from 1 km up to 20km for operational frequency from 17.7GHZ to 29.5GHz. The 26dB antenna gain corresponds to the link distance of 1 km and operational frequencies of 17.7.GHz. The 42dB antenna gain corresponds to the link distance of 20 km and operational frequencies of 29.5.GHz. The link margin was set to 10dB
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	
ID	**Description**
R4.11b	Scanning range in elevation: 0.1°-10°

	The scanning range in elevation for the end node antenna indicates that the end nodes are at longer distances in rural scenarios and they do not need large scanning ranges in elevation even for antennas where the antenna heights differ for couple of tenth meters. The upper limit with 10° is for hilly scenarios and corresponds to the antenna height difference of 1000m for about 5km link distance.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	
ID	**Description**
4.12b	Number of nulls: 0-4 In case of the end node antenna, it is assumed that there are not so many neighbouring terrestrial links in a rural scenario. Thus, the number of nulls is given just by the number of satellite terminals that must be protected from terrestrial links. It was also taken into account that not all interference will be handled by null steering but by using proper radio resource management will help to mitigate interference as well.
Coordinates	
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*	

ID	Description
R4.13b	Depth of nulls: -9dB to -54dB The reasoning is the same as in the description of R4.13a. However, since in a rural scenario the distance between the backhaul nodes is higher than the dense urban case for the satellite user terminal involved interfering scenarios then the values can be relaxed 13dB which refers to longer distances between nodes in the rural scenario. In some cases this distance between the nodes can be higher than 10 km so that the above values can be relaxed

Coordinates
Weight: *Should* ***Category:*** *Design Parameters* ***Applicable To:*** *Antenna Architecture*

5 Requirements for Hybrid Network Manager

The HNM is a crucial component of the SANSA architecture as it is described in section 3 of this report. In this Section, the general requirements and more detailed specifications are derived for the HNM.

5.1 General requirements for the HNM

The general requirements for the HNM are presented in Table 5-1.3

Table 5-1: General requirements for the HNM

ID	Description
R5.1	The HNM must be valid for both rural and urban scenarios.
Coordinates	
Weight: *Must* ***Category:*** *General* ***Applicable To:*** *Architecture*	

ID	Description
R5.2	The HNM must interface with the satellite network Hub. The interface will be based on a wired infrastructure in the core network.
Coordinates	
Weight: *Must* ***Category:*** *General* ***Applicable To:*** *Architecture*	

ID	Description
R5.3	The HNM must connect with the intelligent backhaul node (iBN). The interface between the iBNs and the HNM is based on the wireless backhaul (or potential wired network in the prototype case) network between both components.
Coordinates	
Weight: *Must* ***Category:*** *General* ***Applicable To:*** *Architecture*	

ID	Description
R5.4	The HNM should be able to collect network traffic statistics from remote iBNs, such as the congestion level (i.e., queue occupancies) of each backhaul interface in an iBN.
Coordinates	
Weight: *Should* ***Category:*** *Functional* ***Applicable To:*** *Network monitoring*	

ID	Description
R5.5	The HNM should be able to collect air interface signal statistics from remote iBNs, such as the interference level.
Coordinates	
Weight: *Should* ***Category:*** *Functional* ***Applicable To:*** *Network monitoring*	

ID	Description

R5.6	The HNM should be able to register antenna/modem node status (on/off) from remote iBNs.
Coordinates	
Weight: *Should* ***Category:*** *Functional* ***Applicable To:*** *Network monitoring*	

ID	Description
R5.7	The HNM may calculate a new iBNs network topology upon link failure or traffic congestion events. This topology will depend on the network complexity (i.e., the size of the network).
Coordinates	
Weight: *May* ***Category:*** *Functional* ***Applicable To:*** *Topology management*	

ID	Description
R5.8	The HNM must command the use of satellite link for multicast transmission in case it is detected and notified by the iBN.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Topology management*	

ID	Description
R5.9	The HNM must transmit topology updates to remote iBNs and satellites through the interface formed by the terrestrial wireless backhaul or the satellite connection.
Coordinates	

Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Topology management*	

ID	Description
R5.10	The HNM must allow configuration of bandwidth occupation thresholds for the backhaul interfaces of remote iBNs.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

ID	Description
R5.11	The HNM must allow to configure general parameters of smart antennas attached to the iBNs.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

ID	Description
R5.12	The HNM must be able to configure power energy mode parameter of terrestrial modems attached to the iBNs.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

ID	Description

R5.13	The HNM must be able to configure general parameters of satellite modems attached to the iBNs, as long as the modem supports a standard protocol for those parameters.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

ID	Description
R5.14	The HNM must be able to configure general parameters of the satellite Hub hosting the satellite links used by the iBNs.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

ID	Description
R5.15	The HNM must have means for querying the iBNs about the status of its links (e.g., ON, OFF)
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Configuration management*	

5.2 Specifications for the HNM

This chapter describes some specifications that the HNM should satisfy. These are presented in Table 5-2.

Table 5-2: Specifications for the HNM

ID	Description
R5.16	The HNM must support up to four terrestrial beams per iBN.
Coordinates	
Weight: *Must* ***Category:*** *General* ***Applicable To:*** *Dimensioning*	

ID	Description
R5.17	The HNM must support up to 1 satellite beam per iBN.
Coordinates	
Weight: *Must* ***Category:*** *General* ***Applicable To:*** *Dimensioning*	

6 Requirements for the intelligent Backhaul Node (iBN)

The intelligent Backhaul Node (iBN) is the component that implements the SANSA network on the ground at a node level. It interacts with the HNM in order to communicate the status of the nodes and implement the HNM decisions at a node level. This interaction imposes requirements that need to be satisfied by the iBN.

ID	Description
R6.1	The iBN must include the HeNB and a transport network layer stack.
Coordinates	
Weight: *Must* ***Category:*** *Technical* ***Applicable To:*** *Architecture*	

ID	Description
R6.2	The iBN must include the routing and load balancing algorithm based on backpressure that improves SoA single path routing protocols whenever there is enough redundancy in the network (e.g., around 30% of aggregated throughput improvements).
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Architecture*	
ID	**Description**
R6.4	The iBN should include a mechanism for classifying traffic and priority between different services.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Architecture*	

ID	Description
R6.5	The iBN must include the Energy Efficiency function which is in charge of controlling access and backhaul energy consumption based on reinforcement learning, aiming at reducing by a 30% energy consumption while satisfying traffic demands.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Architecture*	

ID	Description

R6.5	The iBN may include up to four terrestrial modems
Coordinates	
Weight: *May* ***Category:*** *General* ***Applicable To:*** *Architecture*	

ID	Description
R6.6	The iBN may include up to one satellite modem. The importance of the satellite modem is increased under rural deployments. In urban deployments iBN may not employ a satellite modem.
Coordinates	
Weight: *May* ***Category:*** *General* ***Applicable To:*** *Architecture*	

ID	Description
R6.7	The iBN must interface the beamforming network of the smart antenna.
Coordinates	
Weight: *Must* ***Category:*** *Functional* ***Applicable To:*** *Architecture*	

7 Conclusions

The objective of this deliverable was to describe the requirements and specifications for the key enabling components of the SANSA system, namely, the Smart Antennas, the Hybrid Network Manager (HNM) and the intelligent Backhaul Nodes (iBNs). General aspects and considerations of key network parameters for a wireless backhaul, satellite and a hybrid network are discussed for the sake of completeness but also for the provision of a smooth transition of the capabilities of current technology to the hybrid one proposed by SANSA. This provides a smooth transition of what the key enabling components of the SANSA system should satisfy in order to be able to improve the capacity, resilience and coverage of mobile backhaul networks and to maximize the energy efficiency at the same time.

The projected requirements show that SANSA can play a significant role in backhauling traffic from future mobile networks. It is challenging for the architecture to satisfy the stringent requirements that have been proposed by 5GPPP forum but these systems will exist in 5-10 years from now according to what the history has shown in the advancement of mobile technologies.

The SANSA project foresees that the advancement techniques on smart antennas, the new interference cancellation algorithms, especially when the same frequency is used for the satellite and the terrestrial components, and the developed advanced routing algorithms depict that the desired improvement in the capacity and energy efficiency can be achieved.

8 References

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