SMART ANTENNA & RADIO FOR ACCESS AND BACKHAUL FOR ADVANCED NETWORK NODES

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ABSTRACT

This deliverable provides a report of the standardization and regulation activities within the project. In this first version of this document, standardization organizations related to SARABAND topics are described with their associated and most interesting standards. Moreover, the potential contributions that the project can provide to the standardization bodies are detailed and finally the standardization activities performed during the first years of the project are summarized.

KEYWORD LIST

Standardization, multipoint systems, frequency band 40,5 GHz to 43,5 GHz.

EXECUTIVE SUMMARY

SARABAND project will follow carefully all relevant EU norms and international standards and will contribute to their further development. In particular, it is the goal of SARABAND to contribute to the standards dealing with Q-band and the definition and development of broadband wireless access networks.

The objective of the present deliverable is to provide a report of the SARABAND contributions to the standardization bodies. In this deliverable we present an overview of the standards relevant for SARABAND activities and the possible contribution areas. Moreover, we also describe the current and planned contributions of SARABAND to the working groups of different standardization bodies, such as ETSI ATTM and IEEE 802.16. In particular, different areas of standardization have been identified such as those related to the ETSI standards EN 301 997 and EN 301 215.

The document is organized as follows. In Section 1 we briefly describe the bodies which are focused on standardization areas relevant for the SARABAND project. Areas of standardization where SARABAND could contribute are mentioned in Section 2. Section 3 describes the activities and the current contributions of SARABAND to the standards, including the participation in the elaboration of the ECC Report 173, the proposal for the update of the standards EN 301 997 and EN 301 215, and other standardization activities inside the NGMN and Small Cell Forum. Finally in Section 4 we briefly describe the planned standardization activities until the end of the project.

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LIST OF ABBREVIATIONS

AP	Access Point
AT	Access Termination
ATPC	Automatic Transmit Power Control
ATTM	Access, Terminals, Transmission and Multiplexing
BEM	Block Edge Mask
BRAN	Broadband Radio Access Networks
BS	Broadcasting Service
BWA	Broadband Wireless Access
CEPT	European Conference of Postal and Telecommunications Administrations
CERP	European Committee for Postal Regulation
Com-ITU	Committee for ITU Policy
CPE	Customer Premises Equipment
CS	Central Station
DAS	Distributed Antenna System
DLC	Data Link Control
EC	European Commission
ECC	Electronic Communications Committee
ECO	European Central Office
EIRP	Equivalent Isotropically Radiated Power
EMC	Electromagnetic compatibility
ETSI	European Telecommunications Standards Institute
EU	European Union
Fc	Cut-off frequency
FDD	Frequency Division Duplexing
FS	Fixed Service
FWA	Fixed Wireless Access
Gbps	Gigabit per second
GSM	Global System for Mobile communications
ICT	Information and Communications Technologies
ISO	International Organization for Standardization
ITU	International Telecommunication Union
HA	HiperACCESS
HetNet	Heterogeneous Network
IEEE	Institute of Electrical and Electronics Engineers
IEEE-SA	IEEE Standard Association
IPR	Intellectual Property Rights
ISG	Industry Specification Group
LAN	Local Area Network
LTE	Long Term Evolution
MAC	Medium Access Control
MAN	Metropolitan Area Network
MP	Multipoint
MWS	Multimedia Wireless Systems
NNI	Network Node Interface
OMNI	Open Mobile Network Interface
PAN	Personal Area Network
PHY	Physical layer

PMP	Point to Multipoint
ppm	parts per million
PSTN	Public Switched Telephone Network
PtP	Point to Point
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
RPE	Radiation pattern envelope
RS	Repeater Station
RTPC	Remote Transmit Power Control
SCB	Small Cell Backhaul
SG	Study Group
SNI	Service Node Interface
SON	Self-Organizing Network
Std	Standard
TC	Technical Committees
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TS	Terminal Station
Tx	Transmitter
UMTS	Universal Mobile Telecommunications System
UNI	User Network Interface
VSWR	Voltage Standing Wave Ratio
WG	Working Group
WP	Work Package

1. Standardization bodies and relevant standardization activities

In this section we briefly describe the bodies which are focused on standardization areas relevant for the SARABAND project. Among available initiatives, associations, consortia, etc. which are active in different fields of standardization, in SARABAND we are mainly focused on the following ones: CEPT Electronic Communications Committee (ECC), the European Telecommunications Standards Institute (ETSI), and the IEEE Standards Association (IEEE-SA). The CEPT ECC is relevant for SARABAND as the organization which harmonizes the use of the radio spectrum, in particular the use of the Q-band. The ETSI is relevant as the source of several standards in the Q-band such as the EN 301 997, EN 301 215, and HiperACCESS. Finally, IEEE is active in the field of Broadband Wireless Access and is of interest for the SARABAND project, too. Additional details for these three standardization bodies mentioned above and the on-going standardisation activities are provided in following sub-sections.

1.1. CEPT– Electronic Communications Committee

The European Conference of Postal and Telecommunications Administrations (CEPT) is an organization where policy makers and regulators from 48 countries across Europe collaborate to harmonize telecommunication, radio spectrum, and postal regulations to improve efficiency and co-ordination for the benefit of European society [1]. The CEPT conducts its work through three autonomous business committees:

- The **Electronic Communications Committee** (ECC), which develops common policies and regulations in electronic communications for Europe, and is a focal point for information on spectrum use. Its primary objective is to harmonize the efficient use of the radio spectrum, satellite orbits and numbering resources across Europe. It takes an active role at the international level, preparing common European proposals to represent European interests in international organizations, especially in the ITU.
- The **Committee for ITU Policy** (Com-ITU), which is responsible for organizing the CEPT’s engagement with the ITU for all activities except World Radiocommunication Conferences.
- The **European Committee for Postal Regulation** (CERP), which is responsible for postal regulation and European co-ordination and preparation for Universal Postal Union meetings.

Of certain interest for the SARABAND project is the ECC Committee since it carries out expert regulatory and technical studies on electronic communications activities and provides ‘Decisions’ and ‘Recommendations’ on major harmonization issues [2]. The ECC itself is supported by Working Groups (WG) and Project Teams as shown in Figure 1.

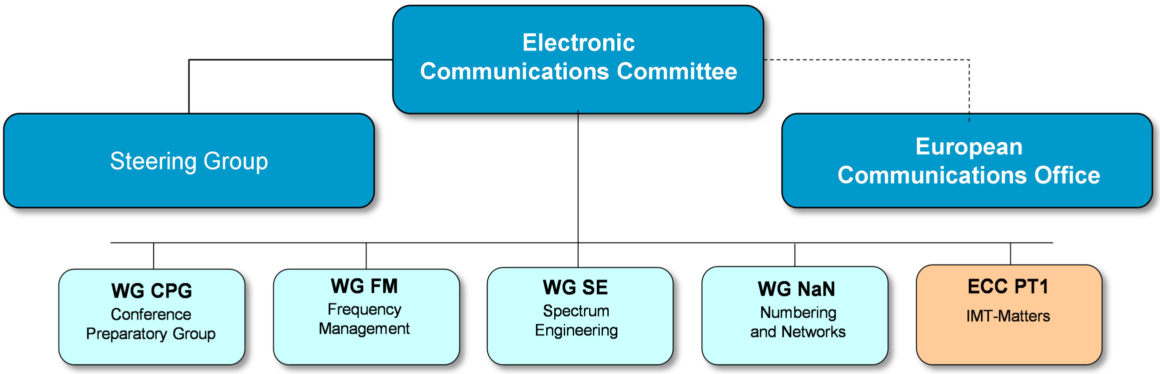

Figure 1. ECC Working Groups and Project Teams

Among these WGs, SARABAND is related to the WG focused on Spectrum Engineering (SE), which is responsible for developing technical guidelines and sharing and compatibility arrangements for radio spectrum use by various radiocommunications services using the same or different frequency bands respectively. In the frame of this WG, some work has been focused on the designation of the harmonized frequency band 40,5 to 43,5 GHz for the introduction of Multimedia Wireless Systems (MWS) and point to point (PtP) Fixed Wireless Systems, resulting in the ERC Decision ERC/DEC/(99)15 [3]. To better cope with national market demand, this decision envisages the following options for the long-term use of the 40,5 – 43,5 GHz band:

- Mixed and flexible use of different systems (e.g. point to point, point to multipoint and multipoint to multipoint systems with both FDD and TDD) using block assignment with "Block Edge Mask (BEM) methodology" within the band;
- Use of channel arrangement for the deployment of point to point systems by conventional "link by link assignment";
- Flexible band segmentation for the use of both of the above assignment methodologies.

In order to support the mix of technologies and services to be delivered this decision recommends the assignment of a block (or blocks) of spectrum to a potential operator in a manner consistent with the technology and market that the operator may wish to address. It is a requirement of the block assignment process, detailed in revised ECC/REC/(01)04 [4], that systems supporting both symmetric and asymmetric traffic are accommodated as well as systems that employ FDD and TDD techniques. No presumption is made regarding the architecture of any MWS network or PtP Fixed Wireless Systems within the blocks. This assignment process will be explained in more detail in section 1.1.1.

Additionally, the WG SE has a section focused on fixed service (SE 19), in which point to point and point to multipoint (PMP) architectures in higher frequencies bands such as the 42 GHz band are considered. More details are provided in section 1.1.2.

1.1.1. ECC RECOMMENDATION (01)04 – ECC/REC/(01)04

Multimedia Wireless Systems in the Q-band have been defined in the ERC Decision ERC/DEC/(99)15 as terrestrial multipoint systems which have their origin in telecommunication and/or broadcasting, and which provide fixed wireless access direct to the end user for multimedia services. This term has been introduced to cater for the phenomena of convergence between terrestrial fixed service (FS) and broadcasting service (BS) applications, whereby distributors of entertainment services (broadcasters) are wishing to provide interactive services and telecommunications operators are wishing to supply broader band services to wider markets. Therefore MWS are wireless systems which support information exchange of more than one type, such as text, graphics, voice, sound, image, data and video.

The standardization work for MWS was completed in 2002; however, as access networks need considerable high capacity, typically PtP, this frequency band has been also adopted for PtP fixed wireless systems. Therefore, to allow administrators to adopt mixed and flexible use of different technologies, for both fixed MWS and for PtP links within the band, the ECC/REC/(01)04 recommends:

- Create block assignments based upon an aggregation of frequency slots and assign such blocks in a manner that might assist future expansion of successful services.
- Consider the radio frequency channel arrangement proposed in the document for conventional coordinated deployment of PtP links.
- Adopt a flexible use of the band for both assignment methodologies, blocks of frequency and assigned PtP links.
- Fulfill the maximum allowed EIRP density and block-edge requirements defined in the recommendation to allow flexibility in the choice of system technology, without the need for specific co-ordination between operators assigned adjacent frequency blocks.

In particular, the SARABAND project uses large blocks of contiguous spectrum at the Q-band and wide TDD channels to deliver high capacity fixed wireless data services, following the frequency block assignment plan proposed in this recommendation. The allocation plan consists of 3000 adjacent 1 MHz slots starting at 40,5 GHz, as shown in Figure 2. Any number of these slots may be aggregated to form a block assignment.

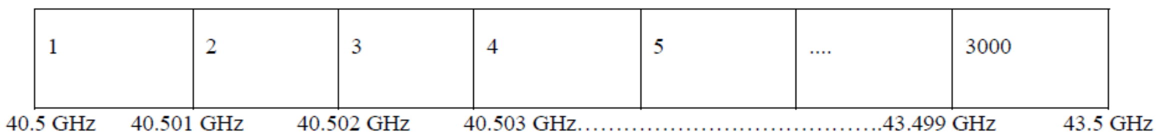

Figure 2. Basic frequency allocation plan granularity based on 1 MHz slots

Moreover, the assigned blocks would contain a channelization scheme defined by the operator according to the actual technologies adopted. The diagram in Figure 3 illustrates the relationship between elements of the frequency plan consisting of frequency slots, operator assigned blocks, technology specific channelization and guard bands.

Following these guidelines, SARABAND system equipment uses a 1-GHz wide transmitter that can be loaded with 25 channels (nominally 40 MHz wide) in a manner that a base station can be configured to use as little as 40 MHz or all 3 GHz (@ 40 GHz using 3 transmitters fully loaded) to deliver high capacity links.

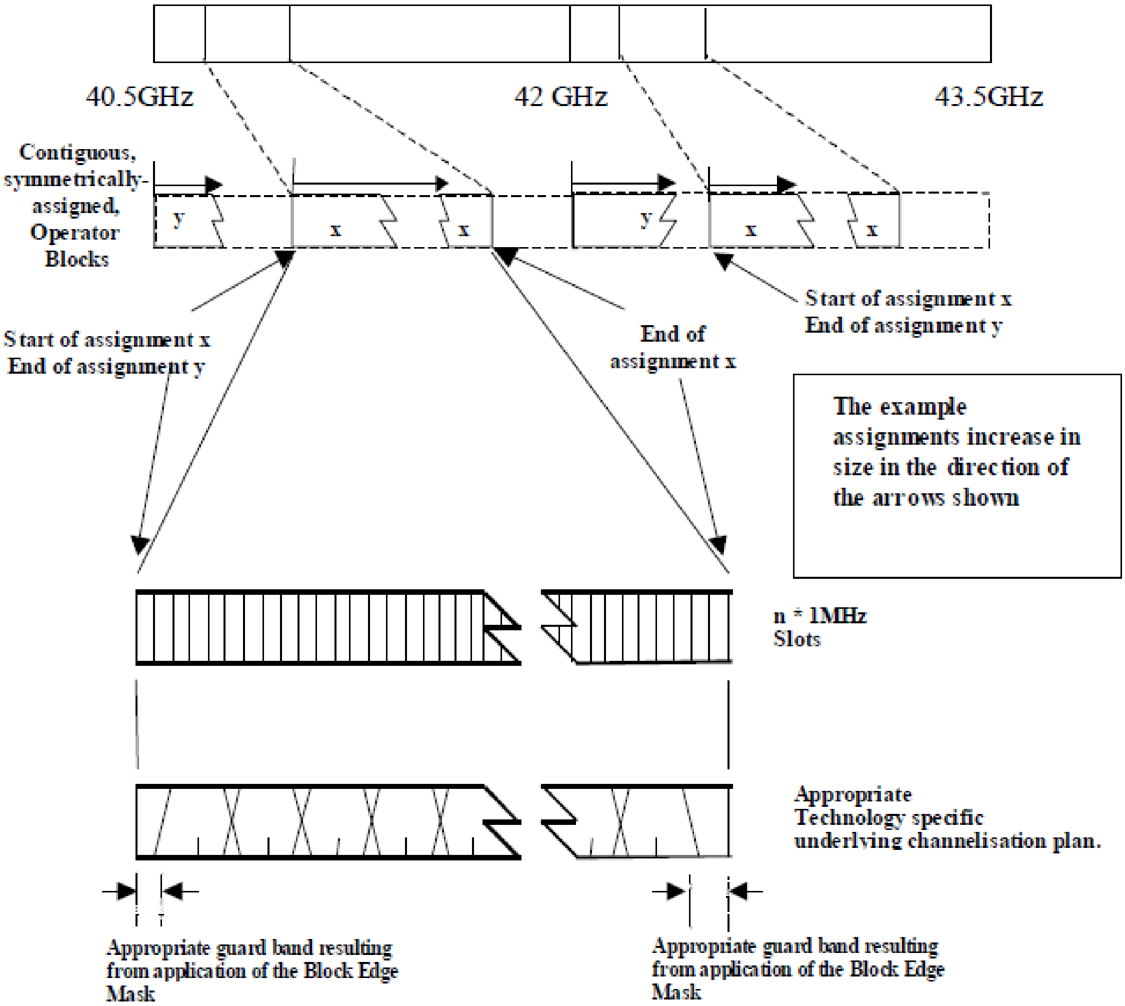

Figure 3. Frequency plan elements

1.1.2. SE19 - Fixed Service

The Fixed Service is and remains a key service for telecommunication infrastructure development. Fixed radio links provide a transmission path between two or more fixed points for provision of telecommunication services, such as voice, data or video transmission. Typical user sectors for fixed links are telecom operators (mobile network infrastructure or backhaul, fixed/mobile network backbone links), corporate users (private data networks, connection of remote premises) and private users (customer access to PSTN or other networks).

Fixed radio links, instead of cable and fiber, are often the preferred solution where constraints such as cost, local topography (e.g., mountainous terrain or paths across water) and the need for access to remote rural regions are fundamental considerations. In many such cases fixed radio links are the only practical solution. Additionally, in today’s competitive environment the ability to further roll out a network rapidly by using radio as transmission media provides an operator with the flexibility to install and scale transmission paths as and when required. This is particularly important as it allows the possibility to reduce and better distribute the required investments, by testing the service and directing revenues as they appear into further development of a network where most use occurs.

Given the benefits of the fixed service, since 1997, the CEPT has provided public information to present a picture of the FS deployment in Europe with the intention to use it as a reference and for guidance purposes for administrations, operators and manufacturers. The working Group SE 19 is the responsible for this task [5]. Other responsibilities of this WG are:

- To prepare harmonized frequency plans and guidelines for introducing novel broadband applications in the fixed service.
- To study developments in new FS technologies.
- To study compatibility/sharing issues involving traditional FS (such as radio relay links) as well as broadband FS applications.
- To contribute to ETSI ATTM/TM4 in accordance with the CEPT/ETSI MoU.

Within this WG, in 2010, the ECC decided to start the edition of a new report as an updated version of the ECC Report 003 (published in 2002), in order to verify the assumptions of the previous studies and to collect updated information on the number of fixed links for each band in CEPT countries. This report (ECC Report 173) gives the evidence that the current trends in the FS market place are for an ever increasing provision of high bandwidth capacity for the mobile networks infrastructures [6]. These very high capacity links are able to provide a viable alternative to deploying fiber optic especially in rural areas but equally in high density urban areas.

As a consequence, the report highlights the strategic importance of some frequency bands for the FS. Some of these bands have already started to show a rapid growth in terms of number of links (13 GHz, 15 GHz, 18 GHz, 23 GHz, 38 GHz), and on which special attention from administrations should be taken; while others are still preparing to take off (32 GHz, 42 GHz, 50 GHz, 70/80 GHz, 92 GHz). This report highlights also the fact that the CEPT proactively responds to the industry demand for efficient usage in the new millimetric wave bands with a set of new or revised recommendations.

Regarding the assignment procedures used, the responses show that for PtP links the most used method foresees conventional link-by-link license and centralized coordination. However, assignment/auction of frequency blocks in certain bands becomes also popular; this is particularly true when also PMP (or, in some cases, even mixed FS and other telecommunication service) are permitted.

Note that Bluwan participated in the elaboration of the ECC Report 173, as will be explained in 3.1.

1.2. ETSI

The European Telecommunications Standards Institute (ETSI) produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, roadcast and internet technologies [7]. ETSI is officially recognized by the European Union (EU) as a European Standards Organization.

Founded initially to serve European needs, ETSI has become highly-respected as a producer of technical standards for worldwide use. ETSI is a not-for-profit organization with more than 700 ETSI member organizations drawn from 62 countries across 5 continents world-wide.

ETSI has recently introduced the 'cluster' concept to provide a simplified, yet comprehensive, introduction to its activities in the standardization of ICT Technologies (ICT). This new approach facilitates access to ETSI's diverse work, enabling the identification of areas of interest based on business relevance or application domain rather than purely on technical work areas.

Each cluster represents a major component of a global ICT architecture and covers the work of a number of Technical Committees (TCs) and Working Groups (WGs) that share a common technological scope and vision, as shown in Figure 4. The work of a single Technical Committee may be represented in several clusters.

Figure 4. ETSI Clusters

Among the different clusters, ‘Wireless Systems cluster’ is relevant for the SARABAND project since it deals with Broadband Wireless Access (BWA) technologies, which provide broadband data access by wireless means to consumer and business markets [8]. Such technologies are an attractive option to operators in areas that do not have a wired access network available. Savings in speed of deployment and in installation costs will ensure that interest in BWA Standards continues.

Broadband Wireless Access includes a large variety of radio technologies and corresponding services therefore several ETSI technical committees are active in this area, among which the TC ATTM (Access, Terminals, Transmission and Multiplexing) and TC BRAN (Broadband Radio Access Networks) can be highlighted for SARABAND interest. The work performed in the frame of these TCs will be explained in the following sub-sections.

1.2.1. Access, Terminals, Transmission and Multiplexing (ATTM)

The Technical Committee ATTM is responsible for the standardization of access, terminals, transmission and multiplexing, including cabling, installations, signal transmission and other forms of signal treatment up to digitalization in the private and public domains, focusing on the specific technology, equipment, installations and regulatory aspects of the physical layer [9]. Therefore, TC ATTM mainly addresses the operational and physical parts of ICT Technologies – the three lowest layers, as defined by the International Organization for Standardization (ISO) [10].

TC ATTM consists of three Working Groups: WG AT2 (Infrastructure, Physical Networks & Communication Systems), WG TM4 (Fixed Radio Systems) and WG TM6 (Wireline Access Network Systems). The SARABAND project is interested in the WG TM4, which is responsible for:

- Specifications for point to point and multipoint radio systems, in the fixed service used in core and access networks, covering all equipment aspects including antenna parameters.
- Functional requirements for radio-frequency equipment interface, including allocation of overhead.
- Co-operation and technical support towards ECC SE19 for channel arrangements and improved spectrum usage in the frequency bands allocated to fixed service.

New frequency bands are still being designated for the use of fixed radio links, so the need for a harmonized approach with regard to standardization is required in such cases. Actually, these specifications address many frequency bands, e.g. 38 GHz and 65 GHz for point to point radio systems and 3,5 GHz, 10 GHz and 26 GHz for multipoint radio systems. In particular, TC ATTM has also worked on several standards in the Q-band (40,5 GHz – 43,5 GHz) such as the EN 301 997 and the EN 301 215, which are relevant for the SARABAND project.

1.2.1.1. EN 301 997

This standard applies to Multimedia Wireless Systems in the Q-band, which operate in block assignments, according to ECC Recommendation (01)04. These systems have a multipoint (MP) topology, in which user traffic flows to and from points of connection with external networks to the user terminal equipment interface(s). The MWS may behave as an access network, a broadcast network or combine the two. The general system architecture is shown in Figure 5, where the system elements and interfaces for different types of MP system are included. The numbers of each type of station in a real deployment can vary considerably.

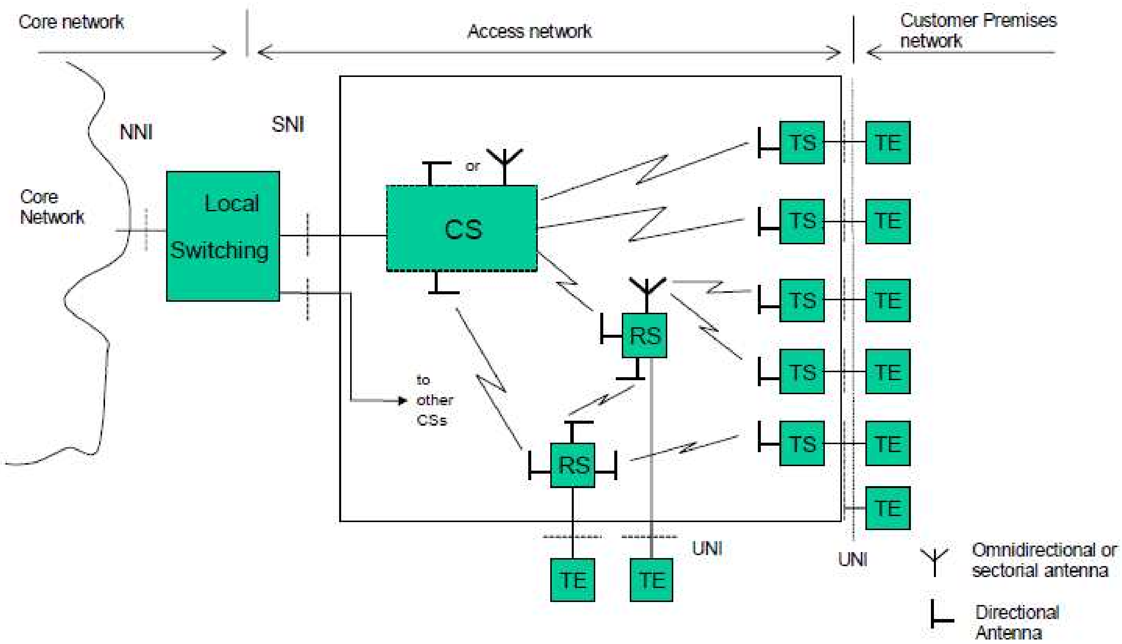

Figure 5. Reference diagram (CS: central station; RS: repeater station, TS: terminal station, TE: terminal equipment, UNI: user network interface, SNI: service node interface, NNI: network node interface)

The standard EN 301 997 specifies the minimum requirements for equipment and the parameters of MWS systems operating in this frequency band for a range of applications (telecommunication and entertainment services). The EN 301 997 has two parts, as shown in Table 1.

Table 1. EN 301 997 description

EN 301 997	
Part	Subject
EN 301 997-1	Multipoint equipment; Radio Equipment for use in Multimedia Wireless Systems (MWS) in the frequency band 40.5 to 43.5 GHz; Part 1: General requirements
EN 301 997-2	Multipoint equipment; Radio Equipment for use in Multimedia Wireless Systems (MWS) in the frequency band 40.5 to 43.5 GHz; Part 2: Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive

In particular, the standard **EN 301 997-1** [11] specifies the general parameters for the network equipment:

- Environmental conditions, as defined in EN 300 019 [12].
- Power supply interface in accordance with EN 60950 [13].
- EMC conditions, as specified in EN 300 385 [14].
- Synchronization of interface bit rates according to ITU-T Recommendation G.810 [15].
- Antenna/feeder/branching requirements. An MWS may employ directional, sectored and omni-directional antenna types. The choice depends on the system configuration and type of station (see Figure 5). The antenna characteristics are specified in EN 301 215-3 [16].
- System parameters such as system capacity, round trip delay, voice coding, RF block diagram.
- Transmitter characteristics, including output power, power control, remote frequency control, RF spectrum mask, spurious emissions, RF tolerance.
- Receiver characteristics.
- System performances.

On the other hand, the **EN 301 997-2** [17] includes those parameters considered to be essential under article 3.2 of the Directive1999/5/EC. A range of antenna and equipment types and corresponding test methods are covered by this standard, namely:

- Environmental specifications and tests.
- Radio-frequency range for which specifications and tests for equipment are applicable (Radio equipment and Antennas for MWS).
- Multi-rate/multi-format covering equipment specification and tests.
- Transmitting phenomena, including frequency error/stability, transmitter maximum EIRP density limit, adjacent channel power (EIRP density mask), and spurious emissions.
- Directional phenomena, including off-axis EIRP density (radiation pattern envelope), and antennas gain.
- Receiving phenomena.

1.2.1.2. EN 301 215

This standard specifies the essential electrical requirements for linear polarization, fixed-beam antennas to be utilized with new PMP systems, including central station and terminal station applications, which operate in frequency bands from 11 GHz to 60 GHz. Table 2 summarizes the essential parts of the standard, being the part 3 focused on the Q-band.

Table 2. EN 301 215 description

EN 301 215	
Part	Subject
EN 301 215-1	Fixed Radio Systems; Point to Multipoint Antennas; Antennas for PMP fixed radio systems in the 11 GHz to 60 GHz band; Part 1: General aspects
EN 301 215-2	Fixed Radio Systems; Point to Multipoint Antennas; Antennas for PMP fixed radio systems in the 11 GHz to 60 GHz band; Part 2: 24 GHz to 30 GHz
EN 301 215-3	Fixed Radio Systems; Point to Multipoint Antennas; Antennas for PMP fixed radio systems in the 11 GHz to 60 GHz band; Part 3: Multipoint Multimedia Wireless System in 40.5 GHz to 43.5 GHz
EN 301 215-4	Fixed Radio Systems; Point to Multipoint Antennas; Antennas for PMP fixed radio systems in the 11 GHz to 60 GHz band; Part 4: 30 GHz to 40,5 GHz

The part 1 of this standard, **EN 301 215-1** [18], gives general information about electrical parameters of the antennas comprising the PMP fixed radio systems. Namely, the standard addresses fixed-beam antennas used in the central and terminal stations including repeaters, as shown in Figure 5. These antennas shall be grouped into the following types:

- Central and Repeater Stations:
  - Omni-directional
  - Sectored
  - Directional as per Terminal Stations
- Terminal Stations:
  - Directional

Concerning the electrical characteristics, the radiation pattern envelope (RPE) and gain define the antenna type and class. Moreover, a 0° reference direction shall be defined for each antenna as all the radiation parameters are referred to this reference. This standard specifies the maximum co-polar and cross-polar radiation patterns for both azimuth and elevation.

Concerning the mechanical characteristics, the standard defines the environmental conditions under which the antennas should operate.

Other parameters detailed in the standard are the antenna input connectors, the VSWR at the input ports, inter-port isolation, passive intermodulation performance, among others.

The part 3 of this standard, **EN 301 215-3** [16], is focused on the definition of the antenna parameters in the Q-band. In particular, the following electrical parameters are specified:

- TS radiation pattern envelope.
- TS and CS minimum antenna boresight gain.
- CS azimuth radiation pattern envelopes, sectored.
- CS sectored elevation RPEs.
- The minimum nominal gain, gain ripple, cross-polar discrimination, and elevation RPE for CS omnidirectional antennas.
- Polarization, terminal station and central station antennas.

1.2.2. Broadband Radio Access Networks (BRAN)

In response to growing market demand for low-cost, high-capacity radio links, ETSI established a standardization project for Broadband Radio Access Networks (BRAN) in the spring of 1997, which was turned into an ETSI Technical Committee later on. So ETSI TC BRAN is the successor of the former Sub-Technical Committee RES10 which developed the HIPERLAN/1 specifications. Since then ETSI TC BRAN produces standards and specifications for various BWA technologies in various frequency ranges.

The aim of the BRAN Project is to develop standards for a new generation of service independent broadband radio access networks and systems using licensed and license-exempt spectrum [19]. In particular, TC BRAN has developed a family of high performance radio standards:

- **HiperLAN** (High Performance Local Area Networks), which is a short-range variant of a broadband radio access network and is intended for complementary access mechanism for UMTS systems as well as for private use as a wireless LAN type system.
- **HiperACCESS** (High Performance Access Networks), which is a fixed wireless broadband access network operating above 11 GHz.
- **HiperMAN** (High Performance Metropolitan Area Networks), which is principally for provision of broadband Wireless DSL, while covering a large geographic area. The standardization focuses on broadband solutions optimized for access in frequency bands below 11 GHz.

The primary focus of the work carried out in the above competence areas is on the standardization of the lower layers whereas core network, user and service issues and higher layer protocol aspects are not part of the prime work areas of BRAN.

TC BRAN closely follows the standardization work in other bodies, and maintains active liaison arrangements with several external bodies as required for on-going work. This applies notably to the ITU-R, IEEE 802.11 and 802.16 committees, and TC TM4 (which provides the coexistence part of the specification for HiperACCESS). Additionally, TC BRAN recognizes the potential of HiperACCESS as a Multimedia Wireless System and the value of the on-going CEPT work regarding MWS which has already resulted in the ERC Decision for MWS in the 40,5GHz to 43,5GHz band. Due to the correlation with the SARABAND project, HiperACCESS standard will be explained in section 1.2.2.1.

1.2.2.1. HiperACCESS

HiperACCESS is intended for point to multipoint, high-speed (up to 120 Mb/s) and high-QoS fixed wireless access. One of the most important applications is backhauling within cellular networks like GSM and UMTS [20]. Other applications include broadband access for residential and small business users to a wide variety of networks including IP-based core networks. Actually, HiperACCESS systems could be a choice for the provision of Fixed Wireless Access (FWA) applications in frequency bands in the range of 3-60GHz. The BRAN HiperACCESS group has chosen to focus on systems in the band 40,5GHz to 43,5GHz. This choice is consistent with the ERC Decision mentioned above, the ERC Recommendation on preferred frequency bands for FWA and the work item within ETSI TM4 regarding coexistence parameters for MWS in the Q-band.

HiperACCESS (HA) network deployments potentially cover large areas (i.e., cities). Due to large capacity requirements of the network, millimeter wave spectrum is used hence limiting transmission ranges to a few kilometers. A typical network therefore consists of some number of cells, each covering part of the designated deployment area. Each cell operates, in a PMP manner, where an Access Point (AP) equipment device located approximately at the cell center, communicates with a number of fixed positioned Access Termination (AT) devices (also known as Terminal or Subscriber Equipment) which are spread within the cell.

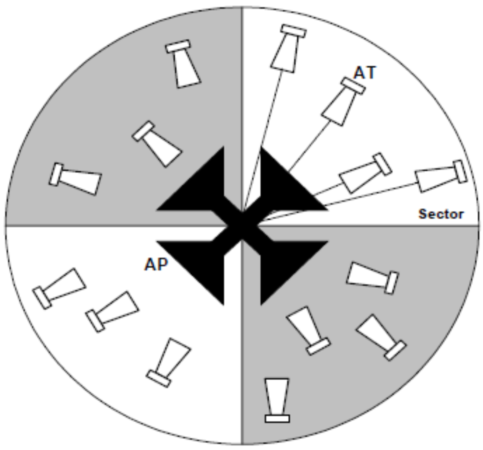

Figure 6. Example of cellular configuration (4 x 90° sectors)

A cell is partitioned into a small number of sectors (i.e. 4) by using sector azimuth patterned antennas at the AP, increasing spectrum efficiency by the possibility of re-using available RF channels in a systematic manner within the deployment region. It is emphasized that more than one subscriber within the sector may share a RF channel assigned to a specific sector. Sharing of the link leads to increased spectrum efficiency due to statistical multiplex capacity gain hence PMP is the superior choice for HiperACCESS.

As the communication channel between the AP and ATs is bi-directional, downlink (AP to AT direction) and uplink (AT to AP direction) paths must be established utilizing the spectrum resource available to the operator. Two duplex schemes are available, one is frequency domain based and one is time domain based. Moreover, time division multiple access (TDMA) is selected as multiple access method.

Based on these requirements and channel characteristics, the architecture of the HA physical layer (PHY) is determined mainly by the following features:

- Single carrier transmission.
- Adaptive coding and modulation.
- Adaptive power control mechanism.
- Adaptive load leveling.

- Support of different duplex schemes.
- Cell sectorization.

Apart from the definition of the PHY layer, HiperACCESS provides specifications for the data link control (DLC) layer and interworking functions as well as the relevant documents for regulatory compliance and protocol conformance. In case of the PHY layer, the project develops coexistence specifications and interoperability specifications. For the DLC layer and for the convergence sub-layers, coexistence is not an issue and only interoperability is specified. The specifications for network management functions include the managed objects needed to perform remote management of equipment developed by different suppliers. The following table presents the technical specifications for HIPERACCESS.

Table 3. Technical specifications for HiperACCESS

HiperACCESS	
Specification	Subject
TS 101 999 [21]	Broadband Radio Access Networks (BRAN); HIPERACCESS; PHY protocol specification
TS 102 000 [22]	Broadband Radio Access Networks (BRAN); HIPERACCESS; Data Link Control (DLC) layer
TS 102 115-1 [23]	Broadband Radio Access Networks (BRAN); HIPERACCESS; Cell based Convergence Layer; Part 1: Common Part
TS 112 115-2 [24]	Broadband Radio Access Networks (BRAN); HIPERACCESS; Cell based Convergence Layer; Part 2: UNI Service Specific Convergence Sublayer (SSCS)
TS 112 117-1 [25]	Broadband Radio Access Networks (BRAN); HIPERACCESS; Packet based Convergence Layer; Part 1: Common Part
TS 102 117-2 [26]	Broadband Radio Access Networks (BRAN); HIPERACCESS; Packet based Convergence Layer; Part 2: Ethernet Service Specific Convergence Sublayer

1.3. IEEE Standards Association

The IEEE Standards Association (IEEE-SA) is a leading consensus building organization that nurtures, develops and advances global technologies, through IEEE external link [27]. It brings together a broad range of individuals and organizations from a wide range of technical and geographic points of origin to facilitate standards development and standards related to collaboration in a diversity of industries, including: power and energy, biomedical and health care, information technology, telecommunication, transportation, nanotechnology, information assurance, and many more. With collaborative thought leaders in more than 160 countries, it promotes innovation, enables the creation and expansion of international markets and helps protect health and public safety.

The IEEE-SA is comprised of a variety of groups, active in publications, conferences, and building technical communities with the objective of setting priorities and developing appropriate standards. There are working groups in diverse areas such as aerospace, electronics, communications, internet of things, microwave theory and techniques, information technology, among others.

Of special interest for SARABAND is the IEEE Working Group on LAN/MAN (IEEE 802), which develops and maintains networking standards and recommended practices for local, metropolitan, and other area networks, using an open and accredited process, and advocates them on a global basis [28]. The most widely used standards are for Ethernet, Bridging and Virtual Bridged LANs, Wireless LAN, Wireless PAN, Wireless MAN, Wireless Coexistence, Media Independent Handover Services, and Wireless RAN. An individual Working Group provides the focus for each area. Within the IEEE 802, there are the following Working Groups and Study Groups:

- 802.1 Higher Layer LAN Protocols Working Group
- 802.3 Ethernet Working Group
- 802.11 Wireless LAN Working Group
- 802.15 Wireless Personal Area Network (WPAN) Working Group
- 802.16 Broadband Wireless Access Working Group
- 802.18 Radio Regulatory TAG
- 802.19 Wireless Coexistence Working Group
- 802.21 Media Independent Handover Services Working Group
- 802.22 Wireless Regional Area Networks
- 802.24 Smart Grid TAG
- OmniRAN EC Study Group

For SARABAND we will focus on the WG on Broadband Wireless Access (IEEE 802.16) and the WG on Open Mobile Network Interface for Omni-Range Area Networks based on IEEE 802 access technologies (OmniRAN).

1.3.1. Working Group on Broadband Wireless Access Standards (IEEE 802.16)

The IEEE 802.16 Working Group on Broadband Wireless Access develops standards and recommended practices to support the development and deployment of broadband Wireless Metropolitan Area Networks [29]. Namely, the IEEE 802.16 standard specifies the WirelessMAN air interface for wireless metropolitan area networks. The standard includes a medium access control layer (MAC) specification structured to support multiple physical layer (PHY) specifications, each suited to a particular operational environment. The most popular air interface, known as "WirelessMAN-OFDMA" [30], is the basis of external system specifications, including WiMAX Forum Release 1 and the "OFDMA TDD WMAN" radio interface in ITU's IMT-2000 standard.

Within the IEEE 802.16 WG there are currently some active projects which are working on amendments to IEEE Std 802.16 for small cell backhaul (SCB) and multi-tier networks.

1.3.1.1. P802.16r Project: Small Cell Backhaul with Carrier Ethernet

As the spectral efficiency of wireless links approaches its theoretical limits, and with the data traffic requirements continuing to grow rapidly, cell density and cooperation among base stations must increase in order to further improve network capacity and efficiently manage radio resources. Multi-tier access network architecture consisting of macrocells and a variety of overlaid smaller cells provides an approach towards solving the problem, allowing low cost per bit and efficiently utilizing all spectral resources in the system. Some such systems will be deployed using radio access technology outside the realm of IEEE 802.16. In such cases, IEEE Std 802.16, as enhanced, can provide out-of-band wireless backhaul to the small cells, allowing those cells to be positioned for optimal performance without regard to the local availability of high-capacity wired backhaul. The resulting system design will offer improvements in spectral efficiency needed to support the rapidly expanding demand for mobile broadband access.

In particular, P802.16r project will specify enhancements to the WirelessMAN-OFDMA air interface for effective use in wireless fixed and nomadic Ethernet transport, including small cell backhaul applications, providing core network services to radio access networks [31]. It will focus on backhaul operating in licensed bands below 6 GHz, in which the backhaul radio operates far enough outside the band of the small cells so that interference is negligible. It will add 256QAM, 512QAM, and 1024QAM options in both uplink and downlink, with optional 4x4 MIMO in both directions, along with further enhancements that address small cell backhaul efficiency. Significant latency improvements will be attained. Enhancements to the Convergence Sublayer specifications will be incorporated as necessary for support of Carrier Ethernet 2.0 backhaul requirements. The functionalities required for small cell backhaul support will be specified in this standard.

1.3.1.2. P802.16q Project: Multi-tier Networks

As commented previously, multi-tier access network architecture, consisting of macrocells and a variety of overlaid smaller cells, are considered as a promising approach to solve the problem of continuous demand for data traffic. The current IEEE Std 802.16 and the amendments under development do not address the requirements for radio resource management based on cooperation among base stations in a multi-tier access network architecture. The P802.16q project will address these needs, enabling cost-effective improvements in system capacity and user quality of service with interoperable and efficient management of network resources, mobility, and spectrum [32].

In particular, P802.16q project specifies MAC/PHY protocol enhancements for cooperation among base stations in multi-tier networks to enhance interference mitigation, mobility management, and base station power management. Enhanced base stations shall support legacy mobile stations. PHY changes to any mobile stations are out of scope. In addition, these protocol enhancements include management messaging between base stations, and between base stations and mobile stations.

1.3.2. OmniRAN

On 15 November 2012, the IEEE 802 Executive Committee chartered the OmniRAN Executive Committee Study Group (SG) to study an Open Mobile Network Interface (OMNI) for Omni-Range Area Networks. This standard specifies a common method of heterogeneous networking among all (or at least many) IEEE 802 access technologies for mobile broadband IP services [33]. Namely, OmniRAN provides an abstraction of access networks based on IEEE 802 technologies to foster interoperability and integration into common control infrastructures in a manner that its use can open the door to the use of more IEEE 802 technologies as part of the operator´s RAN in a managed way.

This standard has created reference points, which build the foundation for realizing interoperability for real world access networks and capture the control information necessary to allow dynamic control of network functions. These reference points denote the interconnections between functional entities of an access network, and are:

- R1 between terminal and base station, which is completely covered by IEEE 802 specifications.

- R2 between terminal and core network, which carries control information for IEEE 802 functions.
- R3 between access network and core network, which carries control information for IEEE 802 functions.
- R4 between access networks, which enhances direct cooperation among multiple IEEE 802 access networks.
- R5 between core networks to enable co-use of access networks, which is present for conceptual purposes to foster the cooperation among cores.

Within this study group, the main areas for contributions are:

- OmniRAN use cases.
- Proposals regarding the OmniRAN architecture as it might be developed within IEEE 802.
- Proposals regarding the specific functionality to be provided by the OmniRAN, with prioritization expectations for the first project.

1.4. Other standardization bodies

Apart from the standardization bodies explained previously which develop standards related to SARABAND topics, there are other institutions or forum dealing with the definition of future mobile networks.

1.4.1. Next Generation Mobile Networks (NGMN)

The Next Generation Mobile Network (NGMN) Alliance was founded by leading international mobile network operators in 2006. Its objective is to ensure that the functionality and performance of next generation network infrastructure, service platforms and devices will meet the requirements of operators and, ultimately, will satisfy end user demand and expectations [34].

NGMN seeks to provide guidance to the industry in its role of developing requirements for technology evolution and in fostering system implementations as well as efficient network operations. The NGMN Alliance has also initiated information exchange among its members by encouraging dialogue with a focus on issues of immediate and significant concern. The NGMN recommendations have been acknowledged by organizations such as ETSI, 3GPP and IEEE.

On one hand, to implement and accomplish the overall objectives of NGMN, a comprehensive work programme has been set up within the NGMN Alliance. The NGMN work programme covers key aspects that need to be addressed in order to develop a fertile next-generation mobile broadband ecosystem. On the other hand, to execute the NGMN work programme, a number of projects have been established within the NGMN Alliance. Each project has a defined scope and dedicated objectives and is staffed with participants from the NGMN Partners (Members, Sponsors, and Advisors) as appropriate. Currently, the projects being executed within NGMN are shown in Figure 7.

The work programme also includes the following areas and selected topics: Service Quality Definition and Measurement, Spectrum, Intellectual Property Rights, ETSI ISG Open Radio equipment Interface, Standards Alignment. In addition, a platform for Information and Experience Exchange amongst NGMN Partners has been established on "Congestion Management" and "LTE/LTE-Advanced Deployment".

Mobile Content Delivery Optimisation	▪ Use cases and current practice: Mobile CDN deployment, transparent cache, access cache, coordination with the core nodes ▪ Architecture and functionalities: CDN functional entities in core and access network ▪ 3GPP EPC enhancements to support mobile content delivery
RAN Evolution	▪ Centralized RAN (C-RAN): RAN sharing, functional split radio/digital unit, virtualisation ▪ Coordinated Multipoint (CoMP): Performance/CoMP schemes evaluation, CoMP based on C-RAN architecture ▪ Backhaul / Fronthaul architecture and use cases ▪ Multi-RAN architecture, Dynamic Spectrum Allocation
NGCOR (Next Gen. Converged Operations Requirements)	▪ Configuration Management ▪ Performance Management ▪ Service Inventory Management ▪ Architecture scenarios for management of converged networks ▪ Verification of compliance to the standard specifications
Small Cells	▪ System architecture and functional requirements – focus on 3GPP technologies and Wi-Fi ▪ Operational issues and SON requirements for Small Cells ▪ Multi-vendor network definition and deployment ▪ Small Cell backhaul solutions: Inclusion of LTE-A features

Figure 7. Current NGMN projects

For SARABAND, the Small Cell project is of special interest [35]. In particular, the objective of this project is to define scenarios, use cases, system architecture and functional requirements for the fast and efficient introduction and operations of Small Cells. The work-streams of the project activity will deal in particular with the aspects of Wi-Fi integration, cost efficient deployment, operational issues, multi-vendor deployment and backhauling for Small Cells.

1.4.2. Small Cell Forum

The Small Cell Forum, formerly the Femto Forum, is a not-for-profit membership organization which supports, promotes and helps drive the wide-scale adoption of small cell technologies to improve coverage, capacity and services delivered by mobile networks [36]. The Small Cell Forum is not a standards-setting body, but works with standards organizations and regulators worldwide to provide an aggregated view of the small cell market. The Forum has more than 140 members including 68 operators, telecoms hardware and software vendors, content providers and innovative start-ups.

Small Cell Forum's work incorporates all small cell technology that uses licensed spectrum and is managed by a carrier. It is concerned with the multiple ways in which licensed small cells can be deployed by carriers across network architectures including metro femto, rural femto, metrocells, picocells and microcells, as shown in Figure 8. In some areas the forum cooperates with organizations where they overlap or integrate with small cells, such as the interworking of unlicensed technologies such as Wi-Fi. Other areas may also be represented in Small Cell Forum workstreams where they overlap with small cell technology (for example this may include heterogeneous networks –HetNet-, self-organizing networks –SON-, cloud radio access network – Cloud RAN-, and distributed antenna systems - DAS).

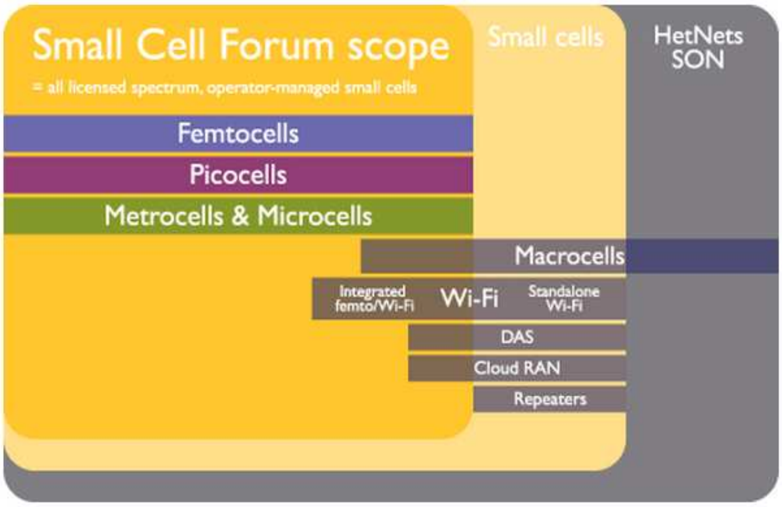

Figure 8. Small Cell Forum scope

The key policy priorities of the Small Cell Forum include:

- providing an independent impartial voice for all stakeholders in the small cell sector, including vendors and operators;
- developing a policy framework that encourages and drives the standardization of key aspects of small cell technologies worldwide;
- building and maintaining dialogue with other relevant industry and official standards bodies to further small cell technologies for the benefit of residential & business consumers, the industry and Forum members;
- the promotion of such standards-based solutions across the industry and to the relevant industry standards bodies, opinion formers and the broader communications community;
- building and maintaining an ecosystem that delivers the most commercial and technically efficient solutions.

Small Cell Forum has created six working groups to address the key issues affecting the effective development of the small cell industry: Marketing and Promotion, Radio and Physical Layer, Network, Regulatory, Services, and Interoperability. The aim of the groups is to ensure the rapid and effective deployment of small cells to support a wide variety of customer needs and operator business models. It also has four special interest groups that interact with all the main working groups and focus on issues associated with backhaul, LTE, rural deployment and 3GPP2 standards development.

The Small Cell Forum activities focused on standardization and regulation are relevant for SARABAND as a support for the adoption of industry wide standards to enable the widespread adoption and deployment of small cell technologies by telecom operators around the world.

2. Main areas of standardization

The SARABAND project aims at designing point to multipoint transmissions with disruptive technology on antennas and front-end radio modules providing final network performances comparable to fiber optics. In particular, SARABAND is focused on the development of new Q-band components such as high-gain and smart antennas, and front-end radio modules with high bandwidth and high level of integration to be introduced in future wireless backhaul networks and last mile access.

From the review of the existing standardization activities dealing with topics related to SARABAND, it is concluded that the ETSI TC ATTM has worked on several standards in the Q-band (40,5 GHz – 43,5 GHz) such as the EN 301 997 and the EN 301 215 that perfectly fit into our target.

As commented previously, the standard **EN 301 997** applies to Multimedia Wireless Systems in the Q-band and specifies the minimum requirements for equipment and systems parameters, including parameters necessary to plan co-existence of the possible solutions for implementing MWS in the 40 GHz frequency band. The frequency assignment criteria in this band is based on “frequency blocks” according to the recommendation CEPT/ECC/REC(01)04, therefore the radio frequency co-ordination parameters specified in this standard may be subdivided into two categories:

- those related to the minimum requirements for frequency co-ordination of various systems deployed by an operator inside the same block of frequency. They are specified as ETSI "minimum voluntary parameters" for all MWS systems which will co-exist in this band.
- those related to adjacent "block-edge" interference control; these will be considered as "essential requirements" for the application of Directive 1999/5/EC (R&TTE Directive) [37].

Among these parameters, SARABAND will propose slightly modification in terms of parameters precision, test and certification issues to ensure the MWS deployment in good conditions. Namely, SARABAND will propose some updates for the EN 301 997 in the following issues:

- Transmitter characteristics measurement in integral equipment
- Automatic Transmit Power Control (ATPC)
- Remote Transmit Power Control (RTPC)
- Spurious emission measurements
- Radio Frequency Tolerance
- Interfaces

Apart from the standard EN 301 997, the standard **EN 301 215** is closely correlated to the SARABAND project as it specifies the essential electrical requirements for antennas to be used in multipoint systems. In particular, the EN 301 215 03 develops in more detail the antenna parameters in Q-band. Within this standard, SARABAND will propose an update of the chapter 4.2 focused on central station sectored antenna. In particular, SARABAND will consider the inclusion of multi-beam concept into the standard.

On the other hand, **TC BRAN** continued its work on Ultra-Broadband Wireless Systems preparing a technical report on system architecture and technical requirements for a broadband wireless system providing 1 Gbps per km^2 [38]. With the SARABAND solution, operators can create 4 sectors of coverage with a range of 2 km, generating up to 8 Gbps of capacity in one polarization. This capacity can be scaled and increased with the introduction of multi-beam antennas deploying smaller coverage and capacity per km^2 segment. Therefore, after the validation of the wireless network platform delivering high-capacity Q-band transmissions, SARABAND will consider to present these results to the TC BRAN as a solution to offer capacity density of 1 Gbit/s/km^2 within the frequency band of the HiperACCESS standard.

Concerning the **IEEE P802.16r**, this project aims at developing an amendment specifying enhancements to the WirelessMAN-OFDMA air interface for small cell backhaul applications operating in licensed bands below 6 GHz. As there is a lack of enough spectrum at low frequencies to deliver sufficient capacity, this amendment adds 256QAM, 512QAM, and 1024QAM options in both uplink and downlink, with optional 4x4 MIMO in both directions, along with further enhancements that address small cell backhaul efficiency. SARABAND is also focused on backhaul solution, but it operates in a different frequency band, which offers large amount of spectral bandwidth. As a result, SARABAND follows different approach and is more addressed to the development of new Q-band technology providing an improvement in performances and competitiveness of backhaul and last mile access networks. Therefore, it is not expected any SARABAND contribution to the P802.16r.

The IEEE 802.16 Working Group is working in the definition of heterogeneous networks (HetNet) through the **P802.16q project** and **OmniRAN** study group. In particular, the P802.16q amendment addresses the requirements for radio resource management based on cooperation among base stations in a multi-tier access network architecture and the OmniRAN initiative specifies a common method of heterogeneous networking among all IEEE 802 access technologies for mobile broadband IP services. SARABAND can provide a Het-Net solution with elasticity and flexible capacity allocation for backhaul of 3G/4G macro cells, micro cells, small cells, relay sites, WiFi and SMEs within the same solution; however, networking and protocol enhancements for cooperation in a Het-Net environment is out of the scope.

Therefore, standardization activities of the SARABAND project will be mainly focused on the update of the EN 301 997 and EN 301 215 standards. Anyway, SARABAND will continue monitoring and analyzing the evolution of the standards described in the previous section in order to identify any possible contribution. Additionally, SARABAND will closely follow the **NGMN and Small Cell Forum** activities to be in line with the industry trends in terms of adoption and deployment of small cell.

3. Standardization activities within the project

In this Section we describe the current contributions of SARABAND to the standards, produced from the beginning of the project. In summary the list of contributions is the following:

- Contribution to the ECC Report 173 on fixed service trends
- Contribution to the ETSI standards EN 301 997 and EN 301 215
- Contact with the chairmen of the IEEE P802.16r active project and the TC BRAN to identify possible synergies
- Participation in events supported by standardization bodies such as the NGMN and the Small Cell Forum

3.1. CEPT ECC

As commented in the previous section, the CEPT ECC decided to start the edition of a new report, “**ECC Report 173: Fixed Service in Europe - Current use and future trends post 2011**”, with the major aim to update and revise the previous reports on Fixed Service Trends post-1998 and post-2002 (ECC Report 003) [39]. The first report was prepared as a result of a study, undertaken by a team of experts between February 1997 and February 1998, as a work order for the European Commission. The second report was prepared between 2001 and 2002 and updated the information on the fixed service at that time.

The ECC Report 173 of the fixed service had three objectives, namely:

- To provide a comprehensive overview of the development of civil fixed services from 1997 up to 2011.
- To provide a useful reference for administrations, manufacturers and telecom operators on issues surrounding the developments of civil fixed services in Europe.
- To provide a rationale for the general trends with information gathered for the whole CEPT highlighting the basis for these observations.

The major source of factual data used in the development of this report, was the questionnaire on FS use and future trends, conducted through CEPT administrations. In total 31 administrations and 13 operating/manufacturer companies responded to this questionnaire, including Bluwan.

The results obtained from the questionnaire enabled the evaluation of the FS situation in Europe for the year 2011. On the other hand, comparison of data obtained with the data originally obtained in 1997 and 2001 allowed the dynamic evaluation of FS developments over those years. The most significant increases of FS assignments over the last two decades still came in particular from the area of infrastructure support for public mobile networks, where the reported number of PtP links increased by more than 24.5% per year in average between 1997 and 2011.

The conclusion of the report shows that this demand is expected to increase further with the expected growth in capacity and number of connected nodes with the introduction of UMTS/HSPA/HSPA+/LTE/IMT-Advanced. Provisioning of infrastructure support through various PMP technologies is also being considered, or already implemented in some countries as a viable alternative option in the environment with high density of served base stations (e.g. dense urban areas). Additionally, the results show that the growth in number of FS links is likely to continue for the foreseeable future. In that respect it may be noted, that CEPT has already made several successful moves towards ensuring favourable conditions for such growth, by developing ERC and ECC Decisions, Recommendations with relevant channel arrangements and identifying additional bands for high density applications in the FS, including FWA and infrastructure support. Among these recommendations, the ECC/REC/(01)04 for the use of Q-band can be highlighted. In particular, this band is just at the beginning of its use; however, it could be a good candidate for high capacity network infrastructure.

In the frame of the ECC Report 173, Bluwan as liaison for the SARABAND consortium participated particularly by giving its vision on the use of point to multipoint links and the Q-band spectrum to deliver high capacity fixed wireless data services. Namely, its contributions were:

- **Wireless Backhaul Architecture exploiting Q-band Frequencies**.
  With the progressive introduction of more and more broadband services offered by new generation of LTE mobile systems, backhaul networks need to suitably respond to the change. The expected growth of needed capacity implies that, at least in highly populated urban areas, the base stations will use smaller size cell footprint and thus their density will increase. In this scenario, Bluwan has considered millimeter-wave point to multipoint solution (in Q-band) as the most beneficial solution for the implementation of next generation wireless backhaul networks. This backhaul network is based on a new multiplexing technology that allows the aggregation of multiple independent channels (modems) through wideband radios and antennas onto a single air interface. This solution offers an all-IP PMP architecture providing multi-gigabit throughput to multiple base stations in a single sector. The use of millimeter wave technology, concretely the use of Q-band spectrum (40,5 – 43,5 GHz), provides the required amount of spectral bandwidth needed for the aggregation of sub-channels to the wide radios and antennas.

- **Block assignment and use of wide band channels.**
  Following the guidelines provided by the ECC/REC/(01)04, SARABAND system uses block assignment. Actually, SARABAND network can deliver high capacity fixed wireless data services by leveraging large blocks of cost-effective TDD spectrum in ultra wide channels available at higher bands such as 42 GHz. Indeed, Q-band offers 3GHz bandwidth, 6GHz with cross-polarization. This wide bandwidth also enables the capability to scale the capacity of wireless links as demanded by market needs. In particular, SARABAND equipment uses a 1-GHz wide transmitter that can be loaded with 25 channels (nominally 40 MHz wide) in a manner that a base station can be configured to use as little as 40 MHz or all 3 GHz (@ 40 GHz using 3 transmitters fully loaded) to deliver high capacity links.

- **Point to multipoint architecture**.
  To provide broadband data services, operators need to expand the capacity of their backhaul. As a large number of links for tens of thousands of wireless base stations is required, we must consider how transmission networks can evolve cost effectively. At this point, the best network topology for the backhaul should be considered. The main network topologies used for existing backhaul solutions are: point to point and point to multipoint. PtP microwave radio links are a well-established and mature technology that has been applied often to backhaul mobile traffic. However, PMP has recently gained interest with the new generation of PMP equipment available on the market. PMP may be a useful element in the architecture, including mobile backhauling, for carrying packet data traffic in networks. PMP systems are inherently characterized by the ability for a single radio or hub terminal to sustain links with multiple remote terminals. This ability to support *n* radio links with only *(n+1)* radios is PMP’s fundamental advantage over PTP systems, which need to bear the

higher cost of *2n* radios to support the same *n* links. As a consequence, a PMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. This provides for a flexible network topology which lends itself to subscriber adds, moves and changes thus lowering OPEX for an operator and facilitating rapid subscriber acquisition.

- **New technology in the Q-band.**
  High frequency bands such as the Q-band result particularly promising in terms of capacity (multi Gbit/s radio); however, equipment in such bands is challenging in terms of phase noise, component analogue bandwidth and processing/sampling frequency. Therefore, for the deployment of future wireless backhaul network in high frequency bands some improvement in terms of antennas technologies and radio modules will be needed to enhance network performance. In this sense, SARABAND designs wireless network nodes with Q-band multi-beam antennas and radios with high bandwidth and a high degree of integration to meet performance, cost efficiency and acceptability.
  Near future evolution in antenna technology may be related to the deployment of new mobile access networks and backhauling which will use smaller size cell footprint, especially in urban areas. Therefore, one objective of SARABAND is to design small form factor, high-gain and multi-beam antennas.
  Concerning RF radio modules, SARABAND produces modules with the combination of qualities such as Gigahertz bandwidth, linearity, phase noise and frequency precision, allowing ultra wide band modems to be coupled in order to achieve nodes with multiple high capacity links in programmable directions.
  These technological developments could lead to effective commercialization of new infrastructures in multipoint technology in this frequency band.

- **Applications.**
  SARABAND solution can be a suitable solution to provide high capacity links for the following applications:
    - Infrastructure networks: The growth of internal infrastructures of 2G/3G networks was required to support the permanent growth of subscriber bases. This growth will continue and with the continuous expansion of mobile broadband networks (HSPA, HSPA+, LTE), further demand for infrastructure support solutions can be expected. Wireless technology often provides a more practical and economic infrastructure alternative for quick roll out of such mobile networks. Actually, SARABAND system is ideally suited for infrastructure networks because it can provide high capacity radio transmissions and offers a highly flexible PMP network topology which can rapidly adapt to an operator's coverage and capacity requirements.
    - Fixed Wireless Access Networks: FWA networks are designed to provide a direct connection between the Customer Premises Equipment (CPE, user terminal or data servers) and an operator's core network (data communication network). FWA normally uses PMP radio technology to serve a large number of CPEs within the coverage area of a central station. Thus, FWA essentially applies the principle of a cellular network, already well-established in mobile communication networks, into a fixed service scenario. FWA is also aiming at providing access solutions capable of provisioning truly broadband (multimedia) services to end-customers. SARABAND solution can offer high capacity fiber extension to different business customers from a single point of presence, providing peak throughput to enterprises up to 120 Mbps, and is a viable alternative that can help service providers optimize their network build to meet customer demand with a fast return on investment.

3.2. ETSI EN 301 997 and EN 301 215

During year 2, EN 301 997 and EN 301 215-03 have been analyzed in depth. The conclusion of this analysis is that some updates of the 2 norms should be proposed to ETSI group. Indeed the norms are now more than 10 years old and technology evolutions would slightly modify the norms in terms of parameters precision, test and certification issues. In order to foster Multimedia Wireless Systems development in good conditions it is therefore valuable to update the norms. In that sense, SARABAND proposes to write “up-date” paragraphs named “UD-x” to be inserted in the relevant chapters within the 2 norms. The result of this contribution would be to issue an EN 301 997-03 and an EN 301 215 3.1.

Concerning the **EN 301 997**, SARABAND proposes the following updates in the chapters detailed below:

- *Transmitter (Tx) characteristics*: The specified Tx characteristics as defined in EN 301 997 shall be met with the appropriate input signals applied at point E' of Figure 9 and measured at point E. The standard says that the points shown in Figure 9 are reference points only so that points B, C and D, B', C' and D' may coincide.
  SARABAND proposes also that A, B, C and D as A’, B’, C’ and D’ may coincide, resulting in an integral design. Filtering function is better to be included inside transmitter and could be complemented in transition and in antenna. The design of integrated microelectronics is technically efficient for mm-wave losses and overall performances. Moreover, compactness is required by operators for simple installation and low rental on building or towers.
  According to the standard, the values and measurements are referred to point C'; however, SARABAND proposes to be referred to point C’ or D’ (in lab), if an integral design is considered.

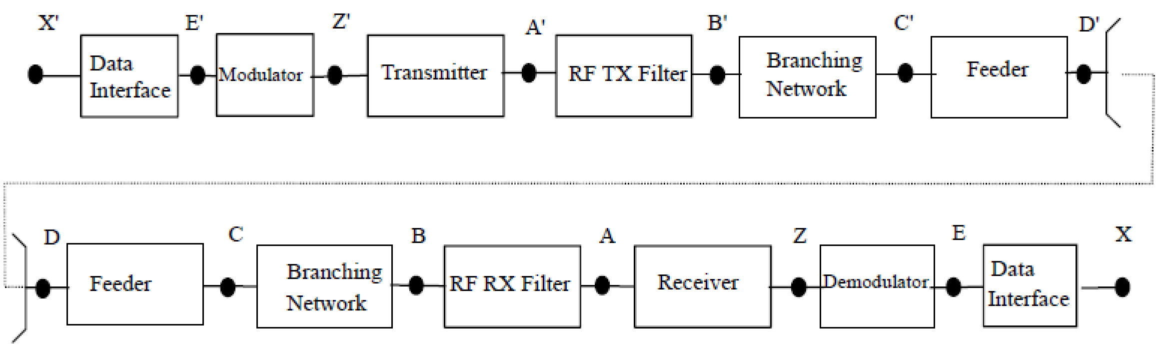

Figure 9. RF system block diagram

- *Output power*: ECC/REC/(01)04 defines the maximum allowed transmitted spectral EIRP density inside the block based on the typical ranges of antenna gains and equipment power output. For testing purposes the EIRP may be evaluated as the sum of the measured power at the antenna port plus the antenna gain. SARABAND proposes that EIRP may be measured directly with antenna when integral design is used.

- *Remote Transmit Power Control (RTPC)*: According to the standard, RTPC is an optional feature; however, SARABAND considers that RTPC is recommended to control block edge mask and to optimize the MWS and it is mandatory if no ATPC is applied. Therefore, the use of the RTPC may depend on the access scheme.

- *Automatic Transmit Power Control (ATPC)*: ATPC is mandatory for terminal station transmitters that have a maximum Tx power density greater than 0,5 dBm/MHz. However, SARABAND explains that ATPC is not mandatory when RTPC is implemented with global power control. Moreover, ATPC does not optimize the MWS and creates independent loops that cannot be controlled.

- *Spurious emissions (external)*: According to CEPT/ERC/REC/(74)01 [40] and the more stringent EN 301 390 [41], the external spurious emissions are defined as emissions at frequencies which are removed from the nominal carrier frequency more than ±250 % of the relevant channel separation. The limits and the practical measurement range (see Note 1) shall be in accordance with EN 301 390.
  The standard specified the Note 1: When waveguide is used between reference point A' and D' (and/or A and D), whose length is greater than twice the free space wavelength of cut-off frequency (Fc), the lower limit of measurement will be increased to 0,7*Fc, and to 0,9*Fc when the length is greater than four times the free space wavelength of Fc.
  SARABAND proposes the addition of the Note 2: When MWS equipment follows an integral design, spurious are measured on the integrated equipment, including antennas, and antenna gain is subtracted. Manufacturer will provide the measured diagram from anechoic chamber. The argument for this new definition is that lens and patch antennas are built in the equipment and cannot be separated at certification. Moreover effects and consequences of mask and spurious are to be assessed with antenna and would be measured in the same time at certification.

- *RF tolerance:* The maximum RF tolerance considered in the standard shall be less than 30 ppm; however, SARABAND recommends less than 1 ppm for TDD since precision and stability has been experimented around the intended nominal channel central frequency.

- *Types of interface:* Table 4 shows some common standardized interfaces and is included for information in the standard. Due to the wide range of possible MWS services, a particular system may use any (or none) of the interfaces listed here. Additional interfaces not listed here may also be applicable. Where a system interface at either the NNI or UNI in the reference diagram of Figure 5 is with a recognized standard network, the system operator will require conformance with relevant standards. However, in some cases, the services provided may be novel and interfaces may not yet be specified in standards. SARABAND has identified that the standard 1000 Base-T for Gigabit Ethernet should be included in the interfaces detailed in Table 4.

Table 4. Commonly used standardized interfaces

Interface	Proposed standard
TE (Subscriber Equipment) UNI Interface	
Analogue (2 wires)	ITU-T Recommendation Q.552 [20]
Analogue (4 W + E & M)	ITU-T Recommendation Q.553 [21]
Digital data port (electrical)	Digital data port (electrical) ITU-T Recommendation G.703 [14], ITU-T Recommendation X series [23] and ITU-T Recommendation V series [22]
ISDN basic rate U; S	ITU-T Recommendation G.961 [24] and ETS 300 012 [25]
ISDN primary rate U; S	ITU-T Recommendation G.962 [27] and ETS 300 011 [26]
2 Mbit/s (E1)	ITU-T Recommendation G.703 [14]
N*64 kbits/s Mbit/s (fractional E1)	ITU-T Recommendations G.703 [14] and G.704 [38]
10 Mbit/s LAN interface (Ethernet like)	ISO 8802-3/IEEE 802.3 (10 Base-T) [39]
100 Mbit/s LAN interface (Ethernet like)	ISO 8802-3/IEEE 802.3 (100 Base-T) [39]
ATM UNI 3.1	ATMF UNI 3.1 (af-uni-0010.002 [63]) ATMF 25,6 Mbit/s (af-phy-0040.000 [64])
B-ISDN UNI	ITU-T Recommendation I.432 series [57] to [61] ITU-T Recommendation I.413 [62]
Service Node Interface	
Digital data port (electrical)	Digital data port (electrical) ITU-T Recommendation G.703 [14], ITU-T Recommendation X series [23] and ITU-T Recommendation V series [22]
ISDN basic rate U; S	ITU-T Recommendation G.961 [24] and ETS 300 012 [25]
ISDN primary rate U; S	ITU-T Recommendation G.962 [27] and ETS 300 011 [26]
PDH/SDH interfaces	ITU-T Recommendations G.703 [14]; G.707 [28] and G.957 [31]
2 Mbit/s (E1)	ITU-T Recommendation G.703 [14]
N × 64 kbits/s Mbit/s (fractional E1)	ITU-T Recommendations G.703 [14] and G.704 [38]
B-ISDN	ITU-T Recommendation G.967.1 (VB5.1) [65] ITU-T Recommendation G.967.2 (VB5.2) [66]
ISDN + Analogue subscribers + Leased lines 2 Mbit/s Interface	ITU-T Recommendation G.703 [14] ITU-T Recommendation G.964 [29] ITU-T Recommendation G.965 [30] EN 300 324 [32] EN 300 347 [33]
ATM NNI	ITU-T Recommendation G.966 [40] ITU-T Recommendation I.610 [41] ITU-T Recommendation I.732 [42]
ATM UNI 3.1	ATMF UNI 3.1 (af-uni-0010.002 [63]) ATMF 25,6 Mbit/s (af-phy-0040.000 [64])

Concerning the **EN 301 215**, SARABAND proposes an update of the chapter 4.2 focused on central station sectored antenna. In particular, SARABAND will consider the inclusion of the multi-beam concept into the standard in such a way that the multi-beam is included in the main beam of the sector (e.g. the ensemble of beams makes a sector then we can apply the norms).

3.3. Other activities

During the second year of the SARABAND project, the standards of the IEEE 802.16 have been analyzed. Among them, the active project **P802.16r** deals with small cell backhaul with carrier Ethernet applications operating in frequency bands below 6 GHz. In particular, this project is focused on the specification of an enhanced WirelessMAN-OFDMA air interface. Despite the scope of this project being different than SARABAND's and no direct relation being identified, we have contacted with the chairman of this working group in order to introduce the SARABAND project and to seek future synergies.

On the other hand, the activities of the **ETSI TC BRAN** have been also analyzed. In particular, the HiperACCESS standard has been studied as a solution for the provision of Fixed Wireless Access (FWA) applications operating in the band from 40,5GHz to 43,5GHz. Additionally, this working group has recently prepared a technical report describing the architecture of a broadband wireless system providing 1Gbit/s per km^2. Given these activities, SARABAND has contacted with the chairman of this working group in order to introduce the SARABAND project and to express its interest in collaborating in future initiatives.

Apart from these activities, SARABAND has also participated in events organized and supported by other standardization bodies such as the NGMN and the Small Cell Forum.

Bluwan was one of the sponsors of the Small Cell Backhaul Summit held in London in June 2013. This event was co-located with Small Cells World Summit and supported by the **Small Cell Forum**. During these events some key issues related to small cell backhaul were addressed. Actually, the question of reliable and affordable backhaul continued to attract operators’ attention as a sticking point to drive the business case for further deployment. Bluwan gave also a presentation on next generation backhaul strategies for the pragmatic deployment of small cells.

Moreover, Bluwan was also associate sponsor for the Layer 123 - Packet Microwave & Backhaul Forum held in Düsseldorf in September 2013. This event was supported by the **NGMN**, operators, and services providers, and was designed to further support operators as they make key strategic design and procurement decisions to build out next-generation mobile backhaul infrastructure. During this event, the expansion of the role of microwave in LTE applying microwave to small cell deployments was discussed. Operators, regulators and industry analyst took an active role in the exchange debates, and group discussions. Bluwan participated in the panel discussion about “LTE Backhaul – Experiences from the Field” and gave a presentation focused on operator case studies.

4. Conclusion

In this deliverable we have presented an exhaustive list of the standardization bodies together with their current activities on topics related to SARABAND. Among available initiatives, associations, consortia, etc. which are active in different fields of standardization, in SARABAND we are mainly focused on the CEPT Electronic Communications Committee (ECC), the European Telecommunications Standards Institute (ETSI), and the IEEE Standards Association (IEEE-SA). A briefly description of the main standards relevant for SARABAND has been provided.

Moreover, in this document the main areas of standardization in which SARABAND can contribute have been summarized. SARABAND concrete plans for contributions to standards can be outlined as follows. SARABAND aims at designing point to multipoint transmissions with disruptive technology on antennas and front-end radio modules providing final network performances comparable to fiber optics. Given the nature of the project, SARABAND expects to mainly contribute in the ETSI EN 301 997 and EN 301 215 standards. Both standards deal with the specification of the minimum requirements for equipment and systems parameters for implementing MWS in the 40 GHz frequency band. Concerning the EN 301 997, SARABAND will propose slightly modification in terms of parameters precision, test and certification issues to ensure the MWS deployment in good conditions. Concerning the EN 301 215, where antenna parameters in Q-band are more accurately defined, SARABAND will propose an update of the chapter 4.2 focused on central station sectored antenna. Both contributions will lead to issue an EN 301 997 03 and an EN 301 215 3.1**.**

On the other hand, SARABAND has also analyzed other standards such as the IEEE P802.16r, IEEE P802.16q and the ETSI HiperACCESS. Although these standardization activities deal with topics relevant for SARABAND (small cell backhaul, HetNet, FWA applications in Q-band), no direct relation has been identified. However, SARABAND contacted with the chairmen of the standards and will continue monitoring and analyzing their evolution in order to identify any possible contribution.

In the remaining months of the project lifetime we will keep on the activities described in this document. We will participate to the events organized by standardization bodies such as the NGMN and the Small Cell Forum, will monitor the evolution of the standards described in this deliverable, and will focus on the contributions to the ETSI standards mentioned above. The evolution of the proposed contributions to standards will be reported in the final deliverable D8.8 (Final Standardization activities report).

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