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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Broadband Radio Access Networks (BRAN).

1 Scope

The present document describes the specific protocols for systems providing a throughput of 1 Gbit/s/km^2. Such systems include features such as self-backhauling in both licensed and un-licensed bands, cognitive-radio based self-organization, etc.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 101 534 (V1.1.1) (2012): "Broadband Radio Access Networks (BRAN); Very high capacity density BWA networks; System architecture, economic model and derivation of technical requirements".

[i.2] S. Haykin: "Cognitive Radio: Brain-Empowered Wireless Communications", IEEE Journal on selected areas in communications, vol. 23, pp. 201-220, February 2005.

[i.3] R. S. Sutton and A. G. Barto: "Reinforcement learning: An Introduction", The MIT Press, 1998.

[i.4] Ana Galindo-Serrano, Lorenza Giupponi, Pol Blasco and Mischa Dohler: "Learning from Experts in Cognitive Radio Networks: The Docitive Paradigm" in Proceedings of 5th International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CrownCom 2010), 9-11 June 2010, Cannes (France).

[i.5] M. N. Ahmadabadi and M. Asadpour: "Expertness based cooperative Qlearning", IEEE Transactions on Systems, Man, and Cybernetics, Part B, vol. 32, no. 1, pp. 66-76, February 2002.

[i.6] IEEE 802.16-2012: "IEEE Standard for Air Interface for Broadband Wireless Access Systems".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

DL-MAP: structured data sequence that defined the mapping of the downlink

self-backhauling: wireless links between HBS and ABS which may share a frequency channel with the access operation (in-band) and use in addition license-exempt spectrum such as 5 GHz or 60 GHz bands (out-of-band)

UL-MAP: structured data sequence that defined the mapping of the uplink

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AAA	Authentication, Authorization, and Accounting
ABS	Access BS
ACK	Acknowledge
ARA	Adaptive Resource Allocation
ASN	Access Service Network
BS	Base Station
BS-BS	Base Station to Base Station
BSID	Base Station IDentifier
BWA user	Fixed, Nomadic or Mobile user
BWA	Broadband Wireless Access
CIM	Centralized Interference Mitigation
CINR	Carrier to Interference and Noise Ratio
CM	Conditional-Mandatory
CNR	Carrier-to-Noise Ratio
DCD	Downlink Channel Description
DFP	Dynamic Frequency Planning
DL	Downlink
DNS	Directory Name Server
FA	Frequency Assignment
FAID	Frequency Assignment ID
FFR	Fractional Frequency Reuse
FQDN	Fully Qualified Domain Name
GPS	Global Positioning System
GW	Gateway
HBS	Hub Base Station
HO	HandOver
HSPA	High Speed Packed Access
HSS	Subscriber Station connected to HBS
ICIC	Inter Cell Interference Coordination
ICS	Interference Control Server
ID	IDentifier
IE	Information Element
IP	Internet Protocol
IQ	Intelligence Quotient
LE	License Exempt
LRT	Last Reset Time
LTE	Long Term Evolution
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIMO	Multi-Input-Multi-Output
MME	Mobile Management Entity
MS	Mobile Station

NBL	NeighBour List
NBR	NeighBour Relation
NBS	Neighbour BS
NDS	Neighbours Data Synchronization
NV	Non-Volatile
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PHY	PHYsical
P-MP	Point to MultiPoint
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Resource Block
REQ	Request
RF	Radio Frequency
RP	Recovering Protocol
RRA	Averaging/Reporting Period
RRC	Radio Resource Control
RRM	Radio Resource Management
RRM-E	RRM-Entity
RSP	Response
RSSI	Received Signal Strength Indicator
RTD	Round Trip Delay
SBS	Serving BS
SON	Self Organizing Network
SOTA	State Of The Art
SSDFA	Spectrum Sensing based Dynamic Frequency Assignment
TBS	Target BS
TLV	Type - Length - Value (data structure)
TS	Time Stamp
UCD	Uplink Channel Description
UL	Uplink

4 Introduction

The present document presents new possible protocols specific to wireless BWA network, as described in [i.1], including heterogeneous elements (a two tier approach), combined use of licensed and license-exempt spectrum, very low delay communications between network elements, enabling the operation of the network MIMO technology and of the self-organization approaches.

The description of the networking features is in general done using the WiMAX^{TM} terminology, however should be no barrier in using the 3GPP network for implementing this network.

4.1 Architecture for the underlaying system

The architecture presented in [i.1] is summarized below, for easing the reader understanding. Its main features are:

- Multiple access links aggregation.
- Self-backhauling link aggregation.
- Network MIMO (for downlink and uplink).
- Radio Resource Management.
- Direct BS-BS or MS-MS communication.

The system architecture aims to offer a cost efficient capacity density of 1 Gbit/s/km^2. Here, a HBS serves several below-rooftop ABSs, which in turn serve the associated MSs. The HBS possesses several beams which are used to communicate with ABSs in its beam-space. ABSs can communicate with each other via the serving HBS.

The Femto-BS and their associated subscribers may also operate in the un-licensed spectrum.

To simplify the presentation, the HBS-ABS links, which are self-backhaul links inside this system, may be named in the present document "backhaul links". This naming should not be understood as HBS backhauling, which is outside of the scope of the present document.

The system presented in the present document has the following basic architecture:

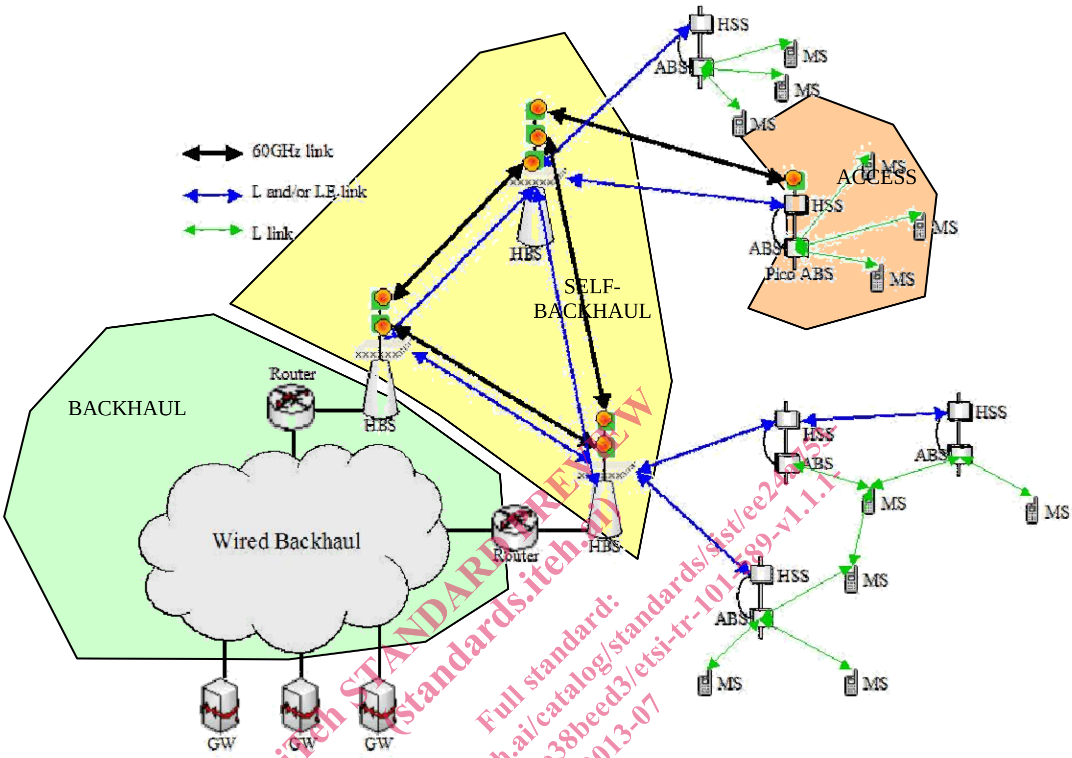

Figure 4.1: Basic architecture

The scheme in figure 4.1 provides an overview of most of the possible wireless links in the present document. At the top level of the architecture, HBSs are directly connected to the wired backhaul. If in some cases a wired link could not be done, this link should be replaced by LE high data rate connectivity.

An in-band backhaul link and a LE link between HBSs may not be systematically done but could offer additional networking capacities and an alternative, in case of a router failure for example.

At the ABS location there are two elements, which are the HSS and the ABS. The HSS component is associated to an HBS or to another HSS (for direct communication and collaborative MIMO). ABS provides connectivity for the BWA users.

To increase the coverage or to provide a larger throughput in a given area exists the possibility to deploy additional stations called pico-ABS. Those stations are basically similar to ABSs as they are providing connectivity to BWA users.

The lower level of the architecture shows mobile station connectivity possibilities. MS connects itself to ABS as in the standard P-MP architecture, but can also directly connect one to each other, and associate with two ABSs for MIMO support.

4.2 Radio resource management

This clause presents protocols and procedures related to RAN RRM and dynamic resource (frequency, power) assignment. The description relates to the air interface and the network interfaces and presents reference design for procedures and protocol primitives, required to support the aforementioned RRM mechanisms.

4.2.1 RRM functional decomposition in system architecture

The functional decomposition is based on the state-of-the-art WiMAX^{TM} and 3GPP standards, where Radio Resource Management (RRM) functional entity is located in the Base Station/eNodeB, while ASN GW/MME may act as a protocol relay function, but do not implement RRM-specific functions.

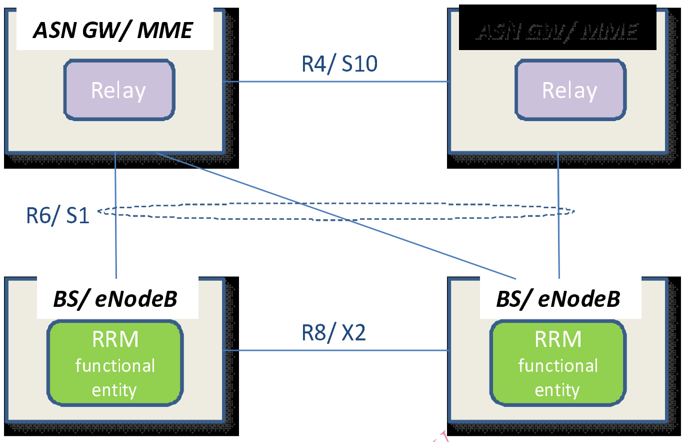

Figure 4.2: RRM functional entities in the SOTA WiMAX^{TM} and 3GPP LTE architectures

The RRM entity may implement both RRM Client and RRM Server entities, thus being able to issue information queries and to provide instructions. This is the de-centralized RRM approach, where there is no centralized entity controlling and coordinating the radio resource allocation in the particular geographical area with multiple BSs providing coverage and capacity. Coordination is done between RRM entities of different BSs over the R8/X2 reference points or over R6/S1 reference points via ASN GW/MME assuming "relay" functionality.

The following RRM features are considered in the present document and may be taking the advantage of the addressed system RRM split:

- Dynamic centralized and autonomous distributed frequency assignment.
- Cognitive and docitive power assignment.
- Support of advanced MIMO schemes.
- Self-Organization and Optimization features.

5 Frequency channel assignment

5.1 Dynamic centralized frequency assignment

5.1.1 Overall objectives

The centralized dynamic RRM protocol is based on an overall supervision of the radio network status, and tries to optimize radio link resources depending on interference levels, throughput load and architecture deployment.

Certain extent of information is required for this purpose, which mainly consist of different requests or triggered alarms informing the centralized RRM entity of the current status. The dynamic protocols act only by restraining or increasing stations resources, and providing local RRM segments the choice to optimize links to a more specific level. Coexistence is therefore easily ensured.

The centralized dynamic RRM entity (RRM-E) can be hosted either in HBS or in external equipment. It includes different operating functions realized on a proactive basis with regular survey or in a reactive fashion while receiving resource deficit alarms from the given sectors.

The knowledge of deployment topology allows Centralized RRM-E to perform initial distribution of frequency resources to the overlapping stations, with further iterative dynamic adaptations. This function is called *Dynamic Frequency Planning (DFP).*

In a second step, deployment topology awareness may allow it to realize adaptation of the network in case of a station failure. This function is called *Recovering Protocol (RP).*

In the case of significant interference detection, which cannot be compensated on the local level, the centralized RRM can impose a more robust link on specific network sections. This function is called *Centralized Interference Mitigation (CIM).*

Finally, for the purpose of user data throughput maximization in the given segment (cluster), the centralized RRM may dynamically redistribute radio resources, providing some selected stations with more resources while other stations are provided with fewer resources, resulting in lower capacities. This function is called *Adaptive Resource Allocation (ARA).*

5.2 Description of the algorithms

The procedures related to Dynamic Frequency Planning (DFP) should be performed automatically upon initial RAN segment activation and after that periodically or event driven to take into consideration global evolutions of the radio access network deployment characteristics. The main purpose of the cluster radio resource management is to minimize interference impact in the system's deployment providing Centralized RRM-E with information available in other distributed RRM entities, e.g. ABSs (for example, to report interferences at a cell edge).

The centralized RRM entity collects all useful information required to adapt the frequency planning and allow channels allocations suiting the traffic load requirements

To avoid the performance degradation, these periodic updates should be scheduled while network load decreases (at night or during off-load hours). However, an operator can force the centralized algorithm to operate and then to update the overall channels allocation for the different stations. This process can be relevant especially while a station is being removed, added or modified.

Figure 5.1 then explains the algorithm in its fundamental steps.

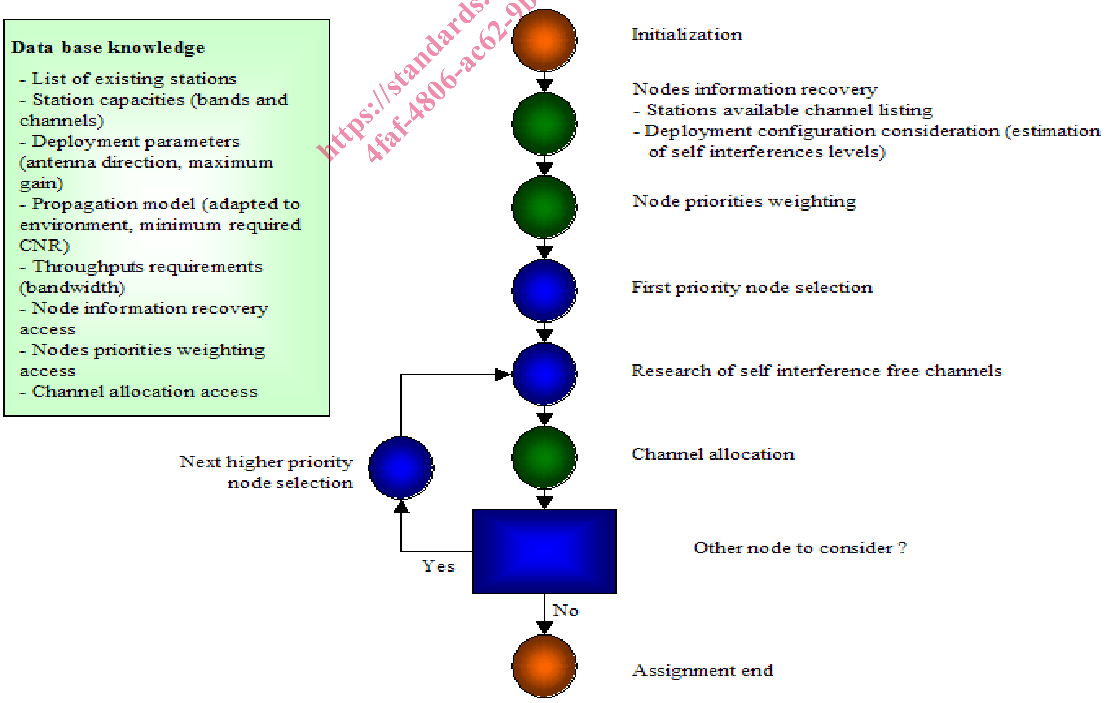

Figure 5.1: Dynamic frequency planning algorithm

As shown above, and apart from the initial state configuration, the process includes different sub-processes which will be depicted later. A certain amount of information about the network segment is required. Having prior fresh information will result in more effective channel allocation.

This information list includes the following parameters:

- List of ABS stations
- For each of those stations:
  - Deployment parameters:
    - Location
    - Antenna type (among a known list, for gain, and aperture)
    - Antenna orientation
  - Station capacities (time stamped):
    - Available bandwidth
    - Available channels (with interferences levels of them)
    - CNR/CINR threshold
  - Required throughput (time stamped)
- The general propagation model for the Network surrounding environment

Two of those information elements are critical and have to be known:

- List of ABS stations the centralized RRM-E is responsible for
- The adapted propagation model

The aforementioned frequency assignment process results in configuration of the relevant stations with the channels allowed for their usage.

The process starts with the identification of the network segment requirements in terms of throughput. Based on this information, different priorities are assigned for the corresponding stations. The priority of the station is the determinant factor for the channel assignment protocol, as the nodes with higher priority will be the firsts to get channel assignments, and, correspondingly, will be less dependent on other stations assignments.

Once the station prioritization is accomplished, nodes are iteratively assigned with a frequency channel, one channel at a time, meaning that after all stations were assigned a primary channel, the process restarts with the top priority station assigning a secondary channel and so on. The process terminates when no available channels have been left.

Finally the Centralized RRM-E sends the requests to each station informing it about the assigned frequency channels.

Figure 5.2 presents the steps required for the stations information collection process.

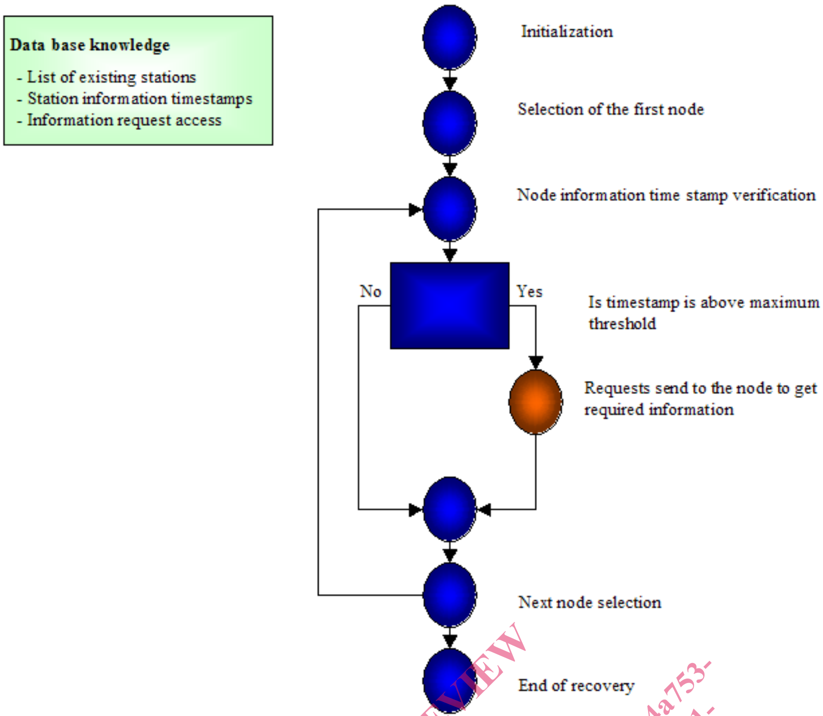

Figure 5.2: Stations information collection process

This process uses another set of primitives designed for the collection of information from the known stations. The details of those primitives are given in continuation.

In this process, the Centralized RRM-E is checking the timestamp of the data related to the corresponding node in order to ensure its freshness.

In the case of periodic information collection process, the delivered data may be suppressed, sending only the parameters that have been changed and thus reducing backhauling throughput requirements. Otherwise, if the process is event-driven, all the parameters have to be included in the response message.

Once the network database is updated, the stations are assigned with the priorities based on different kinds of parameters.