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for Remote Rural Communities**

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Foreword

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

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Introduction

Broadband access for rural communities is one of the objectives of the European Commission. The EC FP7 project ICT-601102 STP TUCAN3G, "Wireless technologies for isolated rural communities in developing countries based on cellular 3G femtocell deployments" has addressed this problem and has provided a system design for deployments of Telefonica in Peru.

The present document includes the main outcome of the project.

1 Scope

The present document describes the architecture and implementation guidance for rural BWA based on 3G femto base stations, and a variety of terrestrial and satellite backhaul solutions. The implementation guidance includes self-optimization of physical layer parameters and recommendations for femto-to-femto and femto-to-backhaul interaction. Additionally, deployment examples, at least for Peru, are included.

2 References

2.1 Normative 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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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.

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[i.2] Lin Y., B. Gan, C. H. & Liang C. F.: "Reducing call routing cost for femtocells". IEEE Transactions on Wireless Communications, pp. 2302-2309, vol. 9, no. 7, July 2010.

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[i.4] Khan M., F. Khan M. I. & Raahemifar K.: "Local IP Access (LIPA) enabled 3G and 4G femtocell architectures". In Proceedings of the 24th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), pp. 1049-1053, May 2011.

[i.5] Small Cell Forum Release Two documents.

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[i.7] TUCAN3G D42: "Optimization and monitoring of HNB network", November 2014.

NOTE: Available at http://www.ict-tucan3g.eu/.

[i.8] TUCAN3G D41: "UMTS/HSPA network dimensioning", November 2013.

NOTE: Available at http://www.ict-tucan3g.eu/.

[i.9] TUCAN3G D51: "Technical requirements and evaluation of WiLD, WIMAX and VSAT for backhauling rural femtocells networks", October 2013.

NOTE: Available at http://www.ict-tucan3g.eu/.

[i.10] TUCAN3G D52: "Heterogeneous transport network testbed deployed and validated in laboratory", April 2014.

NOTE: Available at http://www.ict-tucan3g.eu/.

[i.11] Recommendation ITU-T G.114: "One way transmission time", May 2003.

[i.12] 3GPP TR 25.853: "Delay Budget within the access stratum".

[i.13] ETSI TS 125 467: "Universal Mobile Telecommunications System (UMTS); UTRAN architecture for 3G Home Node B (HNB); Stage 2 (3GPP TS 25.467)".

[i.14] ETSI TS 123 207: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); End-to-end Quality of Service (QoS) concept and architecture (3GPP TS 23.207 version 6.6.0 Release 6)".

[i.15] ETSI TS 125 444: "Universal Mobile Telecommunications System (UMTS); Iuh data transport (3GPP TS 25.444 version 11.0.0 Release 11)".

[i.16] ETSI TS 133 320: "Universal Mobile Telecommunications System (UMTS); LTE; Security of Home Node B (HNB) / Home evolved Node B (HeNB) (3GPP TS 33.320 version 12.1.0 Release 12)".

[i.17] IEEE 802.11™: "IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.18] IEEE 802.16™: "IEEE Standard for Air Interface for Broadband Wireless Access Systems".

[i.19] TUCAN3G D43: "Interoperability of access and transport network", April 2013.

NOTE: Available at http://www.ict-tucan3g.eu/.

3 Definitions and abbreviations

3.1 Definitions

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

heterogeneous network: network consisting of cells with different sized coverage areas, possibly overlapping and possibly of different wireless technologies

Location Area Code (LAC): code to group cells together for circuit-switched mobility purposes

WiFi™: Technology based on IEEE 802.11 [i.17] standard.

WiMAX™: Technology based on IEEE 802.16 [i.18] standard.

3.2 Abbreviations

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

ABI Access-Backhaul interface
AC Access Controller

ACK	Acknowledgement
ADSL	Asymetrical Digital Subscriber Line
AICH	Acquisition Indicator Channel
AMC	Adaptive Modulation and Coding
AN	Access Network
ATM	Asynchroneous Transfer Mode
AWGN	Additive White Gaussian Noise
BH	Backhaul
BS	Base Station
BWA	Broadband Wireless Access
CAPEX	Capital Expenditure
CDMA	Code Division Multiple Access
CPE	Customer Premises Equipment
CRE	Cell Range Extension
CRL	Certificate Revocation List
CS	Circuit Switched
DivServ	Differential Services
DL	Downlink
DNS	Domain Name System
DSCP	Differentiated Services Code Point
ECM	EPS Connection Management
eNB	Evolved Node B
EPC	Evolved Packet Core
EPS	Evolved Packet System
Er	Erlang
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FCAP	Frequency and Code Assignment Problem
GCP	Graph Colouring Problem
GEO	Geostationary Earth Orbit
GGSN	Gateway GPRS Service Node
GPS	Global Position System
GW	Gateway
HetNet	Heterogeneous Network
HMS	HNB Management System
HNB	Home Node B
HNB-GW	Home Node B Gateway
HNBAP	HNB Application Protocol
HSDPA	High Speed Downlink Packet Access
IP	Internet Protocol
IPsec	IP security scheme
ISP	Internet Service Provider
Iuh	Iu home
KPI	Key Performance Indicator
LAC	Location Area Code
LEO	Low Earth Orbit
LIPA	Local IP Access
LTE	Long Term Evolution
MDT	Minimization Drive Tests
MEO	Medium Earth Orbit
MPLS	Multi Protocol Label Switching
NCell	Neighbour Cell
NCL	Neighbour Cell List
NOS	Network Orchestration System
NP	Non Polynomial
NRT	Neighbour Routing Table
NTP	Network Time Protocol
NWL	Network Listen
OPC	Optimal Power and Code allocation
OPEX	Operational Expenditure
PCI	Physical Cell Identity (LTE equivalent of the 3G PSC)
P-CPICH	Primary Common Pilot Channel
PDP	Packet Data Protocol

PF	Proportional Fair
PLMN	Public Land Mobile Network
PM	Performance Management
PS	Packet Switched
PSC	Primary scrambling code
QoS	Quality of Service
RAC	Routing Area Code

NOTE: Code to group cells together for packet-switched mobility purposes. Routing Areas are contained within Location Areas.

RACH	Random Access Channel
RANAP	Radio Access Network Application Part
RAT	Radio Access Technology
RF	Radio Frequency
RRC	Radio Resource Control
RSSI	Received Signal Strength Indication - Power level received at the antenna
RSVP	Resource Reservation Protocol
RTP	Real Time Protocol
RTT	Round Trip delay Time
RUA	RANAP User Adaption
SF	Spreading Factor
SIB	System Information Block
SINR	Signal to Interference and Noise Ratio
SIP	Session Initiated Protocol
SIPTO	Selected IP Traffic Offload
SON	Self-Organizing Networks
SRVCC	Single Radio Voice Call Continuity
STP	Specific Targeted Research Project
SW	Software
TNL	Transport Network Layer
TTI	Time Transmission Interval
UARFCN	UTRA Absolute Radio Frequency Channel Number
UE	User Equipment
UL	Uplink
VSAT	Very Small Aperture Terminal
WCDMA	Wideband Code Division Multiple Access
WiLD	Long distance WiFi

4 Technical scenarios and architecture

4.1 Technical scenarios

4.1.1 Introduction

The scenarios regarded in the present document are rural areas that are far away from well-connected places. Rural femtocells may be deployed in remote villages, and the mission of the transport network is to connect those femtocells to the operator's core network. It is assumed that the transport network uses wireless technologies to cover distances of tens or even hundreds of kilometres. In most of the scenarios, several hops will be required, and a common transport infrastructure will be used to serve several villages. Several femtocells will be deployed in each village.

The use of satellite communications is considered for scenarios that need to cover extremely long distances between the operator's core network and the access network; more details will be given below. For the rest of the cases, and even for the connection of several femtos to a common satellite communications gateway, a combination of WiFi and WiMAX will be explored. This does not mean that other alternatives may not be used.

Both share a common objective of proposing low-cost appropriate technologies that may help operators to provide access to sparsely populated remote villages. In the case of the transport network, the technologies considered are relatively cheap, may be used in non-licensed bands, have a low power consumption profile, may provide broadband data transport services and may support QoS at a certain level. However, other professional solutions commonly used as backhaul for small cells can be considered.

4.1.2 Traffic characteristics

The following traffic characteristics are considered as typical:

- The backhaul connecting each femtocell to the operator's core network transports different traffic classes, such as control traffic, telephony and data traffic as a minimum.
- The transport network assumes that different traffic classes require different QoS levels.
- It is assumed that different traffic classes receives different priorities, and a minimum QoS support would consist of a unified end-to-end strategy in the transport network to give consistent relative priorities to the different classes.
- It is also assumed that certain traffic classes have strict requirements in terms of throughput (maximum and minimum), delay (maximum), jitter (maximum) and packet loss (maximum).

4.1.3 Deployment constraints

Scenarios are considered following these rules:

- Access networks that are too far for any point of presence of the operator's core network require a terrestrial wireless transport network to connect the femtocells to a gateway (using any combination of WiLD and WiMAX links) and a satellite link that connects the gateway to the operator's network.
- Access networks that can be deployed using terrestrial hops less than 50 km long and may be connected to the operator's network following this rule will not require a satellite link.
- Links that are closer to towns and may be influenced by urban wireless networks operating in non-licensed bands will use licensed frequencies or a non-licensed band that is known to be relatively free of interferences.

Links will be considered reliable under the following conditions:

- RF planning with appropriated propagation models shows availability 99,9 % of the time.
- Sites are known to be accessible and physically protected.

4.2 Radio transport technologies

4.2.1 Introduction

There are two options in transport technologies:

- Wired networks (pair cable, coaxial cable or optical fiber): with high capacity and null interference with other networks.
- Wireless networks: with interference with other networks, with lower capacity and where the attenuation decreases the coverage, but with lower cost of network deployment.

  In rural areas the deployment of wired networks is often neither reasonable nor worthwhile. In contrast, the features of the rural scenarios reduce the drawbacks of the wireless networks (lower capacity demand; and the scarce presence of other networks produce a significant decrease in the interference) and increase the advantages (the infrastructure is concentrated in selected geographical locations; no needs of maintenance or supervision out of this locations; and the network deployment is faster and with lower cost compared with wired networks).

  Consequently, the options to offer voice and broadband data connectivity in isolated rural areas are radio transport technologies: WiFi, WiMAX and VSAT.

4.2.2 WiLD (WiFi-based Long Distance) networks

The first WiFi standards were conceived for WLAN (Wireless Local Area Networks). The main obstacle to the application for long distances is their MAC (Medium Access Control) protocol: CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). This protocol is very sensitive to the propagation delay and its performance level decreases with the distance between stations.

The PHY layer and the MAC layer establish limits in the coverage distance.

In PHY layer, the higher nominal bit rates are achieved with powerful modulations and low redundancy coding schemes, but it only works in short distances because the received power is high. So, the bit rate decreases with the distance. In point to point transmissions the transmitted power is the allowed maximum and the antenna gains are high. Figure 4.1 shows that long distances can be reached only if high gain directive antennas are used, i.e. 12 dB for omnidirectional antennas and 24 dBi for directional antennas.

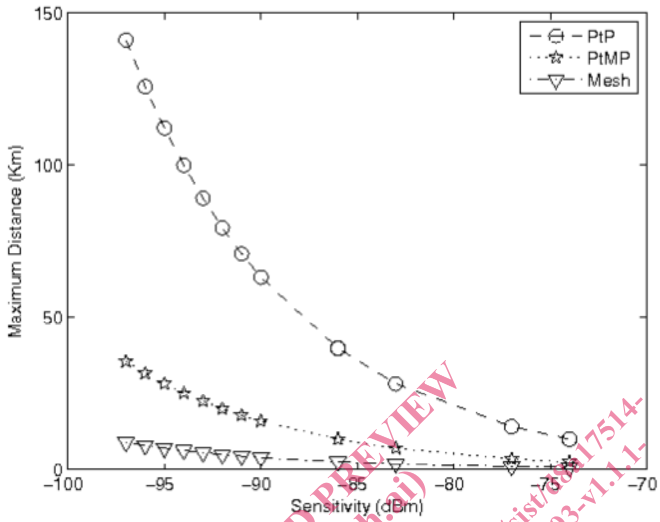

Figure 4.1: Achievable distance for point to point, point to multipoint or mesh WiFi [i.9]

4.2.3 WiMAX (Worldwide Interoperability for Microwave Access)

The equipment based on IEEE 802.16 [i.18] standard is suitable to provide coverage to isolated areas with low cost and low time of deployment. The standard provides advantages like equipment interoperability, great robustness, higher security and the possibility to offer strict QoS support to all the communications in the network. It includes flexibility in the frequency bands (licensed and non-licensed) and in scenarios (fixed or mobile).

4.2.4 VSAT

The objective of the satellite links in rural BWA is to serve as IP transport network between gateways and the operator's network, mainly where the distance between gateways and operator's network is greater than 50 km. For broadband access and IP backhauling, and for the group of services where the cellular backhauling needed for remote rural can be considered into, it is accepted by industry that the best performance/cost solution for a satellite link is using a GEO (Geostationary Earth Orbit) satellite.

A geostationary orbit is a particular type of geosynchronous orbit. It is a circular orbit 35 786 km above the Earth's equator and following the direction of the Earth's rotation. A satellite in such an orbit has an orbital period equal to the Earth's rotational period (one sidereal day), and thus appears motionless, at a fixed position in the sky, to ground observers. The ground satellite antennas that communicate with the satellite do not have to move to track the satellite; they are pointed permanently at the position in the sky where the satellite stays.

While it is industry accepted that GEO satellites are the best option for fixed broadband access or IP backhauling, there are also recently industry developments and studies to offer these types of fixed services using MEO (Medium Earth Orbit) satellites.

MEO is the region of space around the Earth, located above LEO (Low Earth Orbit, altitude of 2 000 km) and below GEO (Geostationary Earth Orbit, altitude of 35 786 km). MEO satellites are widely used for navigation and geodetic/space environment science. The orbital periods of MEO satellites range from about 2 hours to nearly 24 hours. Examples of satellite systems in MEO for navigation are GPS (Global Positioning System) and Galileo.

As MEO satellites are not fixed in the sky from the point of view of a ground observer on Earth, these satellites are not single ones and the system in composed of several ones, and named constellation. If used for fixed broadband access or IP backhaul, there is the need of using at least two antennas with tracking devices. Each antenna moves and tracks one visible satellite, and a switchover of the communications link from one antenna to the other is done periodically as one antenna is losing visibility of one satellite and the other one is locked to the next satellite in the constellation.

Using MEO satellites instead of GEO satellites improve IP communications performance, as the delay is significantly reduced. IP communications trough a GEO satellite has an RTT of 600 ms to 650 ms, while with MEO satellites it can be reduced four or five times (estimated RTT is 130 ms to 140 ms). This improvement is especially important when backhauling GPRS/EDGE and 3G traffic, whose performance is very sensitive to delay in the transport network.

Another difference between GEO and MEO satellite systems, for broadband access and backhauling, is that GEO satellites can provide full coverage to the Earth (but Poles) with only 3 satellites (if strategically deployed in the orbit, covering 120º each one), while with MEO satellites are needed more. For example, O3b will start with 8 satellites, to be upgraded to 12 satellites and 16 satellites.

Increase in cost of antenna subsystem to be able to track at least two MEO satellites, comparing to one single antenna pointed to a GEO satellite, makes difficult to adopt this type of solutions for backhauling in very remote areas with very low traffic needs. They will be widely used for backhauling between medium and big cities with high demand of traffic.

So for rural area deployments the best option is to use a GEO satellite, as there will be more available satellites and the satellite terminal will be cheaper.

4.3 Architecture example

4.3.1 Overview

The architecture example has three main sections:

- Access network (composed by femtocells)
- Backhaul (an IP heterogeneous transport network)
- Network controller that manages the cells and acts as gateway with the core network

These elements and the connection scheme can be seen in figure 4.2.

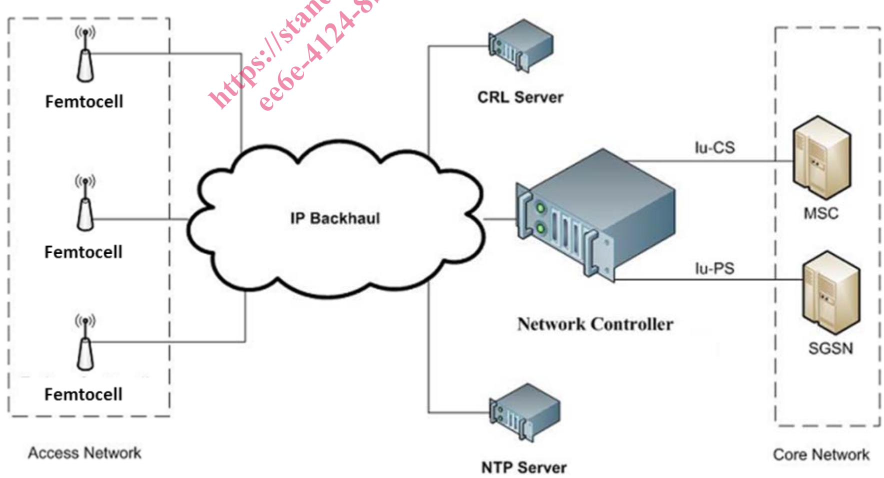

Figure 4.2: Network architecture example

4.3.2 Network Controller

The Network Controller provides the following functionality:

- **Access Controller (AC)** that aggregates the traffic carried over IP from the femtocells and provides standard interfaces (Iu-CS and Iu-PS) to the core network.