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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Converged Fixed-Nomadic Broadband Wireless Access (BWA); Part 1: Frequencies above 3,4 GHz - System reference document

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document is part 1 of a multi-part deliverable covering the technical characteristics for spectrum usage of converged fixed-nomadic Broadband Wireless Access (BWA), as identified below:

Part 1: "Frequencies above 3,4 GHz - System reference document".

Part 2: "Frequencies below 3,4 GHz - System reference document".

1 Scope

The present document defines the spectrum requirements based on new standardization and the evolving market requirements for Converged Fixed-Nomadic broadband wireless access systems above 3,4 GHz. The information in the present document is mainly derived from standardization activities within ETSI BRAN HiperMAN and IEEE 802.16 [4], which are subject to a cooperation agreement for harmonizing the relevant standards. In the present document, the term "nomadic" is used in accordance with the definition in ITU-R Recommendation F.1399 [12] that quotes: "the location of the *end-user termination* may be in different places but it must be stationary while in use".

Part 1 takes into account the fact that there are established frequency bands already identified within the ECC framework for BFWA and/or P-MP (e.g. 3,4 GHz to 3,6 GHz), and additionally, identifies interest in adjacent frequency bands, specifically up to 4,2 GHz.

It includes necessary information to support the co-operation between ETSI and the Electronic Communication Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT), including:

- Detailed market information (annex A).
- Technical information (annex B).
- Expected compatibility issues (annex C).

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ETSI TS 102 177 (V1.3.2): "Broadband Radio Access Networks (BRAN); HiperMAN; Physical (PHY) Layer".

[2] ETSI TS 102 178 (V1.3.2): "Broadband Radio Access Networks (BRAN); HiperMAN; Data Link Control (DLC) Layer".

[3] ETSI TS 102 210 (V1.2.1): "Broadband Radio Access Networks (BRAN); HiperMAN; System Profiles".

[4] IEEE 802.16: "Standard for local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems".

[5] BROADWAN (Broadband services for everyone over fixed wireless access networks) Consortium, under the FP6 001930 contract of the European Union IST Thematic Priority of the Sixth Framework Programme. BROADWAN is partially funded by the European Commission.

[6] 001930 BROADWAN; Deliverable D6; "User and Service requirements".

[7] IEEE C802.16.d-03-78r1: "Coverage/Capacity simulations for OFDMA PHY in with ITU-T channel model".

[8] ITU Radio Regulations (2004): "Articles".

[9] European Radiocommunications Committee (ERC) within the European Conference of Postal and Telecommunications Administrations (CEPT), Report 025: "The European Table of Frequency allocations and utilizations covering the frequency range 9 kHz to 275 GHz".

[10] CEPT/ERC/Recommendation 13-04: "Preferred frequency bands for fixed wireless access in the frequency range between 3 and 29.5 GHz".

[11] ETSI EN 302 326-3 (V1.2.1): "Fixed Radio Systems; Multipoint Equipment and Antennas; Part 3: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive for Multipoint Radio Antennas".

[12] ITU-R Recommendation F.1399: "Vocabulary of terms for wireless access".

[13] CEPT/ERC/Recommendation 14-03: "Harmonized radio frequency channel arrangements and block allocation for low and medium capacity systems in the band 3400 MHz to 3600 MHz".

[14] CEPT/ERC/Recommendation 12-08: "Harmonized radio frequency channel arrangements and block allocations for low, medium and high capacity systems in the band 3600 MHz to 4200 MHz".

[15] CEPT/ERC Recommendation T/R 13-01: "Preferred channel arrangements for fixed services in the range 1-3 GHz".

[16] IDATE News 343, February 3d 2005.

[17] IEEE 802.11 - 05/173: "A Designer's Companion".

[18] ETSI TR 102 079 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document for licence-exempt Fixed Wireless Access (HIPERMAN) for band C (5,725 GHz to 5,875 GHz)".

[19] IEEE 802.16e: "Air Interface for Fixed and Mobile Broadband Wireless Access Systems; Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands".

[20] ETSI EN 301 021: "Fixed Radio Systems; Point-to-multipoint equipment; Time Division Multiple Access (TDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[21] ETSI EN 302 326-2: "Fixed Radio Systems; Multipoint Equipment and Antennas; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive for Digital Multipoint Radio Equipment".

[22] ETSI EN 301 753: "Fixed Radio Systems; Multipoint equipment and antennas; Generic harmonized standard for multipoint digital fixed radio systems and antennas covering the essential requirements under article 3.2 of the Directive 1999/5/EC".

[23] European Commission: "Mandate to CEPT to identify the conditions relating to the provision of harmonized radio frequency bands in the European Union for Broadband Wireless Access applications".

[24] IEEE Project 802.16h: "Amendment to IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems - Improved Coexistence Mechanisms for License-Exempt Operation".

[25] ECC/Report 33: "The analysis of the coexistence of Point-to-Multipoint FWS cells in the 3,4 - 3,8 GHz band".

[26] ECC Recommendation 04-05: "The analysis of the coexistence of Point-to-Multipoint FWS cells in the 3.4 - 3.8 GHz band".

[27] ETSI TR 102 453-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Converged Fixed-Nomadic Broadband Wireless Access (BWA); Part 2: Frequencies below 3,4 GHz - System reference document".

[28] ETSI EN 302 502: "Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Fixed Wireless Access (FWA): wireless access application in which the **location of the end-user termination** and the network access point to be connected to the end-user are **fixed**

Mobile Wireless Access (MWA): wireless access application in which the **location of the end-user termination is mobile**

Nomadic Wireless Access (NWA): wireless access application in which the location of the end-user termination may be in different places but it must be stationary while in use

triple play: Data, Voice and Video services

3.2 Symbols

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

Ø No interference between the mentioned radio units

3.3 Abbreviations

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

AAS	Advanced Antenna Systems
ADSL	Asymmetric Digital Subscriber Line
ARQ	Automatic Repeat reQuest
BEM	Block Edge Mask
BFWA	Broadband Fixed Wireless Access
BSU	Base Station Unit
BWA	Broadband Wireless Access
CPE	Customer Premises Equipment
DL	Down-Link
DSL	Digital Subscriber Loop
eirp	echivalent isotropic radiated power
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
FNWA	Fixed/Nomadic Wireless Access
FSS	Fixed Satelite Service
FWA	Fixed Wireless Access
HDTV	High Definition TeleVision
HM	HiperMAN
ICT	Information and Communications Technologies
LE	License Exempt
LMDS	Local Multipoint Distribution Service
MIMO	Multiple-Input Multiple-Output
MWA	Mobile Wireless Access
NLOS	Non Line Of Sight
NWA	Nomadic Wireless Access
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PIFA	Planar Inverted F Antennas
P-MP	Point-to-MultiPoint
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

R-BB	Repeater-Base Band
R-RF	Repeater-RF level
SISO	Single Input, Single Output
SOFDMA	Scalable OFDMA
ST	Subscriber Terminal
STC	Space-Time Coding
ST-F	Subscriber Terminal-Fixed
ST-N	Subscriber Terminal-Nomadic
TDD	Time Division Duplex
UL	Up-Link
VDSL	Very high Data Subscriber Line
VoD	Video on Demand
VoIP	Voice over IP
WA	Wireless Access
WDSL	Wireless Digital Subscriber Loop
WGSE	ECC Working Group on Spectrum Engineering
WIMAX	Worldwide Interoperability for Microwave ACCess

4 Executive summary

4.1 Status of the System Reference Document

The present document has prepared in cooperation with BRAN.

The present document has been reviewed and approved by WG ERM RM#33 for publication, on behalf of TC ERM.

4.1.1 Statement from BMWI (BNetzA - Bundesnetzagentur) and Deutsche Telekom AG

BMWI (BNetzA) does not support the proposal to investigate the designation of more licensed spectrum to BWA in the frequency range from 3,8 GHz to 4,2 GHz. It is noted that this frequency range is heavily used by wide-range Fixed Service links in the long-term (e.g. for backbone application having very high availability requirements). FS usage is expected to further increase due to migration of Fixed Services from the frequency range below (which was decided in favour of BWA) as well as due to further demand.

4.2 Technical developments

4.2.1 Enabling interoperability

The Broadband Fixed Wireless Access technology deployed to date has been based around proprietary solutions with no possibility for interoperability between vendors or across different BFWA networks. Recent concerted standardization effort and collaboration in both ETSI and IEEE has resulted in new air interface standards that facilitate a new breed of technology that can be interoperable. Further focussing of the technology options has resulted from the activities of certification bodies who are developing test procedures to certify standards compliance and ensure interoperability. These developments open up the opportunities for:

- Multi-source BFWA equipment.
- Greater economies of scale reducing equipment costs.
- Interoperability allowing operation across networks.
- The possibility for nomadic terminal devices.

Other features included in the standards will facilitate indoor terminal operation which will also support nomadic device operation so that fixed and nomadic operation, as defined by the ITU-R Recommendation F.1399 [12], is possible.

4.2.2 Nomadic operation

Nomadic operation will allow to the BFWA service users to connect in any service area, covered by the Broadband Fixed service, to the Internet or to their enterprise network (see note). They will use indoor subscriber units or units built into laptop computers. Given that such a "wireless indoor modem" is not tethered to its source of connectivity, it can be characterized as an end user terminal which is stationary while in use, but whose location can change as identified in ITU-R Recommendation F.1399 [12].

NOTE: Where wireless indoor modems have been deployed for broadband access (e.g. in Australia), users have been observed to carry the modem around with them in order to use it at home and at their place of employment.

Such an operating environment requires a wireless system that can support both NLOS and indoor operation and provides sufficiently high enough data throughput to sustain the user applications.

4.2.3 Broadband capability

Traditional BFWA systems deployed in the past in the lower frequency ranges were more closely associated with WLL operation and considered as lower data rate systems. The standardization in HiperMAN and IEEE 802.16 [4] has been based around broadband service provision.

The broadband capabilities of the new standards include:

- Ability to use high width radio channels, up to 28 MHz, without performance degradation due to multi-path.
- Ability to use, in high width channels, smart antenna systems, increasing the system gain or the data rates.
- Ability to use higher modulation states in the same C/(I+N) conditions, as compared with traditional WLL technologies, due to Turbo-coding.
- Ability to keep the up-link system gain almost independent of channel width, by using scalable OFDMA sub-channel number.
- Ability to keep data rate performance, in both up-link and downlink, almost independent of user number.

4.2.4 Applications

The Quality of Service features of the IEEE 802.16 [4] and ETSI BRAN HiperMAN standards enable applications in both the private and commercial sectors. These applications revolve around data services for email, internet access, VoIP, VoD (Video on Demand), teleconference, triple-play and dedicated data leased lines. Such applications place different expectations on the system requirements. For example, email services require reasonable symmetry of the up and downlink data rates, however latency is not a prime requirement, internet access tends to be asymmetric, with a relatively higher downlink data rate than that needed by the uplink. VoIP and video teleconference requires both a symmetrical bandwidth, and a low latency, although the data rate may not be relatively high. VoD require mainly downlink spectrum. Dedicated data leased lines generally have the requirement for both symmetrical data service and low latency coupled with the need for continuous operation.

4.2.5 Key Technology Features of Converged Fixed Nomadic Broadband Wireless Access

The IEEE 802.16 [4]/ ETSI HiperMAN [1], [2] and [3] standards specify the air interface for Point-to-Multipoint systems. Features such as transmit/receive diversity and quality of service increase the coverage area especially for indoor terminals and allow real-time applications. These systems can provide multiple services in a extended coverage area network based on the new technologies described in continuation.

Industry activity (WIMAX Forum - see note) is focussing on OFDM and OFDMA based systems that are directed towards providing a harmonized approach for such a wireless operating environment.

NOTE: WIMAX Forum is a non profit organization developing a certification process for equipment based on the ETSI HiperMAN [1], [2] and [3] and IEEE 802.16 [4] standards.

4.2.5.1 OFDM technology

The robust nature of OFDM multiple carrier technology is well known and demonstrated already in the field of RLANs and broadcasting. It has proven capability for mitigating the dynamic nature of the NLOS environment associated with the operation of nomadic terminals.

The basic OFDM technology is an efficient and robust means of providing service in a NLOS environment. It uses a 256 FFT size. The sub-channelization is a further enhancement, which enables both economic use of the available bandwidth and a balanced link budget using low power subscriber terminal equipment, through the use of sub-channelization of the signal. Low power subscriber devices allow fixed and nomadic/indoor operation to become a reality. The system comprises a base station with one or more sectors as dictated by the capacity requirements of the application, the frequency reuse needs and the location, and a number of subscriber stations that can either be fixed in an indoor or outdoor location, or nomadic in terms of a subscriber station that is moveable and can be used at one or more locations (e.g. Laptops). In general a fixed terminal can use a directional antenna that allows a larger cell radius or better coverage/QoS than that of nomadic terminals that use antennas with less directionality. However, in areas where nomadic and or indoor devices are dominant, use of smaller cells enables the coverage and performance to be optimized.

Adaptive Antenna Systems (AAS) might also be used to optimize the coverage or the capacity, based on the actual terminal requirements.

4.2.5.2 SOFDMA technology

SOFDMA is an enhancement of OFDMA [19] that allows to use quasi-constant sub-carrier spacing, for a large variety of channel sizes, by using different FFT sizes as 512 points, 1 024 points and 2 048 points. The 512 and higher FFT sizes are suitable for fixed/nomadic applications using more than 7 MHz channel width.

Some SOFDMA specific features designed to enhance performance (capacity, coverage, reduced probability of outage, etc.) are listed here:

- UL STC (Space Time Coding) and Spatial Multiplexing in single and collaborative modes; in the collaborative mode two STs collaborate on transmission of special multiplexing signal, where each subscriber station does not need more than one transmit antenna and amplifier, achieving higher capacity at low ST cost.
- DL MIMO (2^{nd}, 3^{rd} and 4^{th} orders, the order corresponding to the number of used antennas), allowing capacity improvement. This is an essential feature to significantly improve the spectral efficiency.
- Special sub-carrier allocation modes designed for support of frequency reuse 1 as well as more conservative reuse factors.
- Special sub-carrier allocation modes designed for effective support of advanced antenna techniques and beamforming.
- Scalable OFDMA, using FFT sizes of 512,1 k and 2 k points, reduces the guard time overhead at least by a factor of two.

The up-link sub-channelization in the OFDM mode or the up-link OFDMA allows to increase the link budget up to 12 dB to 15 dB and provide the basis for indoor deployment.

The use of UL/DL sub-channels and their transmit powers in a coordinated mode between base-stations will allow to avoid/reduce the experienced interference, enabling reuse factor 1, especially when using omnidirectional antennas for ST (Laptop or indoor units).

Another possibility is to separate users of directional antennas from users of omni antennas in the same frequency channel, by using OFDMA sub-channels. In this way, the new nomadic users will not affect the spectral efficiency and QoS of traditional fixed users.

4.2.5.3 Adaptive Antenna Systems (AAS)

Traditionally point to point systems direct their energy between two points, and point to multi-point system are based on covering a defined area. Both of these methods are static, adaptive antenna systems are dynamic and try and combine the best of each method, by directing the maximum gain of the antenna toward a particular area of the active subscriber terminal. They can also generate nulls in the overall antenna pattern to reduce the interference from unwanted sources. The implementations of AAS are in the form of two or more antennas that either use a switched beam or beam steering principle. In a real world environment where the sources of interference are continually changing, because of the ability to introduce nulls in one or more axis, AAS enable the system co-channel interference rejection ratio to be increased, which permits higher modulation schemes and hence higher throughput. The advantage for the service provider is that the capacity, range, availability and the coverage can be increased.

4.2.5.4 Multiple-Input Multiple-Output (MIMO)

The MIMO technology will allow to increase significantly the spectral efficiency in downlink, at relatively low cost for the subscriber units. The downlink MIMO will use for the beginning two transmit channels on Base Station and two receive channels on ST.

The support for this arrangement is defined in the IEEE 802.16e [19] amendment and will have as result at the beginning double spectral efficiency or higher cell size, depending on the target improvement. The first products implementing this technology will come up in 2007. For the immediate needs of BWA services should be taken into consideration the sooner-available SISO technology.

4.2.6 Broadband market information

4.2.6.1 Market need

The BFWA market is today a niche market due to a number of causes:

- Lack of open standards, that will reduce the component costs.
- Problematic business case, due to high cost of installing outdoor antennas.
- Lack of sufficient licensed spectrum, to offer competitive broadband services in medium/long term.
- Lack of light-licensed spectrum, having power allowance suitable to large cell deployments for municipalities' applications.

The European need for broadband services is detailed in clauses A.2.1 and A.2.2.

It is identified that the following services requiring spectrum:

a) Small businesses and enterprises, which seek a competitive offering for broadband service with a guaranteed, service level agreement. In this scenario an outdoor, fixed subscriber terminal with a directional antenna is employed to provide the highest throughput connectivity. This bandwidth is then dispersed to many users within the business. Generally speaking, the amount a service provider can charge for such a business class service more than offsets the costs of professionally installing the fixed outdoor subscriber station.

   Some local carriers can take up to three months or more to provision a new E1/T1 line for a business customer if the service is not already available in the building. With BWA, the same service provider can provision the same speed of network access as the wired solution in a matter of days and at a lower deployment cost.

   Similarly, a service provider can offer "on demand" high-speed connectivity for events such as conferences, with hundreds or even thousands of IEEE 802.11 [17] hot spot users. These Wi-Fi hot spots would use broadband HiperMAN solutions as their backhaul to the core IP network. Such "on demand" connectivity could also benefit industries such as construction, mining, transportation, oil and gas and agriculture with nomadic and/or sporadic broadband connectivity needs. "On demand" or "as needed" last mile broadband services are a differentiated value proposition for BWA.

b) Residential users in areas where DSL or cable broadband services are not available. In this scenario, a service similar to consumer DSL connectivity is offered, generally at a premium to current DSL broadband service rates. This premium is required to offset the cost of the "truck roll" required to professionally install the fixed outdoor subscriber station.

   This scenario is the primary target for nomadic application in fixed services bands. Without the ability to deploy indoor modems (which are nomadic by ITU definition), wireless providers cannot offer a broadband service competitive with those offered by wireline providers, and therefore will be limited to offering BWA only where wireline services are not available. If competition is to be established for broadband services to residential customers, indoor or "self-install" modems are essential. These self-install modems do not require a costly truck roll and, additionally, are less expensive due to their smaller form factor and indoor environment (no need for protection against outdoor environmental factors). The throughput for indoor modems will be substantially less than that for an outdoor subscriber station, but still more than adequate for a consumer level broadband service.

   Longer term, there will be a convergence of fixed and mobile services. Because spectrum is scarce at lower frequency ranges, mobile service providers will logically start to target traditionally "fixed" service bands such as the 3 GHz and 4 GHz bands. (In order to support nomadic or even mobile application at these higher frequencies, smaller cell sizes and/or cost-optimized advanced antenna techniques will have to be employed). At this point, services providers offering fixed wireless services in the same bands would likely be required to offer nomadic connectivity to their customers in order to remain competitive.

c) A residential service, similar with VDSL, generally complementing the VDSL offering by the Fixed operator. The VDSL reach is approximately 1 km, while the existing wire-plant is designed to cover 5 km to 6 km reach. A re-deployment of the telephone wires will be needed, in order to provide the VDSL service to all the customers. The wireless approach can provide the same service quicker and with lower cost, if enough licensed spectrum will be available.

d) A service similar with Triple-play service, using:

   - VDSL approach, for data, VoIP, VoD.

   - IP multicast, for common video channels.

Broadband has a high penetration in Korea and Japan. Due to specific differences between the city layouts in Europe and Korea, the Fiber-to-the-Home installation cost is very high in Europe (in Korean cities there are many high-rise buildings). In Europe, the wireless can be added to the Fiber deployment, to spread the traffic to the last 200 m to 300 m, while having good business case and fast deployment.

Municipalities want to provide a best-effort data coverage for their residents. The needed spectrum attributes are different from the existing ISM bands, due to the need for high BS power (50 dBm eirp) and some form of interference avoidance, which include BS registration and a coexistence protocol, as the one developed in IEEE Project 802.16h [24].

There are also vertical markets, for example related to security, traffic monitoring, medical applications, etc. that wish to use the BWA equipment with some mobility, as Nomadic capabilities. Similarly, a service provider can use the shared spectrum to provide access in some cases.

4.2.6.2 Market size, forecasts and timing

The European market size is dependent of:

- Penetration of existing wired services.
- Service offering.

Table 1 summarize the relation between services, deployment area and penetration, for licensed spectrum.

Table 1

	Areas already covered with DSL wired access	Areas not yet covered with DSL wired access
SME		√
Residential DSL		√
Residential VDSL	√	
Triple-play	√	
Penetration at maturity	30 %	> 40 %

The experience shows that if the existing wired service has a positive business case, it will cost less than the wireless service. However, for customers beyond the wired service reach, where new infrastructure has to be deployed, the wireless service is preferable.

There is a huge market potential, to extend the broadband reach, as long as enough spectrum will be available to provide the requested services.

It is considered that in 2006 the WIMAX certified equipment will be available on the market and we propose that the new spectrum will be made available in the same year.

4.2.7 Broadband spectrum requirement and justifications

Based on the information available to ETSI, the amount of spectrum required is estimated based on the calculations given in clauses A.3 (needed data rates) and B.2.2.2 (spectrum calculation). In these calculations, the assumed spectral efficiency was relatively lower than in conventional Fixed wireless access due to the low directivity of antennas used for Subscriber Terminals. However, we consider that only with indoor terminals and Nomadic services it is a positive business case possible. This outweighs the disadvantage of lower spectral efficiency.

We address two general cases:

1) Basic spectrum needed per operator, to provide the target services, only for subscribers in direct BS coverage.

2) Spectrum needed per operator, to provide the target services with good coverage, by using in-band feeding and Relays to cover those areas which are not reachable directly from the Base Station.

We do not address the spectrum calculation for light-licensing regime, however we recommend to limit the operator number in a given area.

The needed operational (see note) spectrum per operator is summarized in table 2. The spectrum calculation assumed the TDD deployment. The considered channel spacing are 7 MHz, 10 MHz, 14 MHz and 20 MHz, which have conducted to the rounded values in table 2.

NOTE: In addition to the operational spectrum suitable guard bands should be provided.

Table 2: The needed amount of spectrum

	xDSL-like services	Triple play
Basic spectrum	56 MHz	120 MHz
Spectrum including in-band feeding for Relays	80 MHz	140 MHz

According to the resulting amounts of spectrum, and the high asymmetry of the envisaged services, we conclude that:

- it might be more suitable to use TDD allocations;
- the FDD allocations should be asymmetrical as well, and with suitable duplex spacing to accommodate the traffic patterns.

4.2.8 Frequency bands

4.2.8.1 Existing Frequency bands

A Fixed-Nomadic system may operate in existing Fixed allocations (3,4 GHz to 3,6 GHz and 3,6 GHz to 3,8 GHz), for P-MP systems. The reality is that the amount of spectrum that is available is far less that the 400 MHz in discussion. At present licensing in the 3 400 MHZ to 3 600 MHz range across Europe is fragmented in terms of licence block sizes. The availability of new spectrum or wider assignments for higher capacity services is questionable. In the 3 600 MHz to 3 800 MHz range other services are operating and this band is not currently widely available.

The System parameters for 3,4 GHz to 3,8 GHz are included in clauses B.1 and D.1.

4.2.8.2 Alternative Higher Frequency Ranges

There are a number of other frequency ranges already recognized by CEPT for wireless access and LMDS applications in the Fixed Service around 10 GHz and 26/28 GHz. In addition spectrum in the 40 GHz band has been identified for Multimedia Wireless Services. There has been interest in using these frequencies driven generally by the larger bandwidths that are available. However, although licences have been awarded in these ranges, the deployment has not been widespread or particularly successful in achieving objectives for increased competition amongst telecommunications companies for data service provision.

The 10 GHz band is not open in many countries in Europe and is therefore not a suitable candidate for widespread (nomadic) interoperable devices. There is considerable bandwidth available in the 26 and 28 GHz bands and licensing has been more widespread across Europe. Unfortunately, licence holders have struggled to develop a positive business case as equipment operating in these frequency bands can cost more than ten times that of equipment in the 3,5 GHz region. Furthermore, poor in-building penetration, much higher losses and the need for line of sight connection would make nomadic user terminals impossible to realize in the frequency ranges above 10 GHz with a reasonable cost objective. However, there could still be the possibility for these frequencies to support infrastructure deployments for access networks providing nomadic device deployments. These frequencies have not been considered further for addressing converged fixed-nomadic user access applications in the present document.

4.2.8.3 Licence-Exempt Frequencies

There is considerable interest in the opportunities offered by licence exempt spectrum (which might also include some form of light-licensing) particularly in the 5 GHz ranges.

Short range nomadic devices operate in the bands 5,15 GHz up to 5,725 GHz in the form of RLAN devices. There is interest also in the possibility of longer range licence exempt services in the 5725 – 5875 MHz (5,8 GHz) band and currently ETSI BRAN supports these developments with a version of the HIPERMAN air interface adapted for licence exempt operation and a draft harmonized standard for equipment in that band.

However the nature of the wireless access opportunity is different to that in licensed bands. Access to licence exempt frequencies opens up opportunities that may not be possible in licensed bands which are generally tied to a single or a few operator(s). Licence exemption provides ready access to spectrum for new applications and services without the need for a commitment to a long term (and possibly expensive) licence. Examples include offering services to community networks run by local associations, private networks around schools and colleges and so on. Licence exempt spectrum allows these early applications to evolve and develop before being taken up by more established licensed network operators.

The lack of protection from interference is a major concern in licence exempt bands. This makes them less attractive when operators want to offer an assured data rate and quality of service perhaps for business customers or for real time services. This is one reason why they may not be considered for mainstream services. In addition, licence exemption brings technical constraints necessary to ensure sharing with other services. EIRP limitations in the European licence-exempt spectrum reduce the link budget making it virtually impossible to serve indoor/nomadic terminal devices over any reasonable range.

For these reasons the licence exempt spectrum opportunity is seen as something complementary but not on an equal footing or interchangeable with the licensed band opportunities, and therefore has not been included in the evaluation contained in the present document, which targets the nomadic/indoor residential service.

4.2.8.4 Geographic area licensing

Licences may be awarded as either:

- a country-wide licence, i.e. authorizing deployment of services across an entire country;
- a regional licence, i.e. authorizing provision of service in a given region/market area (e.g. large municipal areas, provinces, etc.);
- a local licence, such as an individual station licence, whereas each new base/central station is licensed individually on a station-by-station basis.

The choice may be dependant to some extent upon the competition objectives of the administration, as well as any constraints arising from other existing use of the frequency band.

Usually operators will prefer to establish a national footprint by obtaining a country-wide licence, and in most circumstances this would be the preferred option since it both simplifies the auctioning and licensing process for the regulator, and minimizes the necessary co-ordination for the operator. However in some circumstances, especially if the available frequency band is capable of supporting more than one operator in a given geographic area, the band might be more flexibly and more fully exploited by adopting the regional or local licensing, either separately, or in combination with the country-wide licences. For example, if the frequency band is capable of supporting more than two operators in each area, then administration could choose to issue two country-wide licences for nation-wide competing operators, and dedicate the remaining part of the spectrum for regional/station licensing. The advantages for regional/local licensing are outlined below.

The national licensing is considered suitable for large telecommunications operators providing a range of nation-wide telecommunications services and wishing to add wireless access to their service portfolio. This type of licence would be also preferred by new entrants having sufficient capital for investment, and wishing to compete with incumbent nation-wide operators by providing wireless access services throughout a country. It should be also kept in mind, that the nation-wide licences usually carry the minimum coverage obligations (e.g. the minimum percentage of country area/population to be covered within the prescribed timeline), and these obligations also require a significant financial and operating capacity to satisfy.

On the other hand, the regional/local licensing is more flexible and may not carry any coverage obligations, and as such may be more attractive to the smaller (local) operators, who would prefer a regional/local licence for building the business gradually without high up-front budgets, and targeting a geographic area. There are many applications that can benefit from localized BWA service solutions. These kinds of applications can be offered on a regional basis and therefore regional/local licensing might be more suitable for their deployment. In particular local licensing on a station-by-station basis would provide the most flexible approach by allowing very targeted deployment and would help to avoid any degree of spectrum hoarding.

Regional licences might also be considered if there is significant existing use of the frequency band, which would necessitate many "exclusion zones" to avoid the new system from interfering into the existing user(s). In such cases, rather than defining the exclusion zones, regional licences would be offered which specify the area in which operation is permitted, rather than where operation is not permitted. However it should be recognized that for such limited operation to be attractive, the licensed areas should be covering significant markets (i.e. areas with reasonable population sizes). This might be possible, especially if the other incumbent service to be protected is not operating in highly populated areas (e.g. the incumbent use of point-to-point trans-regional trunk radio links, or military links deployed in military exercise areas, etc.). Otherwise, if the offered regional licences would be covering scarcely populated areas then they will often be unattractive for developing a strong business case so this option should not be widely encouraged.

It is also very important to note that, in the context of nomadic systems, the user will often be looking for wide area coverage, and therefore the use of regional/local licensing may be less attractive, unless there is both interoperability between systems and roaming agreements. Clearly national licensing would avoid this problem.

4.2.9 Spectrum parameters

The spectrum parameters are detailed in clause B.2.

The allowance for the high Base Station power is essential for the business case of the operators. The computation of this power, for the OFDMA systems, is exemplified in the clause B.2.1.

4.2.10 Current regulations

4.2.10.1 European P-MP Fixed Service - Spectrum allocations

4.2.10.1.1 Nomadic applications in P-MP Fixed Service allocations

There is no clear and harmonized indication on how nomadic application should be foreseen in licensee rules. Therefore Administrations made their own interpretation of the issue.

It is reminded that, from strict technical point of view, also in conventional P-MP systems, the Terminal location is not generally requested to be notified. Therefore, present Subscriber Terminals might, in principle, be already moved around, as far as the connection to the service allows, without Administration be aware of that. Then they could, de facto, already be nomadic.

The only limitation that, in practice, made this situation unlikely is the use of directional antenna that renders the terminal re-location a technically difficult and costly operation.

Also from the interference point of view, considering that most Subscriber Terminals could transmit only if recognized by a Central Station of the subscribed Operator, the "nomadicity" of Terminals might not constitute a problem.

Also the use of "omnidirectional antennas" in terminals should not be considered "excluded" a priori; it is more correctly said that there are not harmonized standards useful for self-declaration of conformity to R&TTE Directive; however, there are other ways for demonstrating conformance.

The absence of specific HEN for omnidirectional antennas is due only to absence of detailed compatibility studies that have not been made insofar for lack of emerging technologies that justified the effort of developing suitable propagation models for NLOS applications that are the basis for the use of such terminals antennas in indoor applications.

Regarding license conditions, also in this case, there is no uniform and harmonized approach by various Administrations (some forbid them, some are silent).

In conclusion, given that the necessary compatibility studies would demonstrate possible coexistence among various P-MP technologies, including omnidirectional terminals for "indoor" applications, the issue of "nomadic" application in Fixed licensed bands might be considered only a matter of due harmonization of licensing rules as often auspicated by the European Commission.

4.2.10.1.2 CEPT Recommendations

CEPT/ERC Recommendation 13-04

Quite aged since it was produced in 1998, identifies only the frequency bands 3,4 GHz to 3,6 GHz for Fixed P-MP use and does not consider Nomadic use in Fixed frequencies above 3 GHz, as a result of the statements below.

…………..

"Fixed Wireless Access (FWA) is encompassed by the definition of Wireless Access (WA), also known as Wireless Local Loop (WLL)." recently developed by ITU-R. WA is 3 fold: FWA, Mobile Wireless Access (MWA) and Nomadic Wireless Access (NWA). The latter two variants are not considered in this Recommendation."

……………

"recommends

1) that the frequency bands 3,4 GHZ to 3,6 GHz, 10,15 GHz to 10,30 GHz/10,50 GHz to 10,65 GHz, be identified as preferred bands for FWA applications within CEPT;"

…………….

ETSI assumes that this recommendation, dated 1998, is at the origin of the fact that Nomadic access in 3,5 GHz is generally not treated in harmonized way or even not allowed at all; however, we also consider that considerable evolutions have taken place in technology and market demand, improving the general understanding of "Broadband Wireless Access" (BWA) potential benefits and problems.

In practice, the implementation of the CEPT/ERC Recommendation 13-04 E [10] is as follows:

- A number of European countries have offered licences, generally parts of the 3,410 GHz to 3,600 GHz band; typical allocations are 15 MHz × 2, but in some countries there are also licenses of 28 MHz × 2.
- Some countries, like Italy, did not release any spectrum.

4.2.10.2 ETSI Harmonized Standards under R&TTE Directive

4.2.10.2.1 HEN 301 753 and ETSI draft HEN 302 326 (multipart)

EN 301 753 [22] is the current "cross-reference container" Harmonized EN to be used for self assessment of P-MP radio equipment and related antennas. Draft EN 302 326 is the new multipart EN, undergoing PE, produced by ETSI for rationalizing all the scenario of multipoint related ENs (presently ~25 different EN "cross-referenced" by HEN 301 753 [22]) into a single document (as recommended by the EC for reducing the risk of market fragmentation).

According to present status of both above ENs, it will be difficult, in Europe, to achieve the simple target of using low cost, indoor radio units, self-installable, or Laptops, due to the fact that the omni directional/sector antennas for the Terminal stations are not considered in those standards.

This is historically due to the above uncertainty about Nomadic operations (strictly related to omni-directional TS antennas), and also to the equipment technology, until now not yet mature enough, for ETSI member to actually contribute to remove this lack of standardization.

When Harmonized Standards are not available, possible suppliers of these applications are then forced, for assessing equipment according to R&TTE Directive, to use directive Annex III and IV procedures and consult with to pass through a Notified Body. However, a Notified Body, in the absence of any ETSI deliverable, might not feel in the position to define the requested essential test suites for the assessment or give an opinion on conformity to R&TTE Directive essential requirements.

This is now creating a chicken-and-egg situation between ETSI (responsible for equipment standards) and ECC (responsible for assignment regulations). However, WGSE has recently approved to extend coexistence studies in ECC/Report 33 [25], for P-MP systems including omni-directional and other types of TS antennas while ETSI will supply (in the present document) initial information on this application for the studies to be carried on.

4.2.11 Compatibility issues

There are three areas to be addressed:

- Interference from omnidirectional, indoor STs to conventional P-MP FWA, within same block assignment to a single Operator (this is, however, considered an "intra-system" problem of ETSI interest only).
- Interference from omnidirectional, indoor STs to similar systems and to/from conventional P-MP FWA, between different licenses in adjacent blocks (this activity is already on going within WGSE in cooperation with ETSI BRAN, see ECC Recommendation 04-05 [26] and revision of ECC Report 33 [25]).
- Inter-service sharing studies between P-MP FWA and other systems/services (P-P links, ENG/OB, radars, FSS (Space-to-Earth) in the 3,4 GHz to 3,8 GHz band (this activity is already on going within WGSE in cooperation with ETSI BRAN).

Additional studies are foreseen if the ECC agrees to consider also the bands 3,8 GHz to 4,2 GHz.

5 Main conclusions

The allocation of sufficient spectrum in the 3,4 GHz to 4,2 GHz bands for Fixed/Nomadic broadband applications, will allow for all the European countries to reach high broadband penetration. The new OFDM/OFDMA technology, supported by more than 350 companies in WIMAX Forum, and developed in collaboration by ETSI HiperMAN and IEEE 802.16 [4], is able to extend the cell sizes, working in high multi-path environment characteristic for indoor/Nomadic deployment, to eliminate the installation costs and allow low cost subscriber terminals, as indoor boxes and Laptops. The bundling of different services, including data, voice, video, business data, nomadic usage, according to the market needs, will allow a positive business case for Service Providers that want to provide broadband services.

The TDD duplexing might be attractive from the point of view of the traffic characteristics, which include a substantial amount of down-link only traffic. For these applications, in order to reduce equipment complexity and make use of less guard bands, the single block allocation would be the preferred mode of allocation.

According to the resulting amounts of spectrum, and the high asymmetry of the envisaged services, we conclude that also asymmetric FDD allocations should be considered as well, which should also have the benefit of a suitable duplex spacing to accommodate the traffic patterns. The required licensed spectrum per operator depends on the application and can range from 56 MHz to 140 MHz.

The considerations in the present document should not detract from the continued need for spectrum to be freely used by municipalities and other applications. A higher power level than currently permitted in license exempt bands and the use of a light-licensing regime can be beneficial for successful deployment. We did not calculate the needed spectrum for such operation, however the national radio administrations have a good view of this demand.

The WIMAX Forum has started the certification of equipment in 2005. It can be expected that a drastic price reduction will take place in 2006, and the residential deployment will be feasible. ETSI considers that the spectrum should be made available no later than mid. 2006.

6 Requested ECC actions

As a consequence of the studies and conclusions given in the present document, the following proposals and suggestions have been identified for consideration by ECC:

1) The present document is intended to assist ECC in the on-going work on the creation of a new ECC deliverable for the harmonized implementation of frequency bands for BWA. This work has already started and is in response to an EC Mandate [23].

2) In case that the amount of spectrum does not allow two operators to provide WDSL and wireless Triple Play services, according to traffic and spectrum needs justified in the present document, in fully licensed bands, ETSI invites the ECC:

    a) To investigate the designation of more licensed spectrum to BWA in 3,8 GHz to 4,2 GHz. The system and spectrum parameters defined by the present document are also applicable in this extended frequency range.

    b) To indicate the frequency bands in which BRAN should provide system parameters for further compatibility studies.

3) It is proposed that the ECC will create a new ECC Decision providing harmonized spectrum for these applications, including TDD and asymmetrical FDD duplex modes. The scope of the ECC decision should be established after considering the availability of additional spectrum.

4) Standardization activities are investigating new channel access protocols allowing for dynamic cooperation between systems, which allow sharing with the existing spectrum users, so that the BWA Base Stations may use higher transmit powers. The impact of these on the spectrum efficiency and on the regulatory environment will need to be considered by ECC.

5) It is suggested that ECC extends the scope of the compatibility studies, in order to cover also the spectrum sharing in 3,8 GHz to 4,2 GHz.

6) The compatibility studies should be done by ECC, in order to lead to a harmonized European approach regarding the license conditions.

Annex A:
Detailed market information

A.1 Range of applications

In the last years, became clear that fixed wireless access is part of the broadband access technologies, and "Broadband for All" is part of the European focus areas. For understanding the importance of Broadband in European environment, please tale a look at the following WEB sites:

BROADWAN	http://www.telenor.no/fou/prosjekter/broadwan/
BREAD-Broadband for All	http://www.ist-bread.org/events_item.asp?id=42
IST - Broadband for All	http://www.cordis.lu/ist/workprogramme/en/2_3_1_3.htm
WIBRACE - Wireless Broadband Access Everywhere	www.wibrace.org

However, even if it is recognized today that BWA is part of the solution, the operator business model has to be positive in order to make it happen. The main factor of success is the "cost per line", and from this one, 85 % is represented by the CPE unit cost and installation cost.

The CPE unit cost, in 3,5 GHz, is 500 USD to 700 USD today, the standardization and use of indoor units should bring it down to 100 USD.

The installation cost is 100 USD to 250 USD, the self-installation should bring it down to zero.

So indoor, self-installation, are necessary in order to drop the cost of the broadband wireless to aprox. twice the cost of a ADSL line (50 USD). The CPE antenna in this case should be omni-directional or wide-beam sectorial (allowing very rough manual alignment by the user); this would dramatically change the conventional P-MP architecture, in bands lower than 6 GHz, insofar standardized by ETSI and currently deployed mostly in rural areas with CPE directional antennas only.

A wireless Laptop card provides the lowest CPE cost. The cost of a Wi-Fi PC card is today 20 USD to 30 USD, and this is the cheapest possible CPE. Only access directly to the Laptop will bring the cost of wireless to the same level as the ADSL cost. Regulatory wise, this is Nomadic access. The problem of the access direct to the Laptop is the cell size: significantly lower, and this influences negatively the business case.

The solution is to let the operators bundle 3ple and 4le play applications: by bundling services, the business case may turn positive again. Regulatory wise, nomadic applications may be provided in a fixed band.

A.2 Market size and value

We perceive two different markets for the broadband converged Fixed-Nomadic systems, depending actually on the broadband definition and target services.

- Services similar with VDSL offering, to be provided mainly in the developed areas, where the population income will allow a relatively high penetration ratio for this kind of new services.
- Services to provide ADSL-like broadband, and where the requirements for data rates are relatively modest.

A.2.1 Broadband for ALL - European vision

In July 2003, a new legal framework regulating electronic communications services and networks came into force in the European Union. The EU regulatory framework aims to promote competition, to reinforce the single market and to safeguard consumer interests in the electronic communications sector.

New Information and Communications Technologies are vital for the health of the European economy. The adoption of new ICT increases productivity throughout the economy, generates new consumer services and creates jobs for the European work force.

ICT is therefore an important building block of the "Lisbon Agenda" - the drive to make the EU economy the most dynamic and competitive in the world. Electronic communications networks and services form a large part of the ICT landscape, creating the conditions for a flourishing e-communications sector is a key aim of EU regulatory policy (see more at http://europa.eu.int/information_society/doc/factsheets/006-eeurope_next.pdf).

The Europe has clear plans and puts forward research funds for achieving the target of e-Europe by 2010 and is taking measures to improve the pace of achievements. The i2010 objectives spelt out by commissioner Reding include the convergence between Internet, voice and video services:

- Creating a "borderless European information space" including an "internal market for electronic communication and digital services". **The aim is to steer the convergence between internet, telephone and TV** through increased competition in key "enabling" services **such as high-speed broadband** connections. "The use of the internet to provide voice telephony (VoIP) and television will revolutionize the way in which we communicate" (see http://www.euractiv.com/Article?tcmuri=tcm:29-134976-16&type=News).

The target is to make possible the user access to video, including VoD (video on demand), high-speed data and voice. From ADSL today, generally offered as 512 kb/s downstream and 128 kb/s upstream, the evolution path goes to VDSL, ADSL2 and Fiber, offering up to 100 Mb/s in Japan or 40 Mb/s in Korea.

The data targets per user have been widely presented in international conferences, using the experience in Japan or Korea. However, the success of Japan and Korean fiber usage is based on very high population densities in urban areas, where the 20+ floor buildings are typical and make the "fiber to the house" an economical option.

The fiber penetration in Europe is very low, as shown in figure A.1.

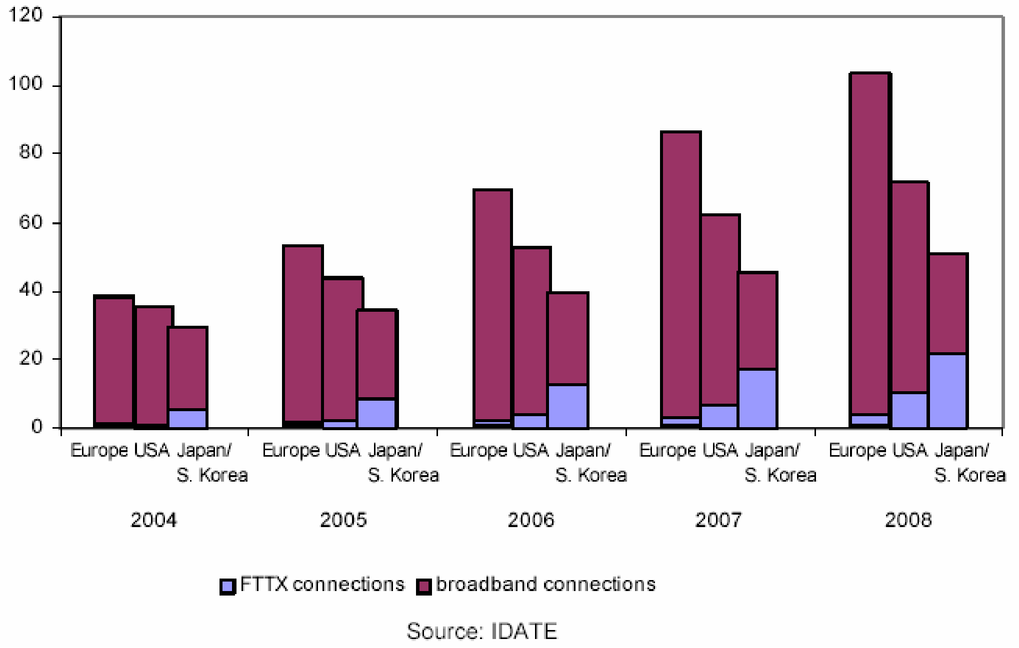

Figure A.1: Fiber penetration in Europe, USA, Japan/Korea

The new VDSL improvements can provide VoD and high data rates, however the reach radius is limited to 1 km or 1,5 km. The "wireless cable", to be deployed in the higher mm-wave frequencies, has failed due to lack of business model.

The broadband wireless access, at relatively low frequencies, using WIMAX technology, may provide cost-effective converged broadband services and compete with other technologies. However, this will happen only if enough spectrum, having suitable attributes (radio frequency, allocation size, allowed power) will be made available.

A.2.2 Digital divide

There are many European areas, in which the Internet penetration is very low.

Figure A.2 (http://www.point-topic.com/content/dslanalysis/bbana04050401.htm) will give an idea regarding the Internet penetration in European developing countries.

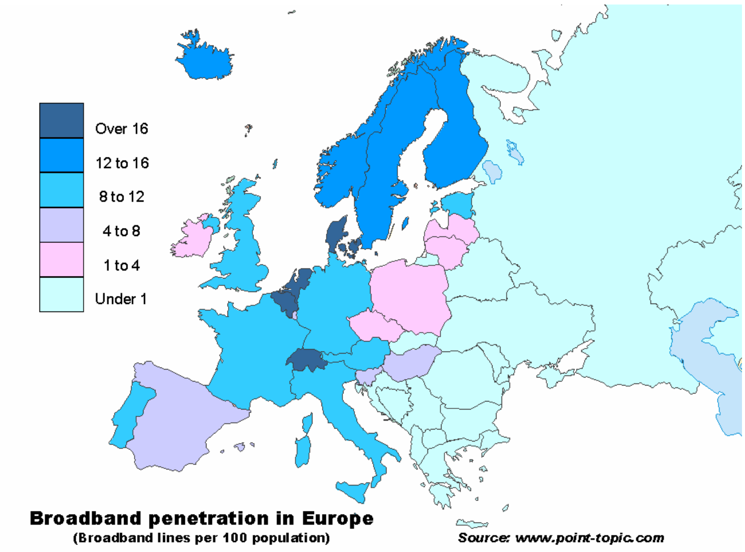

Figure A.2: Internet penetration in Europe

It can be seen the poor penetration in Eastern Europe, illustrating the dimensions of the "digital divide". In these countries, the market requires Internet access solutions for both residential and business, at the ADSL data rates.

A.3 Traffic evaluation

A.3.1 Population density

The European population density is considered [18], for different areas, in table A.1.

Table A.1: Typical household density in Europe (Households per square km)

Environment:	Rural	Suburban	Urban	City center
Average household density		1 000	3 000	
Household density range	5 to 500	500 to 3 000	1 000 to 8 000	8 000 to 30 000
NOTE: Source: TR 102 079 [18].				

A.3.2 Traffic estimation

Due to the high population density and requested data rates, efforts should be make to:

- Reduce the inter-cell interference.
- Provide very high data dates per cell.

The AT&T research [17] gives a good direction for a solution, by using micro-cells having the Base-Stations placed at small distances, using lighting poles. Here is the deployment vision.

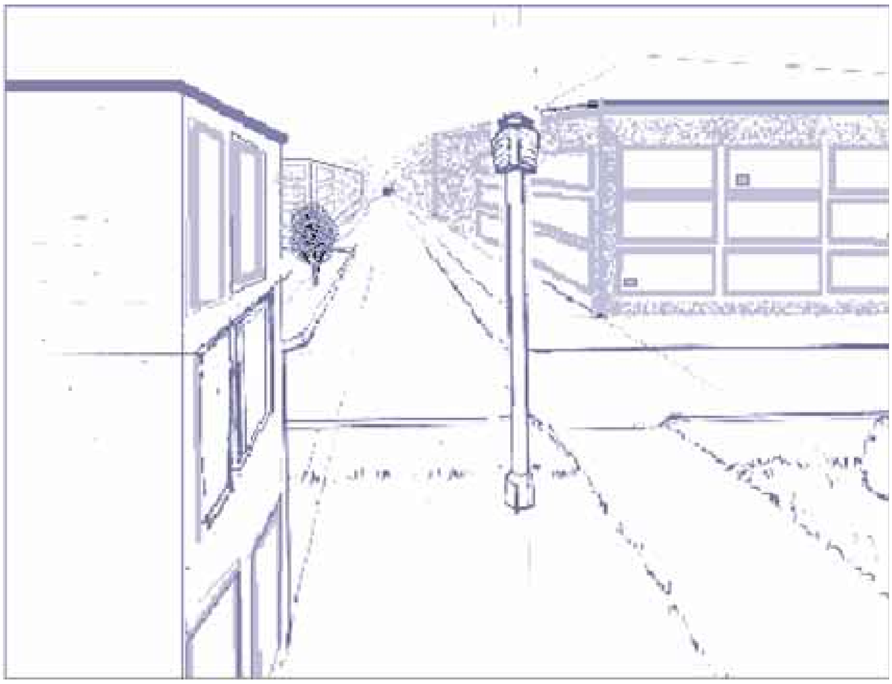

Figure A.3: Micro-cell visions

We will consider different cell sizes, with the view that the small cell sizes are adequate for triple-play, while the large cell sizes are adequate for deployment in the developing countries. We consider the deployment using 4 or 2 (double bandwidth/channel) channels/cell, suitable for both micro-cells, which follow the street geometry, and microcels. We take into account the cell overlapping, bringing to a mostly square cell, of area L×L, from point of view of subscriber distribution. In the following calculations the cell was considered square, having a L×L area.

The spectrum calculation will be done for a first deployment phase, using SISO systems. We consider that the MIMO will become available for commercial deployments in 2008, and will permit to up-grade the service offering to higher data rates and more HDTV channels, including VoD channels.

Considering that the maximum penetration rate is 30 % for the target broadband services, in sub-urban and rural areas, results the maximum subscriber number. The urban penetration was considered also 30 % due to the special attractiveness of the nomadic usage.

Table A.2: Total number of households/cell

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Area (sq km)	4	1	0,25	0,0625
Urban	12 000	3 000	750	187,5
Sub-urban	4 000	1 000	250	62,5
Rural	1 000	250	62,5	15,625

Table A.3: Total number of subscribers/cell

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban	3 600	900	225	56
Sub-urban	1 200	300	75	19
Rural	300	75	19	5

The traffic estimation will be done for the assumption of VDSL-like services, allowing broadband data and VoD, using the shared traffic assumption.

Supplementary, will be calculated the data traffic generated by video IP multicast services, needed for triple-play service concept.

The 5 subscribers/cell, in rural like deployment, cannot provide any positive business case; due to this, the variant of 250 m cell in Rural deployment has been omitted in the following calculations.

A.3.2.1 Shared traffic, VDSL like

The data rate calculation is done for the following assumptions:

- Peak data rate: 10 Mb/s, UL+DL, shared between 20 users.
- VoD using MPEG2, regular video, at 2,2 Mb/s: 30 % of users.
- 2 frequencies/cell.

Table A.4: Shared traffic/cell for VDSL-like services, Mb/s

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban (Mb/s)	4 176	1 054	269,6	79,6
Sub-urban (Mb/s)	1 392	358	92,8	33,2
Rural (Mb/s)	358	92,8	33,2	

A.3.2.2 Shared traffic, ADSL like

We will calculate separately the residential and business traffic.

The following assumptions are used for the estimation of the ADSL residential traffic:

- Peak data rate, UL+DL: 1,25 Mb/s.
- Over-subscription factor: 30.

Table A.5: Shared traffic/cell for residential ADSL-like services, Mb/s

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban (Mb/s)	150	37,5	10	2,5
Sub-urban (Mb/s)	50	12,5	3,75	1,25
Rural (Mb/s)	12,5	3,75	1,25	

The ADSL business traffic is estimated based on:

- Peak data rate, UL+DL: 2,4 Mb/s.
- Over-subscription factor: 5.
- Household/business density in urban: 1:10.
- Household/business density in sub-urban and rural: 1:15.

Table A.6: Shared traffic/cell for business ADSL-like services, Mb/s

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban (Mb/s)	201,6	50,4	14	5,6
Sub-urban (Mb/s)	44,8	11,2	2,8	2,8
Rural (Mb/s)	11,2	2,8	2,8	

A.3.2.3 Video IP multicast traffic

Assuming that a competitive proposition for triple-play service will need 30 regular video-channels, MPEG2 compressed at 2,2 Mb/s, and 5 HDTV channels, MPEG4 compressed at 9 Mb/s, the resulting aggregate data rate will be:

$$DR_{broadcast} = 30 \times 2 + 5 \times 9 = 105 \text{ Mb/s}$$

Annex B: Technical information

B.1 Detailed technical description

A fixed and nomadic base station will be very similar in functionality to that of a fixed only base station; the key differentiator is in the subscriber terminal and the type of antenna used. The antenna at the terminal can be broadly categorized into one of the following types described below.

B.1.1 Antennas

B.1.1.1 On roof antennas

For fixed applications a roof antenna usually provides the optimal performance, at the expense of installation cost and re-orientation cost, when a new Base Station is added to increase the offered capacity. These antennas will comply with the current requirements of HEN 301 753 [22].

B.1.1.2 Window antennas

These antennas have the advantage of not being exposed to the external climate and also having ease of access, however their field of view may not be ideal; nevertheless avoiding outdoor units or reducing cable connection losses, while easing the installation. They could be also used for a fixed terminal and for a nomadic terminal that have an external antenna connection. These antennas will comply with the current requirements of HEN 301 753 [22].

B.1.1.3 Indoor antennas

The use of indoor antenna, either wall, ceiling or tabletop located, requires the use of NLOS technology to be user friendly. Having a static PC, multimedia or VoIP device connected to an indoor antenna, the user is required to position the antenna once on installation, therefore a compromise is required between the antenna size, its easy connection and alignment, the building penetration losses and the system gain. The conclusion of studies regarding the in-building propagation is that for being effective and comparable with wireline services, the system gain requirement and user expectations regarding the ease of the installation need to be carefully considered. The indoor antenna may be separate or integral from/with the subscriber terminal. It is expected, with the technology developments and cost drop, that beam switching or beam forming will be costly effective even for CPE equipment.

These kinds of antenna are presently not standardized in lack of any finalized coexistence study and consequent regulation securing the market for nomadic applications, subject of the present Document. It is therefore expected that, once CEPT have clarified the possible regulatory approach, ETSI will endeavour, at least for the typical FWA coordinated bands, the task of producing the relevant standardization.

The characteristics of some possible directional and omni indoor antennas are reported below.

B.1.1.3.1 Directional

Table B.1

Directional antenna Case 1				Directional antenna Case 2		
Angle	Case 1 Co-pol	Case 1 Cross-pol		Angle	Case 2 Co-pol	Case 2 Cross pol
0	0	-10		0	0	-10
90	0	-10		45	0	-10
90	-9	-10		90	-9	-10
180	-9	-10		180	-9	-10

Typical gain of these directional indoor antennas might be ~10 dB.

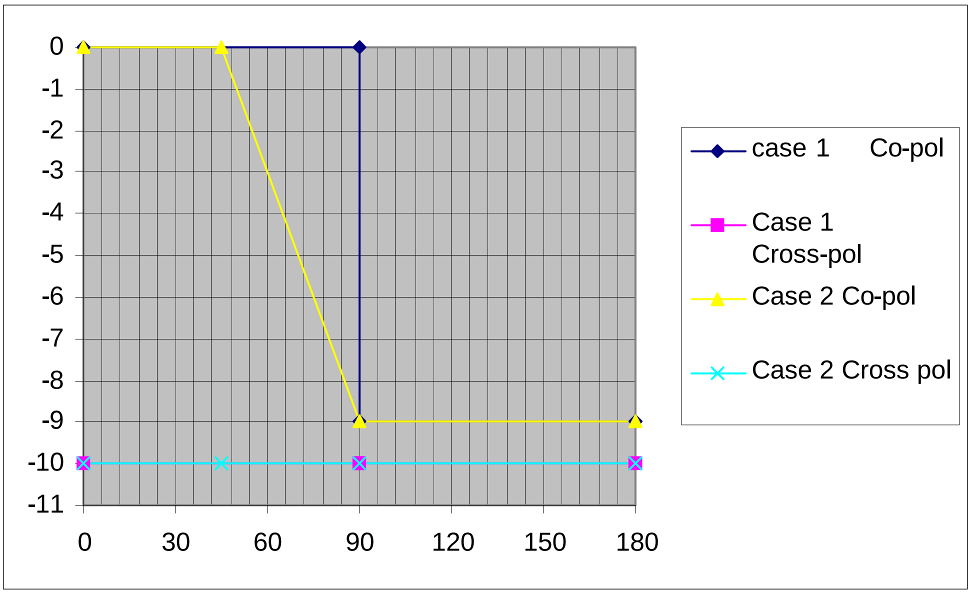

Figure B.1

B.1.1.3.2 Omni-Directional

Table B.2

Omni antenna case 3 - chip antenna		
Angle	**Case 3 Co -pol**	**Case 3 Cross -pol**
0	0	-10
180	0	-10

Typical gain of these directional indoor antennas might range from 2 dB to 5 dB.

B.1.1.4 Laptop antennas

Nomadic antennas, that are integral to the subscriber terminals, offer both fixed and nomadic operation. The simple solution is to use an omni directional antenna to permit freedom of orientation, this does mean that the coverage area for both indoor and nomadic operation will be reduced compared to area of coverage. Although as techniques for terminals using multiple antennas reduce in cost it will again increase the area of coverage.

The antenna implementation in laptops/nomadic/mobile devices is dominated by PIFA (Planar Inverted F Antennas). Although other antenna architectures exist (such as patches, loops, mono/di-poles, etc.), the PIFA is preferred for cost/size reasons. The gain numbers shown in the following diagrams are representative of 3,5 GHz antennas while mounted in a laptop.

Also in this case ETSI standardization might be envisaged.

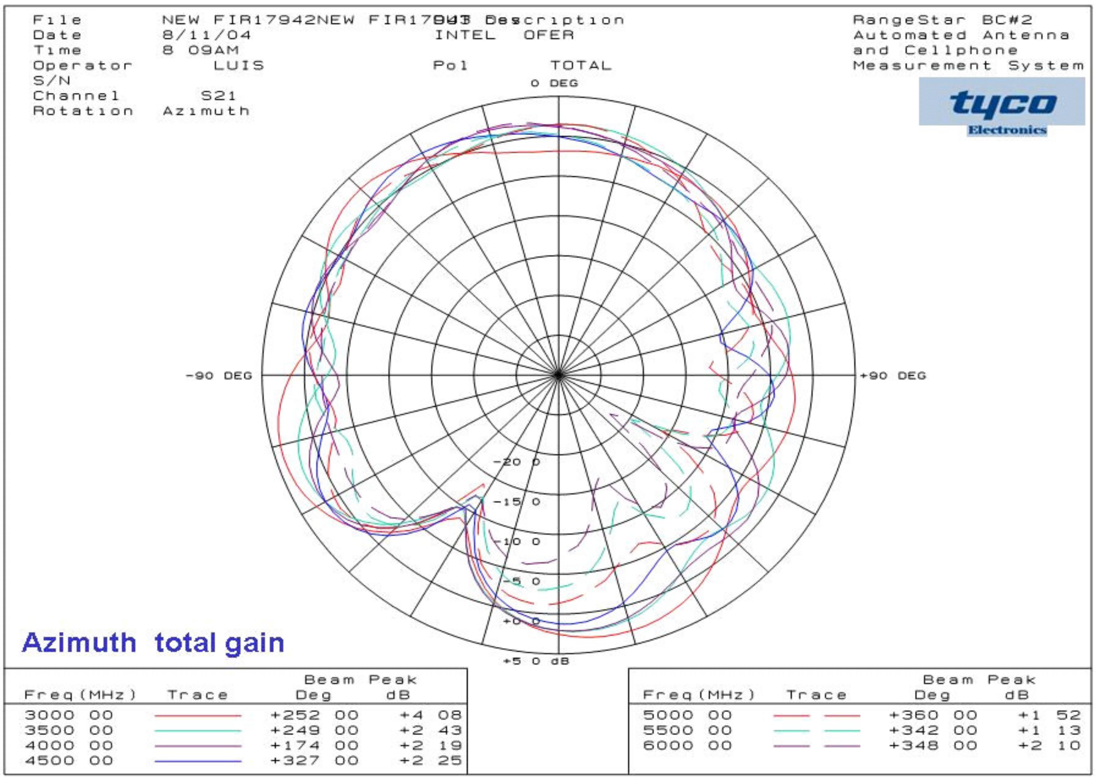

Figure B.2

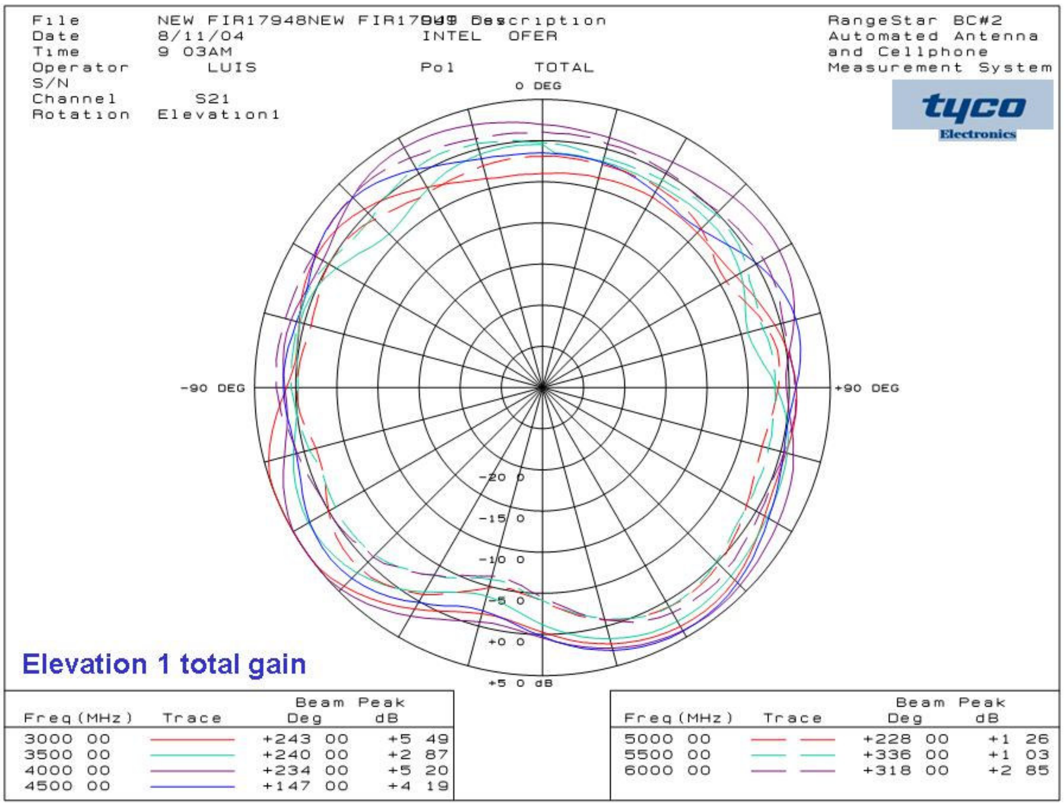

Figure B.3

B.1.1.5 Topology

From the system architecture point of view, besides the use of modulation formats and/or access methods for suitably cover the indoor ST location and related necessary low directional/omni antennas and adverse propagation, there is no technical difference between fixed and nomadic applications, which will coexist also within the same system.

A combined Fixed-Nomadic system may use P-MP architectures, including Repeaters for range extension.

In figure B.4 is presented the system topology and its elements.

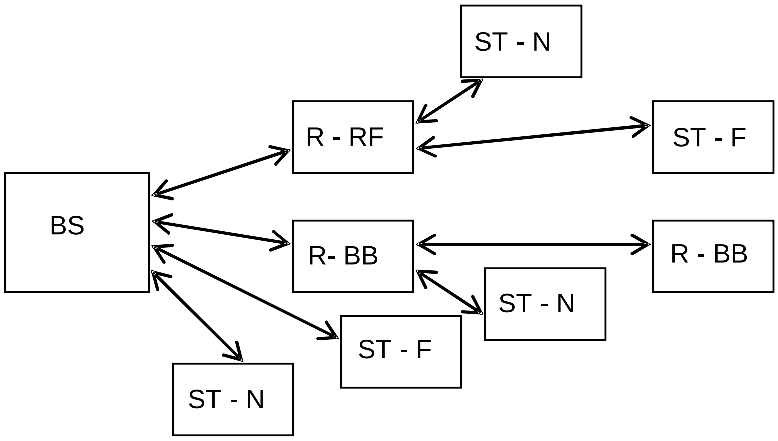

Figure B.4

The wireless network elements are:

- BSU - Base Station Unit, providing connection to the core network.
- ST-F - Subscriber Terminal - Fixed.
- ST-N - Subscriber Terminal - Nomadic.
- R - RF - Repeater - RF level; this Repeater will amplify the received signal, introducing only a small delay (max. few microseconds).
- R - BB - Repeater - Base Band - this Repeater will communicate with the Base Station and with the connected ST at different moments of time.

Any of the wireless network components may use directional or omni-directional antennas. The Repeaters will generally use directional antennas towards the Base Station and omni antennas for the created micro-cell.

The Base-Band Repeater is also used in Mesh systems: it allows to extend the cell size, with some penalty of frequency efficiency, due to the fact that the same data is transmitted twice (BSU-R and R-ST).

The ST-F may be used indoors or outdoors.

Each ST, fixed or nomadic, when turned on, will connect to the closer BS of the subscribed Operator through standard access protocols. Fixed SF would normally connect to the same BS, while nomadic/indoor ST might be used everywhere one or more BS of the subscribed Operator offer coverage, selecting the best C/I or loading conditions.

Standing the possible heavy NLOS conditions, not necessarily the network will provide service to indoor/Nomadic terminals inside the entire cell: in rural deployments, for example, the remote ST may need the rooftop antennas, for achieving connectivity above woodlands and hills; as well, in urban cases, a desk ST locations in a lower or basement floor might not have connection unless with an outdoor more elevated antenna.

B.1.2 System design options

Several new technology developments are also available for cost-effective design for improving system performance.

In particular the Adaptive Antenna System (AAS) and OFDMA/sub-channelization on Subscriber Terminal (ST) provide to the system designers options for improving the link budget without need of very high RF power amplifiers.

B.1.2.1 Impact of AAS on system gain, fade margin and interference

When AAS is used for providing diversity and space-time coding, it may considerably decrease the needed fade margin in multi-path channels.

When AAS is used for beam forming, it allows an increase in the system gain and reduces the interference to/from other systems.

As shown in several reports, if the weights are chosen as to coherently combine the transmitted signals from all antennas in the array towards a certain direction, then the signal strength increases by 10lg(M), assuming that M is the number of antenna elements in AAS.

UL is also improved when using AAS, assuring an increase of 10lg(M) of the received power and of the link budget.

B.1.2.2 Impact of sub-channelization on improved link budget

The ST transmits with power spectral density between $P_m \ldots P_M$ (dBm/Hz).

A [dB] is an attenuation factor which includes the path loss and the fade margin.

The BS receiver sensitivity is $P_{r,m}$, i.e. the minimum receive signal power that allows a post-detection bit error rate below a certain value. This generally depends on the channel bandwidth and on the modulation scheme.

If the transmit power is P_t, then the received power at BS is $P_r = P_t - A$.

Let us assume that the ST is far enough and must transmit with the greatest power level, $P_t = P_M$, and still, the received power level at BS is below the threshold value, $P_{r,m}$. The threshold value depends on the modulation scheme and on the imposed BER.

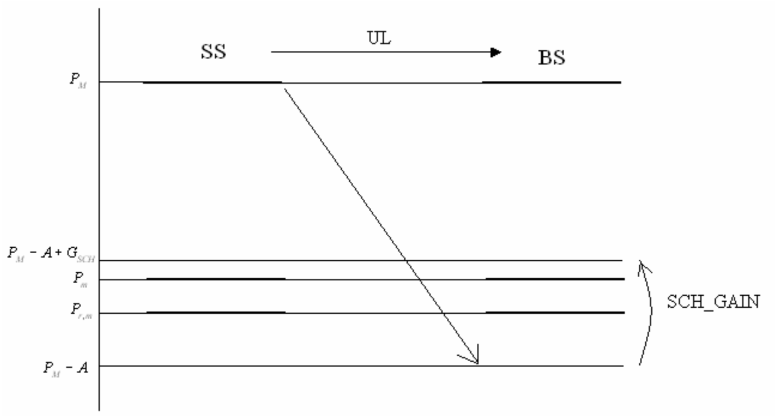

Figure B.5: ST transmits with maximum power level, but the received power level at BS is below the threshold

ST may switch to sub-channelization capability and use only a fraction of all sub-channels (S=1/2, 1/4, 1/8 or 1/16) and *only in this case* (when $P_t = P_M$), it may preserve the total transmitted power, by increasing the power spectral density (as defined in IEEE 802.16 [4], i.e. computed along a single OFDM symbol) with a factor of 1/S. The system will always use the minimum sub-channelization mode in order to exceed the receiver sensitivity (for instance, if sensitivity requires a power increase of 5 dB, the system uses the 1/4 sub-channelization with a gain of 6 dB and not 1/8 or 1/16 which could bring a higher gain, of 9 dB and 12 dB respectively).

Otherwise if $P_t \neq P_M$, it should preserve the PSD and accordingly decrease the total transmitted power.

The link budget takes two siuations into account: the most favourable and the worst-case scenario.

Most favourable (P_t=P_M): ST transmits with maximum power and still the received power at BS may be under the sensitivity threshold. ST may increase the power spectral density by deploying sub-channelization, until the received signal has enough power as to be decoded with desired BER. The maximum power density occurs when ST needs extra 12 dB as to provide sufficient power at the receiver and it manages to provide it if switching to 1/16 sub-channelization.

$$P_M' = P_M + 10 1g\left(\left(\frac{1}{S}\right)_{\max}\right) = P_M + 12\ dB$$

Worst-case scenario ($P_t = P_m$): it is clear that the minimum transmitted power will not be affected, as sub-channelization with modifying the power spectral density in is adopted only at maximum transmitted PSD: $P_m' = P_m$.

B.1.2.3 Examples of link budget evaluation

The tables below show examples of link-budget evaluation based on OFDMA/sub-channelization, which is suitable for Broadband Wireless Access, including Nomadic.

Table B.3: Conventional fixed outdoor applications, using OFDMA/sub-channelization

	UL typ	UL max	DL typ	DL max
Frequency (MHz)	3 500	3 500	3 500	3 500
Channel width (MHz)	3,5	1,75	3,5	1,75
Tx power [dBm]	22	23,5	34	43
Tx Antenna (BS=omni) Gain [dB]	10	18,5	17	17
Feeder	1	0	1	0
Tx EIRP [dBm]	31	42	50	60
Rx antenna gain [dB]	17	17	10	18
Diversity gain	0	0	0	5,5
Feeder loss	1	1	1	0
Rx Noise figure [dB]	5	4,5	7	7
Rx noise power [dBm]	-103,6	-107,1	-101,6	-104,6
SNR at max rate (64QAM 3/4)	24,4	24,4	24,4	24,4
Sensitivity at max rate	-79,2	-82,7	-77,2	-80,2
SNR at average rate (16QAM 1/2)	16,4	16,4	16,4	16,4
Sensitivity at average rate	-87,2	-90,7	-85,2	-88,2
SNR at min rate (QPSK 1/2)	9,4	9,4	9,4	9,4
Sensitivity at min rate	-94,2	-97,7	-92,2	-95,2
Sub-channel number	8,0	16,0	1,0	1,0
OFDMA/sub-channelization gain	9,0	12,0	0,0	0,0
System gain at max rate	135,2	152,7	136,2	163,7
System gain at average rate	143,2	160,7	144,2	171,7
System gain at min rate	150,2	167,7	151,2	178,7

Table B.4: Nomadic applications, using OFDMA/sub-channelization

	UL typ	UL max	DL typ	DL max
Frequency (MHz)	3 500	3 500	3 500	3 500
Channel width (MHz)	3,5	1,75	3,5	1,75
Tx power [dBm]	20	25	34	43
Tx Antenna (BS=omni) Gain [dB]	3	6	17	17
Feeder	1	0	1	0
Tx EIRP [dBm]	22	31	50	60
Rx antenna gain [dB]	17	17	3	6
Diversity gain	0	0	0	5.5
Feeder loss	1	1	1	0
Rx Noise figure [dB]	5	4.5	7	7
Rx noise power [dBm]	-103,6	-107,1	-101,6	-104,6
SNR at max rate (64QAM 3/4)	24,4	24,4	24,4	24,4
Sensitivity at max rate	-79,2	-82,7	-77,2	-80,2
SNR at average rate (16QAM 1/2)	16,4	16,4	16,4	16,4
Sensitivity at average rate	-87,2	-90,7	-85,2	-88,2
SNR at min rate (QPSK 1/2)	9,4	9,4	9,4	9,4
Sensitivity at min rate	-94,2	-97,7	-92,2	-95,2
Sub-channel number	8,0	16,0	1,0	1,0
OFDMA/sub-channelization gain	9,0	12,0	0,0	0,0
System gain at max rate	126,2	141,7	129,2	151,7
System gain at average rate	134,2	149,7	137,2	159,7
System gain at min rate	141,2	156,7	144,2	166,7

B.2 Technical justifications for spectrum

B.2.1 Power

For the licensed 3,5 GHz the local national regulations dictate the maximum system, OFDMA techniques have the effect of balancing the down and uplink system gains.

- ST power: the use of OFDMA enables the output power of the terminal to be balanced with that of the base station, typical values of the terminal station output RF power range from +15 dBm to +22 dBm based on the cost target and area of coverage.

- OFDMA gain is based on the number of sub-channels and the channel bandwidth, typically being either 4 or 8 sub-channels for a 3,5 MHz channel, based on the application being offered. 32 sub-channels can be supported in 7 MHz or higher channel spacing. Based on 8 sub-channels, this gives a OFDMA gain of 9 dB, and 32 sub-channels give a gain of 15 dB. This can be used close the gap of the down and up link system gains, caused by the reduced output at the terminal and the reduced gain of the subscriber terminal antenna.

- DL data rate asymmetry, a consequence of the OFDMA gain is the proportional reduction in uplink peak data rate, hence for 8 sub-channels the uplink peak data rate would be an eighth of the peak. For email and typical internet applications, this asymmetry is not a major concern, if the downlink peak data rate can satisfy the user's requirement, then the reduction in uplink data rate can be masked by the user focussing on other activities whilst the upload takes place. For applications requiring a symmetrical data rate, the application would be uplink limited, again in many applications used in fixed and nomadic situation this will be acceptable. As a comparison in 1xEV-DO, the peak downlink is 2,4 Mbit/s, whereas the uplink is 153 kbit/s, in the mobile sector this has been generally well received, so for the fixed and nomadic environment having typical ratios of 8 should meet the expectations.

- AAS BS, Using AAS at the base station enables more efficient use to be made of the available output power and increases the co-channel interference ratio to enable higher modulation schemes to be used over a wider area.

B.2.1.1 General considerations

The Base Station power is generally derived from DL system gain calculations; however, the ST transmission power on the UL, which is the limiting factor, should be kept in mind for suitable balancing of DL/UL budget. For example, we consider a typical F-N system, targeting residential access, and having:

- Fixed ST, transmitting 22 dBm and using 21 dBi antennas.

- Nomadic ST, transmitting 20 dBm and using 8 dBi antennas.

- OFDMA gain: 12 dB (16 sub-channels).

When dimensioning a system, it should be considered the expected traffic asymmetry and minimum guaranteed UL peak-rate per user. We suppose that the BS aggregate traffic has a DL/UL relation of 2:1 for Fixed subscribers and 4:1 for Nomadic subscribers. The UL peak-rate is the same for both fixed subscribers and Nomadic subscribers.

We show below a system gain calculation example, for a typical system, using up-link OFDMA, having 12 dB gain. A basic assumption is that for both TDD and FDD systems, the data rate asymmetry is compensated by higher Base Station power, and provided that the Base Station may use higher modulation states.

Beamforming techniques can concentrate the power from a number of antennas, while narrowing the interfered areas and having the possibility to null interference from undesired directions; the Tx power limitation shall refer only to a single antenna element.

B.2.1.2 Maximum BS power for transmission to Fixed ST

We assume that the aggregate down-link traffic is 100 % higher than the up-link traffic, and the system gain shall be 7 dB higher in downlink to compensate for the traffic asymmetry (see clause D.1.2.1). The difference between the noise figures (delta_NF) is 2 dB, better on Base Station. The power control loss is assumed 2 dB.

The Base Station electrical power should be:

$$Tx\_bs = Tx\_st + OFDMA\_st + delta\_NF + delta\_rate \quad Tx\_bs = 22 + 12 + 2 + 7 = 43 \text{ dBm}.$$

In practice, the actual transmitted power may be lower in a number of cases, due to:

- Cost limitations.

- Capacity limitations, requiring lower cell sizes.

B.2.1.3 Maximum BS power for transmission to Nomadic ST

We will use the same assumptions as in the previous case, with the exceptions of Nomadic ST transmitted power, and assumed to be 2 dB less.

The maximum Base Station power, in case of nomadic application only, will be 41 dBm.

B.2.2 Frequency

B.2.2.1 Radio frequency

A Fixed-Nomadic system may operate in existing Fixed allocations (3,4 GHz to 3,6 GHz and 3,6 GHz to 3,8 GHz), for P-MP systems.

Supplementary, it is a need for the use of lower frequencies, to be addressed in the Converged Fixed-Nomadic Broadband Wireless Access (BWA) System Reference Document, Part 2. In CEPT countries no suitable uncoordinated bands (sometimes identified also as License-Exempt (LE) bands) have been identified for low cost broadband access, to be used by municipalities and communities.

The 5 GHz NWA band, where the power allowance is 1 W eirp, if taking into account the frequency influence on cell-size, is reduced to an equivalent of 22 dBm in 2,4 GHz.

B.2.2.2 Amount of spectrum

The needed amount of spectrum depends on offered services and spectral efficiency, to convey for a positive business case. We will use here down the research work done in [5].

B.2.2.2.1 Target services

We identify the following services requiring spectrum:

a) Small businesses and enterprises, which seek a competitive offering for broadband service with a guaranteed, service level agreement. In this scenario an outdoor, fixed subscriber terminal with a directional antenna is employed to provide the highest throughput connectivity. This bandwidth is then dispersed to many users within the business. Generally speaking, the amount a service provider can charge for such a business class service more than offsets the costs of professionally installing the fixed outdoor subscriber station.

   Some local exchange carriers can take up to three months or more to provision a new E1/T1 line for a business customer if the service is not already available in the building. With BWA, the same service provider can provision the same speed of network access as the wired solution in a matter of days and at a lower deployment cost.

   Similarly, a service provider can offer "on demand" high-speed connectivity for events such as conferences, with hundreds or even thousands of IEEE 802.11 [17] hot spot users. These Wi-Fi hot spots would use IEEE 802.16 [4] solutions as their backhaul to the core IP network. Such "on demand" connectivity could also benefit industries such as construction, mining, transportation, oil and gas and agriculture with nomadic and/or sporadic broadband connectivity needs. "On demand" or "as needed" last mile broadband services are a differentiated value proposition for BWA.

b) Residential users in areas where DSL or cable broadband services are not available. In this scenario, a service similar to consumer DSL connectivity is offered, generally at a higher cost to current DSL broadband service rates. This higher cost is required to offset the cost of the "truck roll" required to professionally install the fixed outdoor subscriber station.

   This scenario is the primary target for nomadic application in fixed services bands. Without the ability to deploy indoor modems (which are nomadic by ITU definition), wireless providers cannot offer a broadband service competitive with those offered by wireline providers, and therefore will be limited to offering BWA only where wireline services are not available. If competition is to be established for broadband services to residential customers, indoor or "self-install" modems are essential. These self-install modems do not require a costly truck roll and, additionally, are less expensive due to their smaller form factor and indoor environment (no need for protection against outdoor environmental factors.) The throughput for indoor modems will be substantially less than that for an outdoor subscriber station, but still more than adequate for a consumer level broadband service.

Longer term, there will be a convergence of fixed and mobile services. Because spectrum is scarce at lower frequency ranges, mobile service providers will logically start to target traditionally "fixed" service bands such as the 3 GHz and 4 GHz bands. (In order to support nomadic or even mobile application at these higher frequencies, smaller cell sizes and/or cost-optimized advanced antenna techniques will have to be employed.) At this point, services providers offering fixed wireless services in the same bands would likely be required to offer nomadic connectivity to their customers in order to remain competitive.

c) A residential service, similar with VDSL, generally complementing the VDSL offering by the Fixed operator. The VDSL reach is approximately 1 km, while the existing wire-plant is designed to cover 5 km to 6 km reach. A re-deployment of the telephone wires will be needed, in order to provide the VDSL service to all the customers. The wireless approach can provide the same service quicker and with lower cost, if enough licensed spectrum will be available.

d) Triple-play service, using:

- VDSL approach, for data, VoIP, VoD.
- Video common channel transmission using IP multicast.

Broadband has a high penetration in Korea and Japan. Due to specific differences between the city layouts in Europe and Korea, the Fiber-to-the-Home installation cost is very high in Europe (in Korea there are in average 25 floors/building). The wireless can be added to the Fiber deployment, to spread the traffic to the last 200 m to 300 m, while having good business case and fast deployment.

Municipalities want to provide a best-effort data coverage for their residents, using license-exempt spectrum. The needed spectrum attributes are different from the existing ISM bands, due to the need for high BS power (50 dBm eirp) and some form of interference avoidance, which include BS registration and a coexistence protocol, as the one developed in the IEEE Project 802.16h [24].

There are also vertical markets, for example related to security, traffic monitoring, medical applications, etc. that wish to use the BWA equipment with some mobility allowance.

B.2.2.2.2 Spectral efficiency

The average spectral efficiency in a wide area cellular deployment will depend on many factors, including the antenna used. From simulations presented in [7], for different reuse-factors, we may conclude that for Nomadic deployments, targeting Laptops/fixed ST with omni antennas, the frequency efficiency will be 1,2 b/s/Hz at PHY level and probably 1 b/s/Hz after MAC level.

The spectral efficiency in case of using directive antenna will be able to reach more than 3 b/s/Hz.

B.2.2.2.3 Spectrum needed

B.2.2.2.3.1 Classical P-MP, TDD

The needed amount of spectrum depends on offered services and spectral efficiency, to convey for a positive business case. There are a number of factors to be considered for a minimum spectrum request and good business case:

- Low propagation attenuation permits to use relatively low power amplifier and indoor CPEs, improving the business case.
- Minimum inter-cell interference, which is limiting the spectral efficiency; high attenuation of the path loss increases the C/I.
- Business case is affected by the deployment and the Base Station costs; large cell sizes may have a better business case, due to the fact that costs are shared between more subscribers, but they need also a higher amount of spectrum as compared with low cell sizes.

For the high data rates, characteristics for the broadband services may be not realistic to request the amount of spectrum appropriate for large cell sizes.

This is why we consider a compromise using relatively low cell sizes, while the cell radius is high enough for having high path-loss coefficients.

In the following calculations the cell was considered square, having a L×L area.

The deployment solution for video and VDSL-like services is innovative, including two different paradigms:

- Video broadcast services, based on a "radio cloud" concept, using OFDM channel equalization capabilities.
- VoD, VoIP and fast Internet access, based on OFDM/OFDMA technology.

The spectrum estimate does not take into account the business model; the number of subscribers/cell may and the cost of implementing space-time diversity in Base Station may request the split the Base Station cost between a higher number of subscribers; in this case, higher cell size and lower modulations may provide a more suitable option.

Shared traffic

The C/I estimation for the micro-cell deployment gives a possible 1,5,b/s/Hz spectral efficiency, at reuse factor = 2.

The actual deployment may use a number of different models. Few examples are shown below.

With OFDMA in downlink, the frequency channel will use different partitions for sending data to different antennas. For minimizing the interference, it may be assumed that every sector in a Base Station will use a different frequency.

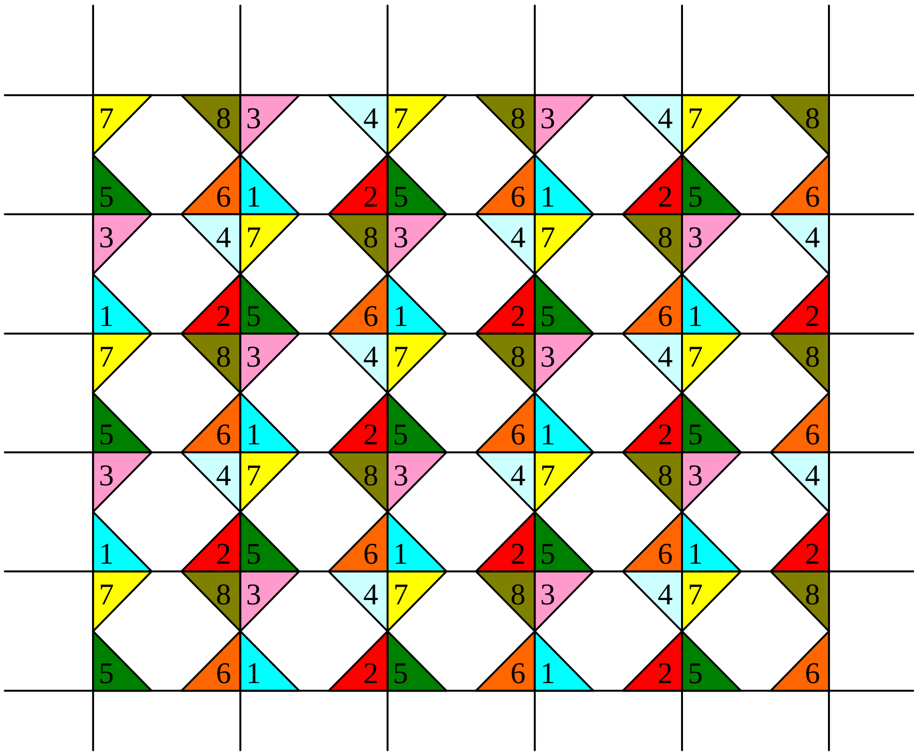

Figure B.6: Example 1 of frequency distribution, reuse factor = 2

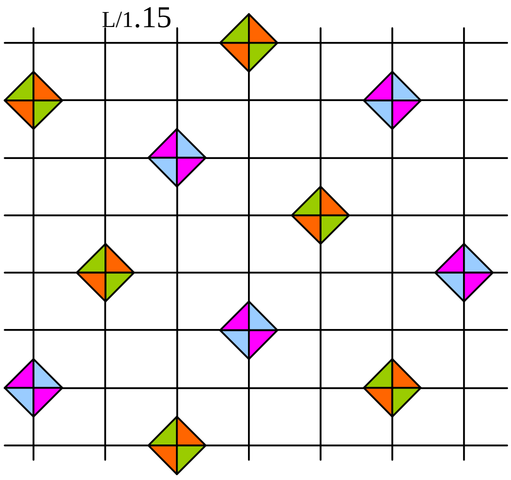

Figure B.7: Example 2 of frequency distribution, reuse factor = 2

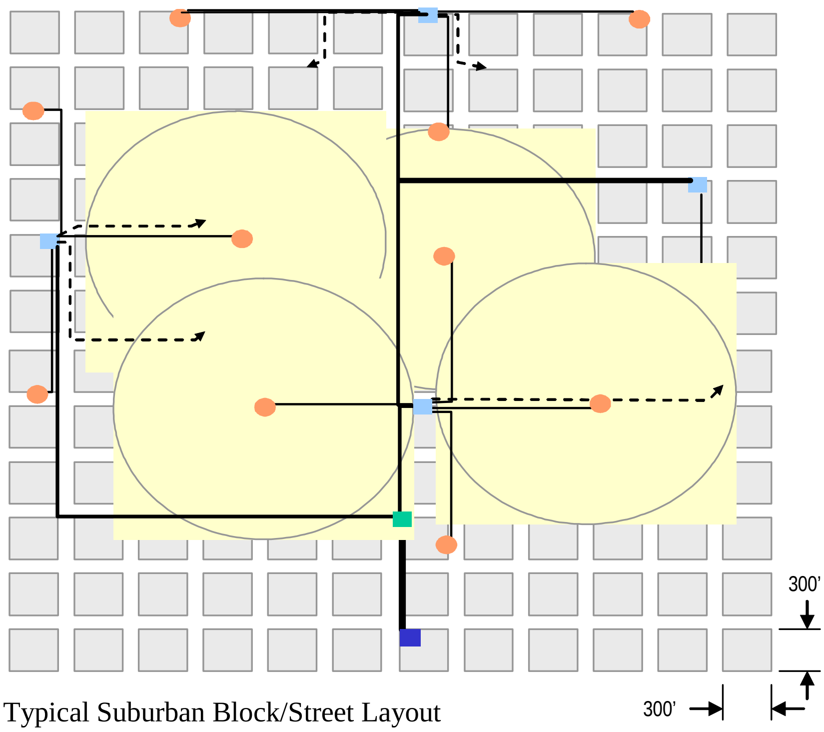

Figure B.8: Deployment layout recommended in [17]

A Subscriber Station at the cell edge will see interference from the neighbour cells, as shown in figure B.9.

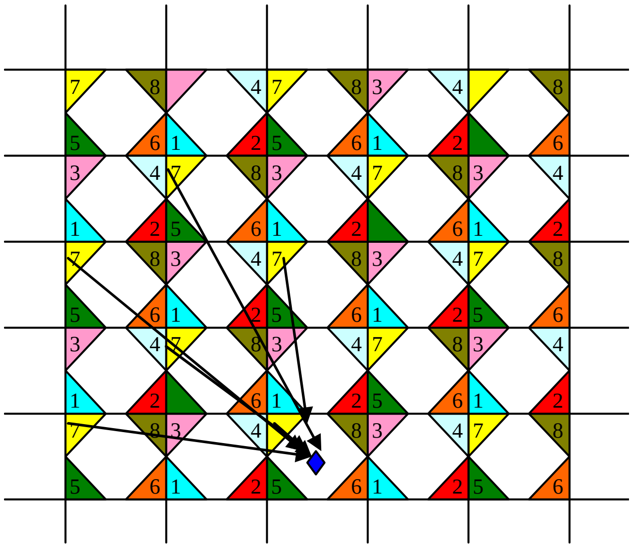

Figure B.9: Interference at cell margin

The best interference attenuation takes place if the cell size is such that it is equal with the slope transition breakpoint Rb in the dual-slope model, presented in the following equations, together with the field measurements (see figure B.10) reported in [17] for 2,4 GHz. The desired signal has minimum attenuation, while the un-wanted signal is attenuated with a double slope. However, due to the fact that we evaluate the deployment at 3,5 GHz, the resulting values for Rb are higher than the optimal cell size, creating the situation of LOS between adjacent Base Stations.

$$PG = \begin{cases} PG_0 + 20\log_{10}(d/d_0) & \text{for } d \le R_b \\ PG_{R_b} + 10 + 40\log_{10}(d/R_b) & \text{for } d > R_b \end{cases}$$

PG_0 = Path gain at reference distance

d_0 = Reference point in meters

PG_{R_b} = Path gain at the break point

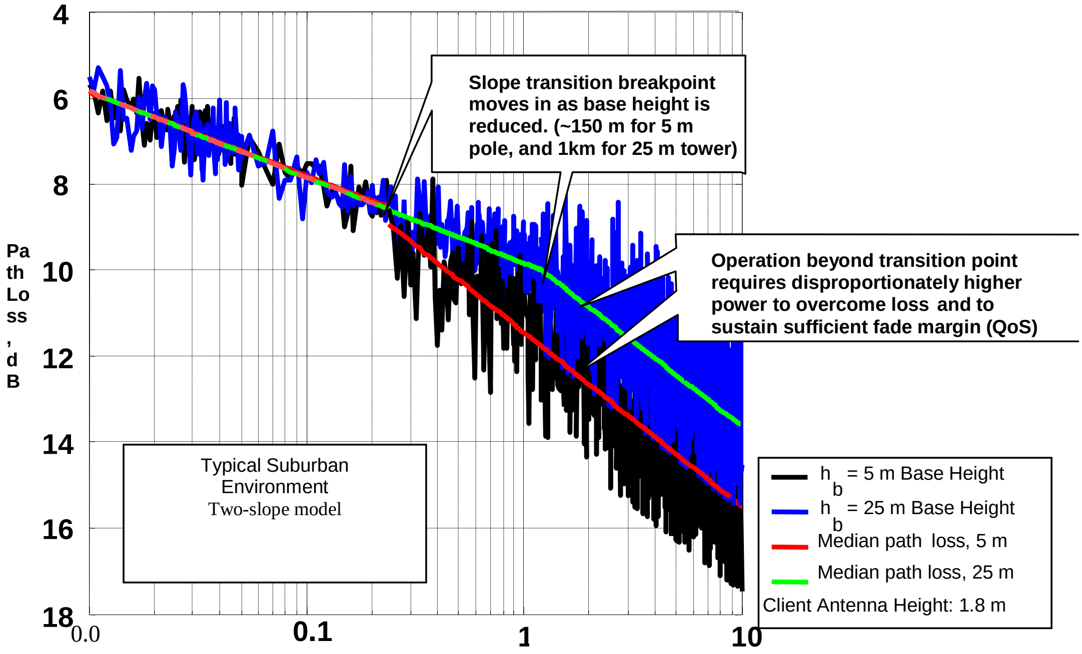

Figure B.10: Measured path loss at 2.4 GHz

Sensitivity to the deployment model

We have evaluated the C/(N+I) ratio, in the points of maximum interference in order to analyse the efficiency of the reuse 1 or reuse 2 scenarios. In the reuse 1 scenario every frequency channel is used in every cell, while in reuse 2 scenario every frequency channel is used every 2 cells. If the reuse 1 approach (figure B.11) is used, due to the smaller distance between cells and worse interference attenuation, the amount of interference becomes significantly higher.

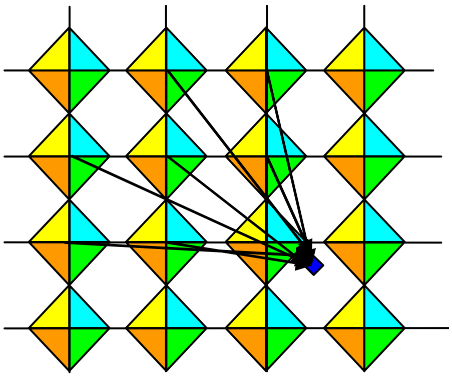

Figure B.11: Reuse 1 scenario for evaluation of interference

Our calculations, at the cell edge, show the following results:

Table B.5: Spectral efficiency at cell margin

Reuse Factor	S/(N+I) (dB)	Modulation	PHY efficiency (b/s/Hz)
1	4	BPSK 1/2	0,35
2	10.5	QPSK 3/4	1,05

Table B.5 shows a comparison between re-use factor 1 and reuse factor 2. The comparison assumes that there is the same density of base stations. For the re-use factor of 1, each sector uses 1/4 of the available channels, whilst for the re-use factor of 2, each sector uses 1/8 of the available channels. Because of the difference in interference level, the re-use factor of 2 enables the use of a higher order modulation scheme, which results in a different PHY efficiency. It is possible to see that the achievable data rates are up to three times higher with a re-use factor of 2, as compared with a reuse factor of 1, for the STs at cell edge. However, for a re-use factor of 1, each sector would have twice as many channels available. Therefore, for a re-use factor of 2, the overall data capacity for each sector would be up to 50 % higher than the capacity for a re-use factor of 1.

In conclusion, for the same required capacity, the spectrum needed for a reuse factor of 2 will be lower than for a reuse factor of 1.

The needed spectrum per cell, for VDSL like services, assuming:

- MAC efficiency equal with 0,8;
- PHY efficiency: 1,5 b/s/Hz;
- Reuse factor: 2;
- TDD mode;

is given in table B.6.

Table B.6: Spectrum estimate per operator, in MHz, for VDSL-like services - UL+DL

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban	6 960	1 757	449	133
Sub-urban	2 320	597	155	55
Rural	597	155	55	41

We consider that **56 MHz** of spectrum, TDD, will constitute the minimum allocation for VDSL shared services. In order to reduce the guard bands between two different allocation, will be needed the synchronization of the Tx/Rx frames between different operators.

The needed spectrum per cell, for ADSL-like services, for residential and business use, has been calculated assuming that most of the residential deployment will use indoor units, while the business deployment will use outdoor units, with directional antennas. Other assumptions are:

- MAC efficiency: 0,8 for residential, 0,9 for business.
- Spectral efficiency: 1b/s/Hz for residential and nomadic, 3 bit/s/Hz for business.
- 8 sectors, high antenna Base Stations.

The required spectrum results from table B.7.

Table B.7: Spectrum estimate per operator, in MHz, for ADSL-like services - UL+DL

	L = 2 km	L = 1 km	L = 500 m	L = 250 m
Urban	262	66	18	
Sub-urban	79	20		
Rural	20	6		

We consider that also in this case 56 MHz is the suitable choice for the ASDL-like deployment. The resulting cell size will be 900 m in urban and 1,6 km in sub-urban.

Common channel video traffic

The deployment for common video traffic will be according to the concept of cellular deployment using a single-frequency network.

Interference, range and availability estimations show that for a 14 MHz channel and a 1k-FFT size is achievable a spectral efficiency of 2 bit/s/Hz. Due to business case considerations, the cell size should be increased to 500 m in sub-urban and 750 m in rural areas.

IP Video traffic

The IP Video traffic is the most suitable possibility for Triple Play. European experiments (like BBC's **interactive Media Player - iMP**) offer to UK viewers the chance to catch up on TV and radio programmes they may have missed for up to seven days after they have been broadcast, using the Internet to legally download programmes to their home computers. As part of the next phase of iMP's development, the BBC will now open up more of its radio and TV schedule - around 190 hours of TV programmes and 310 hours of radio programmes, as well as local programming and rights-cleared feature films.

IP Video has already been successful in a number of Asian countries.

We estimate that same 56 MHz amount of spectrum will be enough to allow the IP Video distribution to residential users.

We consider that the spectrum should be allocated for minimum two operators proving broadband fixed-nomadic DSL services, while at least one of them should be able to offer triple play services. The incumbent operator should be allowed to use wireless, in order to be able to cover areas in which the wired access is not economical. In the case of multiple operators, even if the cumulated penetration factors will be maximum 60 %, every one should have enough spectrum for reaching the 30 % penetration.

B.2.2.2.3.2 Classical P-MP, FDD

It is difficult to calculate the FDD needed spectrum, due to the assumptions on the traffic asymmetry, which may vary from 1:1 (symmetrical) to 4:1 (asymmetrical). The traffic considerations for broadband services will lead to larger per operator spectrum blocks than have been traditionally considered in the CEPT channel plans in CEPT/ECC Recommendation 14-03 E [13]. The 100 MHz duplex rule might not longer be suitable.

B.2.2.2.3.3 P-MP with Base-Band Repeaters

The in-band feeding will be considered only for the shared DSL traffic, to reach the subscribers working in NLOS that are situated in zones not covered by the Base Station.

Assuming that the BB-R is connected to the Base Station using directional antennas, allowing high modulation states, and a two-phase system:

- Phase 1: BS works with directional ST or BB-R, spectral efficiency 3 b/s/Hz and we assume that only 50 % of traffic will use the BB-R.
- Phase 2: connectivity with STs, using omni/directional antennas, spectral efficiency 1,5 b/s/Hz. The needed spectrum is 25 % higher than in the previous case.

Per operator, the spectrum for shared applications should be increased to 56 MHz $\times$ 1,25 = 70 MHz.

Conclusion for using base-band repeaters

The spectrum/operator should be 70 MHz, to allow the use of in-band repeaters for extended coverage.

B.2.2.2.4 Amount of spectrum - conclusion

The amount of needed spectrum is summarized in table B.8.

Table B.8: The needed amount of spectrum

	xDSL-like services	Triple play
Basic spectrum	56 MHz	120 MHz
Spectrum including in-band feeding for Relays	80 MHz	140 MHz

Note that the 100 MHz duplex mode is not suitable to contiguous allocation of the needed spectrum. In the present document we have evaluated the traffic that exhibits a high degree of asymmetry between up-link and down-link and a TDD duplexing or asymmetrical FDD with more than 150 MHz duplex might be more appropriate for spectrum utilization efficiency.

B.2.3 Bandwidth and other radio parameters

B.2.3.1 Transmission mask

The transmission masks for OFDM systems should be compliant with the requirements in EN 301 021 [20] or the new HEN EN 302 326-2 [21].

ECC project team SE19 is developing an ECC Recommendation providing frequency assignment guidance for the 3,4 GHz and 3,6 GHz frequency bands. One aspect of the work is based around identifying a frequency Block Edge Mask (BEM) to limit interference between operators in neighbouring frequency blocks. The impact of this mask is to limit the emissions outside the block edge to a tolerable level and constrains operation either by forcing a limit on the eirp ystems operating in the outermost channels in a block (with subsequent range implications) or imposing a more stringent filtering requirement at the edge (with subsequent equipment cost impact). The consequence of the BEM must also be factored into any consideration of the total amount of spectrum required per operator by the factors detailed in the recommendation.

It may be considered that tight masks have a negative influence on costs and business case, due to the potential cost of class A amplifiers, higher cost power supply and filters/operator. Furthermore, the masks do not resolve the interference between units situated in proximity of one to each other.

A Coexistence Protocol, used in conjunction with the existing EN 301 021 [20] or the new EN 302 326, can provide better coexistence than the sharp masks, while avoiding the associated costs and logistic, for providing filters per operator. A coexistence protocol extends the coexistence from the frequency domain (mask approach) to both frequency and time domain. We propose that masks more stringent than those defined in the existing harmonized standards will be required only for the case that service providers using adjacent spectrum allocations do not implement the same coexistence protocol.

B.2.3.2 Spectrum Power Density

The Spectrum Power Density can be calculated from the maximum allowed power divided by the channel width. We consider that a broadband system will use minimum 7 MHz channels.

B.2.3.3 Channel width

We consider that 7 MHz, 10 MHz, 14 MHz and 20 MHz will be the suitable channel width for broadband Fixed-Nomadic applications.

B.3 Information on current version of relevant ETSI standard

Presently the majority of multipoint systems, in conventional coordinated bands, are placed on the CEPT market following R&TTE Directive declaration of conformity to the appropriate Harmonized EN 301 753 [22]. ETSI is now progressing PE on new superseding drafts HEN 302 326-2 (for equipment parameters) and EN 302 326-3 [11] (for antenna parameters).

The above harmonized standards do not explicitly address nomadic systems; however, from equipment point of view there should be no difference; therefore, besides possible clarification, if necessary, in the introduction and scope, no action might be required for using them for nomadic terminals also. On the contrary, for indoor antennas, provided that they are not insofar considered in current Harmonized EN 301 753 [22] and in draft EN 302 326-3 [11], the need of easing the placement on the market under R&TTE Directive, without the need for a Notified Body intervention, a revision of the forthcoming EN 302 326-3 [11] (and for some related references of Part 2 also) should be sought, once CEPT has clarified a possible harmonized regulatory environment for nomadic applications.

For not coordinated bands (e.g. the possible 5,8 GHz) ETSI is also in the process of producing a harmonized EN (EN 302 502 [28]), which, standing the expected non essentiality of antenna radiation patterns, should not differentiate between fixed and nomadic applications.

Regarding specific and more extensive HiperMAN standards, they are of different nature than the above harmonized ENs. Therefore they are released in the form of technical standards (TS), useful for additional conformance testing (to those for legally required for R&TTE conformance) for ensuring interoperability and higher spectral efficiency and performance to the final Operator.

Annex C: Expected compatibility issues

C.1 Coexistence studies (if any)

C.1.1 Intra-system interference

We analyse in this clause some interference scenarios between fixed and nomadic subscribers, for the case that BFWA bands will be used for converged fixed-nomadic service. In this case, same Access Point will serve both Fixed and Nomadic users, inside the same frequency channel.

C.1.1.1 Requirements for combined Fixed-Nomadic operation

In a FNWA operation the Nomadic users should not affect the performance of Fixed users, using directive antennas. In case of the systems using directive antennas, it is possible to use high modulation states, as 64QAM, due to front-to-back isolation of the antenna, and the Nomadic users should not affect this capability.

Such a requirement is justified by the fact that a Nomadic ST (Subscriber Terminal) generally uses omni-directional antenna, and its transmissions may affect all the Base Stations around and also other subscribers using directional antennas.

Figure C.1 shows the interference potential, at the BSU, created by subscribers using omni-directional antennas (blue rays) to the receptions of signals coming from the subscribers using directional antennas.

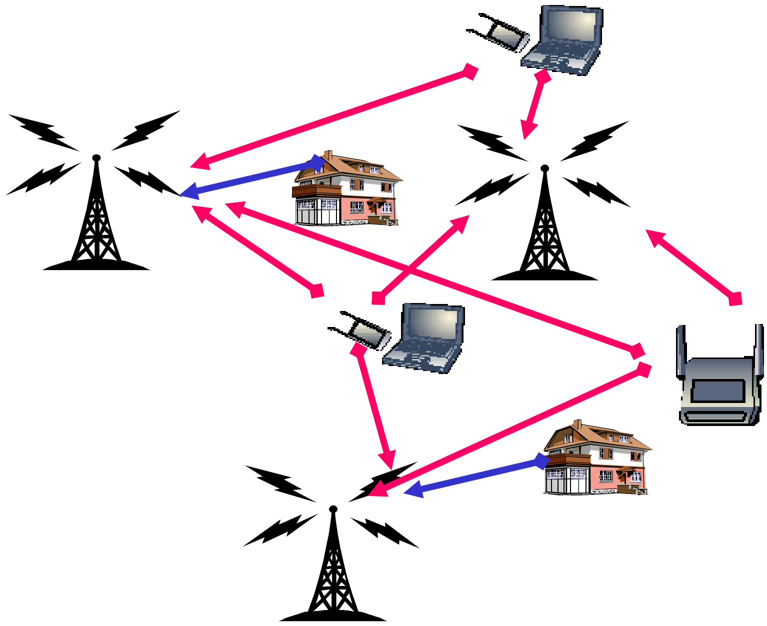

Figure C.1: Up-link interference in a converged Fixed-Nomadic system

C.1.1.2 Possible solutions for combined Fixed-Nomadic operation

Efficient spectrum use for combined FNWA will be possible with scheduled protocols, as described in TS 102 178 [2] and IEEE 802.16 [4].

A Base Station can separate, using scheduling in time domain or OFDMA domain, the users using directional antennas from the users using omni antennas. To avoid interference from other Base Stations, will be necessary to have coordination between different Base Stations, inside the operator network.

ETSI HiperMAN uses in principle OFDM/OFDMA technology, that allows to separate the fix users from Nomadic users in a number of ways:

- If same FFT size will be used for both Fixed and Nomadic users:
  - Down-link:
    - The subscribers with directional antennas will behave as in BFWA systems. The Base Station can separate, using scheduling in time domain or OFDMA domain, the users using directional antennas from the users using omni antennas. To avoid interference from other Base Stations, will be necessary to have coordination between different Base Stations, inside the operator network.
    - The Nomadic or Fixed, indoor subscribers, using omni antennas, will behave like in Mobile systems: they may be victim to inter-cell interference, due to the fact that their antenna has no front-to-back isolation. The amount of interference depends of the number of available frequencies. If the reuse factor is high (small number of available frequencies), the raw bit rate will be reduced, the coding overhead will be increased and ARQ will be used.
  - Up-link:
    - The subscribers, using omni antennas, will be seen by (will radiate to) a multitude of Base Stations, rising the level of interference at every Base Station receiver.
    - In order to reduce the interference during the reception of the subscribers using directional antennas, the Base Station shall separate, using scheduling in time domain or OFDMA domain, the users using directional antennas from the users using omni antennas. To avoid interference from other Base Stations, will be necessary to have coordination between different Base Stations, inside the operator network.

C.1.2 Inter-system spectrum sharing

C.1.2.1 Data base of registered BS

This database may give an indication to the actual spectrum use in a country. When installing the Fixed/Nomadic Base Stations, the information may be used to avoid frequencies on which operate the preferred spectrum users, in given geographic areas, or to use coexistence protocols using the geographic location information. For this, the operator of a Fixed-Nomadic system should notify the Radio Authority, before installing a new Base Station, so that it may be possible to avoid band portion already used by a "primary" user. If the operators of the Base Stations are registered within such a database, prior to the installation of a new preferred station, these operators may be asked to change their operating frequencies, in order to avoid the new "preferred" station.

This approach will allow for spectrum use in an uncoordinated (License Exempt) regime.

C.1.2.2 Active cognitive approach

A possible approach is to define a signalling frequency, adjacent to the band in discussion. The devices requiring protection will signal its presence with a standardized signal on this frequency, to indicate the actual operating frequency. In this way, the detection time can be shortened and false detections avoided.

Another possibility is to send, at short and cyclic time intervals, standardized signals on the working frequency. A Fixed/Nomadic device will detect such signals and immediately will have to switch to another working frequency. The standardized signals will enforce a pro-active cognitive approach.

Services as "aeronautical telemetry", operating in 2,3 GHz, and active for short time only, may use this identification of activity. Another example are ENG operations or microphones, TV receivers, etc.

The drafting of regulations for the active cognitive approach should be done in cooperation between ETSI BRAN and ECC.

C.1.3 Inter-operator spectrum sharing

In our view, due to the fact that the Nomadic users will have lower EIRPs as compared with Fixed STs, the inclusion of Nomadic services will not affect the inter-system interference.

The HiperMAN/802.16 standards define procedures for ST activation, based on the fact that the ST detects the signals sent by a Central Station and associate with that Central Station. The ST is transmitting only if a suitable Central Station is detected.

In the following clauses, we present some principles of a possible Coexistence Protocol, which will allow sharing the spectrum in both frequency and time domain. As we have written in annex B, this protocol, in combination with the existing masks defined in EN 301 021 [20] and HEN 302 326 part 2 [21] and 3 [11], may avoid the cost increase following the usage of the allocation masks defined by SE19.

C.1.3.1 Principles for a Coexistence Protocol

A coexistence protocol, to improve the spectrum sharing between different operators, is currently drafted in IEEE Project 802.16h [24], having as scope the improvement of coexistence in LE bands. We considered that the same basic mechanisms might be used for improving the coexistence in Licensed bands as well. Some of the basic mechanisms are presented below:

- ACS - Adaptive Channel Selection: taking into consideration the minimum received and created interference.
- Scheduling of interference: free zones in a MAC frame, including a set of possible rules for initial allocation of the sub-frames and a negotiation protocol for flexible interference-free sub-frames assignments.
- Interferer identification, using the radio signature at known absolute time.
- Coexistence protocol, to control the system functionality.
- Base Station Identification Server, including the BS GPS position, BS IP address, BS Operator information, BS Radio Signature scheduling info, etc.

Every Base Station is building a "Coexistence community", based on the maximum interference radius. The discovery of "neighbours" is obtained from a Coexistence Server and it is based on the GPS locations of neighbour Base Stations.

For coexistence in TDD operation, the MAC frames have same duration and the Rx/Tx splitting is synchronized using a GPS receiver. The scheduling of interference - free zones in a MAC frame is exemplified below.

- In these examples every network will become in turn and in a fair mode the owner of the radio resource. The time intervals in which a system is owner of the radio resource are called "master sub-frames".

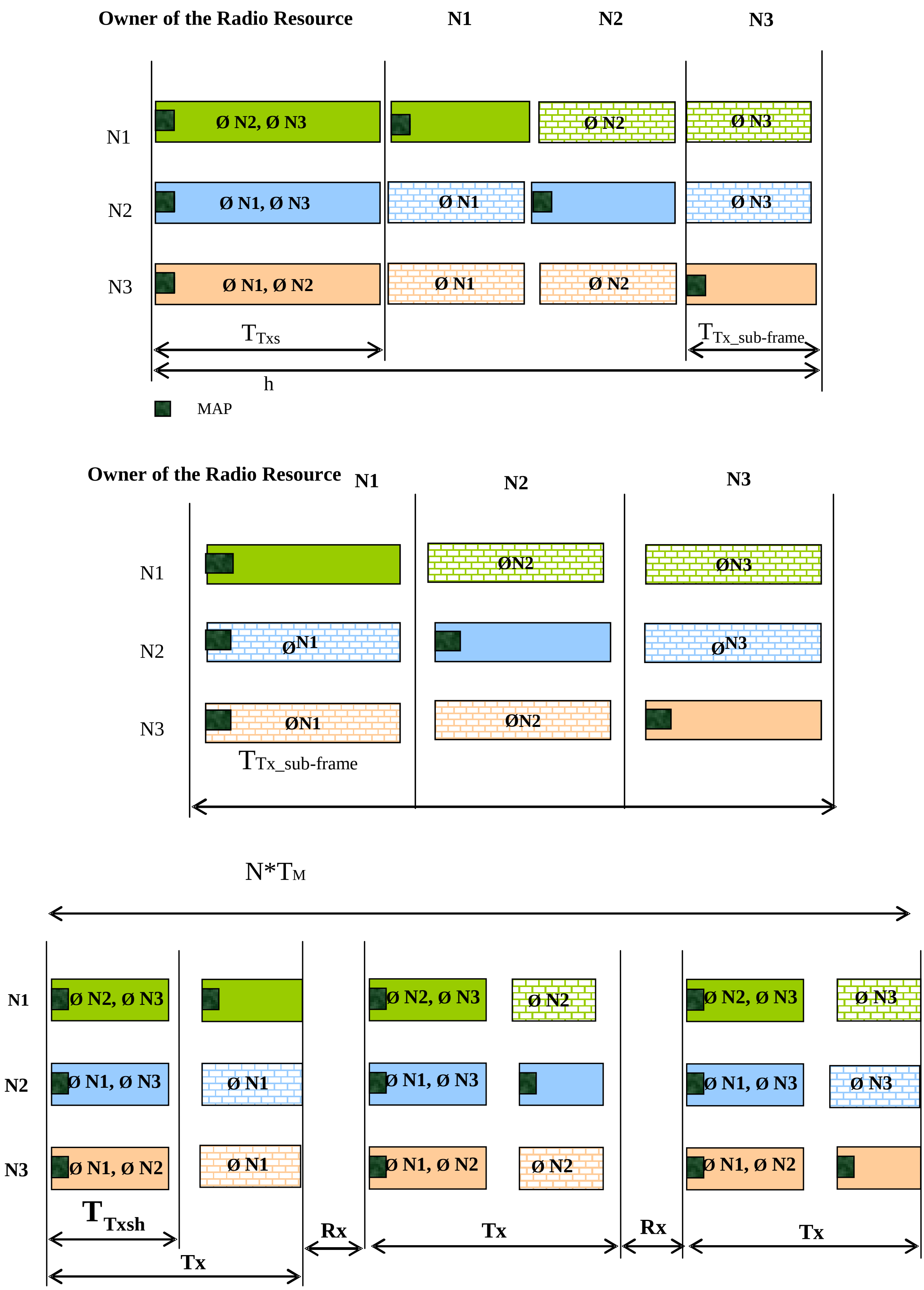

Figure C.2: Power control and traffic scheduling with a Coexistence Protocol

In the above figures, the meaning of Tx or Rx is relative to the usage of the MAC Frame by a Base Station. During the Master sub-frame the Base Stations assuming Master role may use their maximum power.

During every Master sub-frame, the Base Stations will create a slot, not overlapping with another slot of a neighbour Base Station, during each every transmitter (BS or associated ST) will send a predefined signal; this signal, called "radio signature", will be used to measure the interference created by that transmitter.

More details may be found at http://grouper.ieee.org/groups/802/16/le/index.html, using the last available draft.

C.2 Current ITU allocations

The tables below reflect, between 3,4 GHz and 4,2 GHz, the ITU-R allocations in Region 1 and specific CEPT allocations and applications [9].

Table C.1

Frequency Band	ITU-R allocations Region 1	CEPT allocations	Applications
3 400,0 MHz to 3 500,0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) Mobile Radiolocation	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE Amateur Radiolocation	Radiolocation (military) (upper limit 3 410,0 MHz) Amateur Fixed links including P-MP SAP/SAB and ENG/OB FWA
3 500,0 MHz to 3 600,0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) Mobile Radiolocation	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE	SAP/SAB and ENG/OB FWA Fixed links including P-MP
3 600,0 MHz to 4 200,0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) Mobile	FIXED FIXED-SATELLITE (space-to-Earth)	Coordinated earth stations in FSS Fixed wireless access systems - 3 600 MHz to 3 800 MHz including point-to-multipoint Medium/high capacity fixed links

Annex D: Initial assessment of compatibility issues by ETSI BRAN for the information of CEPT

This annex contains information on a preliminary analysis of sharing issues.

D.1 Assumptions on FWA-NWA systems

In this clause it is provided a short description of the FWA systems and services proposed for operation in the band 3,410 GHz to 3,8 GHz, together with the necessary parameters for the subsequent interference analysis.

D.1.1 P-MP system parameters

The Point to Multi-Point system shall be assumed to have the characteristics as shown below.

Table D.1: P-MP system parameters

Parameter	Value	Unit	Remarks
Considered channel bandwidth	1,75…14	MHz	Narrower channels are preferable to minimize probability of interference. Also, support for frequency re-use in cellular deployments as well as concurrent service providers in same area make these channel bandwidth optimal.
FDD; duplexing	100	MHz	This is the preferred duplexing value; in extreme cases, 50 MHz can be also used.
Tx peak output power, BS	35	dBm	In some scenarios the Base Station power may need to be up to 43 dBm, to cope with Nomadic deployment.
Tx peak output power, ST-Fixed	22	dBm	The typical ST power is limited by cost and limitation of the BS power: the OFDMA/sub-channelization gain compensates for the power difference. In some scenarios the ST power may need to be up to 30 dBm.
Tx peak output power, ST-Nomadic	20	dBm	
OFDMA/channelization up-link gain	3…15	dB	
UL/DL ratio, ST-Fixed	0,01…1		For FDD, max. 1:1.
UL/DL ratio, BS	0,3…1		For FDD, max. 1:1.
BS sector antenna gain	17	dBi	Assuming 60° and 90° antennas.
BS omni antenna gain	9	dBi	
Adaptive antenna gain improvement	20×logN	dB	N=number of antennas (N=4 typically), assuming beamforming.
Roof-top ST-Fixed antenna gain	20	dBi	
Roof-top ST-Fixed antenna beam-width	20	Degrees	
Window ST-Fixed antenna gain	10	dBi	
Indoor ST directional antenna gain	9	dBi	
Indoor ST omni antenna gain	3…5	dBi	
% rooftop STs	10-50	%	
% window STs	20-60	%	
% indoor ST-Fixed + ST-Nomadic	30-70	%	A bias to Nomadic use is anticipated.
Number of channel in reuse pattern	6		Based on hex scheme with 6 sectors.
Receiver sensitivity (BS)	-96…-74	dBm	Evaluated for 7 MHz. NF= 5 dB; SNR= 2,5…24,5 dB, for different modulation/coding variants; 2 dB-implementation loss.
Receiver sensitivity (ST)	-94…-72	dBm	Evaluated for 7 MHz. NF=7 dB; SNR=2,5…24,5 dB, for different modulation/coding variants; 2 dB-implementation loss.

D.1.2 Radio parameters

The following values may be considered as typical radio parameters.

D.1.2.1 Receiver SNR

The SNR values are taken from TS 102 177 [1].

Table D.2: Receiver SNR for OFDM mode

Modulation	Coding rate	Receiver SNR (dB)
BPSK	1/2	3
QPSK	1/2	6
	3/4	8,5
16QAM	1/2	11.5
	3/4	15
64QAM	2/3	19
	3/4	21

Similar values are defined in IEEE 802.16e [19], for OFDMA modulation, that will be probably implemented in Laptops.

Table D.3: Receiver SNR for the OFDMA mode

Modulation	Coding rate	Receiver SNR (dB)
QPSK	1/2	5
	3/4	8
16QAM	1/2	10,5
	3/4	14
64QAM	2/3	18
	3/4	20

D.1.2.2 Receiver Sensitivity Level

The receiver typical input level sensitivity (*RSS*) will be (assuming 2 dB implementation margin and 7 dB Noise figure):

$$RSS = -174 + Impl\_loss + NF + SNR_{Rx} + 10\times\log_{10}(Equiv\_channel\_width).$$

where:

- Impl_loss - implementation loss (2 dB typ).
- Noise Factor (NF) - typical 5 dB for BS, 7 dB for ST.
- SNR_{Rx} the assumed receiver SNR as per tables D.1 and D.2, in dB.
- *Equiv_channel_width* - equivalent channel width, when not all the bandwidth is used (for example, the OFDMA case), in Hz.

D.1.2.3 Adjacent and alternate channel rejection

Tables D.4 and D.5 are given the adjacent and alternate channel rejection, for OFDM respectively OFDMA modulations.

Table D.4: Adjacent and Alternate Channel rejection - OFDM

Modulation/coding	Adjacent channel interference C/I (dB)	Non-adjacent channel rejection C/I (dB)
16QAM-3/4	-11	-30
64QAM-3/4	-4	-23

Table D.5: Adjacent and Alternate Channel rejection - OFDMA

Modulation/coding	Adjacent channel rejection (dB)	Non-adjacent channel rejection (dB)
16QAM-3/4	11	30
64QAM-2/3	4	23

History

Document history		
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