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Revision History

The following table describes the main changes done in the document since it was created.

Revision	Date	Description	Author (Organisation)
0.5	2008-06-30	Draft	Codium Networks
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216751	REWIND	REWIND Operator Market Research

Table of Contents

1 Introduction

GSM networks have attained ubiquity. Service is not perfect, but it is reliable and of good quality. It took close to 20 years, but the benefits have reached the limit of the imagination. In most places on the planet, where there is mobile phone coverage the best chance is that a three-band, GSM900, GSM1800 or GSM1900, phone will work. Traditional CDMA countries have also embraced GSM technology, no doubt due to its popularity in the rest of the world. Locations where GSM is still not available now have UMTS2100 licenses. Probably the last bastion of the CDMA technologies, South Korea has now two mobile operators with UMTS2100 licenses: SK Telecom and KTF (Korea Telecom Freetel). This is 2G and 3G.

How far is this from mobile data and 4G? Quite far , but the industry has definitely learned the GSM lesson in terms of allowing technology diversity to prosper within the same eco-system as opposed to setting up parallel ones. As we have noticed, the speed of change increases as time goes by. It will take a lot less time to achieve data ubiquity. The obstacles are significant:

- Different technologies
- Different spectrum frequencies
- The ongoing pressure on companies to increase profits year after year
- The ongoing pressure to at least keep up with the competition, if not to be ahead of it

Keeping in mind that the focus of the operator market research is on the 4G relay stations technology, this report analyses the current state of the telecommunications operators in the EU space and points to the effects of different technologies on ubiquity.
There are two important factors to understand from the beginning.

- First is that in the mature European market of today the main driver for telecoms operators is profit, not ubiquity or the aesthetic imperative of 4G networks deployment. These concepts are just ways of attracting more customers and be able to drive revenue.
- Second, not only existing mobile operators are in the running to increase profits by achieving mobile data ubiquity. The race is also open for the fixed-line operators and for the so called ‘greenfield’ operators.

Following this introduction, the document explains how the struggle to keep up with the competition and shareholder demands for profit sustainability are pushing more and more telecommunication companies into the mobile data business. Following sections of the document show the different advantages and handicaps of various market players in acquiring market share for mobile data. Traditional cellular companies and WiMAX operators are presented. The document ends by summarizing the conclusions on how RS technologies help in achieving mobile data ubiquity and consequently how they will become a vital tool for operators in this field.

The countries considered for this research are the countries which officially belong to the European Union[1]. In presenting a coherent image of the Western European market Switzerland and Norway are also included in this research. This makes a total of 29 countries.

2 Operators Current Imperative: Profit

The deployment of ubiquitous telecoms networks entailing the installation of tens of thousands of base stations across each national market has meant the investment of billions of Euros over the last decade or so. End-users might be excited by services previously thought impossible, such as watching videos while in motion, using Skype over data sessions on mobile phone or HDTV over the broadband link, the sole reason for these services however is to provide a business model that offers strong profit sustainability.

There are several ways of achieving this:

- Cut costs (by re-structuring and spin-offs)
- Attract more customers (aside from organic growth, by acquisitions, mergers, partnerships)
- Provide more services, preferably differentiated from those of the competition (by constant invention and introduction of new services to the market)
- Provide higher revenue generation services (by adding value to services) and by closely monitoring end-user habits so as to be able to focus on encouraging the higher spenders)
- Developing new business models (thus penetrating new markets)
- Protect market share by defensive measures (by neutralising competitors' actions which will increase their market share). This could end up being considered anti-competitive behavior, but the limit depends on the legislation.
- Minimise new investments (depending on the risk profile of the shareholding investors, a company can be aggressive or conservative in committing new Capex to the business).

3 European Competitive Landscape

Europe is today perhaps the most competitive telecom market in the world. Standards, telecommunication regulators and EU laws are making it increasingly easier for operators in one country to set up similar businesses in another EU territory. The high cellular market penetration shown by Table 3 confirms this fact. Out of 29 countries, 23 have penetration of over 100%.

Also the number of operators in each country shows most territories have attained the optimum number of operators. Some countries are still in the settling period but close to maturity.

From the number of companies operating in each territory point of view, the market competitiveness usually follows these rules:

- One operator is a monopoly
- Two operators are a duopoly, prices end up being similar and at a high value. This state is usually for a limited period of time, before a third operator enters the market.
- Three operators offer some competition, but usually the 'oligopoly' rule still applies, with one operator lagging. If a market is reduced to three operators from an original four by merger or acquisition between two of them, it might mean a healthy competitive environment if that territory cannot sustain four operators.
- Four operators offer competition.
- Five or more operators for a territory as large as an EU country, usually points to the overshoot of a non-matured market, which gets corrected by a reduction in the number of operators. Another explanation for a large number of operators is an unusually active market.

Statistics show that out of 29 EU countries 14 have 3 mobile operators and 9 have 4 operators. Complete statistics is shown in **Error! Reference source not found.**. Data is available from Table 8, in section 10.1.

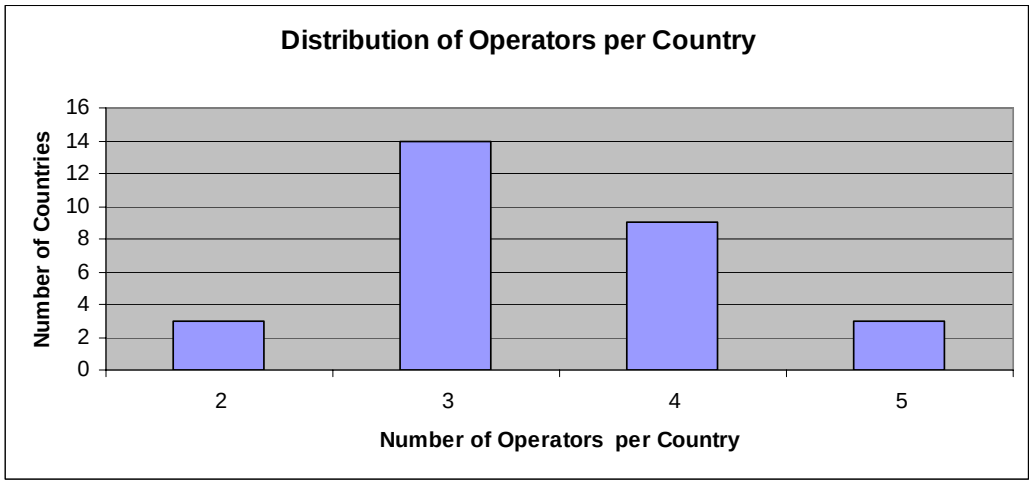


Figure 1 Distribution of Number of Mobile Operators per Country in EU

Looking at the table above out of 29 EU countries 23 of them reached optimum competitive conditions.

Other facts should be understood when looking at the number of operators, such as size of the country and dynamic of the national regulators. More incentives apply in some territories for more competition.
Also, a market with three or four operators should not be seen as static. In the perpetual effort to maximize profit, each company is continually looking at better ways to operate and attract more customers.

4 Research of Network Operators

This section describes the research criteria and methodology used to gather relevant information to the REWIND project. We have come up with a set of questions to discuss with different types of network operators. The questions are different for each type of operator. Preference has been given to existing Codium Networks customers and contacts followed by phone calls to other operators.

4.1 Types of Network Operators

One may categorise telecommunications operators in different ways. We have chosen to group them by network infrastructure and risk profiles. These types are defined in the section below.

4.1.1 Network Infrastructure Types

4.1.1.1 Mobile wireless operators

These are the traditional mobile cellular operators who own radio spectrum which permits them to offer mobile communications. Their infrastructure was built with direct equity and debt investments and their capex recovered over a five to ten year period by providing highly profitable mobile phone services to their subscribers. While studying the profiles of European mobile cellular operators, (see Table 3), there are 3 sub-categories considered for this group:

- Cellular operators with GSM and 3G licenses. They are the best positioned companies in the market, with deep pockets, large national coverage and a wide choice of voice and data services.
- Cellular operators with 2G licenses only. Companies who missed acquiring a 3G license usually have very good national coverage; however voice capacity is limited to GSM technology and data services to EDGE bitrates.
- Cellular operators with only 3G license. Greenfield companies, usually with telecoms background, they benefit of the latest technology and although the spectrum license is national, their coverage is patchy, lacking the national cell sites infrastructure.

4.1.1.2 Fixed Wireless operators

Most (pre)WiMAX network operators fit into this category. They normally own some spectrum although some of the smaller so-called WISPs launch their ventures in unlicensed bands in the hope that later they will be able to convince regulators as to the necessity of administering some licensed spectrum to guarantee the long term sustainability of their business (GANAG in Germany, and Introweb in Holland. Fixed wireless operators owning spectrum may move into mobility, latest Brussels directive on this matter forces regulators to make all 3.5GHz fixed wireless licenses compatible with mobile service. Mobility will become increasingly important for them in any case as it is expected that their market will shrink due to the trend for all fixed locations to be connected by wired infrastructure with much higher bandwidth capabilities (adsl2+/VDSL/ftth/etc.). Any remaining sites with no wired connectivity

will also receive service via the new 4G infrastructure; so the market for fixed wireless operators will be severely limited over time.
Fixed wireless operators are not taken into consideration in this market research for the reason that in their present state they will not impact the 4G scene.

4.1.1.3 Wireline operators

Typical operators for this category are the incumbent national operators and the cable TV operators. They both own fixed infrastructure.
Incumbent National telephony operators inherited the copper network from the State. Now regulators are asking these operators to share these assets with other network operators. In some cases the copper access network sharing with the rest of the operators is fair, in other cases it is difficult and competitive operators suffer greatly in attempting to take advantage of Unbundled Local Loop regulation.
The cable TV operators have built their infrastructure on the Triple Play principle.
Now, due to technology advances such as ADSL2+ and VDSL for the copper loops and DOCSIS3.0 for HFC networks, the operators of wired networks are able to offer far greater service performance than what the networks were originally designed for.
There is also a new breed of operators using the unbundled local loop maintained by the national telephony operator, these are normally denominated CLECs or alternative fixed line telcos.

4.1.2 Risk Profile Types

4.1.2.1 Aggressive operators

These are operators who are proactively and meticulously researching their target market and coming up with new and innovative services. It is the typical behavior of new market entrants with minimal market share who are looking to deploy "disruptive" strategies in breaking down barriers to market entry; these are operators who often have the younger age groups as their target market.

4.1.2.2 Passive operators

The actions of these companies are rather reactive then proactive. They only act when the competition threatens to get ahead. This is the typical behavior of large organizations, which previously enjoyed a monopoly in the market.
The risk profiles should not be misunderstood as aggressive operators are more desirable in the market compared to the passive one. It all comes down to the usual risk/reward equation, for incumbents it is safer to let things work as they were instead of getting into risky ventures or trying out new services which might prove unpopular: "If it ain't broken, don't fix it".
Managers of passive operators usually monitor the market and take decisions only if a disruptive element emerges and threatens their business. Of course, there is the risk that this disruptive element is observed too late or that the disruption is larger than initially predicted, meaning the passive operator might loose control of the market it used to serve.

4.1.3 Network Operator Type Summary

By careful consideration of all facts explained above, we have grouped all European network operators in five groups, shown in Table 1. The reason is to keep the number of subjects to a manageable size, given our time and financial constraints.

Operator Type	Network Infrastructure	Risk Profile
A	Cellular operator with 2G license only	Passive
B	Cellular Operator with 3G license only	Aggressive
C	Cellular operator with 2G and 3G licenses	Passive
D	Fixed wireless operators with national licensed spectrum	Aggressive
E	Fixed wireline operators	Passive

Table 1 Network Operator Types

4.2 Research Questions Set

A common set of questions has been compiled in order to have comparable answers. The questions vary slightly according to the type of operator being interviewed so that all questions make sense.

Due to time constraints, the interviews were not formal; the questions being asked were used as discussion starting points. In order to get the most relevant and reliable information, some of which might seem sensitive by some of our contacts, we have been forced to keep all data sources confidential. Given the close relationship of Codium Networks employees to most of the interviewed people, we were told, more often than not, that if we want to use company names in our market research reports, then "we are only authorized to include comments already made public as press releases and the like"; all other information is strictly confidential and our contacts threatened to decline to participate in our market research for fear of breaching corporate disclosure rules. Essentially therefore we had to agree on a verbal Confidentiality Agreement with them in order for our interviews to take place.

What should be the criteria on which we build our questions set?

While looking at how services are used as driven by different technologies, there is an increase of services driven by mobile infrastructure, to the detriment of the fixed or wired operators. Operators who don't have mobile wireless technologies have only two options to survive in the medium and long term: become mobile or provide such high bandwidth to subscribers that mobile networks cannot keep up. And since customers buy services, not technologies, those high bandwidth pipes need to have appropriate services running through them, which, again, become a key differentiator against MNOs.

From the REWIND perspective the question arises: which type of operators are most likely to move to 4G technologies? Industry analysts offer the following facts in order to make an informed guess:

1. Traditional cellular operators owners of a 3G license are not rushing to get into 4G. Many (and the largest) of them have already publicly announced their support for LTE. As the mobile market stands right now, there is no incentive for them to make a decision. The services they offer and technology they use have no major competition yet and the mobile data revenue is increasing on the back of 3.5G technology upgrades (HSPDA/HSPDUA, etc.). Plus, LTE will let them re-use existing 3G spectrum, which gives them extra leverage in business. However, the 3G spectrum is not enough on its own to achieve full performance and capacity as specified by 4G systems. These operators might have to opt for a 4G license.

2. Traditional cellular operators ***without*** a 3G license are in a very different position. Their voice revenue is dropping and they cannot compensate that with mobile data as 3G license holders can. These operators are actually under pressure to do something to increase revenue. They are happy and willing to deploy 4G technology as soon as spectrum, infrastructure equipment and handsets become available. Much of the required infrastructure, such as cell sites is already in place and while some optimisation and gap-filling will be necessary, this is not going to be a big risk or expenditure. The biggest variable here is probably spectrum availability and cost (The international GSM operator Comium is a good example; they have several GSM networks deployed and having failed to attain 3G spectrum and licenses are now focusing their efforts on acquiring 802.16-compatible spectrum and on deploying Mobile WiMAX infrastructure.)

3. Fixed wireless operators using (pre)WiMAX equipment are other candidates to jump into 4G as soon as spectrum becomes available. With the introduction of horizontal drilling and the increased efficiency of fibre roll-outs, the market share is shrinking for wireless fixed technology. Wherever there is a road, soon fixed infrastructure (optical fibre) is installed. Fixed wireless network access, which is already a niche technology, is becoming even more marginalised. Another disadvantage is the fact that the spectrum most these operators use is not currently licensed for mobility although, as previously mentioned, this is now changing. The opportunity for these operators is 4G, if they have enough financial resources to acquire spectrum, equipment and all related deployment costs. Existing cell-site infrastructure is not as comprehensive as for the 3G-less mobile operators and for this reason amongst others, for this category of operators the way forward presents significant challenges. NeoSky in Spain and Cosmoline in Greece are just two examples that have been identified that fit the above analysed scenario.

4. 4G spectrum auctions have taken place in just 2 of the 29 EU countries. The UK auction was supposed to be the third but it has been delayed[2], Spain, France and Germany are amongst several countries that at this time have been identified as having plans for 4G spectrum auctions. As indicated above, there would be many interested parties willing to acquire spectrum and start

deployment as soon as possible. This would imply usage of WiMAX over this spectrum and also premature competition for 3G license holders. Any delay of 4G spectrum allocations narrows the window of opportunity for WiMAX. Renowned wireless market analyst Caroline Gabriel expands this topic in Wimaxtrends[3].

What does the above signify for the REWIND project? That probably the first relay stations to be developed will be using WiMAX technology, but then shortly followed by LTE.

Based on the REWIND D2.3 Operator Market Research recommendations and the points mentioned above, the list of questions covered is shown in Table 2.

Q #	Question	Applies to
1	What is your existing mobile data network architecture?	A, B, C
2	Do you plan to deploy a mobile data network? What technology are you thinking of: 2.5G, 3G, WiMAX, LTE?	D, E
3	What are you trying to achieve from the data mobility point of view?	A, B, C, D, E
4	How are you trying to achieve the goal stated in point 3?	A, B, C, D, E
5	Have you considered other ways of achieving the targets of point 3? Why did you pick the existing strategy?	A, B, C, D, E
6	Which are the risks involved with your existing strategy?	A, B, C, D, E
7	Why do you think you'll achieve the target by using the strategy you picked?	A, B, C, D, E
8	Have you considered using anything else apart from macro BTSs, such as micro, pico or femtocells to fine-tune coverage? If yes, what is evolution and deployment criteria for such units?	A, B, C, D
9	Do you have any demands or requirements from mobile data end-users?	A, B, C, D
10	How do you see fixed or mobile WiMAX for your business?	A, B, C, D, E
11	Do you have any problems with mobile data right now?	A, B, C, D
12	Are there any new problems with mobile data you foresee for the next 2-3 years?	A, B, C, D
13	What are your biggest concerns regarding data mobility?	A, B, C, D
14	Have you heard of 802.16j MRS concept?	A, B, C, D
15	Do you think the MRS might help your business?	A, B, C, D

Table 2 Operator Market Research Question Set

4.3 Research Responses

The answers to the questions and the main points of the discussions with various network operators are detailed in this section.

4.3.1 Responses from Operators Type A

There are not many operators of this type in the EU.

4.3.1.1 MNO in Romania

Q #	Answer
1	At the moment the typical 2G, GPRS architecture with SGSNs and GGSN.
2	N/A
3	At the moment we are offering i-Mode services. We are looking at other options such as EDGE and waiting for other spectrum auctions. We are the only MNO in Romania without a 3G license and it's a significant handicap.
4	No real goal set yet for mobile data. We are missing spectrum.
5	N/A
6	N/A
7	N/A
8	N/A
9	N/A
10	Mobile WiMAX is a technology we would consider if the spectrum would become available, dual GSM/WiMAX handsets and WiMAX PC cards.
11	Yes, to slow.
12	No point to discuss now, we need to get there first.
13	Speed and coverage.
14	Yes, the MRS concept will probably be useful, although not having a need for it yet, we have not spent too much time on it.
15	Not right now.

4.3.1.2 International Operator in Switzerland

Q #	Answer
1	At the moment the typical 2G, GPRS architecture with SGSNs and GGSN.
2	N/A
3	No special data services just general Internet access via GPRS.
4	No plans from Headoffice, neither from the Swiss Ofcom for 4G spectrum yet.
5	N/A
6	N/A
7	N/A
8	N/A
9	N/A

Q #	Answer
10	Mobile WiMAX might be an option, however, not likely. Given the 4G spectrum won by mother company in Sweden and Ericsson's promises to have LTE equipment next year, together with Swiss Ofcom delay in 4G spectrum, it all points to LTE.
11	Yes, slow bitrate on GPRS..
12	Once we know wich way we'll go we'll find also the problems.
13	Speed, coverage and data handovers
14	Yes, the MRS needs to be standardized first for WiMAX and LTE. There's still some time before that happens.
15	4G will definitely have 3G-typical data indoor coverage and performance problems. If MRS has a proven business case, might help there.

4.3.2 Responses from Operators Type B

4.3.2.1 International Operator in Austria

Q #	Question
1	Standard 3GPP mobile data architecture
2	N/A
3	Create a pan European mobile data network where with no roaming extra charges. Offer new services and be sensitive to our customers.
4	By deploying 3G data networks to as many European countries as possible. In countries where we are present we partner with other local operators where we have no coverage. We charge no data roaming charges for Internet access, because we don't have to: Internet is local.
5	We are trying everything that comes up to our mind and can do to grow and be successful. Point 4 shows an example of how we are different then other operators. If you have any ideas, let us know.
6	We are a small operator, quick and flexible when it's about services and customers. Our handicap is patchy coverage, which we are trying to address by partnering with larger operators. These large operators can "eat our lunch very fast if they really want to and they will probably will". They are not doing it right now because they would cannibalise their own data revenue stream. We are aware of the fact that at some point in time large operators will offer similar services to what we offer right now.
7	We couldn't think of anything better. We are constantly monitoring the market, services and technology and are ready to quickly react to any change. If we make a mistake we'll also quickly fix it.
8	We are using everything that the technology can offer in order to fine tune our network and make the best of it. Acquiring new cell-sites is increasingly difficult. The same for high-speed backhaul. The industry is not sure of femtocells yet, large operators can afford to play with it. We do not see macro BTS in highly dense urban environment. There are too many difficulties: extremely high rental costs, environmental objections with the usually perceived health hazard of radio emissions being the first amongst them.

Q #	Question
9	3G services are fairly new. If customers get flat rate, unrestricted high speed Internet access, they know what to do with it. What we get so far from customers are complaints due to performance and coverage.
10	Being a 3G operator, WiMAX is not essential to our business. However, we must keep an eye on it as our competitors might use it. We have many options for speed upgrades: HSDPA, HSUPA, HSPA+ and then LTE. As we see right now, WiMAX will affect our business only through what our competitors can do with it.
11	Problems are: coverage, data/connection loss at handovers, indoor coverage and performance at the cell edge.
12	Hard to say. If somebody can foresee problems, then they won't exist because they'll get fixed before implementation. I think the industry needs to look for solutions for a deterministic way to evaluate capacity and performance under load. Coverage is also very important at the cell edge, indoors and underground.
13	So far the big concerns are the problem handovers and cell capacity.
14	Yes, the concept sounds great: self-backhauling. But this feels like capacity will decrease for the benefit of coverage or speed. I'm not sure of 3GPP has a similar project.
15	Definitely and absolutely. Although not much point to have self-backhaul at 3G speed, but it makes sense for HSPA. We also need to check the business model.

4.3.2.2 Greenfield Operator in Europe Emerging Country

Q #	Question
1	We have currently deployed a 3G network. Data network architecture is the standard 3GPP architecture.
2	N/A
3	Our plan is to be a mobile voice and data player. From the data perspective, we are trying to be one of the important mobile ISP. We are optimizing our network and offering attractive and aggressive data services.
4	The acquisition of the 3G license and deployment of HSDPA network gives us enough network capacity, which if correctly managed, provides a solid infrastructure on which we can base our data services.
5	Yes, we considered other options and we picked the best. The standard 3G capacity of 384kbps would have not been enough to provide satisfactory mobile Internet access service. The HSDPA provides 1Mbps, which is adequate for most applications. Other options we considered are HSUPA, but we don't see the benefits for such an upgrade yet. Once customer grows, we will consider HSPA+.
6	Risks are coming from large international operators dropping prices for mobile Internet. We hope we can stay ahead of them.

Q #	Question
7	The experience of other operators has shown that this is possible. We have a solid business plan and we execute it with accuracy. We constantly keep an eye on emerging technologies and competition. If a radically disruptive technology does not threaten to totally dislocate our current business model, then we run with a manageable risk.
8	We use macro, micro and pico cells to provide coverage. We will use whatever technology makes business sense to achieve our targets. As mobile wireless becomes mainstream voice and data connection option, we expect to encounter new restrictions from the local administration on installation and visual impact of infrastructure. We deal with each problem when it comes and consider the technology that is most appropriate.
9	End-users desire higher speed, cheaper prices and larger coverage. We constantly may come up with new marketing plans to show customers we are active and doing our best for them.
10	Not right now. WiMAX will provide higher data capacity. How much higher in the mobile real environment is to be seen. Also it involves a different voice platform, not talking about spectrum and other variables which make it too hard to bother. Right now, if higher data speed is desired the upgrade to higher order HSPA techniques is the best option for us.
11	The problems that all mobile data operators have: performance at cell edge, difficult data handovers and speed when there are many users in the same cell. Some can be fixed but others we just have to live with them; there is the limiting factor of the technology. As long as our competitors have the same problems, it's ok.
12	Biggest problem is network capacity. As more people will use mobile data, current networks are probably going to suffer major congestion. One solution is not to make data services so affordable that the masses will buy them; we don't want to think of this "dirty fix". We hope that new spectrum and technologies will become available to allow customers to use the data-enabled handsets as they use mobile phones now.
13	Cell capacity and performance, meaning speed and latency; the quality of experience.
14	Yes, we know the WiMAX 802.16 work group are working on a relay standard. We don't know of a similar program at 3GPP.
15	High speed backhaul cost and coverage at cell-edge are some aspects which should be improved and where the MRS can help.

4.3.3 Responses from Operator Type C

4.3.3.1 International MNO in the UK

Q #	Question
1	We are operating probably the most advanced mobile data network in Europe. Our services span a large number of countries in the EU. We use equipment operating on the 3GPP standards and so is the mobile data network architecture.
2	N/A

Q #	Question
3	Mobile data is the natural next step for any mobile network operator. Given our position in the market, our goal is to offer connectivity of our mobile customers to Internet or any private networks at mutually agreed parameters.
4	We are using state of the art equipment, most modern network architectures and technologies, together with a flexible multi-plan business model, allowing changes in strategy to be able to follow the market.
5	We are not using just one strategy to reach our goals. We use different business models, we optimise them and focus on the ones providing highest returns.
6	Every time you break new grounds there are a multitude of risks. We continually assess risks on our new ventures. Given our size and position, we are market drivers. Our main risk is investing in services which the market will not accept to the degree we estimate.
7	We study the market and also look at end-user behavior before investing in new services. We do our homework to our best ability in order to minimise risk.
8	We are using all available technologies. We are currently working on femtocell business models and conducting risk assessment for femtocell deployment. This is the latest option in getting 3G signal indoors.
9	Our customer service department compiles all feedback from end-users. Requests are for higher speeds in some areas, public instead of private IP addresses, capability of IPSec pass-through when using private IP addresses, capability to check upload/download traffic for the current month etc.
10	Right now, Mobile WiMAX is on our radar screen only as a technology, potentially disruptive, which could be deployed by some of our competitors. The 4G spectrum issue will help clarify things when it will be handled. At this stage we are leaning towards LTE for the 4G technology of choice.
11	Mobile data, especially the performance of it, namely the consistent characteristics over all covered territory is the hardest task. Performance decreases significant at cell edges and indoor coverage must be improved.
12	Handling of the spectrum by the national regulators is for us the most important variable when estimating business plans for the medium and long term. The ideal environment is having a global frequency band for mobile services and just one converged standard WiMAX-LTE. Then we can focus on services to our customers.
13	Multitude of standards and 3G/4G spectrum. We wish all “it gets harmonized, standardized and unified”.
14	This concept is also investigated in the LTE-Advanced proposal. “It’s good and offers another option when trying to solve coverage and performance problems”.
15	Yes, the relay concept is of help. Although different, it overlaps somehow with the femtocell model.

4.3.3.2 Large Mobile Operator in Spain

Q #	Question
1	We are using the standard 3GPP SGSN/GGSN architecture for our mobile data services.
2	N/A
3	We are a one-stop shop when it comes to mobile services. Whatever service end-users might be looking for, they can find it part of our portfolio.
4	Our infrastructure network in combination with CPEs allows us to offer the most complete range of mobile voice and data services. We keep up with all industry news and developments and strive to keep ahead of our competitors.
5	We are constantly searching and thinking of new products and services to offer to the market. We go through a new business analysis process to estimate the potential and risks of any new investment. Our analytical processes are very thorough and include a lot of What-if scenarios to better understand what we are looking at.
6	We minimise the risk of our global and local strategy by not "keeping all our eggs in one basket". Our multi-strategy business development approach is key to assuring constant growth with small risk.
7	Mobile network operators are the king of businesses that once they reached a certain size, they just work. People continue to make mobile calls and to use their mobile internet connections. Only major mistakes have negative consequences to the business. By monitoring the telecommunications landscape and the market behavior we can stay on track in achieving our targets.
8	Equipment vendors, system integrators and consultants have a wide range of tools for operators to use to solve their problems and answer end-user requests. To provide adequate coverage we use micro and pico-cells. We are right now in the planning process of a large femtocell trial.
9	We monitor and take feedback not only from our own customers but also from the market. Right now the demands are for lower price and flat rate monthly plans for data usage. We also get a significant number of requests for affordable prepaid mobile data service, such as the prepaid 3G dongles. Other requests refer to speed increase for the cellsites not upgraded yet to 3G.
10	At this stage WiMAX is not part of our future development plans. We, however keep it under close observation for the reason that we don't want to be taken by surprise by any disruptive technology.
11	There are always problems with mobile wireless technology, both voice and data. On the data side, the performance at the edge of the cell and coverage, especially indoors, are our most important issues.
12	From the technology viewpoint, mobile data has a lot to mature. Switching from CDMA to OFDM systems will probably improve mobile data experience but new issues will surface and they will need to be solved. I know the problems we have right now and we are working to fix them. I don't know what problems we'll have in the future, but I'm sure there will be; and I'm also sure we'll fix those as well.
13	"No concerns, I only acknowledge that there is a lot of work to be done and money to be spent to bring mobile data to a service comparable in popularity and affordability as mobile voice calls."

Q #	Question
14	"Yes, the relay concept is also part of LTE-A. Unfortunately there is no 3G or 3.5G relay concept."
15	The Multi-hop Relay Stations systems are interesting as described by the vendor. They have the potential to fix some of the painful issues of the moment, performance at the edge of the cell, increase coverage and reduce the increasing backhaul costs. There is still a lot of work to be done to bring this good concept to reality.

4.3.4 Responses from Operator Type D

4.3.4.1 Fixed Wireless Operator in Spain

Q #	Question
1	Our network is not capable of handling mobility. The wireless network architecture we employ is the typical fixed point to multipoint BWA system using a mix of LMDS/pre-WiMAX technologies.
2	We plan to deploy a mobile network as soon as mobile spectrum becomes available either as an amendment to our existing 3.5GHz license or new spectrum is auctioned.
3	Our plans are not at all modest. We would like to be a national mobile IP network operator, somehow similar to what Clearwire intends to do in the USA. We are going to depend a lot on the handset equipment manufacturers, but we are confident that since large companies like Intel has such large financial investments in this technology, we have a very good chance at meeting our goals.
4	First, we are working very close with the spectrum regulator trying to get our license converted to a mobile license. Second, we've planned the conversion of our macro BTS sites for mobility and third, we've considered the impact of the new mobile IP core network to handle all IP traffic.
5	We are a wireless operator. We own no wireline or optical fibre infrastructure. Our future is either wireless or none. We don't have other options to consider. From the equipment standpoint, only WiMAX has a working profile in the 3.5GHz spectrum, there are no other options here.
6	There is one big risk: out market is continually shrinking. If the spectrum regulators don't convert our license into a mobile one or don't auction new spectrum soon enough, we might go out of business. We don't see another way out.
7	It's the only strategy we could come up with.
8	At the moment we are only using macro BTSs. We position customer antenna and CPE in such a way to ensure performance of the service within specifications. In locations close to the BTS site, our CPE equipment also operates in Non-LOS. Micro or pico BTS are required for fixed wireless deployments.
9	We plan to offer our customers mobile high-speed data services. The voice services we currently offer on the fixed wireless infrastructure will also be ported to the new mobile network.

Q #	Question
10	Mobile WiMAX is the technology of choice for our business, provided we obtain the license from the spectrum regulator.
11	N/A, no mobile services provided for the moment.
12	Mobile data is going to radically change in the next 5 years. This means the next 2-3 years are going to be in the middle of this migration from CDMA systems to OFDMA plus the new entrants starting brand new, mobile IP networks. We envisage lots of problems in all areas, such as performance, coverage, interoperability and integration.
13	Capacity, performance and indoor coverage are perceived as the biggest concerns of mobile data systems.
14	Yes, multihop relay stations are an important element of the mobile WiMAX toolkit.
15	MRS are crucial elements when designing an RF network. No operator can afford to install macro BTS wherever coverage or performance needs to be improved. In most cases smaller units bring more benefits. Being self-backhauling, the MRS elements can be used to allocations where a macro BTS cannot be installed.

4.3.4.2 Fixed Wireless Operator in Greece

Q #	Question
1	We operate a fixed, not mobile, point-to-multipoint wireless network.
2	As soon as a mobile license becomes available, we plan to bid for it, win it and then deploy a mobile data network. Another option is to have our existing, national, fixed 3.5GHz license amended to mobility. While this option is probably cheaper, the 3.5GHz frequency is not particularly suitable for mobile services.
3	Our target is to become a provider of advanced voice and data mobile services.
4	Our first priority, the most important (and probably the most difficult) is to obtain frequency spectrum licensed for mobility. The rest depends on us, deploy the network and provide services. Technology-wise, mobile WiMAX is ready for deployments and some big names, such as Intel, is working on handset chipsets.
5	Our options are limited when it comes to what strategies can we use to continue operations in this business. Frequency spectrum is released only by the national regulator and right now the only technology up to the task is WiMAX. If release of spectrum licensed for mobility is delayed, then LTE might become available and we will also consider this option; LTE option is considered to be 2-3 years away.
6	There are risks; for example the spectrum license might be too expensive and we can’t justify paying for it. Another risk is that the mobile spectrum becomes available too late and we loose too many customers to sustain the business. We found no contingency plans to avoid those risks.

Q #	Question
7	Our targets are achievable. There are also other operators interested in mobile licenses and not all of them will obtain one. We have picked the only strategy we could think of. The other options we thought about were not to continue this business but to exit it.
8	We have considered different network elements from different vendors. We ended up using only macro BTSs and professional installation of the CPE devices (customer antenna and indoor units). We have found that, considering the CPE available on the market, we had to execute the customer install or visit in order for the service to perform as specified. The self-install option did not produce the expected results. The customer professional installation does not require micro or pico BTSs, their lack of presence being compensated for proper antenna installation and alignment.
9	We have no mobile customers at the present time.
10	Mobile WiMAX is the technology we plan to use. We, however, need to obtain a mobile license first.
11	N/A
12	Mobile data is in it's infancy. The problems to be sorted are many: spectrum and technology harmonisation, speed, capacity and coverage problems and the most subtle latency and handover issues.
13	We have no major concerns on data mobility. We think that data will get mobile as voice calls did. We need to do the work of bringing it out of infancy to a mature level. We also need to learn to handle constant change.
14	Yes, when the standard is approved and certified equipment available on the market, we'll have another network element to build our networks.
15	The MRS concept is very helpful in reducing costs and fine-tuning coverage. There are, however, problems with avoiding interference.

4.3.5 Operators Type E

Based on their history, wireline operators are either the national incumbents or new operators, most of them coming out of the cable TV companies.
In the EU space all national incumbent operators have either started separate businesses to provide mobile services or they have investments in mobile operators. As shown in Table 11, section 10.4, all national telephony companies have a corresponding mobile operator. The type of mobile operator they are controlling/investing in is type C.
This business strategy proves that the telephony company has now no interest in developing new mobile operations, they are just focusing on the wireline services, managing the copper plant or deploying FTTx infrastructure.

The new wireline operators are cable TV companies, which became ISPs and later telephony providers. These companies have two options:

- Upgrade infrastructure for very high data speeds, 20Mbps seems to be the norm
- Acquire a mobile license and start a mobile operator business.

The estimation is that all low speed services, below 1Mbps are migrating to mobile devices. Fixed infrastructure will handle only data rates either not possible for mobile networks or requiring big appliances for their services. An example is a HDTV set.

If these companies are acquiring a wireless license they become a greenfield wireless operator and at this stage they can be either an operator type B if they obtained a mobile license or type D for fixed wireless.

The responses to our questions from the types of operators (B, C and D) mentioned in this section are given in the corresponding previous sections.

5 Cellular Mobile Operators - Summary

Cellular operators developed over a time period of 15 years approximately. Even today, the bulk of the revenue comes from mobile phone calls and related services. Within this time, price for one minute of mobile voice calls dropped more than 100 times from one Euro plus (different currency at that time) to about 1 eurocent per minute.

There are multiple reasons for the mobile voice calls price reduction, some of them listed below:

- competition, more mobile operators active in the same market
- new technologies allow a higher number of simultaneous calls per cell, meaning cheaper cost for operators
- for the older technology, such as GSM, the amortization of equipment is complete,.
- competition from the fixed phone operators who are offering low flat monthly rates in order to limit subscribers churn

Given the reduction in revenue, mobile operators are continuously looking for new ways to make up for the lost revenue. The new services targeted as new revenue generators are:

- mobile data services (mainly mobile Internet)
- mobileTV
- multimedia content generation and/or distribution
- mobile payments
- mobile gaming

The business models are not set yet and vary widely not only from country to country, but from one operator to another and also from one service to another.
It seems the service that is closest to demonstrating a viable business model is mobile Internet. Flat-rate pricing with bandwidth limitations being applied if more than a number of gigabytes per month of traffic is consumed is the norm for this service in the more developed markets. The 3G USB dongles have now become very popular amongst the European business community.

Given the higher capacities of the newer 3G and 3.5G networks, most operators are still trying to find the “sweet spot” in terms of the number of subscribers best served by one cell and the prices they should charge. By using the trial and error method, the optimum point was found to maximize the revenue for a given technology. The more expensive the service the less number of end-users, leaving un-used network capacity, thus damaging overall network profitability. The cheaper the service, the more subscribers on the networks potentially leading to congestion and service degradation. Operators are permanently adjusting prices as they upgrade technology used in the 3G spectrum from UMTS to HSDPS to HSUPA to HSPA+.

One of the most important differences between different mobile operators is the ownership of a 3G license, giving the right to use a pair of 5MHz channels for voice calls. The de-facto standard in Europe for 3G licenses is UMTS, operating in the 2100MHz frequency band, this seems to be accepted by all national telecom

regulators. Of course, the main difference that a 3G license makes is the lucrative high-speed mobile data market. This in the long term is only a stepping stone to the promised 4G wireless broadband experience, but it is important for mobile operators for a number of reasons:

- Increased revenues
- Developing a mobile data service and experience in running a mobile data network as preparation for 4G
- Better understanding of coverage problems when operating at higher frequencies and modulations schemes thus requiring optimisation of BTS locations to maximize signal strength and quality of service.
- Initiation in 3G network infrastructures also opens the door to further network upgrades leading ever closer to 4G,: HSDPA, HSUPA and HSPA+

Possession of a 3G license is not necessarily crucial in the long run. The 5MHz channel bandwidth allocated for this technology is not enough for the high speeds promised by 4G. New spectrum will be allocated for 4G networks and the channel bandwidths will reach 20MHz.
European spectrum regulators have started to release spectrum for 4G mobiles. The frequencies are normally in the 2600MHz spectrum, more precisely in the range 2500MHz-2690MHz. The first two countries to auction 4G spectrum are Norway in November 2007[4] and Sweden[5] in May 2008.
As mentioned before another important asset of cellular operators, even if they don't have a 3G license, is the macro BTS towers and antenna sites. It is increasingly harder for new operators to find new locations for macro BTSs given the large size of the equipment and accessories, and much more so if the current difficulties of attaining, planning permission for new antennas is taken into consideration.

Different countries allocate the frequency spectrum differently but it seems there is consensus for FDD UMTS to use the range 1920-1980MHz for upload and 2110-2170MHz for download. Depending on the number of 5MHz channels allocated to each operator (for frequency re-use), there might be a 10MHz or 15MHz channel left for TDD communications. There are some countries which are now also auctioning this segment of spectrum.
For example, in Norway, telecommunications company Inquam Broadband Gmbh has acquired the national license for the 2110-2125MHz band. Inquam Broadband GmbH is a joint venture between NextWave Wireless, a leading developer of WiMAX technologies and end-to-end solutions, and financial investors with substantial experience in the telecoms market, including Omnia Holdings Limited, which controls the Zapp mobile broadband networks in Romania and Portugal. Inquam Broadband intends to build and operate BWA networks in Europe in cooperation with partner companies interested in providing wireless broadband services to their customers. From the technology viewpoint, this spectrum could be used by either 4G technologies, WiMAX or LTE.

As soon as the Swedish auction for the 2600MHz spectrum was finalised, Swedish manufacturer Ericsson issued a press release[6] mentioning that winners of that spectrum can begin to prepare for deployment of LTE technology.

The conclusion to be drawn is that all spectrum for 3G and 4G communications is above 2000MHz. It is a well known fact (as discussed in previous REWIND research

documents) that these frequencies do not offer propagation characteristics as good as the lower, GSM spectrum; in fact a certain lobby is gathering strength that proposes the 700MHz band for future 4G services. This of course has a negative impact on coverage and in-building penetration in these higher frequencies. The performance degradation is mostly noticeable when using mobile data services.
For mobile voice the service degradation is not significant. The reason is that voice only needs a very small amount of bandwidth, less than 20kbps per call. This speed can be achieved even in the case of poor signal quality and low modulation schemes.
Keeping in mind that mobile data end-users in a 4G context require 1-4Mbps connections, it soon becomes apparent that a 4G mobile data service is very demanding with RF signal performance.

Most mobile operators suffer the problem of 3G in-building coverage; the proof of this is to be found in the significant number of RSs that some of the largest 3G operators such as Telefonica for instance are now procuring from specialised vendors. Verizon and Vodafone have also announced plans for 3G RS deployments for the next 12 months. This difficulty will of course become much greater once 4G technologies are deployed.; due primarily to the higher spectrum bands and modulation schemes to be used.

The solution mobile networks operators are looking at right now most intensively are femtocells. This technology has been discussed in deliverable D2.2, End-user Applications of the REWIND project. This solution has as many disadvantages as it has advantages but for now the industry seems to find it the easier of all options worth contemplating.
One of the aspects that are of most concern to mobile operators is the fact that there is no clear business case for femtocells.

The reality is that there is no other solution available today. Ideally, mobile operators would like a constant overall RF signal, not to strong to become a health hazard, but powerful enough to enable wireless devices to work at their highest performance. This is actually one of the few advantages of femtocells. It generates a low-power RF signal nearest to where the users are: indoors.

To better understand operators current thinking as to this whole indoor coverage topic it is useful to briefly describe the pros and cons of femtocells:

Femtocell advantages:

1. It generates the optimum RF level signal indoors, where the end-users are.
2. Cheap backhaul via existing Internet connection to the premises served by the femtocell.
3. Saves capacity of the macro BTS.

Femtocell disadvantages:

1. Business model not clearly understood. Why would a subscriber use the slow 3G connection when the faster WiFi or wired home connection can be used? Femtocells assume availability of wired internet to the premises.
2. Operators wanting to deploy femtocells must have access to fixed broadband infrastructure. If not, a call via femtocell might have poorer quality than a call via the macro BTS because of overused Internet connection.

3. Smartphones might be used as entertainment devices when on the go, but at home when subscribers are more likely to switch to their TV sets and HiFi chains for entertainment.
4. Battery life is another reason why the smartphones are used as multifunction devices while subscribers are out, but in their homes end-users might look for a solution without such limitations.
5. To take full advantage of femtocell benefits, such as cheaper pricing when using the femtocell, modifications to the handsets are necessary. The estimation is that these won't be in place before 2010.
6. Assuming femtocells provide adequate RF signal where they are used; since deployment is only a personal subscriber choice, what happens with coverage in area where no femtocells are installed?
7. In overly dense areas of femtocells they create problems to mobile handsets as these have to spend time to decide which the true "home" femtocell is.
8. No standards in place for handsets to know when they are attached to femtocells.

As reported by Unstrung[7], the Vodafone Visionary, Mr. Kenny Graham at the Femtocells Europe 2008 conference in London proposed to take the mini home base stations out of the home/office and onto the streets. The name he used was Metro Femto.
Without perhaps realising it, Mr. Graham was actually referring to the Relay Stations. Having zero footprint, they are the most likely to blanket areas of interest with a constant, optimum RF field which insures optimum performance of handheld devices.

Another interesting observation is made by Dean Bubley in his report "Femtocell-Aware Mobile Handsets"[8], he mentions the concept of "shared" femtocell as being able to solve some of the standard femtocell issues. Again, the shared femtocell is close to the Relay Station concept.

The examples above show the industry analysts and operators are aware of the benefits brought to the market of the Multi-hop Relay Stations model.

From the statistical viewpoint, in the 29 countries considered for this research document there are 38 operators in existence. The number of operators and the countries they operate in obviously changes over time as mergers and acquisitions continue to take place and a small number of 'greenfield' service providers are born.

This document incorporates the latest transaction between Deutsche Telekom and the Greek government regarding a controlling stake in OTE[9]. Industry analysts speculate that the mobile networks operated by Cosmote in Greece, Bulgaria and Romania will be re-branded T-Mobile.

Looking at the statistics from the operator's perspective, there are a number of multinational operators. They operate in more than country.

Number of Mobile Operators in EU	Number of countries where they are active	Operators Brands or Comments
26	1	See Table 9 for operators active in one country only
3	2	Zapp, KPN, Elisa
1	4	Telenor
1	5	TDC
3	6	Telefonica/O2, 3(Three), Tele2, TeliaSonera
1	7	Orange
1	10	T-Mobile
1	16	Vodafone

Table 3 Number of Countries Served by Mobile Operators

6 Fixed WiMAX Operators - Summary

Traditionally, the BWA (Broadband Wireless Access) acronym assumed fixed wireless technology. Operators of these networks are employing pre-WiMAX or more recently certified WiMAX 802.16d equipment.
They are niche players, offering voice and data connectivity to buildings and locations not served by fixed infrastructure such as copper cables or optical fiber. Irish broadband in Ireland, NeoSky in Spain, PIPEX and UK Broadband in the UK, and the TDF BWA subsidiary in France are all of this profile.

From the REWIND perspective, the applicability of relay stations to this environment is analysed.

BWA operators are positioning BTSs and subscriber units in such a way that performance for the link is optimised. Usually the location of a BTS is at a point where direct LoS visibility to most buildings in the target area is achieved. Subscribers units are not located within the subscriber premises but at the point where optimum performance is achieved, normally on the rooftop. This means custom ised installation for 90% of subscribers. The remaining 10% of subscriber units are considered to be so close to the BTS that technicians don't need to be dispatched in order to achieve appropriate performance.
As described throughout the market research delivered for the REWIND project, the main goal of relay stations is to provide ubiquitous and uniform RF coverage over the whole target area. Given the customised nature of subscriber devices in fixed wireless networks, the usage of relay stations in this environment is not envisaged. However, to offer a more complete picture of the European wireless operators market scene, an analysis of the fixed wireless operators is provided in this section.

6.1 WiMAX in Europe

Table 10 shows the (pre)WiMAX networks in the EU. All of them are fixed networks. One of the key issue in WiMAX is the frequencies employed. It is hoped that the 2.5-2.6GHz frequency band will be allocated for 4G networks across the continent. Another frequency band used by fixed BWA operators is 3.3-3.6GHz. Its main characteristic is that it has the capability to cover 300MHz of bandwidth, from 3.3 to 3.6GHz and in some cases up to 3.8GHz[10]. Consequently, this band offers great potential for fixed applications whether it is for backhaul or last mile access. In Europe, operators such as Altitude in France[11] and Iberbanda in Spain[12] are already building broadband wireless networks in this band with the intention of migrating them to certified WiMAX infrastructures.
As mobile wireless broadband services will become the principal application offered with this spectrum the European Commission announced that it has adopted a decision aimed at harmonising the use of 3400 ~ 3800 MHz frequencies in Europe[13] so that both fixed and mobile services may be offered without regulatory hindrances. This decision will have a positive impact for WiMAX network operators in Europe, where the majority use 3.5 GHz spectrum. According to Article 3 of the Decision, Member States of the European Community must allow this spectrum range to be used for "fixed, nomadic and mobile electronic communications networks," by January 2012. Almost all licenses for 3.5 GHz spectrum in Europe currently restrict usage to fixed or nomadic services. Few countries allow the spectrum to be used for

mobility services, and other countries are in various stages of planning to open the frequencies for such usage[14].

The Unlicensed National Information Infrastructure (U-NII) table has three major frequency bands: low and mild U-NII bands (5150-5350) (802.11a), WRC (new) (5470-5725), and upper U-NII / ISM band (5725-5850). Wi-Fi exists in the lower and middle U-NII bands, which have demonstrated viability for BWA (Broadband Wireless Access). Many overlapping 5GHz frequency bands earmarked for BWA growth exist around the world. The newly allocated World Radio Conference (WRC) 5470 to 5725MHz band adds significant license-exempt bandwidth. Most metropolitan deployments are in the upper U-NII 5725 to 5850 band because there is less interference there, for instance, Wi-Fi and the outdoor power allowance are in the higher 2 to 4W range as compared to only 1W in the lower and middle U-NII bands[15].

6.2 Germany

Europe appears to be fertile ground for new WiMAX networks. Despite the fact that in Germany, Deutsche Telekom, the country's telecoms incumbent, has decided to utilize other technologies to expand its high-speed internet offering into rural areas[16], Deutsche Breitband Dienste, Germany's first and largest WiMAX operator, provides broadband access services in the 3.5GHz band, for both residential and enterprise customers. The company operates wireless networks in both metropolitan areas (under the MAXXonair brand) and rural areas (under the DSLonair brand) across Germany[17]. Deutsche Breitband Dienste (DBD) started its commercial WiMAX operation in Berlin in November 2005 under its brand MAXXonair. Several networks in Wuppertal, Dresden, Leipzig were deployed in 2006, other cities to follow in January 2007[18]. The same company has deployed networks in rural areas under its brand DSLonair. German telco Arcor operates a commercial WiMAX network in Kaiserslautern since December 2005. Both companies use 3.5 GHz WLL (Wireless Local Loop) licenses with WiMAX technology[19].

6.3 U.K.

In U.K., the regulatory authority Office of Communications (Ofcom) has announced that it will release the spectrum in the 2010-2025 MHz and 2500-2690 MHz bands (known as 2.6 GHz). Although the procedure has not been finalized and neither have the spectrum specifics, Ofcom proposes that of the 215 MHz of spectrum, between 50 MHz and 190 MHz will be suitable for WiMax[20]. BT Group wants to bid for spectrum not only in the U.K. but also in other European markets when such spectrum becomes available. The company is said to be interested in combining cellular, WiFi, and WiMax as part of its service offerings[21]. Pipex Wireless holds 3.6 GHz licensed spectrum and is deploying WiMAX throughout the UK[22]. UK Broadband a subsidiary of PCCW, owns 3.5 GHz licenses[23]. Urban WiMAX Plc is another operator using the 4.9 and 5.8 GHz bands selling up to 10 Mbit/s symmetrical access to businesses and next day delivery[24].

6.4 France

In France, 175 candidates applied for WiMax licenses, among which one found Neuf Télécom and the country's incumbent, France Télécom but there where also some atypical applicants such as "les Autoroutes du Sud de la France"[25]. Among the license winners were France Telecom, Maxtel and Guyatel of French Guyana. Also, six local government authorities received licenses. The government will also consider licensing the 5.4 GHz to 5.7 GHz band at a later date, according to a statement from France's telecom regulatory body Arcep (l'Autorité de Régulation des Communications Electroniques et des Postes). The French market is considered one of the most stable ones when it comes to ADSL

(Asynchronous Digital Subscriber Line) broadband Internet with speeds of up to 20 MBps; once new wireless broadband networks are introduced Internet service usage is expected to grow exponentially[26].

6.5 Ireland

Irish Broadband, Ireland's leading wireless broadband service provider, has launched WiMAX broadband networks in fourteen of Ireland's major urban centres. Some of these cities are Athlone, Arklow, cities Carlow, Cork, Dublin, Ennis, Galway, Kilkenny, Killaloe, Letterkenny, Limerick, Newbridge, Portlaoise and Wexford. Both residential and business users in each of these locations will be able to avail of WiMAX broadband, which offers very high download and upload speeds for data, of up to 12 megabits per second[27].

6.6 Italy

In Italy, WiMax is expected to solve the thorny issue of the so-called digital divide and a number of operators have already declared an interest to enter this market,[28]. The Italian Ministry of Defense are the traditional holders of the 3.5 GHz band but in order to make space for the new technology, Italy has reassigned the 3.4-3.6 GHz frequencies away from military use[29].

The city of Bari will be the first city in Italy to have a WiMAX network. AFT-Linkem, which acquired licenses for 3.5 GHz spectrum at auction in February this year for € 34 million Euros, announced that it plans to launch its first network there in June 2008. Thereafter, the Bari network will be expanded throughout the city during the summer. The network will be launched in partnership with Telebari, a local cable TV operator[30].

6.7 Central Europe

Austria-based WiMAX Telecom is one of the leading European Broadband Wireless Access (BWA) operators using IEEE 802.16 technology. The Company owns 3.5 GHz frequencies and licenses in Austria, Slovakia and Croatia.

Since winning another 3.5 GHz license in Croatia in May 2006, WiMAX Telecom is now preparing to expand that network, as well as expansion of their existing networks. WiMAX Telecom was founded in October, 2004 after winning its first license in Austria. In August 2005 the Company won the tender in Slovakia. Since the end of 2005, WiMAX Telecom has operated networks in Austria and Slovakia and is

serving more than 3,000 subscribers in these markets. WiMAX Telecom is also supporting the government of Burgenland and the government Styria (Steiermark) in Austria to enable the people in remote areas to have access to broadband at home[31].

6.8 Norway

The Norwegian telecoms group Telenor has announced that it will launch the first stage of a WiMAX network in Norway[32].
Telenor acquired licenses for 3.5 GHz spectrum in December 2004 that cover the whole of Norway, and has been testing WiMAX technology since 2005. Some of the testing by Telenor has been in the North Sea where the company plans to bring broadband to oil rigs working several miles offshore.

6.9 Sweden

The National Post and Telecom Agency (PTS) in Sweden announced that it has concluded the auction of 2.6 GHz spectrum[33]. A total of 190 MHz was auctioned, with five companies winning licenses. Intel Capital acquired one block of 50 MHz TDD (Time Division Duplex) spectrum for USD 26.2 million. The blocks of FDD (Frequency Division Duplex) frequencies went to Tele2, Telenor, and TeliaSonera, each paying approximately USD 90 million each for 2×20 MHz, and 3G operator HI3G Access AB paid USD 49 million for 2×10 MHz. The licenses will be technology and service neutral, allowing use for mobile telephone and wireless broadband[34].

7 Regulatory and Licensing Environment

Radio spectrum is the most important asset for wireless communications. It is also a source of revenue for governments. Availability of radio spectrum is limited and the efficient use of available resources is crucial.

The regulatory and licensing topic is one of the very important issues in the wireless industry. The European Union has a special situation where the spectrum tends to be controlled by two entities: one is the European Commission; the other ones are the national telecommunication and radio spectrum regulators. The focus is now on the spectrum to be released for the pre-4G (WiMAX 802.16e and LTE) and the 4G (WiMAX 802.16m and LTE-A) wireless systems. They each have slightly different views and continuous negotiations are in place to reach a conclusion.

The wireless operators are directly impacted by availability of spectrum. Ahead of any business plans and investments, wireless operators need to know not only the frequency of the radio spectrum (for coverage) but also the channel bandwidth (for performance).

This section expands on the perspective of the European Commission, the National Spectrum Regulators and of the wireless operators on spectrum.

7.1 European Commission

The European Commission (EC) is looking at the whole European Union as a unified territory. The main goal is to have a unified radio spectrum allocation policy, which will allow equipment vendors, network operators, and service subscribers to take advantage of common platforms. The European territory is not only the European Union but there are also other significant countries, such as Switzerland or Norway, not part of the EU but their allocation of spectrum might negatively influence the uniform spectrum allocation for the whole European territory. There are also a number of very small countries in Europe, such as Andorra, Gibraltar, Liechtenstein, Monaco and others, which are usually following the regulations of one of the main neighbor country. One last variable in the European territory are emerging countries with significant market size. Examples are: Croatia, Bosnia-Herzegovina, Serbia, Albania, Belarus etc. It is hoped that the government and regulators of these latter countries are following the EC radio spectrum policies even if there is no legal obligation to do so.

The starting point of the EC radio spectrum regulation policies is the success of the GSM technology and radio spectrum allocation. No other region in the world has enjoyed more success in using one common platform. This achievement of the European standard for GSM phones is a clear example of the benefits that a well coordinated radio spectrum policy can bring to society. We now take it for granted that we can use our phones seamlessly as we move around the continent. EU regulation of the radio spectrum was essential in the success of this standard, which has not only benefited GSM phone users, but also enabled European industry to establish a competitive edge in this global sector.

As more and more opportunities for radio-based technologies emerge, it will be increasingly important that radio spectrum is managed on a pan-European basis to ensure that the full potential of these innovative systems is fulfilled.

The EU is currently working on a radio spectrum policy to achieve the following targets:

- The development of a single EU market for wireless equipment and services through a coherent approach to radio spectrum management. This will create economies of scale and business opportunities.
- More diversified, sophisticated and affordable wireless applications available to all Europeans for personal and professional use.
- Stimulation of economic growth by supporting wireless industries and reaping the benefits offered by increasingly efficient wireless applications and services.
- Creating jobs by offering an innovative environment and keeping Europe competitive.

Having a single spectrum policy for the whole EU is not the only target for the European Commission. The management of the radio spectrum must be radically improved and made more efficient. The current rules governing the radio spectrum allocation and management in Europe is largely based on decisions made by local public administrations. Wireless industries are increasingly at risk of not using the radio spectrum in an optimal way. This results in increased costs, lost market opportunities for spectrum users and slower take-up of innovative applications and services. This has its costs in terms of lost potential for economic growth and innovation of wireless systems in Europe. Better regulation of radio spectrum will release the full socio-economic potential of this scarce resource. It can be achieved by simplifying access and use of spectrum resources and by giving spectrum users maximum freedom in how they use the spectrum.

The European Commission plans to reform the radio spectrum management by:

- Facilitating access to spectrum usage rights, e.g. by allowing more unlicensed use of spectrum or by permitting the transfer of exclusive usage rights within agreed bands between spectrum users (secondary trading).
- Remove unnecessary restrictions to spectrum usage and allow greater freedom to use radio spectrum for any electronic communications services and with any technology.

The European Commission in charge of telecommunications policies is the Information Society and Media Commission. This commission represents an economic sector which is crucial for prosperity and quality of life in the European Union.
This portfolio stretches from the underlying communications infrastructures to the content and services they deliver. It encompasses telecommunication networks, broadband internet access and satellite communications, new communications technologies such as ‘3G’ mobile communications and Internet telephony, and digital material as diverse as cinema releases and advanced eHealth services.

The radio spectrum is handled by two organisations within the Information Society and Media Commission:

- The Radio Spectrum Policy Group
- The Radio MSpectrum Committee

These two bodies work together with the European Conference of Postal and Telecommunications Administrations as the technical competency for telecommunications technologies.
A short descriptions of each organization follows in the next sections.

7.1.1 Radio Spectrum Policy Group

The Radio Spectrum Policy Group (RSPG) is a high-level advisory group that assists the European Commission in the development of radio spectrum policy.
The RSPG is established under Commission Decision 2002/622/EC, which was one of the Commission initiatives following the adoption of the Radio Spectrum Decision 676/2002/EC and it adopts opinions, position papers and reports, as well as issuing statements, which are aimed at assisting and advising the Commission at strategic level on:

- radio spectrum policy issues,
- coordination of policy approaches and,
- harmonised conditions, where appropriate, with regard to the availability and efficient use of radio spectrum necessary for the establishment and functioning of the internal market.

The members of the RSPG are senior representatives of the Member States and the official representative of the European Commission. Delegations include representatives from both the regulatory authorities and the ministries having responsibility for radio spectrum related matters in each Member State. The Chairperson of the RSPG is a Member elected by the Group for a period of one year. Representatives of the European Economic Area (EEA) countries, the candidate countries, the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Telecommunications Standardisation Institute (ETSI) are also invited to attend plenary meetings as observers.
As part of its advisory function, the RSPG consults extensively and in a forward-looking manner on a variety of technological, market and regulatory developments relating to the use of radio spectrum in the context of relevant EU policies such as electronic communications and the information society, as well as other sectors and activities such as transport, research and development, or health. Such consultations are conducted with the objective of involving all relevant stakeholders, radio spectrum users, both commercial and non-commercial, as well as any other interested party. In addition, most of the deliverables of the RSPG are subject to formal public consultations.
The RSPG publishes an annual work programme and most official deliverables of the RSPG are made public on http://rspg.groups.eu.int.

7.1.2 Radio Spectrum Commitee

The Radio Spectrum Committee (RSC) has been created under the 2002 Radio Spectrum Decision to look after the specific technical issues required to implement radio spectrum policy in the EU. It is composed of Member State representatives and chaired by the Commission.
Its main role is the development of decisions with respect to technical implementation measures that ensure harmonised conditions across Europe for the availability and

efficient use of radio spectrum. It also develops measures to ensure that information on the use of radio spectrum is provided accurately and in a timely manner.
The activities of the RSC are established in a work programme which allows prioritisation and scheduling of the various topics and issues it is required to address.
The Committee exercises its function through advisory and regulatory procedures that are set out in the EU's Comitology Decision. The comitology process allows the Commission to discuss its proposals with national administrations before implementation in order to ensure that any measure is optimised to the various national situations.
The majority of RSC documents are openly available to interested parties and the public. Detailed information on the activities of the RSC, including rules of procedure, membership and committee documents are available on a dedicated website.
As part of its remit under the Radio Spectrum Decision, the Commission may issue mandates to the European Conference of Postal and Telecommunications Administrations for the development of technical implementing measures that can ensure harmonised conditions for the availability and efficient use of radio spectrum. These mandates specify the task to be undertaken and the timeframe in which they should be achieved.
A Memorandum of Understanding has been established between CEPT and the Commission to support on-going activities on harmonisation of radio spectrum and benefit all parties concerned.

7.1.3 European Conference of Postal and Telecommunications Administrations

The European Conference of Postal and Telecommunications Administrations (CEPT) was established in 1959 by 19 countries, which expanded to 26 during its first ten years. Original members were the monopoly-holding postal and telecommunications administrations. CEPT's activities included co-operation on commercial, operational, regulatory and technical standardisation issues. Today, 40 countries in the European region are part of CEPT. For details, www.cept.org provides all relevant information.

CEPT offers its members the chance of:

- establishing a European forum for discussions on sovereign and regulatory issues in the field of post and telecommunications issues;
- providing mutual assistance among members with regard to the settlement of sovereign/regulatory issues;
- exerting an influence on the goals and priorities in the field of European Post and Telecommunications through common positions;
- shaping, in the field of European posts and telecoms, those areas coming under its responsibilities;
- carrying out its activities at a pan-European level;
- strengthening and fostering more intensive co-operation with Eastern and Central European countries;
- promoting and facilitating relations between European regulators (e.g. through personal contacts);

- influencing, through common positions, developments within ITU and UPU in accordance with European goals;
- responding to new circumstances in a non-bureaucratic and cost-effective way and carrying out its activities in the time allocated;
- settling common problems at committee level, through close collaboration between its committees;
- giving its activities more binding force, if required, than in the past; creating a single Europe on posts and telecommunications sectors.

CEPT established three committees, one on postal matters, CERP (Comité européen de Réglementation Postale) and two on Electronic Communications issues: ERC (European Radiocommunications Committee) and ECTRA (European Committee for Regulatory Telecommunications Affairs), now replaced by one committee (see below). The field of responsibility for each committee is decided by CEPT's Plenary Assembly, while each committee establishes its own rules of procedure and elects its chairman.
The committees handle harmonisation activities within their respective fields of responsibility, and adopt recommendations and decisions. These recommendations and decisions are normally prepared by their working groups and project teams.

7.2 Radio Spectrum Policies for 4G

The definitions for 4G technologies are still being worked on. The IMT-2000 subsection of the ITU include technologies such as UMTS, HSPA, LTE and WiMAX 802.16e. For the sake of radio spectrum allocation this section takes into consideration policies which allocate sections of radio spectrum large enough to justify use of technologies such as WIMAX or LTE. The minimum amount of bandwidth to be considered is a 5MHz channel. Although both LTE and WiMAX can use narrower and wider channels than 5MHz, HSPA needs the fixed amount of 5MHz in order to be deployed. Therefore, new radio spectrum policies are centered on being able to allocate at least 5MHz channels (paired or unpaired) to licensees. Mobile network operators are not required to use the whole channel width, they can subdivide the allocated channel as their business case requires. Every operator is interested to maximize efficiency of the owned spectrum. Certain technology limits will apply, such as dividing unpaired radio spectrum to use it for an FDD technology. In this case, the required frequency guard bands must be observed and taken into consideration.

The spectrum policies are based on the following facts:

- The radio spectrum available in each member state of the EU and the capability to free up spectrum in the bands believed to be suitable for mobile cellular service.
- The duplexing mechanism (FDD or TDD) required by technologies likely to use the spectrum
- The channel bandwidth available in different spectrum bands.

At the moment, in the EU, the frequency bands are used as per Table 4.

Frequency Band (MHz)	Technology	Application	Bandwidth
880-915 (uplink) 925-960 (downlink)	GSM-900	2G: GSM, GPRS, EDGE	2 x 35MHz
1710-1785 (uplink) 1805-1880 (downlink)	GSM-1800	2G: GSM, GPRS, EDGE	2 x 75MHz
1920-1980 (uplink) 2110-2170 (downlink)	IMT-2000	3G, 3.5G: UMTS, HSPA, HSPA+	2 x 60MHz
2500-2690	IMT-2000 extension	3.5G, 3.9G: UMTS, HSPA, HSPA+, WiMAX, LTE	190MHz
3400-3800	BWA	TDD WiMAX	Not yet harmonised

Table 4 Radio Frequency Bands Allocated in the EU

The mobile telecommunications industry is looking at different ways of better using the available spectrum. A recent initiative is re-farming the 900MHz spectrum. This means re-allocating the GSM frequencies in that band in such a way that contiguous blocks of 5MHz are made available for UMTS and the rest of 5MHz channels related technologies. Refarming of the 900MHz band has minimal impact on WiMAX and LTE, as these technologies make a difference when they are used over channel bandwidths of 10MHz or larger.

The technologies providing high capacity per sector to be used in 5MHZ channels are HSPA+, WiMAX and LTE. When used in 5MHz channels the capacity per sector is of similar performance. This is the reason why it is expected that the mobile telecoms industry will not deploy WiMAX or LTE in 5MHz channels. Other solid points to be taken into consideration are the facts that most operators in Europe are so far using only one 5MHz channel of the three channels allocated with the initial 3G spectrum auction and the lack of built-in voice service when using WiMAX or LTE. However, some players might prove to be the exception, keeping existing 3G networks for voice services in existing 5MHz channels and using anther 5MHz channel for data services only using LTE or WiMAX. LTE is the technology of choice due to the existing paired spectrum. The WiMAX profiles don't include an FDD profile yet. The only duplexing mode employed by WiMAX at the moment is TDD, as shown in Table 5.

Band Class Index	Frequency Range (GHz)	Channel Frequency Step (kHz)	Channel Bandwidth(s) (MHz)	FFT Size	Duplexing Mode	Comments
1	2.3-2.4	250	5	512	TDD	Both bandwidths must be supported by the MS
			10	1024	TDD	
			8.75	1024	TDD	
2	2.305-2.320, 2.345-2.360	250	3.5	512	TDD	
			5	512	TDD	
			10	1024	TDD	
3	2.496-2.69	250 (200 KHz step size is also	5	512	TDD	Both bandwidths must be supported
			10	1024	TDD	

Table 5 WiMAX 802.16e Profiles

The 2500-2690 spectrum is the band with the largest channels and thus, most suitable for WiMAX and LTE. The channel allocation and Paired/Unpaired segments of the 2500-2690 radio spectrum are shown in Figure 2.

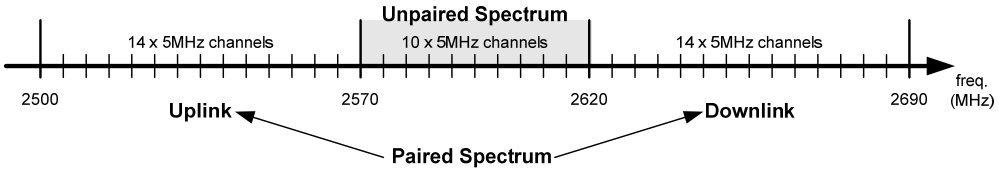


Figure 2 2,500-2,690 MHz Band Plan

The European Commission releases appropriate documentation in the Official Journal of the European Union for use of each of the bands listed in Table 4. The most recent decisions referring to the potential use of UMTS and LTE in the 900MHz and 2500-2690MHz bands and WiMAX in the 2500-2690MHZ and 3400-3800MHz bands are presented in Table 6.

Frequency Band	Document Title	Document Number
900MHz	ECC Decision of 1 December 2006 on the designation of the bands 880-915 MHz, 925-960 MHz, 1710-1785 MHz and 1805-1880 MHz for terrestrial IMT-2000/UMTS systems	ECC/DEC/(06)13
2500-2690MHz	COMMISSION DECISION of 13 June 2008 on the harmonisation of the 2 500-2 690 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community	2008/477/EC
3400-3800MHz	COMMISSION DECISION of 21 May 2008 on the harmonisation of the 3 400-3 800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community	2008/411/EC
	ELECTRONIC COMMUNICATIONS COMMITTEE ECC Decision of 30 March 2007 on availability of frequency bands between 3400-3800 MHz for the harmonised implementation of Broadband Wireless Access systems (BWA)	ECC/DEC/(07)02

Table 6 EC Documents for Radio Spectrum Harmonisation in the EU

7.3 Impact on REWIND Project

As stated throughout this Work Package, the focus of the REWIND project is the WiMAX 802.16e technology. By looking at the spectrum used by operators in the EU to run WiMAX networks, the majority are using 3.4-3.6GHz spectrum. Details can be found in Table 10 List of WiMAX Operators in EU Countries. From more than 60 WiMAX operators in the EU, only around 5 are using spectrum other than 3.5GHz.
This makes the relay market very attractive at 3.5GHz, which makes sense not only from the number of deployments, but also from the fact that the radio wave propagation at 3.5GHz is significantly less than below 2.6GHz.

The trials of the REWIND prototypes are planned to be run in GREECE using OTE's 3.5GHz license.

While evaluating manufacturing costs of 802.16j relays, it is estimated that the operators, interested in using relays to improve network performance, are not going to be interested in multi-frequency equipment. Each operator will purchase only relays running in the spectrum they are licensed to operate in. A relay manufacturer will have to build relay units operating in either 3.4-3.6GHZ band, 2.3GHz or 2.5-2.7GHz bands. Therefore, multi-band relays are not likely to be build, which will enable manufacturers to minimise costs.
Considering now the costs differences between units running in different spectrum, it is believed that it is not going to be significant for the total manufacturing cost. The price and assembly cost for different RF head-ends for the 802.16j relays is considered to be close enough not to influence significant the complete unit's manufacturing costs.

7.4 Example Countries

The European Union is a mix of countries with diverse backgrounds and geographical differences. In each country there is a state-owned radio spectrum regulator, whose role is more or less involved in how wireless telecommunications business is run, depending on the political and economic circumstances. This section analyses the regulatory environment in some countries and offers a number of examples of WiMAX networks using licensed spectrum.

Making sure the available spectrum is used efficiently is not an easy task. At present, the regulation, control and facilitation of radio spectrum is managed by national organizations, who are subject to local politics, domestic economics and each country's history, culture and sensibilities. The European Commission is moving towards the idea of creating a pan-European regulator to ensure scarce spectrum resources are used in the most effective manner on an EU-wide basis. This change is directly in line with the EU's aims to create wealth for its citizens through achievement of a single market by behaving as a 'regulatory state'.

The challenges such a body would face are enormous; not least of which would be to evolve an operating philosophy that would be acceptable to all the differing member state administrations currently running spectrum management business on a national basis. As the EU has found throughout its history, all countries are happy with intergovernmental agreements but are quick to complain of loss of sovereignty following any supranational structural developments. The existing regulators see the

world very different and are founded on diverse concepts. The divergent thinking in the EU's major territories is the main obstacle to be passed by the EC in order to achieve the radio spectrum harmonisation goals in the EU.

7.4.1 Bulgaria

7.4.1.1 Spectrum License

Max Telecom Ltd and TransTelecom hold a class A license in the 3.5GHz band (2x21MHz). Nexcom Bulgaria, Mtel and Carrier 3G hold class B licenses.

7.4.1.2 Deployments and Devices

TransTelecom has decided to deploy a commercial WiMAX network, covering central business districts and hot-spots in the country's major cities, including its capital, Sofia, and Varna, Bulgaria's largest harbor city. HUAWEI will supply an end-to-end WiMAX solution including terminals, as well as a major upgrade of the TransTelecom central exchange equipment for the operation of a fully mobile WiMAX network in 2009. HUAWEI's 802.16e-based WiMAX solution integrates the most advanced technologies such as MIMO and OFDMA which features high bandwidth, wide area coverage, large capacity as well as better mobility. HUAWEI's portfolio includes indoor CPEs with Fast Ethernet ports, VoIP ports, outdoor CPEs with the same features as well as a future planning for WiMAX mobile internet devices such as PDAs, laptops and mobile phones. Furthermore, MAX Telecom has already completed the first phase of it WiMAX rollout in Bulgaria using the Cisco WiMAX technology. Max Telecom plans to expand coverage to 90% of Bulgaria's population by the end of 2009. It also offers its subscribers high-quality and fast mobile internet access, voice services as well as virtual private networks (VPN) services over WiMAX. The company launched at the beginning of 2008 mobile television over WiMAX so consumers can watch their favorite TV channel. Cisco Mobile WiMAX combines both adaptive beamforming and beamformed MIMO technologies. Cisco provides the network with BWX 210 Desktop modem which is an indoor unit.

7.4.2 Croatia

7.4.2.1 Spectrum License

WiMAX Telecom has been awarded licenses in 18 major counties in Croatia. In addition Hrvatski Telecom, a Deutsche Telecom's ownership, has also license in 3.5 GHz frequency band. Some other smaller companies such as VIPnet and Odašiljaèi i Veze (OiV) have received licenses in the capital Zagreb

7.4.2.2 Deployments and Devices

Hrvatski Telecom delivers broadband services to businesses and data services in the northern part of Croatia using Redline RedMAX equipment. RedMAX consists of a carrier class base station (AN-100U) which delivers voice, video and prioritized data traffic to the indoor and outdoor subscribes units. In addition, in the mid of 2008, WiMAX Telecom chose Alcatel-Lucent for supplying the first 802.16e complaint network in Croatia. This project will start in the area of Split and Osijek. Alcatel-

Lucent will supply almost 400 base stations and CPEs from various vendors. WiMAX Telecom started its operation in certain regions during the second half of 2008.

7.4.3 Estonia

7.4.3.1 Spectrum License

In Estonia, a total of 4 licenses in the 3.5 – 3.6 GHz range have been issued to five companies. Norby Telecom, Baltic Broadband and Telia have national-wide licenses and Levira, Elion share the same frequency. Norby Telecom has also recently announced that it has acquired a license for 2.3 GHz spectrum that was acquired from GVS, a small service provider in Estonia, and is the only national 2.3 GHz license in Estonia, giving Norby coverage of the entire territory

7.4.3.2 Deployments and Devices

Today, Norby Telecom provides fixed WiMAX services using a 3.5GHZ frequency, with equipment from Alvarion. In addition, Elion uses WiMAX equipment from Alcatel-Lucent in Harju Country. The 2.3 GHz frequency is an IMT spectrum band approved for mobile use and the company intends to deploy a network using this spectrum with equipment based on the 802.16e standard for mobile WiMAX services.

7.4.4 Finland

7.4.4.1 Spectrum License

Finnish operator Mikkelin Puhelin received a license for 3.5 GHz spectrum Telecom operator Savonlinna (SPY), received its license for Savo in 2005 and the license for Karelias in April 2006. There are also some small companies that have regional licenses in Finland mainly for rural areas.

7.4.4.2 Deployments and Devices

In Finland, two Finnet Group operators have deployed WiMAX networks using Alvarion BreezeMAX 3500 portfolio. The devices offered are indoor, outdoor units and mobile devices. Savinlinnan Puhelin and Mikkelin Puhelin offer broadband data services to permanent residential users as well as to summer tourists in multiple regions across Finland. The network is consisted of almost 100 base stations on an area of 10.000 km^2, covering around 50.000 summer cottages. In addition, SPY has announced the successful deployment of the first mobile WiMAX field testing in Savonlinna. In 2008, Finland had approximately 15.00 WIMAX users in several regions.

7.4.5 France

7.4.5.1 Spectrum License

Fifteen companies and six regional councils shared the licences for WiMAX at 3.5 GHz band. Maxtel, a group including motorway operator APRR and Iliad, won 13 licences which recently were bought by Altitude Wireless. Bollore Telecom, owned by the Bollore Group and Aeroports de Paris (ADP), has won 12 licences, while

HDRR, a consortium that includes Bouygues, won 11 licences. SHD, backed by SFR and Neuf Cegetel, won two licences, but France Telecom only has licences in French Guyana and Mayotte. Nomotech, which is a smaller company has also licenses for certain areas in France.

7.4.5.2 Deployments and Devices

Nomotech, the largest alternative telecommunications network provider in France, has selected Redline RedMAX products for covering more than 1.000 regions and municipalities in Brittany and Pyrenees where it delivers broadband wireless services to business and residents throughout the area. This network will expand further in 2009 and 2010. Redline's WiMAX products include the RedMAX Indoor Subscriber Unit (SU-I) and Outdoor Subscriber Unit (SU-O) designed for enterprise and residential services. SDH and Alcatel Lucent has signed a two-year contract for the supply and installation of the first next-generation WiMAX network in France, which will begin by mid-2009 and will operate in 3.4-3.6 GHz frequency band. In Paris there is already an operational network due to a pilot deployed in 2009. Altitude, that has regional licenses for 3.5GHz spectrum throughout France, has deployed a WiMAX network using the 4Motion equipment supplied by Alvarion Ltd. In addition, TDF has selected Motorola to design and deploy 802.16e WiMAX for several regions in France. This agreement follows an initial pilot at the end of 2009 and successful deployments in Loivet, Sarthe and Limousin regions. Motorola provides deployment, integration and support services to TDF in addition to WiMAX equipment such as WiMAX access points (WAP 400 series) and outdoor and indoor CPEs such as CPEo 400 series and CPEi 200 series. The WAP 400 is based on the IEEE 802.16e-2005 technology and includes S-OFDMA interface, diversity MIMO capabilities and additional QoS features. It can operate in 2.3, 2.5 and 3.5 GHz spectrum bands. CPEo 400 is a typical outdoor unit with all the advantages mentioned for the WAP 400. Furthermore, Bollore Telecom has deployed a mobile WiMAX network at the band of 3.5 GHz. Alcatel-Lucent which is the equipment provider deliver end-to-end solution integrating the latest technological innovation such as beamforming and MIMO.

7.4.6 Germany

7.4.6.1 Spectrum License

Deutsche Breitband Dienste (DBD), Germany's first and largest WiMAX operator, has been awarded spectrum licenses in the 3.5GHz band throughout Germany covering 83 million inhabitants with 70MHz of spectrum in some of the largest cities – reaching a combined population of 21million- and 42MHz spectrum nationwide. Furthermore, Clearwire, Inquam now hold licenses for the entire country, 2 smaller companies hold regional licenses. These licenses which are applied for the band of 3.4-3.6 GHz are designed for the use with WiMAX technology.

7.4.6.2 Deployments and Devices

Until early 2009, DBD had 180 WiMAX BS installed with 3 to 6 sectors covering approximately 100.000 households in urban centers and suburban deployments. DBD provides broadband access services using Airspan WiMAX technology for both residential and enterprise customers. In addition, DBD is one of the first operators to

deploy Airspan VoiceMAX technology on a WiMAX network. VoiceMAX is a SIP-based solution which takes advantage of the special QoS features of the IEEE 802.16d standard and advanced admission control mechanisms. Another provider that is actively present in WiMAX technology in Germany is VSE NET which uses Alcatel-Lucent equipment. At the time being, VSE network, supports high speed internet access, VoIP and other data services with transfer rates up to 6Mbps. VSE plans to enable mobile and nomadic application except for the existing stationary users based on the WiMAX Rev-e. Furthermore, Televersa Online has deployed a WiMAX network using 3.5 GHz spectrum in a mostly rural area in the south east of Germany. Televersa has already deployed Proxim Tsunami MP.11 base stations and subscriber units across a 20.000 km^2 region. MP.11 product family offers fixed and mobile WiMAX capabilities in 900 MHz, 5.3, 5.4 5.8 and 4.9 GHz bands and are suitable for indoor and outdoor deployments. They support quadruple-play application such as Video, VoIP, data and mobility applications with QoS capabilities.

7.4.7 Greece

7.4.7.1 Spectrum License

In Greece, OTE which is the biggest telecommunication provider holds a license of 28 MHz spectrum (2x14MHz) in 3.5 GHz band. In addition WIND, Q-Telecom, Cosmoline and Craig have also a spectrum portion in 3.5 GHz.

7.4.7.2 Deployments and Devices

OTE has already deployed pilot WiMAX networks in eastern Attica and Mount Athos in the Halkidiki region of Northern Greece, in advance of a nationwide rollout. In eastern Attica Redline's equipment is being used for providing data and VoIP services to stationary users. The network consists of eight base stations and covers about seventy households which use only outdoor CPEs. In Mount Athos, Aperto has been chosen for covering a variety of monasteries. OTE plans to further expand its network and will begin trials on 802.16e technology in 2009.

7.4.8 Italy

7.4.8.1 Spectrum License

WiMAX licenses have been awarded to 11 different companies. Ariaadsl and AFT-Linkem were able to gain an almost nationwide coverage, while incumbent Telecom Italia concentrated mostly on the Central and Southern part of the country. Among the biggest investors, Retelit was able to gain coverage on all Northern Italian regions.

7.4.8.2 Deployments and Devices

WiMAX has been rapidly developed in Italy. AFT-Linkem has already deployed WIMAX across Italy using Alvarion 4Motion solution for the 3.5 GHZ frequency band. The first phase of the project has commended in October 2008 and offered voice and data services to SOHO, businesses and vertical markets. Alvarion provides BreezeMAX base stations, CPEs and WIMAX embedded PC cards. BreezeMAX portable devices include PCMCIA and USB adaptors which utilize advanced handoff algorithms. BreezeMAX portfolio also includes indoor units with 4 10/100 baseT

ports, 802.11b/g for Wi-Fi access , two VoIP ports for voice services as well as an optional backup battery. Furthermore, BreezeMAX PRO, serving as an outdoor unit, is comprised of an outdoor radio unit (ODU) and an indoor network interface unit (IDU). The ODU contains a modem, a radio and integral or external high gain flat antenna. IDU connects to the ODU via a Cat5 Ethernet cable which carries the data traffic, power and control signals between ODU and IDU. BreezeMAX also offers an integrated solution for data and voice services with a docking station that carries a self-install unit and a voice gateway providing up to 2 VoIP and 1 data port. The same provider, Linkem, has previously used Alcatel-Lucent for WiMAX network in the Lazio region of Italy based on the 80216e standard. Another Italian Internet access provider, ARIA has awarded Alcatel-Lucent as its prime supplier for building and maintaining a nationwide WiMAX Rev-e network which will cover more than 8 million in first phase (until August 2009) in Puglia and Veneto with 130 base station sites. AriaDSL already provides municipalities, businesses and residential users with high speed Internet access in addition to advanced broadband multimedia services such as video streaming and in second phase of the project plans to introduce VoIP and VPN services. During May 2009, Retelit SPA has selected HUAWEI to deploy its commercial WiMAX covering north and central part of Italy where they own a 3.5GHZ frequency license. HUAWEI will provide an end-to-end WiMAX Rev-e mobile solution including base stations, ASN Gateway, Hybrid TDM_IP microwave equipment and network management systems. HUAWEI has also delivered the first batches of its WiMAX terminals, which are already in use in the areas where the network has been activated.

7.4.9 Lithuania

Balticum TV has assigned a contract with Alvarion. At present, Balticum offers basic services to residential and business customers and plans to add mobile capabilities soon.

7.4.10 Montenegro

7.4.10.1 Spectrum License

Four operators have won licenses for WiMAX operation in Montenegro. These companies are: T-Mobile, Broadband Montenegro, MTEL and Promonte.

7.4.10.2 Deployments and Devices

Comarch has chosen Airspan’s WiMAX solution for a high-speed WiMAX network deployment by Promonte which is the largest mobile operator in the European nation of Montenegro. Comarch and Promonte plan a country-wide WiMAX deployment to provide Montenegrin businesses with high-quality IP services, delivered through Airspan's subscriber terminals. The first phase of deployment includes 10 Airspan base stations already installed in the major cities of Montenegro, with immediate plans to continue the deployment with additional base stations throughout the country. The nationwide project focuses on three areas: construction of the WiMAX access network, deployment and integration with the transport network, and access to Wi-Fi infrastructure and core equipment (OSS/BSS systems, routing & switching). The construction of the WiMAX network includes delivery and installation of WiMAX base stations in major cities of the country. The last stage of the project includes

installation of OSS/BSS systems and core routing/switching equipment. In a country with a population of less than 700.000, Promonte has more than 450.000 subscribers, and is thus the largest mobile provider in Montenegro.

7.4.11 The Netherlands

In Netherlands, WorldMAX, which uses the 3.5 GHz band, has selected Motorola for mobile WiMAX network. Motorola is providing WorldMAX with WiMAX equipment such as WiMAX access points – the WAP 400 series – and WiMAX PC cards. The same company is using Alcatel – Lucent equipment for a network covering Amsterdam with a USB dongle to access the network.

7.4.12 Norway

7.4.12.1 Spectrum License

In Norway, NextGenTel has an auction for a 2.3GHz spectrum license while Telenor has 3.5GHz licenses in Norway covering the entire country.

7.4.12.2 Deployments and Devices

Telenor has awarded Airspan to expand the operator's national WiMAX network across Norway. Telenor is offering business and residential high-speed data services in several additional regions nationwide. Airspan offers a variety of end-user devices: MiMAX USB that is a quad-band USB device and EasyST-2 which is an indoor self-install WiMAX subscriber station with optional IEEE 802.11b/g Wi-Fi and Voice over IP add-ons. In addition, it includes a residential gateway with 2 VoIP ports and one Ethernet that integrates with the EasyST to create a combined WiMAX subscriber station with VoIP and Ethernet ports. Furthermore, it provides outdoor CPEs developed to provide superior link budget performance in difficult deployment conditions.

7.4.13 Poland

7.4.13.1 Spectrum License

In Poland there are four companies that have nationwide licenses at 3.5 GHz band for WiMAX services. The main providers are Netia, Exatel and Crowley and Multimedia Polska.

7.4.13.2 Deployments and Devices

Netia, which is a leading Polish telecommunication provider, has selected Alvarion for a 20-city WiMAX deployment. The BreezeMAX 3600 portfolio contains base stations and customer premises equipment that use OFDM technology for advanced non-line-of sight functionality. This equipment is operating from 3.6 to 3.8 GHz. BreezeMAX portable devices include PCMCIA and USB WiMAX adaptors as well as fixed indoor and outdoor single-box devices. These devices have Ethernet interfaces for IP data, Wi-Fi functionality and VoIP ports. Another Polish provider, Crowley, chose Redline WiMAX products for a large deployment. Redline RedMAX family consists of a RedMAX carrier class base station (AN-100U) which delivers voice,

video and prioritizes data traffic to the indoor and outdoor subscriber's units. Furthermore, Multimedia Polska is using Airspan network equipment to expand its network in order to provide wireless voice and data services. Airspan's HiperMAX and microMAX base stations and CPEs are used in urban and suburban regions throughout Poland. HiperMAX is a dual mode (802.16d and 802.16e) macro base station with a split outdoor/indoor architecture designed to support multiple transceiver and smart antenna techniques. MicroMAX is a family of single mode highly integrated microcell base station with all-in-one packaging of RF and baseband components. Airspan equipment which is compatible with 3.5GHz and 5.9 GHZ band also includes VoIP-enabled CPEs. Multimedia Polska's main goal is replacing CTZ and DECT systems with WiMAX. Airspan also supplies a WiMAX infrastructure to MNI telecom with 60 microMAX base stations and approximately 3000 subscriber stations. Exatel, another telecommunication provider in Poland, delivers WiMAX services using software and hardware equipment from Proximetry and Tranzeo Wireless Technologies. WiMAX network architecture contains Tranzeo's carrier class TR-WMX-3.5 pico base stations and TR-WMX-3.5 subscriber units. TR-WMX series operate from 3. 3 to 3.8 GHZ and includes outdoor and indoor units supporting a channel bandwidth of 3.5 and 7 MHZ and they are compliant with 802.16d standard. Another WiMAX network exists at the community of Terespol in Eastern Poland. It operates in the 3.5 GHZ band and utilizes both PacketMAX-5000 and PacketMAX-3000 base stations along with PacketMAX-100 and PacketMAX-300 subscriber units which are gateways for outdoor use only.

7.4.14 Spain

7.4.14.1 Spectrum License

Only three companies are currently own WiMAX licenses in Spain: Iberbanda (bought by Telefónica in 2006), Euskaltel (regional Basque operator) and Aeromax, a small company based in the Mediterranean Coast. Three more companies have a license: Aló (Clearwire), Orange-France Télécom and Neo-Sky (Iberdrola).

7.4.14.2 Deployments and Devices

Neo-Sky in Spain has deployed a field trial of mobile broadband WiMAX network in Madrid. Services anticipated for testing during the trial include VoIP, high-speed Internet access and multimedia broadband for nomadic users. The equipment vendor, Alcatel-Lucent, provided Neo-Sky with an end-to-end WiMAX system, including base stations, WiMAX access controllers and end-user terminals. Iberbanda recently unrolled Alvarion Ltd BreezeMAX system at 3.5 GHz in Navarra which provides voice and data services to residential customers in rural and semi-rural areas throughout the region. Alvarion and Iberbanda are long-term partners and have built successful WiMAX networks in other autonomous communities of Spain including Catalunya, Andalucia and Castilla Leon. In addition Euskaltel has covered a lot of small cities in rural areas of Spain.

7.4.15 Switzerland

Swisscom has tested WiMAX technology in the county of Berne during 2008 with many pilot installations in households. In addition, in 2009 plans an evaluation and field trial of Mobile WiMAX technology.

8 End-user Terminals

There is a large number of WiMAX user terminals available. The diversity, performance and market-readiness of WiMAX devices is very important to operators; no network can operate without end-users and these are the devices designed for them.

From the REWIND perspective, this section is not of less importance, it has been added to this deliverable at the request of the review panel.

Mobile stations connect to either relays or macro BTSs depending on signal strength and configuration. The relays may work in transparent or non-transparent mode. The existence of a relay station and it's operating mode is irrelevant to a mobile station, as illustrated in Figure 3. A standard 802.16e CPE connects to either a macro BTS or a relay station in the same way. Existing CPEs can be used before and after coverage of a WiMAX network is improved by using relays.

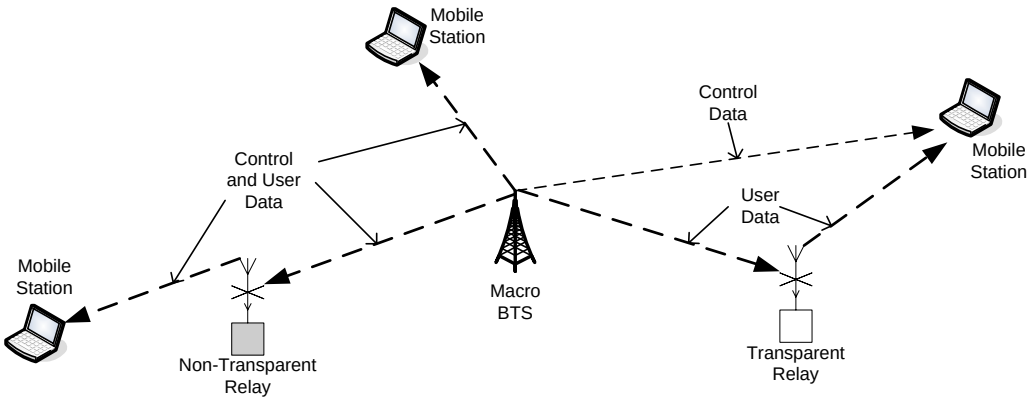


Figure 3 Connections of Mobile Stations to a Macro BTS without and with Transparent or Non-Transparent Relays

This section shows examples of CPEs available as certified units. Different manufacturers are delivering a wide variety of devices, from fixed indoor or outdoor units providing an Ethernet port for a LAN connection to mobile USB dongles, PC Express Cards, PCMCIA Cardbus cards and PDAs or Mobile Internet Devices.

A number of suppliers, such as Intel, Sequans, Beceem, Chip and Wavesat supply standalone WiMAX printed circuit board modules for use in other equipment, such as laptops, notebooks, netbooks and any other equipment requiring wireless communications.

Over 50 devices are available as certified equipment on the WiMAX Forum site. The most representative are listed in Table 7.

As example of form factors, the pictures below show some examples in the following order: an outdoor unit with Ethernet interface, an indoor unit with Ethernet interface, a PDA/MID, the Express Card, the PCMCIA card, an USB dongle and the PCB card.

Figure 4 Examples of WiMAX Devices

Manufacturer Model(s)	Interface Device Type	Profile	Frequency (GHz)	Channel (MHz)	Duplex
Airspan Networks MiMAX-USB-Q1-1	USB	MP05	2.469 - 2.69	5 and 10	TDD
Airspan Networks ProST PST350F	Outdoor Ethernet	Air2	3.5	3.5	FDD
Airspan Networks EasyST EST350F	Indoor Ethernet	Air2	3.5	3.5	FDD
Alcatel-Lucent CARC 500	Indoor Ethernet	MP05	2.469 - 2.69	5 and 10	TDD
Alvarion BreezeMAX Si	Indoor Ethernet	Air2	3.5	3.5	FDD
Alvarion BMAX PRO-S CPE	Outdoor Ethernet	Air2	3.5	3.5	FDD
Aperto Networks PM120/PM320	Outdoor Ethernet	3.5T2	3.4 – 3.6	3.5	TDD
Beceem USB200	USB	MP05	2.469 - 2.69	5 and 10	TDD

Manufacturer Model(s)	Interface Device Type	Profile	Frequency (GHz)	Channel (MHz)	Duplex
E.T. Industries Apollo (MAX) -SU	Outdoor Ethernet	3.5F1	3.5	3.5	FDD
Fujitsu MB86K21-UD1	USB	MP05	2.469 - 2.69	5 and 10	TDD
GCT Semiconductor RD7213UM35	USB	M3500T-05	3.4 - 3.6	10	TDD
GCT Semiconductor GDM7205K	PCB	MP05	2.469 - 2.69	5 and 10	TDD
Gigaset Communications SE680/681 SX682	Outdoor Ethernet Router	MP05	2.469 - 2.69	5 and 10	TDD
Harris Stratex StarMAX 3160-25	Outdoor Ethernet	MP05	2.469 - 2.69	5 and 10	TDD
Harris Stratex StarMAX 2140-3.5G	Indoor Ethernet	3.5T2	3.4 – 3.6	3.5	TDD
Huawei Echolife BM625	Indoor Ethernet	MP05	2.469 - 2.69	5 and 10	TDD
Huawei Echolife BM325	USB	MP05	2.469 - 2.69	5 and 10	TDD
Intel Reference Design	USB	M3500T-05	3.4 - 3.6	10	TDD
Intel WiFiLink5150	PCB	M2500T-01	2.469 - 2.69	5 and 10	TDD
Intel WiFi Link5350	PCB	MP05	2.469 - 2.69	5 and 10	TDD
Kyocera C3900	USB	MP05	2.469 - 2.69	5 and 10	TDD
Modacom MW-25x0E	Express Card	MP05	2.469 - 2.69	5 and 10	TDD
Modacom MW-U25x0	USB	MP05	2.469 - 2.69	5 and 10	TDD
Motorola CPEi25150 CPEi25750	Indoor Ethernet	M2500T-01	2.469 - 2.69	5 and 10	TDD

Manufacturer Model(s)	Interface Device Type	Profile	Frequency (GHz)	Channel (MHz)	Duplex
Motorola WTM1000	USB	MP05	2.469 - 2.69	5 and 10	TDD
NEC Aterm WM3200C	PCMCIA Cardbus	MP05	2.469 - 2.69	5 and 10	TDD
NEC Aterm WM3200U	USB Dongle	MP05	2.469 - 2.69	5 and 10	TDD
NEC TRP-2GW-2A	PCMCIA (Cardbus)	MP05	2.469 - 2.69	5 and 10	TDD
OKI Electric BR3001	USB	MP05	2.469 - 2.69	5 and 10	TDD
Posdata FLYVO U100	USB Dongle	MP01	2.3 – 2.4	8.75	TDD
Redline Comms RPM2500M	Indoor Ethernet	MP05	2.469 - 2.69	5 and 10	TDD
Redline Comms RedMAX OSU	Outdoor Ethernet	M3500T-01	3.4 – 3.6	3.5 and 7	TDD
Runcom Technologies Tornado RNU200	Indoor Ethernet	MP01	2.3 – 2.4	8.75	TDD
Samsung SWD-M100	PDA	M2500T-01	2.469 - 2.69	5 and 10	TDD
Samsung SWC-U20x	USB Dongle	MP05	2.469 - 2.69	5 and 10	TDD
Samsung SWT-P230	PCMCIA	MP01	2.3 – 2.4	8.75	TDD
Samsung EWC-E100	Express Card	MP05	2.469 - 2.69	5 and 10	TDD
Selex Comms WRY035-C	Outdoor Ethernet	Air1	3.5	3.5	TDD
Seowon Intech SWU-322x	USB Dongle	M3500T-02 M3500T-05	3.4 - 3.6	10	TDD
Sequans SQN1110-RD	Indoor Ethernet	MP01	2.3 – 2.4	8.75	TDD
Sequans SQN1010-RD	PCB	M3500T-02	3.5	3.5	TDD
Sequans SQN1130-RD	PCB	MP05	2.469 - 2.69	5 and 10	TDD

Manufacturer Model(s)	Interface Device Type	Profile	Frequency (GHz)	Channel (MHz)	Duplex
Siemens AG Gigaset SE461	Indoor Ethernet	Air2	3.5	3.5	H-FDD
SR Telecom SSU5000	Outdoor Ethernet	3.5T2	3.5	3.5	TDD
ZTE Corporation TU25	USB	MP05	2.469 - 2.69	5 and 10	TDD
Wavesat MiniMAX 3.5 (FDD)	PCB	Air2	3.5	3.5	H-FDD
Wavesat MiniMAX 3.5 (TDD)	PCB	Air2	3.5	3.5	TDD
ZyXEL Comms MAX-206M2	Indoor Ethernet	MP05	2.469 - 2.69	5 and 10	TDD

Table 7 Certified WiMAX User Terminals

9 REWIND Summary

The conclusion to be drawn on the opportunities for Multi-hop Relay Stations is that no matter what technology is used for 4G networks, the MRSs have, according to the operators themselves, an important role to play in optimising coverage of mobile networks.

The most important advantage is given by the self-backhaul capability, giving the operator the capability to install it to the best suitable location for the coverage it must provide and not where it's convenient for backhauling purposes.

Given the small target size of these devices, zero footprint, with minimal effort MRSs can be hidden in light poles or other elevated infrastructures to eliminate any visual impact.

First users of MRS technology are likely to be mobile WiMAX operators. The Swedish spectrum regulator has already released the 2.6GHz spectrum for use by 4G technologies and WiMAX is ready to take advantage of it.

The LTE camp, in LTE-A is also working on a RS concept, but the standards are a number of years away from being stabilized.

MRSs must not use the concept "One size fits all". It is best to allow mobile operators to use choose from a number of options, such as capacity of the relay stations, transmit power and with or without MIMO. The capability to match a product to an application is needed for large projects where over-specification leads to paying more than its needed and under-specification to not meeting the technical criteria.

Management of MRS units must be dual, the main management connection being the backhaul but also via the downstream channels or other local means. This is because MRSs could be located in places with very difficult access after installation, such as in buildings ceilings, the side of tall buildings at high elevation, inside light poles etc.

Observing the focus on mobility of all our respondents, it has a different aspect on the MRS units. Mobile handoffs must be supported not only from one RS to another when they are both served by the same macro BTS, but also when each RS is backhauled to a different macro BTS.

One concern brought up a significant number of times was the imperfect data handovers of current mobile networks. Data handovers are complex transactions, were RF signal levels trigger routing table updates for IP routers along the data path. Supporting double handovers, from one RS to another and one macro BTS to another at the same time, might require the RS units to have additional IP intelligence in order to assist the mobile IP protocol to execute handovers.

10 Appendices

This section lists the EU operators.

10.1 European Union Countries and Mobile Cellular Operators

Country Subscribers Penetration	**Brand (Operator/Owner)**	**Technology(Frequency Bands)**	**Subscribers** millions (when)
Austria 9.4 mil subs 113%	A1 (Telekom Austria)	GSM(900, 1800), UMTS/HSDPA(2100)	3.854 (2007-09)
	T-Mobile	GSM(900, 1800), UMTS/HSDPA(2100)	3.273 (2007-12)
	One	GSM(900, 1800), UMTS/HSDPA(2100)	1.8 (2006-12)
	3	UMTS/HSDPA(2100)	0.474 (2007-08)
Belgium 10.2 mil subs 96.9%	Proximus (Belgacom)	GSM/EDGE(900, 1800), UMTS/HSDPA(2100)	4.42 (2007-06)
	Mobilstar	GSM/EDGE(900, 1800), UMTS/HSDPA(2100)	3.08 (2007-09)
	BASE	GSM/EDGE(900, 1800), UMTS(2100)	2.6 (2007-06)
Bulgaria 10 mil subs 133.2%	M-Tel (Mobiltel/Telekom Austria))	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	5 (2007-12)
	Globul (Cosmote)	GSM/GPRS(900, 1800), UMTS/HSDPA/HSUPA(2100)	4 (2007-12)
	Vivatel (BTc)	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	1 (2007-11)
Cyprus 0.87 mil subs 109.5%	Cytamobile/Vodafone	GSM(900, 1800)	0.67 (2005-12)
	Areeba	GSM(900, 1800), UMTS(2100)	0.106 (2007-09)
Czech Rep. 12.75 mil subs 123.2%	T-Mobile	GSM(900, 1800), UMTS(2100)	5.271 (2007-12)
	Telefonica/O2	GSM(900, 1800), UMTS(2100)	5.125 (2007-12)
	Vodafone	GSM(900, 1800)	2.589 (2007-09)
Denmark 5.76 mil subs 104.9%	TDC	GSM(900, 1800), UMTS(2100)	3 (2007-09)
	Sonofon (Telenor)	GSM(900, 1800), UMTS(2100)	1.680 (2007-12)
	Telia	GSM(900, 1800), UMTS(2100)	1.449 (2007-12)
	3	UMTS(2100)	0.12 (no info)
Estonia 1.57 mil subs 117%	EMT	GSM/EDGE(900, 1800), UMTS/HSPA(2100)	0.765 (2007-12)
	Elisa	GSM/EDGE(900, 1800), UMTS/HSPA(900, 2100)	0.3125 (2007-09)
	Tele2	GSM/EDGE(900, 1800), UMTS/HSPA(2100)	0.5 (no info)
Finland 5.4 mil subs 105%	Sonera (TeliaSonera)	GSM(900, 1800), UMTS(2100)	2.449 (2007-12)
	Elisa	GSM(900, 1800), UMTS(900, 2100)	2.16 (2006-09)
	DNA Finland	GSM(900, 1800), UMTS(2100)	0.81 (2005-12)
France 53.1 mil subs 84%	Orange (France Telecom)	GSM(900, 1800), UMTS(2100)	23.504 (2007-09)
	SFR (Vivendi, Vodafone)	GSM(900, 1800), UMTS(2100)	18 (2007-06)
	Boygues Telecom	GSM(900, 1800), UMTS(2100)	8.293 (2007-09)
Germany 92.8 mil subs 112.7%	T-Mobile	GSM/EDGE(900, 1900), UMTS/HSDPA(2100)	35.952 (2007-12)
	Vodafone	GSM(900, 1900), UMTS/HSDPA(2100)	32.541 (2007-09)
	E-Plus (KPN)	GSM(900, 1800), UMTS(2100)	13.6 (2007-06)
	O2	GSM(900, 1800), UMTS/HSDPA(2100)	12.472 (2007-12)
Greece 15.45 mil subs 138.3%	Cosmote (Deutsche Telekom)	GSM(900, 1800), UMTS(2100)	5.94 (2007-09)
	Vodafone	GSM(900, 1800), UMTS(2100)	5.346 (2007-09)
	Wind (Weather, Wind Hellas)	GSM(900, 1800), UMTS(2100)	4.161 (2007-05)

Country Subscribers Penetration	**Brand (Operator/Owner)**	**Technology(Frequency Bands)**	**Subscribers** millions (when)
Hungary 10.1 mil subs 100.9%	T-Mobile	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA/HSUPA(2100)	4.853 2007-12)
	Pannon (Telenor)	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	3.377 (2007-12)
	Vodafone	GSM/GPRS(900, 1800), UMTS/HSDPA/HSUPA(2100)	2.212 (2007-09)
Ireland 4.8 mil subs 114%	Vodafone	GSM/GPRS(900, 1800), UMTS/HSDPA(2100)	2.217 (2007-09)
	O2	GSM/GPRS(900, 1800), UMTS/HSDPA(2100)	1.646 (2007-12)
	Meteor	GSM/GPRS/EDGE(900, 1800), (UMTS planned)	0.962 (2007-12)
	3	UMTS/HSDPA(2100) (roams on Vodafone where no 3G)	0.13 (??)
Italy 87.35 mil subs 146.1%	TIM	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	35.3 (2007-09)
	Vodafone	GSM/GPRS(900, 1800), UMTS/HSDPA(2100)	29.151 (2007-09)
	Wind (Orascom)	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	15.3 (2007-09)
	3	UMTS/HSDPA (2100)	7.677 (2007-08)
Latvia 2.24 mil subs 98.47%	Latvijas Mobilais Telefons	GSM(900, 1800), UMTS(2100)	1.014 (2008-01)
	Tele2	GSM(900, 1800), UMTS(2100)	1 (2006-07)
	BITE Latvija (TDC)	GSM(900, 1800), UMTS(2100)	0.222 (2007-03)
Lithuania 4.98 mil subs 144%	Omnitel (TeliaSonera)	GSM/EDGE(900, 1800), UMTS(2100)	2.012 (2007-12)
	Bite (TDC)	GSM(900, 1800), UMTS(2100)	1.84 (2006-12)
	Tele2	GSM(900, 1800), UMTS(2100)	1 (no info)
Luxembourg 0.76 mil subs 164%	LuxGSM	GSM(900, 1800), UMTS/HSDPA(2100)	No info
	Tango (Tele2)	GSM(900, 1800), UMTS/HSDPA(2100)	No info
	Vox Mobile	GSM/EDGE(900, 1800), UMTS/HSDPA(2100)	0.076 (2007-09)
Malta 0.36 mil subs 88.8%	Vodafone	GSM/GPRS(900), UMTS(2100)	0.197 (2007-09)
	GO	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	0.16 (no info)
Netherlands 17.5 mil subs 105.6%	KPN	GSM/GPRS(900, 1800), UMTS(2100)	8.8 (2007-06)
	T-Mobile	GSM/GPRS(900, 1800), UMTS(2100)	4.889 (2007-12)
	Vodafone	GSM/GPRS(900, 1800), UMTS(2100)	3.892 (2007-09)
Norway 5.2 mil subs 111%	Telenor	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	2.856 (2007-12)
	Netcom (TeliaSonera)	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	1.577 (2007-12)
Poland 41.5 mil subs 108%	Orange Polska (PTK Centertel)	GSM/GPRS/EDGE9900, 1800), UMTS(2100)	14.158 (2007-12)
	Plus GSM (Vodafone, TDC, KGHM, PKN Orlen, PSE))	GSM/GPRS/EDGE9900, 1800), UMTS(2100)	13.454 (2007-12)
	Era (Deutsche Telekom)	GSM/GPRS/EDGE9900, 1800), UMTS(2100)	12.998 (2007-12)
	Play (Novator, Tollerton)	UMTS(2100)	0.849 (2007-12)
Portugal 12.9 mil subs 122.1%	TMN - Telecomunicações Móveis Nacionais (Portugal Telecom)	GSM/GPRS(900, 1800), UMTS/HSDPA/HSUPA(2100)	6.004 (2007-09)
	Vodafone	GSM/GPRS(900, 1800), UMTS/HSDPA/HSUPA(2100)	4.957 (2007-06)
	Optimus (SonaeCom)	GSM/GPRS(900, 1800), UMTS/HSDPA/HSUPA(2100)	2.28 (2007-12)
	Zapp	CDMA450, UMTS(2100)	No info

Country Subscribers Penetration	**Brand (Operator/Owner)**	**Technology(Frequency Bands)**	**Subscribers** millions (when)
Romania 22.1 mil subs 101.9%	Orange	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	9.8 (2007-12)
	Vodafone	GSM/GPRS,(900, 1800) UMTS/HSDPA(2100)	8.808 (2007-12)
	Cosmote	GSM(900, 1800)	3 (2007-10)
	Zapp	CDMA450, UMTS(2100)	0.5 (2006-12)
	DigiMobil	UMTS(2100)	No info
Slovakia 5.45 mil subs 100.1%	Orange	GSM(900, 1800), UMTS/HSDPA(2100)	2.7 (no info)
	T-Mobile	GSM(900, 1800), UMTS/HSDPA(2100)	2.367 (2007-12)
	O2	GSM(900, 1800), UMTS(2100)	0.565 (2007-12)
Slovenia 1.85 mil subs 89.7%	Mobitel (Telekom Slovenije)	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	1.37 (no info)
	SI.Mobil (Vodafone/Telekom Austria)	GSM/GPRS(900, 1800), UMTS(2100)	0.48 (2007-09)
	Tusmobil	GSM(900, 1800), UMTS/HSPA(2100)	No info
Spain 50.7 mil subs 111%	Movistar (Telefonica)	GSM(900, 1800), UMTS/HSDPA(2100)	22.827 (2007-12)
	Vodafone	GSM(900, 1800), UMTS/HSDPA(2100)	15.473 (2007-09)
	Orange	GSM(900, 1800), UMTS/HSDPA(2100)	10.921 (2007-09)
	Yoigo (TeliaSonera)	UMTS(2100)	0.427 (2007-12)
Sweden 10 mil subs 112%	Telia	GSM(900, 1800), UMTS(2100)	4.807 (2007-12)
	Tele2	GSM(900, 1800), UMTS(2100)	3.55 (2007-12)
	Telenor	GSM(900, 1800), UMTS(2100)	1.855 (2007-12)
	3	UMTS(2100)	No info
Switzerland 7.1 mil subs 97%	Swisscom	GSM(900, 1800), UMTS(2100)	4.469 (2006-06)
	Sunrise (TDC)	GSM(900, 1800), UMTS(2100)	1.289 (2006-06)
	Orange	GSM(1800), UMTS(2100)	1.285 (2006-06)
	Tele2	GSM(1800)	No info
	In&Phone	GSM(1800)	No info
UK 77.35 mil subs 127.6%	O2	GSM/GPRS/EDGE(900, 1800), UMTS/HSDPA(2100)	18.382 (2007-12)
	Vodafone	GSM/GPRS(900, 1800), UMTS/HSDPA(2100)	17.647 (2007-06)
	T-Mobile	GSM/GPRS(1800), UMTS/HSDPA(2100)	17.311 (2007-12)
	Orange	GSM/GPRS/EDGE(1800), UMTS/HSDPA(2100)	15.4 (2007-09)
	3	UMTS/HSDPA(2100) (roams to O2 or Orange GSM/GPRS)	3.9 (2007-03)

Table 8 List of EU Countries and Mobile Network Operators

Source:
http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_Europe
http://en.wikipedia.org/wiki/Mobile_Network_Code

10.2 Mobile Cellular Operators in the EU

Nr	Operator (Owner)	Countries
1	3	Austria, Denmark, Ireland, Italy, Sweden, UK
2	Areeba	Cyprus
3	Base	Belgium
4	Boygues Telecom	France
5	DigiMobil	Romania
6	DNA Finland	Finland
7	EMT	Estonia
8	Elisa	Estonia, Finland
9	Go	Malta
10	In&Phone	Switzerland
11	KPN	Germany, Netherlands
12	Latvijas Mobilais Telefons	Latvia
13	LuxGSM	Luxembourg
14	Meteor	Ireland
15	Mobil Star	Belgium
16	Mobiltel	Bulgaria
17	Mobitel	Slovenia
18	Telefonica/O2	Czech Rep., Germany, Ireland, Slovakia, Spain, UK
19	One	Austria
20	Optimus	Portugal
21	Orange	France, Poland, Romania, Slovakia, Spain, Switzerland, UK
22	Play	Poland
23	Proximus	Belgium
24	Swisscom	Switzerland
25	T-Mobile (Deutsche Telekom)	Austria, Czech Rep., Germany, Hungary, Netherlands, Poland, Slovakia, UK (Greece, Romania, Bulgaria)
26	TDC	Denmark, Latvia, Lithuania, Poland, Switzerland
27	Tele2	Estonia, Latvia, Lithuania, Luxembourg, Sweden, Switzerland
28	Telenor	Denmark, Hungary, Norway, Sweden
29	TeliaSonera	Denmark, Finland, Lithuania, Norway, Spain, Sweden,
30	TIM	Italy
31	TMN Portugal	Portugal
32	Tusmobil	Slovenia
33	Vivatel (BTC)	Bulgaria
34	Vodafone	Cyprus, Czech Rep., France, Germany, Greece, Hungary, Ireland, Italy, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, UK

Nr	Operator (Owner)	Countries
1	3	Austria, Denmark, Ireland, Italy, Sweden, UK
2	Areeba	Cyprus
3	Base	Belgium
4	Boygues Telecom	France
5	DigiMobil	Romania
6	DNA Finland	Finland
7	EMT	Estonia
8	Elisa	Estonia, Finland
9	Go	Malta
10	In&Phone	Switzerland
11	KPN	Germany, Netherlands
12	Latvijas Mobilais Telefons	Latvia
13	LuxGSM	Luxembourg
14	Meteor	Ireland
15	Mobil Star	Belgium
35	Vox Mobile	Luxembourg
36	Wind (Hellas)	Greece
37	Wind (Orascom)	Italy
38	Zapp	Romania, Portugal

Table 9 List of Mobile Network Operators in EU Countries

10.3 WiMAX Operators in European Union

Country	Operator's name	License Type	Website
Austria	WiMAX Telecom	National 3.5GHz	www.wimaxxed.at
Belgium	Clearwire		www.clearwire.be
Bulgaria	Max Telecom Ltd.	National class A license in the 3.5 GHz band (2 x 21 MHz)	www.maxtelecom.bg
	Transtelecom	National class A license in the 3.5 GHz band (2 x 21 MHz)	www.transtelecom.bg
	Nexcom Bulgaria	National class B license in the 3.5 GHz band (2 x 10,5 MHz)	www.nexcom.bg
	Mtel	National class B license in the 3.5 GHz (2 x 10,5 MHz)	www.mtel.bg
	Carrier BG	National class B license in the 3.5 GHz band (2 x 10,5 MHz)	www.carrier.bg
Estonia	Norby Telecom	National 3.5-3.6GHz license	www.norby.ee
	Baltic Broadband	National 3.5-3.6GHz license	www.baltmax.ee
	Tele2	National 3.5-3.6GHz license	
	Levira	Regional 3.5-3.6GHz license	
	Elion	Regional 3.5-3.6GHz license	
Finland	Suomicom + 15 others		www.suomicom.fi
France	Iliad	National, the only one in France	www.iliad.fr
	Altitude Telecom	Regional	www.altitudetelecom.fr
	Maxtel		www.maxtel.fr
	HDRR	Regional	www.tdf.fr
	Spernet Technologies	Regional, 5.8GHz	www.supernet-india.com
Germany	MaxxOnAir	From DBD, Deutsche Breitband Dienste, national license	www.maxxonair.de
	Clearwire	National	
	Inquam	National	
	DSLonair	Regional 3.5 GHz	www.dslonair.de
	Arcor	Regional 3.5GHz	www.airmax.arcor.de
Greece	OTE	Pilot network on Mount Athos	
	Cosmoline	National 3.5GHz license	www.cosmoline.com
	WIND		
	Q-Telecom		
	Craig		
Hungary			
Ireland	Irish Broadband	National 3.5GHz	www.irishbroadband.com
Italy	Aria	National 3.5GHz	www.ariamax.it
	AFT-Linkem	National 3.5GHz	www.linkem.com/max/
Lithuania	BalticumTV		
Malta	Vodafone	National 3.5GHz	
	Go Mobile	National 3.5GHz	
	Cellcom	National 3.5GHz	
Netherlands	Worldmax	National 3.5GHz	www.worldmax.nl
Norway	Telenor	National 3.5GHz	
	NextGenTel	National 2.3GHz	
Poland	Netia Networks	3.5GHz in about 50 cities	
	Exatel	National 3.5GHz	
	Crowley	National 3.5GHz	
	Multimedia Polska	National 3.5GHz	

Country	Operator's name	License Type	Website
Portugal			
Romania	Clearwire	National 3.5GHz for fixed access only	
	Vodafone	National 3.5GHz for fixed access only	
	Orange	National 3.5GHz for fixed access only	
	Zapp	National 3.5GHz for fixed access only	
Slovakia	Wimax Telecom	National 3.5GHz	www.wimax-telecom.net
Slovenia	Telekom Slovenije		www.telekom.si
	Volja.net		www.volja.net
Spain	Euskaltel		www.euskaltel.es
	Iberbanda		www.iberbanda.es
	aLO		www.alo.es
	Neo-Sky/Iberdrola	National 3.5GHz license	www.neo-sky.es
Sweden	Telia Sonera	Service in 21 counties in Sweden.	
UK	Wi-Manx	National 3.6-3.8GHz on Isle of Man	www.wimanx.com
	Freedom4	National 3.6GHz	www.freedom4.com
	UK Broadband	National 3.5GHz	www.ukbroadband.co.uk
	Urban WiMAX	5.4GHz and 5.8GHz bands	www.urbanwimax.co.uk
	MWAG	National 2.5GHz mobile WiMAX (Mobile WiMAX Acceleration Group)	

Table 10 List of WiMAX Operators in EU Countries

Source:
http://en.wikipedia.org/wiki/List_of_deployed_WiMAX_networks

10.4 Wireline Operators in EU

This section lists the incumbent telephony operators in each EU country and their involvement with mobile operators.

Country	Incumbent Operator	Mobile Subsidiary or Investment
Austria	Telekom Austria	A1
Belgium	Belgacom	Proximus
Bulgaria	BTc	Vivatel
Cyprus	Cyta	CytaMobile
Czech Rep.	Telefonica/O2	Telefonica/O2
Denmark	TDC	TDC
Estonia	Elion	EMT
Finland	Sonera	Sonera
France	France Telecom	Orange
Germany	Deutsche Telekom	T-Mobile
Greece	OTE	Cosmote
Hungary	Deutsche Telekom	T-Mobile
Ireland	Eircom	Meteor
Italy	Telecom Italia	TIM
Latvia	Lattelecom	Latvijas Mobilais Telefons
Lithuania	Teo LT	TeliaSonera
Luxembourg	P&T Luxembourg	LuxGSM
Malta	GO (Maltacom)	GO
Netherlands	KPN	KPN
Norway	Telenor	Telenor
Poland	Telekomunikacja Polska S.A. (TPSA)	Orange Polska (PTK Centertel)
Portugal	Portugal Telecom	TMN - Telecomunicações Móveis Nacionais
Romania	Romtelecom	30% ownership of Cosmote-Romania*
Slovakia	Slovak Telecom (Deutsche Telekom)	T-Mobile
Slovenia	Telekom Slovenije	Mobitel
Spain	Telefonica	Movistar
Sweden	Telia	Telia
Switzerland	Swisscom	Swisscom
UK	BT – British Telecom	BT Mobile (MVNO)**

Table 11 EU Incumbent Operators and Mobile Networks

* Cosmote, the mobile arm of Greek incumbent OTE, acquired 70% of Cosmorom, the Romtelecom owned GSM1800 mobile operator.

** BT's only current stake in the UK mobile phone market, since BT Cellnet (O2) was demerged in 2002, is BT Mobile. BT Mobile is a Mobile virtual network operator (MVNO) in the UK which uses the Vodafone UK network.

10.5 Repeater Manufactures

10.5.1 Introduction

The term "repeater" originated with telegraphy and referred to an electromechanical device used to regenerate telegraph signals. Use of the term has continued in telephony and data communications.

A repeater is an electronic device that receives a signal and retransmits it at a higher level and/or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances without degradation.

In telecommunication, the term repeater has the following standardized meanings:

An analog device that amplifies an input signal regardless of its nature (analog or digital).

A digital device that amplifies, reshapes, retimes, or performs a combination of any of these functions on a digital input signal for retransmission.1

In digital communication systems, a repeater is a device that receives a digital signal on an electromagnetic or optical transmission medium and regenerates the signal along the next leg of the medium. In electromagnetic media, repeaters overcome the attenuation caused by free-space electromagnetic-field divergence or cable loss. A series of repeaters make possible the extension of a signal over a distance.

Repeaters remove the unwanted noise in an incoming signal. Unlike an analog signal, the original digital signal, even if weak or distorted, can be clearly perceived and restored. With analog transmission, signals are restrengthened with amplifiers which unfortunately also amplify noise as well as information.

Because digital signals depend on the presence or absence of voltage, they tend to dissipate more quickly than analog signals and need more frequent repeating. Whereas analog signal amplifiers are spaced at 18,000 meter intervals, digital signal repeaters are typically placed at 2,000 to 6,000 meter intervals.

In a wireless communications system, a repeater consists of a radio receiver, an amplifier, a transmitter, an isolator, and two antennas. The transmitter produces a signal on a frequency that differs from the received signal. This so-called frequency offset is necessary to prevent the strong transmitted signal from disabling the receiver. The isolator provides additional protection in this respect. A repeater, when strategically located on top of a high building or a mountain, can greatly enhance the performance of a wireless network by allowing communications over distances much greater than would be possible without it.

In a cellular telephone system, a repeater is one of a group of transceivers in a geographic area that collectively serve a system user. It is a device used to boost the cell phone reception to the local area by the usage of a reception antenna, a signal amplifier and an internal rebroadcast antenna. These are similar to the cellular broadcast towers used to broadcast by the network providers, but are much smaller, usually intended for use by one building. Modern cellular repeater amplifiers work by rebroadcasting cellular signals inside the building. The systems usually use an external, directional antenna to collect the best cellular signal, which is then transmitted to an amplifier unit which amplifies the signal, and retransmits it locally, providing significantly improved signal strength. The more advanced models often

[1] http://en.wikipedia.org/wiki/Repeater

also allow multiple cell phones to use the same repeater at the same time, so are suitable for commercial as well as home use2.

In satellite wireless, a repeater (more frequently called a transponder) receives uplink signals and retransmits them, often on different frequencies, to destination locations.

In a fiber optic network, a repeater consists of a photocell, an amplifier, and a light-emitting diode (LED) or infrared-emitting diode (IRED) for each light or IR signal that requires amplification. Fiber optic repeaters operate at power levels much lower than wireless repeaters, and are also much simpler and cheaper. However, their design requires careful attention to ensure that internal circuit noise is minimized.

Repeaters are commonly used by commercial and amateur radio operators to extend signals in the radio frequency range from one receiver to another. These consist of drop repeaters, similar to the cells in cellular radio, and hub repeaters, which receive and retransmit signals from and to a number of directions3.

As far as WiMAX is concerned, the repeater is a two-way radio transceiver system designed to provide coverage of dark zones not served by WiMAX base stations, bypassing direct Line of Sight obstacles between a base station and a number of remote terminals or extending coverage beyond the Base Station limits.

A WiMAX repeater is composed of two outdoor transceivers (local and remote), specifically designed to minimize the cable running to each antenna and the implicit signal degradation, as well the induced signal delay. The only connection requirement from the outside is a power feed. Each transceiver performs a transparent retransmission of the signal on each way. A frequency offset mechanism avoids co-channel interference and eases the frequency planning process, while an ALC (Automatic Level Control) provides a stable signal regardless of weather and other transient conditions4.

10.5.2 Classification

WiMAX relays are advanced repeating systems which receive and re-transmit radio signals a wireless telecommunication system. They can raise the levels and they can convert the frequency of a received radio signal. The WiMAX relay system is a two-way radio transceiver system especially designed for coverage provision in areas where coverage gaps are detected and is not possible to be served by WiMAX base stations.5 It is used to enhance signals between mobile user equipment and a base station and to extend the coverage of a single base station and consequently can solve design problems for small area coverage and performance issues.

In wireless/mobile technologies there are two types of repeaters that are commonly used:

Band selective repeaters: this type of repeaters is commonly used in cases where large numbers of frequency carriers are repeated or when base station synthesized frequency hopping is used6. For networks that are band-specific or where adjacent channel interference is not a concern, band selective repeaters are more desirable because of their lower delay times.

[2] http://en.wikipedia.org/wiki/Cellular_repeater
[3] http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci212890,00.html

[4] Terminales de Telecomunicación Terrestre, www.ttt.es
[5] Terminals de telecomunicacion terrestre found at www.ttt.es
[6] http://www.powerwave.com/repeaters-band.asp

Channel selective repeaters: they are used in off-air applications where high selectivity is an important feature in urban radio environments with lots of interference7. Channel selective ensures that only channels from your network are enhanced and that the maximum power of the repeater is fully utilized. In the busy SMR bands, channel selective is usually required to prevent interference from or to other networks with adjacent channels.

From the perspective of physical layer repeaters are divided in two main categories: transparent (T-RS) and non transparent (NT-RS)8.

Transparent (T-RS): relays only data traffic and it does not transmit a preamble and it does not broadcast control messages. A mobile station physically connected to a T-RS receives broadcast signals directly from the MR- BS and is not aware of the existence of the RS.

Non transparent (NT-RS): this type operates as a BS for a connected mobile station. It transmits a preamble, broadcasts messages and also relays data traffic. In this case the mobile station is both physically and logically connected to a non transparent RS.

From MAC perspective another classification can be according scheduling and security capabilities. In this case we can have also two main categories of relays9:

Relays which have the capability of scheduling and security can operate in both distributed and centralized mode. The distributed scheduling mode can operate with either distributed or centralized security mode. The centralized scheduling mode is usually operates with centralized security mode. Relays which have centralized scheduling don't have scheduling and security functions.

10.5.3 Benefits

In WiMAX the theoretical maximum data rate per cell can be up to 75 Mbps (64 QAM) with a 20 MHz bandwidth channel in optimum condition. In actual deployments a smaller spectrum width (7 MHz) is used. In non LOS environment the coverage can be up to 3 km while in LOS mode can be over 15 km with signal travelling over a direct path from transmitter to receiver. A LOS link requires that most of the first Fresnel zone is free of any obstruction, if these criteria are not met then there is a significant reduction in signal strength.10 In case of a NLOS link, the signals which reach the receiver through reflections, scattering, and diffractions consist of both secondary and main waves. These signals have different delay spreads, attenuation, polarizations, and stability relative to the direct path.11

In the scheme below a typical overview of MMR infrastructure is illustrated12.

[7] http://www.powerwave.com/repeaters-channel.asp

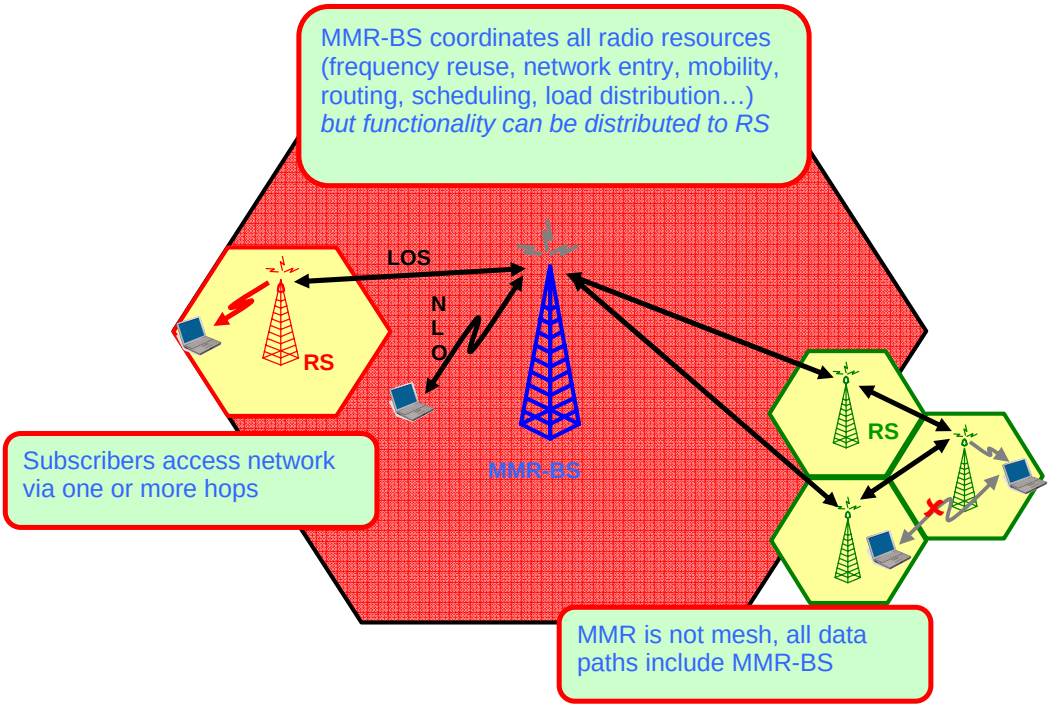
[8] Multihop relay extension for WiMAX networks – Overview and benefits of IEEE 802.16j standard , Masato Okuda, Chenxi Zhu, Dorin Viorel , January 16, 2008

[9] Multihop relay extension for WiMAX networks – Overview and benefits of IEEE 802.16j standard , Masato Okuda, Chenxi Zhu, Dorin Viorel , January 16, 2008

[10] Freeman, R, Radio System Design for Telecommunications (1-100 GHz), New York, Wiley and Sons, 1987.

[11] WiMAX's technology for LOS and NLOS environments found at www.wimaxforum.org

[12] www.intel.com



Today, there are two main applications of WiMAX: fixed WiMAX applications which are point-to-multipoint and enable broadband access to homes and businesses and mobile WiMAX which is based on OFDMA (Orthogonal Frequency Division Multiple Access) technology which along with the OFDMA multiplexing gives WiMAX a performance edge in delivering IP data services compared to 3G technologies. These two solutions ensure a maximum re-use of customer care, control and backbone infrastructure.

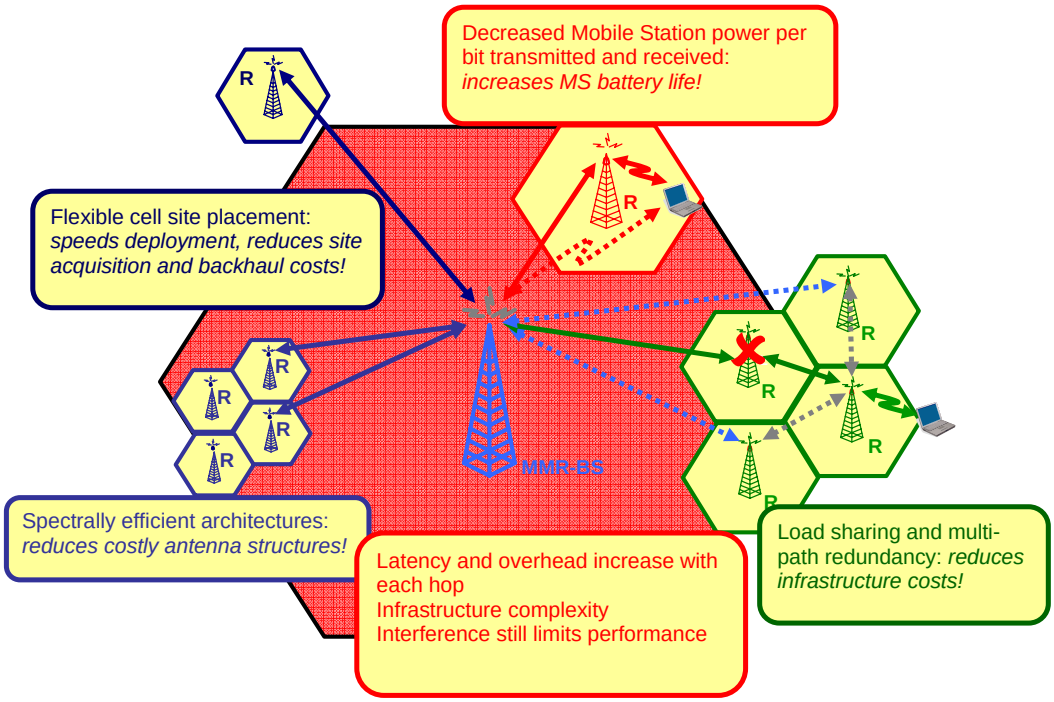
Both fixed and mobile applications are designed to deliver ubiquitous, high-throughput broadband wireless services at a low cost and to provide symmetrical bandwidth over many kilometers and range with stronger encryption and less interference. They can support different application classes at the same time, such as interactive gaming, rich media content downloading, VOIP and video conferencing, informing in cases of emergency and telemedicine even in rural areas. WiMAX target is to achieve a cost effective broadband radio access solution by using advanced coding techniques, new NLOS technologies and by taking benefit of interoperability and higher economy of scale through standardization.

Base stations come in multiple shapes and coverage sizes, including macro, micro, pico and femto cell. The primary difference between these is the size of coverage. Macro cell base stations offer the greatest range, though they also have the most coverage dead zones. Pico and femto cell base stations are used to fill in coverage gaps and establish coverage in buildings where the larger base station signals cannot penetrate. A significant side-effect of placing many base stations in a region is that each one needs a dedicated broadband backhaul connection. In 2006, the IEEE approved a project, called P802.16j (802.16j), for a mobile multihop relay (MMR) specification to extend base station reach and coverage without the backhaul requirement. The MMR base station (BS) provides the primary area of coverage in the diagram. It also has a backhaul connection, such as leased copper or fiber optics. The relay station (RS) extends the base station coverage. A

mobile subscriber station (MS) can connect to a base station, an MMR base station or a relay station13.

The MMR has been specified in a way that does not require mobile devices to be aware of relay nodes. This is important as introducing relaying would otherwise not be possible in already deployed networks. Also the standard is designed in a way that allows a packet to traverse several hops until it reaches a base station that has a backhaul connection. Finally, from the point of view of mobile stations, relays without a dedicated backhaul connection look like a standard base station and have their own base station ID. The specification allows two kinds of relay stations (RS). A simple RS relays everything up to a real base station, including even simple messages such as ranging requests and leaves the processing of all messages to the base station. Such simple relays are also referred to as transparent relays as all links to mobile devices via relay stations are controlled by a base station. More complex relays, referred to as non transparent relays, are able to locally manage the link to the subscriber and only forward user data packets to a base station and higher layer signaling information14.

The picture below shows the expected MMR benefits and limitations15.



10.6 Repeater Equipment Manufacturers

The WiMAX repeater provides a cost-effective solution to extend the coverage of a WiMAX Base Station beyond its boundaries, as it does not holds as much infrastructure requirements (shelter, backhaul, energy consumption, etc.) as in the

[13] http://www.wimax.com/commentary/blog/blog-2008/future-wimax-relay-stations-have-you-hop-until-you-drop
[14] http://mobilesociety.typepad.com/mobile_life/2008/05/wimax-80216j---mobile-multihop-relay---a-first-look.html
[15] www.intel.com

case of a pure WiMAX Base Station. There are many companies that manufacture repeaters as listed below.

10.6.1 C&S Microwave16

C&S produces two models of WiMAX / WiBro repeaters – WI-IBS a distribution-type indoor fibre-optic repeater, and WIRR-M an RF repeater. A synchronized signal detecting circuit is integrated into the WiMAX / WiBro Repeaters making the switching signals stable and enabling ease of communication between base station and terminal.

10.6.2 TTT WiMAX repeater17

RADIO	Specification	Comments
Operating RF frequency range (*)	Band 3.5a: 3399.5-3453.5 MHz UL / 3499.5-3553.5 MHz DL Band 3.5b: 3450-3500 MHz UL / 3550-3600 MHz DL Band 3.5a+b: 3440-3460 MHz UL / 3540-3560 MHz DL	
Downlink/uplink space	100 MHz	
Working mode	FDD	
Frequency step size	0.125 MHz	
Channel bandwidth	1.75 and 3.5 MHz	
Received maximum input power	-53 dBm uplink -33 dBm downlink	
Maximum output power level	26 dBm	
Receiver noise figure	5 dB	
Phase noise	33 dBc integrating 6.8KHz -> 4 MHz	
Maximum gain	80 dB	Both downlink and uplink
Modulation type	OFDM modulation, 256 FFT points: BPSK, QPSK, 16QAM, 64QAM	
Delay	Negligible (<50 ns)	No baseband signal transformation
GENERAL	**Specification**	**Comments**
Standard	802.16-2004	
Management and monitoring	Ethernet port via SNMP	
PHYSICAL AND OPERATIONAL	**Specification**	**Comments**
Antenna RF connector	N type Female	on non-integrated antenna
IF connectors	TNC type Female	
Line Voltage	Internal:24 VDC External: 110-240 VAC / 48 VDC	AC or DC adapter included
Primary Volts Amps	50 VA	Total (both transceivers)
Dimensions W x H x D	31 cm x 31 cm x 7.5 cm	Per transceiver (no antenna)
Weight	8 Kg	Per transceiver (no antenna)
Operating Temperature Range	-33ºC to 50ºC	
Humidity	95% non condensing. Outdoor units weather protected	

[16] http://www.mobilecomms-technology.com/contractors/inbuilding/cs-microwave/
[17] www.tte.es

10.6.3 ZTE WiMAX repeater

ZTE offers several types of repeaters in order to extend the coverage of the network as well as the throughput and also to increase system capacity. The most used types of the company's repeaters are the following:

- Fixed Relay Station (FRS): Permanently installed at fixed locations
- Nomadic Relay Station (NRS): Location fixed for periods of time; but can be moved around
- Mobile Relay Station MRS): For use in mobile environments

10.6.4 Juni WiMAX ICS Repeater (JI24)18

The Juni JI24 WiMax ICS Repeater extends base station coverage to provide high speed data to shadow and no coverage areas. The JI24 is suitable for installation in small buildings, underground parking lots, Subway stations, shopping malls, and solar power sites. It offers high quality communications with lower OPEX and CAPEX costs. The unit is easy to install and uses a weatherproof IP55 rated cabinet.

Using innovative and patented interference cancelling system (ICS) technology, antenna isolation can be improved between 15~25dB (depending on model) when multi-path feedback signals are present.

In the photo a Juni JI24 WiMax ICS Repeater is illustrated.

Its main characteristics, as well as its mechanical and RF specifications are shown in the following tables:

Main characteristics

Output power : Total 24dBm (Total 2FA)
Comply to IEEE 802.16d FDD System

[18] http://www.juni.com.au/webnew/contents/products_wimax_ji24.asp

Protection function for self oscillation
Internal Circuit Protection function when antenna open
HPA overpower protection (Shutdown)
Self isolation check function
ALC (Automatic Level Control)
Remote Monitoring using Juni OMC and wireless modem (optional)
Local monitoring via USB 2.0 connection

RF Specifications

ITEM	SPECIFICATION
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz
Output Power	DL: 24dBm Total UL: 24dBm Total
Gain Range	DL: 70 ~ 100dB UL: 70 ~ 100dB
Noise Figure	≤ 5dB Max.
System Delay	≤ 7.5 μsec
EVM	≤ 5 %

Mechanical Specifications

ITEM	SPECIFICATION
Dimension / Weight	400 X 230 X 160 mm, Max 20Kg
Power Consumption	60W
Operation Temperature	-30 ~ +50 °C
Humidity	5 ~ 95%

10.6.5 Juni WiMAX ICS Repeater (JI37)[19]

The Juni JI37 WiMax ICS (interference Cancellation System) Repeater uses innovative interference cancelling technology to remove unwanted feed back signals minimising the required antenna isolation. With 5W max output and one body weatherproof cabinet, the unit provides coverage extension in large outdoor areas with limited antenna isolation. Gain can be set 23dB higher than the antenna isolation value. In the photo Juni JI37 WiMax ICS Repeater is illustrated

[19] http://www.juni.com.au/webnew/contents/products_wimax_ji37.asp

Main characteristics

Output power: Total 37dBm
Gain can be set 23dB higher than antenna isolation (Lab Test Result)
Comply to IEEE 802.16d/e WiMAX standard
Protection function for self oscillation
Internal Circuit Protection function when antenna open
HPA overpower protection (Shutdown)
Self isolation check function
ALC (Automatic Level Control)
Remote Monitoring using Juni OMC and wireless modem (optional)
Local monitoring via USB 2.0 connection

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 37dBm Total UL: 27dBm Total	
Gain Range	DL: 62 ~ 92dB UL: 55 ~ 95dB	1dB step, +/- 0.5dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 4 μsec	
EVM	≤ 5 %	Compared to Source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension /	550 X 350 X 260 mm, Max 25Kg	

Weight		
Power Consumption	Max 250W	Estimated value
Operation Temperature	-30 ~ +60 °C	No FAN
Humidity	5 ~ 95% @ 40 °C Max	

10.6.6 Juni WiMAX ICS Repeater (JI40)20

The Juni JI40 WiMax ICS (interference Cancellation System) Repeater uses innovative interference cancelling technology to remove unwanted feed back signals minimising the required antenna isolation. With 10W max output and one body weatherproof cabinet, the unit provides coverage extension in large outdoor areas with limited antenna isolation. Gain can be set 23dB higher than the antenna isolation value.

Main characteristics

Output power: Total 40dBm
Gain can be set 23dB higher than antenna isolation (Lab Test Result)
Comply to IEEE 802.16d/e WiMAX standard
Protection function for self oscillation
Internal Circuit Protection function when antenna open
HPA overpower protection (Shutdown)
Self isolation check function
ALC (Automatic Level Control)
Remote Monitoring using Juni OMC and wireless modem (optional)
Local monitoring via USB 2.0 connection

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 40dBm Total UL: 28dBm Total	
Gain Range	DL: 65 ~ 95dB UL: 55 ~ 95dB	1dB step, +/- 0.5dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 4 μsec	
EVM	≤ 5 %	Compared to Source

Mechanical Specifications

[20] http://www.juni.com.au/webnew/contents/products_wimax_ji40.asp

ITEM	SPECIFICATION	REMARK
Dimension / Weight	630 X 400 X 240 mm, Max 38Kg	
Power Consumption	Max 350W	Estimated value
Operation Temperature	-30 ~ +60 °C	No FAN
Humidity	5 ~ 95% @ 40 °C Max	

10.6.7 Juni WiMAX ICS Repeater (JI43)21

The Juni JI43 WiMax ICS (interference Cancellation System) Repeater uses innovative interference cancelling technology to remove unwanted feed back signals minimising the required antenna isolation. With 20W max output and one body weatherproof cabinet, the unit provides coverage extension in large outdoor areas with limited antenna isolation. Gain can be set 25dB higher than the antenna isolation value.

Main characteristics

Output power : Total 43dBm
Gain can be set 25dB higher than antenna isolation (Lab Test Result)
Comply to IEEE 802.16d/e WiMAX standard
Protection function for self oscillation
Internal Circuit Protection function when antenna open
HPA overpower protection (Shutdown)
Self isolation check function
ALC (Automatic Level Control)
Remote Monitoring using Juni OMC and wireless modem (optional)
Local monitoring via USB 2.0 connection

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 43dBm Total UL: 27dBm Total	
Gain Range	DL: 70 ~ 100dB UL: 70 ~ 100dB	1dB step, +/- 0.5dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 4 μsec	

[21] http://www.juni.com.au/webnew/contents/products_wimax_ji43.asp

EVM	≤ 5 %	Compared to Source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	650 X 420 X 308 mm, Max 42Kg	
Power Consumption	Max 450W	Estimated value
Operation Temperature	-10 ~ +60 °C	
Humidity	5 ~ 95% @ 40 °C Max	

10.6.8 Juni WiMAX On-Frequency RF Repeater (JR24)[22]

The Juni JR24 WiMAX On-Frequency RF Repeater extends base station coverage to provide high speed data to shadow and no coverage areas. The JR24 is suitable for installation in small buildings, underground parking lots, Subway stations, shopping malls, and larger solar power sites. It offers high quality communications with lower OPEX and CAPEX costs. The unit is easy to install and uses a weatherproof IP55 rated cabinet.

Main characteristics

Output power : Total 24dBm (Total 5FA with 3.5MHz Channel Bandwidth)
Compliant to IEEE 802.16d/e FDD WiMAX standards
Self oscillation detection
Solar power operation (with larger solar powered sites)
Uplink Mute Feature
HPA overpower protection (Shutdown)
AGC / ALC (Automatic Level Control)
Local monitoring via USB 2.0 connection
SNMP reporting to higher level NMS (Optional)
OMC - Web Based Remote Control and Supervision (Optional)
Channel selection via OMC (Optional)
Remote Software Upgrade via OMC

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	

[22] http://www.juni.com.au/webnew/contents/products_wimax_jr24.asp

Output Power	DL: 24dBm UL: 24dBm	
Gain Range	DL: 60 ~ 90dB UL: 60 ~ 90dB	1dB step, +/- 0.7dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 5μsec	
EVM	≤ 5 %	

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	360 X 290 X 180 mm, Max 15Kg	
Power Consumption	Max 60W	Estimated value
Operation Temperature	-30 ~ +50 °C	
Humidity	5 ~ 95%	

10.6.9 Juni WiMAX On-Frequency RF Repeater (JR30)[23]

The Juni JR30 WiMAX On-Frequency Repeater extends base station coverage to provide high speed data to shadow and no coverage areas. The JR30 is suitable for installation in small buildings, underground parking lots, Subway stations and shopping malls. It offers high quality communications with lower OPEX and CAPEX costs. The unit is easy to install and uses a weatherproof IP55 rated cabinet.

Main characteristics
Output power: Total 30dBm (Total 5FA with 3.5MHz Channel Bandwidth)
Compliant to IEEE 802.16d/e FDD WiMAX standards
Self oscillation detection
Uplink Mute Feature
HPA overpower protection (Shutdown)
AGC / ALC (Automatic Level Control)
Local monitoring via USB 2.0 connection
SNMP reporting to higher level NMS (Optional)
OMC - Web Based Remote Control and Supervision (Optional)
Channel selection via OMC (Optional)
Remote Software Upgrade via OMC

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	

[23] http://www.juni.com.au/webnew/contents/products_wimax_jr30.asp

Output Power	DL: 30dBm UL: 24dBm	
Gain Range	DL: 65 ~ 95dB UL: 65 ~ 95dB	1dB step, +/- 0.7dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 5μsec	
EVM	≤ 5 %	Compared to source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	410 X 360 X 210 mm, Max 24Kg	
Power Consumption	Max 100W	Estimated value
Operation Temperature	-30 ~ +50 °C	
Humidity	5 ~ 95%	

10.6.10 Juni WiMAX On-Frequency RF Repeater (JR33)24

The Juni JR33 WiMax On Frequency Repeater extends base station coverage to provide high speed data to shadow and no coverage areas. The JR33 is suitable for installation in small buildings, underground parking lots, Subway stations, shopping malls, and solar power sites. It offers high quality communications with lower OPEX and CAPEX costs. The unit is easy to install and uses a weatherproof IP55 rated cabinet.

Main characteristics

Output power : Total 33dBm (10 MHz Bandwidth)
Compliant to IEEE 802.16d/e WiMAX standards
Protection function for self oscillation

[24] http://www.juni.com.au/webnew/contents/products_wimax_jr33.asp

Internal Circuit Protection function when antenna open
HPA overpower protection (Shutdown)
AGC / ALC (Automatic Level Control)
Local monitoring via USB 2.0 connection
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 33dBm UL: 30dBm	
Gain Range	DL: 53 ~ 83dB UL: 50 ~ 80dB	1dB step, +/- 0.5dB Tolerance
Noise Figure	≤ 5dB	
System Delay	≤ 5µsec	
EVM	≤ 3 %	Compared to source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	334 X 386 X 202 mm, Max 21Kg	
Power Consumption	Max 250W	Estimated value
Operation Temperature	-10 ~ +50 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.11 Juni WiMAX Fibre Fed Repeater (JF41)25

Juni Fibre Fed Repeater is a type of WiMAX BTS sub-system used to cover the radio shadowed areas generated by unusual landscape or obstructions among base stations. It is a high-tech and high-efficiency service system that provides enhanced quality of service at low cost, as the Tx/Rx Signals between Optic Donor and Remote is transmitted through only 1 Core Fiber Optic. Further cost savings are possible by deploying additional Remotes from the same Donor unit.

[25] http://www.juni.com.au/webnew/contents/products_wimax_jf41.asp

Main characteristics

Remote Output power : Total 15W (41dBm)
Adjustable System Delay (Digital)
TDD Switching Function: PA Switching and LNA Switching
Scaleable architecture by adding additional Remotes (system total of 3 per Donor unit)
IP55 rated weather resistant enclosures enhance system reliability
Reverse Diversity
Optional back-up battery
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 41dBm	
Gain Range	DL: 45~85dB ±1dB UL: 35~60dB ±1dB	Donor + Remote
Noise Figure	≤ 6dB	
System Delay	≤ 4μsec	
EVM	≤ 5 %	Compared to source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor: 19 inch Rack Mounted, 15Kg Remote: 432 X 385 X 231 mm, 18.7Kg	

Power Consumption	Donor: 110W Remote: 365W	Estimated value
Operation Temperature	-20 ~ +50 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.12 Juni WiMAX Fibre Fed Repeater (JF45)[26]

Juni Fibre Fed Repeater is a type of WiMAX BTS sub-system used to cover the radio shadowed areas generated by unusual landscape or obstructions among base stations. It is a high-tech and high-efficiency service system that provides enhanced quality of service at low cost, as the Tx/Rx Signals between Optic Donor and Remote is transmitted through only 1 Core Fiber Optic. Further cost savings are possible by deploying additional Remotes from the same Donor unit.

Main characteristics
Remote Output power : Total 30W (45dBm)
Adjustable System Delay (Digital)
TDD Switching Function: PA Switching and LNA Switching
Scaleable architecture by adding additional Remotes (system total of 3 per Donor unit)
IP55 rated weather resistant enclosures enhance system reliability
Reverse Diversity
Optional back-up battery
Remote Monitoring using Juni OMC and wireless modem (optional)

[26] http://www.juni.com.au/webnew/contents/products_wimax_jf45.asp

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power	DL: 45dBm	
Gain Range	DL: 50~85dB ±1dB UL: 30~60dB ±1dB	Donor + Remote
Noise Figure	≤ 5dB	
System Delay	≤ 4μsec	
EVM	≤ 5 %	Compared to source

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor: 19 inch Rack Mounted, 40Kg Remote: 575 X 400 X 450 mm, 65Kg	
Power Consumption	Donor: 300W Remote: 500W	Estimated value
Operation Temperature	-20 ~ +50 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.13 Juni WiMAX Frequency Shift Repeater (JS37)[27]

The Juni JS37 5W WiMAX FSR (Frequency Shift Repeater) uses a second link frequency between the Donor and Remote units to provide coverage to shadow areas. The Juni FSR comprises of a donor and a remote unit and optional diversity unit. The donor changes the base station frequency to a link frequency and the remote changes the link frequency back to the base station frequency for local cell coverage. This process can be repeated by using a Cascade configuration to provide extended links, providing cost effective coverage solutions over extended areas.

Main characteristics

Perfect Solution for Local service coverage extension
Single, Star or Cascade Coverage
Max 5W output (Single FA)
Optional Diversity
Overpower Shutdown & Auto-recovery
Automatic Gain Setting (AGS)
Automatic Level Control (ALC)
Tower Top Low Noise Amplifier (TTLNA) power feed and alarm supervision

[27] http://www.juni.com.au/webnew/contents/products_wimax_js37.asp

Support for multiple External Alarm Inputs
Weather Proof Cabinets (IP55)
Local control from PC available with Local Maintenance Terminal software
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power (Donor)	DL: 37dBm	
Output Power (Remote)	DL: 37dBm UL: 37dBm	
Gain (Donor)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Gain (Remote)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Noise Figure	≤ 6dB	For the cascade system
System Delay	≤ 10μsec	

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor: TBD Remote: TBD	
Operation Temperature	-20 ~ +60 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.14 Juni WiMAX Frequency Shift Repeater (JS40)[28]

The Juni JS40 10W WiMAX FSR (Frequency Shift Repeater) uses a second link frequency between the Donor and Remote units to provide coverage to shadow areas. The Juni FSR comprises of a donor and a remote unit and optional diversity unit. The donor changes the base station frequency to a link frequency and the remote changes the link frequency back to the base station frequency for local cell coverage. This process can be repeated by using a Cascade configuration to provide extended links, providing cost effective coverage solutions over extended areas.

Main characteristics
Perfect Solution for Local service coverage extension
Single, Star or Cascade Coverage

[28] http://www.juni.com.au/webnew/contents/products_wimax_js40.asp

Max 10W output (Single FA)
Optional Diversity
Overpower Shutdown & Auto-recovery
Automatic Gain Setting (AGS)
Automatic Level Control (ALC)
Tower Top Low Noise Amplifier (TTLNA) power feed and alarm supervision
Support for multiple External Alarm Inputs
Weather Proof Cabinets (IP55)
Local control from PC available with Local Maintenance Terminal software
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power (Donor)	DL: 37dBm	
Output Power (Remote)	DL: 40dBm UL: 37dBm	
Gain (Donor)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Gain (Remote)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Noise Figure	≤ 6dB	For the cascade system
System Delay	≤ 10μsec	

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor: TBD Remote: TBD	
Operation Temperature	-20 ~ +60 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.15 Juni WiMAX Frequency Shift Repeater (JS43)[29]

The Juni JS43 20W WiMAX FSR (Frequency Shift Repeater) uses a second link frequency between the Donor and Remote units to provide coverage to shadow areas. The Juni FSR comprises of a donor and a remote unit and optional diversity unit. The donor changes the base station frequency to a link frequency and the remote changes the link frequency back to the base station frequency for local cell coverage. This process can be repeated by using a Cascade configuration to provide extended links, providing cost effective coverage solutions over extended areas.

[29] http://www.juni.com.au/webnew/contents/products_wimax_js43.asp

Main characteristics
Perfect Solution for Local service coverage extension
Single, Star or Cascade Coverage
Max 20W output (Single FA)
Optional Diversity
Overpower Shutdown & Auto-recovery
Automatic Gain Setting (AGS)
Automatic Level Control (ALC)
Tower Top Low Noise Amplifier (TTLNA) power feed and alarm supervision
Support for multiple External Alarm Inputs
Weather Proof Cabinets (IP55)
Local control from PC available with Local Maintenance Terminal software
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power (Donor)	DL: 37dBm	
Output Power (Remote)	DL: 43dBm UL: 37dBm	
Gain (Donor)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Gain (Remote)	DL: 60dB ± 1dB UL: 105dB ± 1dB	
Noise Figure	≤ 6dB	For the cascade system
System Delay	≤ 10μsec	

Mechanical Specifications

ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor: TBD Remote: TBD	
Operation Temperature	-20 ~ +60 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.16 Juni WiMAX Microwave Repeater (JU43)[30]

The Juni JU43 20W WiMAX Microwave Repeater uses a microwave frequency link (11GHz) between the Donor and Remote units to provide coverage to shadow areas. Utilising this microwave link, the JU43 is ideal for installations where the frequency spectrum is limited. Providing 20W of output power, the JU43 improves call quality by eliminating problems such as weak and unstable signals.

[30] http://www.juni.com.au/webnew/contents/products_wimax_ju43.asp

Main characteristics

Cost-effective rapid installation on roofs and tower structures
Weather-resistant cabinets
Flexible capacity enhancement to meet growing demand
Modular structure for quick and easy maintenance
Exceptional microwave frequency stability
Automatic microwave link fading compensation with dynamic power control algorithms
Remote Monitoring using Juni OMC and wireless modem (optional)

RF Specifications

ITEM	SPECIFICATION	REMARK
Service Frequency Band	2.3 / 2.5 / 3.5 / 5.8 GHz	
Output Power (WC)	DL: 43dBm UL:0dBm	
Output Power (AC)	DL: 43dBm UL:30dBm	
Gain Range	DL: 50~80dB UL: 30~60dB	
Noise Figure	≤ 5dB	
System Delay	≤ 5μsec	
EVM	≤ 5 %	Compared to source

Mechanical Specifications

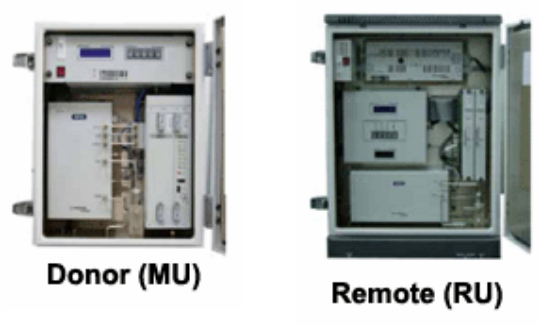
ITEM	SPECIFICATION	REMARK
Dimension / Weight	Donor(WC): 490 X 450 X 45 mm, 6Kg Donor(AC): 370 X 430 X 160 mm, 21Kg Remote: 400 X 600 X 450 mm, 60Kg	
Operation Temperature	-30 ~ +50 °C	
Humidity	5 ~ 95% @40 °C Max	

10.6.17 WiMax In-Building Repeater[31]

Juni WiMax Repeaters are a type of RAS (Radio Access Station) sub-system used to cover radio shadow areas created by unusual landscapes or obstructions among RAS. These high-tech / high-efficiency systems provide enhanced quality of service at relatively lower cost, especially as the Tx/Rx Signals between Optic Donor (MU) and Remote (RU) are transmitted through only 1 Fiber Optic Core. Further cost savings are possible by deploying additional Remotes from the same Donor unit.

[31] http://www.juni.com.au/webnew/contents/products_sub27.asp

10.6.18 JD40-L2300/MNI



Main characteristics

Remote Output power : Total 40dBm
1 MU can support 8 RUs
Comply to IEEE 802.16e and TTA 2.3GHz wireless standard for Potable Internet
Protection function for self oscillation
Receiver Diversity
HPA overpower protection (Shutdown)
Self isolation check function
ALC (Automatic Level Control)
Remoter Monitoring with SNMP and local monitoring with USB 2.0

10.6.19 TDD WiMax Fiber Optic Repeater 20W32

The Optical Fiber Repeater system is composed of two sub-units connected through an Optical Fiber:
BSU – Base Station Unit. An indoor unit, connected to BTS
RTU – Remote Transceiver Unit. An Outdoor unit, connected to the service Antenna

The BSU and RTU are communicating in order to synchronize the TDD frame between them and transferring status, alarms and monitors. The internal communication between the units is done using a dedicated service channel, located out of the WiMax frequency band

Main characteristics

i. Forward path
Output Frequency Range: 2500 - 2700MHz
BW: 10MHz, other BW is also available
VSWR : <1.5:1
Max Output Power: 5W, 10W, 20W
Gain: 30 to 70dB
Gain control step: 1dB
Gain flatness : ±-0.5dB max, over 10MHz

[32] http://www.unitywireless.com/pdf/repeaters/TDD_WiMax_Fiber_Optic_Repeater_20W_new.pdf

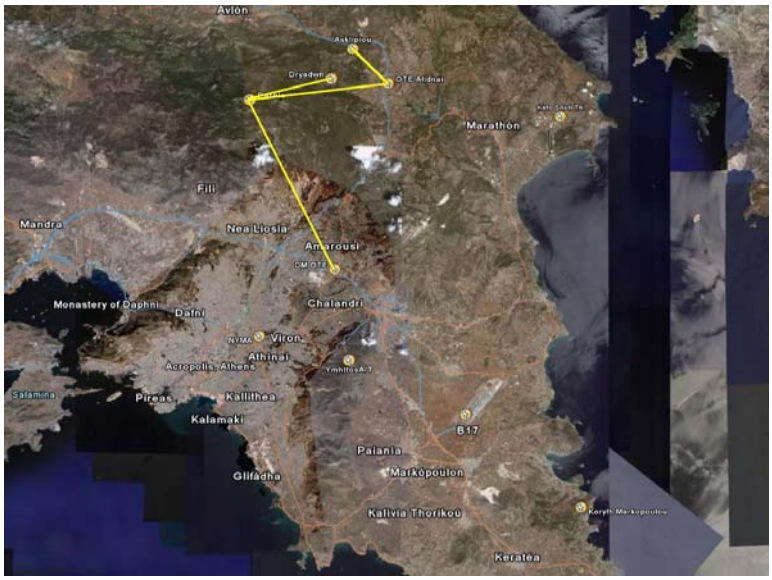
ii. Reverse path
Input Frequency Range 2500 - 2700MHz
VSWR <1.5:1
Noise Figure <5dB
Gain 40 to 70dB
Gain control step 1dB over complete range
Gain flatness ±-0.5dB max, over 10MHz

iii. Electrical Power, Mechanics, Environment
Dimensions WxHxD [cm] 40x60x26
Weight [Kg] 35
Mounting Pole, Wall
RF Connectors N-Type Female
Optical Connectors FC/APC
Operating Temperature -33 ÷ +55 °C
Humidity 95% relative
Power Supply 220VAC
Power Consumption <300W

10.7 OTE WiMAX Pilot Project Deployments33

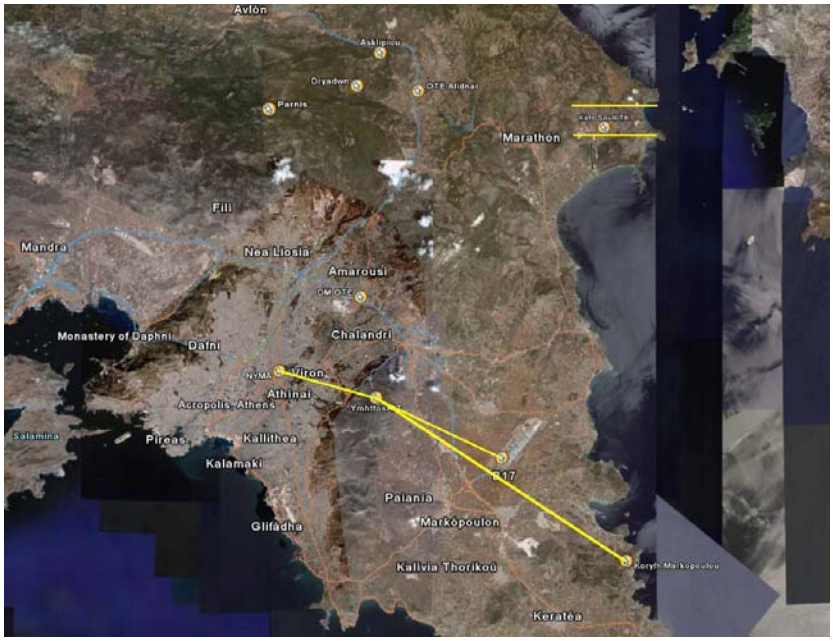
- Vendors: Redline, Aperto
- Services: Internet & VoIP
  - Internet (Best Effort)
  - FAX, VoIP (rtps)
- Other services availability: nomadicity

Pilot I – West Athens

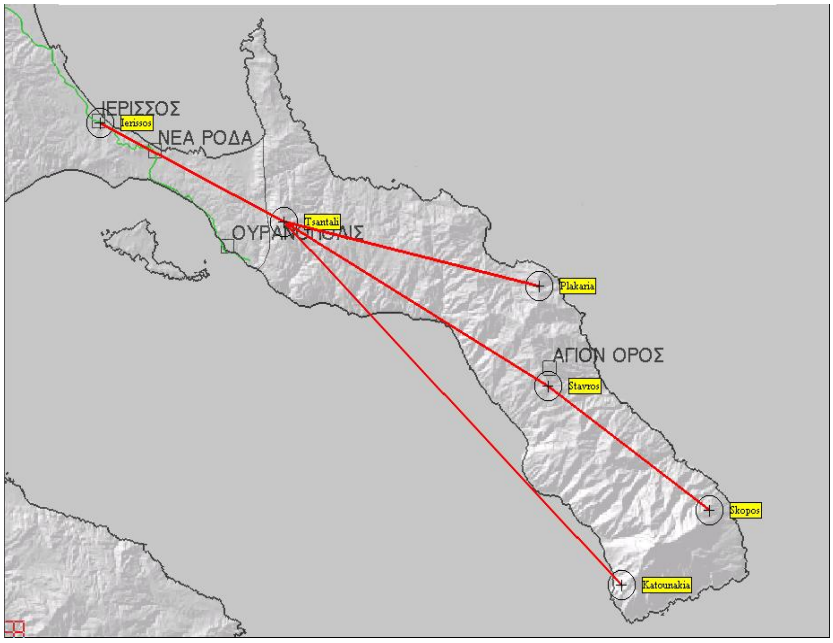


[33] http://www.ote.gr/anakoin.asp?cat=3

Pilot II – East Athens



Pilot III Mount Athos



10.7.1 Other WiMAX Deployments

10.7.1.1 Alvarion Deployment in Scottsburg34

A municipal wireless network in the city of Scottsburg, Indiana, USA, was recognized as the 'Best Municipal Wireless Deployment' at the prestigious Wireless Broadband Innovation Awards ceremony, held in London on May 17th. Built using Alvarion's mobile public safety suite with BreezeACCESS® products

Built by Alvarion solution partner, Advanced Computer Connections of Norwalk, Ohio, the network employs several of Alvarion's BreezeACCESS products including the BreezeACCESS VL, BreezeACCESS 900, and BreezeACCESS Mobile SU-M for mobile public safety applications. With complete coverage citywide, broadband is now available to residents, businesses, schools, and government offices, while also supporting mobile broadband for the city police department.

At a total cost of only $385,000 including all systems and software, the network is much more capital cost efficient than the $6 million necessary for Scottsburg to build its own fiber optic network. Moreover, building a fiber network causes major civic disruptions over several years, while the Alvarion network was up and running in just four months.

10.7.1.2 REDtone launches WiMAX to Eastern Malaysia

REDtone International Berhad (REDtone) has launched the first WiMAX network in Eastern Malaysia. The first phase of the WiMAX network covers Kota Kinabalu business district, enabling high-speed Internet access as well as data applications for enterprises.

In an effort to expand its broadband services offerings in the region, REDtone decided to establish a new network using WiMAX technology, which ensures quick deployment at a lower cost compared to fixed line solutions. Motorola is working with REDtone to deploy WiMAX equipment at base sites and install customer premises equipment (CPE) to provide broadband services in major business districts using REDtone's 2.3 GHz spectrum license.

Motorola's solution incorporates some of the latest techniques for increased coverage and network performance, including MIMO-B. Smart antenna techniques are a recent transmission breakthrough being incorporated into mobile broadband networks using WiMAX and LTE air protocols.

The operator is planning to expand coverage into Sabah and Sarawak through service provider partnerships to provide consumer broadband services. The region currently lacks the capacity required during peak periods to satisfy market demands, which is resulting in slow and limited Internet access. The new WiMAX network will bring additional bandwidth to the areas and improve overall user experiences.

[34] http://www.wimax-industry.com/ar/6i.htm

http://www.wimax.com/commentary/blog/blog-2008/august/redtone-launches-wimax-to-eastern-malaysia

10.7.1.3 BSNL to install WiMax BTS in 1,000 blocks

The state-run telecom company BSNL today announced plans to install WiMax base stations in 1,000 blocks across India by the end of 2008 to provide high-speed internet access to 25,000 villages.

http://www.wimax.com/commentary/news/wimax_industry_news/august-2008/bsnl-to-install-wimax-bts-in-1-000-blocks

10.7.1.4 US WiMAX deployment goes live in Jackson Hole, Wyoming

DigitalBridge Communications mobile WiMAX deployment has gone live in Jackson Hole, Wyoming courtesy of Alvarion's BreezeMAX gear.
DBC is expected to expand the network's reach in the area (which currently hits 3,000 homes and businesses), and then "add mobile capabilities throughout its 200,000-household footprint."
http://www.engadget.com/2008/07/01/first-us-wimax-deployment-goes-live-in-jackson-hole-wyoming/

WiMAX Telecom
WiMAX Telecom operates WiMAX networks in Austria and Slovakia and currently provides wireless broadband service to 8,500 customers. The company has twice received the Best of WiMAX World award for its pioneering efforts in introducing commercial WiMAX service in Europe.
http://www.wimax-telecom.net/en/index.php

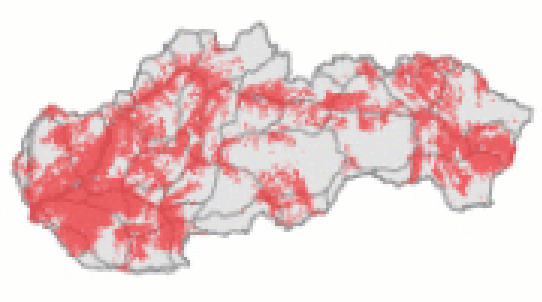
10.7.1.5 WiMAX Austria

3.5 GHz license in Austria (all 6 regions)
Region of Vienna and the surrounding areas (region 1) we have 2 x 28 MHz

http://www.wimax-telecom.net/en/index.php?id=21

10.7.1.6 WiMAX SLOVAKIA

Due to the acquisition of Amtel Networks the available combined spectrum grew to 56 MHz from initially 28 MHz. The enlarged spectrum will enable WiMAX Telecom Slovakia to extend its product portfolio and in the long run to plan for certain mobile services based on the new WiMAX standard 802.16e.
6'000 satisfied customers



10.8 WorldMAX35

WorldMAX is the owner of the nationwide and exclusive 3.5 GHz license in the Netherland. WorldMAX offers services based on Mobile WiMAX (IEEE 802.16e)
Worldmax says36 it has selected Alcatel-Lucent to supply it with a WiMAX 802.16e-2005 (Rev-e) network using the operator's 3.5GHz spectrum
The equipment supplier will provide an end-to-end WiMAX solution, including base stations, wireless access controllers and core equipment. Alcatel-Lucent will also be responsible for project management and integration of the network.

[35] http://www.worldmax.nl/en/Home
[36] http://www.telegeography.com/cu/article.php?article_id=21673

10.8.1.1 Packet One Networks Sdn. Bhd. (P1)

Packet One Networks Sdn. Bhd. (P1), the first Malaysian WiMAX converged telco and a subsidiary of Green Packet Berhad, officially opened its doors Thursday for Malaysians to subscribe to its WiMAX services, branded as P1 W1MAX.
P1 introduced two promotional packages to meet consumer and business needs. The promotion runs from Aug. 20 to Sept. 30, 2008.
P1 W1MAX broadband is available in the following areas: KLCC, Golden Triangle, Pekeliling, Setapak, Gombak, Seri Rampai, Sentul, Pudu, selected areas in Subang Jaya, USJ 1, USJ 7 and Subang Hi-Tech area. P1's deployment is supported by Intel.
P1 W1MAX is offering two initial packages for individual and business consumers through Sept. 30, 2008. Its P1 W1MAX 1200 has speeds up to 1.2 Mbps and starts at RM89 for a 24-month subscription. The P1 W1MAX 2400 offers up to 2.4 Mbps and begins at RM199 under a 24-month contract.
http://www.telecommagazine.com/techzones/wireless/article.asp?HH_ID=AR_4397

10.8.1.2 Max Telecom[37]

For the first time in Bulgaria Max Telecom has started to offer commercial solutions for personal broadband mobile communications using WiMAX technology.
In conformity with its license, Max Telecom is actively building a network with national coverage.
At this moment there is full WiMAX coverage in 14 Bulgarian towns.
Max Telecom will establish coverage in other big cities, where residents will have the opportunity to try the advantages of the high-speed mobile Internet without any monthly limit of consumption.
The expansion of the coverage zone throughout the country will continue to proceed and very soon a complete set of services, including connectivity, Internet access, virtual private networks and voice services with their own numerical number 0999, will be offered in every Bulgarian town and city.

10.9 Radio Spectrum Regulators in the European Union

Country	Name	Acronym	Website
Austria	Rundfunk & Telekom Regulierungs-GmbH	RTR	www.rtr.at/en
Belgium	Belgian Institute for Post and Telecommunications	BIPT	www.bipt.be
Bulgaria	Communications Regulation Commission	CRC	www.crc.bg
Cyprus	Ministry of Communications and Works	MCW	www.mcw.gov.cy
Czech Rep.	Czech Telecommunications Office	CTU	www.ctu.cz

[37] http://www.maxtelecom.bg/en/

Country	Name	Acronym	Website
Denmark	National IT and Telecom Agency	ITST	www.itst.dk
Estonia	Estonian Regulatory and Surveillance Authorities Reform	SA	www.sa.ee
Finland	Finnish Communications Regulatory Authority	FICORA	www.ficora.fi
France	Autorité de Régulation des Communications Électroniques et des Postes	ARCEP	www.arcep.fr
Germany	Bundesnetzagentur - Federal Network Agency		www.bundesnetzagentur.de
Greece	Hellenic Telecommunications and Post Commission	EETT	www.eett.gr
Hungary	National Communications Authority	NHH	www.nhh.hu
Iceland	The Post and Telecom Administration in Iceland	PTA	www.pta.is
Ireland	Commission for Communications Regulation	COMREG	www.comreg.ie
Italy	Autorita per le Garanzie nelle Comunicazioni	AGCOM	www.agcom.it
Latvia	Electronic Communications Office	ECO	www.esd.lv
Liechtenstein	Amt für Kommunikation / Office for Communications	AK	www.ak.llv.li
Lithuania	Communications Regulatory Authority	CRA	www.rrt.lt
Luxembourg	Institut Luxembourgeois de Régulation	ILR	www.ilr.lu
Malta	Malta Communications Authority	MCA	www.mca.org.mt
Netherlands	OPTA	OPTA	www.opta.nl
Norway	Norwegian Post and Telecommunications Authority	NPT	www.npt.no
Poland	Office of Electronic Communications	UKE	www.uke.gov.pl
Portugal	Autoridade Nacional de Comunicacoes	ANACOM	www.anacom.pt

Country	Name	Acronym	Website
Romania	National Authority for Management and Regulation in Communications of Romania	ANCOM	www.igcti.ro
Slovakia	Telecommunication Office of Slovak Republic	TUSR	www.teleoff.gov.sk
Slovenia	Post and Electronic Communications Agency of the Republic of Slovenia	APEK	www.apek.si
Spain	Comision del Mercado de las Telecomunicationes	CMT	www.cmt.es
Sweden	Swedish Post and Telecom Agency	PTS	www.pts.se
Switzerland	Federal Office of Communications	OFCOM	www.bakom.ch
UK	Office of Communications	OFCOM	www.ofcom.org.uk

Table 12 European National Radio Spectrum Regulators

11 Acronyms List

BS Base Station, same meaning as BTS
BTS Base Transceiver Station
BWA Broadband Wireless Access
CEPT European Conference of Postal and Telecommunications Administrations
CPE Customer Premises Equipment
ECC Electronic Communications Committee (of the EU)
EU European Union
FDD Frequency Division Duplex
FMC Fixed-to-Mobile Convergence
FttH Fiber to the Home
HSI High Speed Internet
IM Instant Messaging
IMT International Mobile Telecommunications
IP Internet Protocol
ISP Internet Service Provider
ITU International Telecommunications Union
LTE Long Term Evolution, the 3GPP OFDMA project
LTE-A LTE Advanced
LOS Line-of-Sight
MID Mobile Internet Device
MMR Mobile Multi-hop Relay, same as MRS
MNO Mobile Network Operator
MRS Multi-hop Relay Station
MSS Mobile Subscriber Stations
MVNO Mobile Virtual Network Operator
PCB Printed Circuit Board
PDA Personal Digital Assistant
PMP Point to Multi-Point
RF Radio Frequency
RS Relay Station
RSC Radio Spectrum Committee
RSPG Radio Spectrum Policy Group
TDD Time Division Duplex
ULL Unbundling of the Local Loop

12 Research and Information Sites

The information used to write this document has various sources. One of them is the knowledge and experience developed by Codium Networks as, probably, the most experienced independent system integrator of Mobile WIMAX wireless networks in Europe.
Other sources of information are various websites listed in this section.

12.1 Research Sites

Forrester Research: www.forrester.com
Maravedis: www.maravedis-bwa.com
Unstrung: www.unstrung.com
Trendsmedia: www.trendsmedia.com
ABI Research: www.abiresearch.com
Research and Markets (Wireless category):
http://www.researchandmarkets.com/categories.asp?cat_id=93
WiMAX Trends: www.wimaxtrends.com
Pyramid Research: www.pyramidresearch.com
Market Research: www.marketresearch.com
Telecom Paper: www.telecompaper.com
Juniper Research: http://www.juniperresearch.com
Informa Telecoms and Media: www.informatm.com
Senza Fili Consulting: http://www.senzafiliconsulting.com/
World Cellular Information Service: http://www.wcisdata.com/

12.2 Information sites

www.infonetics.com
www.wimaxforum.com
www.wimax.com
www.redherring.com
www.tamilstar.com
www.wimax360.com
www.m-trends.org
mobilesociety.typepad.com - Martin Sauter
3g4g.blogspot.com
orrtechnology.com – Jeff Orr
www.fiercewireless.com
www.intomobile.com
www.mmetrics.com
www.ucstrategies.com
www.wimaxxed.com
www.wimaxnetnews.com
www.wimax-industry.com
www.80216news.com
www.wimax-vision.com
www.mobilebroadbandgroup.com
www.mobilebroadbandnews.com

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[2] http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/update090608/
[3] http://www.wimaxtrends.com/2008/05/possible-uk-auction-delay-woul.html
[4] http://www.npt.no
[5] http://www.pts.se
[6] http://www.ericsson.com/ericsson/press/releases/20080509-1217750.shtml
[7] http://www.unstrung.com/document.asp?doc_id=157410
[8] http://www.disruptive-analysis.com/femto-aware_handsets.htm
[9] http://www.broadbandtvnews.com/?p=5311
[10] http://www.wimax.com/
[11] www.bbwexchange.com/publications/newswires/page546-1294458.asp
[12] http://www.wimax-industry.com/ar/1a.htm
[13] *Commission Decision of 21.5.2008, on the harmonisation of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community [C(2008) 1873 final, 21.05.2008]*. Brussels, Belgium: Commission of the European Communities. [http://ec.europa.eu/information_society/policy/radio_spectrum/docs/in_transit/bwa/bwa_en.pdf.]
[14] http://www.wimaxday.net/site/2008/05/28/wimax-spectrum-given-mobility-status-in-europe/
[15] The WiMAX Spectrum Picture, Adlane Fellah - Maravedis Inc. - 4-25-05.
[16] http://www.cellular-news.com/story/20223.php
[17] http://findarticles.com/p/articles/mi_pwwi/is_200804/ai_n25160688
[18] http://www.dslonair.de/dslonair/technik/was_ist_wimax
[19] http://en.wikipedia.org/wiki/List_of_deployed_WiMAX_networks
[20] http://www.ofcom.org.uk/media/news/2008/04/nr_20080404
[21] http://www.unstrung.com/
[22] http://www.freedom4communications.com/pg.asp?p=1219
[23] http://www.ukbroadband.co.uk/news.html#january2008
[24] http://www.urbanwimax.co.uk/
[25] http://news.softpedia.com/news/France-Is-at-War-Over-WiMax-Licenses-10818.shtml
[26] http://telephonyonline.com/wimax/regulatory/french_wimax_licenses_071006/
[27] http://www.irishbroadband.ie
[28] http://ninopatane.wordpress.com/2007/08/03/wimax-italy-guide-lines-are-now-officially-realased/
[29] http://arstechnica.com/news.ars/post/20061228-8516.html
[30] http://www.wimaxday.net/site/2008/04/16/bari-set-to-get-wimax-this-summer/
[31] http://www.wimax-telecom.net/en/index.php?id=21
[32] http://www.wimaxday.net/site/2007/10/03/telenor-launches-wimax-in-norway/
[33] http://all4wimax.com/?p=110
[34] http://www.wimaxday.net/site/2008/05/08/swedish-auction-fetches-21-billion-for-wimax-frequencies/