# Two-way Wireless Media Network with WiMax – Bridging the Digital Divide

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**Abstract**

This paper describes one of the largest WiMax based wireless broadband networks in the world and how it was implemented in co-operation between public authorities and private companies. The aim of the network is to ensure regional equality and increase the competitiveness of the sparsely populated area. There are two major findings in our paper. Firstly, our preliminary evaluations indicate that WiMax provides an effective and reliable transmission network also for video streaming. Secondly, we give an innovative example how wireless broadband networks can be used for value added services in sport events or other occasions for opening new business opportunities.

*Keywords:* Broadband access; WiMax; Digital divide; Public funding

## 1. Introduction

Digital divide does not exist only between nations but also between different areas of a country. Providing broadband connections in areas with low population density is an economical challenge for a network operator even in developed countries. Access to information is essential in the information society but it is not enough. For the development of rural areas it is important that content can also be created and not only consumed. Most of the access technologies used today offer an asymmetric service with lower uplink capacity. The service offering in addition to the service consumption instead requires symmetric communications. Only this way the vision of the Information Society "where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life" (WSIS, 2003) is reality also in developing areas.

WiMax (Worldwide for Microwave Interoperability Access) is a new promising wireless broadband technology, which can deliver high data rates for both directions over large areas to a large number of users. It looks especially promising to rural and developing areas where broadband is currently unavailable (Ghosh, 2005). So far it has been difficult to judge the WiMax's competitiveness in the marketplace and ability to open new business opportunities, because it has mainly been used in small-scale test networks and there has not been enough information about its performance.

Our paper describes one of the largest commercial WiMax networks in the world and preliminary delay and packet loss evaluations in it. In performance evaluations we use analytical cloud model to analyse the network performance of inter-connected networks. We also demonstrate how the network can be used for increasing the business potential of the area. In our example WiMax is used for two-way media services in a motor sport event with estimated 10 000 spectators. The WiMax network makes it possible to provide media feeds from remote special stages to the event centre, and the remote places can also be served with contents coming from other locations. Due the media services, the audience considers the event more valuable and therefore, the event attracts more advertisers and spectators who spend more time and money in it.

The structure of our study is as follows. In Chapter 2 we give a short introduction to the WiMax technology followed by a description of how the case network was implemented together with regional council, local municipalities, and private companies. In Chapter 3 the suitability of WiMax to two-way media transmission is analysed. A small scale network performance evaluation in inter-connected network environment is carried out and the results are compared against the specifications made by the Third Generation Partnership Project (3GPP). The actual case is covered in Chapter 4, and the final conclusions are in Chapter 5.

## 2. Wireless Broadband Networks

### *2.1 Technology Overview*

WiMax is the current IEEE standard for Broadband Wireless MAN networks supported by members of WiMax Forum. It provides a wireless alternative to cable, DSL and T1/E1 for last mile broadband access. WiMax or more officially 802.16 standards are created by the IEEE 802.16 Broadband Wireless Access (BWA) Working Group, which was established by IEEE Standards Board in 1999, with the aim to prepare formal specifications for the global deployment of broadband Wireless Metropolitan Area Networks (Eklund, 2002).

Like all telecommunication standards 802.16 has gone through several steps. The first 802.16 standard was approved in December 2001 followed by updates – 802.16c in 2002, and 802.16a in 2003 (WiMax, 2005). In September 2003, a revision project called 802.16REVd commenced aiming to align the standard with aspects of the European Telecommunications Standards Institute (ETSI) HIPERMAN standard. This project finished in 2004 with the release of 802.16-2004 (also called 802.16d) and the withdrawal of the earlier 802.16 documents (IEEE, 2004).

Devices based on this standard are now used for implementing fixed wireless networks all over the world. In the future WiMax will be able to offer also mobility as the 802.16e (IEEE, 2005) amendment will enable not just fixed, but also portable and mobile operation.

Fig. 1 shows the typical WiMax network and how it interconnects to other networks. It should be noticed that WiMax is only a part of the end-to-end network. WiMax is a Radio Access Network (RAN) technology which connects users wirelessly to the Core Network (CN). The CN is a wired infrastructure typically implemented with high capacity optical links. The WiMax operator’s CN interconnects further to other Internet Service Providers’ (ISP) networks allowing two-way communication between WiMax and other networks.

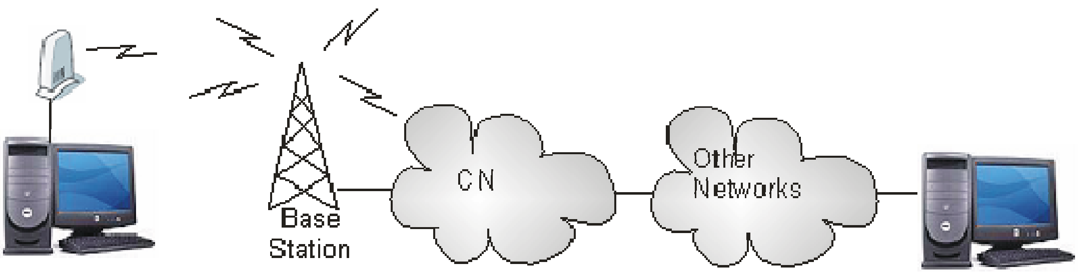


**Fig. 1. Structure of a WiMax network.**

### *2.2 eSavo Network*

In this section we shortly describe the development process of our case network. The network is located in Etelä-Savo region in Finland. We first give some details of the area and then proceed to explaining how the public funding of the network was organised. Finally, we explain the structure and implementation of the network.

#### *2.2.1 Etelä-Savo Region*

The region of Etelä-Savo is located in south-eastern Finland. Some statistics of the area are shown in Table 1. With a low population density and moderate share of urban population, Etelä-Savo is a typical example of a challenging area for operators to offer broadband access to their customers. Located in the heart of the Finnish Lake District, Etelä-Savo region has some 43 000 summer cottages and the large number of summer citizens increases the size of the broadband market as well.

**Table 1.**
**Statistics of the Etelä-Savo and Mainland Finland (Statistics Finland, 2005).**

| | **Etelä-Savo** | **Mainland Finland** |
|---|---|---|
| Total area ($km^2$) | 18 768 | 338 144 |
| Land area ($km^2$) | 14 137 | 304 472 |
| Population | 161 381 | 5 236 611 |
| Population density (person / $km^2$) | 11.4 | 17.2 |
| Urban population (%) | 68.6 | 83.4 |

#### *2.2.2 Public Funding of the eSavo Broadband Network*

The widespread introduction of broadband at affordable prices is one of the chief objectives of the EU's e-Europe 2005 action plan (EU, 2002). The Finnish national broadband strategy also highlights that comprehensive provision of high-speed telecommunications is vital in ensuring regional equality. The national strategy required regional councils and municipalities to jointly prepare a broadband strategy for their region and promote its implementation (Ministry of Transport and Communications, 2004). That also happened in Etelä-Savo.

Although multiple operators offered their broadband services in urban areas of the region, it was obvious that their networks were not spreading to rural areas quickly enough. To speed up the development, the regional council of Etelä-Savo decided to create a project for building the broadband network in those areas without broadband services. Based on the results of the pre-study, the regional council requested offers from operators in October 2004. The invitation of tenders did not specify the technology but it was up to the operators to select the suitable technology. However, the terms of public funding required that the coverage of the network must be 96 % and the network must be fully operational by 31.7.2006 (Regional Council, 2005a). In January 2005 the regional council selected the network operator. The total cost of the project was 1.7 M€ and public funding was 497 000 € or 29.2 per cent. Equal shares of public money came from EU and local municipalities (Regional Council, 2005b). The public funding was granted only to cover the cost of the initial investment. The operator should then cover all operational costs.

*2.2.3 Network Implementation*

The winning tender was a joint offer made by two companies, Mikkelin Puhelin and Savonlinnan Puhelin, and they shared the service area according to Fig. 2. As the Fig. shows, there was already a pre-WiMax based wireless network in the middle of the region which was not included to this network. The eSavo network has been reported to be the largest WiMax based commercial network in the world (Omnitele, 2005), and it has received some public interest in many countries.

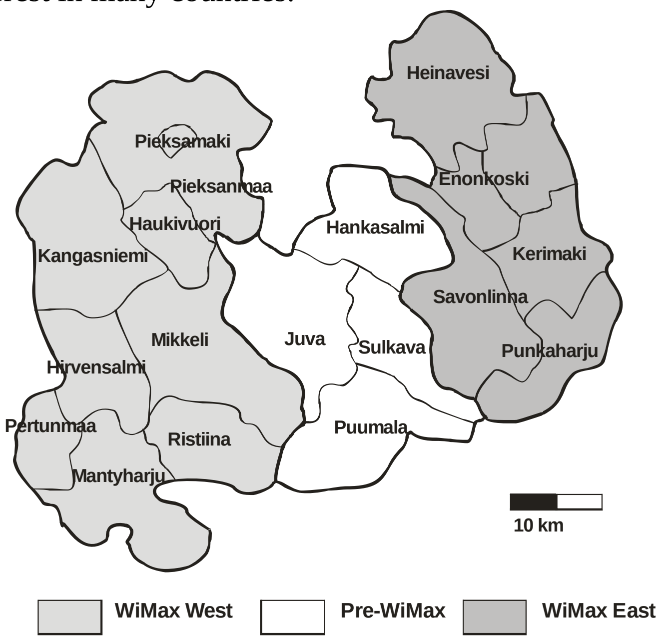


**Fig. 2. The coverage area of the eSavo network.**

Economics of scope have always had an important role in telecommunication networks and have also affected the network design in this case. Base stations are practically in all sites co-located with existing mobile phone network infrastructure. Without the existing infrastructure the implementation cost of the WiMax network would have been manifold.

The network speeds offered to the customers so far have been moderate (512 kbps to 2 Mbps) but higher bandwidths will be available in the future. The monthly fee of the WiMax connections are 0 – 20 per cent higher than similar ADSL services of the same operators. The introduction of the service has been successful and the number of customers has met all expectations. This clearly indicates that there has been a need for broadband service in these rural areas.

## 3. Preliminary Network Performance Evaluation

### *3.1 Quality of Service in Inter-Connected Networks*

The competitiveness of WiMax in marketplace depends on its performance characteristics like data rates, ranges, delays and loss ratios. A large number of performance measurements for other wireless networks exist (e.g. Moltchanov, 2002 and Xylomenos, 2004), but they cannot be used to predict the performance of WiMax. Ghosh (2005) has carried out extensive model-based performance evaluations of WiMax technology, but as far as we know no empirical measurements of commercial WiMax networks have been reported.

Network performance can be analysed from many perspectives. The Third Generation Partnership Project (3GPP) has classified applications into four general categories according to their quality of service characteristics (see Table 2).

**Table 2.**
**Traffic classes by 3GPP (3GPP, 2006).**

| | **Conversational** | **Interactive** | **Streaming** | **Background** |
|---|---|---|---|---|
| Fundamental characteristics | Preserve time relation (variation) between information entities of the stream<br><br>Conversational pattern (stringent and low delay) | Preserve payload content<br><br>Request response pattern | Preserve time relation (variation) between information entities of the stream | Preserve payload content<br><br>Destination is not expecting the data within a certain time |
| Example of the application | Voice | Web browsing | Streaming video | Background download of emails |
| Delay | << 1 sec | About 1 sec | < 10 sec | > 10 sec |

3GPP also gives more detailed descriptions of end user requirements for some popular services. The requirements of the most relevant applications are shown in Table 3.

**Table 3.**
**End User Requirements of Some Services (3GPP, 2005).**

| **Traffic class** | **Application** | **Degree of Symmetry** | **Data rate (kbps)** | **Delay (one way)** | **Information loss** |
|---|---|---|---|---|---|
| Conversational | Videophone | Two-way | 32 -384 | < 150 msec<br>< 100 msec lip sync | < 1 % FER |
| Interactive | Voice messaging | Primary one-way | 4 – 13 | < 1 sec for playback<br>< 2 sec for record | < 3 % FER |
| Streaming | Real-time video | Primary one-way | 20 – 384 | < 10 sec start-up<br>< 2 sec transport delay variation | < 2 % PLR |
| Streaming | Music | Primary One-way | 5 – 128 | < 10 sec start-up<br>< 2 sec transport delay variation | < 1 % PLR |

The QoS values in Table 3 represent end to end performance. However, WiMax is an access network technology and the other end of the communication is often located in some other network. This means that instead of analysing only the performance of a single network we must analyse the characteristics of interconnected networks.

Baumgartner (2003) has developed an analytical cloud model for performance evaluations of inter-connected networks. In the cloud model the network is divided into clouds or domains and inter-domain links. For each domain the set of edge nodes and their links to other domains are known but the topology of the domains is unknown. The original model makes an assumption that there is only negligible congestion and therefore packet loss in a single domain. Koivisto (2006) has applied the model for wireless networks where higher packet error ratios and reduced maximum throughputs of RAN must be included into the model.

According to the analytical cloud model the end to end connection can be seen as a group of interconnected clouds. Fig. 3 shows an example of three clouds. The first cloud is the WiMax RAN and the second one is the CN of the WiMax operator. The third cloud is the network of the other ISP or some other network.

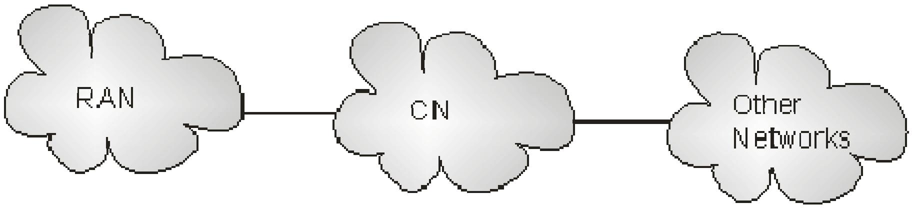


**Fig. 3. Cloud Model of Inter-Connected Networks.**

### *3.2 Performance Evaluation of the Case Network*

The structure of the media transmission network in our case is similar to the one in Fig. 3. The end points of the communication are in different ISP's networks and the access technology used in the other end is WiMax. The distance between the wireless subscriber station and WiMax base station is about two km providing a good signal strength and signal to noise ratio.

To be able to analyse both the end-to-end and cloud or network specific characteristics of our case we specified delay and packet loss coefficients for each cloud. We used ICMP Echo Request and Echo Reply message streams to find out the loss and delay characteristics of our case. We want to point out that our results apply to this case only and cannot be generalized to cover other network environments. The main reason for this is that in radio networks several parameters such as signal strength, co- and inter-channel interference as well as fading processes affect the transmission quality (Vornefeld, 2002). Also the implementation of the CN may vary. In most of the cases it is implemented with optical connections but in some place wireless links with higher error rates may be used.

The results of our measurements are summarized in Table 4. Although our results are preliminary they support the earlier findings of inter-connected wired and wireless networks. Our data suggest that in heterogeneous networks where both wired and wireless networks are used packet loss can be neglected in wired clouds. Packet loss coefficients of the WiMax RAN are close to one per cent and longer packets generate higher error rates. If the results are compared against the GPP specifications the network fulfills the requirements set to real time video streams (< 2 % PLR).

**Table 4.**
**Packet Loss and Delay in Inter-Connected Clouds (n = 20000).**

| | **RAN** | **CN** | **ISP** |
|---|---|---|---|
| Packet loss | | | |
| - packet size 128 bytes | 0.47 % | 0.00 % | 0.00 % |
| - packet size 1024 bytes | 1.11 % | 0.00 % | 0.00 % |
| Average delay (msec) | | | |
| - packet size 128 bytes | 60 | 3 | 6 |
| - packet size 1024 bytes | 78 | 3 | 7 |

Because our packet loss ratios were calculated as an average from quite a large sample and over a long period of time, there might be shorter periods with higher error rates. In order to find out possible error bursts we also analysed the packet loss distribution over time. However, we were not able to find noticeable error bursts since packet losses are equally distributed over time as shown in Fig. 4.

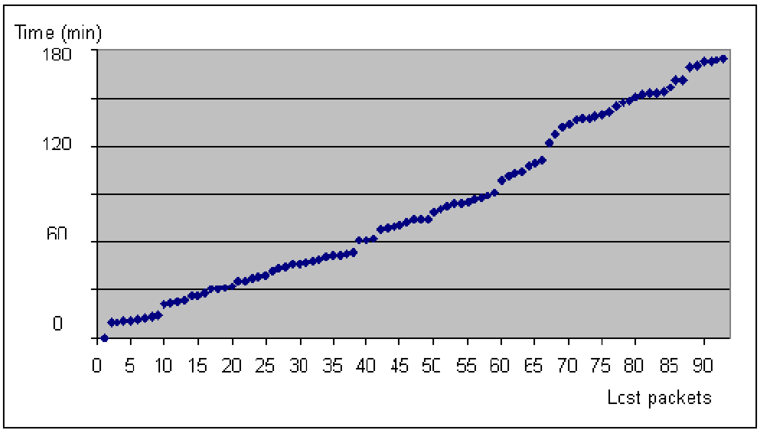

**Fig. 4. Lost packets as a function of time (packet length 128 bytes).**

Table 4 shows that delay is also mainly concentrated on the wireless access network. According to the 3GPP specifications, delays are, however, acceptable for interactive and even for conversational applications in excellent conditions.

## 4. Value Added Media Services with WiMax

### *4.1 Media Network in the Motor Sport Event*

In Finland motor sports are extremely popular. They get bigger TV audiences than any other sport. Finnish drivers have been very successful during the last decades. Although international events like Formula 1 or World Rally Championship (WRC) events attract a large number of viewers, national level rally events also have their fans.

As the rally consists of multiple special stages or legs which are located several kilometres from each other it is impossible for a spectator to be physically present in all locations. In the WRC events big TV companies have cameras in all special stages and they can broadcast all events to the audience. In national level events resources of this sort are not available but smaller-scale solutions are needed. The main challenge in smaller events has been the lack of communication capabilities between sites. Broadband networks now offer a new solution to this problem.

In a Finnish national rally event called Vaakuna-ralli 2006 the organizers wanted to test a two-way media transmission network between a remotely located special stage and the main event location with its service area. The structure of the media network is shown in Fig. 5.

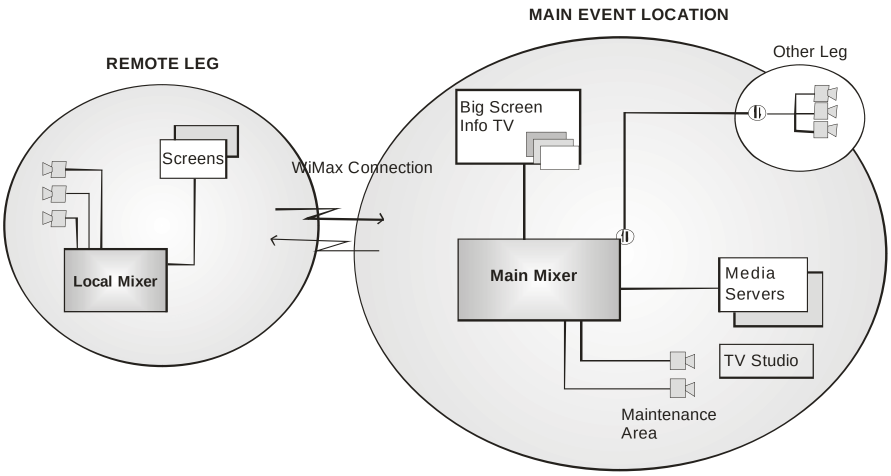

**Fig. 5. The Structure of the Media Network.**

In the special stage located some 15 km from the service park there were multiple cameras, some small screens in VIP and bar tents and a local video mixer. The result of the local mixer was sent to the local screens and through the WiMax network to the main event location. In the main event location there were cameras in the service park and in the TV studio for interviews etc. There were also pre-recorded materials on the media servers and fibre optical connections to another leg with three cameras. The program from the main mixer was sent to a large video wall in the service park and to an internal TV network as well as to the remote stage. Naturally the video feeds were highly compressed before they we sent over the public Internet and WiMax to the other end.

### *4.2 Results*

The aim of the media network was to offer better service to the audiences both in the special stage and in the main location. The main motivation for the local organizer is to be competitive compared with other organizers in Finland. The media project aimed at pleasing the audience and attracting more spectators who would spend more time and money in the event. Video walls, screens and the internal TV network also served advertisers and thus provided a revenue source for the organizers.

From a technical point of view the service level of the media network was good but some quality and reliability issues must still be developed further. However, the spectators were highly satisfied with the media services of the event. According to the satisfaction survey (Korkalainen, 2006) the audience highly appreciated the media service as can be seen from Table 4. More than half of the audience found the interviews and live video feeds from other special stages good or very good and only a small minority did not regard them as valuable.

**Table 4.**
**Satisfaction Ratings of the Audience (n= 190) (Korkalainen, 2006).**

| | Not at all | A little | Much | Very much | Cannot say |
|---|---|---|---|---|---|
| To what extent did the interviews shown on the screen make the event more enjoyable? | 2.9 % | 15.0 % | 34.7 % | 16.2 % | 31.2 % |
| To what extent did the live video feeds from other special stages make the event more enjoyable? | 6.8 % | 5.7 % | 39.0 % | 23.2 % | 25.4 % |

The results of the satisfaction survey and discussions with the organizers indicate that the whole concept of experiencing a rally event might change. People expect to see more than just a motor sport event. Already today in a WRC event there are a rally show, a kid's rally park, a rally expo, a rally party and a rally golf in addition to rally itself (Mahonen, 2005). In the future the service park with media services might enable the organizers to provide various rally-related services and entertainment in a small competition as well. The value-added services are likely to attract new audiences and the number of visitors in the service park can increase the total number of spectators. The new services may also attract spectators from special stages to main event location. To prevent that the value-added services should be available also in special stages and here a media transmission network has an important role.

According to the estimates of the Vaakuna-ralli organisers the new services in the service park did not decrease the number of spectators at the special stages. This is a positive signal, because it is possible to advertise the service park in advance unlike the special stages due the rules and regulations of the rally.

## 5. Conclusions

During the last decades the aim of telecommunication policies all over the world has been to increase competition and to ensure better services and lower prices for users. The policy has undoubtedly been successful, and we have witnessed a rapid growth of mobile, broadband, and Internet services. The new competitive environment has however made a clear separation between urban and rural areas. Although multiple operators are competing in cities and municipality centres there is not enough market potential in rural areas even for one operator. This is a real challenge because from the regional equality point of view the comprehensive provision of high-speed communications is crucial.

The regional council of Etelä-Savo wanted to speed up the introduction of broadband services in sparsely populated areas with public funding. The selection of the access network operator was based on competitive tenders. The public funding was 29.2 per cent of the initial investment. The winning offer was based on WiMax technology and our preliminary estimates suggest that the network is reliable and suitable for carrying video and other media streams as well.

The aim of the regional council’s project was to increase the competitiveness of the region and to establish new service and business opportunities. In this kind of projects the main interest has typically been in information access but we want to emphasize the importance of delivery as well. In symmetric networks the full potential of communication capabilities can be utilized and information can also be created and not only consumed.

In our motor sport case a two-way media transmission service was used between a service park and a special stage. This aimed at increasing the number of visitors and at better serving the spectators in order to make them spend more time and money. The main limitation of our study is that it cannot give any quantitative data on how much the media services have increased the market potential of the event. On the other hand, the audience satisfaction survey indicated that spectators highly valued the media services. The organizers of the event also shared this view.

In addition to increased satisfaction the result suggest that the whole concept of experiencing a rally event might be changing. Although the sport itself still is the core of the event, value added services are growing more and more important. It seems evident that media contributes to making the experience for the spectators even more enjoyable and to attracting more spectators and advertisers. Special attention should be paid to attracting new audiences instead of just moving visitors of special stages to the main even location. Our results indicates that when media services are available in multiple locations, the number of spectators at special stages does not decrease and the new service park visitors increase the total number of spectators. However, this phenomenon still needs to be studied in detail.

The concept used in the motor sport event can easily be modified for other occasions like culture festivals or village parties. Because WiMax is wireless technology it requires no wired infrastructure in the event location. Consequently, the new business potential is available in the whole coverage area of the network.

## References

Baumgartner, F., Scheidegger, M., & Braun, T. (2003). Enhancing discrete event network simulators with analytical network cloud models, *Proc. International Workshop on Inter-domain Performance and Simulation,* Salzburg, Austria.

Ghosh, A., & Wolter, D. (2005). Broadband Wireless Access with WiMax/802.16: Current Performance Benchmarks and Future Potential, *IEEE Communications Magazine, 43* (2), 129 – 136.

Eklund, C., Marks, R., Stanwood, K., & Wang, S. (2002). IEEE Standard 802.16: A Technical Overview of the WirelessMAN™ Air Interface for Broadband Wireless Access. *IEEE Communications Magazine, 40* (6), 98 – 107.

EU, (2002). *eEurope 2005: An information society for all, An action plan*, Commission of the European Communities.

IEEE, (2004). *802.16 IEEE Standard for Local and metropolitan area networks*, IEEE Computer Society & IEEE Microwave Theory and Techniques Society.

IEEE, (2005). *Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems- Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands,* IEEE Computer Society & IEEE Microwave Theory and Techniques Society.

Koivisto, M. (2006). User interface characteristics and network utilization in mobile networks, *to be appeared in Proc. 17th IASTED Conf. on Modelling and Simulation*, Montreal, Canada.

Korkalainen, J., & Hentunen, P. (2006). Unpublished satisfaction survey of Vaakuna-ralli.

Mahonen, J. (2005). Neste Rally Finland, Presentation on Sports and media seminar, Mikkeli Finland.

Ministry of Transport and Communications, (2004). Government resolution on Finland's national broadband strategy.

Moltchanov, D., Koucheryavy, Y., & Harju, J. (2002). Performance evaluation of multimedia services in heterogeneous wireless environment under different mobility patterns, *Proc. Conf. on Network Control and Engineering for QoS*, Paris, France.

Omnitele, (2005). Omnitele responsible for WiMAX network planning in Finland, Press release 5.12.2005.

Regional Council, (2005a). Network Contract, (in Finnish Verkon rakentamissopimus).

Regional Council, (2005b). Official record on Etelä-Savo Regional Council Meeting 17.1.2005 (in Finnish Maakuntahallituksen kokouksen 17.1.2005 pöytäkirja).

Statistics Finland, (2005). Key on Europe, Database on the various nations and regions of Europe.

Vornefeld, U. (2002). Analytical Performance Evaluation of Mobile Internet Access via GPRS Networks, *Proc. 8th European Wireless Conf.*, Florence, Italy.

WiMax, (2005). *Fixed, nomadic, portable and mobile applications for 802.16-2004 and 802.16e WiMAX networks*, WiMAX Forum White Paper.

WSIS, (2003). *Geneva Declaration of Principles*, World Summit on the Information Society.

Xylomenos, G., Polyzos, G., Mähönen, P., & Saaranen, M. (2004). *TCP/IP performance over wireless networks in high performance TCP/IP networking concepts, Issues, and Solutions* (ed. Hassan, M., & Jain, R.), Upper Saddle River, NJ: Pearson Prentice Hall.

3GPP, (2005). TS 22.105 Services and service capabilities, Rel-6, SP-29, The Third Generation Partnership Project.

3GPP, (2006). TS 23.107 Quality of Service (QoS) concept and architecture, Rel-6, SP-31, The Third Generation Partnership Project.