Fixed Broadband Wireless Access Trials at 40 GHz: Results, Conclusions and Future potential.

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INTRODUCTION

Broadband wireless access systems represent a flexible possibility for provision of high capacity last mile connections to smaller enterprises, organisations and private users. Systems operated in the frequency bands above 20 GHz have been under development, testing and implementation since 1995.
In these frequency bands systems can be operated in the 24.5-26.5 and the 28 GHz bands previously used for radio link systems and in the 40.5-43.5 GHz band allocated for this type of usage in Europe. Technology is more readily available at the lower bands, but the high capacity needed for broadband service provision to the public require the large spectrum resources available at 40 GHz. Development and testing of systems for operation at these frequencies has thus been a challenge. Cost is another issue mainly associated with market size, production volume and availability of technology.

This paper focuses on results and conclusions from several trials performed in connection with system studies, development and verification tests of operational principles and user reactions during the last 5 years.
The paper is mainly based on results from three projects, the ACTS project CRABS [1] which had as its main objective to develop and demonstrate a Local Multipoint Distribution System (LMDS) with interactivity, the IST project EMBRACE [2] with its main objective to contribute to develop of a low-cost reliable and efficient broadband wireless access system operated in the 40 GHz band, and an LMDS part of a Telenor trial on hybrid broadband access, employing an IP based Fixed Radio Access prototype system in a community in northern Norway. The two first systems are based on digital satellite broadcast technology (DVB-S) for the downlink [3]. They can provide TV as well as other digital information in the transport multiplex, while the third IP based system will have to deliver TV as IP multicast (TV on demand) if included.
The CRABS project ended in 1999, the other two projects will end in 2002.

SYSTEMS

Fixed broadband radio access systems employ point to multi-point distribution with several users sharing a high capacity channel preferably on an on demand basis, but combinations with a leased line solution are possible. This offers a downlink capacity varying from a few kbits/s up to several Mbits/s (limited by the capacity of the transport stream which is approximately 36 Mbit/s for a DVB-S transport stream). The return channels are individual, and have a lower maximum capacity per user than the downlink, depending on the needs of the user. For data delivery a 1-2 Mbit/s solution is sufficient for most users to day, but if video quality is wanted, 4-8 Mbit/s may be required. Other existing solutions have approximately the same capacities. Solutions for the private market must offer possibilities for broadcast, multicast and individual traffic including Internet and Telephony. It is anticipated that each license will be for minimum 500 MHz of spectrum, preferably more.
Using a cellular architecture of cell diameter 2-4 km, these systems have the potential of becoming a general type of access system addressing the demands of both private users, business organisations, schools etc, providing complete sets of services for each user group. It is observed that the private market may need more capacity than the business market if TV is included.
At millimetre frequencies the operational range is limited by line of sight and attenuation in precipitation. At 40 GHz the maximum range for reliable operation is normally 2-4 km depending somewhat on the local propagation conditions.

TRIALS

The first system developed were broadcast based with TV as the main service and with low interactive capacity. Interactivity was added gradually, starting with 64 kbit/s PSTN/ISDN which was sufficient for the typical Internet users 4-5 years ago and then increasing to 2 Mbit/s employing an in band radio solution. The main objectives of the trials run were to:

- Study performance of technical trials verifying the operational principles and testing the reliability and flexibility of available equipment.
- Identify basic built in limitations of systems operated at millimetre frequencies and test ideas for improvement. Inputs to organisations like ITU, CEPT and ETSI and demonstration of performance for operators and authorities were considered important.
- Perform user trials for verification of the interest for different broadband services on a European scenario.
- Perform registration of propagation parameters in parallel with technical and user trial for evaluation purposes.

Table 1 gives an overview of the CRABS trials [1].

Table 1. Overview of the trials in the ACTS project CRABS.

Partner/Location	**Type of trial**	**Services offered**
Telenor/Kjeller, Lillestrom	Interactive . Return channel: ISDN and a 2 Mb/s ATM compatible in band radio	Digital TV. Fast Internet. Services offered to families and a high school class. Internetworking to satellite demonstration of an remote LMDS slave cell fed through a satellite connection
Eurobell/ West Kent	Broadcast and interactive.	Digital TV. Telephony
RAI/Rome/Milan /Tourin	Interactive. 40 GHz radio link/PSTN	Data, Internet and broadcast. Educational system with remote classrooms main service demonstrated.
Demokritos/Athens	Interactive. Out of band radio for return.	Kiosk Internet to a cultural centre open for the public.
TESTCOM/Prague	Distributional. Low interactivity	
Podlipki/Korolev (Russia)	Broadcast and interactive. 40 GHz radio link for interactivity	TV, Internet , Telephony.

The CRABS project was an early phase project addressing user groups and operators in different European countries and propagation trials for evaluation of availability and coverage. The project included a Telecom operator, a broadcaster, a cable operator and an IP service provider all with somewhat different interest in interactive services in combination with digital TV and Telephony. High speed Internet was considered the service of the future.
The main long term trials were performed at Kjeller Norway, with 5 private homes and one high school class involved as users. During these trials it was demonstrated that LMDS was a flexible access technology for converged broadband services including TV/Interactive TV, Internet and telephony. A system for remote operation of an LMDS slave cell connected to the main cell at Kjeller by satellite was demonstrated at IBC in Amsterdam. In addition the system was used for demonstrations for industry, other operators and regulators.

The project as a whole gave valuable feedback.

- Users were pleased by the possibility of having in particular fast Internet. At that time there was no high capacity connections available. There was in particular a great interest from the high school where a class set was eventually connected. For the families with access it was observed that all the family members were active; husbands , wives and children. The kiosk that was operated in Athens had regular visitors.
- Technical issues represented some problems at the start. The concept was based on availability of DVB-S equipment at both transmitter and user ends and reliable 40 GHz equipment at the same locations. However when equipment was there it proved reliable. The equipment at Kjeller was actually operated a year after the project ended.
- Availability will be an issue. Attenuation caused by precipitation can be estimated from propagation data, and does not represent a major problem if the cell dimension is kept at an acceptable size. The main problems are caused by shielding from buildings and terrain and attenuation through vegetation. These are also effects that will vary with time. New constructions/buildings appear and trees have a tendency of growth. It was concluded that 3D planning tools for coverage prediction are needed, and development of such tools started.

The IST EMBRACE project has taken these ideas further. It has its focus in three main directions, access, interoperability and availability. The trials performed are more technical verification trials and demonstrations rather than user trials. This system is also based on the digital satellite broadcast type of downlink (DVB-S) with a MF-TDMA (Multiple Frequency Time Division Multiple Access) satellite type return [4].
Altogether three verification trials will be performed.
The first demonstration of the system was given during at IBC 2001, testing the functionality of the MF-TDMA return. A system consisting of one base station and two user stations was used for demonstration of WEB browsing, teleconferencing and IP telephony. Further demonstrations addressing interoperability with an interactive satellite network will be performed in June 2002. A diversity experiment utilizing switching between two base stations too improve availability for very demanding users will start at the same time.

The last trials to be mentioned are performed in Svolvær, Norway, with an IP based prototype system. The user terminal is basically a router connecting to a 10/100 Base-T Ethernet for local distribution.
The system has been operated during fall 2001 with 7 terminal locations (more users) representing 3 organisations/businesses and 4 private user groups.
A sketch of the set up at the user locations is shown in Fig. 1. It consists of an outdoor unit down converting the received signal to an L-band intermediate frequency sent to the indoor set top box by a cable. The set top box, which serves as a router, connects to Ethernet. The residential users will normally have both TVs and PCs connected, while the business users are normally equipped with PCs only.

User Equipment Configurations

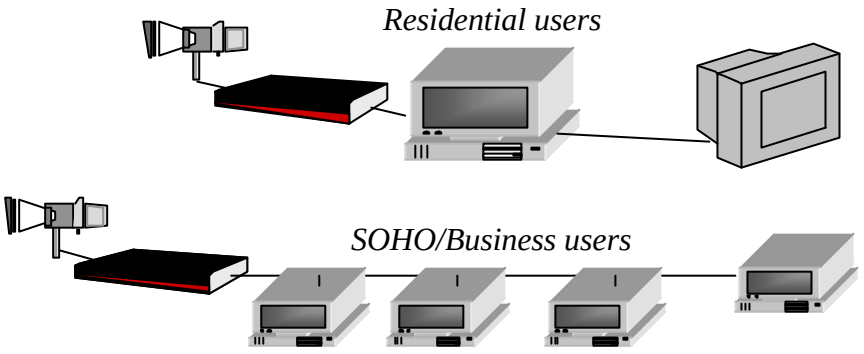

Fig. 1. Representative user equipment configurations for residential and business users.

The different users connected to this system are a local high school, a library, a mechanical industry making propellers, and four private homes with multiple users. The local high school has connected altogether 40 PCs to the system. They seem to be the most engaged user group. This was a solution they needed for their use of internet in education. It was efficient and easy to use. For the library and the engineering business the use seems to increase more gradually. They are also much more dependent on that their customers have a similar type of equipment.
The services offered have been high speed Internet to all users, Voice over IP and Video on demand and TV for private homes.

CONCLUDING REMARKS

The work towards development of 40 GHz fixed wireless systems started in Europe in 1995-96 with the main goal of making a system for combined TV distribution and Internet access with the possibility for inclusion of other services asked for in the future. The start was a broadcast system with some interactivity. The demands of the users have however changed with the growth of Internet and WEB-based services, home offices and use of document transfer downloading. Downloading of music has become very popular and new video services are being introduced. The demands for broadband access are increasing and fixed radio access will contribute together with interactive cable systems, VDSL, satellite and fibre solution for the very demanding user groups. The potential of the different solutions is illustrated in Table 2.

Table 2. Potential of different access technologies

Type technology	**Down link data rate**	**Up link data rate**	**Max range (km)**
Analogue modem	14.4-33.6 kb/s	14.4-33.6 kb/s	N/A
ISDN	128 kb/s	128 kb/s	N/A
ADSL	384 kb/s 640 kb/s	2 Mb/s 6-8 Mb/s	6 2-3
VDSL	640 kb/s 2 Mb/s	13 Mb/s 25 Mb/s	1.4 0.6
Cable Modems	0-384 kb/s	30 Mb/s	N/A
Satellite; DVB-RCS	2 Mb/s	36 Mb/s	Not limited
LMDS	0-8 Mb/s (in band) 25.8 Mb/s future	36 Mb/s 155 Mbit/s(future)	5

The efforts that has been put into development, establishment of operational criteria, understanding of user behaviour, verification of technical solutions, and systems studies are now about to become implemented in industry. The technology performs well and that it can offer the users with varying demands the flexibility they require. It is also a concept that match other potential access technologies well with regard to capacity as illustrated in the table. A shift from broadcast based systems to IP based systems is foreseen in the future.
Technology at these frequencies has so far not been developed to the stage required for low cost mass production, which means that introduction will take some time. The technology does however have possibilities for further improvement, and systems offering capacities of 155 Mbit/s are definitely within range.

REFERENCES

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