CICT Working Paper, no. 102, 2005

Drivers and Barriers for Development of Alternative Broadband

Reza Tadayoni and Halldor Sigurdsson

Center for Information and Communication Technologies CICT

Drivers and barriers for development of alternative broadband

Reza Tadayoni, M.Sc.E.E., Ph.D. & Halldor Sigurdson, M.Sc.E.E., Doctoral Student
Center for Tele-Information
Technical University of Denmark
Contact: reza@cti.dtu.dk
Tlf: +45 4525 5186, Mobile: +45 2926 5496

The status of the paper is 'Work in Progress'.

Abstract:

Alternative broadband infrastructures are emerging and developing very fast. Different technologies and organization/business models have been used to establish these networks. The aim of the paper is to understand and identify the technological, economic and political/regulatory drivers and barriers of this development, including the role of government in this process. The paper has a pure empirical approach and is mainly based on detailed case studies.

1. Introduction

One of the main challenges of network infrastructures in the developed world is efficient deployment of broadband technologies. Broadband is growing fast and its role in creation of values in the new economies is more and more recognized. In the 15 EU member states the number of broadband house holds has more than doubled in one and a half year, from app. 9 million in mid 2002 to app. 23 million in the beginning of 2004 (COCOM 2004). Also other developed regions especially the US and the South East Asian market have experienced tremendous growth in penetration of broadband. In South Korea about 96% of online users have broadband connectivity (ITU 2003). In Europe the development has been dominated by DSL technology, however other broadband technologies count for a substantial part of broadband households and growths rate.

One of the main challenges in the development of broadband has been the ability of regulation to open up the legacy telecom networks for provision of DSL services through, e.g., unbundling and Bit stream access. The open access discussion has further been raised in connection to provision of broadband through cable TV networks. The cable TV open access discussion is mainly important in the US. According to (Bittlingmayer G. et al 2002) the number of cable broadband is many times that of DSL broadband. Also in the European countries cable broadband is becoming an attractive competitor, especially in the era of triple/multi play. Bittlingmayer G. et al argue that open access can spur variety in ISPs and may reduce nominal prices for services.

Another technology which deploys a legacy network infrastructure is PLC, Power Line Communication. The emergence of PLC and argumentations on its viability has been based on the ubiquity of the Power line infrastructures but in reality the PLC technology has at best become a niche broadband product. In a recent paper (Tongia R. 2004) based on a techno-economic analysis, it is argued that PLC will not be able to compete on cost with other broadband technologies and the competitive advantage of this technology may be determined by other factors like the availability of the infrastructures in all rooms in the houses, etc. In this paper the advantages and disadvantages of PLC is briefly discussed at a theoretical level.

The focus of this paper is on the alternative broadband market segment. In the European statistics and discussions the cable modem broadband is also indicated as a part of alternative technologies. In this paper, however, the specificities of cable modem broadband is analyzed at a theoretical level but the notion ‘alternative networks’ is used for the broadband networks other than DSL and cable modem, namely the broadband technologies which implement new infrastructures and extend LAN and WLAN to the residential market segment using technologies like FTTx, WiFi, WiMAX, etc. This market is developing very fast and the focus of this paper is to identify the dynamics of this process.

This paper has mainly an empirical approach. The focus of the paper is on the market organisation of these new networks and the research question of the paper is to identify the drivers and barriers of this development, including the role of government. In a similar paper and by focusing on WiFi and Wireless grids François Bar and Herman Galperin have analysed the organisation issue of these networks. One of their research questions is: ‘..whether these grassroots efforts to build a wireless grid represent a significant alternative to the traditional, centrally driven process by which most large-scale communication networks have been built’ (Bar F. et al 2004). They conclude that the new organization forms create a fundamental challenge to the existing networks. It is argued that one of the main reasons for this is ‘the bottom up dynamics associated with WiFi development, where multiple network players are independently pursuing the development of wireless infrastructure’ (Bar F. et al 2004).

We are witnessing potentials for a paradigm shift, where new actors (in some cases the end user) have end to end control of the networks. In some of common uses, however, the telecom operators are kept as backbone providers. Regarding business model for these new networks, as far as the user have end to end ownership and control of a network the provision can be based on regular operation and maintenance of facilities in the organisation, housing association, etc. If different users own the same network a variety of models can be used; e.g., in the Canadian REN and in a city network in Denmark (frederkisberg.net) a condominium model known from apartments is deployed.

These networks have capabilities of offering Internet, voice and video services (triple play), which gives them possibility for competing with Voice service providers and TV access providers. There are however unsolved problems relate to efficient organisation and regulation of these platforms. Technology wise there are problems related to coverage, capacity, QoS, Security,… and when it comes to regulatory issues there are problems like universal service with regards to voice services, and with regards to TV services, there are a number of challenges like Copy Right, ‘must carry’, etc. known from the multi channel TV regulation. Also as seen in the paper, the market organisation and business models will have vital influence on the future of these platforms.

There is also a major issue of the role of government/local government in development of these networks. Gillett S.E. et al in an article named ‘Local government broadband initiatives’ has developed a taxanomy which distinguishes between four categories of local government action, based on the nature of the government’s role: ‘1) Government as broadband user. Government indirectly attracts commercial broadband deployment through demand-side policies. In particular, government uses its local leadership role or its role as a major telecommunications customer to assess, stimulate or aggregate demand. 2) Government as rule-maker. Government adopts or reforms local ordinances that affect the ease of commercial deployment, such as rights-of-way, utility pole attachments, road and building construction codes, zoning policies affecting wireless antenna placement, and cable franchise agreements. 3) Government as financier. Government provides subsidies for broadband users or providers, which may be direct or indirect in the form of planning or equipment grants, tax credits, or other incentives. 4) Government as infrastructure developer. Government adopts supply side policies in which a division of local government is ultimately responsible for the provision of one or more components of network infrastructure.’ (Gillett, S. E. et al 2004). On this basis (Gillett S.E et al 2004) gives an analysis of the US local government’s involvement in development of broadband and raises some future questions[1] on the universal service aspect and the capabilities of different technologies (wired and wireless). These are among subjects, which are included in the analysis of the current paper.

---

[1] Directly sited from the paper: ‘…Another interesting question of particular relevance to state and federal universal service policies is the impact of local government efforts on private-sector incentives to provide infrastructure. …A further area of inquiry relates to the choice of technology. For example, has the further development of wireless technologies (such as WiFi for LANs, and WiMax for fixed wireless loop alternatives) sufficiently reduced the cost of local infrastructure to the point where more local governments now find it financially viable to offer infrastructure? Does the availability of wireless, withits lower impact on physical infrastructure (less need to dig up roads, etc.), make a larger group of communities—including those with no municipal electric utility—more likely to provide communications infrastructure in the public sector? …. (Gillett S.E et al 2004)

In this paper through detailed case studies a number of these parameters are addressed. The analysis tries to identify the drivers and barriers of the development of alternative networks based on following parameters:

- The deployed technology and the technological capabilities
- The offered services
- The structure and architecture of networks
- The organisation and ownership structure
- The deployed business model and funding, including the role of government

The paper is organized in the following way: First in chapter 2 a technical analysis of the most relevant broadband infrastructures is given, then in chapter 3 the broadband services are discussed and later in chapter 4 the market and business aspects are analysed and finally in chapter 5 the role of government is discussed. In the empirical part in chapter 6 a detailed description of case studies is given. Chapter 7 contains the conclusion and chapter 8 references.

2. Infrastructure technologies

Development of Information and communication Technologies has in the last decades been primarily dominated by three main paradigms: 1) Development and deployment of efficient technologies for data communication, here the Internet Protocol (IP) has in close competition with other packet technologies proven its dominance, 2) The integration of different services in one and the same network, driven by the fact that operation and maintenance of different dedicated networks for different services is not optimal based on techno-economic assessment, and 3) Emergence of different mobile and wireless networks, driven by the need for mobility and flexibility in use of ICT services.

Broadband development took first place within the first paradigm and was an answer to the demand at the consumer side for high speed connections, primarily for improved quality access to the Internet. The development tendency, which we are witnessing now and which is foreseen to continue in the future is that the broadband development expands in scope and more and more is a part of the two other paradigms. Broadband infrastructures offer apart from Internet access to other known services like regular telephony and TV/video distribution, as well as possibility for new services like the intelligent/smart home services. Development in mobile and wireless networks are also in a high degree influenced by broadband development, both when it comes to the mobile 2G and 3G development and the development within the wireless technologies like WiFi and WiMAX.

Infrastructure platforms cover the whole infrastructure necessary for transmission of services from point A to B. Infrastructures contain networks with all their components, i.e., transmission lines, switches, routers, etc. necessary for transmission of data from point A to B. Infrastructures contain, furthermore, service enabler devices, in charge of operation of specific services like different servers, databases, etc.

In this section some of the major broadband infrastructures are described. The section gives a comparative analysis of the technical capabilities and advantages / disadvantages of major access infrastructures to identify how these technical characteristics influence on the market for broadband services, and to what degree these technologies influence on / determine the development of alternative infrastructures.

2.0 Internet protocol and the Internet

The emergence of the Internet, which is based on the IP protocol, is considered as one of the most radical innovations in the communication field in the recent years. IP technology is designed in a way that enables a radically different environment for innovation and competition, both when it comes to infrastructure platforms and service development platforms. In the following some of the important characteristics of IP platforms are outlined (ref.):

- ✓ IP technology is based on a distributed network architecture, where routing and intelligence are distributed in the network.
- ✓ In the IP networks, signaling and data transmission are integrated in the same network so that the end user establishes a connection and transmits data simultaneously. In other words: the network is connection-less, i.e., there is no need to establish connection in advance of data transmission.
- ✓ The service provision is disintegrated from infrastructure operation and the terminals attached at the edges of the network can create and offer services.
- ✓ The service development platforms have mainly been open, however, in development of streaming media technologies new tendencies can be considered.

These characteristics of the technology create optimal conditions for competition where several actors can be involved in service creation and provision. The general Internet is the major IP network in the world but it is far from the only IP network. In recent years, several private IP networks have been established and utilized at corporate and residential areas and the future of communication platforms, namely the NGN[2] architecture is mainly based on IP technology.

The private IP networks mainly have the same characteristics as the general Internet, however with a vital difference which is the possibility of establishing certain levels of QoS within these networks. This enables the providers of private IP networks to offer high quality services to their costumers. QoS in the IP based networks is implemented by allocation and reservation of capacity for different services following predefined prioritization schemes. The main deployment of QoS is, nevertheless, connected to the introduction and development of IPv6, which enables end-to-end QoS.

2.1 PSTN

Due to the wide spread installed based if the physical infrastructure of the PSTN it has been the basis for fast and efficient development and penetration of the Internet. In the pre broadband phase this was implemented by modulation of data signal in the same frequency spectrum of access copper lines as regular voice. The data capacity in this frequency bandwidth is small as it can reach the maximum of 56 kbps. The next phase was introduction of ISDN, which now is replaced by technologies with real broadband potentials, primarily based on different variants of xDSL

[2] For more discussions about NGN refer to EURESCOM: ‘Next Generation Networks: The Service Offering Standpoint, Technical Information, Requirements Analysis and Architecture Definition’, www.eurescom.de, 2001. For the regulatory and competition aspects of NGN please refer to Elixmann D. & Schimmel U.: ‘“Next Generation Networks” and challenges for future competition policy and regulation’, Communication and Strategies, issue 50, 2003.

technologies. The advantage of the xDSL is the availability of the physical infrastructure and by that the low deployment cost. As it is seen in the following, the technology has certain limitations when it comes to coverage and capacity. New xDSL technologies and standards try to solve some of the problems; however, as seen in the following some of the problems are connected to the physical characteristics of the PSTN copper infrastructure and necessities solutions that include changes in the infrastructure. This goes, however, against the mentioned advantages of xDSL related to deployment and cost. These are discussed in details in the following.

In the framework of this paper it is not relevant to analyze all xDSL variants. Therefore only the xDSL standards/technologies which are important in the development of broadband are taken into consideration

2.1.1 ADSL

ADSL (Asymmetric Digital Subscriber Line) is standardized such that the frequency bandwidth of regular telephony (below 4 KHz) on the access lines remains for telephony service. Broadband is transmitted on two other frequency bands: One of them is allocated to the low speed upstream channel (25 KHz to 138 KHz) and the other band is allocated to a high speed downstream channel (139 KHz to 1.1 MHz). The theoretical maximum bit rates of 8.1 Mbps is defined by the standard (Acterna 2002), but the bit rates, which can be achieved in praxis depends on different parameters, for example, of the distance between the household and the central, as the high frequent band of the copper line gets strongly attenuated as the distance increases[3]. This distance dependency results in a situation that some households can simply not be reached by ADSL even though they have access to PSTN infrastructures. Even in a country like Denmark which has a quiet advanced PSTN infrastructure in mid 2004 about 5% of households could not be reached by any ADSL services and only 70% of population could access a 2 Mbps connection.

As seen in the following the new generations of DSL standards try to overcome these limitations and enable the DSL platform to be competitive in the future broadband market.

2.1.2 ADSL2, ADSL2+ & RE-ADSL2

In the ADSL2 standards advanced technologies are implemented to improve the capacity/bit rate, establishing QoS and also in lesser degree to improve the coverage. Furthermore, ADSL 2 standard introduces radical innovations when it comes to power consumption, monitoring, etc. The extended possibilities for monitoring and control give the operators a tool to adjust utilization of resources, such that it becomes possible to deliver reliable capacity in spite of external degrading parameters like ‘Cross talk’ and noise. Improvement of capacity is, further, performed by utilizing more efficient modulation technologies, reduction of overhead, deployment of efficient coding algorithms and a number of other techniques (Aware, ADSL2 2002). Over short distances it is possible to achieve bit rates of about 12 Mbps downstream and 1.2 mbps upstream. Another way of achieving higher bit rates in ADSL2 is by bonding several lines. Here, at the ends of the connection multiplexing and de-multiplexing is deployed to split a connection to several parallel connection at one end and reassemble them at the other end.

ADSL2 enables implementation of QoS by, e.g., to split the bandwidth in different channels with different characteristics and reserve these channels for different applications. It is, e.g., possible to

[3] Apart from distance depends the reachable bit rates of other factors like the ‘Gauge’, ‘Cross talk’, ‘bridge taps’ …. []

allocate a 64 Kbps of the bandwidth for transmission of regular telephony. This makes it possible to establish a transparent communication path for transmission of PSTN services (the so called CVoADSL) without IP conversion or conversion to other protocol. This is a technology that enables PSTN operators to deliver efficient voice and data services. This is, however, not in line with the general VoIP development, which requires interoperable technologies across different platforms. As mention ADSL2 also enables possibility for minor coverage extension; For distances over 5 km a coverage improvement of about 5 Km is possible compared to ADSL.

In ADSL2+ the bit rate is increased by doubling the deployed frequency bandwidth, i.e., by including the frequency band between 1,1 to 2,2 MHz. As mentioned earlier, the high frequencies get strongly attenuated as function of distance which implies that the increase in bandwidth is only valid for short distances of under 2.4 Km. Doubling of capacity can be achieved for distances less than one Km.

RE-ADSL2 (Reach Extended ADSL2) is designed to optimize the coverage by increasing the power used in the lower part of frequency spectrum in the upstream and downstream channels. Here it is possible to achieve coverage extension of about 900 meter (Aware, RE-ADSL2 2004), which increases the potential market for PSTN operators considerably. The coverage problem is however not solved totally as there will still be areas where the PSTN operator cannot reach without changing of current network.

2.1.3 VDSL & UDSL

VDSL enables capacities of about 52 Mbps, which are higher than ADSL family. This is implemented by including more high frequency bandwidth in the copper cables and by deploying more efficient modulation. Furthermore, VDSL enables high speed symmetrical connections. The coverage of VDSL is on the contrary very short and is kept below 1.3 Km. However, due to the mentioned characteristics of copper lines the capacity is very much dependent on the distance and a the maximum distance the achievable capacity is about 13 Mbps. This implies that only in the very last part of the network (from street cabins to the households) the current installed infrastructure is used and there must be established a backbone network infrastructure to supply these street cabins. This backbone network will mainly be based on optical fiber technology. This implies further that compared to ADSL the cost of deployment is very high.

There are some limitations to VDSL, e.g., the co-existence between VDSL and ADSL is a challenge due to interference (Telco Systems 2002). Also interference from AM radio is a source for problem for VDSL. Furthermore there is a problem of supply of electricity to the street cabins, as in the regular telephony it has not been necessary to have power supply to these cabins. When it comes to interoperability, there is some advantages using VDSL (at least in short term) as it will be possible to offer symmetrical 10 Mbps Ethernet connections. VDSL2 is under standardization and the aim is to enable offering bit rates of up to 100 Mbps.

UDSL developed by Texas Instrument is the newest variant of DSL, which tries to utilize the unutilized resources in the Copper network and to give the PSTN operators the possibility to be competitive on the broadband market. UDSL promises aggregated bit rates of up to 200 Mbps, including 100 mbps symmetrical connections.

Uni-DSL comprises the whole DSL family: ADSL, ADSL2, ADSL2+, VDSL, the coming VDSL2 standard and UDSL. Hence the platform gives the operators a flexible possibility to offer a number of different connections to their customers. However, it is important to mention that offering high bit rate connections can not be done using the current PSTN infrastructure and as discussed in relation to VDSL it requires establishing a new infrastructure and utilizing the part of PSTN networks close to the households.

2.2 Cable TV modem

Cable TV infrastructure is another infrastructure with huge a installed base and with great potentials for delivery of broadband connections. In Denmark, e.g., the cable TV penetration is about 70%.

A cable TV system is a distributive system, where the resources are organized as a number of 8 MHz channels for broadcast TV distribution. Cable TV systems have huge capacity, however, the total capacity depends on how modern the system is and consequently on how much frequency bandwidth of the coax is utilized.

When cable TV infrastructure is used for broadband provision, a number of 8 MHz channels are allocated to broadband provision. In a one MHz channel it is possible to transmit between 27 and 56 Mbps depending on the deployed modulation technology and some other parameters, e.g., level of error correction. To enlarge the broadband capacity in the cable TV system several solutions can be used:

- Using new standards with more efficient modulations technology
- Modernize the cable TV system and utilize more frequencies (channels) in the system
- Reallocate more channels from TV to broadband
- Digitalize the cable TV distribution system. Consequently one TV service will occupy less frequencies and in this way it is possible to free some resources for broadband

Or more radically:

- Remove dedicated TV transmission and use the whole capacity for broadband and deliver TV over IP. This solution is however strongly dependent on development if IPTV technology

Cable TV infrastructure is optimally positioned in the future broadband market due to its capabilities in offering triple/multi-play services. This is because the network is optimized for TV distribution and capable to deliver broadband. Many other broadband infrastructures face a huge challenge in delivering of broadcast TV.

One of the weaknesses of Cable TV network in relation to broadband is that it is a shared medium, i.e., a number of users share the capacity in a network segment. Another problem which is connected to the current structure is that it is not a simple task to open the cable networks to a third party operator and establish competition. This is both due to the ‘shared medium’ aspect and because the cable TV networks are not standardized.

An important element in utilization of Cable TV structure for broadband is introduction of VoIP with QoS support. Here the dominating standard DOCSIS form Cable labs have done a quite number of advances (Chris R. 2004). Especially in DOCSIS 1.1 there are specific procedures for establishing prioritization to minimize delay and jitter which are highly necessary for VoIP. The problem is, however, that because of the mentioned problem of opening the network to third part operators, the general VoIP operators can not take advantage of these QoS improving measures.

2.3 Optical fiber

Optical fibers are broadband infrastructures with huge potentials, and they are highly relevant in relation to alternative broadband networks. Here the physical capacity is not indicated by Mbps but by Gbps and with regards to coverage we talk about distances of around 10 Km from the central points. Even though it is possible to offer capacities of Gbps, these capacities are not implemented at the end users site. Different reasons for this are discussed later in the paper and mainly are the cost of termination and the resource planning as well as pricing issues of the service provider.

Optical fiber infrastructures are implemented using different architectures which can be denoted commonly: FTTx (FTTHome, FTTArea, FTTCabinet, FTTCurbe, …). As seen in the case analysis later in the paper, different actors use different strategies.

Cost of deployment of the optical infrastructures is higher than other broadband technologies but the broadband product which can be offered in the fiber infrastructures are incomparable with the traditional broadband. The development in the last couple of years shows that the implementation of fiber infrastructures becomes more and more viable and that especially the power companies has been very active in the area. This is mainly due to decreasing cost of fiber, decreasing cost of termination equipments, general liberalization and the possibilities for offering triple/multi play.

2.4 Power Line Communication

For promotion of competition establishment of new access infrastructures has been very important ("Several pipes to the home"), and in connection to this broadband over power lines has been discussed, especially in Europe, for many years.
PLC utilizes the high frequency part of spectrum in the power lines in the existing power line infrastructure. Electricity supply is provided in the low 50-60 Hz band and the frequencies over 1 MHz can be used for broadband. With regards to the capacity PLC has been able to match DSL technologies in the recent years. One of the important arguments for PLC has been the ubiquity of the physical infrastructure. Power line infrastructures have very high penetration and the idea has been that one can use his infrastructure to offer broadband in an easy way and without establishing a totally new physical infrastructure. Another aspect is that all rooms in a house hold are connected to the power line infrastructure and this gives possibility for new and innovative services within the 'intelligent home' technologies paradigm. However this last aspect is out of the scope of this analysis.

There have been several problems with noise and interference, which are solved in certain degree in the low voltage part of the power line infrastructure. At EU level the EMC-directive is the only regulatory tool, which can be used to assess the level of interference and there is no agreement for harmonizing the interference requirements within power line (and other fixed infrastructures like xDSL) (EU, PLC (2003) & EU, PLC (2004)). According to (COCOM 2004) EU recommends the member countries to remove any barrier to development of services over PLC.

Even though the major technical obstacles like noise and interference are getting solved there are not that many market players (within and without the power line business) that see any future for this technology as a mean to deliver broadband services[4]. Based on a techno-economic analysis there is argued in (Tongia R. 2004) that PLC will not be able to compete on cost with other broadband technologies. In Denmark only one power line firm have commercial trails with PLC but they are planning to out phase it and replace it with FTTH connections. Other power companies like NVE that have a very solid broadband business have decided not to put any efforts for this technology from the very first day. What is evident is that the power companies get more and more involved in the broadband business but mainly by focusing on fiber technology.

In the Danish market PLC is deployed in a niche market with low scale in connection to some FTTx solutions. For example in one case a big apartment complex is supplied by fiber to the cellar. Connecting the apartments to this fiber requires that either the supplier should extend the fiber to the apartments, establish a new electrical cabling to the apartments or use PLC to deliver broadband to the apartments. Here it has been shown that PLC is a good solution when the number of interested apartments is low. The strategy of the provider in this case is that PLC is used only for Internet connectivity and real triple/multi play may wait until new broadband infrastructures are established.

2.5 Wireless and mobile technologies

Broadband development is not only a fixed network phenomenon. In the recent years there have been large developments within the mobile and wireless technologies with the aim of bringing high speed broadband connectivity to the end users. The wireless networks can be seen as competitive as well as complementary to the fixed broadband. Mobile and broadcast networks on the other hand are mainly seen as complementary networks to fixed and wireless broadband. The later (mobile and broadcast networks) is however out of the scope of this paper.

2.5.1 WiFi & FWA/WiMAX

The wireless network standard 802.11, which has gained most attention, was published by the Institute of Electrical and Electronics Engineers (IEEE) in 1999. Several variations of the standard have been published since - the best known is IEEE 802.11b, better known to the public as WiFi (Wireless Fidelity). The 802.11b standard uses the unlicensed Industrial, Science and Medical (ISM) band. In the absence of licensing barriers, and because of the simplicity of the technology and its cost effectiveness, WiFi networks have developed rapidly in both industrialized and developing countries. Indoor coverage of 50 to 100 meter is normal and depending on the standard, bitrates of 11 to 54 Mbps (in some proprietary version even more) is possible. WiFi coverage can be extended using outdoor antennas and also point to point connections can be established using WiFi.

WiMAX is base don IEEE802.16 standard, which can become the international FWA standard. Other FWA standards have shown not to be competitive in the access networks. In some cases FWA is used for business users and in the backbone network. FWAs lack of success in the access

[4] Data communication over PLC can be relevant when it comes to operation and maintainence and monitoring of the power line infrastructures

networks is due to different reasons; among others the lack of open standards and the requirement for Line of Site in the installations.

WiMAX is like WiFi becoming a standard, which is supported by several market actors. WiMAX is forecasted to be a simple and cheap technology with long coverage and high capacity. Coverage of 50 Km and capacity of around 70 Mbpes is a reality in this technology. It is however important to note that the capacity offered over long distances is only a fraction of the maximum capacity. And WiMAX as access technology is offered in distances 0f 5 to 10 Km. WiMAX will then be a good complementary /competitive infrastructure to traditional broadband. Another important aspect is that 70 Mbps will only be achieved if frequency bandwidth of 20 MHz is allocated and assigned by the local authorities. Probably many regulators will assign smaller frequency bands to the potential WiMAX operators.

3. Content and Service aspects

Service development platforms constitute the software environment necessary for the creation of services for given infrastructure platforms. Service development platforms are either open / infrastructure independent or tightly tied to specific infrastructures. This interrelationship between service development platforms and infrastructure platforms is one of the decisive parameters when it comes to development of broadband infrastructures.

To this day, most residential broadband networks have been designed to offer transmission services. These have typically been best effort connections to the Internet targeted for data services. With the addition of voice and video services in the broadband service portfolio, operators have to redefine their role and redesign their networks. The migration strategy chosen does not only affect the technical performance of the network but has also profound effect on the development and competition in service provisioning.

3.1 Real time services

Internet applications that require transport functions suitable for real-time data use the Real-time Transport Protocol (RTP). RTP was developed to support real-time transmission of audio and video over User Datagram Protocol (UDP). Due to the lack of end-to-end guaranties of UDP and inherent problems on the Internet such as Network Address Translation (NAT) and firewalls, much of today’s real-time traffic in residential broadband networks is transported using the Transmission Control Protocol (TCP) instead of UDP. TCP flow control mechanisms assure the correctness of TCP streams but the delay introduced by the retransmission of lost packets creates a bigger damage than the loss itself, if this is reasonably small (i.e. below 10%) [Su, 1999].

3.2 Quality of Service (QoS)

As broadband gains widespread adoption with residential users, revenue generating voice- and video-services have not yet taken off. This slow uptake is often attributed to lack of Quality of Service management in residential broadband networks. To resolve this and induce service variety, network access providers are implementing service differentiation in their networks where voice and video gets prioritised before data.

QoS can be defined as the experienced service quality at the consumption point. This includes partly the quality of service when the connection is established and partly the quality of network resource allocation and management. QoS is affected by following factors: Delay, Packet loss, Speech compresion, Echo, Firewalls, etc.

Different methods can be used to improve QoS. One can provide the necessary capacity in the backbone and access networks by over provisioning. QoS can also be implemented using one or more than following technologies:

- Diffserve(COS), ToS, RSVP,...
- Using priority schemes in the IPv6
- Using appropriate speach codecs
- Buffer size optimisation
- Packet size optimisation

The term IP services is used to denote packet based transmission of multimedia services using the Internet Protocol. The concept can be implemented in different forms, using different protocols, in different application scenarios. To analyse the evolution in the Danish market, this paper will look at three control dimensions: level of infrastructure centralization, level of system integration and system openness. The first dimension indicates the amount of central infrastructure is needed (how close to the user the "intelligence" in the network is placed)[5] while the latter controls to which degree users are integrated into structured communities. These three dimensions are somewhat interrelated but will be treated separately for later clarification of market trends.

Infrastructure Centralization

Broadband services can be deployed with a varying amount of infrastructure. Centralised infrastructure architectures correspond to the current PSTN, and have the following classical characteristics: infrastructure investment, controllability, reliability, and cheap and simple terminals. The contrast is decentralized (peer) architectures which are based on open transport networks (such as the Internet), peer-to-peer signalling paradigms like SIP, and functional elements at the edge of the network. In the middle are loose structures such as presence- or numbering systems.

System Integration

The level of network integration describes to witch degree services are intervened with the underlying infrastructure or service delivery platform. This can be everything from peers communicating on their own preconditions to structured communications platforms, such as the PSTN. Among the issues controlling the integration level is the required resource control, access scheme used, and service bundling. By tightly integrating services to the network infrastructure, infrastructure owners can limit service availability and competition. Infrastructure integration is however not the only type of system integration, by building up usage communities (such as Instant Messaging), service delivery platforms (such as IPTV through a set-top box), or through product

[5] This measurement of centralisation is in conformance with literature such as [BREAD, 2005]

bundling (such as bundling internet access and VoIP), operators can affect service consumption patterns and lock customers to their platforms.

System Openness

The openness of a service indicates the level of ‘lock in’ which the service provider maintains. This can be controlled through network interconnectivity and to which degree the service is based on standardised or proprietary protocols. In the era of IP based multimedia services, two worlds with different traditions towards openness are meeting, i.e. the proprietary world of traditional voice and video operators and the open, standardized world of IP and the Internet.

The trend in IP based services has been away from the decentralized paradigm towards a more structured form. In the Danish market this path can be described in three consecutive steps. The *first step* of this development was based on open computer to computer communication over the Internet (such as MS Netmeeting) where users communicated without any connectivity to any personal or infrastructure networks. In the *second step* users started forming or participating in loosely connected communities where they could communicate with other members of the group. To facilitate these groups, service providers established centralized systems for users could connect to. These systems often integrated different types of services, such as instant messaging, voice, and presence management. Although growing in size, these networks only provided limited functionality, such as one-way connection to the PSTN and did not have the momentum to terrorize the traditional markets, such as PSTN. In the *thirds step*, broadband has developed a service delivery platform which can offer ubiquitous service and quality level and therefore compete as a real alternative to other traditional services.

3.3 Standardization

Standardization is a very important parameters in development of broadband services. The important is obvious when it comes to VoIP and IPTV services. Today there are a number of competing standards and a variety of closed proprietary standards and technologies in these areas. This extends the cost and makes it difficult for the end users to make a choice and to move from one service provider to another one. The problem is comparable with the standardization problems of digital TV both when it comes to Conditional Access and Application Program Interfaces, which have has negative influence on the pay TV and Interactive TV markets.

3.4 Some examples of broadband services

POTS versus VoIP

The POTS (Plain Old Telephony Services) network is a dedicated network, which is optimized for voice communication. Because of the deployed technology and the way POTS services have historically been organized, a centralized structure has been implemented to offer POTS. Two separate networks are deployed in parallel in order to establish a network connection and to transmit services between point A and B, the so called transport and signaling/control layers. Consequently, service creation and provision require access to both the control/signaling layer and the transport layer of the network, which in turn requires access to the whole telecom infrastructure[6]. Even though interconnection to the POTS networks is possible, there are still huge entry barriers for newcomers to offer services in the POTS networks. The precondition for service provision in POTS is access to all infrastructure and services development platforms, which requires huge investments.

For a long time, POTS was seen as a natural monopoly. In the new regulatory paradigm, it is generally accepted that the networks must be opened up for competition through unbundling and interconnection regulation. However, within the traditional telecom paradigm, competition will at best exist between few actors in an oligopolistic market. The central reason for this has its roots in the technological architecture of infrastructure and service development platforms.

Using VoIP in a special technological set up has incrementally changed this situation and through a convergence process has opened up for new conditions for competition. Using VoIP technology and the general Internet as backbone, new providers offer competitive prices, for instance, for international calls. This service that is commonly known as ‘tele card service’ only relies on the POTS networks as facilitator of local calls. It then bypasses other parts of the POTS network and replaces them by VoIP over the general Internet. The transmission of the service over long distances within Internet is much cheaper than keeping the service within POTS with its cost structure and interconnection pricing schemes. The entry barriers for these service providers are lower and the number of them is increasing, contributing to the overall competition in the voice market.

Voice over IP

As depicted in Figure 1, there are three main implementation variants of ubiquitous residential VoIP services. This is consistent with other sources, such as Analysys that identifies three available business models for the future residential VoIP market [Analysys, 2004]. The implementation that prevails depends heavily upon customer adaptation and market dynamics. In the next section the Danish market will be analysed in regards to the hypothetical evolutionary path.

This could theoretically happen through an exhausting extension of isolated VoIP communities but more likely to be based on a two-way interconnection with other telephone networks such as PSTN.

---

[6] From an innovation point of view this architecture is seen as sub-optimal. A detailed discussion of the problems connected to this architecture is given in: Denton, T.M.: ‘Netheads vs. Bellheads - Research into Emerging Policy Issues in the Development and Deployment of Internet Protocols’, http://www.tmdenton.com/netheads.htm , 1999.

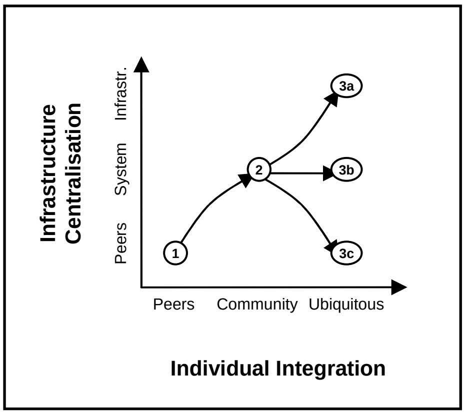

Figure 1: Hypothetical Evolutionary Path of Residential VoIP

Video/Audio service

Also Video and other audio services are important in development of broadband. Video/Audio streaming services have been available on the general Internet for some time. Broadband connections change the potentials for this development radically and enable the operators to offer IPTV and Video (Audio/Music) on Demand. Video and Audio will change the requirements to broadband radically and especially when HDTV gets certain level of development, the requirements to broadband will even change more radically.

Data services

Data services will also continue to develop and broadband will certainly give these services new conditions to develop. Here will traditional services like e-mail and browsing evolve but especially gaming can have vital influence on the requirement to broadband both when it comes to capacity and also QoS. Peer2peer will also be an important platform and will put some pressures on the asymmetrical paradigm that is dominating broadband connections of today.

4. Market and business models

Central to an efficient deployment of multimedia services is the role that network access providers resume in the broadband value chain. Alcatel identifies three basic business models for operators [Alcatel, ref. 1, 2004].

The current Internet is an example of the so called *public garden model* (often called ‘open access’ model), where the application layer is independent of an open access transportation layer and users can freely choose service providers. The advantage of this model is the incurred innovation and service development that takes place, and the resulting competition between service providers that benefits customers. On the downside, this model restricts the income possibilities and forces the network access provider to cover infrastructure and operational expenses from transmission fees from end-users.

In the second model, called *walled garden model*, the operator integrates the service and the infrastructure. Examples are the early telephony and the current satellite broadcasting industry. From the network access provider's point of view, the advantage of this model is the bundling of transmission and services and lock-in of customers. The disadvantage is expensive in-house implementation and low level of innovation and service development.

The third model, called the *gated garden model*, the operator controls the supply of services by specifically granting access to third-party service providers. Being service gatekeepers rather than sole service providers induces innovation and service diversity. Networks access providers can thus focus on their core business while reaping from service provision through fixed fees or profit-sharing. An example of successful implementation of this model is NTT DoCoMo's i-mode in Japan.

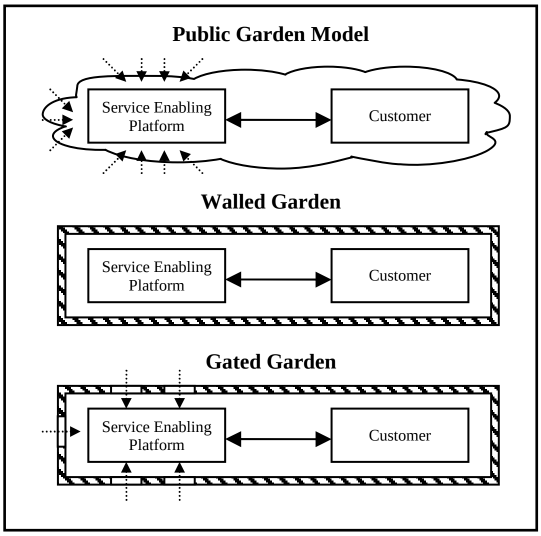

Figure 2: Service Models for Broadband Services

Through the history of telecommunication, the walled garden model has been the mode of operation. In a market dominated by incumbent operators, the traditional broadband market has maintained this legacy by integrating services with centralized infrastructure under heavy regulation, mainly in the form of open access to the last mile, i.e. local loop unbundling [Gabelmann, 2001]. Today however, the gated garden model is becoming the preferred model of many modern telecommunications operators as a mean to acquire new revenue streams from third party service providers. Furthermore, a new market trend is seen in the alternative broadband market where e.g. many municipal electric utilities (MEUs) are adopting the public garden / open access model.

4.1 Self organisation

There is obviously a paradigm shift in the organization of the new alternative networks. Here new actors (in some cases the end user) have end to end control of the networks. In some of common uses, however, the telecom operators are kept as backbone providers. Regarding organization and business model for these new networks, as far as the user have end to end ownership and control of a network the provision can be based on regular operation and maintenance of facilities in the organisation, housing association, etc. If different users own the same network a variety of models can be used; e.g., in the Canadian REN and in a city network in Denmark (frederkisberg.net) a condominium model known from apartments is deployed.

5. Public Sector Involvement

In an effort to influence the direction and pace of broadband development, some level of public sector involvement is often applied. This involvement can both take place on national and local/regional level but in this paper we will primarily focus on the latter. In a recent book on ‘Broadband Services – Business Models and Technologies for Community Networks’ Chlamtac et al (Chlamtac et al, 2005) discusses the possible models for public sector involvement in regional and local broadband projects. Furthermore, he argues that regardless of the model chosen, the local and regional authority bears an important role as stimulant and driver for broadband development by ‘1) raising awareness of the benefits of broadband services to all stakeholders of thee community to simulate interest 2) carry out community needs assessment of both public and private sectors to estimate potential demand 3) establish the business case for whatever type of intervention they choose in order to ensure efficient usage of any public funds 4) decide level of involvement and the model used for broadband deployment’.

To prevent conflict of interests for the public authority in its role as authority awarding rights of way to various operators, the EU regulatory framework for electronic communications requires local authorities that do decide to build a network or offer end user services to set up a separate legal entity at arm’s length from the local authority.

Based on the description of Chlamtac et al and the taxonomy developed by Gillett S.E. et al in an article entitled ‘Local government broadband initiatives’, the remainder of this section will be used to analyse the different models available for public sector involvement in regional and local broadband projects.

5.1 Government as broadband user / Aggregation of Demand

Government indirectly attracts commercial broadband deployment through demand-side policies. In particular, government uses its local leadership role or its role as a major telecommunications customer to assess, stimulate or aggregate demand. By this means, the region has better negotiation power against commercial broadband operators and can possibly attract new infrastructure investment through a guaranteed level of demand, and thus a guaranteed minimum revenue stream. Frequently, aggregation of demand is combined with other initiatives or models for broadband deployment by creating the required critical mass.

5.2. Government as rule-maker

Government adopts or reforms local ordinances that affect the ease of commercial deployment, such as rights-of-way, utility pole attachments, road and building construction codes, zoning policies affecting wireless antenna placement, and cable franchise agreements.

5.3 Government as Financer

Government provides subsidies for broadband users or providers, which may be direct or indirect in the form of planning or equipment grants, tax credits, or other incentives.

5.3 Government as Infrastructure Developer

In this approach the government invests in an infrastructure and thereby directly affects the supply in the market. Here, there are three operational models depending on the depth of involvement into the broadband value-chain (see Figure 3 where the level of intervention is marked by a horizontal dashed line).

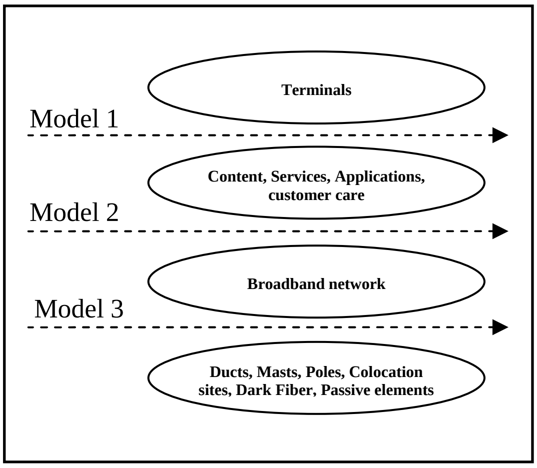

Figure 3: Models for level of government involvement in regional and local broadband projects

5.3.1 Government-operated networks and services

In this operational model, the local authority builds, owns and operates a broadband network and integrates the services to the platform according using the walled garden business model. This model is particularly attractive in rural areas with low level of telecommunications investment as it offers the advantage of a complete solution to the broadband needs of a community by a single actor. Disadvantages include negative impact on competition in networks and services, financial risk on the public sector, and it requires external technical and commercial expertise.

5.3.2 Carrier's carrier model

In this operational model, the local authority build, owns and operates a broadband network but disintegrate the service layer from the infrastructure and either use a public garden or gated garden business model to any commercial service provider interested in providing services via the network. The advantage of this model is that it significantly lowers the market entry cost for service providers and content providers, allowing them to diversity and extend their services to areas where it would otherwise have been prohibitively expensive to invest. Like in the first model, the disadvantages can include negative impact on competition in networks and services, financial risk on the public sector, and it requires external technical and commercial expertise.

5.3.3 Passive infrastructure model

In this operational model, the local authority builds the passive infrastructure, which includes trenches, ducts, masts, manholes, collocation sites, dark fiber and other civil structures necessary for the deployment of broadband networks. Higher level operation is then leased out to one or more competing operators, who complete the deployment with their own network equipment. The advantages of this model over for the carrier’s carrier model is that it only introduces government involvement at the lowest level of the value chain, which can enhance competition in all higher levels of the value chain. The disadvantages are also the same as in the carrier’s carrier model in addition to the entry barriers for network operators in the form of deployment investment.

6. Case studies

In the following four detailed case studies on alternative networks in the Danish market is given. Later some brief case descriptions of innovative initiatives are outlined. The four cases are chosen such that it becomes possible to analyze the parameters we have outlined in this paper. The first case is a City network, case number two is a community network, case number three is a power company provided network and the last case is an operator driven network with a large municipality as a big customer.

To put the cases in a broader perspective, in the following a short description of the Danish broadband market is presented.

In Denmark there are more than five million inhabitants and more than 2.4 million households. Following table shows general statistics on broadband penetration in Denmark and its growth since end 2002.

	12/02	06/03	12/03	06/04
DSL coverage (% of population)	95%	95%	95%	
DSL subscribers	307.000	390.693	473.481	562.112
DSL penetration (% of population)	5,7%	7,2%	8,8%	10,4%
Cable modem coverage (% population)				
Cable modem subscribers	133.548	177.304	243.602	297.155
Cable modem penetration (% population)	2,5%	3,3%	4,5%	5,5%
FTTH subscribers	na	35.000	42.400	86.142
PLC subscribers	0	0	0	0
WLL subscribers	1.485	1.760	2.332	3.019
Satellite subscribers	0	0	0	
Total	442.033	604.757	761.815	948.428
Total penetration (% population)	8,2%	11,2%	14,1%	17,6%

Today the number of broadband subscribers in Denmark is exceeded one million and the portion of alternative networks is increasing rapidly. Following cases give an indication of the variety of network initiatives in spreading out the broadband infrastructures and services in Denmark.

6.1 City network; Frederiksberg net

Freaderiksberg Net (FrbNet) is a 'non profit' community network serving residents in a part of Copenhagen, called the Frederiksberg commune. The company was founded by two entrepreneurs in 2000 following a civil meeting and established with private and bank loans. The company is operated as a partnership organization where all members of the network own an equal share in the company. Independently of the commune, but as customer of some of the services offered by the commune (such as billing and passive infrastructure), the goal of the company is to serve as many as possible from their 20.000 customer base with as cheap broadband, telephone, and television services as possible.

The company has five employees, of which four attend technical matters and one management and administration. To streamline operations and minimize staff, the company uses simple business models (such as flat rate charges rather than usage measured) and outsources as many tasks as possible (billing, PSTN interconnectivity and termination, fibre installation and deployment etc.). The company thus has a relatively simple in-house operation and overhead but a more complex relation to subcontractors.

FrbNet uses a FTTB solution to connect buildings to their own Ethernet backbone network. The backbone network is build up gradually based on requests from building complexes. For deploying the fibre, the company buys access to an already established underground tube infrastructure in Frederiksberg owned and operated by the local fire department[7]. FrbNet thus owns and operates the fibre cables but pays a distance related fee for deployment and a distance related yearly fee.

Upon connectivity, FrbNet installs their own router, switch and ATA (analogue telephone adaptor), but building complexes (condominium) need to rewire all apartments with two sets of eight strand UTP cables themselves. No equipment is needed inside apartments as one cable provides LAN connectivity and 2-4 strands of the other are used for POT services. At his time the company does not offer video or television services.

The pricing structure is based on flat-rate subscriptions to users depending on bandwidth. The current fees are monthly fees of € 13 for 1 Mbps, € 20 for 2 Mbps, and € 36 for 10 Mbps. The VoIP is offered for a flat rate of € 20, including unlimited fixed line minutes. When bundled with internet subscription, VoIP and 2 Mbps are offered with a € 3 discount, and VoIP and 10 Mbps with € 10 discount.

FrbNet uses an immature 'gated garden' business model where the company in the lack of external service providers has implemented both Internet provision and a telephone service in-house.

[7] These special circumstances arise from an over 20 year old initiative by the Frederiksberg fire department to directly connect all apartments in the area with an automatic fire alarm to the fire department headquarters. Today, the fire department openly sells access to this infrastructure.

Technical solutions are based around standardized pure Ethernet equipment which they consider as one of their success criteria. The VoIP service is based on the Asterisk, open source Linux PBX. PSTN interconnectivity is provided through a telephone wholesale contract where FrbNet also gets number series to offer their customers.

With an increasing customer base, the company hopes to attract external multimedia service providers both to replace the existing telephone service as well as to introduce new VoD and IPTV services. Growth in the customer base continuously affects the organizational structure of the company and before video services can be offered organizational decisions about business models and billing solutions need to be taken.

The company regards introduction of video services as the most difficult future task due to the following challenges and barriers:

- *Cabling*
  Access price to incumbent owned coaxial cables from basement to apartments is used as a barrier by the incumbent.
- *Content*
  The cost of content is too high for a small customer base like FrbNet.
- *Standardization*
  There is a lack of standardisation both in encoding (MPEG, WMF, HighDef) as well as in set-top boxes.
- *Planning and organization*
  The addition of VoD and IPTV changes the structure of the existing systems, i.e. transmission pricing and billing.
- *Vendor relations*
  Content owners want to establish direct relationship with viewers instead of through FrbNet.
- *Distribution*
  Distribution is more of a technical challenge (rather than barrier) but can be solved (the network supports it)
- *Demand*
  FrbNet feels that customers are not looking for (there is not demand) for alternative television services. The demand is for cheap Internet and telephone.

On the future horizon, FrbNet see improved service quality rather than price reductions. This could e.g. be in the form of fibre cables from basement to apartments and introduction of VoD and IPTV services.

In conclusion, FrbNet is a ‘non-profit’ city network that due to inexpensive standardized equipment and access to existing public infrastructure and services (lowered entry barrier) can offer cheap IP services. The company has limited financial resources and investment and operational cost is kept at a minimum through steady growth, small overhead and outsourcing. The company uses an immature ‘gated garden’ model to offer Internet and telephone services over a converged Ethernet FTTB infrastructure. Driven by aggregated demand from building complexes (condominium) the company faces continuous financial and organizational challenges.

6.2 Community Network; DjurslandS.Net

DjurslandS.net is a non-profit community network in the rural area of Djursland. The company stems from a grass-root movement ‘Boevl’ that through support from the local commune has been arranging voluntary computer teaching in the community since 1992. Today the company has evolved into an umbrella organisation for eight local community wireless networks. The goal of the company is to avoid an ongoing social regression in the region by providing affordable high-speed internet access to all residents of the region.

During the planning phase of 2000-2002, the company first tried to gather a critical mass of potential customers in the region to strengthen bargaining power against commercial operators. However, since 25% of the 32.000 households (population of 82.000) in the region are outside the reach of traditional DSL and cable, none of the commercial operators could meet the goals of the company. The company therefore started testing and evaluating wireless and satellite access and concluded that wireless access was superior due to the high transmission delay in satellite technology.

In 2002 the company got an EU grant to partly finance the build-up and operation of their own wireless access network based on the 802.11b standard. Being a non-profit community organisation the company had troubles raising the remaining investment capital and therefore the decision was taken to divide the company into the eight local community networks that it now is composed of, each responsible for funding their own access points. For backbone connectivity, the company relies on a mix of an existing public regional fibre network (carrier’s carrier model) and ADSL connections to interconnect its current 150 access points.

The operation is based on standardised equipment and open source software where available and the ‘do-it-yourself’ paradigm (e.g. to minimise cost the company assembles it own access points and antennas). For operation, the company gets indirect support from the regional government through sharing of its 10 employees and housing (e.g. the offices are in the basement of the local gymnasium), and relies on local voluntary work.

To subscribe, users within 1,5 Km of an access point can buy a standard package including an outdoor mountable amplifying receiver for € 265 or users within 5 Km can buy an extended package witch also includes an extra outdoor antenna. The company offers a flat rate monthly subscription fee of € 13,50 for a 1-6 Mbps shared duplex bandwidth (multiplexing of up to 20-30 users). In yearend 2004, DjurslandS.Net had 2.200 customers making them the largest non-commercial wireless network in Europe.

The company adopts a simple mix of ‘public garden’ and ‘walled garden’ business model based on providing Internet access and encourage users to use the connection as much as widely as possible. To provide the required data services, the company however bundles e-mail, homepage etc. into the subscription fee.

As a future development, the company is investigating adoption of new wireless standards such as 802.11a and g and evaluating and testing VoIP. However, there are no concrete plans for upgrading the infrastructure or adding new services such as voice or video. This can both be contributed to the technical limitations of wireless networks but also to the competitive situation with other traditional technologies such as PSTN and terrestrial television.

When asked about the community support and devotion and the commercial viability of the project and the founder of the company points out that the characteristics of rural areas in the form of solidarity, responsibility and common ‘do-it-yourself’ mentality. Operators don’t see a commercial basis in meeting the demand of the rural areas and therefore, as a last resort, necessity and vision drives the users to start a common initiative. The solution then becomes different from the commercial strategy, not only in terms of profitability but also on the social level as the community network is not based on hiring professionals for all task but based on using the available resources and build up competences in the community.

In conclusion, DjurslandS.Net is a ‘non-profit’ rural community network that due to unmet demand for broadband connectivity in regions outside the reach of traditional technologies and financial support from EU has implemented a wireless infrastructure. The company has limited financial resources and minimizes investment and operational cost e.g. through access to a public backbone network, voluntary work, and indirect support from the commune. The company adopts a simple mix of ‘public garden’ and ‘walled garden’ business model to provide inexpensive internet access. Driven by local support and solidarity the company faces continuous financial and organizational challenges.

6.3 Energy Utility; NESA

NESA A/S is energy utility company operating in the vicinity of Copenhagen. The company has its core activities of electricity distribution and trade and is the biggest electricity provider in Denmark with 535.000 customers. For the past 15 years the company has been deploying fiber cables to support its core activities, e.g. through an IP based control system for their electricity installations, and now owns more than 25.000 Km of fibers and more than 700 Km of fiber traces.

In 2002 the company diversified into the broadband market and started implementing and testing a FTTH network. In yearend 2004 the company had 800 active homes participating in a commercial pilot project. The deployment strategy of the company is to lay down empty micro duct tubes with power cables, for subsequent blowing of fiber. The company has already connected 20.000 homes with tubes and intends to lay tubes to 200.000 homes in the next 5-7 years. The company has not yet taken decision about fiber roll-out in the tubes and according to them there is a need for political support in role-out of fiber infrastructure, as they phrase it: “all important infrastructure projects require political support” [].

According to NESA there are several important synergies between electricity supply and fiber optic infrastructure supply: a) common network planning, b) Common digging projects, c) Common network control and monitoring, and d) common service organization. The cost of the fiber cable itself is minor in relation to the groundwork and as NESA phrases it: “It should be illegal not to establish fiber connections to the household when a digging project is ongoing”.

To build up the FTTH network, NESA contracted IBM Denmark as system integrator for the project using a technical solution from Cisco and PacketFront. The network is based on a MPLS backbone network from Cisco, connecting islands of up to 24 homes with an active switch in a curb using a star topology. Inside the homes, NESA installs customer premises equipment (CPE) that terminates the fiber. From the CPE, users are self responsible for installing POT or Ethernet cables to their devices.

NESA's business model: NESA provides an operator independent network, where different service providers can access the households through NESA network and NESA owns, controls and maintains the broadband network and physical infrastructure. Today there are five service providers competing in four service types (see Figure 1).

	Internet	IP-telefoni	Video-on-demand	TV
CyberCity	X			
Dansk Bredbånd	X	X	X	
FTH Bredbånd			X	X
J-net	X			
V2tel		X		

Figure 4: Service Providers in NESA's FTTH network

In the current pilot project, customers pay a fixed monthly fee of € 50 for access to the infrastructure and then buy services directly from service providers through a web portal.
In this approach there is no profit sharing or transportation fee for service providers and NESA covers all expenses (and profit) from the customer connectivity fee (public garden model). However, the specifics of the future business model are under development and as a part of that, NESA is considering introducing transportation fees for service providers. With this transportation fee, NESA hopes to reduce the customer fee, which otherwise can be a barrier to attracting new customers, and to better represent the real transportation cost of different services' requirements.

NESA believes very strongly in the 'open access' business structure and see that as their main success criteria in competition with traditional operators and over for other FTTH projects. They adopt a rather disintegrated service and infrastructure approach, by not providing any additional services or functions that have to do with the services themselves, e.g. not providing set-top boxes, billing nor product support. They believe that distancing themselves from service providers is the only way to ensure fair competition.

When introducing future services, NESA does not encounter technical limitations but regard standardization as barrier to the development, especially in set-top boxes. The company has successfully implemented TV and VoD services but misses a service that is unique to the FTTH platform.

In conclusion, NESA A/S is an Energy Utility Company that due to synergies with its core activities and strong financial situation is planning to establish a FTTH infrastructure. The company uses an 'open-access' model where NESA operates and maintains the broadband network and physical infrastructure and independent service providers compete for customers through a portal. Driven by operational synergies and new market potentials the main barrier to full-scale deployment is ensuring financial sustainability.

6.4 Operator Driven; AarhusNet

NetDesign A/S is, as the name implies, primarily involved in design and consultancy of internal and external data networks for Danish enterprises. In 2003 the company diversified after winning an outsourcing agreement with Aarhus Municipality for establishment and operation of a new backbone network for all public institutions in the Aarhus region, the second largest city of Denmark. NetDesign was granted an exclusive eight year contract that guarantied the critical mass required to build up a multifunctional regional backbone infrastructure that the company has designed to further meet the needs of businesses and eventually residential users.

The network is MPLS based and structured as a number of redundant rings that provide a total of 58 active Points of Presence (PoP) with 1 Gbps connectivity. In addition 22 Local Exchanges are connected from where the company provides 1380 locations with 2,3 Mbps G.SHDSL connectivity. The goal of the design was to limit the distance from PoPs to institutes and enterprises in the area, minimizing deployment cost for new customers and increasing competitiveness.

NetDesign operates the network on the ‘open access’ principles where independent service providers are granted access to customers on competitive basis. The network met public critique from competing traditional operators, such as the incumbent TDC that meant that providing services over the AarhusNet rather than their own, incurred extra cost and skewed competition. In yearend 2004, the Danish incumbent acquired 98% of the company which now is operated as a subsidiary of the Danish incumbent TDC, using the same operational principles.

To reach the residential market, NetDesign looks towards cooperation with the local Energy Utility Companies (EUC) to deploy fiber from their PoPs to individual users. Their view is that public organizations such as EUCs are the only investor with long enough time horizon and Rate of Interest (ROI) to see financial sustainability in FTTH platforms. NetDesign is confident that their competences in design and operation of technically advanced backbone networks make them an attractive partner for the EUCs.

NetDesign regards their main challenge to be the ‘hen and egg’ problem of increasing supply and demand of services in their network. They currently have a platform and an infrastructure that technically can support a broad range of service but to attract service providers they need to build up demand for the service in their network, and vice versa.

On a competitive level, NetDesign considers their established infrastructure and their critical mass of customers to guard them against competing infrastructure establishment, as long as they maintain the ‘open access’ business model. Their future focus is on FTTH rather than advanced DSL as regulation only grants them access to incumbent Local Exchanges but not street cabinets that are required for short range DSL technologies such as VDSL.

NetDesign has the technical platform to guarantee Quality of Service (QoS), negotiate and report Service Level Agreements (SLA). How this platform will be used to implement the details of the ‘open access’ business model is not determined, but in general, NetDesign wants to distance themselves from all aspects of service development and implementation. They therefore identify problems such as standardization in IPTV and set-top boxes as a potential barrier to the development of multimedia services in their network but position the problem within service providers.

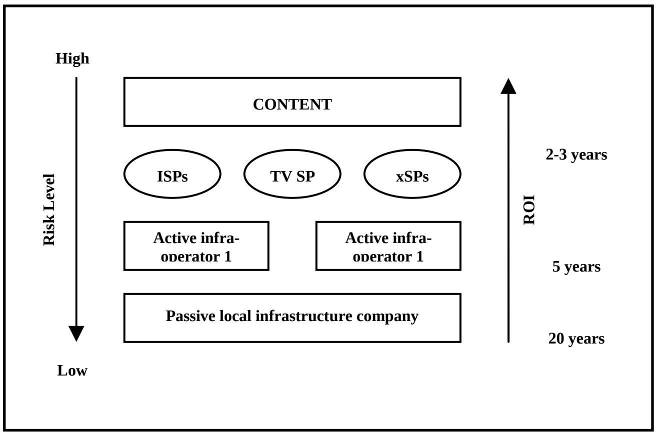

Figure 5: Expected ROI for different levels of the value chain [Chlamtac, 2005]

NetDesign feels that by providing the critical mass through public-private partnerships, the public is the driver for broadband deployment in Denmark. Furthermore, they believe that the ROI will define the future of the broadband market according to Figure 5.

In conclusion, AarhusNet is an operator owned and operated regional backbone network established through a public-private partnership between NetDesign and Aarhus Muicipality. The network was designed to be extended to the enterprises and residential market. The network is currently operated according to the ‘open-access’ paradigm on the public and enterprise market and wishes to diversify to the residential market. Driven by a critical mass provided by the regional government the main barrier to residential deployment is partnership with local FTTH projects.

6.5 Other alternative broadband operators

Operator independent model from Iceland:

Reykjavik Energy is the largest energy utility company in Iceland, providing service to roughly 180.000 residents in the capital of Reykjavik and its vicinity. Much like NESA, Reykjavik Energy is deploying empty micro duct tubes and has been conducting a commercial pilot project with 100 customers on FTTH platform since 2000, using the ‘open access’ business model. The main difference between the approaches of the two is the amount of integration in the service provision. While NESA is fully disintegrated, Reykjavik Energy integrates supportive services such as billing and customer relation.

Operator independent model from Sweden:

MälerEnergi started role out of FTTH in the beginning of 2000 using operator neutral model. Today MälerEnergi offers services to more than 20.000 private and 2000 business customers. There are 20 service providers in the network and they offer 60 services. MälerEnergi has recently made an agreement with Viasat and Canal Digital on delivery of IPTV services in the beginning of 2005. MälerEnergi has recently made an agreement with Telia on delivery of IP-telephony and Internet in the beginning of 2005

Independent Infrastructure / Service provider from Italy:

Today FastWeb, or e.Biscom after the recent merger with its holding company, provides telephony, Internet and television services to over 400.000 homes in 13 Italian cities [Chlamtac, 2005]. Much like NetDesign the company started by creating a metropolitan fiber optic infrastructure based on a public-private partnership. The company used a business model where the infrastructure was separated from the service provider. The service company implemented ‘triple-play’ voice, video and data services and later diversified by providing its services using the DSL platform. Prices for residential services are € 85 per month for limitless domestic landline telephony and limitless 10 Mbps Internet, another € 10 for 80 TV channels and video-on-demand, with a choice of over 5000 titles, some of which are free of charge, and movies for € 3 to 6 per movie [Chlamtac, 2005].

Rural Fiber Community Network in Finland:

Network Co-operative Kuuskaista – is a rural community network that with a grant from EU has been establishing a fiber infrastructure in the rural area of Kuuskaista, Finland. Since it was founded in 2002, the company has connected 500 households in 12 villages with FTTH. During this phase the average connectivity expenses per home / business has been € 4.800 (3.000 – 12.000) with an average pr. km deployment cost of € 5.000 – 6.000. Of this, participants pay € 50 when joining the organization and pay € 1.100 connectivity fee. After that, customers pay a € 40 flat-fee per month.

7. Conclusion

There are structural and technical limitations connected to the development of traditional broadband. The main limitations are that these developments are carried out primarily within the traditional telecom paradigm with its already listed limitations. Even though these networks are opened up to the competitors through interconnection legislations, the structural barriers still exist and are directly connected to the ownership of physical infrastructure. The technical limitation is connected to the capabilities of the ‘old’ telecom and cable TV access networks to offer real broadband services. This ‘path dependent’ limitation will, at best, facilitate a development of incremental innovations in the network. The radical changes and innovations seem to come from another side, namely development of ‘alternative networks’.

The alternative networks’ development is characterized by a converged IP platform that is used to offer different types of content in an affordable and/or efficient way by:

Fixed:

- Establishment of LAN in residential areas using a combination of existing infrastructure and establishment of new cables and network components.
- Extension of LAN technology to MAN and WAN, resulting in bypassing traditional telecom

Wireless:

- Establishment of wireless IP based network in residential and work environments using, e.g., WLAN
- Establishment of wireless hot spots in pubic and private places
- Establishment of wireless network in larger geographical places

Through an empirical study of the Danish alternative broadband market this paper can conclude that two main factors have acted as drivers in the establishment of alternative broadband operators: lower barrier to entry due to inexpensive standardized equipment and technologies, and direct or indirect form for public sector involvement. Different models for the depth of public involvement were presented, but both the theoretical and empirical study emphasized that local and regional authorities bear important roles as stimulants and drivers for broadband development.

Furthermore, the interviews indicated that alternative broadband operators, opposed to the traditional broadband market are leading a trend from closed integrated infrastructure and service systems using closed value-chains, towards more open, disintegrated and standardized networks using operator independent business models, where competing service providers can offer content and services on a common delivery platform.

The study has also revealed that technical problems with implementing advanced services weigh less on alternative broadband operators' scales today, than structural, organization and financial concerns. Commonly, most operators pointed out that video and television services over converged IP networks was the biggest future barrier to their service portfolio, mainly due to the lack of standardization in encoding, digital rights management and set-top boxes. All operators were positively expecting resolution to these problems within the next two years.

The study of the alternative broadband market indicated that a general public-private partnership is emerging where roles in the value chain are defined by the induced risk /rate of interest. In this future structure, governmental institutions sit at the bottom of the value chain with an expected 15-20 year payback period for passive local infrastructure, on top of them are competing active infrastructure operators with an expected payback period and at the top various content and service providers that can easily and inexpensively offer their services on top of an 'open access' service delivery platform.

8. References

Acterna (2002): ADSL technology, Overview, line qualification and service turn-up, April 2002, www.acterna.com

Alcatel, ref. 1 (2004). A Guided Approach to Broadband Entertainment Services, Strategic White Paper, Alcatel, May 2004

Alcatel, ref. 2, (2004. Universal Broadband Access – An architecture for a User-Centric Broadband World, Strategic White Paper, Alcatel, Sep. 2004.

Aware, RE-ADSL2, (2004): White paper, Reach-Extended ADSL2, Expanding the Addressable Market for DSL services, Revision 3, 2004

Aware, ADSL2, (2002): White paper, ADSL2 and ADSL2+, the new ADSL standards, 2002

Bar F. & Galperin H. (2004). Building the wireless Internet Infrastructure: From cordless Ethernet Archipelagos to Wireless Grids, Communication & Strategies, Issue 54, 2004

Bittlingmayer G. & Hazlett T.W. (2002). „open access:“ the ideal and the real, Telecommunications Policy 26, 2002

Blake S. et al, (1998). An Architecture for Differentiated Service. Request For Comment 2475, IETF, Dec. 1998

Blueprint WiFi, WiMAX (2003). The Critical Wireless Standard, October 2003
Commission of the European Communities: eEurope 2005: An information society for all, COM (2002) 264 final, Brussels, 2003

Braden R. et al. (1994). Integrated Services in the Internet Architecture: an Overview. Request For Comment 1633, IETF,Jun. 1994.

Braden R. et al. (1997). Resource ReSerVation Protocol RSVP) Version 1 Functional Specification. Request For Comment 2205, IETF, 1997.

Chris R (2004). Implication of DOCSIS-QoS on Cable broadband, Chris Rohrer and Douglas C. Sicker, University of Colorado, TPRC, August 31, 2004

COCOM (2004). COCOM04-20 FINAL

Danmarks Statistik (2004). Informationssamfundet i Danmark 2004

EU, PLC (2003): Broadband communications through power lines, COCOM03-32, DG ENTR/G/3 and DG INFSO/B2, Brussels 3.6.2003

EU, PLC (2004): Revised proposal for a Communication Recommendation on broadband communications through powerlines, COCOM04-59, Brussels 30.9.2004

Falch, M., Saugstrup, D. og Schneider. M.: How to achieve the goal of broadband for all, præsenteret ved ITS-konference, Berlin, September 2004

Gabelmann A. (2001). Regulating European telecommunications markets: unbundled access to the local loop outside urban areas. Telecommunications Policy, p. 729-741, 2001

Gillett, S.E., Lehr, W.H. & Osario, C. (2004). Local government broadband initiatives, Telecommunications Policy 28, 2004

ITU (1997).Vocabulary of terms for broadband aspects of ISDN. ITU-T recommandation I.113, June 1997

ITU (2003). Birth of Broadband. ITU Internet Reports. International Telecommunication Union (ITU), Geneva, Sep. 2003

ITU. (2003). World Telecommunication Development, Repport 2003 – Access Indicators for the Information Society, Geneva ITU

Mandjes M. (2003) Pricing strategies under heterogeneous service requirements. Computer Networks, vol. 42, p. 231-249, 2003

Tongia R. (2004). Can broadband over powerline carrier (PLC) compete? – A techno-economic analysis, Telecommunications Policy 28, 2004

Ram A. et al (2004). Admission Control by implicit signalling in support of voice over IP over ADSL. Computer Networks vol. 44, p. 757-772, 2004

Roberts J. W. (2004]). Internet Traffic, QoS, and Pricing. Proceedings of the IEEE, Vol. 92, No. 9, Sep. 2004

Schulzrinne H. et al (1996). RTP: a Transport Protocol for Real-Time Applications. Request for Comments 1889, Internet Engineering Task Force, Jan 1996

Svenska Elektriska Kommissionen (2004). Fiberoptisk tilslutning af slutbrugere, SEK Håndbogen 434, 1. udgave, Marts 2004

Su D. Et al (1999). Investigating factors influencing QoS of Internet phone. In Proc. of IEEE International Conference on Multimedia Computing and System, pages 308-313, June 1999

Telco Systems (2002). VDSL white paper, revision 1.0, 2002

Texas Instruments (2004). White paper, Uni-DSL:One DSL for Universal Service, SPY018-June 2004