Development of alternative broadband infrastructures – case studies from Denmark

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Abstract

Alternative broadband infrastructures are emerging and developing fast. These networks are based on different technologies and offer assorted services, applied through various organizational structures, using diverse business models. Due to their alternative nature, these emerging infrastructures operate on other premises than existing operators and face different potentials and challenges in their operations.

This article uses four detailed case studies from Denmark to identify the technological, economic and political/regulatory drivers and barriers of alternative broadband infrastructures, including the role of the government in fostering their existence.

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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). Other developed regions, especially the US and the South East Asian markets, have also experienced tremendous growth in penetration of broadband and in South Korea 96% of online users have broadband connectivity (ITU 2003). In Europe the development has been dominated by DSL technology and has on average 73% market share in the 30 OECD countries. However, OECD also reports that other broadband technologies are becoming increasingly important for broadband access and that in particular 'municipal broadband projects are expanding in many northern European countries and throughout the OECD' (OECD, 2006).

One of the main challenges in the development of broadband has been the ability of regulation to open up the legacy telecom networks for competitive provision of DSL services through, e.g., unbundling and Bit stream access (Falch 2006). The open access discussion has further been raised in connection to provision of broadband through cable TV networks and recently in connection with FCC's ruling that unbundling would no longer be required on fibre-based access networks (FCC, 2006). Bittlingmayer G. et al (2002) argue that open access can spur ISP variety and may reduce nominal prices for services. Whether service competition or infrastructure competition is more favourable for broadband development has been disputed in theory and praxis, but in general infrastructure competition is favoured by regulators, since it is expected to induce long term efficiency and remove heavy regulation requirements in the industry (Bourreau & Dogan, 2003).

Denmark is an interesting case to look at analysing broadband development. Being among the early adopters of both Internet and broadband access, Denmark now leads the OECD with a broadband penetration rate of 29.3 subscribers per 100 inhabitants (OECD, 2006). Denmark has a strong incumbent telecom operator, TDC, which holds 80,2% of the PSTN market and the broadband market share has been increasing steadily from 37% in ultimo 2000 to 53,5% in 2005 (Telestyrelsen, 2006). Additionally Danish power companies are rolling out fibre to consumers as they work to bury overhead power lines. According to a recent report from the Danish Competition Authority (Konkurrancestyrelsen, 2005) the power companies are planning to extend their networks to half a million households by the end of 2007 and 1.2 million households by the end of 2016. In comparison to the 2.4 million residential electricity customers, these plans will result in 20% FTTH availability by 2007 and 50% by 2016. Furthermore, given the 1.3 million current broadband subscribers, Denmark can be expected to lead in international comparison over FTTH deployment. In addition to these plans several smaller alternative broadband platforms are emerging in Denmark. These networks are based on different technologies and offer assorted services, applied through various organizational structures, using diverse business models. Due to their alternative nature, these emerging infrastructures operate on other premises than existing operators and face different potentials and challenges in their operations.

The aim of this article is to analyse alternative broadband initiatives with the goal of identifying the dynamics of their development. In the European statistics and discussions cable modem broadband is indicated as a part of alternative technologies. However, in this article the term ‘alternative networks’ is used for broadband networks other than DSL and cable modem, namely broadband technologies that require new infrastructures. The paper has an empirical approach, relying on four detailed case studies from Denmark. The focus of the article is on the market organization of these new networks and the research question is to identify the drivers and barriers of this development, including the role of government.

In a similar article and by focusing on WiFi and Wireless grids François Bar and Herman Galperin have addressed the organizational issues of alternative 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).

In addition to wireless platforms and operator driven fibre platforms, condominium fibre infrastructures are gaining foothold in urban Denmark. These infrastructures are characterised by increasing end-user control and ownership of broadband access, often through collaboration with alternative operators using telecom operators as backbone providers. The business models for this kind of initiatives vary but most often are in some way intervened with existing operation and maintenance of facilities in the organization, housing association, etc.

Although successful in providing high-speed Internet connectivity, alternative network providers often possess underutilised capabilities of offering a combination of Internet, voice and video services (triple play). This makes them potential competitors of existing voice, video and TV providers. However, as the paper shows, most alternative providers are experiencing some sort of challenges that limit the offered service portfolio. Our study shows that these problems range from well known organisational problems of small business growth (Churchill & Lewis, 1983) to technological problems related to coverage, capacity, QoS, digital rights management (DRM), and security. They also lack the expertise to acquire content and face regulatory uncertainty on issues like Copy Right, 'must carry', etc. known from the multi channel TV regulation. Last but not least, the business models adapted play a vital role in the future of these platforms.

There is also a major issue of the role of government/local government in development of these networks. In an article entitled 'Local government broadband initiatives' Gillett et al. (2004) has developed a taxanomy to 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 the US local governments' involvement in development of broadband is analysed and additional questions[2] posed on universal service aspect and the capabilities of different technologies (wired and wireless).

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[2] 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, with its 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 article, through detailed case studies, a number of these parameters are addressed. In this analysis we try 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 organization and ownership structure
- The deployed business model and funding, including the role of government

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

2. Infrastructure technologies

The emergence of the Internet, which is based on the Internet Protocol (IP) is, along with mobile telephony, considered the 'single most simultaneously creative and destructive influence unleashing the creation of new infrastructures, businesses, business models, and economic concepts in the last decade' (Majumdar et al., 2005). In the following some of the important characteristics of IP platforms are outlined:

- IP technology is based on a distributed network architecture, where routing and intelligence are distributed in the network.
- In IP networks, signalling and data transmission are integrated in the same network so that the end users establish connections and transmit data simultaneously.
- Service provision is disintegrated from infrastructure operation and the terminals attached at the edges of the network can independently create and offer services.
- The service development platforms have mainly been open.

These characteristics of the Internet, through which several actors can be involved in service creation and provision, have fostered innovation and competition. While the general Internet is the major IP network in the world, it is far from the only IP network. In recent years, several 'managed' IP networks have been deployed at corporate and residential level. 'Managed' IP networks share many of the same characteristics as the general Internet, with the fundamental difference of offering discrete levels of QoS, often based on high capacity transmission technologies, such as optical fibre, and Next-Generation-Networks[3] (NGN) concepts. This enables the providers of private IP networks to offer guaranteed high quality service levels to their costumers. This is implemented through QoS management, allocating and reserving capacity for different services following predefined prioritization schemes (Sigurdsson, 2004).

Development of Information and Communication Technologies has in the last decades been dominated by three trends: 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.

Initially, broadband development took place within the first trend and was an answer to the demand at the consumer side for high speed connections, primarily for improved quality access to the Internet. However, there is a tendency for broadband development to extend in scope over to the two other trends. Today, in addition to access to the Internet, broadband infrastructures offer access to a range of multimedia services, such as 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. This fixed-mobile convergence is materialising through a technology platform called IP Multimedia Subsystem (IMS) that 'claims timely and cost effective delivery of IP-based services that can be accessed over any device, be it fixed or mobile' (Telecommunications International, 2006).

[3] 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.

3. Content and service aspects

Service development platforms (often also called middleware)[4] 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 important parameters when it comes to development of broadband services.

To this day, most residential broadband networks have been designed and optimised to offer simple transmission services. These have typically been low capacity '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. Multimedia services

The formal definition of multimedia is 'a service in which the interchanged information consists of more than one type, such as text, graphics, sound, image and video (ITU, 1997). Multimedia services can be classified based on how tolerant they are in regards to error and delay. In this classification, interactive voice and video pose real-time requirements on error tolerance and delay.

When real-time information is transmitted over a packet based network, information is sent in flows of packets between senders and receivers. As the transmission delay (known as latency), the transmission delay variance (known as jitter), and the loss of packets, increases the perceived quality of the communication deteriorates. Quantitative measurements of these values are called Quality of Service (QoS) parameters. While advanced coding schemes can reduce perceived quality decay, successful real-time multimedia systems are always contingent upon loss and timing constraints with respect to end-to-end QoS requirements.

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

[4] K.R. Rao et al. (2006, p.24) describe middleware as 'a horizontal layer residing on top of a set of networked computers, providing a set of distributed services with standard programming interfaces and communications protocols, even though the modelling host and OS may be heterogeneous'.

Protocol (UDP) and IP multicast (Schulzrinne, 1996). 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 problem than the loss itself, if the rate of loss is reasonably small (i.e. below 10%) (Su, 1999).

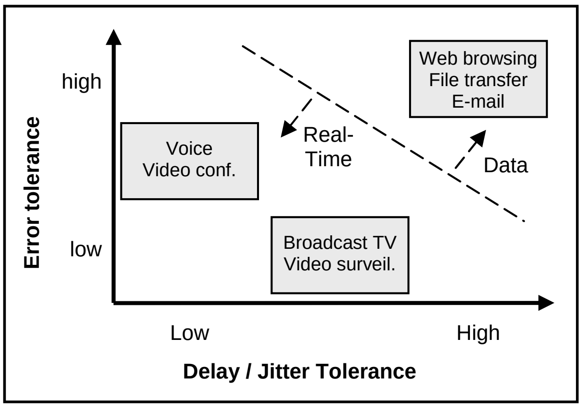

Figure 2, Classification of multimedia services

3.2. Resource provisioning strategies

In recognition of the fact that current legacy network architectures provide insufficient capacity and support for robust multi-service offering, evolution toward some sort of resource provisioning is inevitable. There have been several proposals for solutions to this problem where most fall into one of the following techniques:

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

3.3. Evolution of multimedia services

To analyze the evolution of multimedia services we use three control dimensions applied to the Danish market: level of infrastructure centralization, level of system integration and system openness. The first dimension indicates the amount of central infrastructure needed (how close to the user the "intelligence" in the network is placed) 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 clarification of market trends.

Infrastructure centralization

Broadband services can be deployed with a varying amount of infrastructure. Centralized 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 signaling 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. However, infrastructure integration 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 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 standardized 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 connectivity to any overlay 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 that 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 facilitated a service delivery platform capable of offering ubiquitous services and quality levels and therefore compete as a real alternative to traditional services.

3.4. Standardization

Standardization is a very important parameter in development of broadband services, especially voice and video services. Today there are a number of competing open standards as well as a variety of proprietary standards and technologies. This increases the cost and limits customers, making it difficult for them to move from one service provider to the next. The problem is comparable with the standardization problems of digital TV both when it comes to Conditional Access and Application Program Interfaces, which has had negative influence on the pay TV and Interactive TV markets.

3.5. Some examples of broadband services

Voice over IP

For a long time, POTS (Plain Old Telephony Services) 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 a few actors in an oligopolistic market. The central reason for this has its roots in the technological architecture of infrastructure and service development platforms.

The POTS 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 network layers 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. Even though interconnection to the POTS networks is possible, there are still large 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.

VoIP has gradually changed this situation and the convergence process has opened up new possibilities for service development. Using VoIP technology and the general Internet as backbone, new providers can plummet prices, particularly for long distance and international calls. This is due to low international transmission cost over the internet compared to transmission charges within POTS that rely on distance-related cost structure and interconnection pricing schemes. The entry barriers for VoIP service providers are therefore lower and their number thus increasing, contributing to the overall competition in the public voice market.

Video/Audio over IP

Audio and video transmission over IP networks has existed for over two decades. In addition, the past years have seen an increase in streaming and downloading of multimedia content over the Internet. However, limited capacity and transmission properties of the general Internet have restricted both quality and scope. To compensate for the limited real-time transmission capabilities of the Internet and lack of legal content, users have formed peer-to-peer based overlay networks (Sigurdsson et al., 2006). Emerging managed IP platforms with built in resource management do not face these problems and can therefore offer a bundle of voice, video, and data services (often called triple-play services).

Data services

Data services are developing continuously and broadband will certainly give these services new conditions. Traditional services, such as e-mail and browsing can evolve but especially new services such as gaming can have great influence on broadband, both in terms of capacity and QoS. Peer-to-peer technology will also continue to evolve and put pressures on the asymmetrical nature of the 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, 2004a).

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 the 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.

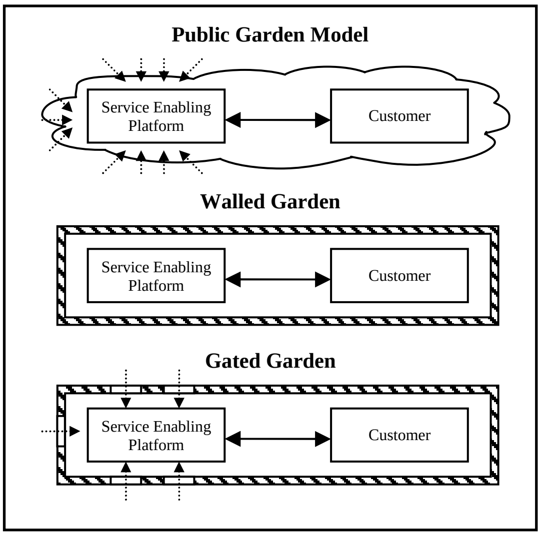

Figure 1: Service Models for Broadband Services

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 organization

Based on our observations in Denmark, as well as published research (Bar F. et al., 2004), we claim that a shift is occurring in the organization of the new alternative networks[5]. In the new paradigm, emerging actors (in some cases the end users) operate and maintain their own networks, only relying on telecom operators or alternative providers for backbone connectivity. In addition to new organisational methods these projects use alternative business models that are often intervened with existing operation and maintenance of facilities in the organization, housing association, etc.

[5] The self organization model is known from the late 19th century telephone cooperatives

When several users own a common network, various ownership models have been witnessed, e.g., in the Canadian REN and in a city network in Denmark (frederkisberg.net) a condominium model known from the apartments and housing market.

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 article 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 possible models for public sector involvement in regional and local broadband projects. He argues that regardless of the model chosen, the local and regional authority bears an important role as stimulant and driver for broadband development. The presents four means by which local governments can achieve this ‘1) by 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’ (Chlamtac et al, 2005).

To prevent conflict of interests for 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.

We will now use the description of Chlamtac et al (2004) and the taxonomy developed by Gillett S.E. et al (2004) to analyze the different models available for public sector involvement in regional and local broadband projects. According to them, governments can play different roles with regards to broadband development, amongst others:

- **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. 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.

- **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.
- **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.

Furthermore, the governments can be directly involved in broadband development, as discussed in the following.

5.1. 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).

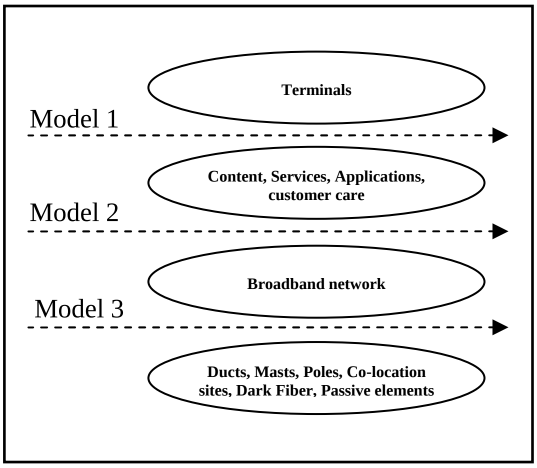

Figure 3: Models for level of government involvement in regional and local broadband projects (Source. (Chlamtac et al., 2005)

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.

Carrier's carrier model

In this operational model, the local authority builds, owns and operates a broadband network but disintegrates the service layer from the infrastructure either using a public garden or gated garden business model. Commercial service providers interested in providing services are granted access to the infrastructure through fixed charges or revenue sharing. The advantage of this model is that it significantly lowers the market entry cost for service providers and content providers, allowing them to offer services to areas that would otherwise have been prohibitively expensive to serve. 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.

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

The remainder of this paper describes the results of four detailed case studies of alternative broadband infrastructures in Denmark. The case studies were performed through series of interviews in 2004. The four cases were chosen to enable analysis of as many of the parameters outlined in this article as possible. The first case is a City network, case number two is a community network, case number three is a power utility 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, a short introductory description of the Danish broadband market is presented.

Denmark has over five million inhabitants and more than 2.4 million households. Following table (based on data from the Danish IT and telecom agency[6]) 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%
FTTx 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%

Denmark now leads the OECD with a broadband penetration rate of 29.3 subscribers per 100 inhabitants (OECD, 2006) 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

[6] For further information see www.itst.dk

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 POTS 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. 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.

[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.

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.

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 standardization both in encoding (MPEG, WMF, HD) 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.** According to FrbNet, the 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 fiber cables from basement to apartments and introduction of VoD and IPTV services.

In conclusion, AarhusNet is an operator owned and operated regional backbone network established through a public-private partnership between NetDesign and Aarhus Municipality. 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.

6.2. 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 organization for eight local community wireless networks. The goal of the company is to provide 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 organization 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 fiber network (carrier’s carrier model) and ADSL connections to interconnect its current 150 access points.

The operation is based on standardized equipment and open source software where available and the ‘do-it-yourself’ paradigm (e.g. to minimize 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 2200 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 535000 customers. For the past 15 years the company has been deploying fibre cables to support its core activities, e.g. through an IP based control system for their electricity installations, and now owns more than 25000 Km of fibres and more than 700 Km of fibre 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 fibre. The company has already connected 20000 homes with tubes and intends to lay tubes to 200000 homes in the next 5-7 years. The company has not yet taken decision about fibre roll-out in the tubes and according to them there is a need for political support in role-out of fibre infrastructure, as they phrase it: “all important infrastructure projects require political support”.

According to NESA there are several important synergies between electricity supply and fibre 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 fibre cable itself is minor in relation to the groundwork and as NESA phrases it: “It should be illegal not to establish fibre 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.

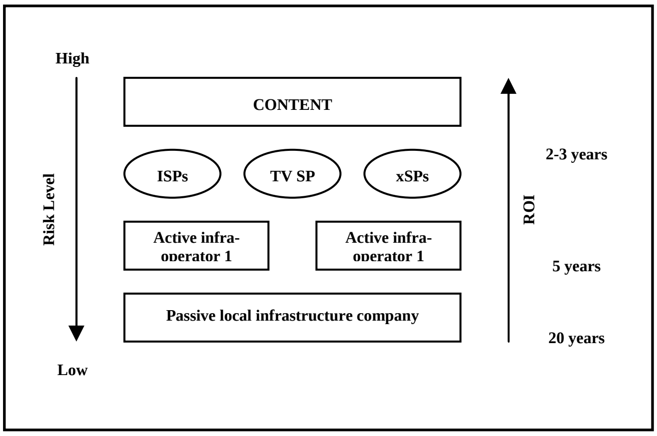

Figure 5: NetDesign beliefs in ROI differentiation in telecommunications according to Chlamtac (2005)

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 Municipality. 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.

7. Conclusion

There are structural, technical, and feasibility limitations related to the development of traditional broadband. The limitations arise from the operational environment in which deployment takes place, i.e. within telecom operators. Even though legacy networks are opened up to competitors through unbundling and interconnection legislations, the structural barriers still exist and are directly related to the ownership of the physical infrastructure. Path dependency from the existing infrastructures also affects the direction and strategy chosen, resulting in slow and incremental changes. This has opened up markets for different alternative networks which employ new technologies, business models, and organisational structures. 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, bypassing traditional telecom operations

Wireless:

- Establishment of wireless IP based networks in residential and business environments using, e.g., WLAN and WiMAX
- 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 article 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 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.

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