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IT infrastructure planning from a North Denmark perspective: Major problems, consequences and possible solutions

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Abstract: This paper gives an overview of the more prominent problems in IT infrastructure evolution and in particular the necessary planning process in Denmark. A discussion of consequences and possible solutions is presented. Through the DDN-project Nordjysk Netforum, NJNF, and its partners and attendant research at Aalborg University, AAU, it has become apparent that several problems pose significant hindrances to an efficient IT-infrastructure planning and implementation. These problems range from awareness of IT-infrastructure issues, over education and research to implementation capacity. The problems are classified according to their main cause and possible solutions are proposed. These problems appear on the background of a dawning understanding of IT infrastructure as a crucial part of the modern society comparable to the recognised infrastructures, such as roads and electricity. The IT-infrastructure and the problems are placed in the context of the growing importance of IT in the information age. A short background and characterisation of the present IT-infrastructure is given and put in relief by a comparison with the electricity supply infrastructure.

Keywords: IT-infrastructure; Network Planning; WAN

1. Introduction

Faced with the prospect of constructing a new complete IT infrastructure in a short span of years, a central aspect of DDN has been the IT-infrastructure. The urgency of this matter is a result of the combination of the phenomenal growth rates network access speed, around 25% per year (Nielsen, J. 1998), and the increasing societal dependence on Wide Area Networks, WAN, data communications. For the first three decades of WAN data communications the traffic has either been carried by specialised networks or for the overwhelming number of users during the last decade on the pre-existing telephony network. Thus, until now the need for a speedy construction of an infrastructure has not presented itself; the telephony networks have for decades been growing at about 3% per year as an extension of the first networks originally begun back in the late 19'th century. This slow development has changed with GSM mobile telephony, where within a decade the number of mobile phones has risen above the number of landlines. This development of upgrading backbone components while continuing to rely on the in-place access structure is swiftly approaching its end, and at present growth rates the capacity of the telephony access network will be exhausted within the decade. There are a number of further changes to be expected within the decade. The traditional landline will probably be replaced by IP-telephony within the next 3-5 years. The 3G and 4G mobile networks will necessitate new and far more fine-meshed mobile access networks supported by fiber (4G), and development on 4G is also aimed at IP-based connectivity. In a longer perspective looms IPv6 and a growth in network terminating points by orders of magnitude as most old electronics become connected and new technologies such as miniature mobile sensors (Warneke, B. et al. 2001) appear. Due to the bandwidth limitations in the spectrum available for wireless communication a complementary high-speed wired infrastructure remains necessary. At the same time the privatisation of the telecommunications sector in Denmark has resulted in marked changes in the research and lack of long term planning; the present focus in the sector is now on relatively short-term pay-back of investments, and research has been curtailed to the necessary minimum.

Given this situation the IT-infrastructure part of DDN with Nordjysk Netforum as primary WAN project has, in cooperation with AAU, pioneered the field of present-day planning of a new IT infrastructure. The term pioneered is chosen for two reasons; firstly, when the present infrastructure developed IT was still non-existent or at best stand alone units and the service provided by telephony, the voice channel, remained unchanged for decades; secondly because IT-infrastructure is markedly different from other more well-established infrastructures in at least one respect. A comparison with the electricity supply will make this point. Both the electricity supply network and IT-infrastructure are networks spanning the whole country and connecting beyond the borders, and both require careful management to avoid breakdowns. In to-days society almost all critical societal functions are dependent on electricity to function, examples are hospitals, water supply and telephony. To safeguard the most sensitive functions against power failure, two potential solutions exist; either the whole electricity supply network can be made sufficiently robust to guarantee the necessary reliability, or each critical installation can independently install safeguards such as battery supply and emergency generators. For several reasons the last solution has been implemented for electricity. By comparison, IT-infrastructure only gives one option for providing sufficient reliability for critical services; the infrastructure network as a whole must be sufficiently robust. Where electricity networks offer merely transport of a resource from installations where it is advantageous to produce it, IT-infrastructure by its nature must be connected and is only as strong as the weakest link. Conceivably, each building could have its own generator and no supply network is necessary; for communication this is not an option. Further, the optical technology itself makes coordination on implementation paramount; with ferrous conductors, whether in the telephony or electricity networks, connecting different types of cables represent only minor problems; with optical fibers even minor differences in type gives rise to very significant signal loss and can necessitate active equipment at the connection. Given this difference a high degree of pioneering has gone into the project work.

This paper will present some prominent problems encountered during this work, consequences thereof and possible solutions. First it will deal with the question of awareness of IT-infrastructure and its nature; then problems related to the different steps of the process from planning to implementation; this is followed by simple scenarios showing the consequences of different choices. Lastly, there is a discussion of the IT-infrastructure and the problems in a wider context.

2. Awareness of IT-infrastructure issues.

From conferences and meetings around the country it has become evident that awareness of IT infrastructure problems and solutions is limited and of new date. This, of cause, is connected to the purpose of computer networks, that they should provide a transparent service to the user. IT infrastructure as the provider of the most fundamental of such services is often taken for granted and as a consequence the infrastructure term has been inappropriately applied to services dependent on the infrastructure, further confusing the issue. The problems with awareness can be broken down into three components.

The first is simply awareness of the existence of an IT-infrastructure and its imminent need for reconstruction. In this regard a high degree of success has been achieved through the information campaign undertaken by NJNF and partners. To day the question of construction of new IT-infrastructure is firmly placed on the agenda as evidenced by the high degree of interest given both from the original municipalities involved in the NJNF project and the rest of the North Denmark region, notably the Region Aalborg, consisting of 12 municipalities around the Aalborg municipality. A specially clear expression hereof is the donation from Hals municipality of 25000 kr to IT-infrastructure research at Aalborg University. Further effect can be seen in the establishment of Vestdansk Netforum and the continuation of Nordjysk Netforum, NJNF of 2004.

The second awareness component concerns the time frame involved in IT-infrastructure planning. As stated in (NJNF 2003a, 42) the life expectancy and, thus, the planning horizon is 30+ years. This time frame exceeds by far almost all other such horizons - even world leading companies such as Intel have a planning horizon of ten years (Hamilton, S. 2003). Not only the time frame, but also the technical specifications reached when extending the development this far into the future represent a formidable barrier for understanding. This has been in evidence even amongst technical professionals. Parallels are only known in construction of major road projects such as the great H plan involving the great belt bridge. Consequently, the focus in IT-infrastructure discussions focus on relatively short term needs leaving a full extension of FTTH and 1+ Gbit/s access speeds little room. Also, the awareness to day is mostly focussed on the needs for new transport networks, mainly in the public sector, where in reality the main bottleneck is in the access networks connecting the private residences and small enterprises to the Internet. The major import of a new properly constructed transport net is its ability to support a new access net removing the bottleneck.

The third component is understanding of the nature of IT-infrastructure, specifically the need for overall coordination in both planning, choice of technologies and implementation. By comparison other infrastructures require far less coordination and some such as water supply are entirely localised and comprised of autonomous units. This is exacerbated by the very new presence in WAN of most public administrative functions and their tendency to emerge localised within, for instance, a single municipality.

These awareness problems represent a barrier to the goal of making Denmark a leading country in the information society. This danger is most acute in selection of short-term solutions; for the private enterprise this is especially problematic as return on investments over a horizon of decades is rarely accepted by investors and involve high uncertainty; even political and economic systems may change! Further, as the societal dependence on the IT-infrastructure rises it will become intolerable not to safeguard it against accidents and terror actions; investments that do not directly add to the profit margin of private enterprise.

The most promising solution is a continuation of the information work carried out by NJNF and partners, and increased education of personnel with expertise in IT-infrastructure, as has already begun at AAU and is planned to be followed up by an education on bachelor level to be developed at Handels- og Ingeniørhøjskolen i Herning. This education is targeted at the technical administrations. There is also to be developed further education for the personnel already employed at the technical administrations. As many of the technical issues are time consuming to gain mastery of, the political system will also be best served by supplementing the technical competencies available for support in the decision making process.

3. Planning Resources

Based on experience from Hudiksval, Sweden, it is estimated that for each network connection ½ hour of planning is needed; for North Jutland with estimated 250.000-300.000 net terminating points, NT, this task requires 150.000 man-hours planning effort; this is roughly equal to 10% of the Danish NT. At present, the only established education giving a background in IT-infrastructure planning is the master program in network planning and management from AAU. This education gives the necessary competencies for planning and dimensioning large scale WAN. For the detailed planning of each access connection and technical support in municipalities no specialised knowledge of overall IT infrastructure dimensioning is necessary. To fill the need for this level of expertise a new education is badly needed. Every year it is postponed will add to the delay in establishing a new IT-infrastructure; the capability to carry out the planning task must be in place before the need for the task becomes acute. Given the size of the planning task and the need for a new IT-infrastructure within a decade, latency in the process becomes a major issue. The two educations targeted at planning tasks are 5 and 3 years respectively with the specialisation period of 2.5 and 3 years. The latency in planning resulting from lack of skilled personnel is longer than that, since it can not be envisioned that sufficient personnel can be educated at once.

During the project period of NJNF significant progress was made in developing methods and guidelines (NJNF 2003b). With these methods the planning task that took 2-2½ years for North Denmark has been carried out for the Viborg region in 6 months. Research at AAU has also made significant progress in automatisation of planning the physical trenches, see further down in the text.

These developments contribute to ameliorating the latency in carrying out the planning tasks.

Another planning problem is the limited research available on parameters for long term planning. Many applications and services are only just emerging into WAN, notably delay sensitive technical applications for control and coordination, and their requirements are, as yet, only to a limited degree applied to the WAN environment. Such applications may demand redesign of topology. It is therefore difficult to take such requirements into account; at the same time disregarding may severely curtail a major economic potential for IT-infrastructure based services.

Another research problem is the long term ability of IT to meet the mounting demands for more capacity; as the current access network cabling soon reaches its capacity limit, so other intractable technical barriers to the present IT development will be encountered in within the next three decades. Such barriers may change some dimensioning parameters and could significantly increase the demand for optical fibers or room and power needs for active equipment in points of presence.

In response to the need for research two major initiatives are starting at AAU this spring: Centre for Teleinfrastructure, CTIF, and Centre for Network Planning, CNP. Together they will carry the research into the next phase, where the focus is on integration of wired and wireless networks and on the ongoing convergence of almost all communications technologies.

The basis for the planning tasks also include Geographic Information Systems, GIS, data in the form of aerial photos and digitised maps. At present there is no standard for GIS data in relation to IT-infrastructure. Because of this some data is stored in varying formats and needs to be complied from several sources with attendant problems. The registration of existing and projected IT-infrastructure is also very limited, partly because there is no mandatory registration of such resources. This severely hampers the effort to use existing resources and to coordinate the digging between projects, a common measure to sharing the cost.

4. Implementation Issues

The distinction between planning and implementation is rather loose as important functions in planning continue into the implementation phase; here the general plans step-by-step become more detailed until the actual trenches are dug and tubes installed. All the way through this process there is an urgent need for documentation to keep GIS data updated. This work is to a large extent carried out in the technical administrations of the municipalities and is the most resource demanding part of the planning process. Without this documentation any subsequent modification of the network becomes an expensive detective work!

With implementation of the fiber network the main concern is the entrepreneur work of digging and placing the tubing for the optical fiber cables. This is a specialised work as the placements must adhere to specific limits for bending of the tubes to enable subsequent filling with optical fiber cables. The work can, thus, only be undertaken by a limited number of entrepreneurs. This limits the number of kilometres of cabling that can be placed per year, and if the need for this expertise rises sharply, there will be a delay measured in years before the capacity can be increased sufficiently. It is entirely unrealistic to expect private entrepreneurs to hire and train personnel years in advance of actual offering of contracts for the work. The fiber networks detailed in (NJNF 2003a) for the North Denmark region extend to 668 km; this only covers the main transport network for the region and an estimated further 17.000 kilometres will be needed to complete the FTTH infrastructure.

In the open landscape scheduling the digging task is relatively easy and the cost per kilometre is the lowest. In city environments both the cost and the "digging window" regulations complicate the task. If for regulatory reasons expensive entrepreneur work must lay fallow for one or two years until sufficient connectivity is achieved, this will be a hindrance for private capital to invest in the IT-infrastructure. Coordination of this matter can easily involve several municipalities and normal regulations may have to be wavered due to the societal import of the project.

Finally, the new infrastructure need is global in nature and the Internet is gaining increased focus in many countries. Once the construction of FTTH takes off there may be a shortfall of optical fiber due to lack of production capacity; due to a previous recession in the optical fiber business there is some reluctance to invest in new production facilities until the demand is evident. An early move also significantly increases the options for reducing the digging costs by coordination with other projects. The result is that late movers on FTTH can be significantly delayed due to global demand and rising prices on fiber. This may paradoxically make an early investment cheaper than one delayed until the need is pressing.

5. Scenarios

Two scenarios for step by step deployment of a new access infrastructure are given as illustration of the crucial importance of a coordinated overall plan for the new access IT infrastructure. One shows the effect of the current market driven IT infrastructure deployment, where the short horizon for return on investment is the governing factor giving rise to a distortion of the market from a customer viewpoint. The other shows the effect of a coordinated long term plan.

Scenario 1

In the first scenario the governing concern is to only make investments with relatively short term pay back; this concerns not only choice of projects, but also the planning and implementation choices involved in each project. It is also central that the risk is minimised and, thus, projects are in the main only started once the demand is manifest; to shorten pay back time the project costs are minimised even where relatively small extra investments could prepare for potential future demand that is not yet manifest, and where no certain time frame for its actualisation is known. This scenario presents the development in four stages.

Step 1: large business and public institutions

The earliest customers for optical fiber based communication are large businesses and public institutions. In a first stage potential customers are identified; only a short window is left open for more to join. These customers appear to the plan as islands to be connected; all other areas are empty. Since only a small subset of all potential customer needs are considered, any extra capacity included in the network, such as extra fibers in cables, extra wells, longer paths to pass through all areas, are considered over investment; even if they are considered the option then falls on who should pay - the present customers or the network owners? As for customer needs the network only incorporates the level of redundancy and QoS that customers are presently willing to contract for. When needs for QoS above the present connectivity, least cost focused market arises, the IT-infrastructure will be incapable of supporting them.

Step 2: small businesses and private residences in attractive areas

In a second stage more customers are included; these are in areas where there is some spare capacity in the transport network and where, for residences, a high percentage of customers joining is to be expected. If there is insufficient capacity, it will be necessary to either use the few extra protection tubes in place or to dig new cabling in the transport network.

Step 3: other private residences in densely populated areas

The third stage includes areas that can carry the cost of modification to the main network, such as digging to place more access wells and more tubing to increase capacity. The network is now planned as an archipelago in a sea of sparsely populated areas. In this stage the additional customers must in effect carry a cost of an entire new network as the main structure is already fully utilised.

Step 4: private residences in sparsely populated areas

In the last stage sparsely populated areas face are to be added. Here fiber cabling will probably be present in close vicinity of most residences, but as no access points are prepared in the network for attaching them, the nearest access point will usually be in the nearest densely population area. Even if a coordinated plan is made to include the remaining residences the cost is still close to that of an entire new network. If left to the demand on a step by step basis the same stretch may be dug up multiple times to include new customers, each time incurring full digging cost. Penetration of FTTH in step 4 will be slow and completion, c, uncertain, see Figure 1.

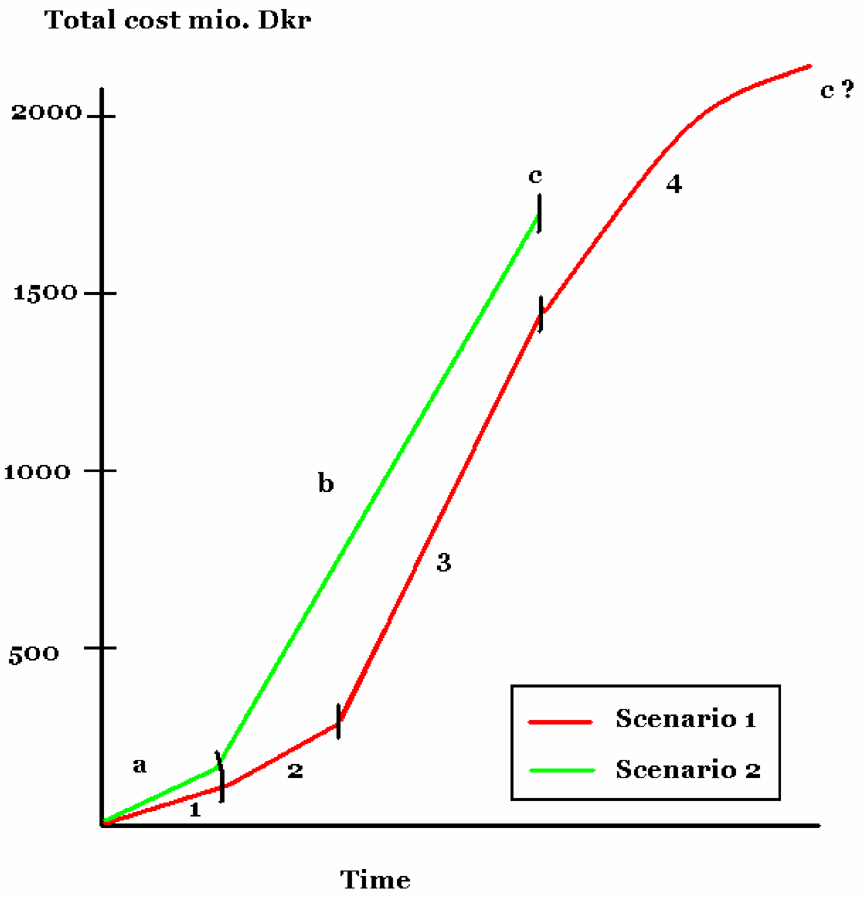

Figure 1. Scenarios

Scenario 2

Scenario 2 closely resembles the strategy plans made by NJNF. In this scenario the network capacity is planned to enable a full FTTH structure; this includes access points, extra tubes, sufficiently fiber rich cabling on main stretches, choice of single mode fibers for all stretches and coordination of the whole network. Here there are only two main stages, stage a, where the transport net is build and major customers are connected; the customer group resembles stage 1 closely. In stage b FTTH is rolled out with engineering concerns and customer demand as timing parameters for the prioritisation of areas covered. Completion, c, is reached at a planned time.

Scenario Evaluation

Scenario 1 can be evaluated from two viewpoints: if it is considered doubtful whether private residences will become customers the strategy has some merit; if, on the other hand, there is little doubt that a new access IT-infrastructure must include all, then scenario 1 calls into doubt the actual goal of reaching all. Even if it is eventually reached, there will be significant delay for the commercially less attractive customers.

At present, it must be noted that FTTH is gaining swiftly around the world, with for instance Korea implementing around 500.000 FTTH connections per year starting this year. Also, there are several indicators that the access speed demand will continue to rise and none that it will halt. So far the growth has been content driven with graphical content gaining in importance. The main standard for live images MPEG2 (DS/ISO/IEC 1997), specifies convergence levels ranging up to 100Mbit/s; the maximum resolution is less than that of current high end computer screens; in addition major improvements in screen technology is to be expected along with resolutions almost an order of magnitude higher than today (Klosowski, J.T. et al. 2002). Based on the human sensory system and Internet properties, the upper bound for internet access speed is orders of magnitude higher than the levels given in the MPEG2 standard (Knudsen, T. et al. 2004). Given these facts, it is likely that once a threshold is passed, the consumer demand for access speed will rise very sharply up to at least 100Mbit/s as the standard; for many larger businesses 1 Gbit/s is already becoming the norm. If the ongoing convergence of LAN and WAN applications is continued it will be the LAN speed that sets the standard; here the speed is already starting to move up to 1Gbit/s. Dimensioning of capacity must therefore both consider the peak user, not the average lest the net becomes a bottleneck, and the likelihood of much higher growth rates on the demand side than predicted by Nielsen's law; higher growth rates have been sustained for more than 35 years as evidenced by Moore's law for semiconductor component density. The cautious move at present is therefore to plan for the contingency of fast dissemination of FTTH to all residences.

6. Discussion

The problems shown here are the most prominent of those encountered by the NJNF project and its partners, and by the accompanying research effort at Aalborg University. The problems here cited all have potentially severe consequences for construction for the new IT-infrastructure, and by extension the national economic growth. With the already large importance of the IT-based economy, a limit on its continued growth will be costly. Already today, the access network creates a bottleneck; if this is further worsened by long delays in planning and implementing a new IT-infrastructure large groups of citizens can experience year-long exclusion from the ongoing development. Such impairment can have severe repercussions both for the private sectors development of new services and for the public sectors ability to replace old fashion administration and services with IT-based services. Also, investments in a new IT-infrastructure must be weighted against the savings on other infrastructures such as roads; with a FTTH infrastructure and high resolution video conferencing the possibilities for significantly reducing the need for person transport can yield a saving on traditional traffic investments. Given the relative costs of the two infrastructures, where the whole national IT-infrastructure is cost-comparable with each of the two latest large bridge projects alone, even a saving of a few percent on the roads budget may cover a large part of the IT-infrastructure cost.

It must also be noted that the quality of IT-infrastructure may become an important parameter amongst nations in vying for international investments and attendant growth of work places.

The cited problems add up to two consequences: possible increase in cost of a new infrastructure through under investment and reduced life-expectancy, and long delays in constructing and modifying the IT-infrastructure to allow unrestricted economic growth of dependent services. Of these the latency problem is the most acute; here many possible delays cumulate: education(planning personnel) + planning time + education(digging personnel) + digging time. The net result is that once the decision making process is over it may be the case that several years must pass before the actual work can gain significant headway.

If the decision on this is to let the market handle the planning and construction it is most probable that scenario 1 will be the result. It is therefore paramount that a coordinated effort be made; this by no means implies a public ownership as with the roads, but at least a standardisation regulating the IT-infrastructure ensuring the needed qualities and consistency. This standardisation must be coupled with some kind of supply obligation to ensure that also economically unattractive areas receive the service; if this is not done, the mounting importance of partaking in the information society can depopulate such areas!

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