

Providing connectivity to the Saami nomadic community

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ABSTRACT

This paper describes the Saami Network Connectivity (SNC) project that seeks to establish Internet communication for the Saami population of Reindeer Herders, who live in remote areas in Swedish Lapland, and relocate their base in accordance with a yearly cycle dictated by the natural behavior of reindeer. This population currently does not have reliable wired, wireless or satellite communication capabilities in major areas within which they work and stay (or would prefer to stay if possible). A radical solution is therefore required, which is compatible with the Saami population's goal to uphold their land by being able to live there and care for the environment. An approach based on the concept of Delay Tolerant Networks is discussed here.

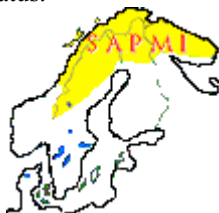
Keywords

Saami, Sámi, Sapmi, Sápmi, SNC, DTN, Delay Tolerant Networks, nomadic, reindeer, herding

INTRODUCTION

Saami herders are traditionally nomadic residents of Sápmi (also known as Lapland), who still move their bread winning activity geographically through the year, in a cycle dictated by a number of factors, which include:

- Natural behavior of reindeer
- Climate and pasture variations
- Laws and regulations
- Impact of various industrial activities (e.g. hydro-power, timber logging, tourism)
- Current herding practice
- Herders' economic and social situation, and health status.



The Saami economy is closely linked to the year cycle

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that is indicated by a name often used to describe them: *The People of the Eight Seasons*. However, migration mainly occurs during spring and autumn seasons. Herders involved with the SNC project typically move their herds by about 150 to 200 Kilometers in about ten days. The distance varies though, and some families move their herds by as much as 600 Kilometers from the Norwegian coast of the Arctic Ocean, to the Bothnian Bay where Sweden's coastline meets that of Finland.



Reindeer

In Sweden, the right to reindeer herding is exclusive to being a Saami and possessing membership in a Saami Village. Saami Villages are juridical entities (*artificial persons*) established by the Swedish state as possessors of rights to use land and water for reindeer pasture and subsidiary bread winning from activities such as fishing and hunting. The reindeer herders involved in SNC at the present stage are primarily members of Sirges Saami village. Sirges is geographically part of Jokkmokk district, which is situated along the upper parts of the two Lule rivers: *Stora Luleälven* and *Lilla Luleälven*, and their springs. The district is 18144 square Kilometers in area and has 6019 inhabitants (2000 census), of which approximately 4000 live in the district centre Jokkmokk. With about 500 inhabitants, Sirges is the largest Saami Village in Swedish territory. It is also one of the villages with the highest number of reindeer.

Today, an increasing number of Saami are taking up jobs in professions such as teaching, nursing, computer programming, journalism etc. A generally accepted estimation is that ten per cent of the community members are herders today. Reindeer herding is, nevertheless, culturally and politically crucial to the

Saami. Increasingly though, the income from reindeer herding is insufficient to sustain the livelihood of herders.

Legislation and praxis have been disadvantageous to women as compared to men, in terms of maintaining Saami aboriginal rights and acting as reindeer herders. Thus Saami women face double oppression of their rights, as aboriginal individuals, and as women, even today. Nevertheless, many Saami women are well educated, which is a resource for the Saami society in making new and useful knowledge and methods available, for example to reindeer herding. At the same time, they carry valuable traditional and cultural knowledge, and are keen to pass them over to future generations. [1][2][3]

INSPIRATION

SNC is a proposition evolved from an initiative to develop women's economic strength and political and economic influence in Sirges Saami Village in the Jokkmokk area of northernmost Sweden. On initiation by the Saami Village, a woman-to-woman contact between the Saami Village and the academic environment at the university situated in the regional capital Lulea was established, with the purpose of conducting analysis of women's situation and initiating research-based development towards gender equality and economic growth. As this paper will show, SNC signifies a valuable and unique combination of frontline technology development and aboriginal and gender equality concerns. [4]

The significance of information and communication technology was evident early in the co-operative research and development project, both for material and strategic reasons. There is potential in this growing industry. Besides, the keen interest that it attracts from industry, state and investors makes it a likely origin for resource allocation.

The original idea for a solution to the problem of providing network connectivity for the nomadic Saami people was derived from notions developed by the Interplanetary Internet (IPN) research group as presented by Vint Cerf at the IETF plenary in 2001. Many, though not all, of the requirements of the interplanetary network project pertain to the SNC project. The primary similarity stems from the scarcity and intermittent nature of link layer communication capabilities in the northern regions occupied by the Saami Reindeer herders. Because of this, it is impossible to create a connection that meets the TCP RTT requirements, which means that none of the applications that rely on TCP for their transport connectivity can be run. The IPN solution has been designed to use an end-to-end layer (above the transport layer) called the bundle layer[5] to allow all protocol elements in a transaction, from initialization to completion, to be combined into a single bundle. Using Delay Tolerant Networking (DTN) technology (which is a generalization of IPN) in a hybrid solution with

other current technologies, it should be possible to provide basic Internet access to the community.

The initial goal of SNC will be to provide email, cached web access and reindeer herd tracking telemetry. The project is currently in its initial (design) stages. Plans for a pilot installation in several Saami herding areas in the summer of 2004 are currently being developed and submitted for funding.[6]

SOCIAL/COMMUNITY IMPACT

A step towards social re-integration

SNC enables the development of practices for education, health service, and distance work that re-establish the possibility of keeping family members together throughout the year-cycle. Modernity and the projects of modern state, built upon a model of stationary livelihood as they are, have put strain to the nomadic cultures of northern Fennoscandia. One example is the modern school system. In Sweden, compulsory education of Saami children was arranged via boarding schools in the first part of the 20th century, in accordance with the state regulated school system, with the result that children started losing contact with their own culture. In the latter part of the century, mothers came to live with their children. So instead of children, their fathers became isolated. In either case, apart from social and economic consequences, imparting unique cultural knowledge became difficult, if not impossible.

SNC will enable the Saami people to keep their children with them yet have them schooled via the proposed network. Without connectivity, women are forced to be closer to towns, where schools are located. With network connectivity, schools can educate children remotely so they are able to acquire Saami nature-based education as well.

As to health care, there is no arrangement of a service analogous to 'Flying doctors'[7] (provided to Australian sheep farmers) for Saami reindeer herders. This highlights another factor where the SNC proposition has potential to make changes, namely to the differences in availability of services between urban and rural areas. When it comes to health care, if there is a big difference in the service provided in two places, the choice to stay in the better one will for obvious reasons be the only feasible at a certain point in most individuals' and families' lives. But also more general services, such as communication systems, availability of leisure and mass media create corresponding straining gradients to a local community, for example in relation to the young.

It is also clear that distance work and net-based business, in self-employed or employed arrangements, has attractive potentials of enabling a shared life, breaking isolation, decreasing stress, and offering new and diversified job opportunities.

In sum, an affordable access to technology can function as a buffer between static, modern systems, and organic, wilderness-based organizations of life. [1]

ICT and the Saami as aboriginal people

Information and communication technologies (ICT) serves the Saami population in a specific way, which is unique to the Scandinavian context and refers to the situation of being an aboriginal population in an area now split between four countries. The electronic media gives an opportunity to exchange information and create discourse in a space controlled by Saami partakers, without interference from mediation, transformation and exclusion which are inherent in traditional media controlled by majority state or business interests. It has been seen that this has had positive consequences, such as the development of epistemology among Saami scholars, the facility for herders to get news and authority feedback of importance to their business, and establishing and maintaining contacts. A prime example is SameNet, an Internet portal originally built for educational purposes at the Saami Educational Center in Jokkmokk, Sweden. Today, it is used in the whole Saami area for gathering information, chatting, and online discussions.

The publication of books is an expensive matter when it comes to small languages. It is also less probable that the unique interests and set of knowledge that are shared among reindeer herders, and their lives and identities will be mirrored in literature, arts, mass media and general public discourse. ICT has the potential to host the creation of a space that can serve for this crucial cultural purpose. This seems to have already taken place to some degree with the creation of a virtual community in SameNet. Unfortunately it can only be accessed when in towns, and is not available in important territories occupied by the Saami reindeer herding population in the course of their normal lives.[1][8][9]

SNC seeks to bridge this gap by bringing connectivity-albeit intermittent-to the doorstep of the Saami population.

Telemetry

Pelto, the Finnish anthropologist, coined the expression 'snow mobile revolution' to describe what happened in Finland, when in 1970's - 1980's the snow scooter became a necessity for maintaining reindeer herding businesses.[10] While making the herding activity more efficient to some degree, the costs for the snow scooter and petrol to run it is however high: so herders who cannot afford them have to leave their businesses. The income decreases for those who stay on, as the scooter consumes resources generated by the company. Thus, even though the snow scooter is judged as necessary today, the search for a technology to replace it is on.

Herding activity requires knowing where the herd is. As of today, this involves long periods of staying away from home, tracking them, which is particularly

difficult for women. Thus the possibility of identifying the position of reindeer from a distance appears attractive. A number of tests of different systems have been performed in Sápmi and other circumpolar areas. In Sirges village, a test project funded by EU is currently being run, based on radio transmitters attached to a pick from villagers' herds, with capability for instant positioning.

An SNC telemetry system would offer data that gives the position of reindeer with respect to time. With telemetry, the location of reindeer can be tracked remotely, thus requiring less time away from home. A breakthrough in positioning technology could trigger the next revolution, after the snow scooter revolution.[1]

Thus, ICT is an enabling technology for reindeer herding, and more so for women herders since they have additional responsibilities.

TECHNICAL IMPLEMENTATION

The initial requirements for the SNC project fall into 2 categories:

- Applications that serve the educational and community needs of the Saami people
- Business applications pertinent to reindeer herding

The basic IP applications that are important to the Saami community in the initial phase of the project are:

- Email
- File Transfer
- Cached Web services

The business application requirement is for the application of telemetry to the movement of reindeer and the ability to confidentially report the movement trends of specific groups of reindeer to the herders that own them.

These application requirements need to be met in an environment where the lower level connectivity is varied and is subject to large delays that are greater than any acceptable TCP RTT.

Other requirements include the prohibition against building permanent infrastructure that is incompatible with the rules that govern protected land. Much of the Saami grazing area is located within National Parks and other natural reserves that prohibit construction of antennas, stringing of cable or power lines and any other construction of durable infrastructure. The network will have to rely on existing infrastructure; i.e. where there are power lines and cables, they can be used. Likewise where GSM access is available, e.g. on the summits and east side of hills and mountains, it can be used in the construction of data link for the network. Additionally, available satellite and digital television

broadcast capabilities will be used where available and cost effective.

A final requirement on the project is the social one. The installation of the network has to be in keeping with the cultural patterns of Saami life. It also has to be a structure that is sustainable in the long run by the Saami population itself. This includes the requirement that there should not be a high recurring cost for network access.

Origins of the Technical Approach

The solution proposed in this framework combines elements of different research approaches to network architecture. Specifically, ideas have been adapted from:

- Delay Tolerant Networks (DTN)[5][11]
- Network Address Translation and Protocol Translation[12][13][14]
- Network Mobility (Manet)[15]
- Web Caching Strategies

Technical Overview

The basic design involves setting each remote area as its own NAT region. At the edge of the NAT a gateway provides an application layer gateway to terminate applications and produce bundles. The data bundles are then relayed between gateways using DTN routing through a series of fixed and mobile relay caches. The mobile relay caches travel periodically between residential communities, meeting points where data bundles can be exchanged, and locations where gateways to the Internet and other community nets are available.

Bundles are essentially a store and forward mechanism that allow for all the information required to complete an action to be combined into a single datagram. The nature of the SNC network will require that these bundles be stored for significant periods before they are forwarded. Thus SNC will, at its core, be a store and forward network. By this is meant not the store and forward model commonly spoken of in networking where a datagram is forwarded as soon it is completely received, but rather that a datagram is stored until the resources necessary to forward it are available. The forwarding latency may be as short as seconds or as long as hours or even more.

Communication between gateways and relays will be primarily based on wireless technology. Part of the research involves mapping available wireless infrastructure to mobile wireless technology. This will involve understanding the dynamic relationship between available wireless hotspots and the spectrum range available on mobile carriers. Given that the mapping will need to occur in natural environments, it is a research activity that will require participation of geographers experienced in computer topography.

Underlying Architectural Principle and Requirements

The next sections will discuss the software architectural elements of SNC under the following general headings:

- Applications
- Middleware
- Addressing and Topology
- Routing in a DTN

Applications

One of the important considerations in this project is to allow use of the same applications in intermittently connected parts of the network that would be used by systems when fully connected to the Internet. This means that users should be able to use standard laptop and desktop systems loaded with the same applications that they would normally use when connected to the Internet via an ISP. In order for this to work, all applications in the disconnected network sections will be terminated at application level gateways (ALG). This is also an important reason for using the middleware solution proposed later in this document.

In the first phase of this project it will be necessary to deploy applications that can tolerate long delays. This includes email, file transfer and cached web service. It does not include transaction based (chatty) applications and peer to peer applications. Also excluded will be applications that require logging onto another system, e.g. SSH, Telnet or RSH.

Community applications

Community applications will include those applications that are necessary for allowing an extended electronic community to exist. This includes at its base email. It will also include applications such as web access that will allow for educational use.

1. *Electronic mail*: Email is possibly the most popular and wide spread Internet application. It is also the typical store and forward application. With the exception of its use of TCP, it is well suited to the SNC network.

Within the local network, email will work exactly as it does elsewhere. When a user sends a message, the Simple Mail Transfer Protocol (SMTP) protocol will relay it either directly to systems in the local network or to an e-mail gateway. The gateway will then take responsibility to relay it further.

2. *Web Caching*: Providing web access will be an interesting challenge and provides several research opportunities. The assumption being made is that a large percentage of a community's web access preferences can be predicted. As a community will normally be isolated from the rest of the web, it will be necessary to redirect all requests to the

community's web cache. This is assumed to be one component of the edge gateway service provided by the SNC network.

In this case, it means that local caches would be preloaded with material. The operating assumption is that the web material will fall into 3 classes:

- Material that is programmed for delivery. This will include material, for example, that is connected to the educational curriculum. Teachers and curriculum supervisors must be able to arrange for materials to be downloaded in advance. These downloads will fall into two sub-classes:
 - Material that is periodically updated
 - Material that is ordered for a specific project or lesson plan
- Material that is ordered periodically based on the history of previous requests. This could include daily newspapers, or monthly journals.
- Material that is ordered on an ad-hoc basis according to the individual needs of the users.

Delivery of material in the first two classes should present a fairly straightforward problem of tracking and downloading. It is also expected to comprise the major chunk of information to be delivered.

It is material in the third class, the on demand requests, that presents the greatest problem. In this case the naïve starting assumption is that the 80/20 rule will apply to this problem. I.e. that 80% of a community's interests can be predicted. This remains to be shown. The strategy will involve taking all requests that cannot be met by data that is cached and post a request. The request, however, would be not only be for the specific page requested, but for a reasonable number of links that might be desired based on information in the requested page.

Business applications

There will be several characteristic differences between the community applications and business applications. Among these are the requirements for:

- Fault tolerance
- Security issues

Reindeer Telemetry

This is a rich field, both in available technology and interesting research problems. Not only are many small and lower power devices being created,[16] but the study of sensor networks is very active. The project will study the available devices to find the right ones for testing.

- Tracking:
A sensor net is proposed to be built which can allow herders to track their herds. It is unclear at this point whether it will be sufficient for this to be based on exception alarms; i.e. when the

herd crosses a warning track that indicates they are headed out of the prescribed zones, or a steady tracking system which allows herders to know where their herds are at any particular time. What also needs to be evaluated is: How fine does the degree of knowledge about herds need to be? While it is important to be able to delineate which herder's reindeer are being tracked, it is probably unnecessary to know which particular reindeer is being tracked. On the other hand, in order to understand the behavior of the herd it may be necessary to show tracking paths for a specific group of reindeer within a herd.

- Reporting:
As important as it will be to record the movement of the herds, applications will be needed to convey that information to the appropriate herders. At a minimum, this will require alarms to indicate that the herd, or a smaller component of the herd, has moved beyond a predetermined alarm point. In the more advanced case, a graphic application that shows the movement of the herd over time with projections of future movements will be required. A question to consider is: Given that the sensor network is of low power, what is the proper means of storing and forwarding the telemetry data?

Middleware - Bundling

A key component of the entire system is the bundling system. A bundle[11] is composed of the entire application message necessary to complete the required task; e.g. send an email message or retrieve a file. Essentially a bundle eliminates the chatty nature of most application interactions. The purpose of bundling is to overcome the limitation of TCP and its RTT. Due to the delay in this system, all of the communication between source and destination that are required for the transaction will be combined in the single datagram. A bundle contains all of the data that would be sent in a normal application as well as any metadata that might be needed to complete the task.

Bundling will occur at the application gateways. Essentially the application will be terminated at the local NAT and the necessary information, data and metadata will be bundled and forwarded across the network.

The intention of the project is to build on the work being done by the Interplanetary Internet researchers.[5]

Addressing and Topology

Each community network will be a separately addressed NAT; i.e. it will use IP addresses in the range allotted for private use by RFC1918. Each community will be addressed by a globally unique assigned IP address. An investigation is currently ongoing into the scheme to be

used to link separate NAT communities with each other and with the Internet. Two possibilities are in active consideration: IP Next Layer[13] design and IPv6 tunneling[14].

Routing in a Delay Tolerant Network

In a DTN it is not necessary that the path from SRC to DST be known at any specified time, but it is necessary that there be a probabilistic expectation that a path will have existed before some predefined time interval, e.g. an hour or a day, has elapsed. In a DTN links to other DTN routers will fall into one of the following categories:

- Persistent
- Intermittent
 - Scheduled
 - Opportunistic
 - Predicted

By its nature, a DTN is a store and forward network. Unlike other store and forward networks where a payload is stored for a very short interval, in a DTN a bundle must be stored until it is reliably forwarded toward its destination. In addition to investigating the use of the current mix of protocols proposed for mobile networking[15], project researchers are investigating other methods of opportunistic routing. Some of the possibilities being investigated include epidemic routing[17] as well as forms of probability vector.

Custody transfer in DTN routing:

In order to balance the need for reliable bundle forwarding, retransmission and the need to minimize system wide storage, the DTN framework includes the ability for a DTN router to transfer the custodianship of a bundle to a downstream DTN router.[5] This in effect delegates the retransmission responsibilities for the bundle and allows the previous custodian to free up its storage resources. The mechanisms for transferring custodian responsibilities need to be studied and incorporated into the routing solution.

Time to Live and Acknowledgements:

In order to minimize network storage requirements in each of the routing schemes studied, attention will be paid to methods for having a destination acknowledge receipt of a bundle before the bundle retention timeout period has expired in upstream DTN routers. This will allow all upstream custodians to free their buffers and will lessen the traffic in the network.

Radio Link Technology

In the area to be covered by SNC, there is an uncertain mix of access technologies:

- Wired access: In some of the areas, there are power lines and phone lines that may be used for Internet access.

- GSM access: In certain areas, e.g. the eastern side of some of the mountains and in various low-lying areas, there may be locations where GSM is useable for Internet access.
- Satellite access: There is intermittent satellite coverage. This offers a narrow bandwidth and is very expensive
- Short Wave: There is an as of yet unexplored possibility that short wave could be used in restricted areas. A key constraint with short wave is the antenna installation that would be required.
- Low powered radio capabilities, e.g. 802.11, that can be carried on relay systems. Use of some of the work being done of focusing 802.11 for greater range is being investigated.
- Very Low powered radio capabilities that can be stationed as telemetry collection points.
- Digital Television Broadcast. Some of the areas that need coverage will be within the broadcast range of digital television. In this case, some of the bandwidth can be used for data delivery. This will be especially useful in delivering material for maintaining the web caches.

It will be necessary to understand the coverage and economic considerations of each of the existing access methods. Gateways can be placed wherever there is a possibility of access to the Internet. In determining where to place gateways, the fixed access opportunities will need to be mapped against the path of relay access flow. The mapping will need to account for the hotspot overlap between current structural access points and the range of the technologies available to the relays.

Study of Area Topography

A critical component of this project is the predictable, though perhaps not scheduled, relay of information from one fixed point to another via mobile relays. The human traffic pattern, especially vehicular patterns, is to be recorded so that we can plot the available flows for the summer land relays. The herding patterns of the reindeer in the winter land needs to be understood to plot the proper placement of the sensor network.

PROJECT PHASES

The SNC project is expected to go through several stages:

- 1 The project is currently in its initial stage. During this stage, background research and architectures are being done. In addition to this, proposals are being created to apply for funding for the later stages. This phase is expected to end by April 2003.
- 2 This stage will involve building simulations and prototypes. The prototypes of required field elements will be created and tested in laboratory conditions. It will also involve plotting the locations for fixed and mobile relays within designated field areas.

- 3 This stage will involve conducting field trials and is planned to begin in Summer 2004. The current plan is to deploy the network in two configurations:
 - a Community based user network in the Sirges village summer lands.
 - b Reindeer telemetry network in Sirges village winter lands.
- 4 Assuming that the field trials are successful, the intention is to make plans for wide spread deployment.

RELEVANCE TO BENEFICIARIES

The educational system is not closed to Saami as individuals today. With regards to reindeer herding however, structural patterns remain, which can best be described as colonial and which lead to, among other things, insufficient contact with frontline technology development. Such a state is likely to result, as a number of international reports have shown, in less favorable living conditions and weak, even negative economic development. Moreover, this situation has relevance in political terms as well as terms of identity to all Saami in Sweden, including those not involved in reindeer herding, as herding has long been the only base for indigenous rights acknowledged by the Swedish state.[18][19]

The SNC project will serve the purpose of driving positive change by not only establishing Internet access and a tracking system, but also by creating close contacts between Saami interests and frontline technological development.

In the long run the primary beneficiaries of SNC will be the Saami population who will gain community, educational and business advantages of ICT. Other beneficiaries include any community with a challenged network structure. Given the strong influence of women on SNC, practical symbolic and know-how factors of the project will contribute to women's better possibilities and gender equality. The project will also provide real application for some of the opportunistic routing methods that are currently under study in several universities.

Some of the problems related to this project are relevant to space travel and satellite installation. There is extensive cooperation between SNC researchers and space agencies working on these technical issues.

CONCLUSION

Because ICT was built up by and for people who are rooted in industrialized society, it carries structures and presumptions that compel a life adjusted to mechanical time and to a closed room. Thus, it does not accommodate the genuinely nomadic life that reindeer herders embrace and strive to develop and pass on to future generations. Building up a system through co-operation with these herders, from the roots of their lives and culture, thus offers an excellent venue for ICT innovation. In the long run, the culture and identity

factors are perhaps the most valuable to this project, as they challenge the built-in contradictions and shortcomings of ICT itself.

Building on many different technologies, it is the goal of the SNC project, once funded, to create a network structure that serves the Saami people. While the immediate goal is to provide Sapmi with a network that matches its natural and cultural imperatives, in the long run it is intended to create a new amalgamation of technology that can serve other network challenged areas as well.

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