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Realizing Delay Tolerant Networking as Access Enabler: Services Arising in New Realms and the Driving Applications

John NÄSLUND[a,1], Maria UDÉN[b], Karl Johan GRØTTUM[c] and Sigurd SJURSEN[d]
[ab] *Luleå University of Technology*
[cd] *Northern Research Institute Tromsø AS*
1 Dpt of Human Work Sciences, Luleå University of Technology, S-97187 Luleå, Sweden.
E-mail: john.naslund@ltu.se Tel: +46-(0)70-6371015 (M) or +46-(0)920-491785 (O)

Abstract. Many locations are not within reach for the physical infrastructure of communications networks. This is a challenge for the Future Internet. One technology currently investigated as a possible enabler is Delay Tolerant Networking (DTN). It is a reasonable assumption that the applications that are the presently most used in the "normal" internet will continue to be of most importance also in hitherto not ICT covered areas. But, for local SMEs the rational may rather be development of specialized services, exploiting DTN technology to increase the efficiency and market potentials for their activities in remote locations. To achieve this, hardware and open source software are put together to form a node system that make up the DTN applications, custom built to the situation with focus on power management, routing schemes and custom made software based on user need. These nodes are tested with users in real life test beds, enabling internet connectivity to reach even further, without the need for new physical infrastructure.

Keywords. Delay tolerant networking, internet, applications, service, rural areas

1. Introduction

The developing networking standard known as Delay Tolerant Networking (DTN) was originally envisioned as a tool for space communications purposes. Delay tolerance was needed as the physical distances make normal internet routines unfeasible. Gradually, the scope targeted widened, as it was realized that terrestrial scenarios were applicable as well. Many locations in the world are not within reach, and additionally not within affordable reach, of the optical fibres, copper cables, radio waves or even satellite links. By 2002 the formerly "Interplanetary networking" was definitely re launched, through the publication of the draft *Delay-tolerant Network Architecture: The Evolving Interplanetary Internet*. [1] The evolving standardization is currently prepared in the DTN research group, DTNRG, within the realms of IETF/IRTF. [2][3]

One area of the Seventh Framework Programme is the future internet. Speaking of future internet, one aspect is the interaction between applications and networking strategies. With new scenarios being opened through the launch of new protocols and infra structures, applications for these new scenarios stand at a front line that can be apprehended as an empirically available aspect of the clean slate state. This article explores the options from a service or application point of view, for DTN implementations to become successful ICT access enablers for challenging scenarios. The template is remote and rural communities, authorities and commercial interests that operate in communication challenged regions. *Networking for Communications Challenged Communities*, N4C, is a three year FP7 project with focus on creating socio-technical networks involving next generation routing,

hardware and at the same time working with people and SMEs in remote and rural areas to reach a sustainable solution for internet access. We have built test beds in remote areas, learning step by step how to set up networks beyond modern infra structure including for instance how to utilise natural power sources. DTN applications are developed and tested with the future every-day user in focus. Presently in our third and last year, we are iterating with new updated software and hardware, using information learnt from previous tests.

2. Pervasive Computing in Extreme Areas

Hiker's personal digital assistants, climate and emissions data observation and DTN test beds are three examples of pervasive systems developed in N4C. They are collaborative but stand-alone applications exploring the use of Delay Tolerant Networks (DTN) to provide connectivity and services in Communications Challenged Regions (CCR), where there is no infrastructure for connection to Internet and no mobile phone coverage. Delay Tolerant Networking is concerned with interconnecting highly heterogeneous networks together even if the end-to-end connectivity may never be available. [4]. In N4C a set of pervasive applications are provided using a DTN infrastructure in remote areas of Swedish Lapland and the Slovenian forests. A prerequisite for pervasive applications is connection to the Internet, usually provided by wireless communication. Since TCP/IP is an end-to-end protocol it tends to time out when communication is delayed or disrupted. However, many types of applications are inherently delay tolerant and could perfectly well have survived such disruptions, if it were not for the behaviour of the underlying network service. In order to extend the realm of pervasive systems to include delay tolerant applications, one must use a delay tolerant protocol. The N4C paradigm emphasises the nomadic nature of both users and by implication the network as a whole – In N4C the user is the network, in contrast to the conventional Internet where the network and the user, with the end-node, are functionally and physically separated.

3. Method; Users and Applications

The template scenarios for N4C include the reindeer grazing areas of Swedish Lapland and the formerly closed military area of Kočevje in Slovenia. Each area represents a concrete, existent use scenario of the communications challenged region type in Europe. The Swedish template scenarios have been developed in conjunction with the every-day situation of an indigenous Sámi population of semi nomadic reindeer herders in northwest Sweden. Kočevje is situated in south-east Slovenia. After the Second World War it became sparsely populated - almost without settlements in the last 60 years. It is now mostly overgrown with forests. Only a few villages with poor infrastructure remain. While the settlements, contrary to the Sámi semi nomadic case are set, mobile outdoor life, such as hunting is central for the area. One example is hunting tourism. Another is forest surveillance. The Slovenian case is developed in conjunction with scientific equipment stations owned by the N4C partner MEIS storitve za okolje d.o.o.

A big part of the N4C methodology is to get as much information about the user scenario as possible, which means that collecting useful data from both developer and user experience from the field (I.e our test beds). Developers in the N4C project spend time in the Lapland rural area test bed during the summer when activity is at maximum. There we meet and interact with tourists and locals, spending time to learn the real situation – which is possible trough a good connection with local SMEs, reindeer herders and with the tourist association. What we hope to gain from this is of course a better understanding of user-need and knowledge that can transformed to new user services and application ideas. Most of the applications in today's N4C DTN solution are based on such knowledge, but there is still a long way to go in terms of usability and technological advancements. For instance, being

able to send a message to anyone in the CCR carrying a DTN compatible device is a very complex task, since there is no effective way to determine where in the region a user might be when a message is being sent. In the N4C testbed, Ad hoc research is used with a optimistic routing algorithm for such user-to-user connectivity, meanwhile infrastructure DTN nodes are placed on various locations providing the basic access to services like email, web caching, weather information and podcasts.

The research/testing itself in the living lab of our project asks for well planned and time consuming activities. Researchers from Ltu, Trinity college, MEIS, Intel and the locals from Tannak SME collaborate months before actually testing anything with users. The real life situation make itself apparent when testing high-tech equipment in extreme environments, such as transportation, accommodations, food, weather. Practically, researchers tests all equipment at or around their offices, then takes it apart and put it in cars, which they drive to the mountains where they switch to helicopters to finally reach the testing area where equipment is again set up. This of course brings a limit to weight and size of equipment and tools. Researchers accommodate in huts in areas without access to power lines and cell-coverage.

Each application has its own history and raison d'être in the project. *Web caching* and also *e-mail* are essential applications for providing what is in every-day terms thought of as "internet access" by end-users. It is well known that people in general often confuse the World Wide Web with the Internet as a whole and, having been one of the first the e-mail remains the most used application. To claim impact on the Future Internet it is hard to think of applications that are more convincing to target today. Hikers' PDA on the other hand, is an application particularly envisioned for use in wilderness and unsettled areas.

3.1 Hiker's PDA and Ad-hoc Connections

The Hiker's PDA is a portable handheld computer (PDA) in a Communications Challenged Region (CCR) equipped with a suite of rather simple and intuitive applications that aims to be useful tools for hikers, tourists and people that are doing any type of professional job in a CCR. The applications are based on user requirements collected from potential users over the last 3-4 years, which should guarantee that the applications are based on user needs.

The Hiker's Apps were designed with three kinds of user groups in mind:

1. Private professional users (business): Reindeer herders living and working in the Arctic area of Scandinavia and tourist guides who are working (and living?) in the Arctic area of Scandinavia.
2. Governmental professional users: Nature Park Rangers and the police working in the vast wilderness areas in the Arctic area of Scandinavia.
3. Private users: Tourists who are hiking in the Arctic area of Scandinavia.

On top of the DTN connectivity they might have access to the following applications: Email, Map service with GPS (for Location Based Services), NotSoIM (Not So Instant Messaging) for communicating with other people in the field, Web Service (e.g. to access cached web pages and RSS) and the GeoBlog. The GeoBlog is a special blog containing field observations where pictures and GPS localization may be added. When random users are within communication range, their PDAs will synchronize geoblogs so that the registrations are exchanged. Hiker's PDA is one of the research areas within N4C that uses DTN with ad-hoc connections, meaning that communication and data exchange can occur just about anywhere when there are two powered devices within reach of each other. This system is also usable for animal tracking, or in the N4C project case, reindeer tracking in northern Sweden, which is being experimenting on.

3.2 E-mail

E-mail is a 'fundamental' service in the Internet which users (almost) always expect to be provided as part of the services where the Internet is extended by means of DTN. Since E-mail is inherently a 'store and forward' application, adaptation to the DTN environment does not require any alteration to the user interface or specific alteration of user expectations. Implementation requires provision of a DTN based E-mail transport mechanism that can be used by mail transfer agents where delivery is configured to take place over links that utilize DTN.

3.3 NSIM

The Not so instant messaging service was originally meant for developers to test the functionality of a setup between nodes in a DTN. A developer can choose a specific node from a list of known DTN nodes and send a text message, and the receiving end can read it when it arrives. It is a purely technically focused service but nevertheless it has seen some usage even from users. N4C aims to keep using NSIM for development reasons, but it might be that it could be useful as a foundation for a messaging system even for other cases in the future as well. It is closely tied to the addressing scheme used for DTN nodes as compared to e-mail that uses a more general addressing scheme. NSIM is therefore restricted to communication with a DTN enabled area.

3.4 Web Caching

Web caching is used as a shorthand for techniques that will allow users who do not have an Internet connection that meets the relatively low round trip time bounds expected by the HTTP protocol and today's web sites. Short round trip times allow a displayed web page to be constructed from the responses returned from a number of separate requests to one or more web servers, each requiring a network round trip. In a DTN network the round trip time might be many hours, making the existing system effectively unusable. The web caching work made in N4C involves both technical development and research. The basic idea is that we are bringing limited web surfing to a CCR. We take something from legacy internet, make a package of it, and sent it out to the DTN. The problems N4C is trying to solve includes the large amount of data that must be sent over DTN, with whatever bottleneck might be out there, and how to supply web pages that contain scripts and are normally meant for the non-delayed legacy internet. On the research side there are questions on how to handle user web page requests and browsing, presenting web pages to users, and building user interfaces.

4. DTN Infrastructure

People (often tourists and locals) with their own laptop, PDA or a DTN kiosk in the rural areas can connect to a strategically placed village router to gain access to *email* service, pre-fetched web content (*web caching*), or they can request new content from the internet. Even a "provider pushed content" model can be used for automatic delivery of daily news and other subscriber based material to the village router. This approach make it suitable for people who frequently stays in the CCR and has access to a WiFi compatible device, who can then connected to the DTN connected village router. A good application example for the future of DTN is remote schooling, when children can stay longer in the remote area with their family – if the learning material could be sent trough a "provider pushed" web caching method to a village router.

4.1 Test bed System Architecture

The backbone DTN system contains a number of new hardware and technologies. For the static nodes (that doesn't move, but easily movable by humans), hardware is fitted into custom boxes, preferably built to withstand the forces of nature, such as wind, rain and snow. The last iteration ground-level DTN system contain nodes that are based on the new Proteus board, a small computer board with Atom CPU. It has Wifi, storage, USB and very low energy consumption. A lead acid gel battery and solar power is connected to it where the energy from the sun hits the mounted solar panels, which power converters keeps the batteries in a charged state during sunny days [6]. Additional DTN research is being made with the use of Prophet DTN and WiFi (802.11) ad-hoc, where the difference is that the computers, laptops and PDA's (such as Hiker's application) is configured with DTN software and applications so the devices can communicate directly with another node, and not just a pre-set node in a infrastructure.

All the N4C hardware is provided in small, low-cost computers, such as PDAs and Net-books. Two different types of computers is tested in the current iteration, Asus Eee PC as gateway nodes, end user DTN "kiosks", and the Nokia N810 as the Hiker's PDA (end-user node). The nodes are interconnected using either ad-hoc or fixed route (infrastructure) WiFi with a DTN protocol whenever they are within WiFi range. One type node is placed as a "data-mule" e.g in a helicopter, where other types of wifi-antennas can be used for extended range. The helicopter node is powered by the electrical outlet from inside the helicopter and from a battery when the helicopter is resting on the ground. Whenever the helicopter gets close to the ground, and the Wifi signal is strong enough, data transfers occur between the internet gateway node and the helicopter node, which is carrying the data from the remote villages. In return it gets data back from the gateway node, which is data from previous requests or data that is being "pushed" to the remote villages, e.g. emails or web-data.

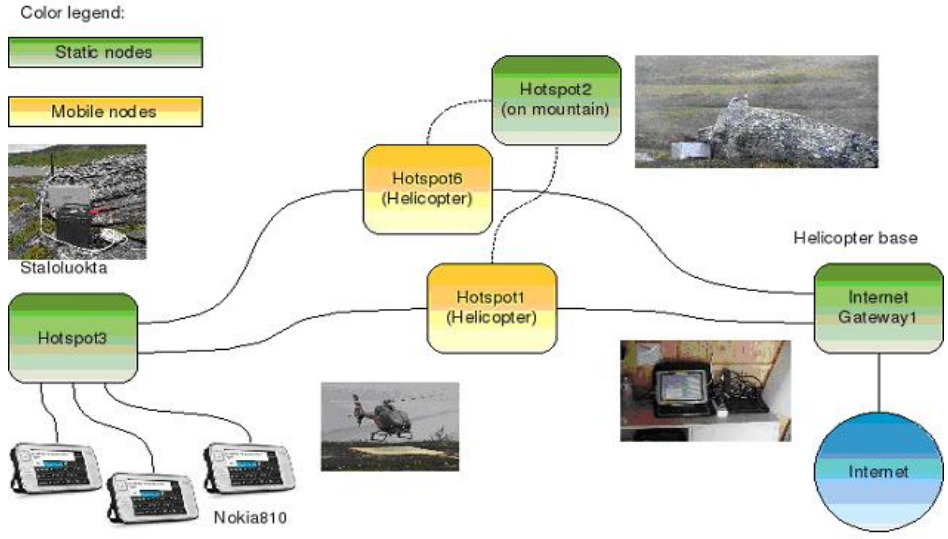

Figure 1: Example topology for summer test in a remote Lappish village using 3 Nokia810. There are 4 hotspots: one in a tent, 2 in helicopters and one on a mountain. The gateway to Internet resides in the helicopter base station in Ritsem.

4.2 Software Architecture

The Software architecture is divided in four different tiers; see figure 2 for an overview seen from the hikers application (which is used in the Nokia 810 during the tests). The Application layer called Hiker's PDA contains the application, user-to-user messaging (NSIM), Web, email utility, hiker, hunter, herder, and ranger's application that is custom

made for the user who need map, tracking, distance and localization features. The middle-ware layer contains meteorological applications, a web cache engine (web browsing from local memory cache), HTTP and meta data synchronization service (XML-RPC) and auto discovery (Ipv6) of other devices. The layer relays with the DTN layer which may provide communication to the Internet or to DTN, depending on where the user is. The Link layer is managing the different communications e.g. WiFi, WiMax and Bluetooth, and a USB connection can be used to get data from a simple data collecting node within the DTN used by any of the applications, such as animal tracking. The implementation of the software platform for the Hiker's PDA is based on Python.

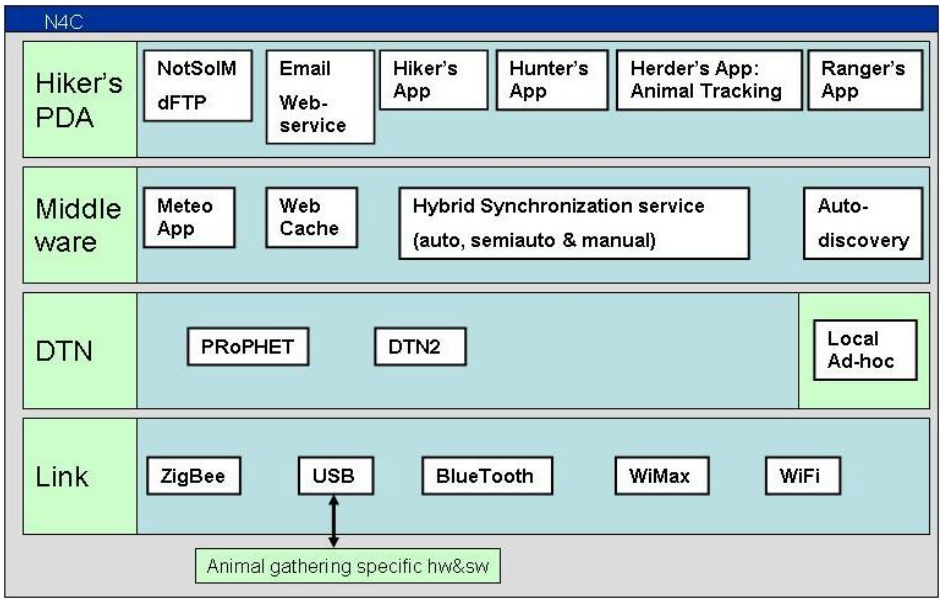

Figure 2. N4C Hiker's Application Software Model with Applications, Middleware, DTN and Link Tiers

5. Early Results and Future Work

After two summer tests and one winter test, the N4C project has gained certain unique experience. The results are interesting both from a hardware/software perspective but we have also gained more understanding about the user situation in the remote areas (the CCR). Aside from test beds, implementing and managing a DTN network is also one the more important things for sustainable solution, and therefore a business model looking on how to make use of open software is being worked on. A dialogue with local population and the tourist association is much of a key issue. The N4C DTN that has been built and tested is using hardware and software anyone should be able to obtain. What we see is that using natural power sources is possible, if combined with the right low power devices. We have seen how our hardware is affected by harsh conditions in our test beds; the hardware mounted in helicopters and open grounds is subject to all kinds of weather. We have a better idea what kind of antennas, batteries, and software will or will not work together.

From a user perspective, we also have ideas what kind of base services is needed. Email turns out to be a commonly requested base service by locals and tourists. Also, we work with web services that can provide information, such as weather forecasts and news. Working versions of these services have been successfully tested.

5.1 Implications and the Economy of DTN Applications

Rural areas are presently not apprehended as economic drivers. However, the management and exploitation of natural resources is among the decisive factors for global economy. Furthermore, rural areas are a part of the social context of Europe. Through the

interconnectedness between rural and urban, the economy of rural populations cannot be dismissed from the European agenda. The potentials for well functioning applications can be assessed only hypothetically at this stage. For instance, it can be noted that one quarter of the world's land mass is reindeer grazing territory [7]. In N4C achieving technical edge brings with it the social and economic goals of growth in remote rural areas; through technical experts co-working with rural inhabitants to address the challenges they put to ICT; through creating business opportunities for rural inhabitants out of this type of co-operation. The economic effects of poor communications coverage are not confined to traditional rural industries as agriculture, forestry, tourism. Studies conducted by N4C coordinator LTU within Process IT shows that robust and flexible communication infrastructure can play a key role in improving the effectiveness of regional and local process industries which have widely distributed infrastructure [5].

6. Conclusion

It is reasonable to pose that providing applications that exploit the progress made in DTN research is vital to getting these advances out into the field. Because of the novelty of DTN, there is a distribution of the actual development work for the applications. The FP7 ICT project *Networking for Communications Challenged Communities* (N4C) is one of the projects currently working on taking the next step to realizing the perceived potentials of DTN. N4C operates with an integrated networking architecture intended to treat the conventional Internet infrastructure and DTN as peers rather than presenting DTN as an alternative link layer technology as is usual when integrating different sort of transmission technology into IP networks. Working with the aim to open areas for internet access that have hitherto not been covered by modern communications and, in that process choosing what applications to take on, highlights that the approach to services can vary largely and, that the interpretations of attractive options are connected to the socio-economic stance from which the situation is viewed. Different hypotheses and geneses can be traced for each application. For instance, one can assume that the applications that are the presently most used in the "normal" internet will continue to be of most importance also in hitherto not ICT covered areas. For members of the internet expert community, e-mail and web access has been the prime target. But, locally active SMEs involved in N4C demonstrate other interests; the rationale for their involvement in the project is the development of specialized services that increase the efficiency and market potentials for their activities in remote locations. It can be noted that the application that generate traffic enough to first motivate a DTN enabled network being built and run, is not necessarily the same as will eventually be the most important for creating sustainable conditions for remote and rural communities.

References

[1] Cerf, V.; Burleigh, S.; Hooke, A.; Torgerson, L.; Durst, R.; Scott, K.; Fall, K.; Weiss, H. (2002): Delay-tolerant Network Architecture: The Evolving Interplanetary Internet. draft-irtf-ipnrg-arch-01.txt. IPN Research Group, Internet Draft. http://www.ipnsig.org/reports/draft-irtf-ipnrg-arch-01.txt

[2] Delay-Tolerant Networking Research Group, http://www.dtnrg.org/wiki, accessed 22nd August 2009.

[3] Farrell, S. and Cahill, V. (2006) Delay- and Disruption-Tolerant Networking, Artech House.

[4] Beck, Richard et al (2007) GPSDTN: Predictive Velocity-Enabled Delay-Tolerant Networks for Arctic Research and Sustainability. The First International Workshop on Tracking Computing Technologies, IARIA-IEEE Track 2007, July 1-6, 2007 - Silicon Valley, USA.

[5] Davies, Elwyn et al. (2009) D3.1Functional Specification Version 1.5. http://www.n4c.eu/Download/N4C-WP3-2-fs-1-5.pdf

[6] Farrell, Stephen et al. (2009) An N4C DTN Router Node Design, Extreme-com 2009 article.

[7] Udén, Maria; Doria, Avri; Sjursen, Sigurd & Theodorsen Arne Wilhelm (2006). Anywhere? Anytime? The Northern challenge to ICT developers. I Matilainen, E. (ed.) ICT – Tools for providing information, advice and services for rural SMEs? RUBIES Seminar proceedings 6.–7. April 2006, Oulu Finland. University of Helsinki Ruralia Institute. Reports 10

