M8.4
Winter Tests Report
(Swedish test side) 2009

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ABSTRACT

The purpose of the document is to describe the set up and the results of the LTU's second winter tests performed in Sweden.

The document includes:

• Description of the used equipment
• Used DTN topology in the winter test
• Presentation and analysis of gathered results from the winter test

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<tr>
<th>Version</th>
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<tbody>
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<thead>
<tr>
<th>Level</th>
<th>Description</th>
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</thead>
<tbody>
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<td>Restricted to other programme participants (including the Commission Services).</td>
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<tr>
<td>PP</td>
<td>Restricted to a group specified by the consortium (including the Commission Services).</td>
</tr>
<tr>
<td>RE</td>
<td>Confidential, only for members of the consortium (including the Commission Services).</td>
</tr>
</tbody>
</table>
0. introduction .................................................................................................................................................................................. 4
1. TEST Description .......................................................................................................................................................................... 5
2. Time duration of the test ............................................................................................................................................................... 8
3. Results ........................................................................................................................................................................................................ 9
4. Accessibility of used code and log files .............................................................................................................................................. 14
INTRODUCTION

This document describes the second LTU's N4C winter test that took place in the Sami village Saltoluokta in Sweden. Main goal for this winter test was to test how the components used in the outdoor DTN node prototype used in the summer test will withstand the cold winter Arctic conditions.

The second goal was to try how much electrical power can be harvested from two natural resources (sun and wind) during the Arctic winter. The data from the DTN node, wind turbine generator, solar panel and temperature probes was logged for a period of three months. All the different type of log files had to be analysed together in order to recreate and understand the conditions that the outdoor DTN node was exposed to.
1. TEST DESCRIPTION

a) Used equipment

The LTU’s summer test outdoor static DTN node was reused in this winter test. The node is based on the Gateworks Cambria board, equipped with 2GB CF flash card. It included 75Ah 12V lead acid solar battery, voltage data loggers, solar and wind charge controllers, three temperature sensors and a Logitech 9000 web-camera mounted on the mast.

![Wind turbine used in the test - Rutland 913](image)

The node was powered by the 12V 80W solar panel and the 12V 100W Rutland wind generator. Two Lascar’s EL-USB-3 Voltage data loggers were connected separately to the wind generator and solar panel outputs. Sampling time for the data loggers was set to 5 minutes and with 32510 stored voltage records that data loggers allows we managed to log the output voltage for 3 and a half months.

![Voltage data logger from Lascar Ltd.](image)
All the components of used DTN prototype node were embedded in cheap plastic box that was additionally covered with the water proof plastic bag to protect it from the rain and the snow. Similar as in the summer test in 2009, high gain WLAN resonate slot antenna, wind turbine and the web-camera were mounted to a metal mast that was additionally anchored to the ground with three steal cables.

Since the sun is really low on horizon during in the Arctic area the solar panel had to be mounted vertically. As it turned out during the summer test, it is very practical and handy to use branches and tress to mount and secure the solar panel. The same practice was used for the winter test.
The outdoor node was mounted at the rivers shore in order to get as much wind as possible. Since it was mounted close to the Sami village, border node was placed inside one of the cabins that was less than 100m away and where we had access to the 220V power from the grid all the time.

b) Network topology

Used network topology included three nodes. Outdoor node was connected using the wireless Adhoc link to the node placed inside the cabin. This node based on the Asus EEE 903 with the 3G USB modem Border node was configured as a border node that used VPN connection in order to connect to the gateway placed in our LTU office in Luleå.

![Simple network topology](image)

Figure 5: Simple network topology

b) Services

The winter test didn't include any users. Three autonomous services were used during the winter test:

- **Web-camera service** was taking image snapshot every half hour. Images were automatically sent to the gateway were they could be seen online during the whole period of winter test.

- **Temperature loggin service** sent graph of three temperatures, node, outside air and soil temperature twice per day to the gateway. The transmitted graph could be then seen online.

- **ProPHET log file service** was collecting daily log files from all the nodes on the gateway. This service allowed us to online monitoring of the system.

All collected images were automatically published on LTU's DTN web site ([http://dtn.n4c.eu/webcam-salto](http://dtn.n4c.eu/webcam-salto)).
2. TIME DURATION OF THE TEST

DTN winter test was set up right after the summer test on the 13th of August 2009 and was left there during the winter. It was predicted in advance that the outdoor node will eventually stay without the power because of the lack of the sun and really cold Arctic conditions that will significantly decrease the capacity or complete fail of used lead acid battery due to a frozen electrolyte inside the battery.

The equipment was collected from the test sight at the end of the winter (middle of March 2009), when we were still able to access it with snowmobile through the frozen river, although it would be interesting to see if the node would „woke up“ itself in the spring when the climate is getting worm and sun starts to shine again. Unfortunately that area is practically inaccessible during the spring time because you can not pass the river that is full of melted ice with the boat.

It is worth mentioning that we were unable to get the soil temperature sensor out of the frozen soil and we had to cut some of the cables that were buried under the snow and ice. Attaching the cables as high as possible could save us from this problem in the future winter tests.
3. RESULTS

a) DTN system up time

The system worked fully without any problem or needed intervention from the 13\textsuperscript{th} of August 2009 until the 2\textsuperscript{nd} of October 2009. Up until then we were receiving web-camera snapshots, daily log files and temperature graphs on the gateway. During this period all the data were available online on the following address: http://dtn.n4c.eu/webcam-salto

The VPN connection with the border node was lost on the 2\textsuperscript{nd} of October 2009. Since then we didn't received any information from the field any more. It is still unclear what exactly happened to the border node inside the cabin, but it assumed that it was disconnected from the power grid. Log files from the border node and the connection log file of the outdoor node shows that the border node didn’t recovered any more.

Surprisingly, the outdoor node lived until the 14\textsuperscript{th} of November 2009, when we can see the last record in the log files. However the daily up-time decreased significantly in November. After examining the web-camera snapshots, we found out that after the 29\textsuperscript{th} of October 2009 daily up time was less than half an hour. That can be seen from the last web-camera image with this date, because the first image is taken after the node is up and running for an half an hour.

b) Services

Web-camera service running on the outdoor node with stored images was found to be very useful in a process of analysing the data and showed us in what kind of weather conditions the node was.

Figure 7: First image taken from the web-camera
After we collected all the images we made an interesting time lapse movie that clearly shows how the nature changes from the summer to the winter time. Because of the very strong wind it happened once that the camera view was tilted down, but it was fixed later one by one of the locals.

Figure 8: Tilted image taken from the web-camera

Figure 9: Last image taken from the web-camera
Final temperature graph shows that the outside temperature went down to -5 degrees C in the week 42 (mid October). An interesting fact is that during the day when the battery was charged in the hermetical closed box with the thin plastic wall, node managed to keep almost 10 degrees higher temperature inside the box compared to outside temperature. This fact did significantly improve the lead acid battery capacity during the winter time.

![Temperature graph from the outdoor node.](image)

**Figure 10: Temperature graph from the outdoor node.**

c) Generated power from the wind and sun

The following graph shows the raw collected data from the voltage loggers.

![Voltage graph generated from raw data](image)

**Figure 11: Voltage graph generated from raw data**
The input voltage range of used loggers is from 0V to 33V. As it is shown on the raw data graph, the voltage output from the wind turbine above 33V. This usually happened when the wind blows really strong and/or the battery is fully charged (in this case charge controller doesn't take any current from the wind turbine that would slow down the turbine).

The following graph shows daily average voltage from the wind turbine and solar panel. We can see that the daily average voltage from the solar panel is much more stable then the one from the wind turbine from day to day.

![Average daily voltage graph from solar panel and wind turbine](image)

In order to know exactly how much power did we got from each power source we would need two more loggers that would that would log the generated and used current from each source. Since this kind of data is not available we decided to make analysis that is based on the „charging time“ instead of the actually generated power that sometimes can not be harvest anyhow (limited by the maximal charging current of the battery and the charge controller).

A daily charge time that is shown on the following graph is a sum of time when the output voltage from the wind turbine and the solar panel was bigger than 12V (allowed us to actually charge the battery).
This graph shows that generated power from the solar panel was much more evenly distributed over time than the power from the wind turbine. The amount power generated from the wind seem to be much more unpredictable over the time. It also shows that if we want to use the wind turbine as a main power supply the battery capacity of the system should be as big as possible in order to store and harvest these peaks of power. This also means that is necessary to use more powerful charge controller as well.
As it turned out, during this winter test the charge controller failed due to a lack of over voltage protection. When exactly this happened is hard to say, but a working wind turbine charge controller would probably prolong the uptime of our outdoor node.

It is also interesting to compare linear regression lines of charge time from the solar panel and wind turbine. It is shown that the power outputs of both power sources are slowly decreasing from the fall to the winter time. It seems that in absence of sun light during the Arctic winter has an effect on the stability of atmosphere which results in the weaker wind. A long term yearly test would be needed to draw any conclusion about on this issue.

Promising fact is that linear regression line for the wind turbine is less tilted than the one for the solar panel, which conforms the initial idea that wind turbine is a better choice for supplying the electronic equipment in the winter Arctic conditions.

4. ACCESSIBILITY OF USED CODE AND LOG FILES

PROPHET

The ProPHET protocol source code is publicly available on Subversion repository located on: http://grasic.net/prophet

It can be easily downloaded and stored using one of the Subversion's client programs. Use the “checkout” command to download the latest version. For further information how to use Subversion repositories go to: http://subversion.tigris.org/

The code can be also seen using only the web browser on address:

http://grasic.net/prophet/

Log files

All the gathered log files from this the test and the raw data from voltage loggers can be downloaded from the following link:

http://dtn.n4c.eu/logfiles-winter-2009.zip

Note: File is big.

The log files will be created separately for each day and type of event. From the in depth analysis of the log files will be later on possible to extract all the node encounters, encountering duration, route of each bundle inside the network, size and type of the bundle, deliverable probability of each node, transferred data size, node's system start-up and shut-down time.