Evaluation DAS Net Performance Monitor

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1 Introduction

DAS[1] is a wide-area distributed computer consisting of 200 Pentium Pro nodes. The machine is built out of clusters of workstations, located at the following Dutch universities:

- Vrije Universiteit, Amsterdam.
- University of Amsterdam.
- Delft University of Technology.
- Leiden University.

The clusters are interconnected by ATM links for wide-area, whereas Myrinet, a Gigabit LAN, is used for local communication.

In this report we will concentrate upon the WAN ATM links, however, their performance will also be compared with the "normal" Internet route. Distributed applications need relative short roundtrip times between the clusters to run effectively; the precise figures are application dependent. The available bandwidth is for distributed applications in general less important. The characteristics of the ATM connections in principle match well with these requirements.

To compare the capacity of the ATM route between the clusters with the "normal" Internet route a network monitor package called rTPL (Remote Throughput, Ping and Load) is used. It is developed at the Institute of Computational Physics on the University of Utrecht. The purpose of this package is to obtain the network performance from an end user viewpoint. Therefore, some basic aspects of the network performance are measured by this script by using standard, general available software. The package uses dedicated scripts to invoke the net performance software. These scripts are also responsible for the sampling and storage of the results. The presentation

[1] http://www.cs.vu.nl/das

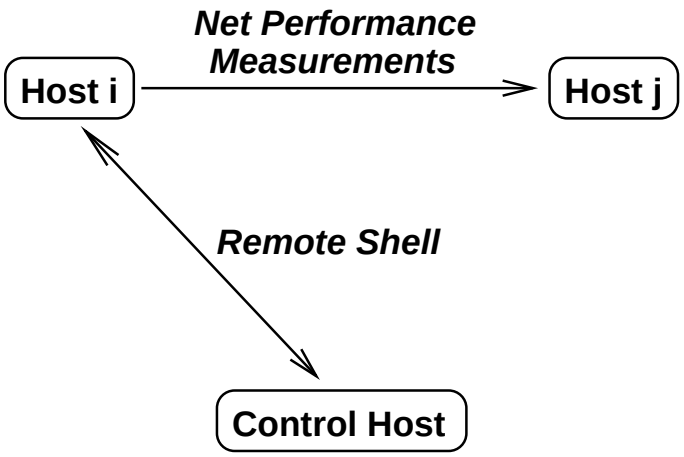

Figure 1: *The control host starts the measurements at all hosts i by means of remote shells. The host i performs the measurements to the hosts j The results are send back by host i to the control host.*

of the results is a separate part. It is Web based and dynamic: the user can select various views at the data.

This report is organized as follows. Section 2 gives a more detailed description of this package. In section 3 the settings, used in the DAS monitor are described. The measurements are presented in section 4. In section 5 some end conclusions are given.

2 Description

2.1 Measurement procedure

In this section a description of the rTPL package (Remote Throughput, Ping and Load) is given in more detail. As already explained in the introduction, this package periodically executes net performance measurements between a set of hosts. The measurements are performed by a, so called, control host. This workstation starts the net performance measurements at each of the participating workstations with a remote shell command, which also sends back the results. The scheme of this process is shown in figure 1.

At each host i of the set hosts, described above, the following net performance measurements are executed:

Throughput. Formal definition from RFC 1224 [1]: "The maximum rate at which none of the offered frames are dropped by the device". It is a way to quantify the traffic flow which can be handled by a network connection. Default it is measured for the connections from the current

host i to all other hosts, but it is also possible to skip connections. The throughput is measured with the public domain command `netperf`.

Roundtrip or Ping. This Internet application is described in RFC 2151 [2] by the paragraph quoted below:

> Ping, reportedly an acronym for the Packet InterNetwork Groper, is one of the most widely available tools bundled with TCP/IP software packages. Ping uses a series of Internet Control Message Protocol (ICMP) [3] Echo messages to determine if a remote host is active or inactive, and to determine the round-trip delay in communicating with it.

The roundtrip time quantifies the response offered by a network connection. It will be measured, before the throughput, across the same connections as the throughput. The roundtrip time is measured with the system command `ping`.

Load. This is expressed here as # fully active processes at a host. It is no network quantity, but it may help to explain unexpected performance decreases. The load is measured at the current host i, using the system command `uptime`.

The sampling of the results at the control host and the measurements at all hosts, participating in the tests, are performed by scripts in the scripting language *Perl*. The Perl script at the control host collects the results of the measurements for each host i and stores the results in ZIP compressed data files. The ZIP compression is used to reduce disk space and download time. See subsection 2.2 for a description of the data files.

Note that the tests are periodically started with the `crontab` command.

2.2 Presentation results and data files

The presentation of these results is Web based: a Java Applet is used to load the data from the files into the memory of the Web browser from a user analyzing the results. The HTML scripting language JavaScript is used to dynamically present the user various HTML tables of the data. That is: the user selects a view at the data and the HTML code is generated on demand by JavaScript. From the JavaScript direct calls to Applet methods are applied to obtain the required data from the HTML tables to display. The Applet can also be used to make various plots of the data which are displayed in a new Applet window.

The following data files are available to be viewed via the Web:

- The data of the last 7 days.

Title	*Hostname*	*University*
VU	`das0gw.cs.vu.nl`	Vrije Universiteit, Amsterdam
RUL	`das1gw.das.liacs.nl`	Leiden University
UVA	`das2gw.wins.uva.nl`	University of Amsterdam
TUD	`das3gw.tn.tudelft.nl`	Delft University of Technology

Table 1: *Titles, hostnames and located universities from the DAS hosts, participating in the network performance tests. The titles are also used in the Web presentation of the results. The hosts are the network gateways of the clusters.*

- The data during a week. There are several week data files available;e. The # weeks where data are stored, can be selected by the user. However, the maximum period is a year.
- The week mean values from the last year.
- The day mean values from the last year.
- The mean values, calculated at the periodic measurement times, and determined for the days of the week. They are averaged during a quarter. The data for the quarters are stored during a year.
- The mean values, calculated at the periodic measurement times, and determined for the workdays of the week (Monday – Friday). They are averaged during a month. The data for the months are stored during a year.

The user can download the current data file to the local host. It can be viewed with a special package of the rTPL package which is also available for downloading.

3 DAS settings

In this section we describe the special setup used for the DAS network monitor.

3.1 Participating hosts

At all DAS clusters the network gateway hosts are used for the network performance measurements. They are specified in table 1. In this table the titles, the hostnames and the universities were the DAS clusters are located, are listed. Please note that the same titles are also used in the Web presentation of the results.

3.2 Connection settings

Between (almost) each pair of the DAS cluster interfaces an ATM PVC (Permanent Virtual Connection) is available. This implies that the net performance measurements (throughput and roundtrip, see page 2 in section 2) has to be executed for the connections between all interface pairs across the ATM route, and when available also across the "normal" Internet route, in the sequel shortly denoted as the *Internet* route.

The available ATM bandwidth can be calculated as follows. The total bandwidth of the connection is 155 Mbit/s. There are also 75 idle cells for each 3 cells. This implies that the bandwidth for the interfaces B_I is

$$B_I = 155 \frac{3}{3+75} \text{Mbit/s} = 6.0 \text{Mbit/s}$$

Because the ATM PVC connections are symmetric, the tests are performed one-directional. This implies that for the interfaces, ordered as $I_1, \ldots, I_4$, the connection $I_i => I_j$ is tested only when $i < j$. For the Internet route this is in general less true, but the main goal of this package, used in this setup, is to watch the ATM route. Another complication is that not all cluster interfaces can be reached from the Internet, so we ordered the gateways such that as many as possible routes across the Internet could be tested.

The only Internet connection which could not be tested is the connection from the VU cluster to the UVA cluster.

Please note that the rTPL package can be configured to:

1. Do the measurements across a Quality-of-Service route *and* across the Internet, or use only one route between a site pair.

2. Do the measurement between a site pair one-directional or two-directional.

Both items can be combined in all four possibilities.

3.3 Measurement parameters

As has already been mentioned in section 1, it is our intension to get an impression of the network performance from an end users point of view. Therefore, the DAS monitor uses only default values for the roundtrip and throughput measurements. The roundtrip parameters are specified in table 2 and the throughput parameters in table 3.

4 Measurements

In this section some results are presented of the net performance measurements at the DAS cluster. Although the monitor is already longer active,

Roundtrip Parameter	*Value*
The packet size	64 bytes
The # packages which are send	40
The initial # packages not used in the measurements	2

Table 2: *Roundtrip parameters used in all examples.*

Throughput Parameter	*Value*
The test duration	10 s
The send size	32768 bytes
The local socket send / receive buffer sizes	32768 bytes
The remote socket send / receive buffer sizes	32768 bytes

Table 3: *Throughput parameters used in all examples.*

the data of the weeks are only stored from May 16, 1999. From this date also the data mean files are calculated. The data are stored for maximal a year. The results of the net performance monitor will be compared during the period 1999/05/16 – 2000/02/12.

4.1 Monthly average tables

In this subsection tables with monthly average values are presented. Please note that these tables are no part of the Web presentation, but these values are calculated from the week data files. Combined with the plots with weekly average values (sub section 4.2) these tables are intended to give an impression of the development of the network during the monitored period.

The following tables are displayed with net performance monitor results from the ATM route and from the Internet route when available:

- Table 4 contains the minimum, average and maximum roundtrip values from the VU cluster to the other clusters.
- Table 5 contains the minimum, average and maximum roundtrip values from the tests started at the UVA and RUL clusters.
- Table 6 contains the percentages roundtrip packages lost from the VU cluster to the other clusters.
- Table 7 contains the percentages roundtrip packages lost from the tests started at the UVA and RUL clusters.
- Table 8 contains the throughput values from the VU cluster to the other clusters.

Monthly mean roundtrip values [ms]										
	VU => UVA			*VU => RUL*			*VU => TUD*			
Month	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*T.*
	1.4	1.4	1.6	3.8	3.9	4.3	3.8	3.8	4.5	A
1999/05				5.3	14.9	50.6	4.9	16.5	115.8	I
	1.2	1.2	1.6	3.6	3.7	4.4	3.5	3.6	4.5	A
1999/06				4.4	8.3	33.8	4.9	16.6	119.3	I
	1.5	1.7	2.5	3.9	4.2	5.3	3.7	3.9	5.1	A
1999/07				5.0	8.7	30.9	5.5	17.2	114.2	I
	1.4	1.6	2.2	3.9	4.0	4.8	3.7	3.8	4.8	A
1999/08				5.3	10.8	25.0	6.2	13.1	42.8	I
	1.4	1.5	2.4	3.9	4.0	5.1	3.7	3.8	4.8	A
1999/09				4.9	8.6	28.0	4.9	9.4	29.6	I
	1.3	1.5	2.8	4.9	5.1	5.8	4.8	5.0	5.9	A
1999/10				6.4	11.3	34.5	6.9	13.6	36.6	I
	1.2	1.2	2.0	5.1	6.1	9.4	5.0	5.1	7.1	A
1999/11				5.3	9.1	31.6	5.9	11.7	37.4	I
	1.2	1.2	2.6	4.7	5.7	13.1	5.0	5.2	8.9	A
1999/12				4.7	6.3	20.5	5.5	9.0	25.4	I
	1.3	1.5	2.8	4.3	4.7	10.8	3.9	4.4	6.4	A
2000/01				4.2	5.1	10.3	4.8	6.6	13.6	I
	1.2	1.3	2.3	4.1	4.7	17.4	3.7	3.8	5.9	A
2000/02				4.1	5.4	9.2	4.5	5.5	9.6	I

Table 4: *The monthly mean minimum, average and maximum roundtrip values from the VU cluster to the other clusters. In the top row of each month the values for the ATM route are displayed. They are denoted with 'A' in the right-most column. In the bottom row of each month the values for the ("normal") Internet route ares shown. These are labeled with 'I' in the right-most column.*

- Table 9 contains the throughput values from the measurements started at the UVA and RUL clusters.

Some direct conclusions from these tables are drawn in subsection 4.3.

4.2 Weekly mean plots

In this subsection some plots with weekly average values are shows. As in section 4.1 these plots are intended to give an impression of the development of the network during the monitored period. The plots are derived from the Applet plot window which is a fragment of the net performance monitor Web pages.

The following figures with monitor data plots are presented below:

- Figure 2 shows the minimum roundtrip values for all ATM (top plot)

Monthly mean roundtrip values [ms]										
	UVA => RUL			*UVA => TUD*			*RUL => TUD*			
Month	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*T.*
	2.9	3.0	3.2	3.0	3.0	3.5	1.7	1.8	2.4	A
1999/05	4.2	8.8	25.4	4.8	20.3	144.3	4.6	15.5	136.2	I
	3.0	3.1	3.2	3.0	3.0	3.3	1.7	1.7	2.2	A
1999/06	4.1	8.7	26.2	4.4	21.3	154.8	4.9	16.7	149.4	I
	3.3	3.5	4.2	3.0	3.1	3.7	1.8	2.1	2.8	A
1999/07	3.7	5.4	14.7	3.5	13.2	104.9	5.5	17.8	138.1	I
	3.3	3.4	4.4	3.0	3.0	3.6	1.9	2.0	2.5	A
1999/08	3.6	4.3	7.5	3.6	5.4	16.3	5.7	7.3	13.6	I
	3.3	3.4	4.0	3.0	3.3	6.2	1.9	2.0	3.0	A
1999/09	3.7	4.6	9.7	3.7	5.8	13.9	6.6	8.7	15.2	I
	4.8	4.8	5.2	4.4	4.5	5.0	1.9	2.0	2.6	A
1999/10	4.3	5.0	9.9	4.3	6.7	14.6	5.1	7.4	13.0	I
	4.9	5.0	7.2	4.6	4.7	5.5	1.9	2.0	3.2	A
1999/11	4.3	5.2	11.9	4.7	7.6	17.9	5.6	8.7	15.2	I
	4.4	4.5	6.5	4.6	4.7	6.5	1.9	2.0	3.7	A
1999/12	3.8	4.7	13.5	4.6	7.6	20.0	6.2	10.2	17.8	I
	3.9	4.4	18.4	3.3	3.5	5.5	1.7	1.9	3.5	A
2000/01	3.4	4.4	14.1	3.8	6.1	19.8	6.0	8.4	13.4	I
	3.8	4.2	14.4	3.2	3.3	4.7	1.6	1.8	3.9	A
2000/02	3.0	4.2	15.9	3.2	4.7	21.1	5.1	6.0	8.6	I

Table 5: *The monthly mean minimum, average and maximum roundtrip values from the UVA and RUL clusters to the remaining ones. In the top row of each month the values for the ATM route are displayed. They are denoted with 'A' in the right-most column. In the bottom row of each month the values for the Internet route ares shown. These are labeled with 'I' in the right-most column.*

Monthly mean roundtrip packages lost [%]						
	VU => UVA		*VU => RUL*		*VU => TUD*	
Month	*ATM*	*Inet*	*ATM*	*Inet*	*ATM*	*Inet*
1999/05	0.00		0.00	1.34	0.00	1.38
1999/06	0.07		0.00	1.07	0.00	1.28
1999/07	0.00		0.00	1.21	0.00	1.44
1999/08	0.00		0.00	0.93	0.00	0.66
1999/09	0.00		0.00	0.92	0.00	0.46
1999/10	0.00		0.00	0.76	0.00	0.79
1999/11	0.00		0.00	0.76	0.00	0.79
1999/12	0.00		0.00	0.36	0.01	1.08
2000/01	0.00		0.00	0.47	0.07	0.74
2000/02	0.00		0.00	0.87	0.00	0.02

Table 6: *The monthly mean roundtrip packages lost from the VU cluster to the other clusters. These values are displayed for the ATM route and for the Internet route. The latter is denoted with "Inet".*

Monthly mean roundtrip packages lost [%]						
	UVA => RUL		*UVA => TUD*		*RUL => TUD*	
Month	*ATM*	*Inet*	*ATM*	*Inet*	*ATM*	*Inet*
1999/05	0.00	0.94	0.00	1.48	0.00	1.71
1999/06	0.00	1.06	0.00	1.55	0.00	2.01
1999/07	0.00	0.64	0.05	1.34	0.00	2.10
1999/08	0.00	0.19	0.00	0.42	0.10	0.62
1999/09	0.00	0.34	0.00	0.45	0.00	0.84
1999/10	0.00	0.31	0.00	0.61	0.00	1.15
1999/11	0.00	0.44	0.00	1.03	0.01	1.60
1999/12	0.00	0.42	0.00	1.08	0.00	1.84
2000/01	0.00	0.56	0.03	0.66	0.00	1.30
2000/02	0.00	1.01	0.00	0.10	0.00	0.87

Table 7: *The monthly mean roundtrip packages lost from the UVA and RUL clusters to the remaining clusters. These values are displayed for the ATM route and for the Internet route. The latter is denoted with "Inet".*

Monthly mean throughput values [Mbit/s]						
	VU => UVA		*VU => RUL*		*VU => TUD*	
Month	*ATM*	*Inet*	*ATM*	*Inet*	*ATM*	*Inet*
1999/05	5.13		4.13	3.66	5.00	5.00
1999/06	5.09		4.19	3.54	5.01	4.96
1999/07	4.76		4.11	3.38	4.99	4.86
1999/08	4.77		4.12	3.43	4.97	4.51
1999/09	4.78		4.12	3.69	4.99	4.51
1999/10	4.83		3.88	3.54	4.91	4.05
1999/11	4.87		3.85	3.77	4.90	3.78
1999/12	4.88		3.96	4.98	4.91	4.95
2000/01	4.84		4.03	3.96	4.96	5.49
2000/02	4.87		4.07	4.26	5.00	7.60

Table 8: *The monthly mean throughput values from the VU cluster to the other clusters. The values are displayed for the ATM route and for the Internet route. The latter is denoted with "Inet".*

Monthly mean throughput values [Mbit/s]						
	UVA => RUL		*UVA => TUD*		*RUL => TUD*	
Month	*ATM*	*Inet*	*ATM*	*Inet*	*ATM*	*Inet*
1999/05	5.04	2.13	5.06	4.31	5.12	3.52
1999/06	4.89	2.64	5.06	4.75	5.12	3.44
1999/07	4.24	5.37	5.03	7.63	5.11	3.37
1999/08	4.25	6.36	5.02	7.71	5.10	3.42
1999/09	4.25	6.20	5.03	6.87	5.11	3.09
1999/10	3.94	6.09	4.95	6.45	5.11	2.89
1999/11	3.91	5.62	4.94	5.46	5.11	2.60
1999/12	4.01	6.16	4.94	5.60	5.11	2.58
2000/01	4.11	5.74	5.01	6.96	5.12	3.17
2000/02	4.13	6.12	5.02	8.95	5.13	3.93

Table 9: *The monthly mean throughput values from the UVA and RUL clusters to the remaining ones. The values are displayed for the ATM route and for the Internet route. The latter is denoted with "Inet".*

and Internet (bottom plot) connections. The y-scale of the bottom plot is logarithmic.

- Figure 3 shows the average roundtrip values for all ATM (top plot) and Internet (bottom plot) connections. The y-scale of the bottom plot is logarithmic.
- Figure 4 shows the maximum roundtrip values for all ATM (top plot) and Internet (bottom plot) connections. The y-scale of the bottom plot is logarithmic.
- Figure 5 shows the throughput values for all ATM (top plot) and Internet (bottom plot) connections.

Some direct conclusions from these plots are presented in subsection 4.3.

4.3 Conclusions from the mean results

From the tables with monthly mean values (table 4, ..., 9) and from the plots with weekly mean values (figure 2, ..., 5) the following conclusions can be drawn:

- From the tables 4 and 5 and the figures 2 ..., 4, showing the minimum, average and maximum roundtrip values, there follows:
  - The ATM minimum, average and maximum roundtrip values are relative invariant during the measurement period. However, there is a slight increase in the average and maximum roundtrip values during the last four months,
  - There is also not much change in the minimum ping values which are obtained along the Internet route. However, there is a considerable decrease in average and maximum roundtrip values when more recent data are compared with the results of older measurements. This is especially true when the results of the first three months are compared with newer data.
  - There is not much difference in minimum roundtrip values when the ATM route is compared with the Internet route. Of course there are local differences, but for instance the variations during time in the minimum roundtrip values are for both routes comparable.
  - When the average and maximum roundtrip values of an ATM route are compared with the corresponding Internet route, it follows that the differences between both routes are getting smaller for more recent data. But the variations in the Internet data are always larger.

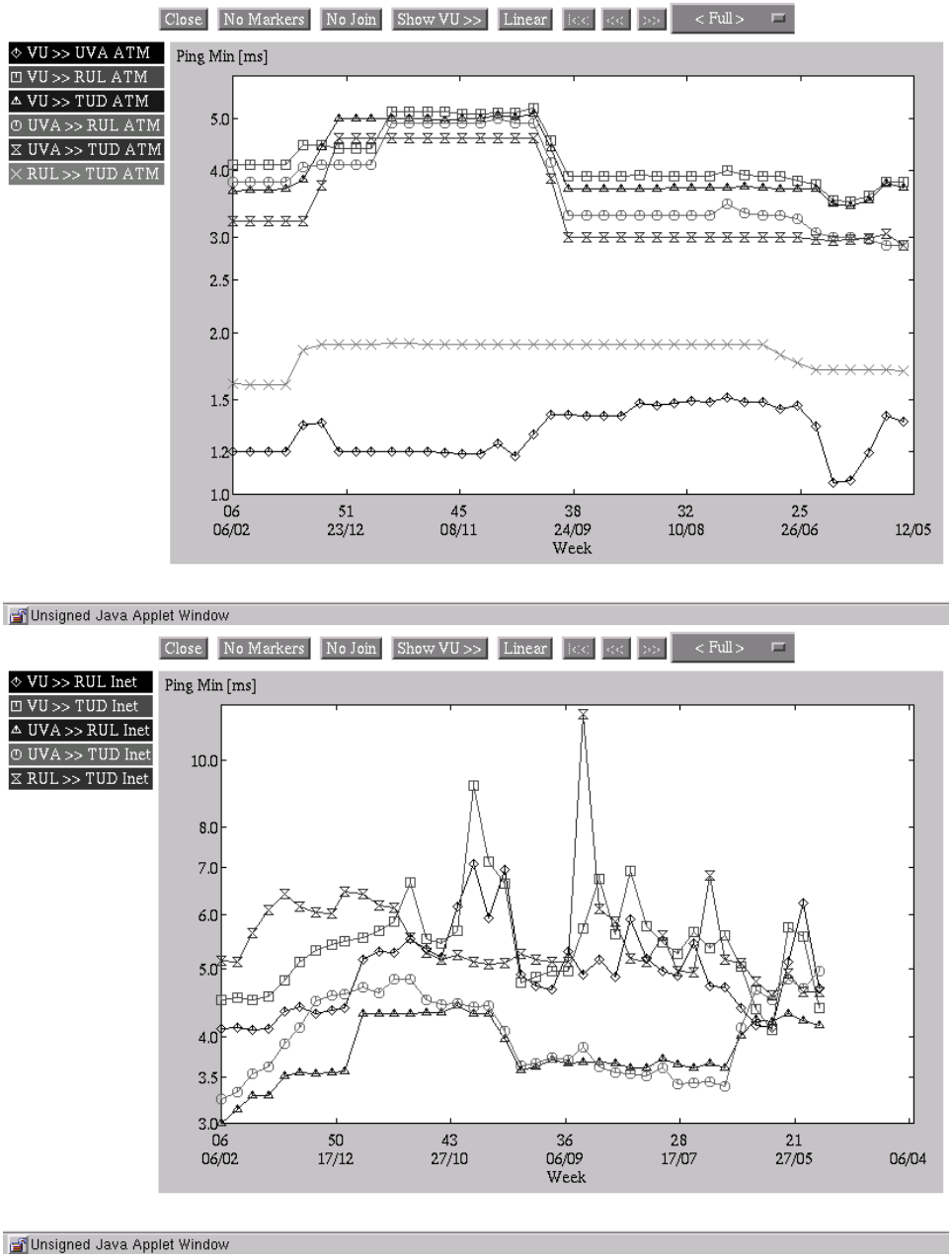

Figure 2: *Plots of the weekly mean minimum roundtrip values plotted for all ATM (top plot) and Internet (bottom plot) connections. The y-axis of the bottom plot is logarithmic.*

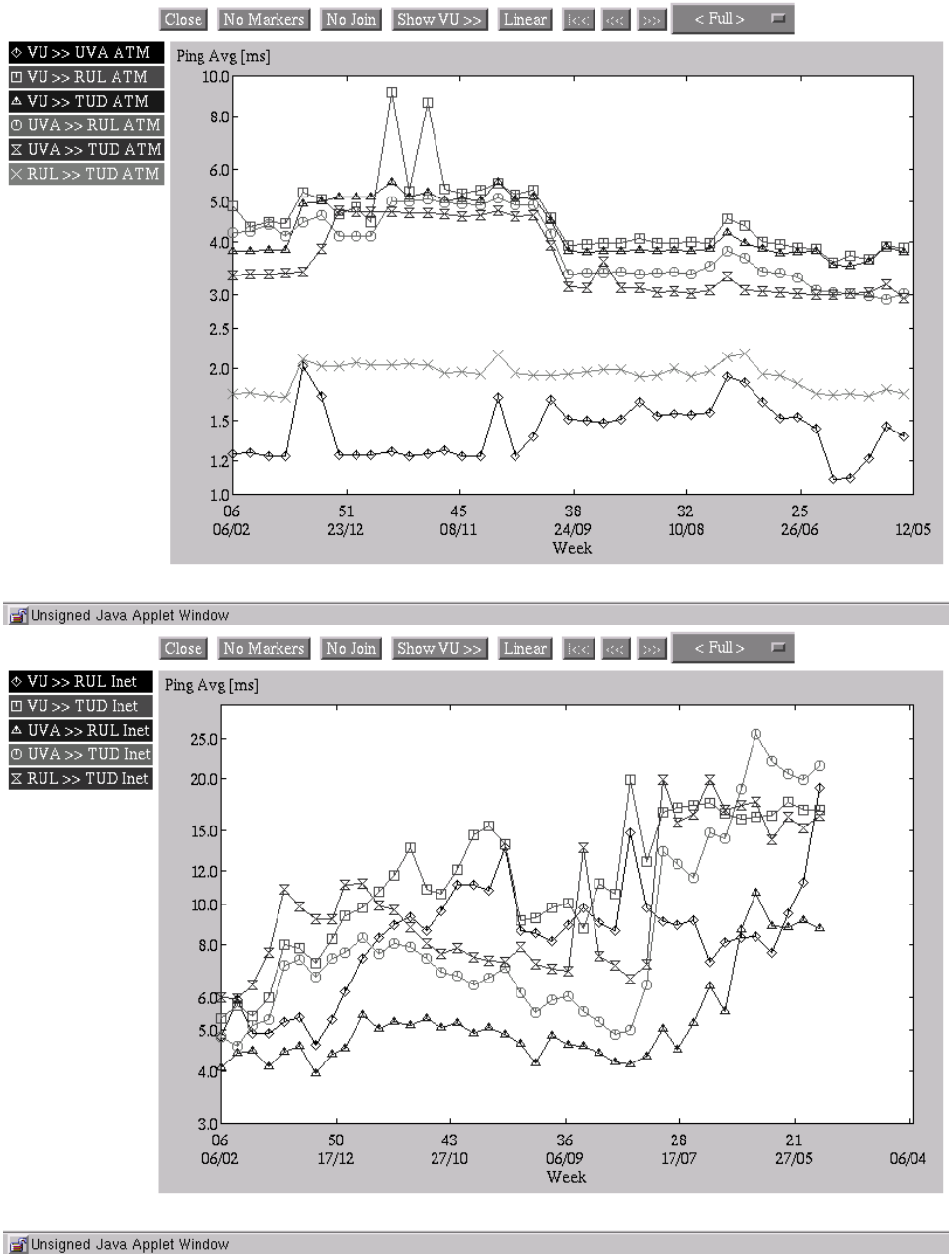

Figure 3: *Plots of the weekly mean average roundtrip values plotted for all ATM (top plot) and Internet (bottom plot) connections. The y-axis of the bottom plot is logarithmic.*

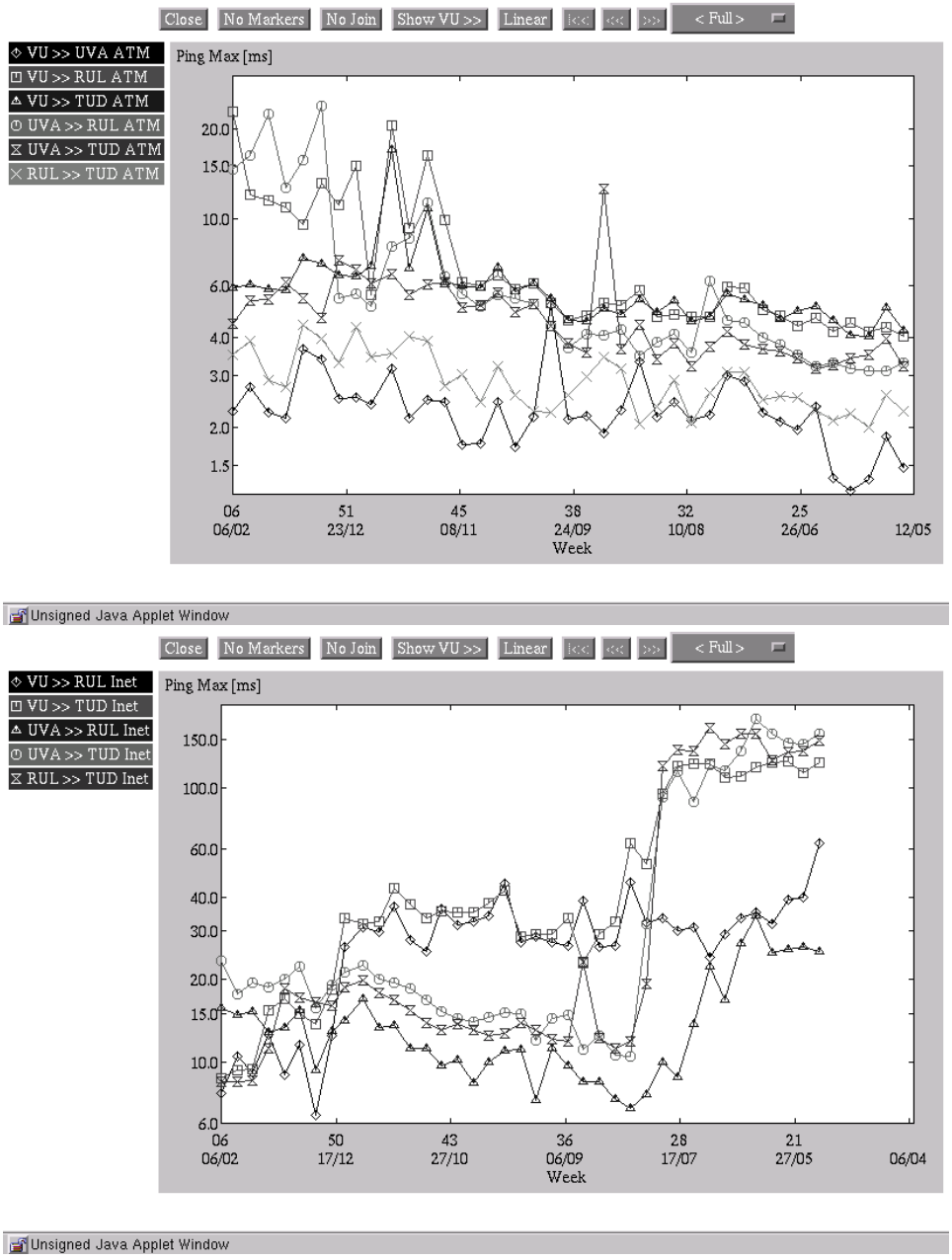

Figure 4: *Plots of the weekly mean maximum roundtrip values plotted for all ATM (top plot) and Internet (bottom plot) connections. The y-axis of the bottom plot is logarithmic.*

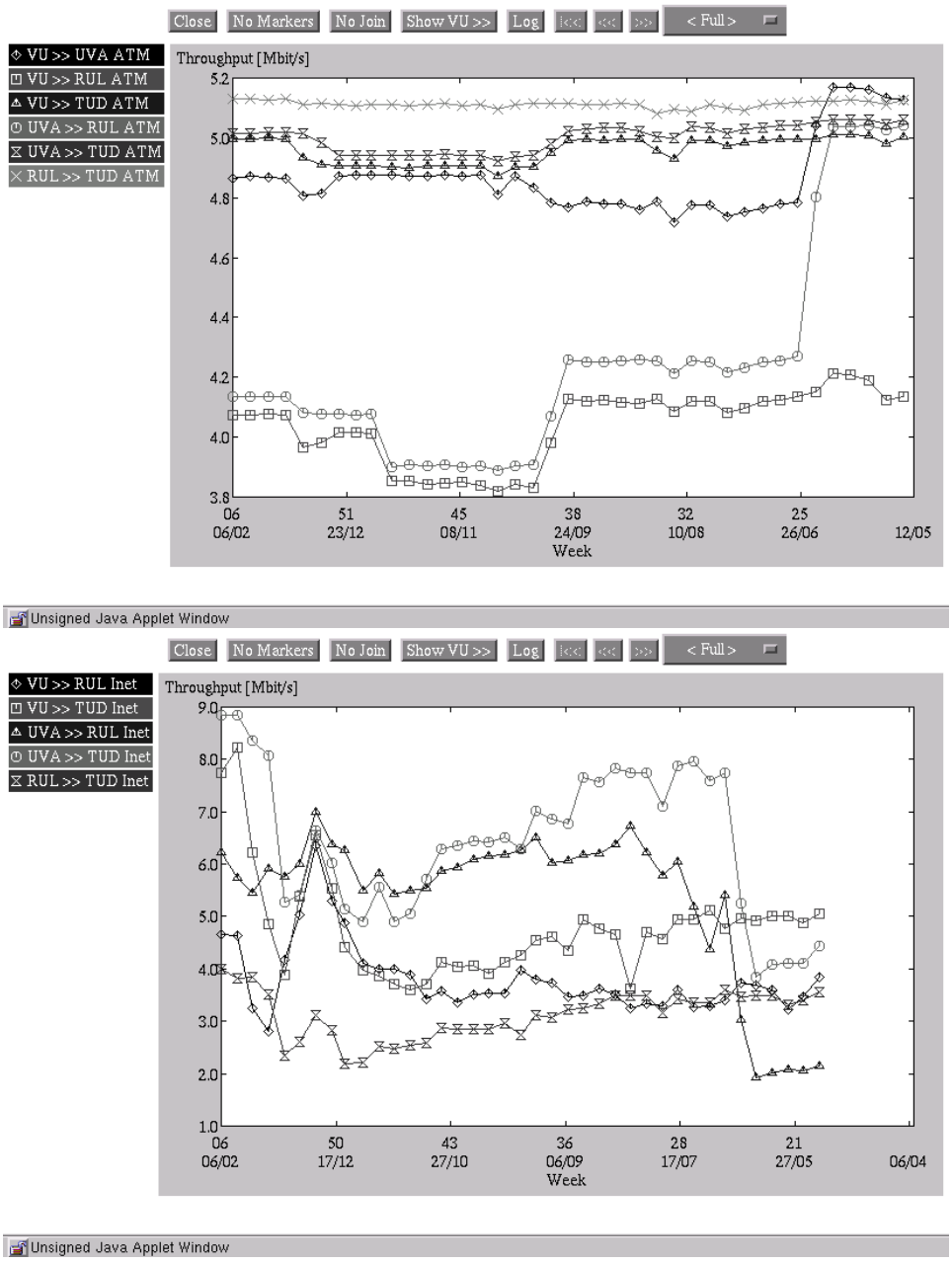

Figure 5: *Plots of the weekly mean throughput values plotted for all ATM (top plot) and Internet (bottom plot) connections.*

- From the tables 6 and 7, showing the percentages roundtrip packages lost, there can be concluded:
  - There is no significant package lost at the ATM connections.
  - There is package lost at the Internet route, however the differences are decreasing for more recent data compared to older results.
- Tables 8, 9 and figure 5 with throughput values show that:
  - The throughput values obtained for the ATM routes are not significant changing for most connections. However, for some connections (VU => UVA and UVA => RUL) they are slightly decreasing when more recent data are compared to older results.
  - The throughput values from the Internet route are increasing when recent data are compared with older results. In most cases the values have become larger that those from the ATM route. Only for the connection RUL => TUD the ATM throughput values are still significant larger than the Internet values.

4.4 Tables with daily results

In this subsection the current monitor results are compared with previous results which were obtained when the first weekly data file was stored. From these weeks the data of the following two days are compared:

- Thursday 2000/02/10, week 06.
- Wednesday 1999/06/26, week 21.

The data are presented by figures with screen dumps of the HTML tables which are fragments taken from the Web presentation pages. The average roundtrip results of the RUL cluster are shown as a typical representation valid for all clusters. Figure 6 displays the average roundtrip value from week 06 and figure 7 shows these values from week 21. Please note that in both tables only the data measured at the full hours (:00) are shown; the measurements at :30 are skipped for visibility reasons.

4.5 Conclusions from the daily results

The following conclusions can be given from the tables with daily values from which the average roundtrip values are presented here:

- When the average roundtrip values from 2000/02/10 (figure 6) are compared with the results from 1999/06/26 (figure 7), it is clear that there are much more variations in the data from 1999/06/26. This is

Date	*Time*	VU		UVA		TUD	
		ATM	Inet	ATM	Inet	ATM	Inet
10/02/2000	23:00:03	4.168	6.676	3.868	3.632	1.682	6.243
10/02/2000	22:00:03	4.195	6.711	5.153	3.732	2.011	5.868
10/02/2000	21:00:04	4.195	6.684	3.874	3.345	1.687	5.839
10/02/2000	20:00:03	4.187	6.384	3.879	3.189	1.676	5.916
10/02/2000	19:00:03	4.168	6.174	3.868	3.508	1.689	5.732
10/02/2000	18:00:04	4.126	5.776	3.900	3.492	1.692	6.318
10/02/2000	17:00:07	4.124	5.108	4.037	4.508	1.679	5.974
10/02/2000	16:00:03	4.147	4.689	3.897	4.143	1.961	6.134
10/02/2000	15:00:03	4.126	5.087	3.924	5.847	1.689	6.408
10/02/2000	14:00:06	4.268	4.782	3.887	4.103	1.839	6.208
10/02/2000	13:00:03	4.208	5.600	4.889	4.000	1.689	6.442
10/02/2000	12:00:06	4.221	4.713	3.905	4.061	1.947	6.197
10/02/2000	11:00:03	4.226	4.942	3.871	4.032	1.937	6.061
10/02/2000	10:00:03	4.226	4.751	3.847	4.468	1.687	6.245
10/02/2000	09:00:03	4.289	4.579	4.761	3.167	1.671	5.789
10/02/2000	08:00:03	4.234	6.211	4.295	3.726	1.679	5.700
10/02/2000	07:00:02	4.205	6.555	4.313	3.084	1.689	5.721
10/02/2000	06:00:04	4.200	6.208	4.279	3.121	1.682	5.711
10/02/2000	05:00:03	4.213	6.476	4.292	3.221	1.689	5.661
10/02/2000	04:00:04	4.208	6.747	4.284	3.151	1.687	5.779
10/02/2000	03:00:03	4.221	4.582	4.308	3.205	1.689	5.800
10/02/2000	02:00:03	4.411	4.408	5.147	3.295	1.692	5.908
10/02/2000	01:00:05	4.229	4.262	4.466	3.463	1.674	5.766
10/02/2000	00:00:03	4.208	4.353	4.892	3.216	1.989	5.911

Figure 6: Average roundtrip values [ms] for the RUL cluster obtained at 2000/02/10.

Date	*Time*	VU		UVA		TUD	
		ATM	Inet	ATM	Inet	ATM	Inet
26/05/1999	23:00:05	3.844	5.761	2.917	7.417	2.206	5.978
26/05/1999	22:00:05	3.856	13.272	2.906	7.672	1.700	36.689
26/05/1999	21:00:06	3.883	18.333	2.906	7.618	1.700	32.200
26/05/1999	20:00:05	3.894	5.622	2.906	7.839	1.700	31.400
26/05/1999	19:00:06	3.878	8.647	2.906	9.239	1.700	27.911
26/05/1999	18:00:07	3.872	11.000	2.906	5.767	1.700	63.024
26/05/1999	17:00:09	4.511	16.844	2.906	14.688	3.128	45.106
26/05/1999	16:00:07	3.889	8.122	2.906	10.818	1.700	49.281
26/05/1999	15:00:09	3.867	13.269	2.911	8.394	1.700	37.719
26/05/1999	14:00:07	3.883	8.888	2.906	6.259	1.700	7.356
26/05/1999	13:00:08	3.889	18.200	2.911	5.924	1.706	8.161
26/05/1999	12:00:09	3.889	6.750	2.917	5.824	1.706	6.931
26/05/1999	11:00:11	3.900	6.444	2.900	9.361	1.706	6.761
26/05/1999	10:00:08	3.878	5.217	2.917	13.878	1.700	85.067
26/05/1999	09:00:06	3.894	8.317	2.917	7.150	1.700	5.533
26/05/1999	08:00:06	3.889	7.122	2.906	5.722	1.700	11.989
26/05/1999	07:00:05	3.878	9.011	2.906	6.250	1.700	6.139
26/05/1999	06:00:05	3.872	4.639	2.906	5.500	1.700	5.089
26/05/1999	05:00:05	3.889	6.524	2.911	4.678	1.700	4.961
26/05/1999	04:00:11	4.267	4.706	2.906	4.472	1.700	18.844
26/05/1999	03:00:05	3.856	8.367	2.911	4.628	1.700	9.139
26/05/1999	02:00:05	3.878	18.683	2.911	4.694	1.700	18.761
26/05/1999	01:00:08	3.933	5.911	2.911	11.500	1.700	4.856
26/05/1999	00:00:05	3.878	26.375	2.906	7.272	1.700	5.133

Figure 7: Average roundtrip values [ms] for the RUL cluster obtained at 1999/06/26.

especially true for the connection between RUL and TUD and for the Internet data. As expected these differences are much larger for the maximum roundtrip values, while they are almost disappeared for the minimum roundtrip values, however, the recently obtained Internet data still show less variations compared with the older data.

- When the throughput values are compared at both days, it is clear that the more recent values for the Internet connections are in general larger compared to the older values. Sometimes they are even larger than the values for the ATM connections. However, for both days the values for the ATM connections contain less variations. In general the ATM throughput values are slightly decreases when the recent data are compared with the older ones.

5 Conclusions

In section 1 the statement has been made that short roundtrip times are more important than high throughput values, because short roundtrip times are essential for fast message passing between remote cluster running a distributed application, while the size of these messages is in general small.

Keeping this in mind, it is clear from the presented results in section 4 that at the beginning of the monitoring period the roundtrip times across the Internet are too large for remote distributed applications. During the monitor period the roundtrip times improved a lot. At the end of the period the difference between ATM and Internet roundtrip times become much less. In some cases the roundtrip times across the Internet routes are shorter than across the corresponding ATM route, but these differences are topology dependent.

Please note that the used Internet routes are in general not very optimal. The interconnection of the DAS clusters was of course focussed to the ATM network: the "normal" Internet route was generally not used, so a short Internet connection from the gateways to the backbone had no priority. Therefore, the Internet roundtrip results may be somewhat pessimistic.

It is difficult to conclude that the current roundtrip times are sufficient for remote applications, because each application has its own characteristic properties. Some benchmarking is needed to bring clarity at this point. However, considering the future investments of SURFnet into the research network, one may expect that a more direct connection of the DAS clusters at the backbone should improve the current situation still more. On the other hand the capacity of the clusters with DAS 2 will also increase. This may lead to the situation that Quality-of-Service aspects are also needed in the future which may also have interesting aspects from a research viewpoint.

Also the recent Internet throughput values show a considerable improvement compared with the older ones. There are still more variations than

at the values from the ATM routes, but the Internet throughput values are seldom lower than 3 Mbit/s: often they are larger than the values obtained from the ATM routes, from which the recent values are somewhat lower than the older ones. So we do not expect that the bandwidths of the Internet routes form limitations for remotely distributed applications.

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