Federation over SSH

Ravishankar Muniraju

1. INTRODUCTION

Federation is a well established technology is DETER and is widely used for experimentation. We recently started to explore using federation in the DEFT consortium to model energy cyber physical systems distributed across three federated testbeds at PNNL, UIUC and ISI. This note presents an empirical characterization of a DETER federation link between the ISI DETER testbed located at Marina del Rey, CA and the UIUC DETER testbed located at Illinois.

The empirical characterization of the federated link can be used to inform the energy cyber physical models developed as part of the DEFT consortium. The DEFT consortium is exploring dependent, time synchronized CPS models that will span the across the three testbeds. Such models are delay sensitive. Hence it is important to quantify the delay properties of the underlining cyber substrate so that the models can correctly designed for this environment.

As seen in Figure 1, the DETER federation framework sets up an ssh tunnel between the two testbeds. All traffic between the testbed nodes, nodedeter and nodeuiuc, is subsequently transfered over the tunnel by directly bridging the the end node to the ssh tunnel using a federation *tap*.

In this note, based on the ISI–UIUC federation as an example, we show that DETER federation link reports a latency measurement average which is —(to be decided after a required measurement is obtained) times higher than the underlying internet link. The impact of this latency is also seen in the applications running on the end nodes. This increased latency makes it challenging to design delay sensitive and time-synchronized applications for energy cyber physical systems.

We discuss our empirical evaluation methodology in Section 2. In section 3 we discuss the performance metrics used to characterize the links. We perform measurement analysis and observation in Section 4. In Section 5, we discuss possible directions that we can follow to get more insight into the properties of the federation substrate and improve its performance.

2. METHODOLOGY

The Methodology used here is very similar to [2]. We are using a active UDP probing mechanism to characterize the federation link. Probing mechanism involves sending a burst of UDP packets of size 46bytes with a certain *inter burst time*. Upon arrival of the each UDP packet, destination node records the timestamp and sequence number of the UDP packet received.

2.1 Connectivity

We use traceroute to find the network path from UIUC to ISI and viceversa. The traceroute from UIUC to ISI, (shown in Figure 2) indicates the path from UIUC to ISI first traverses a few servers at University of Urbana champaign, then traverses throught Internet2 server at Ann Arbor, Michigan, Cenic network at Cypress, CA and finally traverses Los Nettos (`http://www.ln.net/`), a small regional ISP, that provides connectivity to USC/ISI.
Figure 3 indicates the path from ISI to UIUC. first traverses Los nettos, then traverses the following ISPs - Telehouse International Corp. Of America in Los angeles, Hurricane Electric Inc in Los angeles followed by the same ISP at colorado and chicago, Wiscnet in winsconsin, finally traverses few servers at University of Urbana champaign to reach the final destination.

3. PERFOMANCE METRICS

In our study we have used the following metrics to characterize the federation link.

3.1 Packet loss

We identify the loss by observing the gaps in the sequence numbers of received UDP probe packets. We use a metrics called *bursty loss size*, which is defined as the maximum number of consecutive packets lost between two in-order packets.

3.2 Packet delay

Ideally we need to measure the one way delay, but this is limited by the clock synchronisation at deter testbed at ISI and deter testbed in UIUC. Hence we measure the

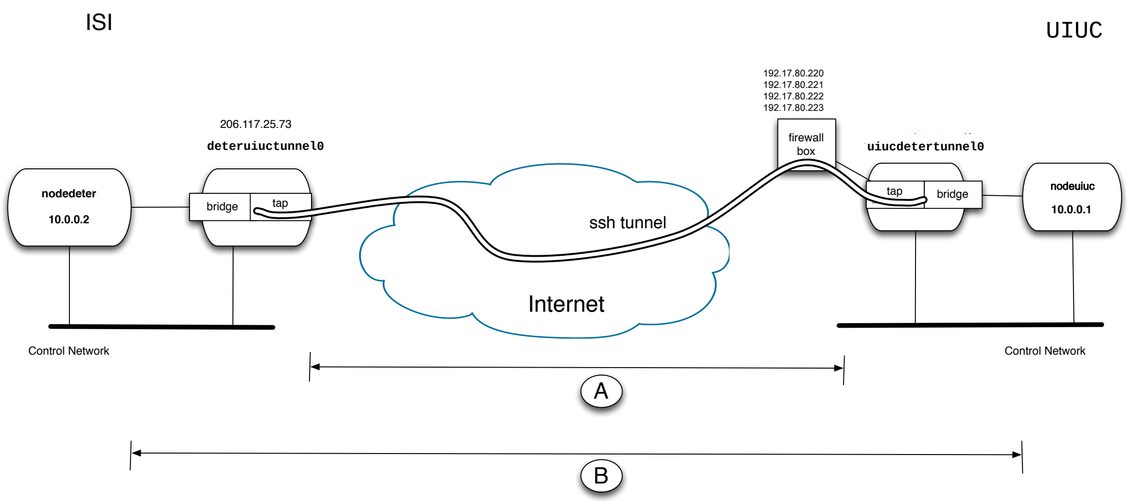
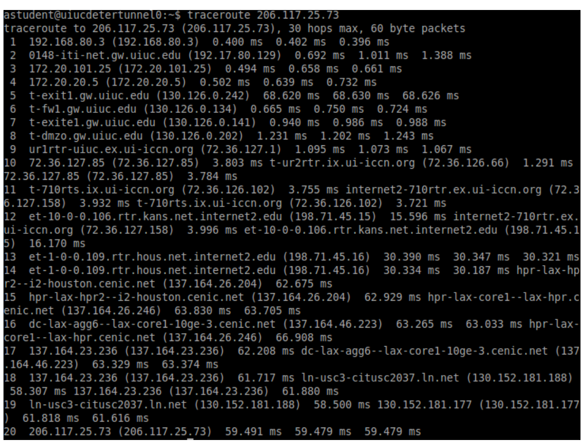
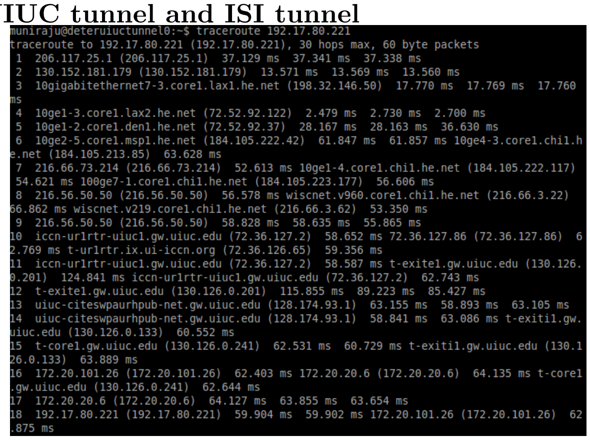


Figure 1: A conceptual representation of the federation link between ISI and UIUC



```
astudent@uiucdetertunnel0:~$ traceroute 206.117.25.73
traceroute to 206.117.25.73 (206.117.25.73), 30 hops max, 60 byte packets
 1  192.168.80.3 (192.168.80.3)  0.400 ms  0.402 ms  0.396 ms
 2  0148-iti-net.gw.uiuc.edu (192.17.80.129)  0.692 ms  1.011 ms  1.388 ms
 3  172.20.101.25 (172.20.101.25)  0.494 ms  0.658 ms  0.661 ms
 4  172.20.20.5 (172.20.20.5)  0.502 ms  0.639 ms  0.732 ms
 5  t-exit1.gw.uiuc.edu (130.126.0.242)  68.620 ms  68.630 ms  68.626 ms
 6  t-fw1.gw.uiuc.edu (130.126.0.134)  0.665 ms  0.750 ms  0.724 ms
 7  t-exite1.gw.uiuc.edu (130.126.0.141)  0.940 ms  0.986 ms  0.988 ms
 8  t-dmzo.gw.uiuc.edu (130.126.0.202)  1.231 ms  1.202 ms  1.243 ms
 9  ur1rtr-uiuc.ex.ui-iccn.org (72.36.127.1)  1.095 ms  1.073 ms  1.067 ms
10  72.36.127.85 (72.36.127.85)  3.803 ms t-ur2rtr.ix.ui-iccn.org (72.36.126.66)  1.291 ms
72.36.127.85 (72.36.127.85)  3.784 ms
11  t-710rts.ix.ui-iccn.org (72.36.126.102)  3.755 ms internet2-710rtr.ex.ui-iccn.org (72.3
6.127.158)  3.932 ms t-710rts.ix.ui-iccn.org (72.36.126.102)  3.721 ms
12  et-10-0-0.106.rtr.kans.net.internet2.edu (198.71.45.15)  15.596 ms internet2-710rtr.ex.
ui-iccn.org (72.36.127.158)  3.996 ms et-10-0-0.106.rtr.kans.net.internet2.edu (198.71.45.1
5)  16.170 ms
13  et-1-0-0.109.rtr.hous.net.internet2.edu (198.71.45.16)  30.390 ms  30.347 ms  30.321 ms
14  et-1-0-0.109.rtr.hous.net.internet2.edu (198.71.45.16)  30.334 ms  30.187 ms hpr-lax-hp
r2--i2-houston.cenic.net (137.164.26.204)  62.675 ms
15  hpr-lax-hpr2--i2-houston.cenic.net (137.164.26.204)  62.929 ms hpr-lax-core1--lax-hpr.c
enic.net (137.164.26.246)  63.830 ms  63.705 ms
16  dc-lax-agg6--lax-core1-10ge-3.cenic.net (137.164.46.223)  63.265 ms  63.033 ms hpr-lax-
core1--lax-hpr.cenic.net (137.164.26.246)  66.908 ms
17  137.164.23.236 (137.164.23.236)  62.208 ms dc-lax-agg6--lax-core1-10ge-3.cenic.net (137
.164.46.223)  63.329 ms  63.374 ms
18  137.164.23.236 (137.164.23.236)  61.717 ms ln-usc3-citusc2037.ln.net (130.152.181.188)
 58.307 ms 137.164.23.236 (137.164.23.236)  61.880 ms
19  ln-usc3-citusc2037.ln.net (130.152.181.188)  58.500 ms 130.152.181.177 (130.152.181.177
)  61.818 ms  61.616 ms
20  206.117.25.73 (206.117.25.73)  59.491 ms  59.479 ms  59.479 ms
```

Figure 2: The output from *traceroute* between UIUC tunnel and ISI tunnel



```
muniraju@deteruiuctunnel0:~$ traceroute 192.17.80.221
traceroute to 192.17.80.221 (192.17.80.221), 30 hops max, 60 byte packets
 1  206.117.25.1 (206.117.25.1)  37.129 ms  37.341 ms  37.338 ms
 2  130.152.181.179 (130.152.181.179)  13.571 ms  13.569 ms  13.560 ms
 3  10gigabitethernet7-3.core1.lax1.he.net (198.32.146.50)  17.770 ms  17.769 ms  17.760
ms
 4  10ge1-3.core1.lax2.he.net (72.52.92.122)  2.479 ms  2.730 ms  2.700 ms
 5  10ge1-2.core1.den1.he.net (72.52.92.37)  28.167 ms  28.163 ms  36.630 ms
 6  10ge2-5.core1.msp1.he.net (184.105.222.42)  61.847 ms  61.857 ms 10ge4-3.core1.chi1.h
e.net (184.105.213.85)  63.628 ms
 7  216.66.73.214 (216.66.73.214)  52.613 ms 10ge1-4.core1.chi1.he.net (184.105.222.117)
 54.621 ms 100ge7-1.core1.chi1.he.net (184.105.223.177)  56.606 ms
 8  216.56.50.50 (216.56.50.50)  56.578 ms wiscnet.v960.core1.chi1.he.net (216.66.3.22)
66.862 ms wiscnet.v219.core1.chi1.he.net (216.66.3.62)  53.350 ms
 9  216.56.50.50 (216.56.50.50)  58.828 ms  58.635 ms  55.865 ms
10  iccn-ur1rtr-uiuc1.gw.uiuc.edu (72.36.127.2)  58.652 ms 72.36.127.86 (72.36.127.86)  6
2.769 ms t-ur1rtr.ix.ui-iccn.org (72.36.126.65)  59.356 ms
11  iccn-ur1rtr-uiuc1.gw.uiuc.edu (72.36.127.2)  58.587 ms t-exite1.gw.uiuc.edu (130.126.
0.201)  124.841 ms iccn-ur1rtr-uiuc1.gw.uiuc.edu (72.36.127.2)  62.743 ms
12  t-exite1.gw.uiuc.edu (130.126.0.201)  115.855 ms  89.223 ms  85.427 ms
13  uiuc-citeswpaurhpub-net.gw.uiuc.edu (128.174.93.1)  63.155 ms  58.893 ms  63.105 ms
14  uiuc-citeswpaurhpub-net.gw.uiuc.edu (128.174.93.1)  58.841 ms  63.086 ms t-exiti1.gw.
uiuc.edu (130.126.0.133)  60.552 ms
15  t-core1.gw.uiuc.edu (130.126.0.241)  62.531 ms  60.729 ms t-exiti1.gw.uiuc.edu (130.1
26.0.133)  63.889 ms
16  172.20.101.26 (172.20.101.26)  62.403 ms 172.20.20.6 (172.20.20.6)  64.135 ms t-core1
.gw.uiuc.edu (130.126.0.241)  62.644 ms
17  172.20.20.6 (172.20.20.6)  64.127 ms  63.855 ms  63.654 ms
18  192.17.80.221 (192.17.80.221)  59.904 ms  59.902 ms 172.20.101.26 (172.20.101.26)  62
.875 ms
```

Figure 3: The output from *traceroute* between ISI tunnel and UIUC tunnel

round trip time using the UDP packets used for probing. The RTT calculation here is similar to what was done in [1] Each UDP probe packet sent is timestamped and sequenced. Let us assume a packet P1 sent at time t1. P1 reaches nodeuiuc at t2. nodeuiuc will now consrtuct UDP packet P2 which includes two time stamp values t1 and t2-t3(time spend in nodeuiuc system) where t3 is the time at which the nodeuiuc sends P2. Let P2 reach nodedeter at t4. Once P2 receives nodedeter, it estimates the round trip time between nodedeter and node uiuc using the following formula **RTT = t4-t1-(t3-t2)**. We estimate the rtt for one in every ten packets the nodeuiuc receives.

3.3 Jitter

Initially we calculate the inter-arrival time of the packets received using which we proceed to calculate the jitter. Jitter is calculated for both in-order and out-of-order packets.

3.3.1 In order packets

Two in order packets arriving one after the other at receiving node may belong to same or different bursts. If the packets belong to same burst burst then the inter-arrrival time is equal to the jitter. Where as if the packets belong to different bursts then the jitter is calculate as shown:

jitter = (inter-arrival time) - (burst difference * *burst inter time).*

3.3.2 Out of order packets

If an out of order packet arrives at receiving node, first we find the UDP packet that was received with highest, but lower than the out of order sequence number received. Find the inter-arrival time between these two packets and then calculate the jitter using the equation used to calculate jitter for in order packets.

3.4 Bandwidth and Flow completion time

NutTCP is a network measurement tool that reports the available bandwidth between two locations. We use NutTCP to measure available bandwidth between testbeds at ISI and UIUC along path B and A. The application continuously transfers a 100MB block of data from ISI to UIUC using tcp every 10 seconds. For each transfer, NutTCP reports the available bandwidth and flow completion time.

4. OBSERVATIONS AND ANALYSIS

4.1 Characterization of path along A and B

In this section we are characterizing the link along path A and B and comparing their performance. we obtain packet delay, jitter and packet loss using the UDP probing mechanism which sends a UDP packet every 5 msec. The bandwidth and flow completion time is obtained using nuttcp as described in Section 3.4.

4.1.1 Bandwidth and flow time

We measure the bandwidth and the flow completion time as described in Section 3.4. Figures 4 and 5 reports the bandwidth in Mbps along left y axis, flow completion time in seconds along the right y axis and epoch time in hours along x axis for measurements along path B and A respectively.

Figures 6 and 8 shows the cdf plot of bandwidth in Mbps along path A and B respectively. Figures 7 and 9 shows the cdf plot of flow completion time in seconds along path A and B respectively. Statistics for both the paths are as shown in the table 1.

Table 1: Bandwidth and flow time measurements along path A and B

	A	B
Mean bandwidth in Mbps	21.37	19.958
Maximum bandwidth in Mbps	27.11	24.10
90% Bandwidth in Mbps	<22	<20
Mean Flow completion time in seconds	39.97	42.35
Maximum Flow completion time in seconds	114.97	85.49
90% Flow completion time in seconds	<=40	42

Implications: We can observe that the bandwidth is higher in along A and lower along B. The reason being the packets along the path B flows through the ssh tunnel hence incurring addition latency where as the packets along the path A doesnt. This results in increase in flow completion time along B.

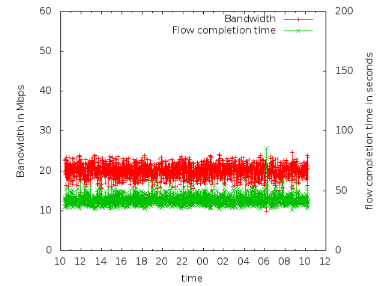


Figure 4: bandwidth in Mbps and flow completion time in seconds along path B

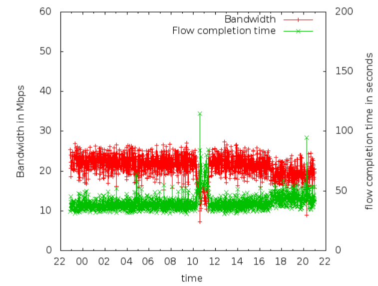


Figure 5: bandwidth in Mbps and flow completion time in seconds along path A

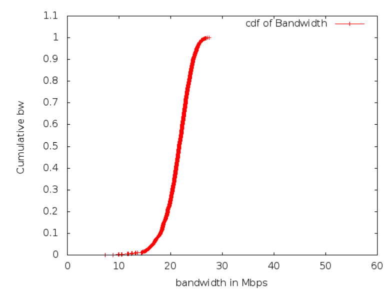


Figure 6: Cdf of bandwidth in Mbps along path A

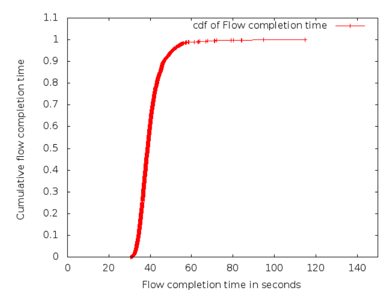


Figure 7: Cdf of flow completion time in seconds along path A

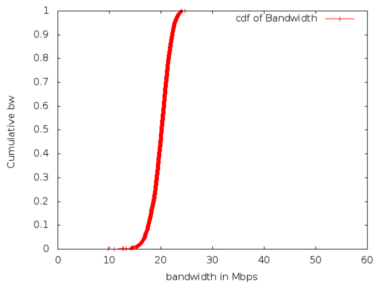


Figure 8: Cdf of bandwidth in Mbps along path B

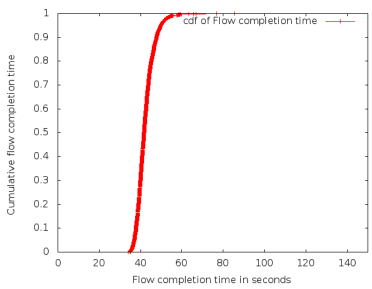


Figure 9: Cdf of flow completion time in seconds along path B

4.1.2 *RTT, Jitter and Packet loss*

TODO : Need to take readings of N=1 and inter burst time = 5msec along node2node to complete this section

4.2 Characterization of path along A

In this section we are characterizing the link along path A and comparing their performance. we obtain packet delay, jitter and packet loss using the UDP probing mechanism. Jitter and packet delay are calculated as described in section 3.3 and 3.2 respectively.

4.2.1 *Packet delay and Jitter*

To measure and analyze RTT and jitter along the path A we use UDP probing mechanism by sending packets with the following inter packet times:
Case 1 : 10msec
Case 2 : 5msec
Case 3 : 15msec : To be done

Figures 11 and 10 reports the cdf of packet delay in microseconds for Case 1 and 2 respectively. Figures 13 and 12 reports the cdf of jitter in microseconds for Case 1 and 2 respectively.

Statistics for packet delay and jitter for cases 1, 2 and 3 are as shown in the table 2.

Implications: Control signals sent along the path A at 5msec suffer very high packet delays and jitter as shown in the table 2 and in the figures 10 and 12. In Case1 we transmit packets at half the rate of Case2.

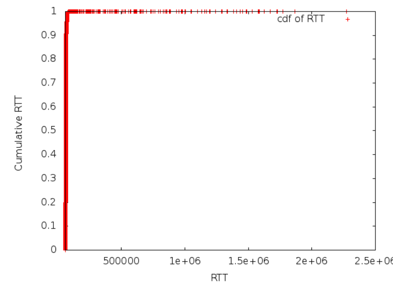


Figure 10: RTT in micro seconds along path A for inter packet time equal to 5msec

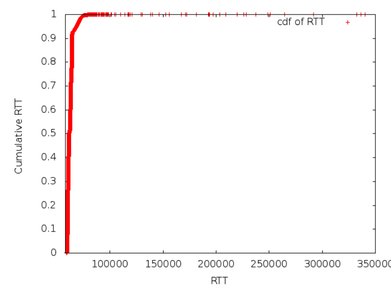


Figure 11: RTT in micro seconds along path A for inter packet time equal to 10msec

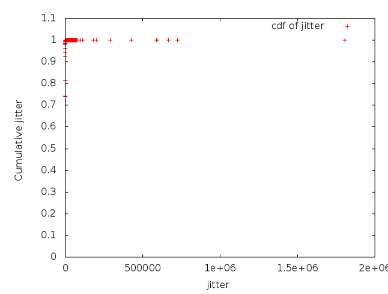


Figure 12: Cdf of Jitter in micro seconds along path A for inter packet time equal to 5msec

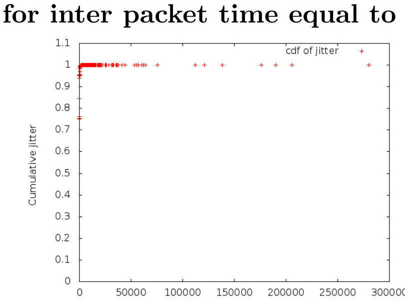


Figure 13: Cdf of Jitter in micro seconds along path A for inter packet time equal to 10msec

Table 2: Packet delay and jitter measurements along path A for cases 1, 2 and 3

	case1	case2	case3
Mean Packet delay in usec	62479	62780	
Maximum Packet delay in usec	340654	2271468	
Mean Jitter in usec	332.33	343	
Maximum Jitter in usec	280317	1805360	

Decrease in the rate by half results in atmost 6 times decrease in the RTT and jitter.

4.2.2 Packet loss

To measure and analyze packet losses along the path A we use UDP probing mechanism by sending packets with inter-burst time of 50msec and with the following burst lengths:
Case 1 : burst length = 2
Case 2 : burst length = 5
Case 3 : burst length = 10

Statistics of *burst loss size* for Case 1 and Case 2 are as shown in the table 3.

Table 3: *burst loss size* **measurements along path A for burst length 5 and 10**

	case1	case2	case3
Percentage of lost packets	0.08	0.16	1.8

Implications: We observe an increase in the percentage of lost packets as we increase the burst size as shown in the table 3

5. OBSERVATION AND PATH FORWARD

/*To be filled later after discussing with the Professor*/

6. REFERENCES

[1] S. Floyd et al. A reliable multicast framework for light-weight session and applicatoin level framing, 2000.

[2] F. Wang et al. A measurement study on the impact of routing events on end-to-end internet path performance. SIGCOMM '06, 2006.