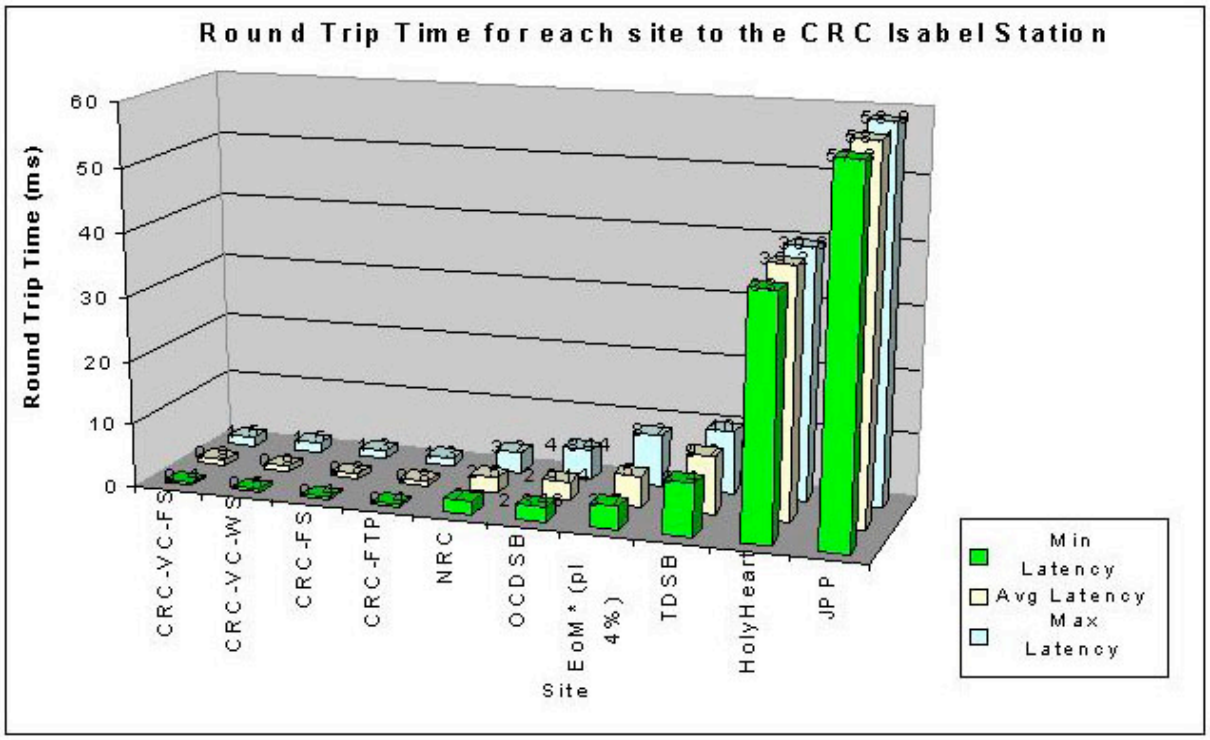
Appendix B

I Introduction

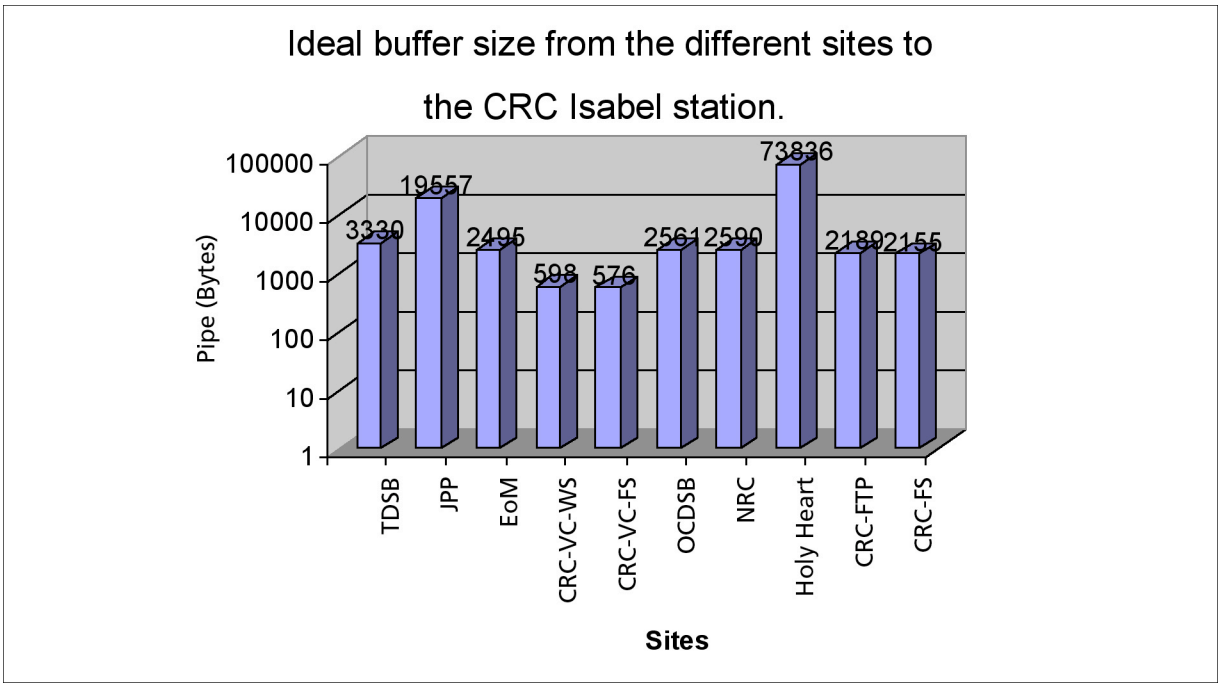
The purpose of this report is to characterize the LearnCanada National Test Network (LC-NTN). Once the network is characterized, it will be possible to improve the performance of the network or application. The document is based on test results for the network path characteristics as well as CPU usage, Linux configuration and other things, which can affect the performance of the video and audio in an Isabel session. Once we have all these information in one document, we will find all flaws and we will be able to improve the performance, when provided with appropriate tools and technologies.

The main problem with the LC-NTN is that each member has to connect to CA*Net3 through different inter-networks solutions. These inter-network solutions sometimes use technologies that don't provide all the reliability Isabel needs. The two main factors which affect the video and sound performance are the packet drops and the bottlenecks in the network. Therefore, we conduct the packet drop tests as well as tests to characterize all the bottlenecks in the network to find out which site were not working at their full potential and the reason for that.

II Network performance characterization



The prime parameter characterizing the performance of network is the latency. First, we measured the round-trip time from each site to the CRC Isabel station. The round-trip is the time it takes for a packet to get to the destination then come back again to the source. This type of packet is called ICMP echo packets. The result might sometimes not be accurate because these packets are considered low priority by some routers and can be dropped if there is too much traffic. These results were achieved by using Pings or Pathchars.



Bandwidth Product Delay for each site

The ideal buffer size in bytes is calculated as follow:

$$\frac{\text{bandwith} \times \text{delay}}{8}$$

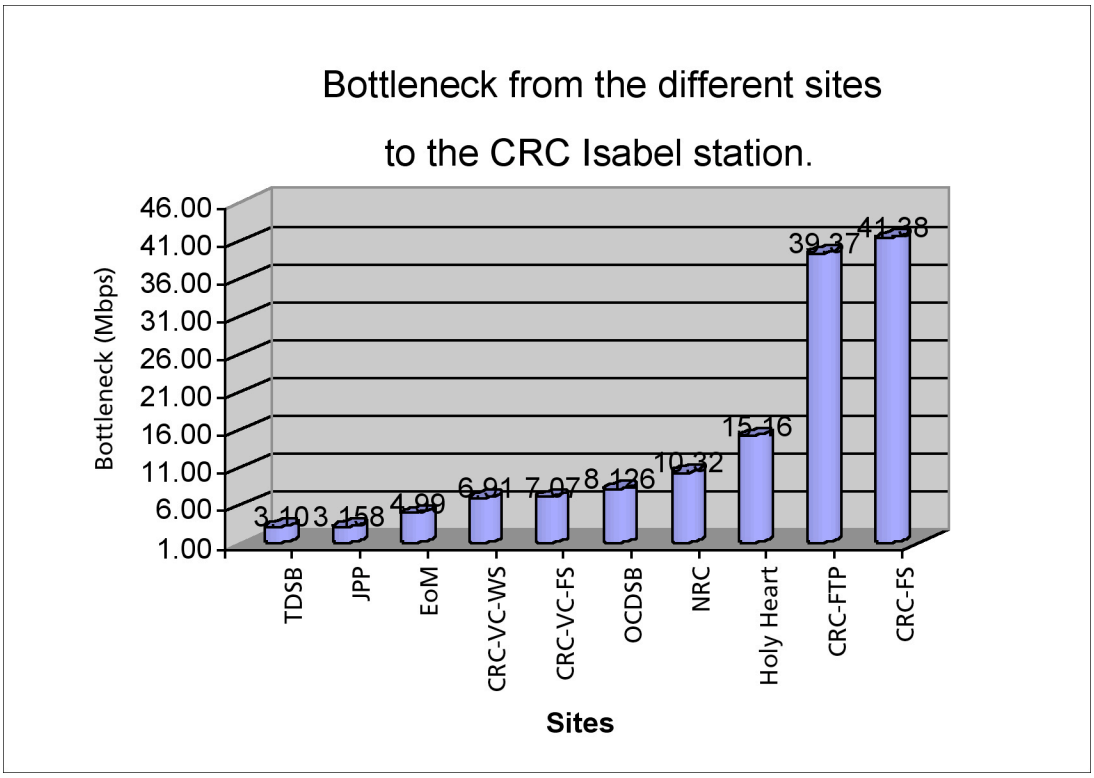
Therefore for long distance, you have to have a receiving or transmitting buffer at close to this value to obtain the best performance in high speed networks. Since HolyHeart is much far from CRC, the rrt (Round Trip Time) is longer therefore a bigger buffer is needed. These buffer apply only to TCP connections (like FTP,TELNET,etc.) and not to UDP connections (like Isabel, Streaming Video, etc.)

Bottleneck for each site

The second parameter characterizing the network performance is its bottleneck. Bottleneck is the lowest bandwidth from one point to another. This lowest value greatly affects and therefore determines the bandwidth for this path.
We measured the bottleneck from the different sites to the CRC Isabel Workstation.

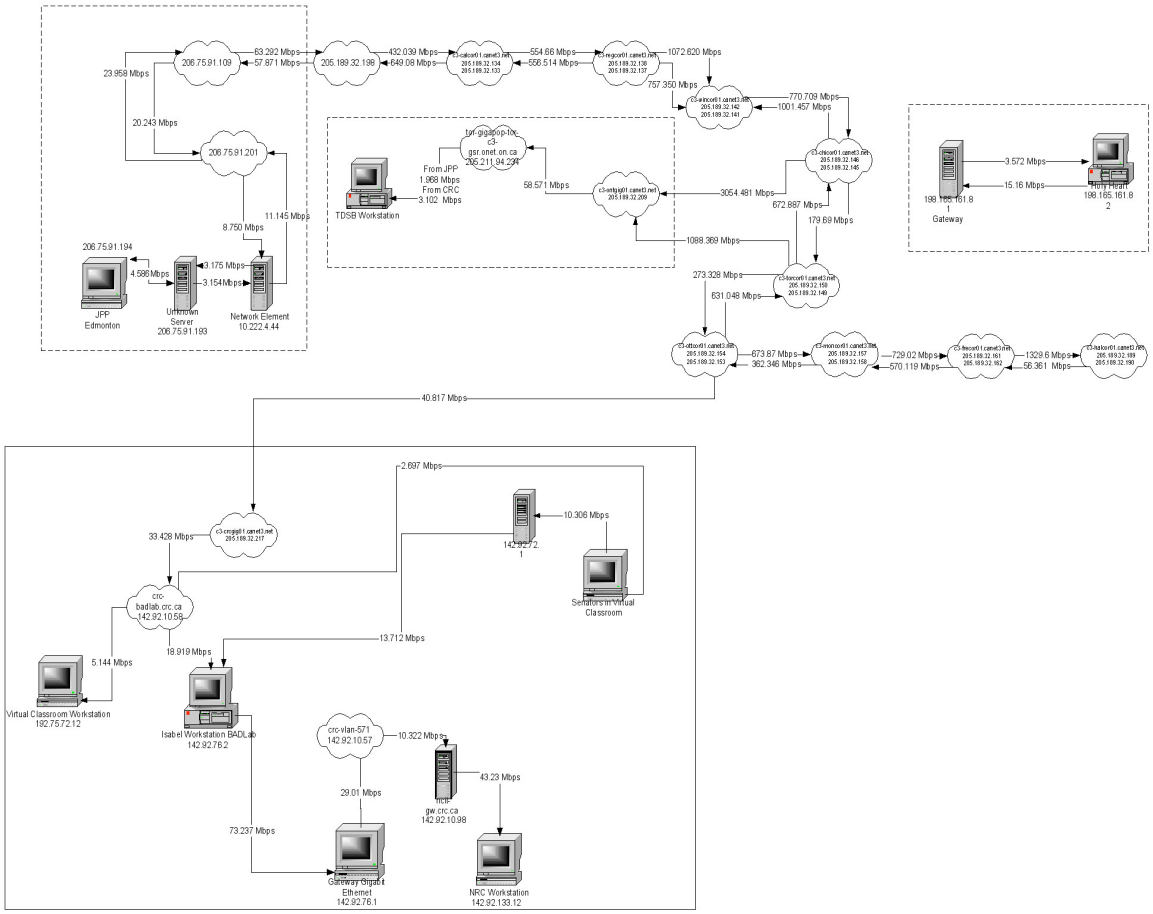
Table of results

Site	Bottle Neck(Mbps)
TDSB	3.10
JPP	3.158
EoM	4.99
CRC-VC-WS	6.91
CRC-VC-FS	7.07
OCDSB	8.126
NRC	10.32
HolyHeart	15.16
CRC-FTP	39.37
CRC-FS	41.38



The diagram above shows the different bottlenecks for the different points in the LearnCanada National Test Network. These values were calculated using pathchar. As indicated the bandwidth measurement changes accordingly to the network traffic.

Network Bandwidth



III Characterization of the ISABEL application performance

Here, we conducted the test on various platforms to try to capture the range of Isabel performance depending on the PC configuration. The objective was to define the operating envelope of the Isabel application for the various components in different network configuration.

Omnicron

CPU: PIII 800MHz
RAM: 256MB
OS: RedHat Linux 7.0 Kernel 2.2.16-22

The tables below show the outgoing bandwidth for different frame rate and grab size taken from omnicron

Outgoing Bandwidth for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	500.0	750.0	1200.0	1350.0	1376.0	1376.0	1446.0
1.0	523.8	1300.0	1400.0	1420.0	1438.0	1424.0	1402.0
1.5	877.0	1500.0	1450.0	1500.0	1470.0	1444.0	1470.0
2.0	888.0	1500.0	1500.0	1500.0	1402.0	1393.5	1402.0
2.5	946.4	1500.0	1500.0	1504.6	1491.0	1446.1	1491.0
3.0	1500.0	1500.0	1500.0	1500.0	1469.0	1457.0	1469.0
3.5	1500.0	1500.0	1500.0	1506.7	1431.0	1437.0	1431.0

Outgoing Bandwidth for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	308	477.8	514	1441	1494	1408	1521
1.0	485	796.7	860	1559	1509	1528	1592
1.5	684.7	1300	1306	1562	1517	1571	1545
2.0	485	1544	1586	1574	1480	1530	1541
2.5	483	1411	1356.7	1527	1503	1461	1481
3.0	1017	1626	1603.5	1509	1500	1474	1525
3.5	1030	1615	1566	1540	1513	1506	1577

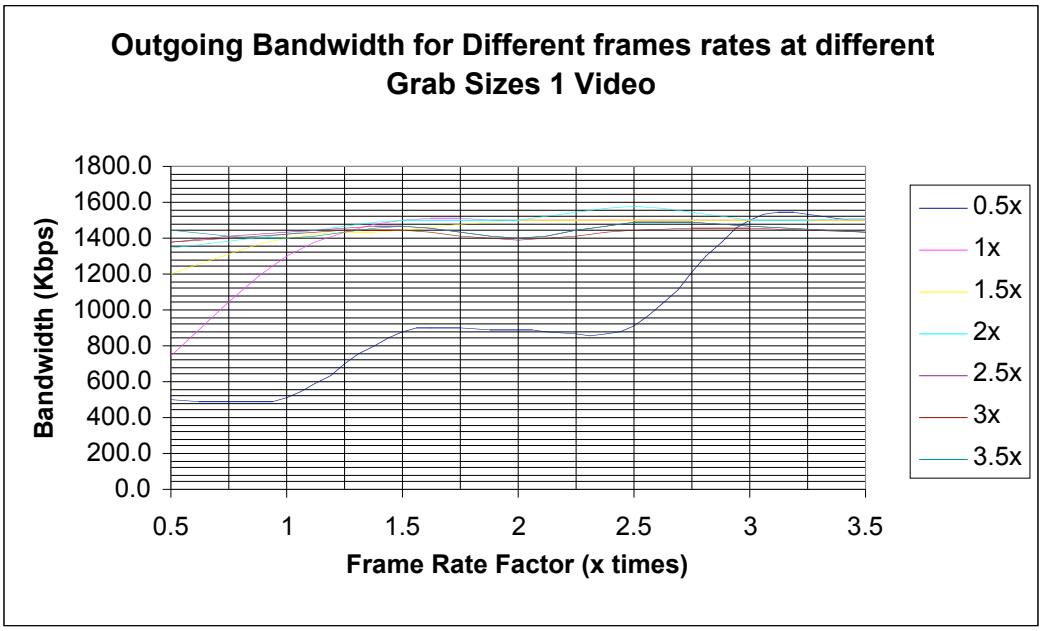
Outgoing Bandwidth for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	100	200	400	650	1141	1362	1476
1.0	200	500	800	1300	1507	1566	1515
1.5	300	700	1200	1300	1592	1527	1592
2.0	300	700	1200	1300	1626	1552	1626
2.5	300	700	1200	1300	1700	1526	1700
3.0	700	1500	1300	1300	1561	1512	1561
3.5	700	1500	1300	1300	1540	1510	1540

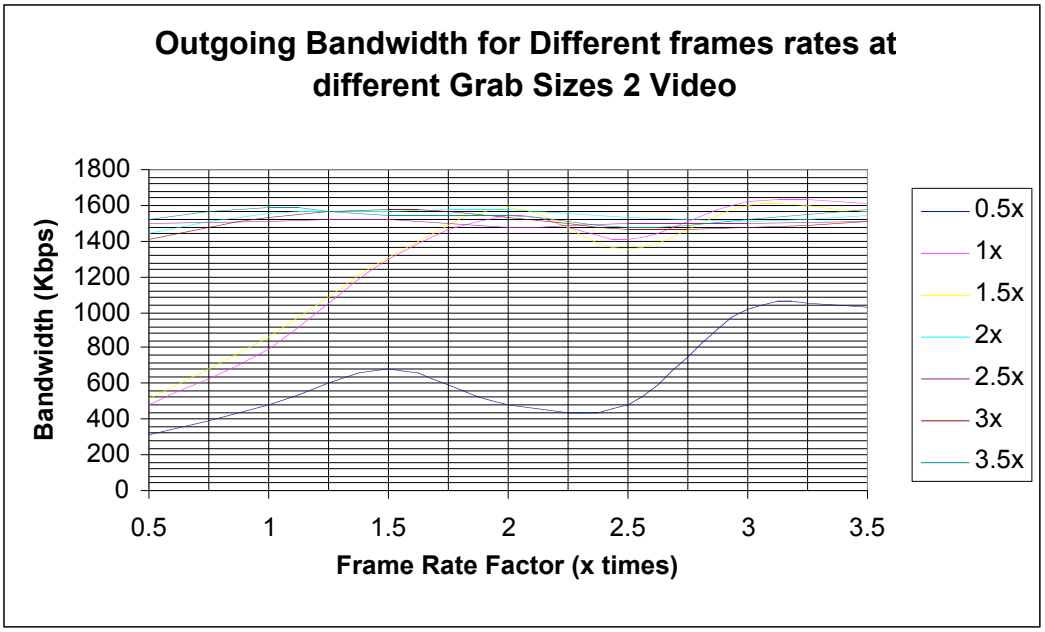
CPU Idling for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	90.0	88.0	85.0	75.0	75.0	75.0	75.0
1.0	89.0	84.0	80.0	73.0	73.0	73.0	73.0
1.5	84.0	75.0	77.0	75.0	75.0	75.0	75.0
2.0	80.0	70.0	74.0	70.0	70.0	72.0	71.8
2.5	76.2	65.0	66.5	65.0	65.0	65.0	65.0
3.0	55.0	70.0	54.5	60.0	60.0	63.0	57.4
3.5	53.0	64.0	48.1	54.9	53.2	60.3	46.6

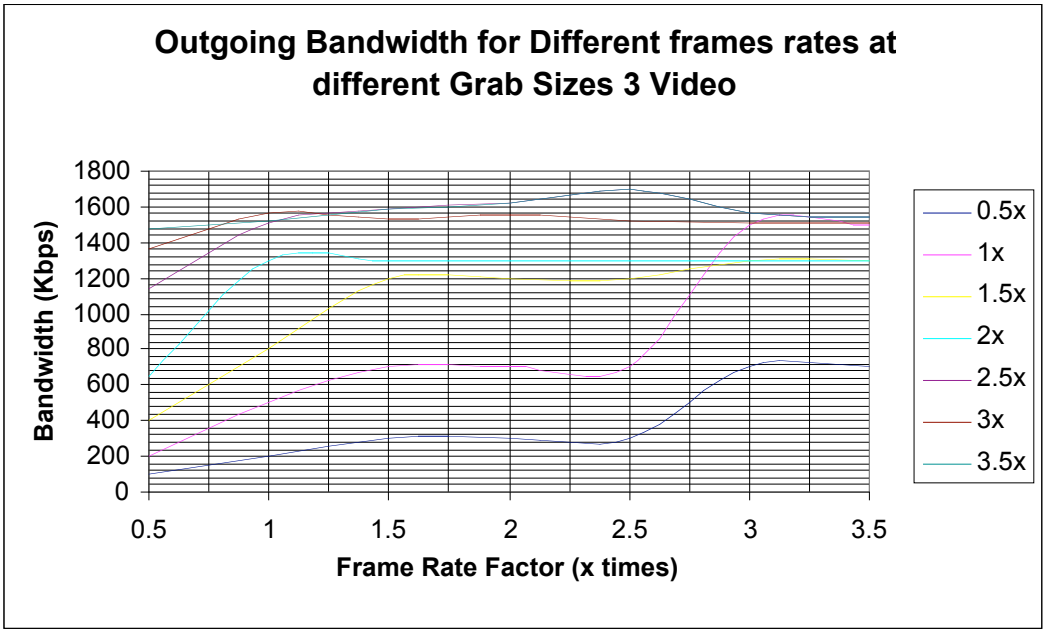
CPU Idling for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	92.1	86	67.3	64.2	65.3	62.1	57.2
1.0	79.3	70.1	53.2	41	44.2	43.2	51.3
1.5	68.2	43	33	44.2	39.6	45.9	42.5
2.0	71.1	52.5	36.1	51.1	46.1	39.6	45.2
2.5	70	53.2	42.6	42.3	44.2	46.2	46.3
3.0	37	21	20.2	35.2	36.2	31.3	32.7
3.5	39.4	22.3	16.3	37.1	25	28.6	30

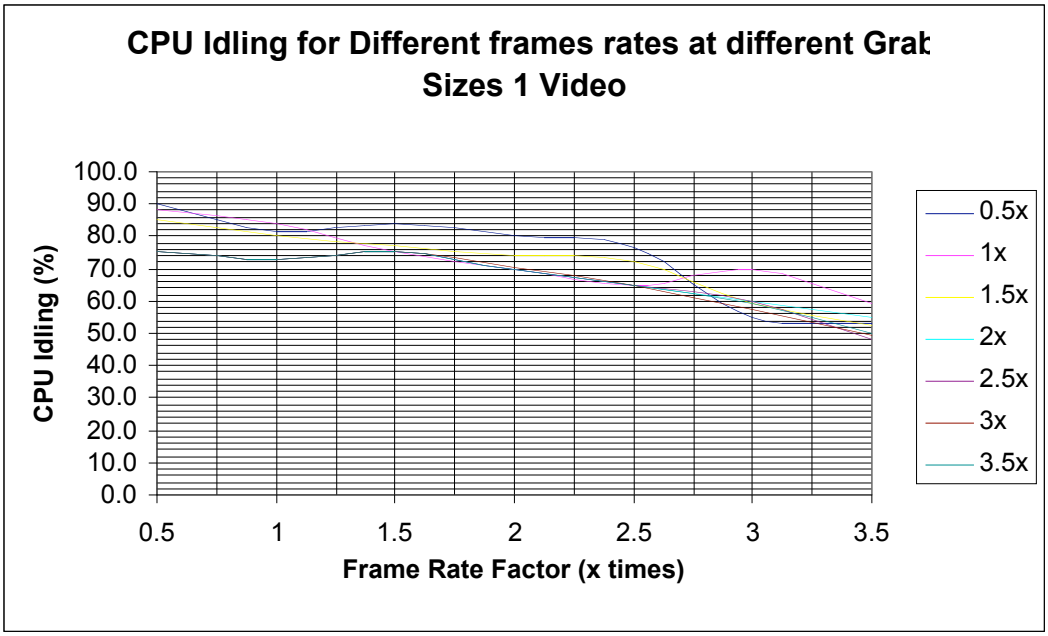
CPU Idling for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	90.0	86.0	76.0	60.0	45.0	41.0	37.0
1.0	80.0	75.0	50.0	20.0	17.0	13.0	9.0
1.5	70.0	55.0	25.0	16.2	16.1	12.1	8.1
2.0	57.3	44.3	22.6	15.1	15.4	11.4	7.4
2.5	50.7	44.2	18.3	16.0	14.0	10.0	6.0
3.0	45.0	10.0	12.0	13.1	13.4	9.4	5.4
3.5	36.5	8.5	11.8	10.6	13.0	9.0	5.0

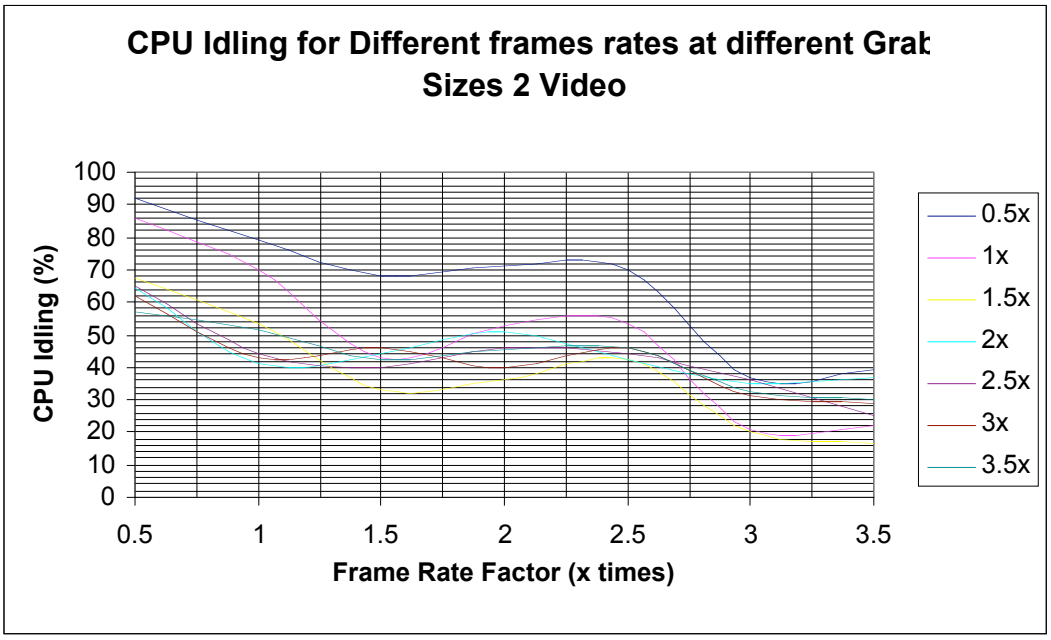
The graphics below show the outgoing bandwidth for different frames rate at different grab size

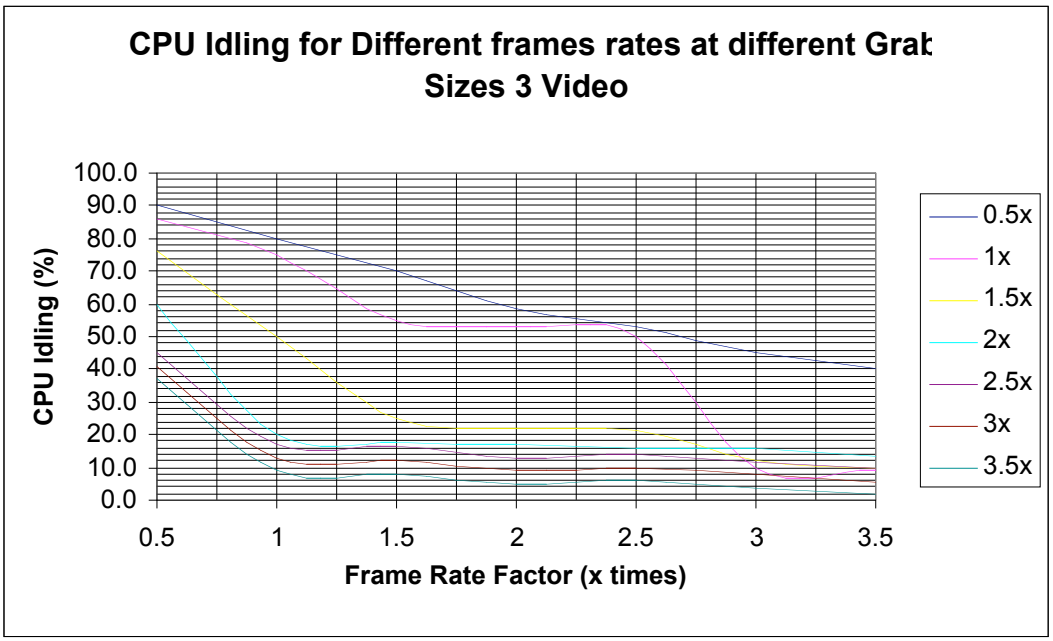



Outgoing Bandwidth for Different frames rates at different Grab Sizes 2 Video
Bandwidth (Kbps)
1800
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


Outgoing Bandwidth for Different frames rates at different Grab Sizes 3 Video
Bandwidth (Kbps)
1800
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 1 Video
CPU Idling (%)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 2 Video
CPU Idling (%)
100
90
80
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x



In general, we can observe that the outgoing bandwidth doesn't change much beyond the grab size factor 2.5X regardless of the frame rate factor. Also the CPU is saturated quickly on this grab size factor with 3 video.

Kappa
CPU: PIII 866MHz
RAM: 256MB
OS: RedHat Linux 7.0 Kernel 2.2.16-22

The tables below show the outgoing bandwidth for different frame rate and grab size taken from kappa

Outgoing Bandwidth for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	480	784.1	1276.8	1414	1376	1376	1446
1.0	665	1286.8	1407	1423	1438	1424	1402
1.5	883.3	1474.7	1470	1444	1470	1444	1470
2.0	888.8	1473.7	1402	1393.5	1402	1393.5	1402
2.5	866.5	1503.7	1491	1446.1	1491	1446.1	1491
3.0	1505.2	1490.8	1469	1457	1469	1457	1469
3.5	1459.9	1490.5	1431	1437	1431	1437	1431

Outgoing Bandwidth for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	308	477.8	514	1441	1494	1408	1521
1.0	485	796.7	860	1559	1509	1528	1592
1.5	684.7	1300	1306	1562	1517	1571	1545
2.0	485	1544	1586	1574	1480	1530	1541
2.5	483	1411	1356.7	1527	1503	1461	1481
3.0	1017	1626	1603.5	1509	1500	1474	1525
3.5	1030	1615	1566	1540	1513	1506	1577

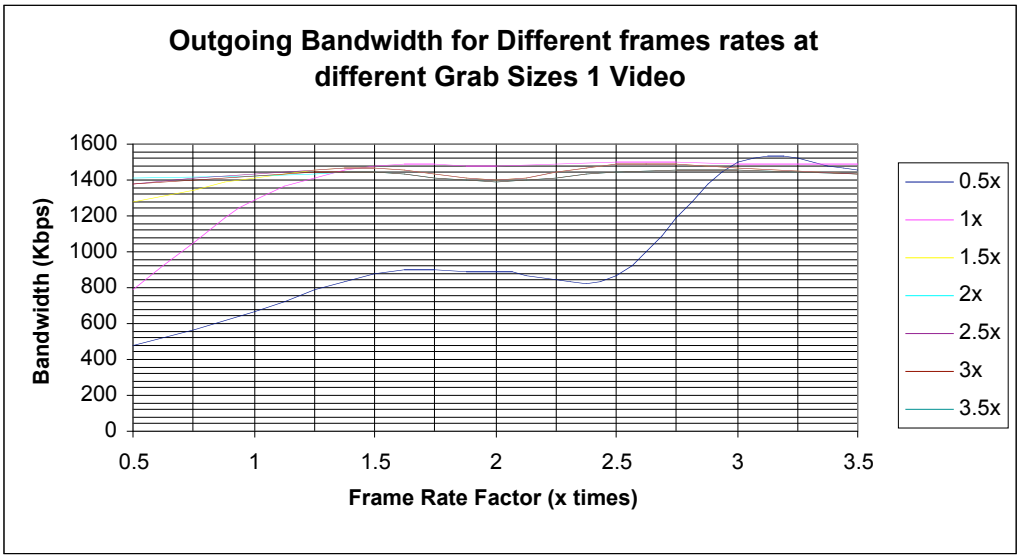
Outgoing Bandwidth for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	328.7	335	414	939	1141	1362	1476
1.0	502	600	1176	1479	1507	1566	1515
1.5	544	946	1571	1664	1592	1527	1592
2.0	512	947	1631	1605	1626	1552	1626
2.5	554	1027	1571	1665	1700	1526	1700
3.0	754	1700	1600	1610	1561	1512	1561
3.5	845	1602	1650	1641	1540	1510	1540

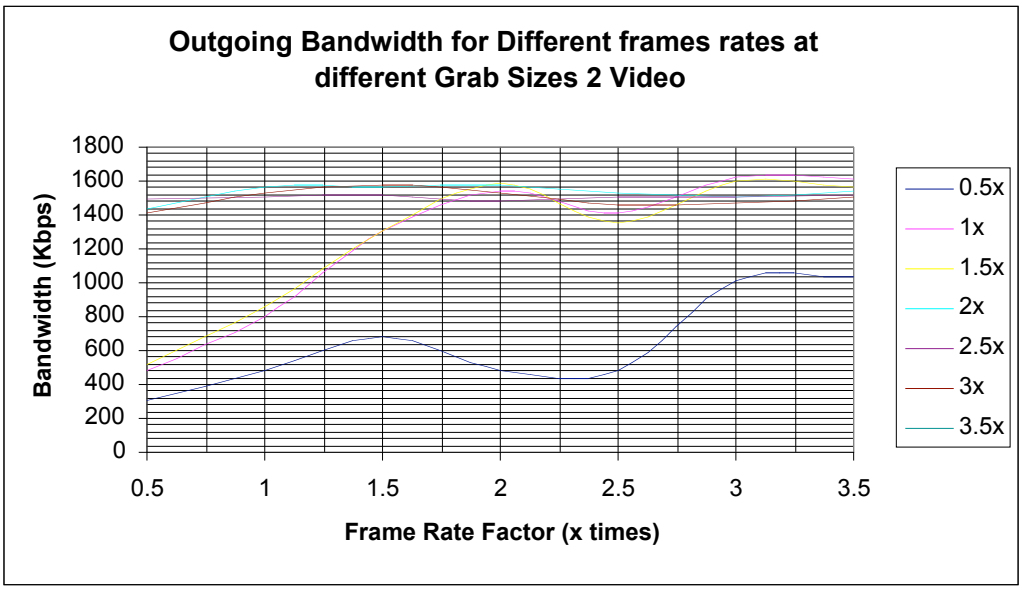
CPU Idling for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	85.3	79.4	71.3	62.4	62.3	62.3	62.3
1.0	72.2	60	38.2	53.4	50	50	50
1.5	59.4	48.2	49.3	48.3	45	45	45
2.0	66	42.3	44.6	46	44	44	44
2.5	67.3	51.4	48.1	47.3	43.2	43.2	43.2
3.0	27.2	20.1	31.1	29.4	28.1	28.1	28.1
3.5	22	13.4	26	23	20	20	20

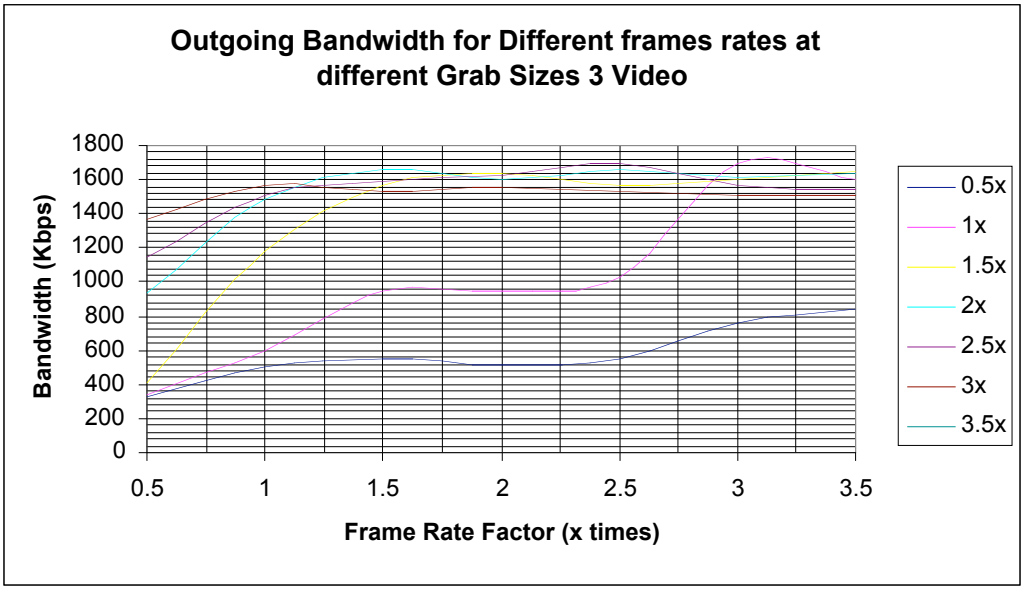
CPU Idling for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	86.1	80	67.3	60.2	62.1	57	51.2
1.0	73.3	69	53.2	37	40.6	39.5	45.3
1.5	62.4	48	33	39.3	36.4	41.3	37.4
2.0	65.2	49.4	36.1	46.3	42	36.2	39.3
2.5	64	48.3	38.8	39.1	42.3	43.1	39.1
3.0	31	17	15.4	30.29	28.1	26.2	28.5
3.5	33.4	16.1	8.8	31.31	22.4	22.3	27

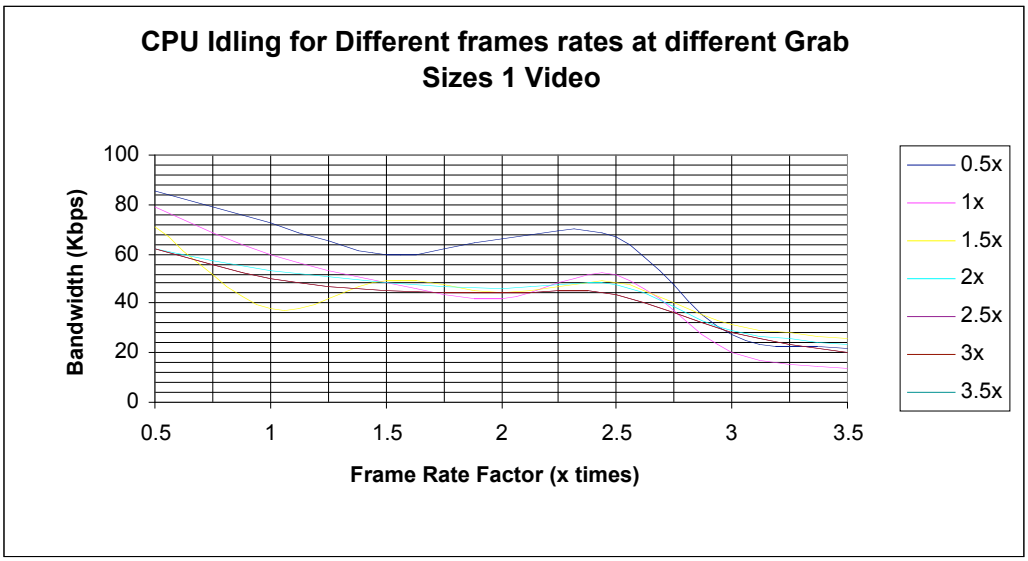
CPU Idling for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	84	86.3	81	71.2	55.4	57.1	51.3
1.0	74.1	62.4	62.3	47	41.4	39.3	33.3
1.5	71.3	62.61	41.1	35	23.7	35	34
2.0	68	66.4	45.2	33.1	35.2	37.2	37
2.5	70	59.2	43	31.4	33.2	34.4	34
3.0	37.3	18	21	24	31.3	26	30.4
3.5	36.4	20	21	28	31.1	32	32

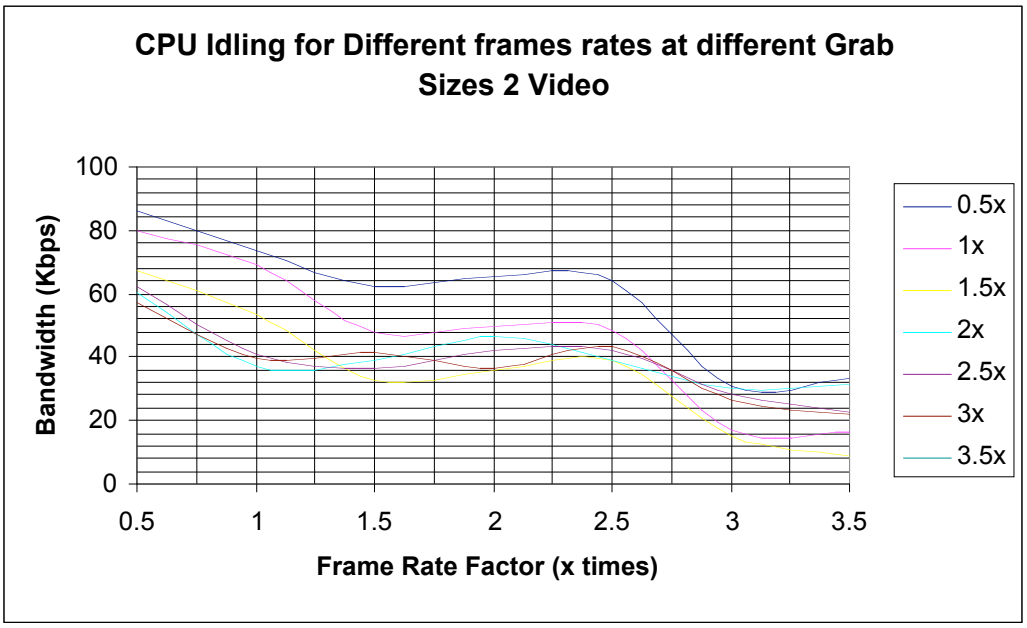
The graphics below show the outgoing bandwidth for different frames rate at different grab size

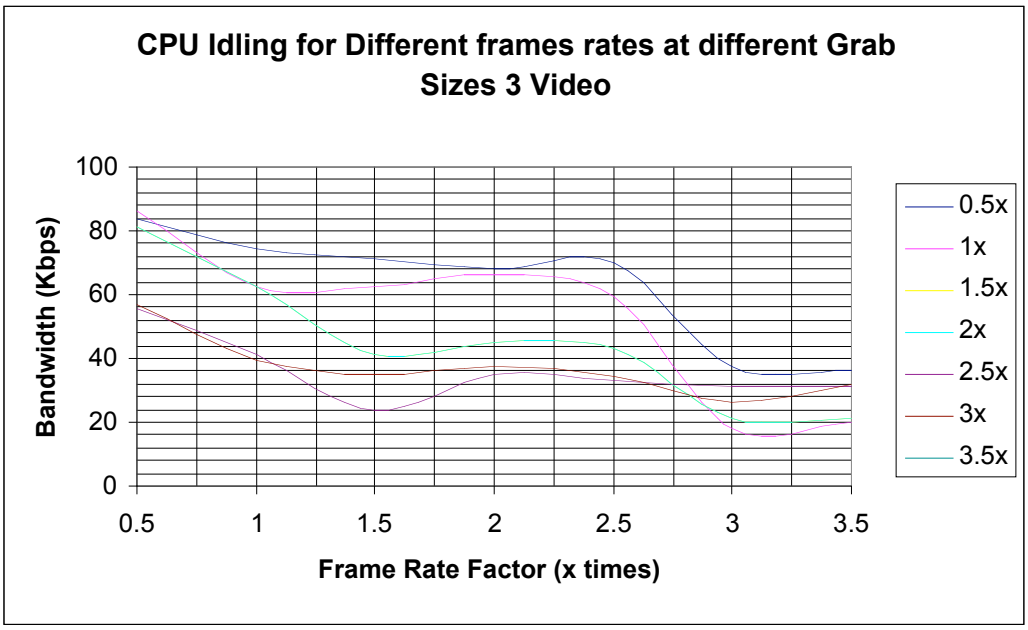



Outgoing Bandwidth for Different frames rates at different Grab Sizes 2 Video
Bandwidth (Kbps)
1800
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


Outgoing Bandwidth for Different frames rates at different Grab Sizes 3 Video
Bandwidth (Kbps)
1800
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 1 Video
Bandwidth (Kbps)
100
80
60
40
20
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 2 Video
Bandwidth (Kbps)
100
80
60
40
20
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x



MapleLeaf

CPU: PIII 933MHz
RAM: 256MB
OS: RedHat Linux 7.0 Kernel 2.2.16-22

The tables below show the outgoing bandwidth for different frame rate and grab size taken from mapleleafs

Outgoing Bandwidth for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	481.4	781.6	1188.3	1411.6	1408.9	1363.3	1388.5
1.0	688.2	1295	1432.5	1432	1459.1	1431.6	1409.2
1.5	881.6	1489.1	1509	1461.3	1461.3	1461.3	1461.3
2.0	901.3	1456.5	1472.2	1461.3	1461.3	1461.3	1461.3
2.5	893.2	1474.7	1489.6	1442.6	1442.6	1442.6	1442.6
3.0	1505	1447.8	1497.4	1481.7	1481.7	1481.7	1481.7
3.5	1508	1500.8	1445.3	1456.1	1456.1	1456.1	1456.1

Outgoing Bandwidth for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	250.4	403	580.4	844.8	1060.3	849.8	962.2
1.0	384.2	703.9	1056.3	1291.6	1048.9	1351.3	1428.3
1.5	521.5	1022	1178.9	1140.9	889.3	1480.3	1394.9
2.0	465	1016.8	1161	1077.8	915.1	1426.8	1372.3
2.5	499.3	970.3	1239	1014.4	802.5	1416.5	1396.7
3.0	885.8	1521.1	1286.2	990.1	886.2	1422.5	1470.4
3.5	874.1	1283.7	1187.7	999.2	918.6	1411.9	1397

Outgoing Bandwidth for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	158.4	345.9	430	737	655.8	1463.7	680.6
1.0	318.2	557.4	662.7	1165.4	1369.9	1155.8	1328.1
1.5	474	777.1	1075	1380	1332.4	967.8	1332.4
2.0	416.8	787	1238.9	1114.6	1258.1	1147.6	1258.1
2.5	420.6	671	1181.6	1271.9	1160.2	1110	1160.2
3.0	683.4	1253	1387.5	1249.7	949.6	824.3	949.6
3.5	684.3	1415	1246.4	1034	904	890.7	904

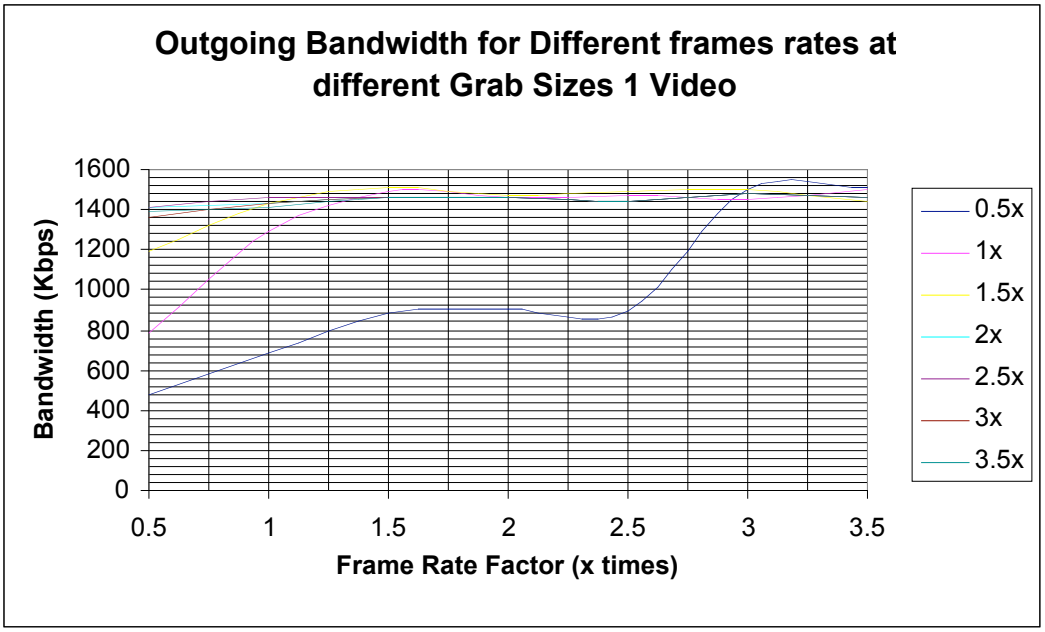
CPU Idling for Different frame rates and Grab Size (1 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	77.5	73	61.6	68.5	58.8	63.3	64.4
1.0	62.1	44.7	52.5	70.6	63.7	70	66.9
1.5	44	48.4	58.4	71	66	68	63
2.0	44.8	50.4	39.1	71	66	68	63
2.5	46.8	41.8	67.2	66.7	61.7	63.7	58.7
3.0	1.1	36	60	58.5	53.5	55.5	50.5
3.5	1.5	47.5	54.4	56.7	51.7	53.7	48.0

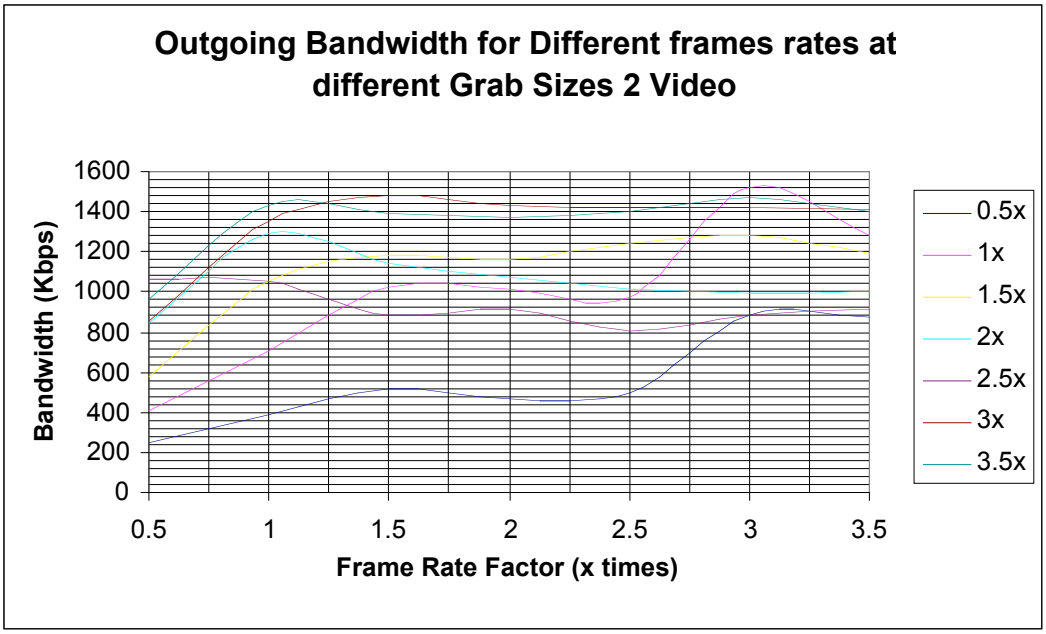
CPU Idling for Different frame rates and Grab Size (2 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	74.4	68.5	57.9	30.9	20.5	51.7	53.2
1.0	52.4	42.6	17.3	11.5	11.6	25.9	37.2
1.5	31.3	12.6	1.1	4.5	5.3	22.8	25.2
2.0	35.9	14.2	0.1	6.7	4.1	22.7	25.4
2.5	33.2	10.5	0.1	6.1	0.9	25.8	24.9
3.0	0.1	0	0	0.1	0	22.2	20

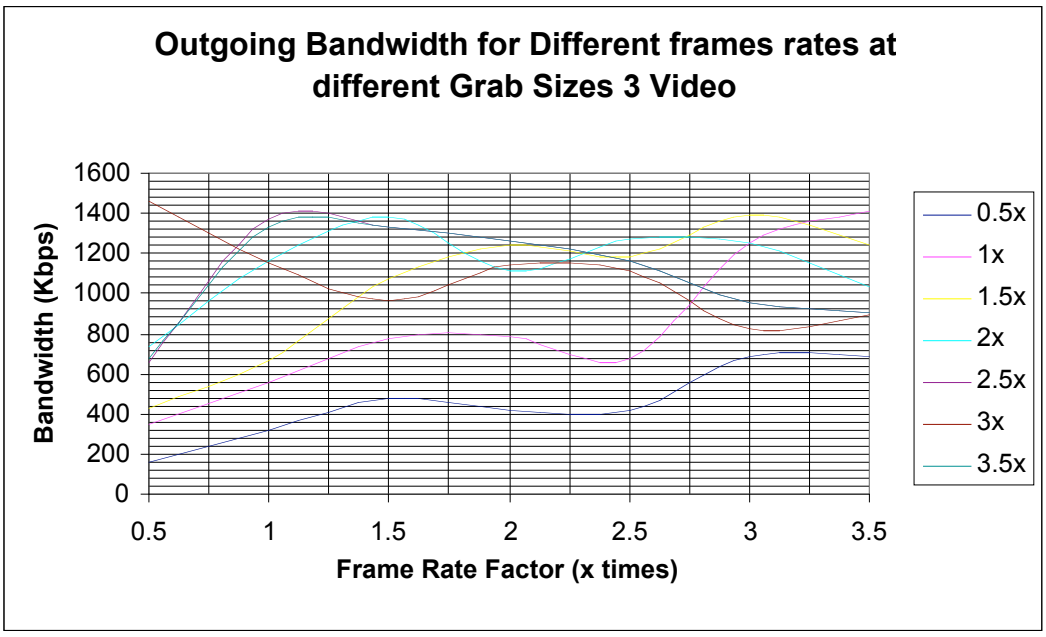
3.5	0.1	0	0	0.1	0.7	19.6	20.1

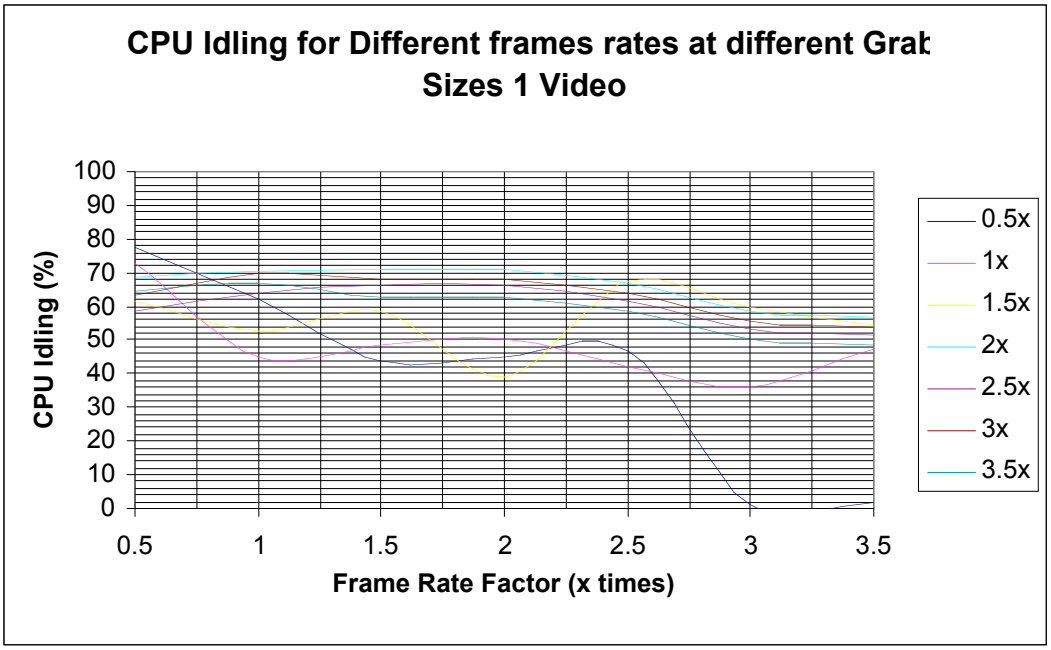
CPU Idling for Different frame rates and Grab Size (3 Video)							
Grab Size Factor	0.5x	1x	1.5x	2x	2.5x	3x	3.5x
Frame Rate Factor							
0.5	78.9	69.8	57.6	43.8	31	22.1	51.1
1.0	59.2	46.3	42.2	16.6	15.7	7.9	37.4
1.5	38.9	30.5	23.6	16.3	11.6	6.4	15.3
2.0	43.6	24	23.5	10	9.4	6.8	7.1
2.5	42	31.2	16.8	13.8	10.4	6.2	6.3
3.0	0	1.3	0.7	3.5	3.1	1.7	1.7
3.5	0	1.5	0.1	3.3	4.7	1.3	1.3

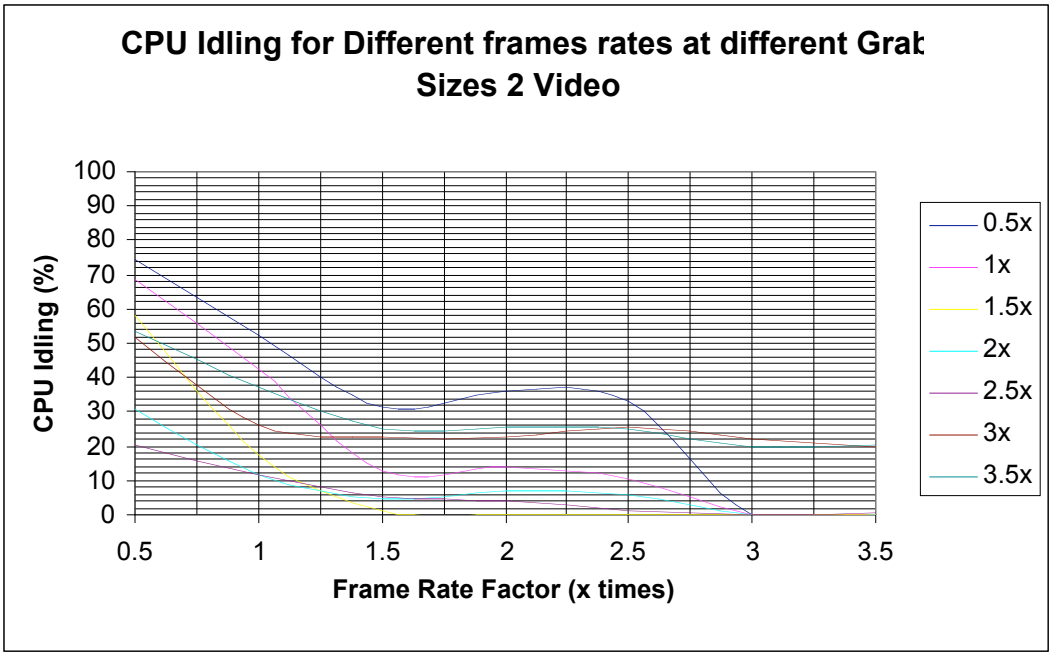
The graphics below show the outgoing bandwidth for different frames rate at different grab size

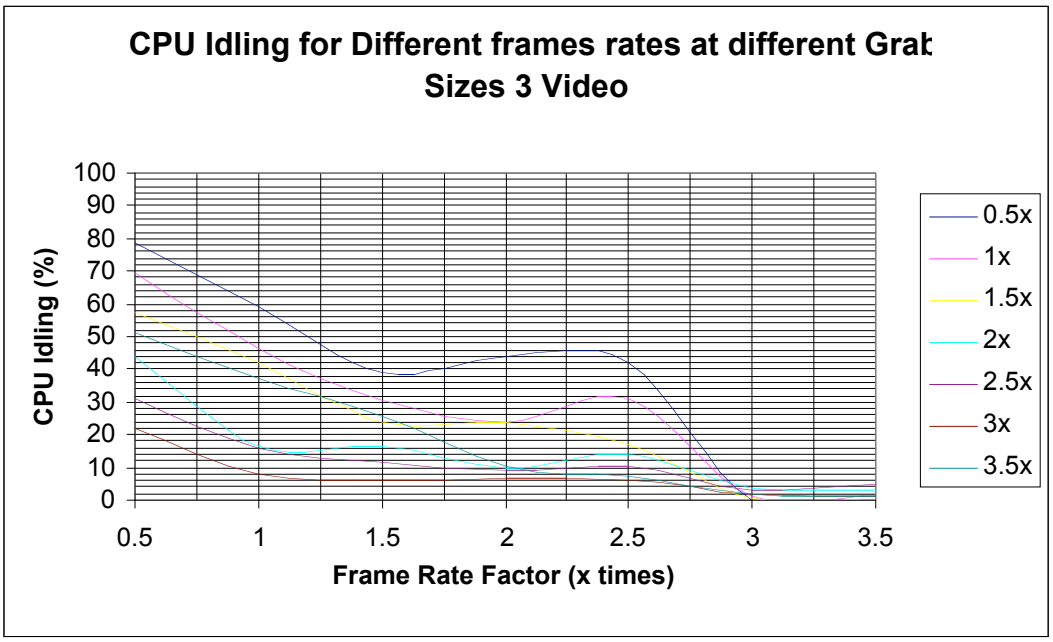



Outgoing Bandwidth for Different frames rates at different Grab Sizes 2 Video
Bandwidth (Kbps)
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


Outgoing Bandwidth for Different frames rates at different Grab Sizes 3 Video
Bandwidth (Kbps)
1600
1400
1200
1000
800
600
400
200
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 1 Video
CPU Idling (%)
100
90
80
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x


CPU Idling for Different frames rates at different Grab Sizes 2 Video
CPU Idling (%)
100
90
80
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
Frame Rate Factor (x times)
0.5x
1x
1.5x
2x
2.5x
3x
3.5x



IV Conclusion

By measuring the RTT, we found that a 4% packet loss problem with the OCDSB caused by bridging bridged to routing PDU on the ATM network. Also longer RTT needs bigger buffer size. The bandwidth is dependent not on the motion of objects in the screen but on the number of colors in the image. This is due to the codecs uses, ie; MJPEG. So colorful backgrounds on a still image will result in higher bandwidth usage than black and white moving object. Finally, the gathered data will be used as reference if future problems occur.

Pathchar Algorithm[1]

The program works by sending packets of varying sizes and measuring their round trip time. It correlates the round trip times with the packet sizes to calculate bandwidth. It uses the results from earlier hops for calculations on father hops. *P*athchar program uses an active algorithm that sends packets varying in size from 64 bytes to the path MTU with a stride of 32 bytes. Therefore, the number of different packet sizes pathchar sends is

$$s = [\frac{MTU}{32}] - 1$$

For Ethernet, the MTU is 1500 bytes, so *s* is 45. In addition, it sends *p* packets per size for every hop. In the default configuration, $p = 32$. It must wait for each packet it sends to be acknowledged before sending the next packet. Thus, the total time for pathchar to run is

$$\prod_{i=1}^{h} p \bullet s \bullet l_i$$

where *h* is the number of hops and l_i is the round trip latency from the sender to hop *i*. We assume that the receiver immediately sends an ack in response to a packet and that the sender immediately sends out the next packet when an ack arrives. For a 10-hop Ethernet network with an average round trip latency of 10ms, pathchar would run in 144 seconds. This is too slow for a host to run it

[1] http://mosquitonet.stanford.edu/~laik/projects/nettimer/publications/infocom1999/html/node4.html

for every TCP connection, or even every 10 minutes. It can be configured to send fewer packets of each size, but at the cost of accuracy.
More importantly, pathchar consumes considerable amounts of network bandwidth. The average bandwidth used for probing a particular hop is

$$\frac{\text{average packetsize}}{\text{round trip latency}} = \frac{\frac{32 \bullet s}{2} + 32}{l_i}$$

in bytes/s, where l_i is the round trip latency (in seconds) across that hop. For a 1-hop Ethernet network with a latency of 1ms, the average bandwidth consumed is 6.02Mb/s. This would be a considerable imposition on a 10Mb/s Ethernet. Farther hops would consume less bandwidth, but pathchar always has to probe closer hops before farther hops. Furthermore, the total data transferred is

$$(p)(h)(\sum_{i=2}^{s} 32\, i)$$

where *h* is the number of hops. For the 10-hop Ethernet network mentioned before, pathchar sends 10 MB of data. In fact, pathchar will send 10 MB of data on a 10-hop network regardless of the bandwidth of the network. It only depends on the number of hops, the path MTU, and *p*. If the path MTU is high and one of the early hops is a low bandwidth network link, such as a 56K modem, then pathchar can consume most of the bandwidth of that link for an extended amount of time. This means that we would have problems scaling pathchar usage up to a large number of hosts.