

SCENARIO NO. 1
SHARED 10 MBs ETHERNET PERFORMANCE

Date Nov. 29, 2001

Node Statistics *	Ethernet Collision	Ethernet Delay ¹	Ethernet Load	Ethernet Load	Ethernet Load
	<u>Count</u>	<u>(sec)</u>	<u>(bits)</u>	<u>(average bits/sec)</u>	<u>(average packets/sec)</u>
Hub	4,571	N/A	N/A	N/A	N/A
Master 1	906	0.000208	2,215,968	616	1.6
Master 2	921	0.000204	2,430,976	675	1.76
Master 3	850	0.000206	2,296,736	638	1.66
Master 4	881	0.000205	2,427,632	675	1.76
Master 5	902	0.00021	2,382,912	662	1.72
Slave 1	923	0.000104	8,280,144	2,300	1.61
Slave 2	311	0.000102	9,084,672	2,524	1.76
Slave 3	884	0.000102	8,576,800	2,382	1.66
Slave 4	948	0.0001	9,074,464	2,521	1.76
Slave 5	1,016	0.000101	8,899,280	2,472	1.73
	IP Processing Delay ⁴	IP Traffic Sent	IP Traffic Received	IP Traffic Dropped	IP Broadcasts
	<u>(sec)</u>	<u>(peak packets/sec)</u>	<u>(peak packets/sec)</u>	<u>(average packets/sec)</u>	<u>(sent / received)</u>
Master 1	0.0002	160	160	0	0 / 0
Master 2	0.0002	176	176	0	0 / 0
Master 3	0.0002	166	166	0	0 / 0
Master 4	0.0002	176	176	0	0 / 0
Master 5	0.0002	172	172	0	0 / 0
Slave 1	0.0002	161	161	0	0 / 0
Slave 2	0.0002	176	176	0	0 / 0
Slave 3	0.0002	166	166	0	0 / 0
Slave 4	0.0002	176	176	0	0 / 0
Slave 5	0.0002	172	172	0	0 / 0

* Based upon simulation model assumptions

¹ Statistical Ethernet Frame Transmission Time⁴ End-to-End IP Datagram Processing Time

SCENARIO NO. 1
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Date Nov. 29, 2001

	TCP Connection <u>Aborts</u>	TCP Delay ⁵ <u>(sec)</u>	TCP Load <u>(bytes)</u>	TCP Load <u>(bytes/sec)</u>	TCP Load <u>(packets)</u>
Master 1	1	0.000665	46,152	1,282	3,846
Master 2	1	0.000661	50,628	1,406	4,219
Master 3	1	0.000662	47,808	1,328	3,984
Master 4	1	0.00066	50,580	1,405	4,215
Master 5	1	0.000862	49,620	1,378	4,135
Slave 1	1	0.000504	803,814	22,328	3,846
Slave 2	1	0.000504	881,980	24,499	4,220
Slave 3	1	0.000502	832,656	23,129	3,984
Slave 4	1	0.000501	884,144	24,560	4,216
Slave 5	1	0.000502	864,006	24,000	4,134

	TCP Segment Delay ⁵ <u>(sec)</u>	TCP Traffic Received <u>(bytes)</u>	TCP Traffic Received <u>(bytes/sec)</u>	TCP Traffic Received <u>(packets)</u>	TCP Connection <u>Segment Round Trip</u> ⁶
Master 1	0.000608	803,814	22,328	3,846	0.00483
Master 2	0.000604	881,980	24,499	4,220	0.00367
Master 3	0.000606	832,656	23,129	3,984	0.00377
Master 4	0.000605	881,144	24,476	4,216	0.00403
Master 5	0.00061	864,006	24,000	4,134	0.00387
Slave 1	0.000504	46,152	1,282	3,846	0.00377
Slave 2	0.000502	50,628	1,406	4,219	0.00296
Slave 3	0.000502	47,808	1,328	3,984	0.004
Slave 4	0.000501	50,580	1,405	4,215	0.00356
Slave 5	0.000501	49,620	1,378	4,134	0.00351

* Based upon simulation model assumptions

⁵ End-to-End TCP Transaction Processing Time

⁶ Round Trip TCP Transaction Processing Time

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CSMA/CD Errors(Single Shared Ethernet
Collision Domain)

<u>Device</u>	<u>Point to Point Bit Error Rate ⁷</u>	<u>Point to Point Queuing Delay (sec) ⁸</u>
Master 1	0.0133	0.000053
Master 2	0.0134	0.000054
Master 3	0.0136	0.000143
Master 4	0.0133	0.000145
Master 5	0.00061	0.000054
Slave 1	0.0134	0.000143
Slave 2	0.0133	0.000145
Slave 3	0.013	0.000145
Slave 4	0.0138	0.000145
Slave 5	0.0148	0.000143

* Based upon simulation model assumptions

⁷ Statistical Probability of a bit being received incorrectly. Example: A Bit Error Rate of 0.01 averages 1 bit error per 100 bits sent⁸ Represents statistical average of waiting time in the transmitters channel queue.

SCENARIO NO. 2
SWITCHED 100 MBs ETHERNET PERFORMANCE

Date Nov. 29, 2001

Nodes Tested

<u>Unit</u>	<u>Host</u>	<u>IPAddress</u>	<u>Device Description</u>	<u>PLC Ethernet Adapter</u>	<u>Link</u>
1	Master 1	10.10.1.10	Quantum PLC	NOE 771 00	100BaseTX
2	Master 2	10.10.1.20	Quantum PLC	NOE 771 00	100BaseTX
3	Master 3	10.10.1.30	Quantum PLC	NOE 771 00	100BaseTX
4	Master 4	10.10.1.40	Quantum PLC	NOE 771 00	100BaseTX
5	Master 5	10.10.1.50	Quantum PLC	NOE 771 00	100BaseTX
6	Slave 1	10.10.1.11	Quantum PLC	NOE 771 00	100BaseTX
7	Slave 2	10.10.1.22	Quantum PLC	NOE 771 00	100BaseTX
8	Slave 3	10.10.1.33	Quantum PLC	NOE 771 00	100BaseTX
9	Slave 4	10.10.1.44	Quantum PLC	NOE 771 00	100BaseTX
10	Slave 5	10.10.1.55	Quantum PLC	NOE 771 00	100BaseTX

Infrastructure

<u>No</u>	<u>Mfr</u>	<u>Model</u>	<u>Encoding</u>	<u>Data Rate</u>
1	Simulated Switch	Advanced 10/100 Switch	MLT3 (Fast Ethernet)	100 Mbs Switched Full Duplex

Global Statistics *

	<u>Average</u>	<u>Maximum</u>	<u>Minimum</u>
Ethernet Delay ¹ (sec)	0.0000252	0.0000252	0.0000252
IP Dropped Packets	0	0	0
TCP Delay ² (sec)	0.000431	0.000431	0.000431
TCP Segment Delay ² (sec)	0.000425	0.000425	0.000425
Sampling Time ³	36 Seconds		

* Based upon simulation model assumptions

¹ Statistical Ethernet Frame Transmission Time

² Statistical Processing Time for ModbusTCP Message

³ Protocol Analyzer Capture Sample Time

SCENARIO NO. 2
SWITCHED 100 MBs ETHERNET PERFORMANCE

Date Nov. 29, 2001

Node Statistics *	Ethernet Collision	Ethernet Delay ⁵	Ethernet Load	Ethernet Load	Ethernet Load
	<u>Count</u> ⁴	<u>(sec)</u>	<u>(bits)</u>	<u>(average bits/sec)</u>	<u>(frames)</u>
Switch	0				
Master 1	0	0.0000357	2,216,608	616	5,773
Master 2	0	0.0000356	2,431,616	675	6,333
Master 3	0	0.0000356	2,296,096	638	5,980
Master 4	0	0.0000357	2,429,632	675	6,328
Master 5	0	0.0000357	2,383,552	662	6,208
Slave 1	0	0.0000147	8,280,144	2,300	5,780
Slave 2	0	0.0000146	9,083,712	2,523	6,337
Slave 3	0	0.0000146	8,577,120	2,383	5,987
Slave 4	0	0.0000147	9,076,384	2,521	6,335
Slave 5	0	0.0000147	8,899,280	2,472	6,210
	IP Processing Delay ⁶	IP Broadcasts	IP Traffic Sent	IP Traffic Received	IP Traffic Dropped
	<u>(sec)</u>	<u>(sent / received)</u>	<u>(peak packets/sec)</u>	<u>(peak packets/sec)</u>	<u>(packets)</u>
Master 1	0.0002	0 / 0	160	161	0
Master 2	0.0002	0 / 0	176	176	0
Master 3	0.0002	0 / 0	166	166	0
Master 4	0.0002	0 / 0	176	176	0
Master 5	0.0002	0 / 0	172	173	0
Slave 1	0.0002	0 / 0	161	160	0
Slave 2	0.0002	0 / 0	176	176	0
Slave 3	0.0002	0 / 0	166	166	0
Slave 4	0.0002	0 / 0	176	176	0
Slave 5	0.0002	0 / 0	173	172	0

* Based upon simulation model assumptions

⁴ Included for Comparison.⁵ Statistical Ethernet Frame Transmission Time⁶ End-to-End IP Datagram Processing Time

SCENARIO NO. 2
SWITCHED 100 MBs ETHERNET PERFORMANCE

Date Nov. 29, 2001

	TCP Connection <u>Aborts</u>	TCP Delay ⁶ <u>(sec)</u>	TCP Traffic Sent <u>(bytes)</u>	TCP Traffic Sent <u>(bytes/sec)</u>	TCP Traffic Sent <u>(packets)</u>
Master 1	1	0.000447	46,152	1,282	3,846
Master 2	1	0.000446	50,628	1,406	4,219
Master 3	1	0.000446	47,808	1,328	3,984
Master 4	1	0.000447	50,580	1,405	4,215
Master 5	1	0.000447	49,620	1,378	4,135
Slave 1	1	0.000415	803,814	22,328	3,846
Slave 2	1	0.000415	881,980	24,499	4,220
Slave 3	1	0.000415	832,656	23,129	3,984
Slave 4	1	0.000415	881,144	24,476	4,216
Slave 5	1	0.000415	864,006	24,000	4,134

	TCP Segment Delay ⁶ <u>(sec)</u>	TCP Traffic Received <u>(total bytes)</u>	TCP Traffic Received <u>(average bytes/sec)</u>	TCP Traffic Received <u>(packets)</u>	TCP Connection Segment Round Trip Time ⁷ (sec)
Master 1	0.000436	803,814	22,328	3,846	0.00483
Master 2	0.000436	881,980	24,499	4,220	0.00367
Master 3	0.000436	832,656	23,129	3,984	0.00377
Master 4	0.000436	881,144	24,476	4,216	0.00403
Master 5	0.000436	864,006	24,000	4,134	0.00387
Slave 1	0.000415	46,152	1,282	3,846	0.00377
Slave 2	0.000415	50,628	1,406	4,219	0.00296
Slave 3	0.000415	47,808	1,328	3,984	0.004
Slave 4	0.000415	50,580	1,405	4,215	0.00356
Slave 5	0.000415	49,620	1,378	4,135	0.00351

* Based upon simulation model assumptions

⁶ End-to-End TCP Message Processing Time

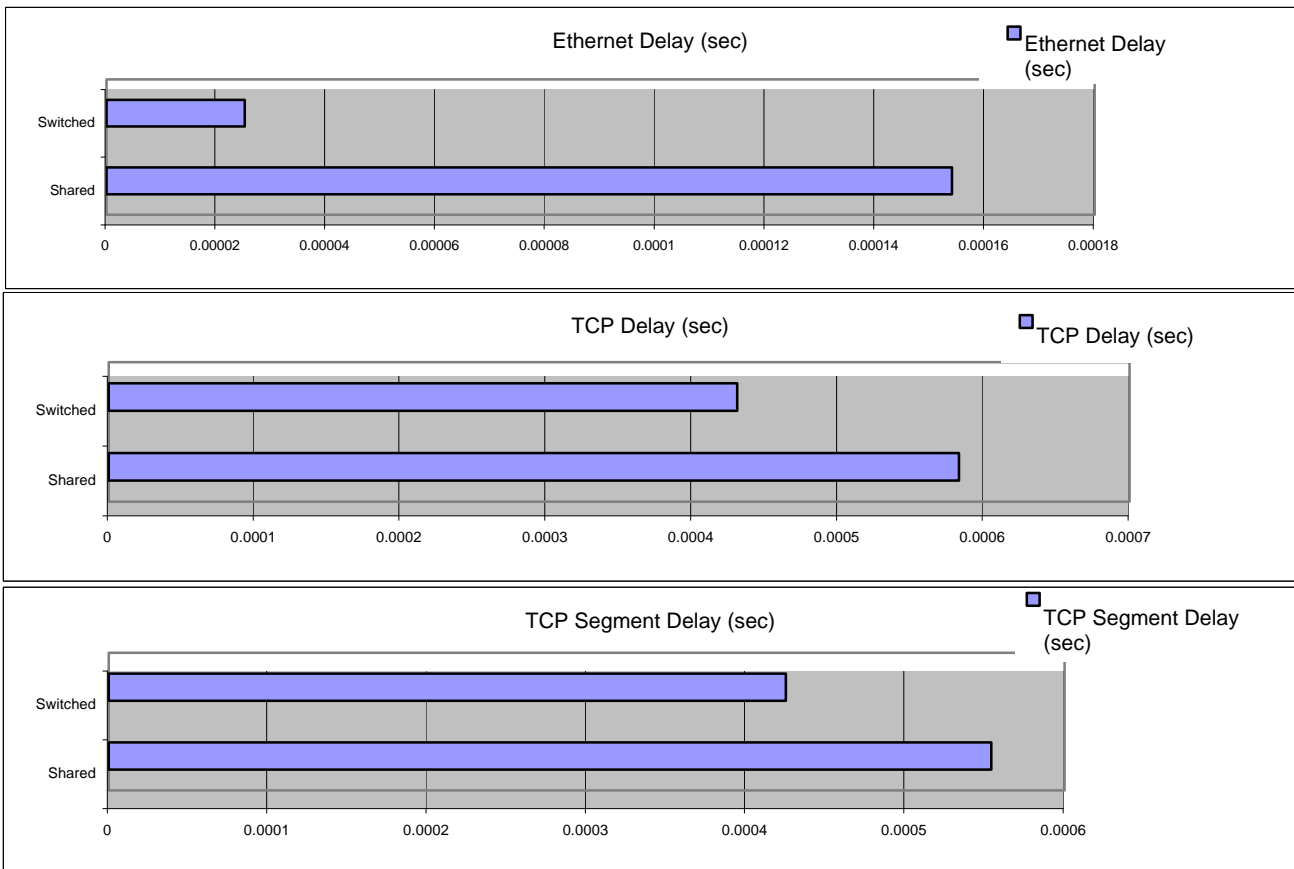
⁷ Statistical ModbusTCP Transaction Turnaround Time

Date Nov. 29, 2001

SCENARIO COMPARISON
10 MBS SHARED VS. SWITCHED 100 MBs ETHERNET PERFORMANCE

Global Comparison *

	<u>Shared</u>	<u>Switched</u>
Ethernet Delay (sec)	0.000154	0.0000252
TCP Delay (sec)	0.000583	0.000431
TCP Segment Delay (sec)	0.000554	0.000425



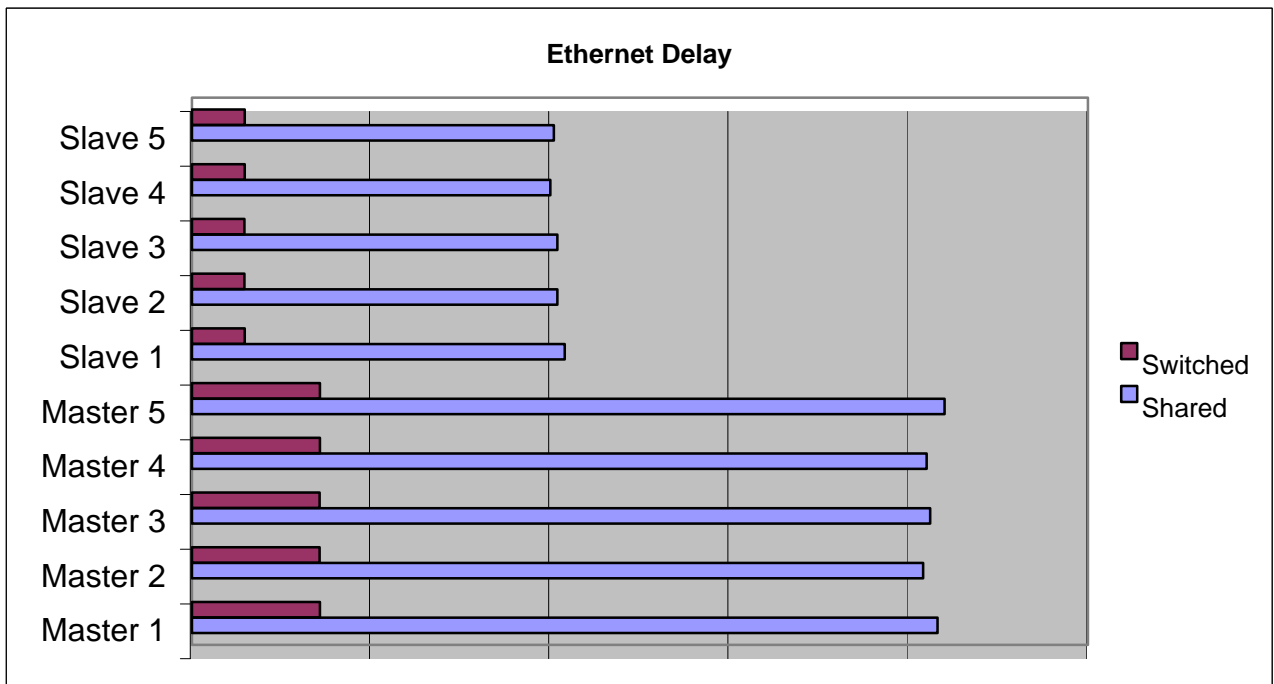
* Based upon simulation model assumptions

Date Nov. 29, 2001

SCENARIO COMPARISON
10 MBS SHARED VS. SWITCHED 100 MBs ETHERNET PERFORMANCE

Node Comparison

Ethernet Delay* (sec)		<u>Shared</u>	<u>Switched</u>
	Master 1	0.000208	0.0000357
	Master 2	0.000204	0.0000356
	Master 3	0.000206	0.0000356
	Master 4	0.000205	0.0000357
	Master 5	0.00021	0.0000357
	Slave 1	0.000104	0.0000147
	Slave 2	0.000102	0.0000146
	Slave 3	0.000102	0.0000146
	Slave 4	0.0001	0.0000147
	Slave 5	0.000101	0.0000147

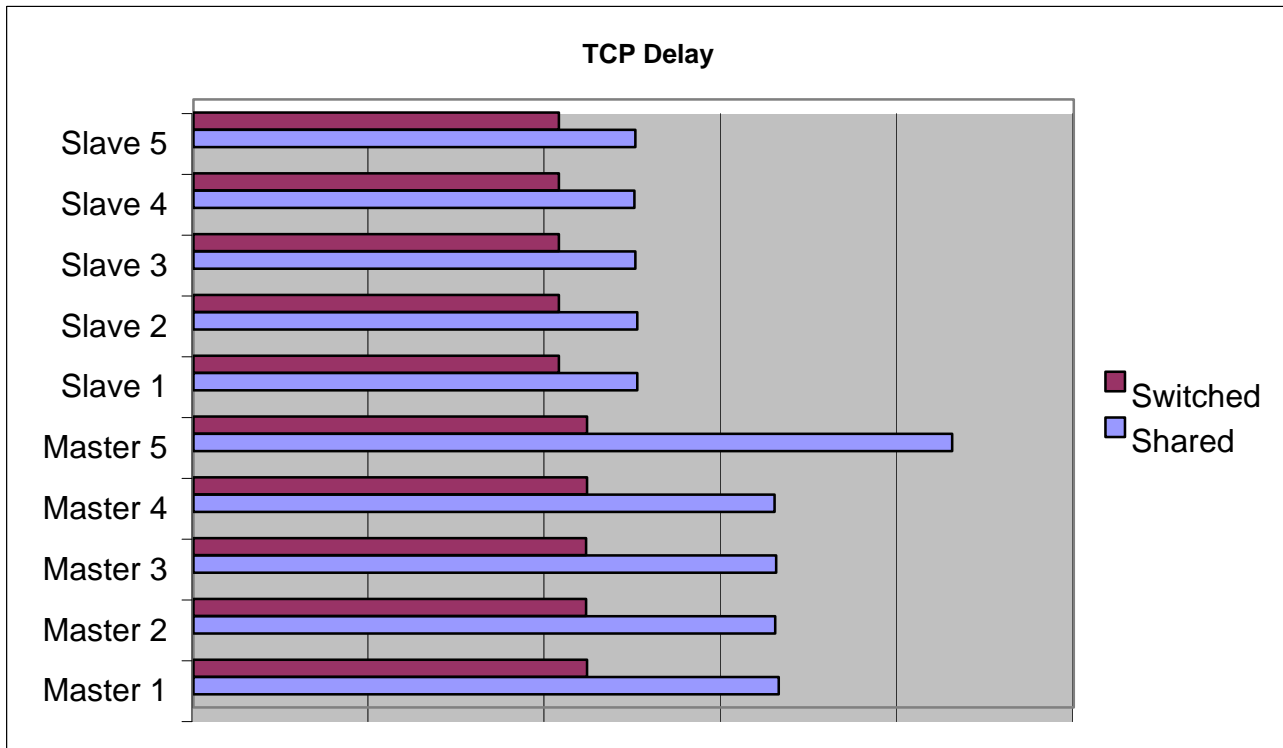


* Based upon simulation model assumptions

Date Nov. 29, 2001

SCENARIO COMPARISON
10 MBS SHARED VS. SWITCHED 100 MBs ETHERNET PERFORMANCE

TCP Delay * (sec)		<u>Shared</u>	<u>Switched</u>
	Master 1	0.000665	0.000447
	Master 2	0.000661	0.000446
	Master 3	0.000662	0.000446
	Master 4	0.00066	0.000447
	Master 5	0.000862	0.000447
	Slave 1	0.000504	0.000415
	Slave 2	0.000504	0.000415
	Slave 3	0.000502	0.000415
	Slave 4	0.000501	0.000415
	Slave 5	0.000502	0.000415



* Based upon simulation model assumptions

Date Nov. 29, 2001

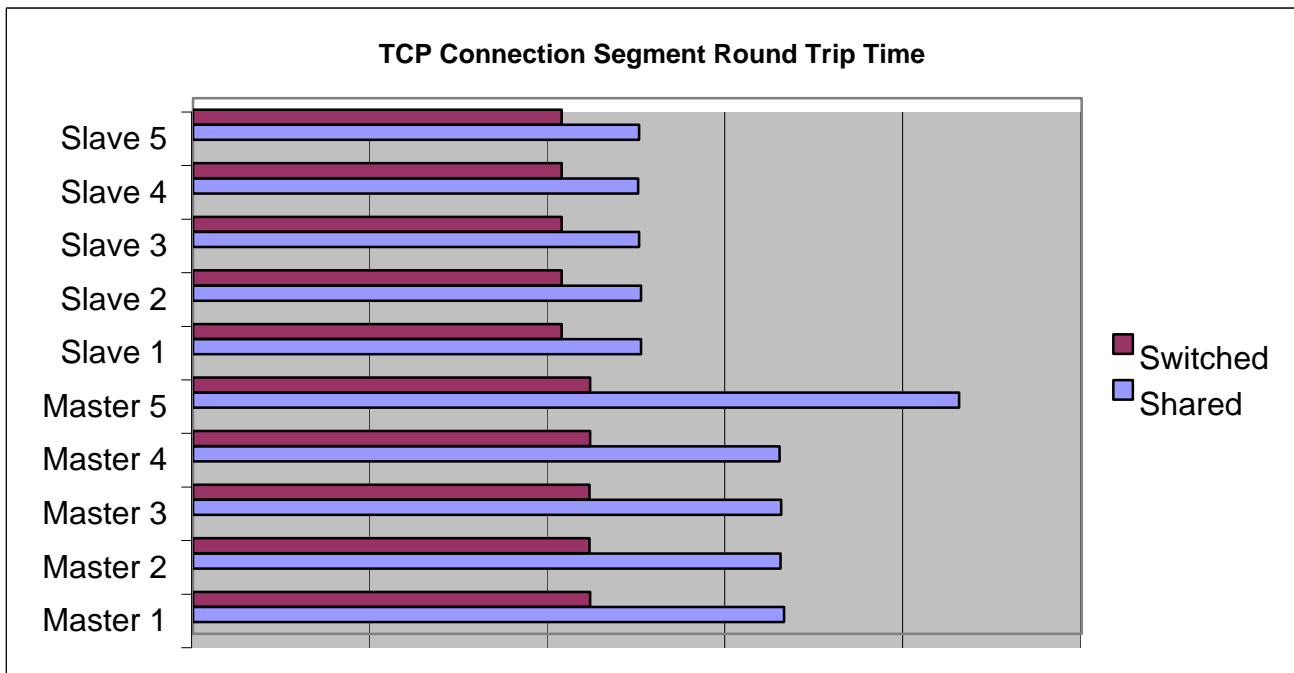
SCENARIO COMPARISON

10 MBS SHARED VS. SWITCHED 100 MBs ETHERNET PERFORMANCE

TCP Connection

Segment Round Trip *
(sec)

	<u>Shared</u>	<u>Switched</u>
Master 1	0.000665	0.000447
Master 2	0.000661	0.000446
Master 3	0.000662	0.000446
Master 4	0.00066	0.000447
Master 5	0.000862	0.000447
Slave 1	0.000504	0.000415
Slave 2	0.000504	0.000415
Slave 3	0.000502	0.000415
Slave 4	0.000501	0.000415
Slave 5	0.000502	0.000415



* Based upon simulation model assumptions