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Project 1: Two-Transmission-Link Queueing System Simulator and Output Instructions

Simulation Diagnostics

Queue = 20	phi = 0.2	phi = 0.4	phi = 0.5	phi = 0.6	phi = 0.8
Total serviced packets	4998	5000	5000	5000	4999
Total dropped packets	2	0	0	0	1
Bocking probability	0.04%	0%	0%	0%	0.02%
Average system throughput (pkts/sec)	8.08049	8.07552	8.00574	8.01831	8.08343
Average number of packets in the system	5.77859	5.25208	4.97963	5.2162	6.59903
Link 1 throughput	1509	1956	2478	3040	3980
Link 1 average throughput (pkts/sec)	2.43967	3.15914	3.96765	4.87513	6.4357
Link 1 average delay (sec)	0.244851	0.267966	0.315332	0.377951	0.582665
Link 2 throughput	3489	3044	2522	1960	1019
Link 2 average throughput (pkts/sec)	5.64082	4.91638	4.0381	3.14318	1.64773
Link 2 average delay (sec)	0.477762	0.388544	0.307122	0.274074	0.242378
Queue = 5	**phi = 0.2**	**phi = 0.4**	**phi = 0.5**	**phi = 0.6**	**phi = 0.8**
Total serviced packets	4485	4835	4917	4840	4428
Total dropped packets	515	165	83	160	572
Bocking probability	10.3%	3.3%	1.66%	3.2%	11.44%
Average system throughput (pkts/sec)	7.11462	7.76587	7.90931	7.87851	7.27862
Average number of packets in the system	4.7181	4.78239	4.89474	4.72555	4.72035
Link 1 throughput	1021	1951	2478	2911	3409
Link 1 average throughput (pkts/sec)	1.61963	3.13365	3.98602	4.7385	5.60362
Link 1 average delay (sec)	0.224203	0.268811	0.313707	0.33969	0.441413
Link 2 throughput	3464	2884	2439	1929	1019
Link 2 average throughput (pkts/sec)	5.49499	4.63221	3.92329	3.14001	1.675
Link 2 average delay (sec)	0.43328	0.349388	0.308463	0.270531	0.224852

Additional Questions:

1. The system changes with Phi in a number of ways.

Phi Trends

	phi -> 0	phi -> 1	phi = 0.5	0 <- phi -> 1
Total serviced packets	–	–	+	–
Total dropped packets	+	+	–	+
Bocking probability	+	+	–	+
Average system throughput (pkts/sec)	–	–	+	–
Average number of packets in the system	+	+	–	+
Link 1 throughput	–	+	N/A	N/A
Link 1 average throughput (pkts/sec)	–	+	N/A	N/A
Link 1 average delay (sec)	–	+	N/A	N/A
Link 2 throughput	+	–	N/A	N/A
Link 2 average throughput (pkts/sec)	+	–	N/A	N/A
Link 2 average delay (sec)	+	–	N/A	N/A

i. As phi increases:
   a. The likelihood of the first service queue being chosen for transmission increases as phi increases.
   b. The throughput for the first service link increases.
   c. The average throughput for the first service queue increases.
   d. The average delay for packet service in the first link increases.
   e. The likelihood of the second service queue being chosen for transmission increases as phi decreases.
   f. The throughput for the second service link decreases.
   g. The average throughput for the second service queue decreases.
   h. The average delay for packet service in the second link decreases.

ii. As phi decreases:
   a. The likelihood of the first service queue being chosen for transmission increases as phi decreases.
   b. The throughput for the first service link decreases.
   c. The average throughput for the first service queue decreases.
   d. The average delay for packet service in the first link decreases.
   e. The likelihood of the second service queue being chosen for transmission increases as phi increases.
   f. The throughput for the second service link increases.
   g. The average throughput for the second service queue increases.
   h. The average delay for packet service in the second link increases.

iii. As phi approaches 0.5:
   a. Blocking probability decreases.
   b. Average system throughput increases.

c. Average number of packets in the system generally decreases.
d. Total serviced packets increases.

iv. As phi approaches 0 or 1:
a. Blocking probability increases.
b. Average system throughput decreases.
c. Average number of packets in the system generally increases.
d. Total serviced packets decreases.

Phi is a variable that governs the probability associated with link determination. A higher phi generally leads to more usage of the first service link. A lower phi leads to more usage of the second service link. The increases and decreases associated with throughput, average throughput, and average delay are an inversely proportional relationship in the two links.

With phi controlling the utilization of the two links, it makes sense that, as the two links are used more equally (phi = 0.5), the blocking probability and average number of packets in the system decrease while the average system throughput and total serviced packets increase. Both links allows less packets to drop because they are splitting the service work in half and preventing one link from being overrun with packets. The even division of the packet service allows more packets to be serviced and decreases the average number of packets in the system resulting in an increase in throughput.

When phi causes a discrimination against a link, it is clear from the data that the blocking probability increases. This is due to the one link doing most of the work and getting backed up easier since there is no division of service between the two queues. The system throughput goes down, naturally, because one of the links is doing way less work than the other link. As the throughput goes down, the average number of packets in the system will increase due to the backups in the more active link.

2. Generally, the system drops less packets as the buffer size increases:

Buffer Trends

	buffer++	buffer--
Total serviced packets	+	-
Total dropped packets	-	+
Bocking probability	-	+
Average system throughput (pkts/sec)	+	-
Average number of packets in the system	-	+
Link 1 throughput	+	-
Link 1 average throughput (pkts/sec)	+	-
Link 1 average delay (sec)	N/A	N/A
Link 2 throughput	+	-
Link 2 average throughput (pkts/sec)	+	-
Link 2 average delay (sec)	N/A	N/A

An increased buffer means a greater capacity to handle packets that would otherwise have been dropped. As the buffer size increases, so too do the system and link throughputs. This is a because there is less "inch-worm" like movement of packets in the queues. With a small buffer, the queue fills up quickly and then will not accept packets while it is backed up. This results in an oscillation between higher throughput and lower throughput. Conversely, with a larger buffer, the queue will seldom fill up and the packets can continue to be received even if the service is not instant. This could contribute to an increase in packet service delays, but overall, the throughput will be higher with a larger buffer.

3. Setting phi to 0.5 with a large buffer (relative to the arrival rate) will result in the lowest blocking probability and the highest system throughput. This is because the two links are sharing the service workload evenly which allows system to service more packets at a given time. This increase in serviced packets yields an increase in system throughput. The large buffer allows packets to become queued continuously, resulting in very few drops. As the buffer size approaches infinity, the number of dropped packets approaches zero. Rather than a packet being dropped, it will just be added to a queue and have a delay related to the number of packets in front of it in the queue.