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Part 1 - Iperfer on Wired Environment

- Client:

```
[szhong@royal-03] (4)$ java Iperfer -c -h royal-02.cs.wisc.edu -p 12345 -t 15
sent=1761621 KB rate=939.531 Mbps
```

- Server:

```
[szhong@royal-02] (6)$ java Iperfer -s -p 12345
received=1761621 KB     rate=939.907 Mbps
```

Part 1 - Iperfer on Wireless Environment

- Client:

```
$ java Iperfer -c -h 10.139.30.7 -p 12345 -t 15
sent=68910 KB   rate=36.752 Mbps
```

- Server:

```
sh-3.2$ java Iperfer -s -p 12345
received=68910 KB       rate=36.240 Mbps
```

Part 3

Q2: Path Latency and Throughput

- The **expected latency** should be the sum of latencies of L1, L2, and L3, which equals 80.158 + 20.338 + 40.271 = 140.767 ms, because when a package is transmitted from h1 to h4, it would go from h1 to s1, s2, s3, s4, and finally to h4, during which it would experience the latency between each pair of nodes. Therefore, the latency is accumulated.
- The **expected throughput** should be the minimum throughput of L1, L2, and L3, which equals min(21.2, 48.8, 40.5) = 21.2 Mbits/sec, because the bandwidth from h1 to h4 is bottlenecked by the bandwidth of each bandwidth it goes through, so it is the minimum of throughput among L1, L2, and L3.
- The **actual latency** is 140.687 ms, and the **actual throughput** is 21.0 Mbits/sec, which matches our prediction.

Q3: Effects of Multiplexing (2 Clients)

- The **expected latency** should be the same as when there is only 1 client talking to 1 host, which is 140.687 ms. Because with multiplexing, packets from both clients take turns to use the link, the first packets of either clients should come to the destination in roughly the same time, resulting in the same latency.
- The **expected throughputs** of the 2 pairs would sum up to the throughput when there is only 1 pair, which is 21.0 Mbits/sec, because in multiplexing, the bandwidth is shared between the 2 client-server pairs, while the total bandwidth remains fixed.
- The **actual latency** for two pairs of hosts are 140.658 ms and 140.605 ms respectively, which averages to 140.6315 ms.
- The **actual throughputs** for two pairs of hosts are 13.1 Mbits/sec and 8.95 Mbits/sec respectively, which sum up to 22.05 Mbits/sec.

Q3: Effects of Multiplexing (3 Clients)

- Similar to the 2 client case, the **expected latency** should be the same as when there is only 1 client talking to 1 host, which is 140.687 ms, and the **expected throughput** of the 3 pairs would sum up to the throughput when there is only 1 pair, which is 21.0 Mbits/sec.
- The **actual latency** for three pairs of hosts are 140.706, 140.651, 140.604 ms respectively, which averages to 140.653667 ms.
- The **actual throughputs** for three pairs of hosts are 9.76, 5.46, 5.55 Mbits/sec respectively, which sum up to 20.77 Mbits/sec.

Q4: Effects of Latency

- The **expected latency between h1 and h4** should be the same as when there is only h1 communicating with h4, which is 140.687 ms, and the **expected latency between h5 and h6** should be the same as when there is only h5 communicating with h6, which is the sum of latency for L2, L4, and L5, which is (20.338 + 30.313 + 30.331) = 80.982 ms
- The **expected throughput between h1 and h4** should be the minimum of the following: throughput of L1, half of throughput of L2, and throughput of L3, which is min(21.2, 48.8/2, 40.5) = 21.2 Mbits/sec. The **expected throughput between h5 and h6** should be the minimum of the following: half of the throughput of L2, throughput of L4, and throughput of L5, which is min(48.8/2, 30.9, 30.9) = 24.4 Mbits/sec
- The **actual latency between h1 and h4** is 140.375 ms, and the **actual latency between h5 and h6** is 80.323 ms, which matches our expectations.
- The **actual throughput between h1 and h4** is 18.5 Mbits/sec, and the **actual throughput between h5 and h6** is 30.5 Mbits/sec, which sums up to 49 Mbits/sec. This result deviates from our expectations because the bandwidth of L2 is not shared evenly between h1-h4 communication and h5-h6 communication. If we let λ = 18.5 Mbits/sec be the bandwidth used by h1-h4 communication, then the throughput between h1 and h4 is min(21.2, λ, 40.5) = 18.5 Mbits/sec, which is the same as the actual throughput. The throughput between h5 and h6 is min(48.8-λ, 30.9, 30.9) = 30.3 Mbits/sec, which is approximately the same as the actual throughput.