COMP9331
Computer Networks and Applications
Assignment 2 Report

Group Members

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Note this assignment was completed using Python 3

Screencast link: https://youtu.be/NQGtQCLUkEw

1. Network Topology Data Structure

Data structure

- **Weighted Adjacency Matrix** graph representation was used to create the internal representation of the network topology.
- The weighting (i.e. each entry in the matrix) for each link (the edge connecting two vertices) has the format (a, b, c) where:
  - **a**: Boolean variable showing whether there exists a link between the 2 vertices (1 is yes and 0 is no). In case a is 1, this also means that it takes 1 hop to go from the source vertex to the destination vertex.
  - **b**: Propagation delay between source and destination vertices.
  - **c**: Current link capacity (i.e. maximum number of virtual circuits that the link from source vertex to destination vertex can handle).

Methodology

- For each request, add the **start time** of the request to the timeline of the entire transmission. Compute and append the **end time** of the request to the timeline;
- At each *time capture* in the timeline created in the above step, a function, namely *updateCapacity*, is called to check the current *time capture* and determine whether a request is to initiate to terminate the end to end link capacity;
- If an initiation is required, determine the 'best' path from source to destination based on the given routing scheme, check whether the end-to-end path returned by the routing protocol has enough capacity to satisfy the initiation request. If yes, decrement the capacity of each link in the path by 1 unit, if not do not update link capacity and deactivate the request
- If a termination is required, determine whether the original request has been successfully routed. If yes, retrieve the path used to route the original request and release all links along the path by incrementing each link capacity by 1 unit. If no, ignore and move on.

2. Routing algorithms performance metrics

a. Virtual Circuit Network (VCN)

Note: running SDP/SHP takes less than 1 minute to complete. Using LLP takes about 2 minutes to complete. In general, LLP takes longer time to complete because for each request, it needs to find all possible paths from source to destination first then compute from those paths the least loaded path to be used.

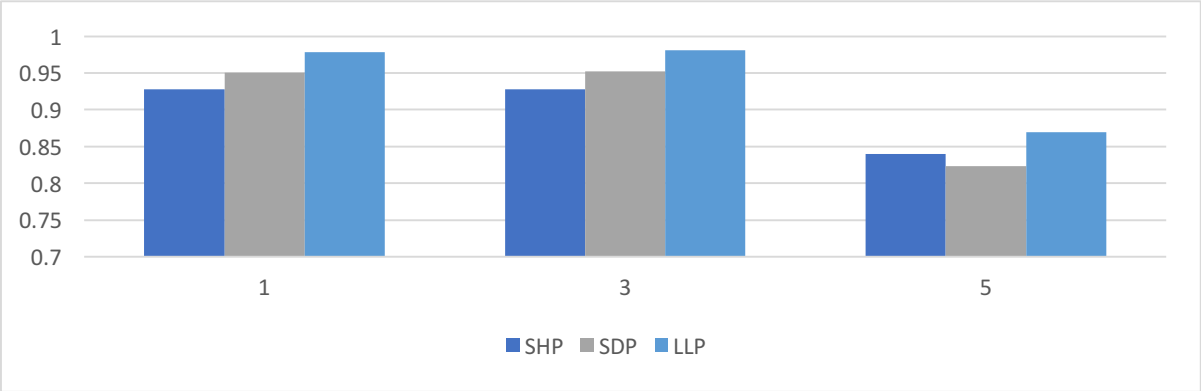
Performance Metrics (packet rate = 1 pks/s)	**SHP**	**SDP**	**LLP**
Total number of virtual connection requests	5,884	5,884	5,884
Total number of packets	176,067	176,067	176,067
Number of successfully routed packets	161,579	165,820	168,225
Percentage of successfully routed packets	91.77	94.18	95.56
Number of blocked packets	14,488	10,247	7,812
Percentage of blocked packets	8.23	5.82	4.44
Average number of hops per circuit	2.66	3.11	4.82
Average cumulative propagation delay per circuit	167.31	146.96	298.17

b. Virtual Packet Network (VPN)

Note: running LLP at packet rate > 2 takes about 50 minutes to complete. LLP at packet rate 1 should take about 2 minutes to complete. Other cases should take less than 2 minutes to complete. VPN consumes a lot more time to process than VCN because it needs to consider all requested packets one-by-one. Also, the higher the packet rate, the greater the number of packets to be sent. Thus, the program would have to process more packets.

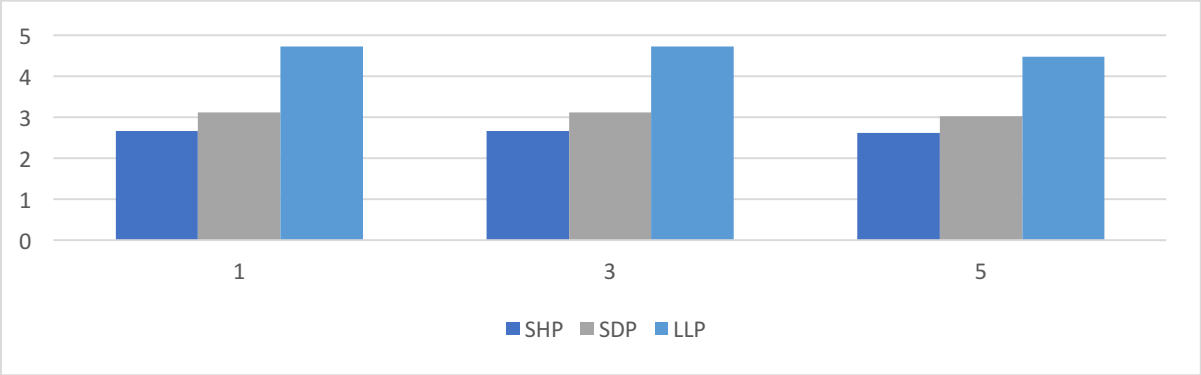
Percentage of successfully routed packets

Packet Rate	**1**	**2**	**3**	**4**	**5**
SHP	92.73%	92.05%	92.75%	92.03%	83.99%
SDP	95.07%	95.25%	95.22%	93.63%	82.33%
LLP	97.83%	97.53%	98.09%	95.01%	86.97%



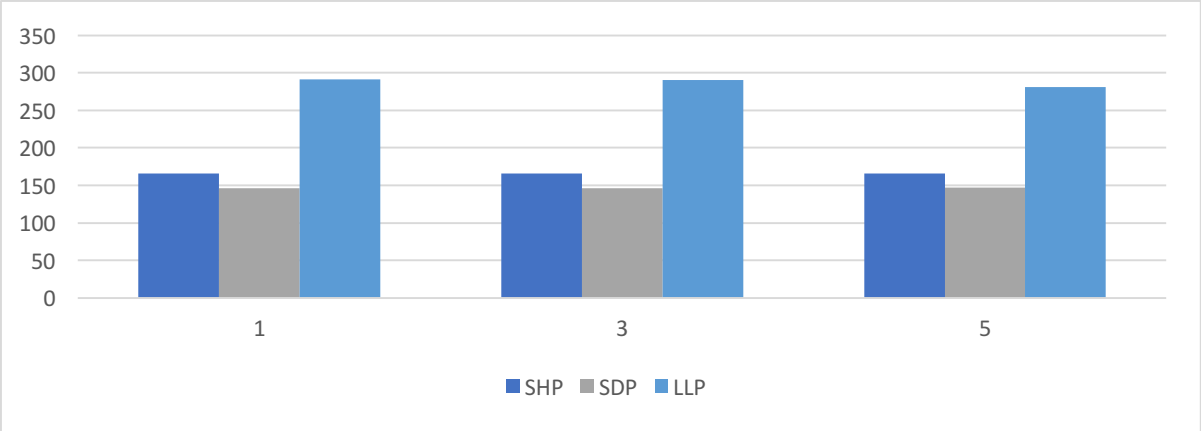
Average number of hops per circuit

Packet Rate	**1**	**2**	**3**	**4**	**5**
SHP	2.66	2.65	2.66	2.65	2.62
SDP	3.11	3.11	3.11	3.09	3.03
LLP	4.72	4.7	4.72	4.61	4.48



Average cumulative propagation delay per circuit

Packet Rate	**1**	**2**	**3**	**4**	**5**
SHP	166.01	164.97	165.98	165.17	165.61
SDP	145.84	145.81	145.88	145.66	147.17
LLP	291.36	289.59	290.59	281.33	280.84



3. Analysis and performance evaluation

3.1 Results analysis

Virtual Circuit Network:

- The average number of hops per circuit is minimum when the SHP routing protocol is used. This is because when routing with SHP, the network always prioritises the paths with the least number of hops. With this protocol, the propagation delay is not the highest preference; therefore, compared to SDP, the average cumulative propagation delay when using SHP is higher. Moreover, because SHP tries to minimise the number of hops required, this would lead to situation where a common link (e.g. link between two vertices with high degree) might be used heavily, and congestion might occur on that link. This explains why SHP results in a small success rate.
- The average propagation delay per circuit is minimum when the SDP routing protocol is in place. This is because when routing with SDP, the paths that have the least cumulative propagation delay would receive higher weighting by the network. In comparison with SHP, routing with this protocol might increase the average number of hops slightly but the difference is relatively small. The success rate is also improved because the requests are distributed more evenly across all links in the topology. As such, the congestion rate is reduced.
- When the LLP routing protocol is used, the number of routed packets would be maximised. This is because, for every request, the protocol ensures the least loaded path will be used to route the packets regardless of how many hops along the path or how high the cumulative propagation delay could be. Thus, congestion (i.e. packets are blocked) occurs at a smaller rate when using LLP. However, while maximizing the success rate, the trade-offs are the higher average number of hops required and a higher average cumulative propagation delay.

Virtual Packet Network

- At lower packet rate, in comparison with VCN, VPN results in a better chance of successful transmission because the network dynamically reserves and releases the links for every individual packet within a request. This helps reduce the congestion rate. Moreover, in case congestion occurs in the network, the network would only discard some packets at the time when the congestion happens and still sends the subsequent packets when the network is free again. This is not the case for VCN as the network would discard all the packets of a request if the any link along the chosen path is out of capacity.
- At higher packet rate, VPN does not perform as well as the network must handle more packets at a time (i.e. the links' capacity will be taken up much faster). This leads to higher congestion rate in the network, resulting in an increased number of packets being blocked.
- The effect of using different routing protocols on the average number of hops per circuit and the average cumulative propagation delay still holds (e.g. SHP results in the least average number of hops per circuit while SDP results in the least average cumulative propagation delay).