Task 5 - Custom Network

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I. Introduction

LEDBAT is a congestion control mechanism used on the Bittorrent client. When developing network applications based on transport layer protocols, a congestion control mechanism should be established. Because the data flow in the network should comply with the following principles: Do not create trouble for the current network; ensure the bandwidth fairness of the data flow and do not maliciously compete for bandwidth.

LEDBAT is still window-based rate control, but it senses network congestion earlier than TCP for better response. LEDBAT uses a one-way delay to estimate the queuing situation in the network. The latency of a data packet's transmission experience in the network consists of three parts: processing delay, propagation delay, and queue delay. When there is no queue in the network, and no queuing delay, the delay experienced by the data packet is the smallest.

II. Ledbat Protocol Implementation

In this part we have implemented the ledbat linux kernel to control all the data flow which has been sent or received by the VM. The linux kernel version is Linux 4.9.0-040900-generic since the most of the existing version is Linux 4.13, you need to downgrade your VM first before implemented the module. The module is provided by silviov and the code can also be found on the github https://github.com/silviov/TCP-LEDBAT.git.

In most cases, the default congestion algorithm is cubic. In this time after compiling and making the module, with the command as followed you need to see three algorithms:

$ cat /proc/sys/net/ipv4/tcp_available_congestion_control
cubic reno ledbat

After that, you can use the Ledbat algorithm for all flows by doing:

$ sudo sysctl -w net.ipv4.tcp_congestion_control=ledbat

You can also check the algorithm by using the following command:

$ sudo sysctl net.ipv4.tcp_congestion_control
net.ipv4.tcp_congestion_control = ledbat

III. Benchmark Ledbat Protocol

In this section we have chosen the region europe-west2-a and asia-east1-a to benchmark the ledbat traffic. Firstly we have benchmark the same zone traffic. You can see the result figure for single transmission.

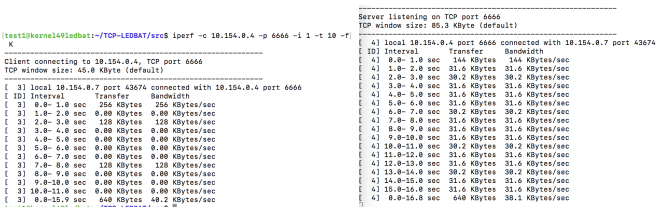

Fig. 1. Europe-west2-a Ledbat Single Transmission

We can observed that the initial speed for the receiver side is really huge, then it will become stable at about 30KB/s. The final average speed is about 38.1KB/s. On the client sender side, the speed is really high in the first second. Since the latency become higher, the sender reduce its congestion and will recover it in a few seconds. You can compared will the cubic algorithm. The following figure shows the result by using it.

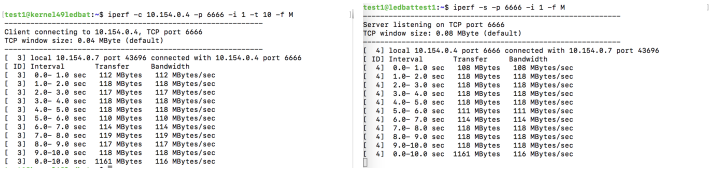

Fig. 2. Europe-west2-a Cubic Single Transmission

The intial speed for the transmission in cubic algorithm is slower than its stable speed. This can prove that the ledbat will fully use the initial bandwidth for the beginning of the transmission. But due to the latency occurs and backoff mechanism for other traffic, sometimes it will need more time to finish the transmission. The following figure is the parallel transmission.

```
test1@kernel49ledbat:~$ iperf -c 10.154.0.4 -p 6666 -i 1 -t 10 -f K -P 2
------------------------------------------------------------
Client connecting to 10.154.0.4, TCP port 6666
TCP window size: 45.0 KByte (default)
------------------------------------------------------------
[  4] local 10.154.0.7 port 43714 connected with 10.154.0.4 port 6666
[  3] local 10.154.0.7 port 43712 connected with 10.154.0.4 port 6666
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0- 1.0 sec   256 KBytes   256 KBytes/sec
[  3]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  3.0- 4.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  0.0- 1.0 sec   256 KBytes   256 KBytes/sec
[SUM]  0.0- 1.0 sec   512 KBytes   512 KBytes/sec
[  4]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  4.0- 5.0 sec   128 KBytes   128 KBytes/sec
[  3]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  3.0- 4.0 sec   128 KBytes   128 KBytes/sec
[SUM]  3.0- 4.0 sec   128 KBytes   128 KBytes/sec
[  4]  4.0- 5.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  4.0- 5.0 sec   128 KBytes   128 KBytes/sec
[  4]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  7.0- 8.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  7.0- 8.0 sec   128 KBytes   128 KBytes/sec
[SUM]  7.0- 8.0 sec   128 KBytes   128 KBytes/sec
[  3]  8.0- 9.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  0.0-16.2 sec   640 KBytes  39.5 KBytes/sec
[  4]  8.0- 9.0 sec   128 KBytes   128 KBytes/sec
[SUM]  8.0- 9.0 sec   128 KBytes   128 KBytes/sec
[  4]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  0.0-16.6 sec   640 KBytes  38.6 KBytes/sec
[SUM]  0.0-16.6 sec  1280 KBytes  77.1 KBytes/sec
```

Fig. 3. Europe-west2-a Ledbat Parallel Transmission (Client Side)

```
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0- 1.0 sec   124 KBytes   124 KBytes/sec
[  5]  0.0- 1.0 sec   124 KBytes   124 KBytes/sec
[SUM]  0.0- 1.0 sec   248 KBytes   248 KBytes/sec
[  4]  1.0- 2.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  1.0- 2.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  1.0- 2.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  2.0- 3.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  2.0- 3.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  2.0- 3.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  3.0- 4.0 sec  30.2 KBytes  30.2 KBytes/sec
[  5]  3.0- 4.0 sec  30.2 KBytes  30.2 KBytes/sec
[SUM]  3.0- 4.0 sec  60.5 KBytes  60.5 KBytes/sec
[  4]  4.0- 5.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  4.0- 5.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  4.0- 5.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  5.0- 6.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  5.0- 6.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  5.0- 6.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  6.0- 7.0 sec  30.2 KBytes  30.2 KBytes/sec
[  5]  6.0- 7.0 sec  30.2 KBytes  30.2 KBytes/sec
[SUM]  6.0- 7.0 sec  60.5 KBytes  60.5 KBytes/sec
[  4]  7.0- 8.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  7.0- 8.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  7.0- 8.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  8.0- 9.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  8.0- 9.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  8.0- 9.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  9.0-10.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5]  9.0-10.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM]  9.0-10.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4] 10.0-11.0 sec  30.2 KBytes  30.2 KBytes/sec
[  5] 10.0-11.0 sec  30.2 KBytes  30.2 KBytes/sec
[SUM] 10.0-11.0 sec  60.5 KBytes  60.5 KBytes/sec
[  4] 11.0-12.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5] 11.0-12.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM] 11.0-12.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4] 12.0-13.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5] 12.0-13.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM] 12.0-13.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4] 13.0-14.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5] 13.0-14.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM] 13.0-14.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4] 14.0-15.0 sec  30.2 KBytes  30.2 KBytes/sec
[  5] 14.0-15.0 sec  30.2 KBytes  30.2 KBytes/sec
[SUM] 14.0-15.0 sec  60.5 KBytes  60.5 KBytes/sec
[  4] 15.0-16.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5] 15.0-16.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM] 15.0-16.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4] 16.0-17.0 sec  31.6 KBytes  31.6 KBytes/sec
[  5] 16.0-17.0 sec  31.6 KBytes  31.6 KBytes/sec
[SUM] 16.0-17.0 sec  63.2 KBytes  63.2 KBytes/sec
[  4]  0.0-17.5 sec   640 KBytes  36.6 KBytes/sec
[  5]  0.0-17.5 sec   640 KBytes  36.6 KBytes/sec
[SUM]  0.0-17.5 sec  1280 KBytes  73.2 KBytes/sec
```

Fig. 4. Europe-west2-a Ledbat Parallel Transmission (Server Side)

In parallel transmission, the bandwidth has been shared between two transmission flows. The speed for each flow can reach 30KB/s. The time consumption is also the same as single transmission.

While in the asia-east1-a zone, the results can be observed in the following figure.

```
test1@kernel49ledbat:~$ iperf -c 10.140.0.2 -p 6666 -i 1 -t 10 -f K
------------------------------------------------------------
Client connecting to 10.140.0.2, TCP port 6666
TCP window size: 45.0 KByte (default)
------------------------------------------------------------
[  3] local 10.154.0.7 port 51124 connected with 10.140.0.2 port 6666
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0- 1.0 sec   128 KBytes   128 KBytes/sec
[  3]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  3.0- 4.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  4.0- 5.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  7.0- 8.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  8.0- 9.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 11.0-12.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 12.0-13.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 13.0-14.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  0.0-45.9 sec   256 KBytes  5.58 KBytes/sec
```

Fig. 5. Asia-East1-a Ledbat Single Transmission (Client Side)

```
test1@ledbat-asia:~$ iperf -s -p 6666 -i 1 -f K
------------------------------------------------------------
Server listening on TCP port 6666
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  4] local 10.140.0.2 port 6666 connected with 10.154.0.7 port 51124
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0- 1.0 sec  17.9 KBytes  17.9 KBytes/sec
[  4]  1.0- 2.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  2.0- 3.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  3.0- 4.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  4.0- 5.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  5.0- 6.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  6.0- 7.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  7.0- 8.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  8.0- 9.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4]  9.0-10.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 10.0-11.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 11.0-12.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 12.0-13.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 13.0-14.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 14.0-15.0 sec  5.50 KBytes  5.50 KBytes/sec
[  4] 15.0-16.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 16.0-17.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 17.0-18.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 18.0-19.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 19.0-20.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 20.0-21.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 21.0-22.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 22.0-23.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 23.0-24.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 24.0-25.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 25.0-26.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 26.0-27.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 27.0-28.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 28.0-29.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 29.0-30.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 30.0-31.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 31.0-32.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 32.0-33.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 33.0-34.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 34.0-35.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 35.0-36.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 36.0-37.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 37.0-38.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 38.0-39.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 39.0-40.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 40.0-41.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 41.0-42.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 42.0-43.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 43.0-44.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 44.0-45.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 45.0-46.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 46.0-47.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 47.0-48.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 48.0-49.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 49.0-50.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 50.0-51.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 51.0-52.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 52.0-53.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 53.0-54.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 54.0-55.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 55.0-56.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 56.0-57.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 57.0-58.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4] 58.0-59.0 sec  4.12 KBytes  4.12 KBytes/sec
[  4] 59.0-60.0 sec  2.75 KBytes  2.75 KBytes/sec
[  4]  0.0-60.9 sec   256 KBytes  4.20 KBytes/sec
```

Fig. 6. Asia-East1-a Ledbat Single Transmission (Server Side)

The connection of the flow to Asia has been rapidly decreased due to the long distance transmission. The average speed is about 5KB/s on both side and the transmission time has reached up to 60 seconds.

Also, for the parallel transmission, here we show the client side result.

```
test1@kernel49ledbat:~$ iperf -c 10.140.0.2 -p 6666 -i 1 -t 10 -f K -P 2
------------------------------------------------------------
Client connecting to 10.140.0.2, TCP port 6666
TCP window size: 45.0 KByte (default)
------------------------------------------------------------
[  4] local 10.154.0.7 port 51154 connected with 10.140.0.2 port 6666
[  3] local 10.154.0.7 port 51152 connected with 10.140.0.2 port 6666
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0- 1.0 sec   128 KBytes   128 KBytes/sec
[  3]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  3.0- 4.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  4.0- 5.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  7.0- 8.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  8.0- 9.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 11.0-12.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 12.0-13.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3] 13.0-14.0 sec  0.00 KBytes  0.00 KBytes/sec
[  3]  0.0-45.9 sec   256 KBytes  5.58 KBytes/sec
[SUM]  0.0-45.9 sec   384 KBytes  8.37 KBytes/sec
[  4]  0.0- 1.0 sec   128 KBytes   128 KBytes/sec
[  4]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  1.0- 2.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  2.0- 3.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  3.0- 4.0 sec  0.00 KBytes  0.00 KBytes/sec
[SUM]  3.0- 4.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  4.0- 5.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  5.0- 6.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  6.0- 7.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  7.0- 8.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  8.0- 9.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  9.0-10.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4] 10.0-11.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4] 11.0-12.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4] 12.0-13.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4] 13.0-14.0 sec  0.00 KBytes  0.00 KBytes/sec
[  4]  0.0-46.2 sec   256 KBytes  5.54 KBytes/sec
[SUM]  0.0-46.2 sec   384 KBytes  8.31 KBytes/sec
```

Fig. 7. Asia-East1-a Ledbat Parallel Transmission (Client Side)

The speed for each flow has reached at about 8KB/s, which is twice as the single transmission.

Before this test we have received a warning from google since we have sent a huge amount of datagram during the test of task 4 and they think we are doing a DoS attack. The task 5 is testing under a limitation from Google.

REFERENCES

[1] Low Extra Delay Background Transport (LEDBAT), Internet Engineering Task Force (IETF), Category: Experimental, ISSN: 2070-1721 [Online]. Available: *https://tools.ietf.org/html/rfc6817#ref-uTorrent*