# Discussion on Design and Implementation of Embedded Operating System Final Report

## Linux Network Stack

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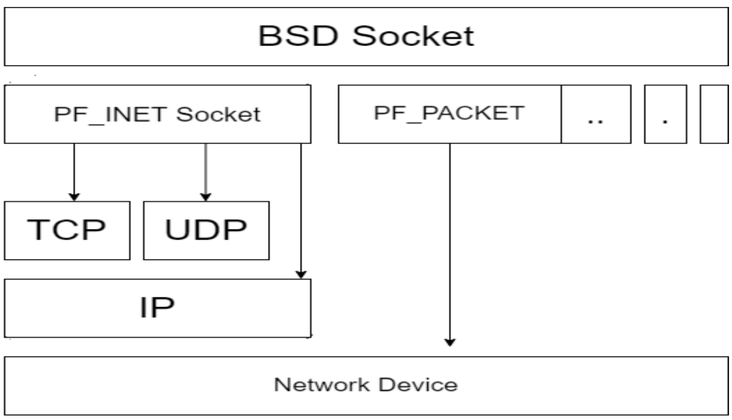
# Introduction




The Linux network stack is divided into four levels:Socket layer、TCP/UDP network layer、IP layer 、Linker layer.

## 1.1、 Socket layer

Various network applications in the Socket layer basically communicate with the network protocol stack in the kernel space through the Linux Socket programming interface. Linux Socket is developed from BSD Socket, which is one of the important components of the Linux operating system, and it is the basis of network applications. Hierarchically, it is located at the application layer and is an API provided by the operating system for application programmers, through which applications can access transport layer protocols.

1.2、TCP/UDP network layer

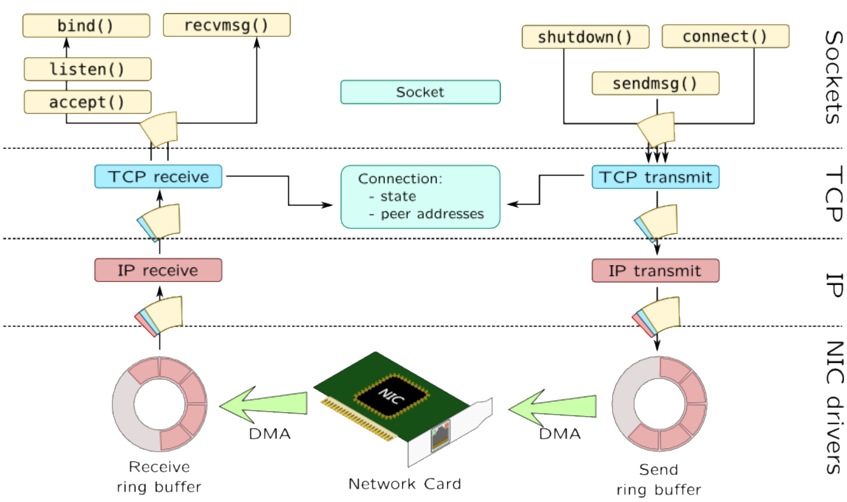
The purpose of the transport layer is to provide its users with efficient, reliable and cost-effective data transmission services. The main functions include (1) constructing TCP segments (2) calculating checksums (3) sending reply (ACK) packets (4) Reliable operations such as sliding windown.

1.3、IP layer

The task of the network layer is to select the appropriate routing and switching nodes between the networks to ensure the timely delivery of data. The network layer composes the frame provided by the data link layer into a data packet, and the packet is encapsulated with a network layer header, which contains logical address information - the network addresses of the source site and destination site addresses. Its main tasks include (1) routing processing, that is, selecting the next hop (2) adding an IP header (3) calculating the IP header checksum, which is used to detect whether there is an error in the IP packet header during the propagation process (4) if possible, carry out After the IP fragmentation (5) is processed, obtain the MAC address of the next hop, set the link layer header, and then transfer to the link layer for processing.

1.4、Linker layer

Functionally, on the basis of the bit stream service provided by the physical layer, it establishes a data link between adjacent nodes, provides error-free transmission of data frames (Frame) on the channel through error control, and performs actions on each circuit. series. The data link layer provides reliable transmission over unreliable physical media. The role of this layer includes: physical address addressing, data framing, flow control, data error detection. At this layer, the unit of data is called a frame. Representatives of data link layer protocols include: SDLC, HDLC, PPP, STP, Frame Relay, etc.

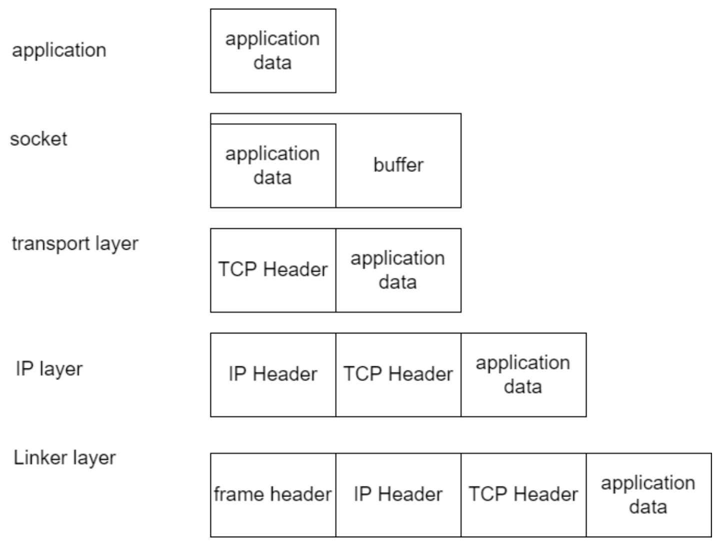


## 1.5、Transmission path of socket in network stack

package arrives at the machine's physical network adapter, and when it receives a data frame, it triggers an interrupt and DMA it to the rx_ring located in the linux kernel memory. The NIC issues an interrupt to notify the CPU that a package needs to be processed. The interrupt handler mainly performs the following operations, including allocating the skb_buff data structure, and copying the received data frame from the network adapter I/O port to the skb_buff buffer; extracting some information from the data frame, and setting the corresponding skb_buff Parameters, these parameters will be used by the upper network protocol, such as protocol; After simple processing, the terminal handler issues a soft interrupt to notify the kernel that a new data frame is received.

A new set of APIs was introduced in kernel to handle received data frames, namely NAPI. Therefore, the driver has two ways to notify the kernel: (1) through the previous function netif_rx; (2) through the NAPI mechanism. The interrupt handler calls the netif_rx_schedule function of the Network device, enters the soft interrupt processing flow, and then calls the net_rx_action function.

This function turns off the interrupt, gets all the packages in the rx_ring of each Network device, and finally removes the pacakage from the rx_ring and enters the netif _receive_skb processing flow. netif_receive_skb is the last stop at the link layer to receive datagrams. It submits the datagram to the receiving functions of different network layer protocols (mainly ip_rcv and arp_rcv in the INET domain) according to the network layer datagram type registered in the global array ptype_all and ptype_base. This function is mainly to call the receiving function of the third-layer protocol to process the skb packet and enter the third-layer network layer for processing.



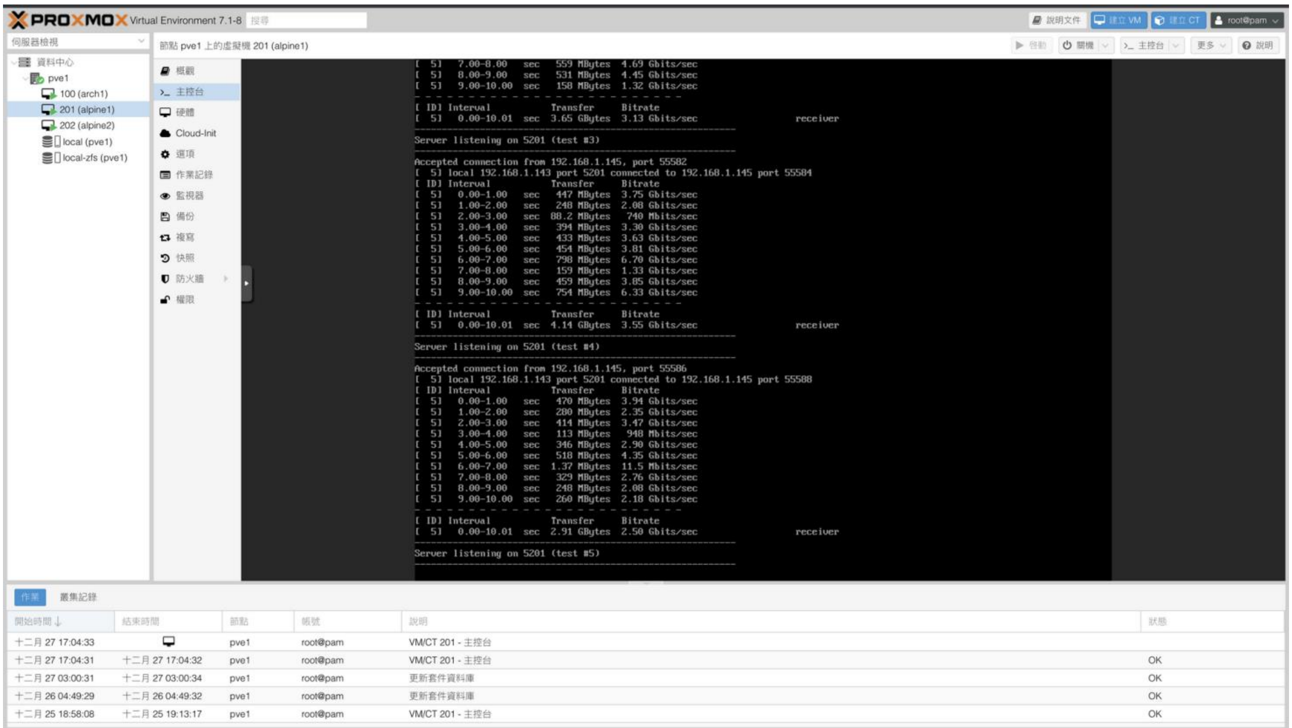
The state of the socket in the each layer

# Experiment

## Environment

This project chooses to use Proxmox VE's Linux distribution to set up a virtual environment. Because most of the current physical network speed is still the mainstream 100Mb, 1000Mb network card and network line. However, because the speed of CPU, Memery and the capability of OS mostly exceed the above-mentioned values, the effect after adjusting the parameters is not obvious. It may be necessary to shrink the parameter values to a small amount to make a difference, but there are too many parameter values for daily use, and the overall experiment is not objective.

Depending on the Linux distribution of the physical machine, the number of background




programs running is mostly different, which will also cause differences in experiments. And

Figure 1.

the physical machine has many variables, and the experimental results will be inaccurate, so here we use the virtual environment as the experimental environment.

## Proxmox VE

Proxmox VE, is an open source server virtualization environment Linux distribution. Provides web console like Figure 1, and command line tools to quickly set up QEMU/KVM virtual machines and simplify peripheral settings.

## Client OS: Alpine

The OS of the virtual machine uses the VIRTUAL version of Alpine, a distribution of Linux. It provides the most basic Linux kernel and is optimized for virtual environments. Alpine is also very popular in docker, its OS image size is only 2.7 MB, which is very lightweight. The network card uses the VirtIO virtualized network card and driver provided by QEMU.

## Network speed test tool: iperf3

We chose iperf3 as a network performance testing tool, It can test the maximum throughput (bits/sec) set by the network stack. It can be installed very quickly, and the server and client can be set up in just two lines of commands.

- `iperf3 -s` -> To launch in server mode
- `iperf3 -c <server_ip>` -> To launch in client mode, and send data to the server.

# Configuration

## Configuration 1：Default

Using two default alpine linux, the client sends data to the server of iperf3. As you can see Figure 2, The bandwidth is up to 12.9 Gbit per second. which is far better than the general physical machine.

## Configuration 2: Reduce `tcp_rmem` buffer

In linux, there are multiple parameters to control the buffer size. like rmem_default, wmem_default, tcp_mem, tcp_rmem. We choose to adjust tcp_rmem to experiment. tcp_rmem controls the size of the socket Receive buffer. In other words, it controls RWND.

```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55032 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   1.00-2.00   sec  1.49 GBytes  12.8 Gbits/sec    0   3.08 MBytes
[  5]   2.00-3.00   sec  1.52 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   3.00-4.00   sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
[  5]   4.00-5.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   5.00-6.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   6.00-7.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   7.00-8.00   sec  1.46 GBytes  12.6 Gbits/sec    0   3.08 MBytes
[  5]   8.00-9.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   9.00-10.00  sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  15.0 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

Figure 2.

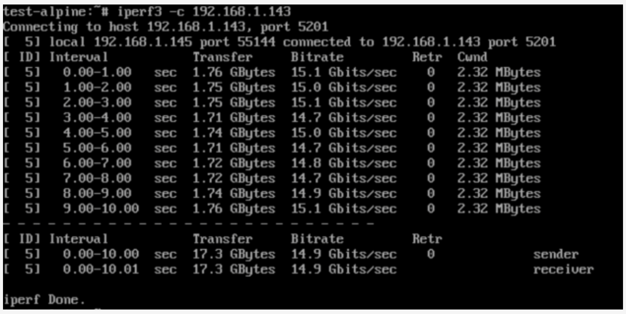
Table 1.

```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 53846 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.73 MBytes
[  5]   1.00-2.00   sec  1.47 GBytes  12.6 Gbits/sec    0   3.91 MBytes
[  5]   2.00-3.00   sec  1.52 GBytes  13.0 Gbits/sec    0   3.91 MBytes
[  5]   3.00-4.00   sec  1.49 GBytes  12.8 Gbits/sec    0   3.91 MBytes
[  5]   4.00-5.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.91 MBytes
[  5]   5.00-6.00   sec  1.52 GBytes  13.0 Gbits/sec    0   3.91 MBytes
[  5]   6.00-7.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.91 MBytes
[  5]   7.00-8.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.91 MBytes
[  5]   8.00-9.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.91 MBytes
[  5]   9.00-10.00  sec  1.51 GBytes  13.0 Gbits/sec    0   3.91 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.1 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 12582912 (2x)
Average Average throughput: 12.9Gbits/sec

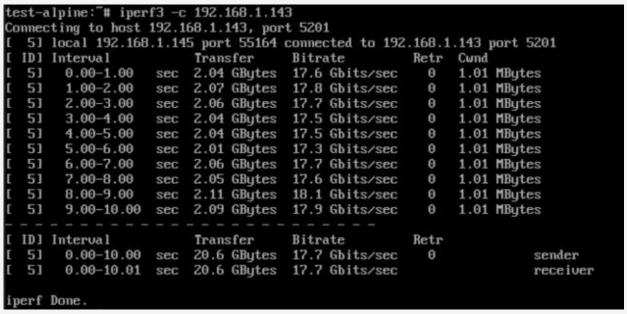
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55032 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   1.00-2.00   sec  1.49 GBytes  12.8 Gbits/sec    0   3.08 MBytes
[  5]   2.00-3.00   sec  1.52 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   3.00-4.00   sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
[  5]   4.00-5.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   5.00-6.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   6.00-7.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   7.00-8.00   sec  1.46 GBytes  12.6 Gbits/sec    0   3.08 MBytes
[  5]   8.00-9.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   9.00-10.00  sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  15.0 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 6291456 (1x)
Average throughput: 12.9Gbits/sec



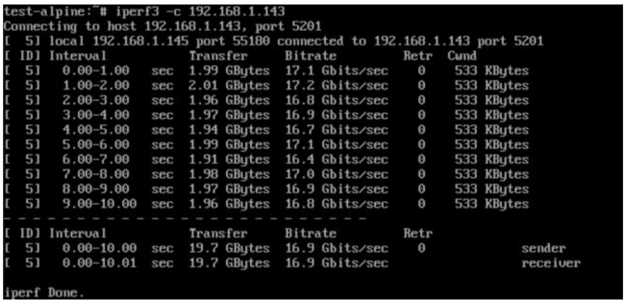
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55144 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.76 GBytes  15.1 Gbits/sec    0   2.32 MBytes
[  5]   1.00-2.00   sec  1.75 GBytes  15.0 Gbits/sec    0   2.32 MBytes
[  5]   2.00-3.00   sec  1.75 GBytes  15.1 Gbits/sec    0   2.32 MBytes
[  5]   3.00-4.00   sec  1.71 GBytes  14.7 Gbits/sec    0   2.32 MBytes
[  5]   4.00-5.00   sec  1.74 GBytes  15.0 Gbits/sec    0   2.32 MBytes
[  5]   5.00-6.00   sec  1.71 GBytes  14.7 Gbits/sec    0   2.32 MBytes
[  5]   6.00-7.00   sec  1.72 GBytes  14.8 Gbits/sec    0   2.32 MBytes
[  5]   7.00-8.00   sec  1.72 GBytes  14.7 Gbits/sec    0   2.32 MBytes
[  5]   8.00-9.00   sec  1.74 GBytes  14.9 Gbits/sec    0   2.32 MBytes
[  5]   9.00-10.00  sec  1.76 GBytes  15.1 Gbits/sec    0   2.32 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  17.3 GBytes  14.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  17.3 GBytes  14.9 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 3145728 (1/2x)
Average throughput: 14.9Gbits/sec



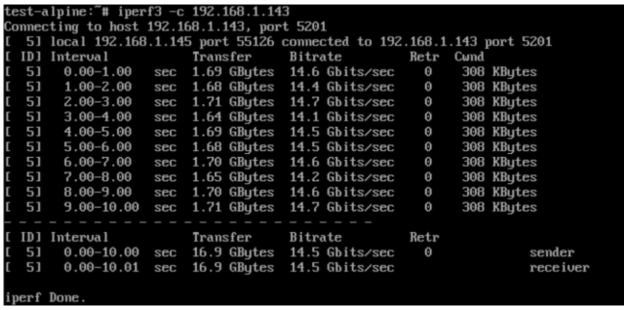
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55164 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  2.04 GBytes  17.6 Gbits/sec    0   1.01 MBytes
[  5]   1.00-2.00   sec  2.07 GBytes  17.8 Gbits/sec    0   1.01 MBytes
[  5]   2.00-3.00   sec  2.06 GBytes  17.7 Gbits/sec    0   1.01 MBytes
[  5]   3.00-4.00   sec  2.04 GBytes  17.5 Gbits/sec    0   1.01 MBytes
[  5]   4.00-5.00   sec  2.04 GBytes  17.5 Gbits/sec    0   1.01 MBytes
[  5]   5.00-6.00   sec  2.01 GBytes  17.3 Gbits/sec    0   1.01 MBytes
[  5]   6.00-7.00   sec  2.06 GBytes  17.7 Gbits/sec    0   1.01 MBytes
[  5]   7.00-8.00   sec  2.05 GBytes  17.6 Gbits/sec    0   1.01 MBytes
[  5]   8.00-9.00   sec  2.11 GBytes  18.1 Gbits/sec    0   1.01 MBytes
[  5]   9.00-10.00  sec  2.09 GBytes  17.9 Gbits/sec    0   1.01 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  20.6 GBytes  17.7 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  20.6 GBytes  17.7 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 2097152 (1/3x)
Average throughput: 17.7Gbits/sec



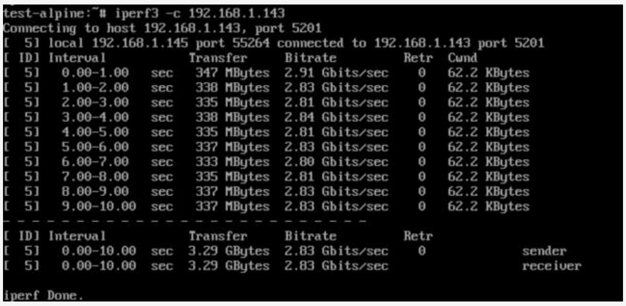
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55180 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.99 GBytes  17.1 Gbits/sec    0    533 KBytes
[  5]   1.00-2.00   sec  2.01 GBytes  17.2 Gbits/sec    0    533 KBytes
[  5]   2.00-3.00   sec  1.96 GBytes  16.8 Gbits/sec    0    533 KBytes
[  5]   3.00-4.00   sec  1.97 GBytes  16.9 Gbits/sec    0    533 KBytes
[  5]   4.00-5.00   sec  1.94 GBytes  16.7 Gbits/sec    0    533 KBytes
[  5]   5.00-6.00   sec  1.99 GBytes  17.1 Gbits/sec    0    533 KBytes
[  5]   6.00-7.00   sec  1.91 GBytes  16.4 Gbits/sec    0    533 KBytes
[  5]   7.00-8.00   sec  1.98 GBytes  17.0 Gbits/sec    0    533 KBytes
[  5]   8.00-9.00   sec  1.97 GBytes  16.9 Gbits/sec    0    533 KBytes
[  5]   9.00-10.00  sec  1.96 GBytes  16.8 Gbits/sec    0    533 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  19.7 GBytes  16.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  19.7 GBytes  16.9 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 1048576 (1/6x)
Average throughput: 16.9Gbits/sec



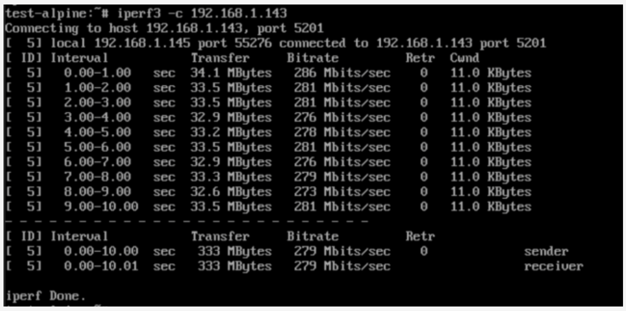
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55126 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.69 GBytes  14.6 Gbits/sec    0    308 KBytes
[  5]   1.00-2.00   sec  1.68 GBytes  14.4 Gbits/sec    0    308 KBytes
[  5]   2.00-3.00   sec  1.71 GBytes  14.7 Gbits/sec    0    308 KBytes
[  5]   3.00-4.00   sec  1.64 GBytes  14.1 Gbits/sec    0    308 KBytes
[  5]   4.00-5.00   sec  1.69 GBytes  14.5 Gbits/sec    0    308 KBytes
[  5]   5.00-6.00   sec  1.68 GBytes  14.5 Gbits/sec    0    308 KBytes
[  5]   6.00-7.00   sec  1.70 GBytes  14.6 Gbits/sec    0    308 KBytes
[  5]   7.00-8.00   sec  1.65 GBytes  14.2 Gbits/sec    0    308 KBytes
[  5]   8.00-9.00   sec  1.70 GBytes  14.6 Gbits/sec    0    308 KBytes
[  5]   9.00-10.00  sec  1.71 GBytes  14.7 Gbits/sec    0    308 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  16.9 GBytes  14.5 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  16.9 GBytes  14.5 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 629145 (1/10x)
Average Average throughput: 14.5Gbits/sec



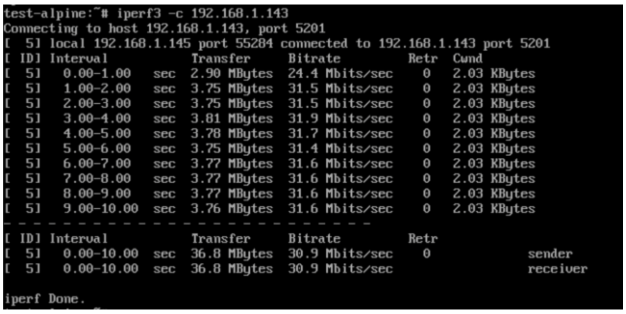
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55264 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec   347 MBytes  2.91 Gbits/sec    0   62.2 KBytes
[  5]   1.00-2.00   sec   338 MBytes  2.83 Gbits/sec    0   62.2 KBytes
[  5]   2.00-3.00   sec   335 MBytes  2.81 Gbits/sec    0   62.2 KBytes
[  5]   3.00-4.00   sec   338 MBytes  2.84 Gbits/sec    0   62.2 KBytes
[  5]   4.00-5.00   sec   335 MBytes  2.81 Gbits/sec    0   62.2 KBytes
[  5]   5.00-6.00   sec   337 MBytes  2.83 Gbits/sec    0   62.2 KBytes
[  5]   6.00-7.00   sec   333 MBytes  2.80 Gbits/sec    0   62.2 KBytes
[  5]   7.00-8.00   sec   335 MBytes  2.81 Gbits/sec    0   62.2 KBytes
[  5]   8.00-9.00   sec   337 MBytes  2.83 Gbits/sec    0   62.2 KBytes
[  5]   9.00-10.00  sec   337 MBytes  2.83 Gbits/sec    0   62.2 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  3.29 GBytes  2.83 Gbits/sec    0             sender
[  5]   0.00-10.00  sec  3.29 GBytes  2.83 Gbits/sec                  receiver

iperf Done.
```

tcp_rmem: 62914 (1/100x)
Average throughput: 2.83Gbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55276 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  34.1 MBytes   286 Mbits/sec    0   11.0 KBytes
[  5]   1.00-2.00   sec  33.5 MBytes   281 Mbits/sec    0   11.0 KBytes
[  5]   2.00-3.00   sec  33.5 MBytes   281 Mbits/sec    0   11.0 KBytes
[  5]   3.00-4.00   sec  32.9 MBytes   276 Mbits/sec    0   11.0 KBytes
[  5]   4.00-5.00   sec  33.2 MBytes   278 Mbits/sec    0   11.0 KBytes
[  5]   5.00-6.00   sec  33.5 MBytes   281 Mbits/sec    0   11.0 KBytes
[  5]   6.00-7.00   sec  32.9 MBytes   276 Mbits/sec    0   11.0 KBytes
[  5]   7.00-8.00   sec  33.3 MBytes   279 Mbits/sec    0   11.0 KBytes
[  5]   8.00-9.00   sec  32.6 MBytes   273 Mbits/sec    0   11.0 KBytes
[  5]   9.00-10.00  sec  33.5 MBytes   281 Mbits/sec    0   11.0 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec   333 MBytes   279 Mbits/sec    0             sender
[  5]   0.00-10.01  sec   333 MBytes   279 Mbits/sec                  receiver

iperf Done.
```

tcp_rmem: 6291 (1/1000x)
Average throughput: 279Mbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55284 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  2.90 MBytes  24.4 Mbits/sec    0   2.03 KBytes
[  5]   1.00-2.00   sec  3.75 MBytes  31.5 Mbits/sec    0   2.03 KBytes
[  5]   2.00-3.00   sec  3.75 MBytes  31.5 Mbits/sec    0   2.03 KBytes
[  5]   3.00-4.00   sec  3.81 MBytes  31.9 Mbits/sec    0   2.03 KBytes
[  5]   4.00-5.00   sec  3.78 MBytes  31.7 Mbits/sec    0   2.03 KBytes
[  5]   5.00-6.00   sec  3.75 MBytes  31.4 Mbits/sec    0   2.03 KBytes
[  5]   6.00-7.00   sec  3.77 MBytes  31.6 Mbits/sec    0   2.03 KBytes
[  5]   7.00-8.00   sec  3.77 MBytes  31.6 Mbits/sec    0   2.03 KBytes
[  5]   8.00-9.00   sec  3.77 MBytes  31.6 Mbits/sec    0   2.03 KBytes
[  5]   9.00-10.00  sec  3.76 MBytes  31.6 Mbits/sec    0   2.03 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  36.8 MBytes  30.9 Mbits/sec    0             sender
[  5]   0.00-10.00  sec  36.8 MBytes  30.9 Mbits/sec                  receiver

iperf Done.
```

tcp_rmem: 629 (1/10000x)
Average throughput: 30.9Mbits/sec

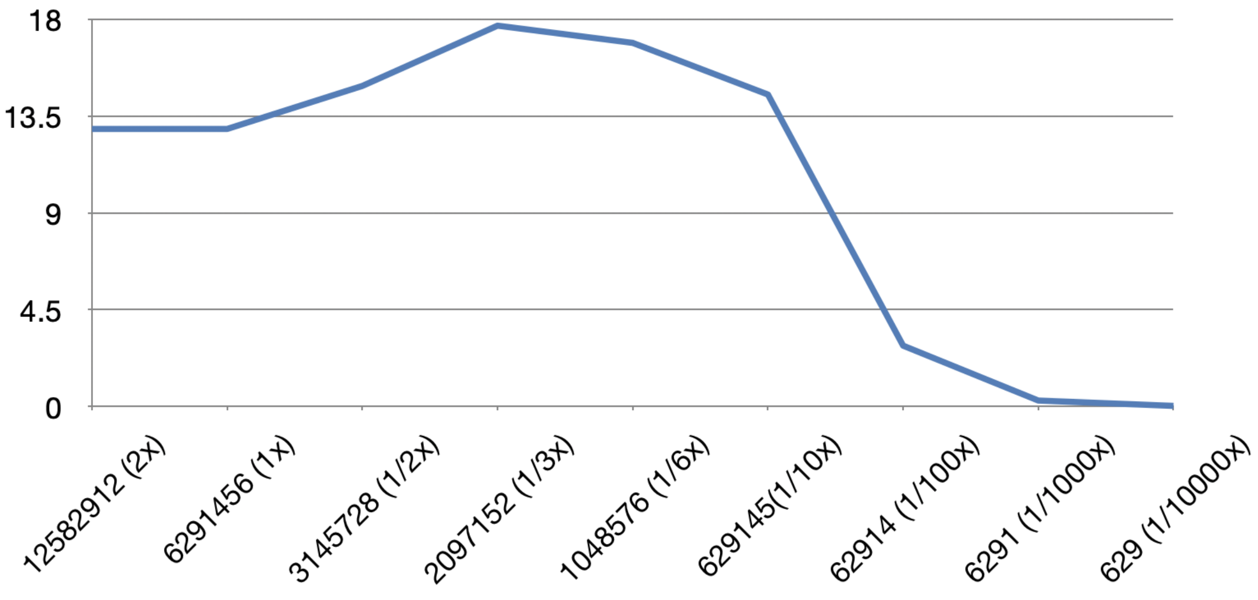



Figure 3.

We can see the Figure 3 that increasing the buffer has no effect on the speed. But reducing the buffer can increase the speed instead. This shows that the default setting of linux is not optimal. Continue to reduce size and speed proportionally until it becomes unusable.

## Configuration 3: Adjust the tcp congestion control algorithm

The congestion control algorithm most directly affects the control of CWND (Congestion Window). In addition to the buffer size of the receiver, the congestion control algorithm also needs to consider the buffer size of the midway switch and router.

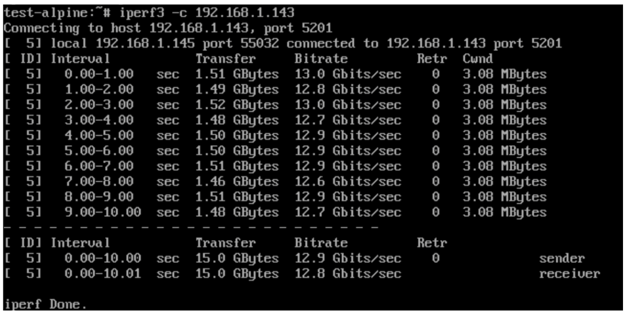
Common algorithms are as follows you can see: Cubic and Reno are default algorithm for Linux. The BBR algorithm was proposed by Google in 2016.

Algorithm:

- Cubic
- Reno
- Bic
- Htcp

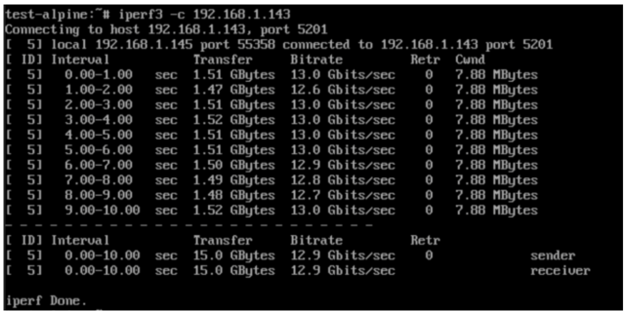
- Vegas
- Westwood
- YeAH
- BBR

Table 2.



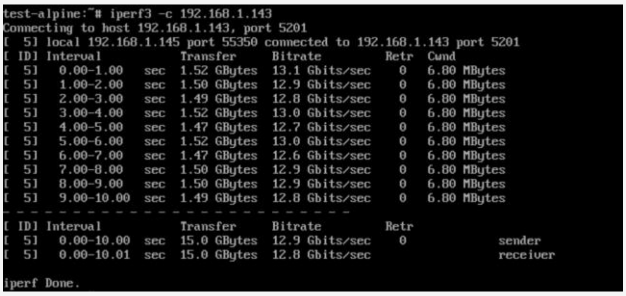
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55032 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.51 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   1.00-2.00   sec  1.49 GBytes  12.8 Gbits/sec    0   3.08 MBytes
[  5]   2.00-3.00   sec  1.52 GBytes  13.0 Gbits/sec    0   3.08 MBytes
[  5]   3.00-4.00   sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
[  5]   4.00-5.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   5.00-6.00   sec  1.50 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   6.00-7.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   7.00-8.00   sec  1.46 GBytes  12.6 Gbits/sec    0   3.08 MBytes
[  5]   8.00-9.00   sec  1.51 GBytes  12.9 Gbits/sec    0   3.08 MBytes
[  5]   9.00-10.00  sec  1.48 GBytes  12.7 Gbits/sec    0   3.08 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  15.0 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

Algorithm: Cubic
Average throughput: 12.9Gbits/sec



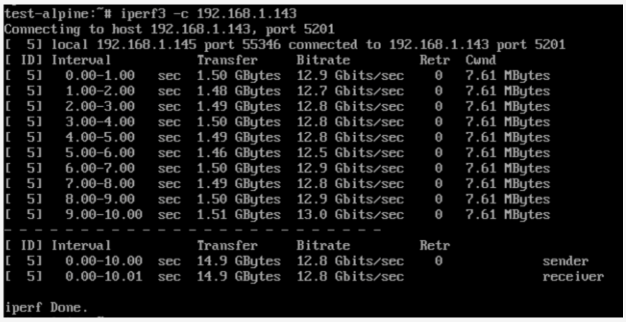
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55358 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.51 GBytes  13.0 Gbits/sec    0   7.88 MBytes
[  5]   1.00-2.00   sec  1.47 GBytes  12.6 Gbits/sec    0   7.88 MBytes
[  5]   2.00-3.00   sec  1.51 GBytes  13.0 Gbits/sec    0   7.88 MBytes
[  5]   3.00-4.00   sec  1.52 GBytes  13.0 Gbits/sec    0   7.88 MBytes
[  5]   4.00-5.00   sec  1.51 GBytes  13.0 Gbits/sec    0   7.88 MBytes
[  5]   5.00-6.00   sec  1.51 GBytes  13.0 Gbits/sec    0   7.88 MBytes
[  5]   6.00-7.00   sec  1.50 GBytes  12.9 Gbits/sec    0   7.88 MBytes
[  5]   7.00-8.00   sec  1.49 GBytes  12.8 Gbits/sec    0   7.88 MBytes
[  5]   8.00-9.00   sec  1.48 GBytes  12.7 Gbits/sec    0   7.88 MBytes
[  5]   9.00-10.00  sec  1.52 GBytes  13.0 Gbits/sec    0   7.88 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec                  receiver

iperf Done.
```

Algorithm: Reno
Average throughput: 12.9Gbits/sec



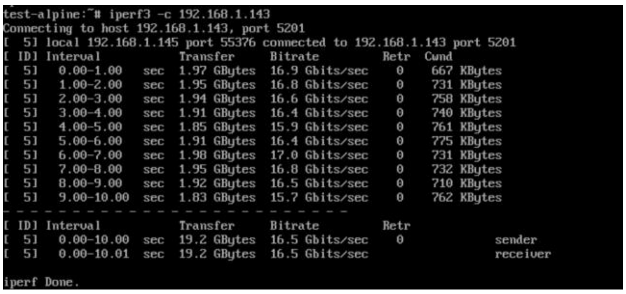
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55350 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.52 GBytes  13.1 Gbits/sec    0   6.80 MBytes
[  5]   1.00-2.00   sec  1.50 GBytes  12.9 Gbits/sec    0   6.80 MBytes
[  5]   2.00-3.00   sec  1.49 GBytes  12.8 Gbits/sec    0   6.80 MBytes
[  5]   3.00-4.00   sec  1.52 GBytes  13.0 Gbits/sec    0   6.80 MBytes
[  5]   4.00-5.00   sec  1.47 GBytes  12.7 Gbits/sec    0   6.80 MBytes
[  5]   5.00-6.00   sec  1.52 GBytes  13.0 Gbits/sec    0   6.80 MBytes
[  5]   6.00-7.00   sec  1.47 GBytes  12.6 Gbits/sec    0   6.80 MBytes
[  5]   7.00-8.00   sec  1.50 GBytes  12.9 Gbits/sec    0   6.80 MBytes
[  5]   8.00-9.00   sec  1.50 GBytes  12.9 Gbits/sec    0   6.80 MBytes
[  5]   9.00-10.00  sec  1.49 GBytes  12.8 Gbits/sec    0   6.80 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  15.0 GBytes  12.9 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  15.0 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

Algorithm: Bic
Average throughput: 12.9Gbits/sec



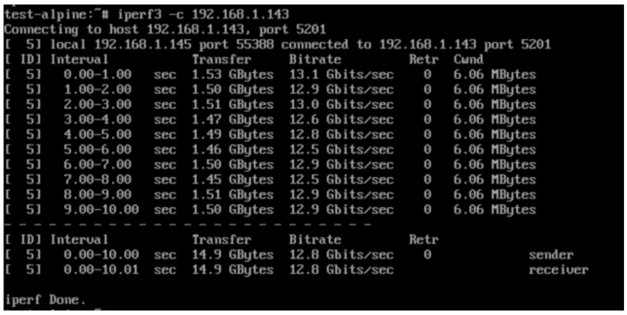
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55346 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.50 GBytes  12.9 Gbits/sec    0   7.61 MBytes
[  5]   1.00-2.00   sec  1.48 GBytes  12.7 Gbits/sec    0   7.61 MBytes
[  5]   2.00-3.00   sec  1.49 GBytes  12.8 Gbits/sec    0   7.61 MBytes
[  5]   3.00-4.00   sec  1.50 GBytes  12.8 Gbits/sec    0   7.61 MBytes
[  5]   4.00-5.00   sec  1.49 GBytes  12.8 Gbits/sec    0   7.61 MBytes
[  5]   5.00-6.00   sec  1.46 GBytes  12.5 Gbits/sec    0   7.61 MBytes
[  5]   6.00-7.00   sec  1.50 GBytes  12.9 Gbits/sec    0   7.61 MBytes
[  5]   7.00-8.00   sec  1.49 GBytes  12.8 Gbits/sec    0   7.61 MBytes
[  5]   8.00-9.00   sec  1.50 GBytes  12.9 Gbits/sec    0   7.61 MBytes
[  5]   9.00-10.00  sec  1.51 GBytes  13.0 Gbits/sec    0   7.61 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  14.9 GBytes  12.8 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  14.9 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

Algorithm: http
Average throughput: 12.8Gbits/sec



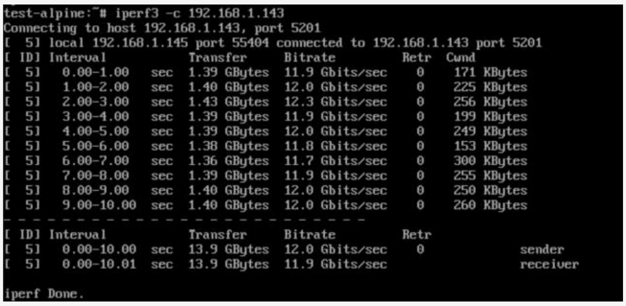
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55376 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.97 GBytes  16.9 Gbits/sec    0    667 KBytes
[  5]   1.00-2.00   sec  1.95 GBytes  16.8 Gbits/sec    0    731 KBytes
[  5]   2.00-3.00   sec  1.94 GBytes  16.6 Gbits/sec    0    758 KBytes
[  5]   3.00-4.00   sec  1.91 GBytes  16.4 Gbits/sec    0    740 KBytes
[  5]   4.00-5.00   sec  1.85 GBytes  15.9 Gbits/sec    0    761 KBytes
[  5]   5.00-6.00   sec  1.91 GBytes  16.4 Gbits/sec    0    775 KBytes
[  5]   6.00-7.00   sec  1.98 GBytes  17.0 Gbits/sec    0    731 KBytes
[  5]   7.00-8.00   sec  1.95 GBytes  16.8 Gbits/sec    0    732 KBytes
[  5]   8.00-9.00   sec  1.92 GBytes  16.5 Gbits/sec    0    710 KBytes
[  5]   9.00-10.00  sec  1.83 GBytes  15.7 Gbits/sec    0    762 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  19.2 GBytes  16.5 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  19.2 GBytes  16.5 Gbits/sec                  receiver

iperf Done.
```

Algorithm: Vegas
Average throughput: 16.5Gbits/sec



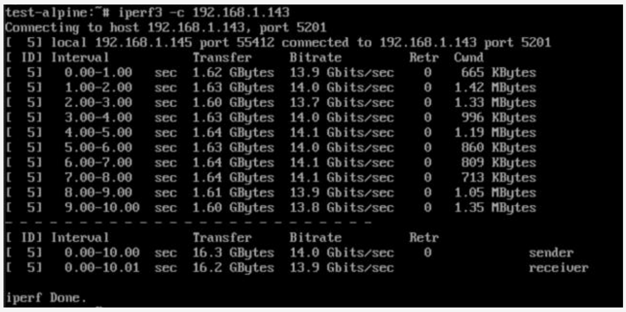
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55388 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.53 GBytes  13.1 Gbits/sec    0   6.06 MBytes
[  5]   1.00-2.00   sec  1.50 GBytes  12.9 Gbits/sec    0   6.06 MBytes
[  5]   2.00-3.00   sec  1.51 GBytes  13.0 Gbits/sec    0   6.06 MBytes
[  5]   3.00-4.00   sec  1.47 GBytes  12.6 Gbits/sec    0   6.06 MBytes
[  5]   4.00-5.00   sec  1.49 GBytes  12.8 Gbits/sec    0   6.06 MBytes
[  5]   5.00-6.00   sec  1.46 GBytes  12.5 Gbits/sec    0   6.06 MBytes
[  5]   6.00-7.00   sec  1.50 GBytes  12.9 Gbits/sec    0   6.06 MBytes
[  5]   7.00-8.00   sec  1.45 GBytes  12.5 Gbits/sec    0   6.06 MBytes
[  5]   8.00-9.00   sec  1.51 GBytes  12.9 Gbits/sec    0   6.06 MBytes
[  5]   9.00-10.00  sec  1.50 GBytes  12.9 Gbits/sec    0   6.06 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  14.9 GBytes  12.8 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  14.9 GBytes  12.8 Gbits/sec                  receiver

iperf Done.
```

Algorithm: Westwood
Average throughput: 12.8Gbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55404 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.39 GBytes  11.9 Gbits/sec    0    171 KBytes
[  5]   1.00-2.00   sec  1.40 GBytes  12.0 Gbits/sec    0    225 KBytes
[  5]   2.00-3.00   sec  1.43 GBytes  12.3 Gbits/sec    0    256 KBytes
[  5]   3.00-4.00   sec  1.39 GBytes  11.9 Gbits/sec    0    199 KBytes
[  5]   4.00-5.00   sec  1.39 GBytes  12.0 Gbits/sec    0    249 KBytes
[  5]   5.00-6.00   sec  1.38 GBytes  11.8 Gbits/sec    0    153 KBytes
[  5]   6.00-7.00   sec  1.36 GBytes  11.7 Gbits/sec    0    300 KBytes
[  5]   7.00-8.00   sec  1.39 GBytes  11.9 Gbits/sec    0    255 KBytes
[  5]   8.00-9.00   sec  1.40 GBytes  12.0 Gbits/sec    0    250 KBytes
[  5]   9.00-10.00  sec  1.40 GBytes  12.0 Gbits/sec    0    260 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  13.9 GBytes  12.0 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  13.9 GBytes  11.9 Gbits/sec                  receiver

iperf Done.
```

Algorithm: YeAH
Average throughput: 12.0Gbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55412 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.62 GBytes  13.9 Gbits/sec    0    665 KBytes
[  5]   1.00-2.00   sec  1.63 GBytes  14.0 Gbits/sec    0   1.42 MBytes
[  5]   2.00-3.00   sec  1.60 GBytes  13.7 Gbits/sec    0   1.33 MBytes
[  5]   3.00-4.00   sec  1.63 GBytes  14.0 Gbits/sec    0    996 KBytes
[  5]   4.00-5.00   sec  1.64 GBytes  14.1 Gbits/sec    0   1.19 MBytes
[  5]   5.00-6.00   sec  1.63 GBytes  14.0 Gbits/sec    0    860 KBytes
[  5]   6.00-7.00   sec  1.64 GBytes  14.1 Gbits/sec    0    809 KBytes
[  5]   7.00-8.00   sec  1.64 GBytes  14.1 Gbits/sec    0    713 KBytes
[  5]   8.00-9.00   sec  1.61 GBytes  13.9 Gbits/sec    0   1.05 MBytes
[  5]   9.00-10.00  sec  1.60 GBytes  13.8 Gbits/sec    0   1.35 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  16.3 GBytes  14.0 Gbits/sec    0             sender
[  5]   0.00-10.01  sec  16.2 GBytes  13.9 Gbits/sec                  receiver

iperf Done.
```

Algorithm: BBR
Average throughput: 14.0Gbits/sec

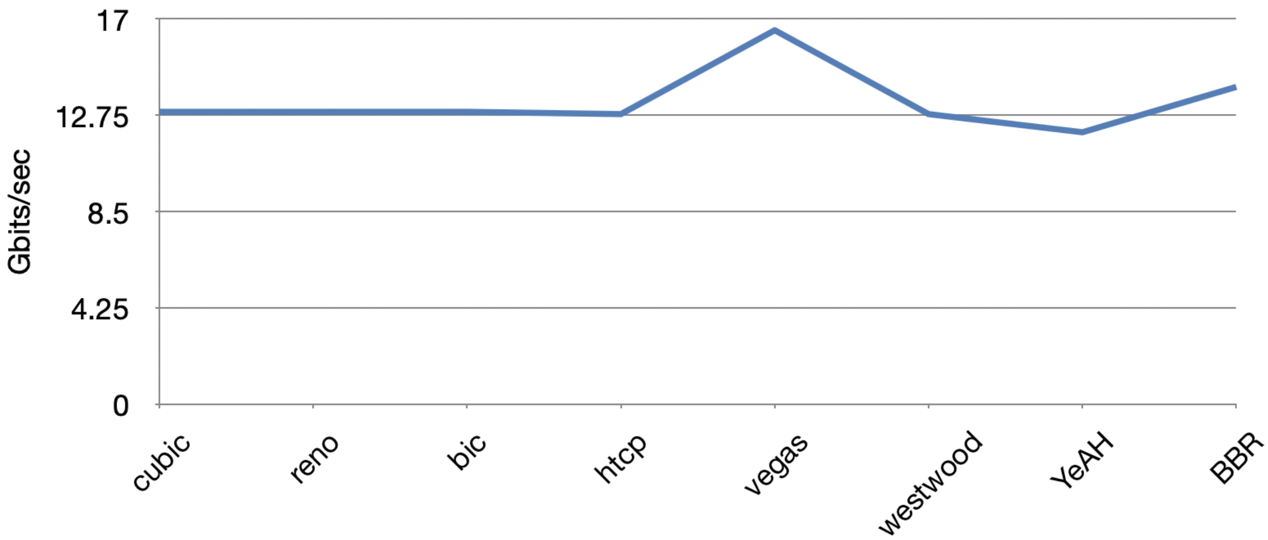



Figure 4.

Now let’s take a look at Figure 4, When the network quality is stable, the various congestion control are similar. The performance of BBR is slightly higher than the average. but vegas is the best. However, vegas has some shortcomings, resulting in not often used in reality. We will see its shortcomings later. As you can see, reno or cubic, which is most frequently used by Linux, does not perform the best.

## Configuration 4: Following configuration 3, but lost packet purposely.

Next, we use the Traffic Control tool in linux here, which is to use `tc`. Artificially add 10% packet loss to simulate network congestion. Commands such as: `tc qdisc change dev eth0 root netem loss 10%`

Table 3.

```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55474 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  11.2 MBytes  93.6 Mbits/sec  907   17.0 KBytes
[  5]   1.00-2.00   sec  2.67 MBytes  22.4 Mbits/sec  217   2.83 KBytes
[  5]   2.00-3.00   sec  3.36 MBytes  28.2 Mbits/sec  235   7.07 KBytes
[  5]   3.00-4.00   sec   127 KBytes  1.04 Mbits/sec   18   1.41 KBytes
[  5]   4.00-5.00   sec  4.83 MBytes  40.5 Mbits/sec  384   7.07 KBytes
[  5]   5.00-6.00   sec  2.00 MBytes  16.7 Mbits/sec  151   2.83 KBytes
[  5]   6.00-7.00   sec  2.30 MBytes  19.3 Mbits/sec  237   2.83 KBytes
[  5]   7.00-8.00   sec   382 KBytes  3.13 Mbits/sec   37   1.41 KBytes
[  5]   8.00-9.00   sec  11.8 MBytes  99.0 Mbits/sec  584   1.41 KBytes
[  5]   9.00-10.00  sec  5.90 MBytes  49.5 Mbits/sec  397   18.4 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  44.5 MBytes  37.3 Mbits/sec  3167             sender
[  5]   0.00-10.24  sec  43.0 MBytes  35.2 Mbits/sec                  receiver

iperf Done.
```

Algorithm: Cubic
Average throughput: 37.3Mbits/sec

```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55494 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  2.23 MBytes  18.7 Mbits/sec  182   2.83 KBytes
[  5]   1.00-2.00   sec  1.77 MBytes  14.9 Mbits/sec  167   2.83 KBytes
[  5]   2.00-3.00   sec  1.90 MBytes  15.9 Mbits/sec  170   1.41 KBytes
[  5]   3.00-4.00   sec  1.20 MBytes  10.1 Mbits/sec   81   11.3 KBytes
[  5]   4.00-5.00   sec  2.34 MBytes  19.6 Mbits/sec  198   22.6 KBytes
[  5]   5.00-6.00   sec  1.09 MBytes  9.11 Mbits/sec  104   4.24 KBytes
[  5]   6.00-7.00   sec  1.16 MBytes  9.73 Mbits/sec  103   1.41 KBytes
[  5]   7.00-8.00   sec  2.12 MBytes  17.8 Mbits/sec  191   1.41 KBytes
[  5]   8.00-9.00   sec  1.23 MBytes  10.3 Mbits/sec   95   5.66 KBytes
[  5]   9.00-10.00  sec  1.44 MBytes  12.1 Mbits/sec  133   4.24 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  16.5 MBytes  13.8 Mbits/sec  1424             sender
[  5]   0.00-10.00  sec  16.4 MBytes  13.8 Mbits/sec                  receiver

iperf Done.
```

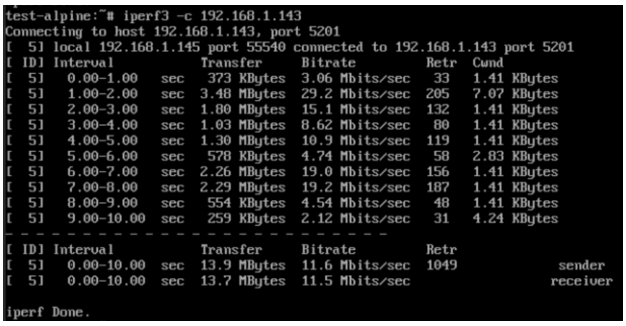
Algorithm: Reno
Average throughput: 13.8Mbits/sec

```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55510 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec   114 MBytes   954 Mbits/sec  7480    751 KBytes
[  5]   1.00-2.00   sec   146 MBytes  1.23 Gbits/sec  11278    779 KBytes
[  5]   2.00-3.00   sec  22.5 MBytes   189 Mbits/sec  2000   1.41 KBytes
[  5]   3.00-4.00   sec   134 MBytes  1.12 Gbits/sec  11228    556 KBytes
[  5]   4.00-5.00   sec   195 MBytes  1.64 Gbits/sec  15913    566 KBytes
[  5]   5.00-6.00   sec   160 MBytes  1.34 Gbits/sec  13848    144 KBytes
[  5]   6.00-7.00   sec   152 MBytes  1.28 Gbits/sec  12037    779 KBytes
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec  195   1.41 KBytes
[  5]   8.00-9.00   sec   109 MBytes   913 Mbits/sec  9501    577 KBytes
[  5]   9.00-10.00  sec   108 MBytes   902 Mbits/sec  8552    580 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  1.12 GBytes   958 Mbits/sec  92032             sender
[  5]   0.00-10.22  sec  1.12 GBytes   938 Mbits/sec                  receiver

iperf Done.
```

Algorithm: Bic
Average throughput: 958Mbits/sec

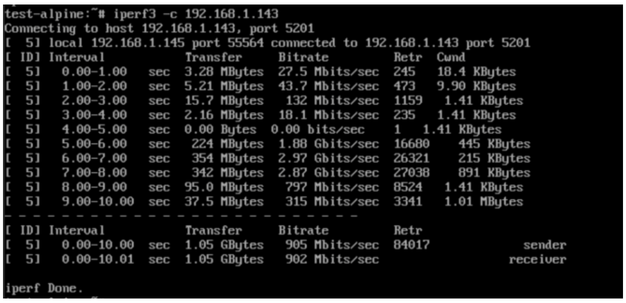
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55522 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  1.01 MBytes  8.51 Mbits/sec   97   8.48 KBytes
[  5]   1.00-2.00   sec   440 KBytes  3.60 Mbits/sec   40   2.83 KBytes
[  5]   2.00-3.00   sec   923 KBytes  7.56 Mbits/sec   73   2.83 KBytes
[  5]   3.00-4.00   sec   421 KBytes  3.45 Mbits/sec   40   2.83 KBytes
[  5]   4.00-5.00   sec  1.32 MBytes  11.1 Mbits/sec  104   1.41 KBytes
[  5]   5.00-6.00   sec   619 KBytes  5.07 Mbits/sec   36   11.3 KBytes
[  5]   6.00-7.00   sec  1.40 MBytes  11.7 Mbits/sec  114   2.83 KBytes
[  5]   7.00-8.00   sec  1.04 MBytes  8.69 Mbits/sec   82   1.41 KBytes
[  5]   8.00-9.00   sec  1.54 MBytes  12.9 Mbits/sec   98   1.41 KBytes
[  5]   9.00-10.00  sec   686 KBytes  5.62 Mbits/sec   57   1.41 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  9.32 MBytes  7.82 Mbits/sec  741             sender
[  5]   0.00-10.00  sec  9.26 MBytes  7.76 Mbits/sec                  receiver

iperf Done.
```

Algorithm: Htcp
Average throughput: 7.82Mbits/sec



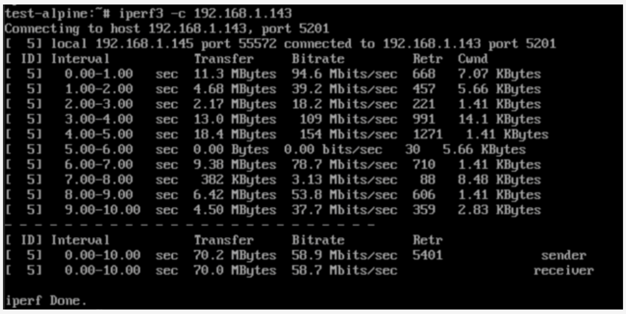
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55540 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec   373 KBytes  3.06 Mbits/sec   33   1.41 KBytes
[  5]   1.00-2.00   sec  3.48 MBytes  29.2 Mbits/sec  205   7.07 KBytes
[  5]   2.00-3.00   sec  1.80 MBytes  15.1 Mbits/sec  132   1.41 KBytes
[  5]   3.00-4.00   sec  1.03 MBytes  8.62 Mbits/sec   80   1.41 KBytes
[  5]   4.00-5.00   sec  1.30 MBytes  10.9 Mbits/sec  119   1.41 KBytes
[  5]   5.00-6.00   sec   578 KBytes  4.74 Mbits/sec   58   2.83 KBytes
[  5]   6.00-7.00   sec  2.26 MBytes  19.0 Mbits/sec  156   1.41 KBytes
[  5]   7.00-8.00   sec  2.29 MBytes  19.2 Mbits/sec  187   1.41 KBytes
[  5]   8.00-9.00   sec   554 KBytes  4.54 Mbits/sec   48   1.41 KBytes
[  5]   9.00-10.00  sec   259 KBytes  2.12 Mbits/sec   31   4.24 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  13.9 MBytes  11.6 Mbits/sec  1049             sender
[  5]   0.00-10.00  sec  13.7 MBytes  11.5 Mbits/sec                  receiver

iperf Done.
```

Algorithm: Vegas
Average throughput: 11.6Mbits/sec



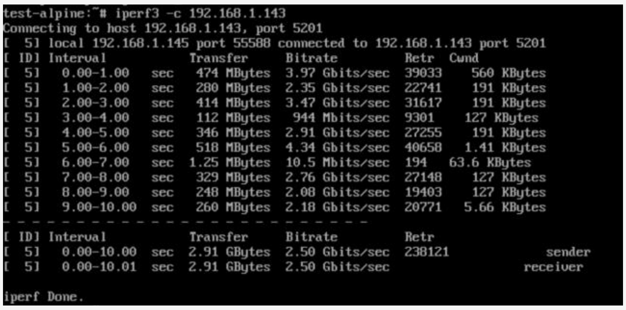
```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55564 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  3.28 MBytes  27.5 Mbits/sec  245    18.4 KBytes
[  5]   1.00-2.00   sec  5.21 MBytes  43.7 Mbits/sec  473    9.90 KBytes
[  5]   2.00-3.00   sec  15.7 MBytes   132 Mbits/sec  1159   1.41 KBytes
[  5]   3.00-4.00   sec  2.16 MBytes  18.1 Mbits/sec  235    1.41 KBytes
[  5]   4.00-5.00   sec  0.00 Bytes  0.00 bits/sec    1    1.41 KBytes
[  5]   5.00-6.00   sec   224 MBytes  1.88 Gbits/sec  16680    445 KBytes
[  5]   6.00-7.00   sec   354 MBytes  2.97 Gbits/sec  26321    215 KBytes
[  5]   7.00-8.00   sec   342 MBytes  2.87 Gbits/sec  27038    891 KBytes
[  5]   8.00-9.00   sec  95.0 MBytes   797 Mbits/sec  8524   1.41 KBytes
[  5]   9.00-10.00  sec  37.5 MBytes   315 Mbits/sec  3341   1.01 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  1.05 GBytes   905 Mbits/sec  84017             sender
[  5]   0.00-10.01  sec  1.05 GBytes   902 Mbits/sec                  receiver

iperf Done.
```

Algorithm: Westwood
Average throughput: 905Mbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55572 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec  11.3 MBytes  94.6 Mbits/sec  668   7.07 KBytes
[  5]   1.00-2.00   sec  4.68 MBytes  39.2 Mbits/sec  457   5.66 KBytes
[  5]   2.00-3.00   sec  2.17 MBytes  18.2 Mbits/sec  221   1.41 KBytes
[  5]   3.00-4.00   sec  13.0 MBytes   109 Mbits/sec  991   14.1 KBytes
[  5]   4.00-5.00   sec  18.4 MBytes   154 Mbits/sec  1271   1.41 KBytes
[  5]   5.00-6.00   sec  0.00 Bytes  0.00 bits/sec   30   5.66 KBytes
[  5]   6.00-7.00   sec  9.38 MBytes  78.7 Mbits/sec  710   1.41 KBytes
[  5]   7.00-8.00   sec   382 KBytes  3.13 Mbits/sec   88   8.48 KBytes
[  5]   8.00-9.00   sec  6.42 MBytes  53.8 Mbits/sec  606   1.41 KBytes
[  5]   9.00-10.00  sec  4.50 MBytes  37.7 Mbits/sec  359   2.83 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  70.2 MBytes  58.9 Mbits/sec  5401             sender
[  5]   0.00-10.00  sec  70.0 MBytes  58.7 Mbits/sec                  receiver

iperf Done.
```

Algorithm: YeAH
Average throughput: 58.9Mbits/sec



```
test-alpine:~# iperf3 -c 192.168.1.143
Connecting to host 192.168.1.143, port 5201
[  5] local 192.168.1.145 port 55588 connected to 192.168.1.143 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec   474 MBytes  3.97 Gbits/sec  39033    560 KBytes
[  5]   1.00-2.00   sec   280 MBytes  2.35 Gbits/sec  22741    191 KBytes
[  5]   2.00-3.00   sec   414 MBytes  3.47 Gbits/sec  31617    191 KBytes
[  5]   3.00-4.00   sec   112 MBytes   944 Mbits/sec  9301    127 KBytes
[  5]   4.00-5.00   sec   346 MBytes  2.91 Gbits/sec  27255    191 KBytes
[  5]   5.00-6.00   sec   518 MBytes  4.34 Gbits/sec  40658   1.41 KBytes
[  5]   6.00-7.00   sec  1.25 MBytes  10.5 Mbits/sec  194   63.6 KBytes
[  5]   7.00-8.00   sec   329 MBytes  2.76 Gbits/sec  27148    127 KBytes
[  5]   8.00-9.00   sec   248 MBytes  2.08 Gbits/sec  19403    127 KBytes
[  5]   9.00-10.00  sec   260 MBytes  2.18 Gbits/sec  20771   5.66 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-10.00  sec  2.91 GBytes  2.50 Gbits/sec  238121             sender
[  5]   0.00-10.01  sec  2.91 GBytes  2.50 Gbits/sec                  receiver

iperf Done.
```

Algorithm: BBR
Average throughput: 2.50Gbits/sec

As you can see Figure 5, simply adding 10% of the packet loss will greatly reduce the network performance.

Vegas, the strongest performer under good network conditions, also performs poorly here. On the contrary, The BBR algorithm is far better than other algorithms.

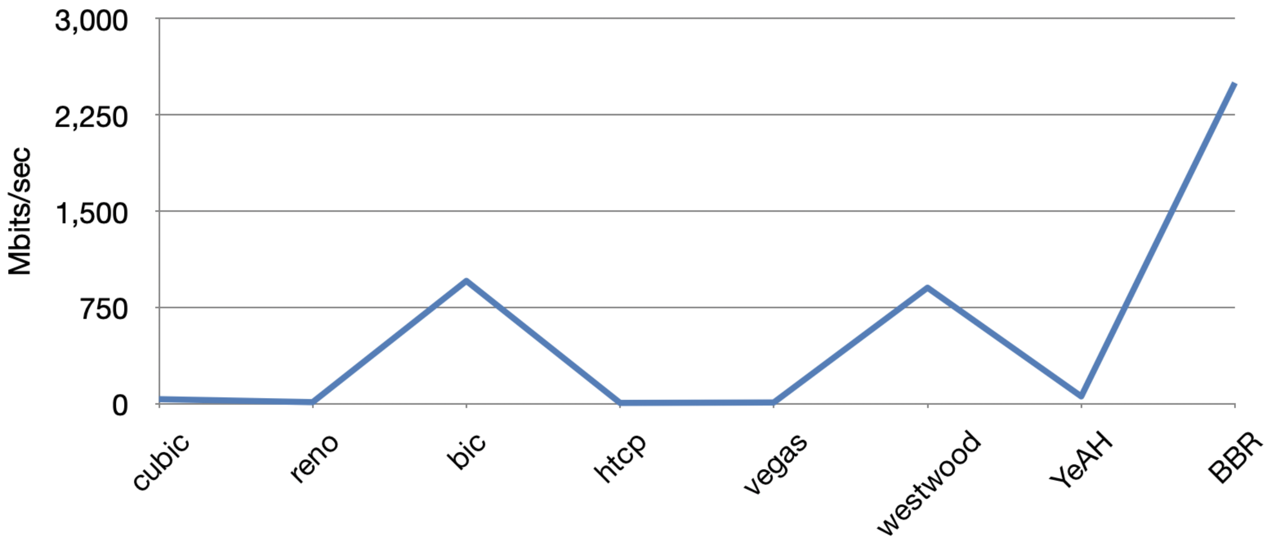



Figure 5.

# Conclusion

Since the functions of the network cannot be limited to certain processes, part of the network needs to be The business system is directly responsible. After a packet comes in from the interface, it still has to go through the layer in the middle The protocol stack of the layer (such as TCP, IP, etc.) is only assigned to the application program of the user space; Here Networking refers specifically to the part of the intermediate protocol stack.

We can see from experiments that Linux settings are often not optimal. The difference may not be obvious on traditional physical machines, but if it is a virtual machine cluster that seeks high network performance, or if you use a network device such as infiniband that can reach speeds of up to 400Gbit/sec, the difference will be very noticeable. Although the congestion control algorithm in the case of no packet loss, all algorithms perform about the same. Although Vegas, BBR is slightly better than others, but most of them are still usable. But when 10% of the packets are lost, the performance of most algorithms drops drastically, and some are even unusable. Only BBR still retains some performance. This also shows the robustness of the BBR algorithm, which should be greatly improved when encountering wifi or poor mobile network signals in real-world situations.