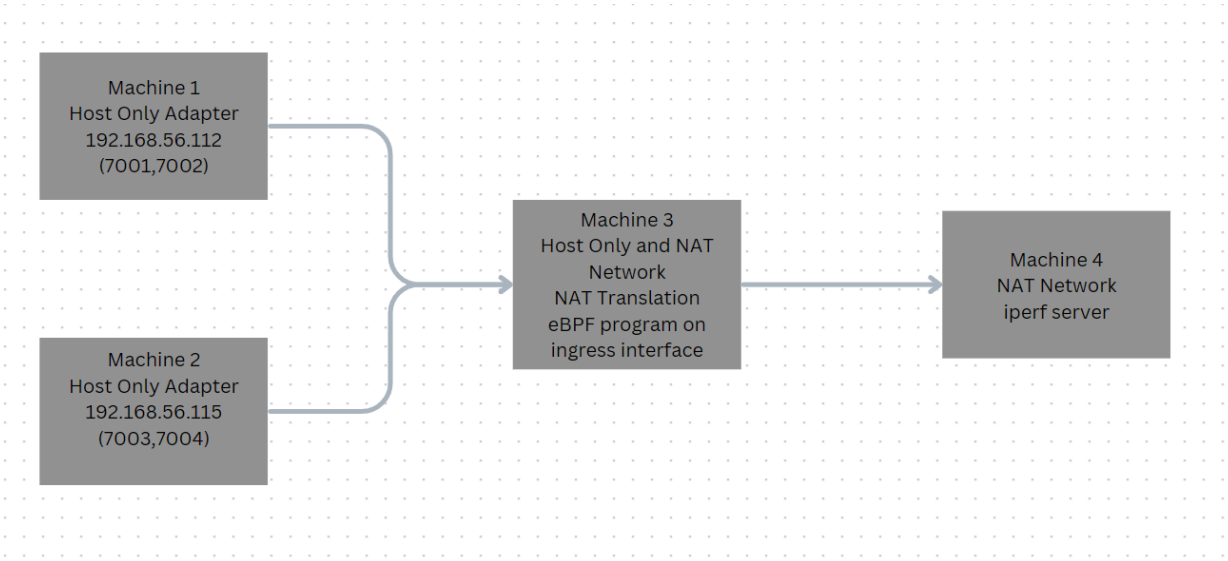
Observation:-

In this experiment, we implemented and observed the behavior of an eBPF-based traffic shaping mechanism. The goal was to control the rate of network traffic at the packet level using token bucket algorithms. The setup involves categorizing traffic into high-priority (HP) and low-priority (LP) streams, with each stream subjected to different rate limits.

Setup:



IP Addresses and Ports

We utilized the following IP addresses and ports in our setup:

High-Priority IP (HP_IP): `**192.168.56.112**`
Low-Priority IP (LP_IP): `**192.168.56.113**`

Ports:

HP_HPP: `**7001**` belongs to(HP_IP)
HP_LPP: `**7002**` belongs to(HP_IP)
LP_HPP: `**7003**` belongs to(LP_IP)
LP_LPP: `**7004**` belongs to(LP_IP)

Traffic Shaping Mechanism

The traffic shaping is implemented using an eBPF program, which is attached to a network interface(ingress) using XDP (Express Data Path). The eBPF program categorizes packets based on their source IP addresses and destination ports and processes them according to the configured rate limits.

High-Priority Traffic (HP)

Port 7001 : This traffic is always allowed and is not subject to rate limiting. It represents high-priority traffic within the same priority level.

Port 7002: This traffic is allowed only if there are sufficient tokens in the high-priority token bucket. If there are not enough tokens, the packet is either dropped or, if conditions allow, processed using low-priority tokens.

Low-Priority Traffic (LP)

Port 7004: This traffic is processed using the low-priority token bucket. If there are insufficient tokens in the low-priority bucket it will consume high-priority tokens,but with the condition of no flow of HP_LPP traffic.

Port 7003: This traffic can use high-priority tokens even if there is a HP_HPP traffic, providing a mechanism for low-priority traffic to utilize excess high-priority bandwidth under certain conditions.

Token Buckets

The eBPF program uses two token buckets to manage rate limits:
-High-Priority Token Bucket: Refilled at a rate of 100 Mbps.
-Low-Priority Token Bucket: Refilled at a rate of 20 Mbps.

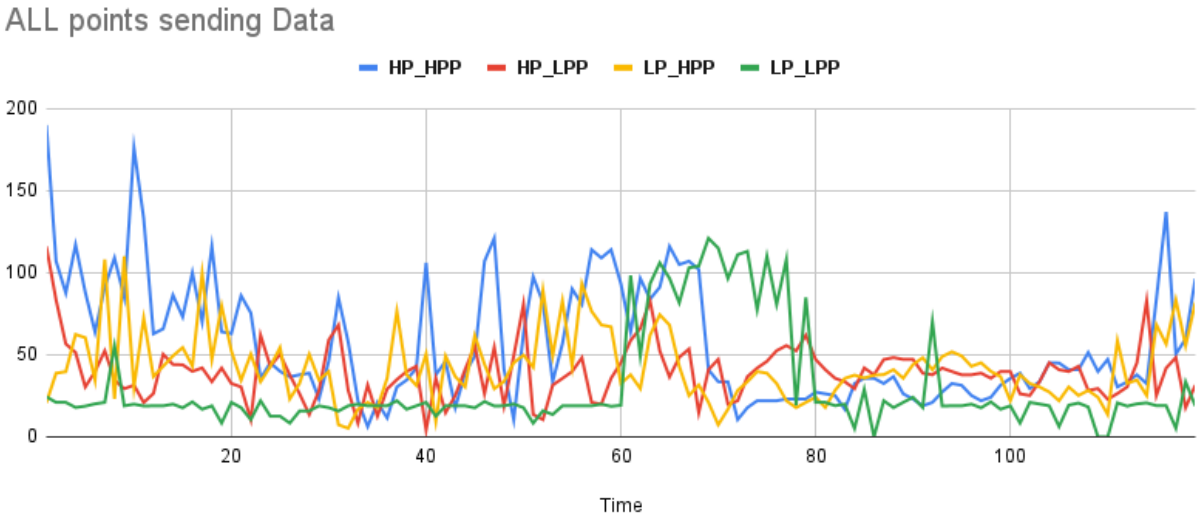
The token buckets are refilled periodically, ensuring that the traffic conforms to the desired rate limits.

Packet Processing

1.Packet Arrival: The eBPF program inspects incoming packets to determine their source IP and destination port.
2.Token Check: The program checks the appropriate token bucket to see if there are enough tokens to process the packet.
3.Token Deduction: If sufficient tokens are available, the program deducts the corresponding number of tokens and allows the packet to pass.
4.Packet Dropping: If there are insufficient tokens, the packet is dropped, and the drop count for the corresponding port is incremented.

Situation 1:

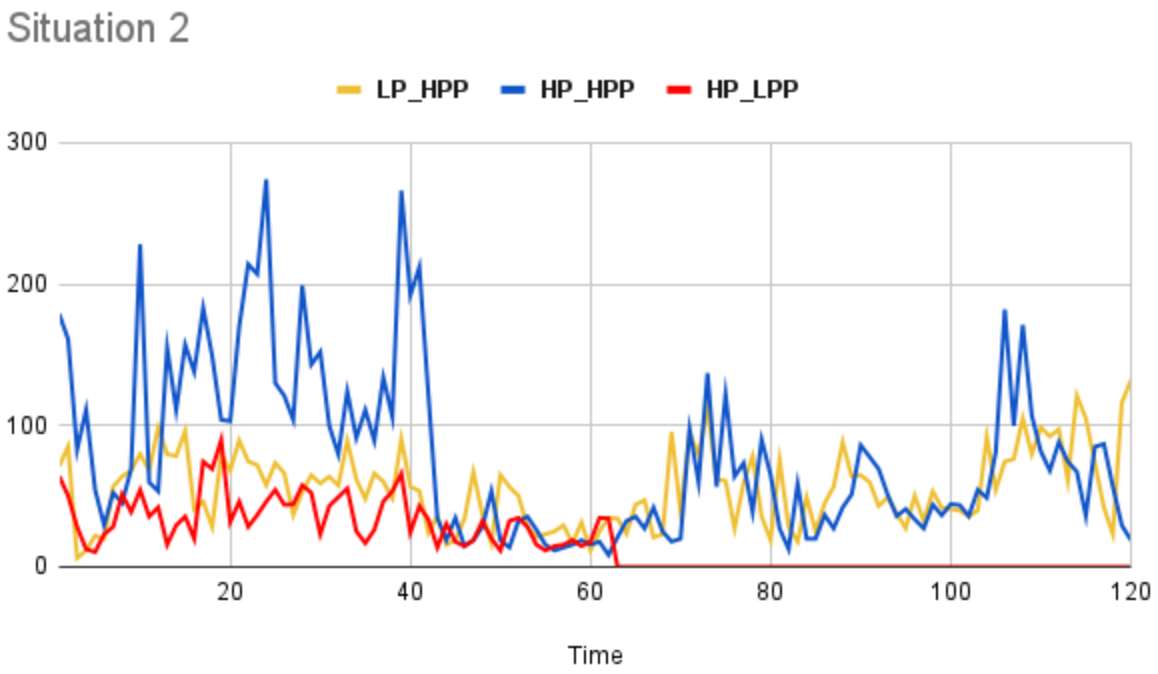
All Ports are sending traffic simultaneously.



	Bitrate	HP_LPP	LP_HPP	LP_LPP
Packet dropped	0	1953	2954	1387
Packet Received	596974	405841	444908	13718
Throughput	57.4 Mbits/sec	39.3 Mbits/sec	42.48 Mbits/sec	30.5 Mbits/sec
(Min,Max)Mbits/s	(6.29,190)	(4.19,116)	(5.24,110)	(0,120)

Situation 2:

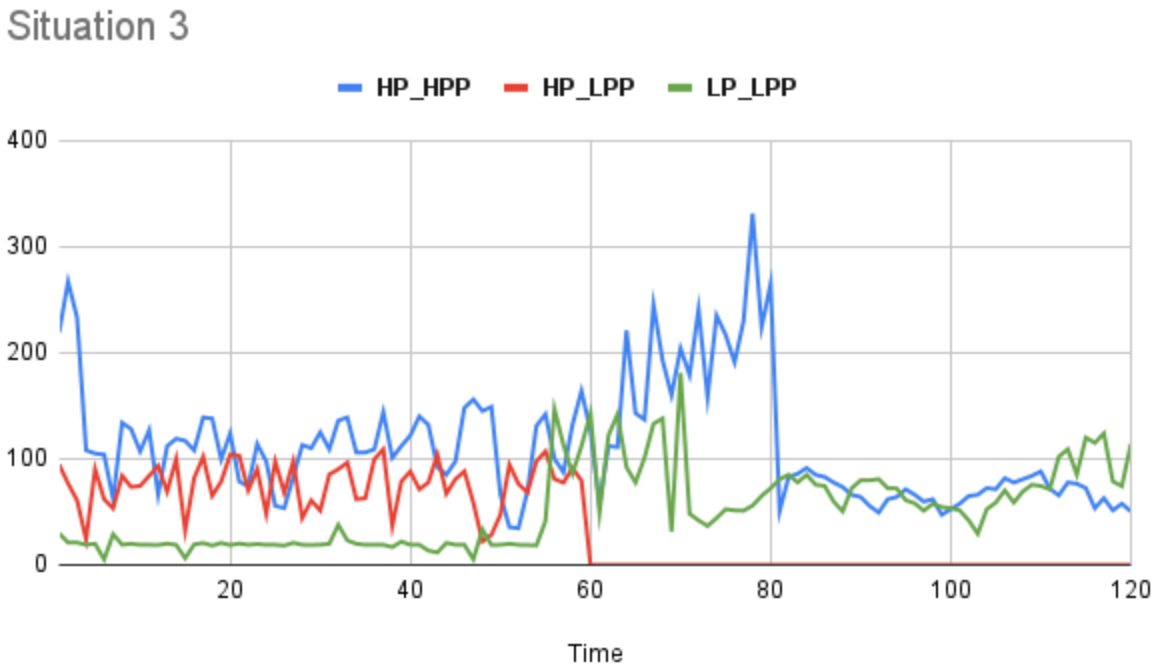
HP_HPP and LP_HPP will send traffic for 120 sec.
HP_LPP will send traffic for 60 sec.



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped	0	552	1608	—Nil—
Packet Received	672663	191195	570092	—Nil—
Throughput	78.32 Mbits/sec	34.73 Mbits/sec	55.36 Mbits/sec	—Nil—
(Min,Max)Mbits/s	(8.39,274)	(10.5,89.8)	(6.27,132)	—Nil—

Situation 3:

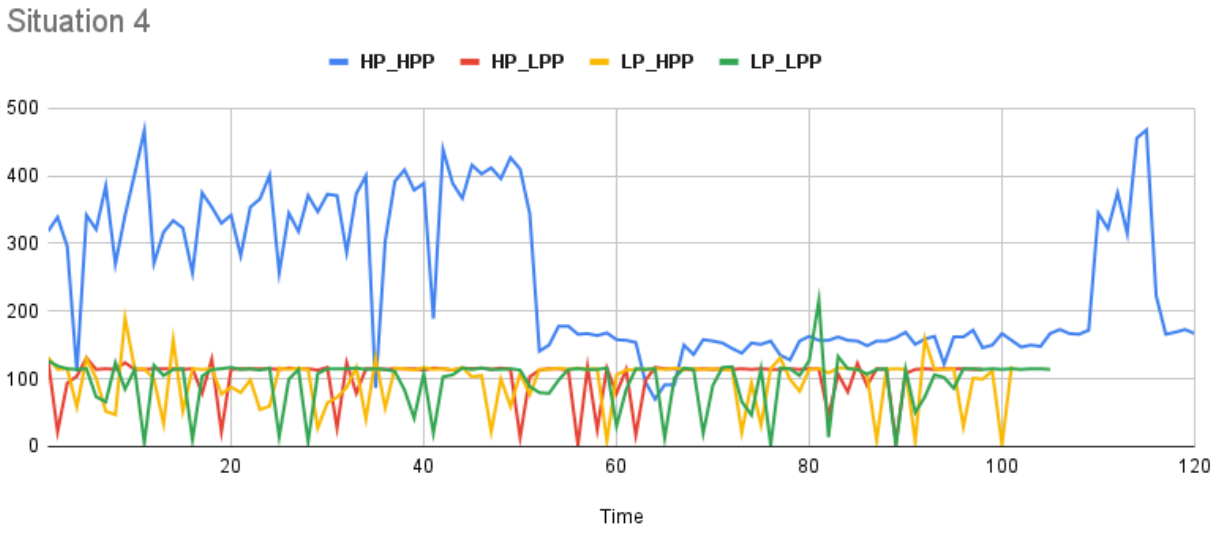
HP_HPP and LP_LPP will send traffic for 120 sec.
HP_LPP will send traffic for 60sec.



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped	0	1697	—Nil—	8632
Packet Received	1166812	392274	—Nil—	502381
Throughput(First Phase)	115 Mbits/sec	75.61 Mbits/s	—Nil—	26.17 Mbits/sec
Throughput(Second Phase)	110 Mbits/sec	0 Mbits/sec	—Nil—	76.8 Mbits/sec
(Min,Max)Mbits/s	(34,331)	(22.1,109)	—Nil—	(5.11,181)

Situation 4:

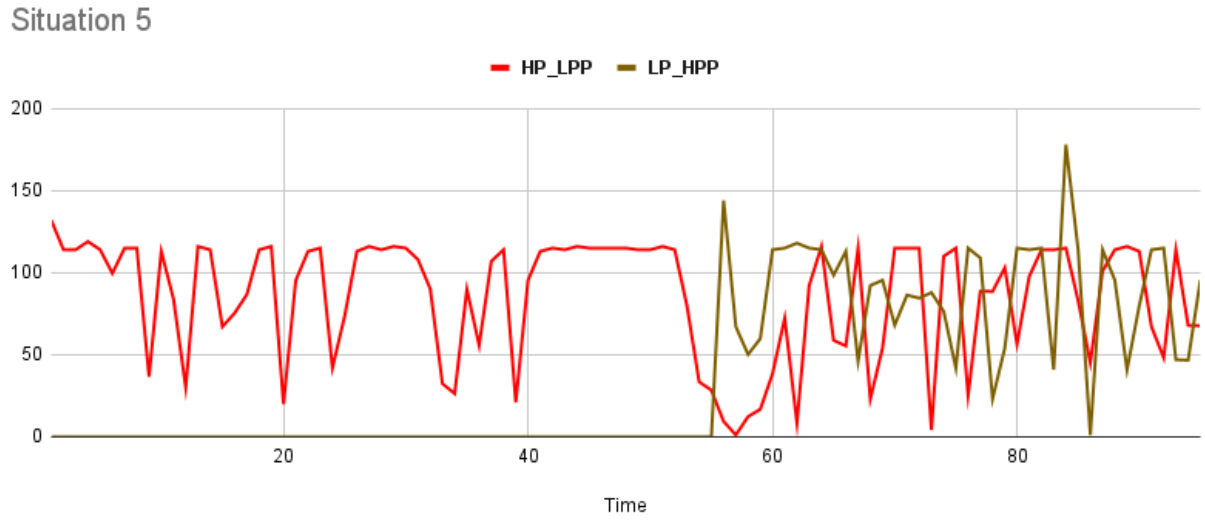
All Port will send traffic individually



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped	0	14690	14059	14713
Packet Received	2542329	879805	848669	888130
Throughput	245 Mbits/sec	104 Mbits/sec	97.4 Mbits/sec	98.2 Mbits/sec
(Min,Max)Mbits/s	(70,468)	(2,131)	(2,190)	(1,216)

Situation 5:

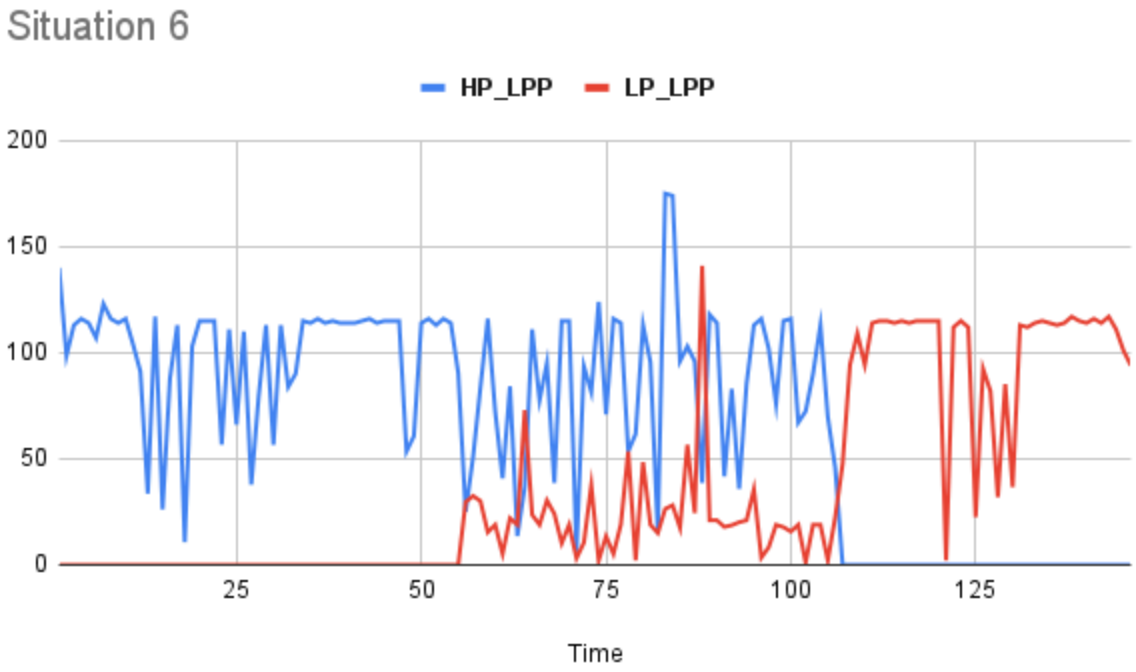
HP_LPP will send traffic for 120 sec and after 60 sec LP_HPP will send traffic for 60 sec



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped (first phase	—Nil—	7585	-----	—Nil—
Packet Dropped(2nd phase	—Nil—	2148	7489	—Nil—
Throughput(First Phase)	—Nil—	94 Mbits/sec	0 Mbits/sec	—Nil—
Throughput(second Phase)	—Nil—	74 Mbits/sec	87 Mbits/s	—Nil—
(Min,Max)Mbits/s	—Nil—	(19.9,132)	(1,178)	—Nil—

Situation 6:

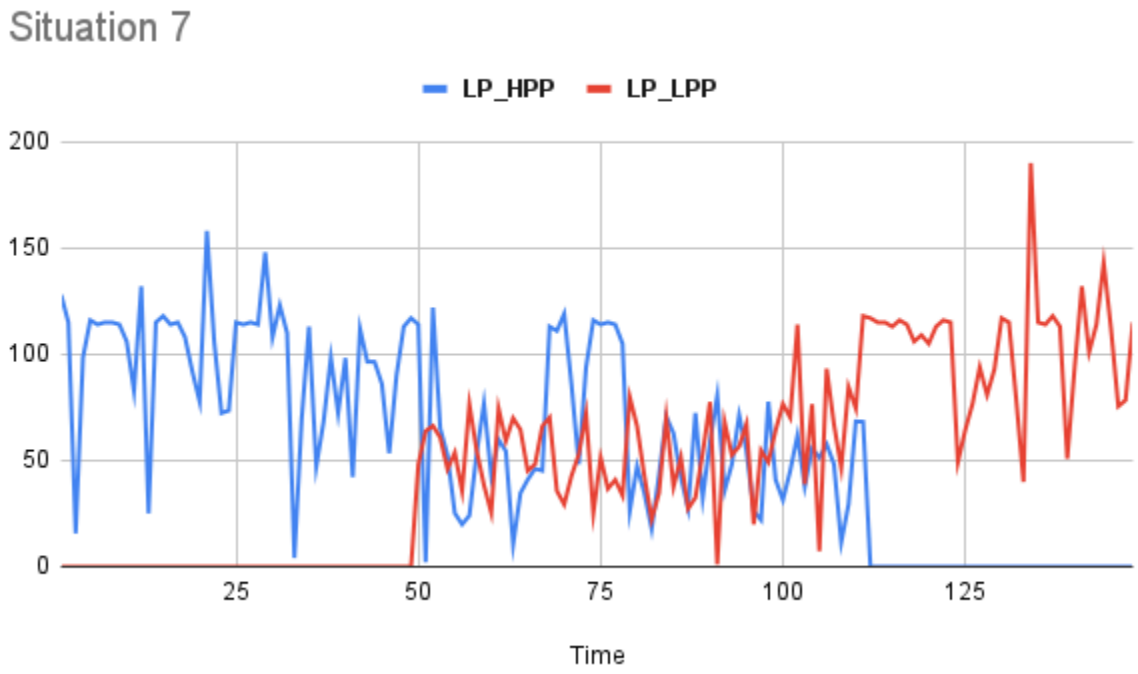
HP_LPP will send traffic for 120 sec. After 60 sec LP_LPP will send traffic for 120 sec.



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped(first phase)	—Nil—	7794	—Nil—	———
Packet Dropped(Second phase)	—Nil—	7387	—Nil—	4211
Packet Dropped(Third phase)	—Nil—	——-	—Nil—	7567
Throughput(First Phase)	—Nil—	99.8 Mbits/sec	—Nil—	0
Throughput(second Phase)	—Nil—	83.8 Mbits/sec	—Nil—	23.4 Mbits/sex
Throughput(Third Phase)	—Nil—	0	—Nil—	99.45 Mbits/sec
(Min,Max)Mbits/s	—Nil—	(0,175)	—Nil—	(0,141)

Situation 7:

LP_HPP will send traffic for 120 sec. After 60 sec LP_LPP will send traffic for 120 sec.



	HP_HPP	HP_LPP	LP_HPP	LP_LPP
Packet Dropped(First Phase)	—Nil—	—Nil—	6804	—-
Packet Dropped(Second phase)	—Nil—	—Nil—	5404	4333
Packet Dropped(Third phase)	—Nil—	—Nil—	—-	6614
Throughput(First Phase)	—Nil—	—Nil—	96.96 Mbits/sec	0 Mbits/sec
Throughput(Second Phase)	—Nil—	—Nil—	57.79 Mbits/sec	54.57 Mbits/sec
Throughput(Third Phase)	—Nil—	—Nil—	0 Mbits/sec	102.43 Mbits/sec
(Min,Max)Mbits/s	—Nil—	—Nil—	(0,258)	(0,190)