Cisco 1921 router performance test

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About test

Test was carried out for clarify the performance characteristics of the router with different configurations during transmission of packets with different length. Some background information is present in document also for better understanding.

During the test were used:

- Cisco 1921/K9, IOS Software C1900-UNIVERSALK9-M, Version 15,2(4)M5, Technology Package License – Security, VPN module onboard.
- JDSU SmartClass Ethernet Testers.

Measured L1 Rate [Mbps] results in tables are rounded. However, it is sufficient for the review. A more accurate value you can get out from Packets Measured Rate.

For example: for 64Byte packets L1 Rate is 43,4Mbps and packets rate is 53170 packets per seconds, In this case 49,83Mbps is rounded. A more accurate value is 53170 [packets/s] x 102 [bytes on wire] x 8 [bits in byte] = 43,386720 Mbps.

Background

Each layer have own unit of measure.
PDU – Protocol Data Unit

- Layer 1 Physical Layer - Bit
- Layer 2 Data Link Layer - Frame
- Layer 3 Network Layer - Packet

Ethernet frame Ethernet II / DIX

Figure 1 shows fields and lengths of Ethernet II/DIX frame.

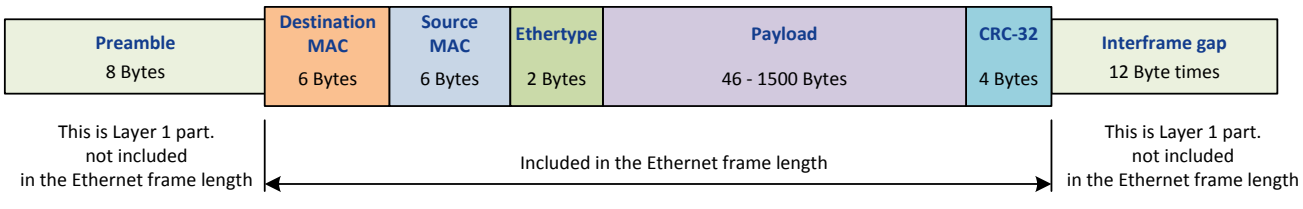


Figure 1. Untagged Ethernet frame

Maximum throughput

The interframe gap is inserted between frames during transmitting (Figure 2)

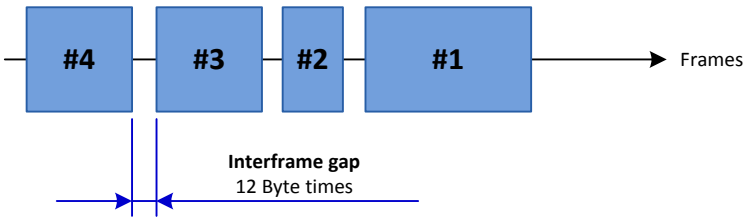


Figure 2 Ethernet interframe gap

Preamble 8 Bytes + Destination MAC 6 Bytes + Source MAC 6 Bytes + Ethertype 2Bytes + Payload 1500 bytes + FCS 4 Bytes + Inter frame Gap "12 Bytes" = 1538 Bytes. In this way 1538 bytes are needed to transmit 1518 bytes untagged frame.

Layer 3 maximum throughput can't reach 100% wire speed and depends from packet length.
1538 Bytes are needed for transmitting 1500 bytes of L3 data -> 1500/1538*100% = **97,53% @ untagged frame**.
84 Bytes are needed for transmitting 46 bytes of L3 data -> 64/84*100% = **76,19% @ untagged frame**.

Cisco Router order of operation

Cisco Router execution order of operations defines how the router processes traffic.

Packet is received on the port,

- If IPSec, then check input access list
- Decryption—for Cisco Encryption Technology (CET) or IPSec
- Check input access list
- Check input rate limits
- Input accounting
- NAT outside to inside (global to local translation)
- Policy routing
- Routing
- Redirect to Web cache
- NAT inside to outside (local to global translation)
- Crypto (check map and mark for encryption)
- Check output access list
- Inspect context-based access control (CBAC)
- TCP intercept
- Encryption

Packet is transmitted to the port.

Test #1

Cisco 1921 switching performance in the case No service enabled or ACL.

The router configured with the IP address, no service enabled or ACL. Router works as gateway between two subnets.
Test type: Layer 3 RFC2544.

Router has:
Processor type MIPS64, CAVIUM Octeon Plus CN5120
Gigabit Ethernet PHY ICs Marvell 88E1114 ports Gi0/0, Gi0/1

Two variants were tested:
- 1st variant: IP CEF is enabled
- 2nd variant: IP CEF is disabled

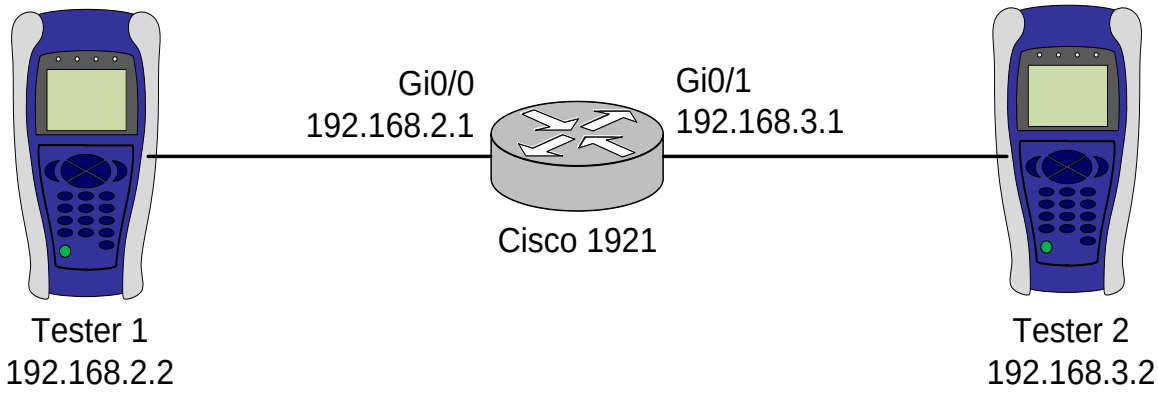


Figure 3 Schematic diagram of Test #1

The `#sh processes cpu sorted 1min` and `#sh processes cpu history` were used for CPU statistics gathering. Please see the example below:

```
R1#sh processes cpu sorted 1min | i CPU utilization
CPU utilization for five seconds: 99%/98%; one minute: 68%; five minutes: 26%

R1#sh processes cpu history

     9999999999999999999999999999999999999999999999999993333
     9999999988888999999777779999999999999999999999999991111
 100 ***************************************************
  90 ***************************************************
  80 ***************************************************
  70 ***************************************************
  60 ***************************************************
  50 ***************************************************
  40 ***************************************************
  30 ***********************************************************
  20 ***********************************************************
  10 ***********************************************************
    0....5....1....1....2....2....3....3....4....4....5....5....6
              0    5    0    5    0    5    0    5    0    5    0
              CPU% per second (last 60 seconds)
```

The CPU utilization for five seconds: 99%/98%; should be read as "Total CPU usage"/"CPU Usage Caused by traffic".

Test results are present in the Table 1. Looking ahead, I will say that there are incorrect results (red) due to nuances of the tester. This will be discussed below.

Packet Length [Bytes]	1st variant, IP CEF is enabled			
	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec
40	172,3	93	92	151548
64	194,5	92	91	153170
128	268,2	92	91	153145
256	419,9	92	91	153044
512	728,5	92	91	152476
1024	1000,0	93	92	117702
1500	1000,0	56	55	81274
random	400,0	65	64	

Table 1, Throughput and CPU utilization, Test #1, No service enabled or ACL, Flow Control is ON.

Please note

The measured L1 Rate [Mbps] results can be calculated from Packet Rate, and vice versa.

For example: The Packets Rate for 64Byte packets is 151548 packets per seconds, In this case L1 Rate value must be 151548 [packets/s] x 102 [bytes on wire] x 8 [bits in byte] = 123,663168 Mbps.

However, you can see in the Table 1 that numbers are 172,3 Mbps for 64byte packet. It is very big difference and possible to say “your rule does not work” or “tester is lying”.

All right, let me explain. Tester shows in RFC2544 log the Packet Rate and the L1 Rate.

Packet Rate - rate of L3 packets, what tester sends and receives back without errors.

L1 Rate – tester calculates this rate for all frames on the wire, not only for L3 probe packets.

802.3x Flow Control functionality built into Gigabit Ethernet. The PAUSE frame (Figure 4) is a packet that tells the far-end device to stop the transmitting of packets until the sender is able to handle all the traffic and clear its buffers. The PAUSE frame has a timer included, which tells the far-end device when to start to send packets again. If that timer expires without getting another PAUSE frame, the far-end device can then send packets again.

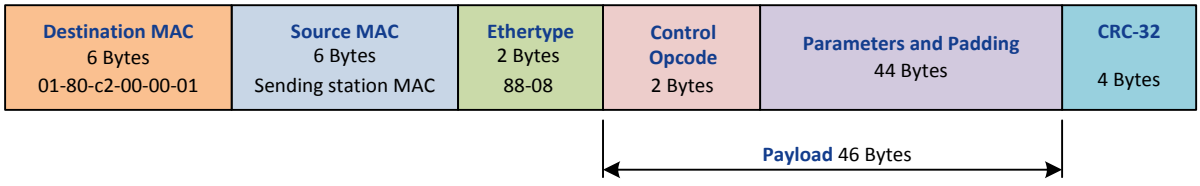


Figure 4 Pause Frame format

Flow-Control is an optional item and must be negotiated. However Flow Control can’t be manually disabled on the Cisco 1921 router for interfaces Gi0/0 and Gi0/1. Tester JDSU SmartClass Ethernet also can be negotiated about Flow Control but this control cannot be disabled for 1Gbps link. As a result, the Flow Control is used and a router generates huge number of PAUSE frames.

```
R1#sh int g0/0 | i flow-control
  output flow-control is XON, input flow-control is XON
```

```
R1#sh int g0/0 | i pause
     0 watchdog, 33 multicast, 0 pause input
     0 lost carrier, 0 no carrier, 96583096 pause output
```

Tester also shows huge count of ***Pause Frames*** and same count of ***Multicast Frames*** (Pause frame is multicast frame) in the menu *Results - > Link Counts*.

☞ For information, the tester shows real throughputs without Pause Frames. You can see it in the menu *Results -> Link Stats -> **Rx/Tx Mbps Cur L1*** and ***Rx/Tx Mbps Cur L2*** counters. But these counters show current numbers and they are cleared after end of test and counters are not present in the RFC2544 log files.

As a result these Pause Frames are added to L1 Rate value and it confuses the real throughput in the RFC2544 results.

The new schematic is used for eliminating these nuances (Figure 5).

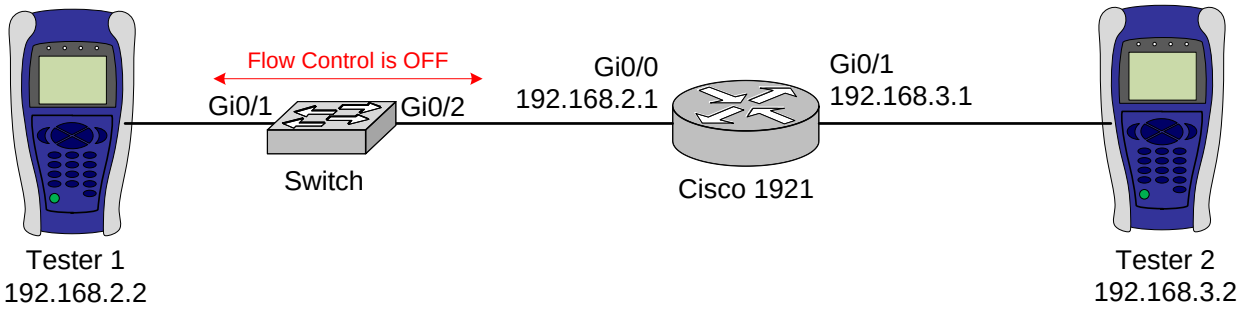


Figure 5 New schematic diagram for tests

Switch is connected between router and tester. Flow Control negotiation is disabled on the switch. In this case the router Cisco 1921 switches off the flow control also.

```
R1#sh int g0/0 | i flow-control
  output flow-control is unsupported, input flow-control is unsupported
```

Now the Flow Control is disabled and you can see another L1 Rate numbers in the Table 2. The calculated values and the measured L1 Rate are same.

For example:

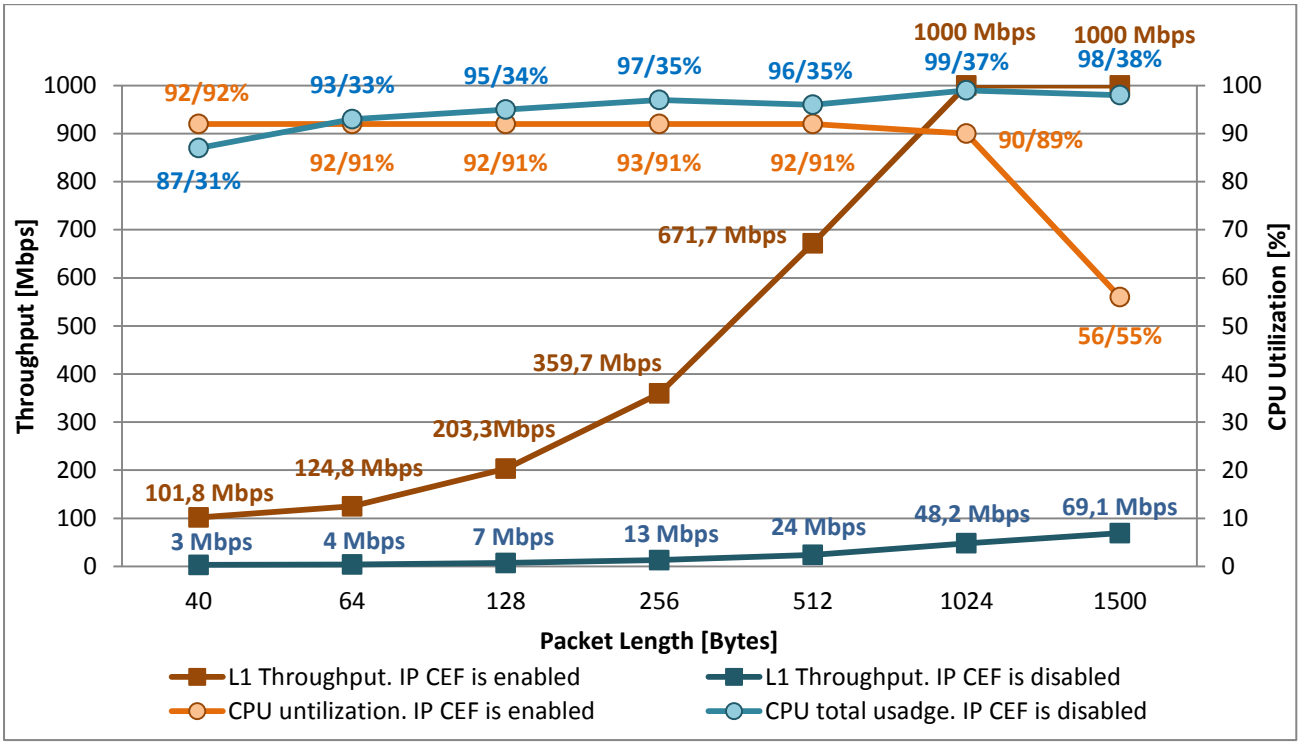
The Packets Rate for 256 Byte packets is 152921 packets per seconds, In this case L1 Rate value is 152921 [packets/s] x 294 [bytes on wire] x 8 [bits in byte] = 359,670192Mbps.

or

The Packets Rate for 1500 Byte packets is 81273 packets per seconds, In this case L1 Rate value is 81273 [packets/s] x 1538 [bytes on wire] x 8 [bits in byte] = 999,982992 Mbps.

Packet Length [Bytes]	1st variant, IP CEF is enabled				2nd variant, IP CEF is disabled			
	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec
40	101,8	92	92	151433	3,0	87	31	4465
64	124,8	92	91	152982	4,0	93	33	4902
128	203,3	92	91	153056	7,0	95	34	5274
256	359,7	92	91	152921	13,0	97	35	5537
512	671,7	92	91	152666	24,0	96	35	5455
1024	1000	90	89	117700	48,2	99	37	5674
1500	1000	56	55	81273	69,1	98	38	5612
random	400,0	66	65		15,0	72	26	

Table 2 Throughput and CPU utilization, Test #1, No service enabled or ACL, Flow Control is OFF.



Graph 1 Throughput and CPU utilization. Test #1. No service enabled or ACL, Flow Control is OFF.

If we compare results in the Table 1 and the Table 2, we can see that router generates 50-70 Mbps traffic of Pause Frames.

Test #2

Cisco 1921 switching performance in the case with single ACL line.

The router configured with the IP address, single ACL line, no additional service enabled. Router works as gateway between two subnets. Test type: Layer 3 RFC2544.

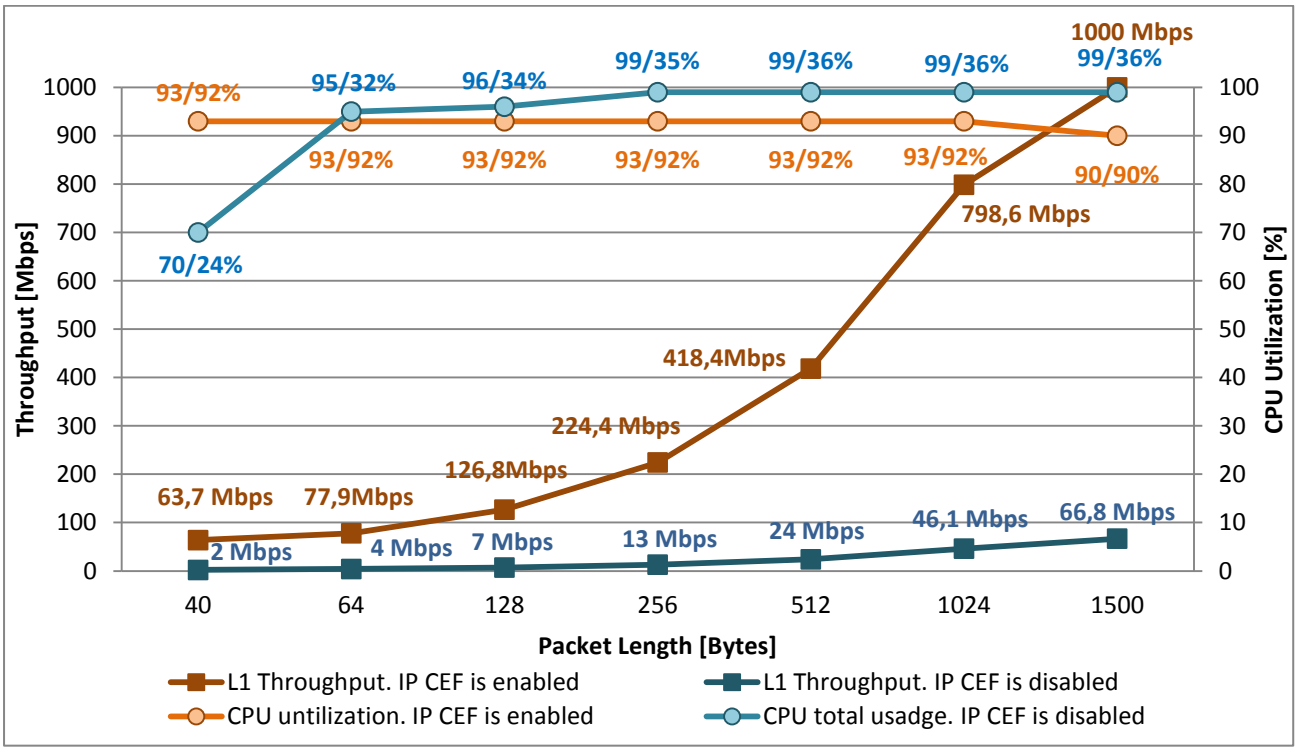
Part of R1 router configuration is presented below:

```
interface Gi0/0
 ip address 192.168.2.1 255.255.255.0
 ip access-group 100 in
access-list 100 permit ip host 192.168.2.2 host 192.168.3.2
```

Test results are present in the Table 3 and on the Graph 2.

Packet Length [Bytes]	IP CEF is enabled				2nd variant, IP CEF is disabled			
	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec
40	63,7	93	92	94839	2,0	70	24	2995
64	77,9	93	92	95516	4,0	95	32	4902
128	126,8	93	92	95511	7,0	96	34	5272
256	224,4	93	92	95408	13,0	99	35	5535
512	418,4	93	92	95096	24,0	99	36	5458
1024	798,6	93	92	93999	46,1	99	36	5429
1500	1000	90	90	81273	66,8	99	36	5429
random	250,0	66	65		15,0	73	25	

Table 3 Throughput and CPU utilization. Test #2 with a single ACL line. Flow Control is OFF.



Graph 2 Throughput and CPU utilization. Test #2 with a single ACL line. Flow Control is OFF.

Test #3

Cisco 1921 switching performance in the case of two ACL lines.

New ACL rules are added into the configuration. The router configured with the IP address, with ACL lines, no additional service enabled. Router works as gateway between two subnets.
Test type: Layer 3 RFC2544.

Part of R1 router configuration is presented below:

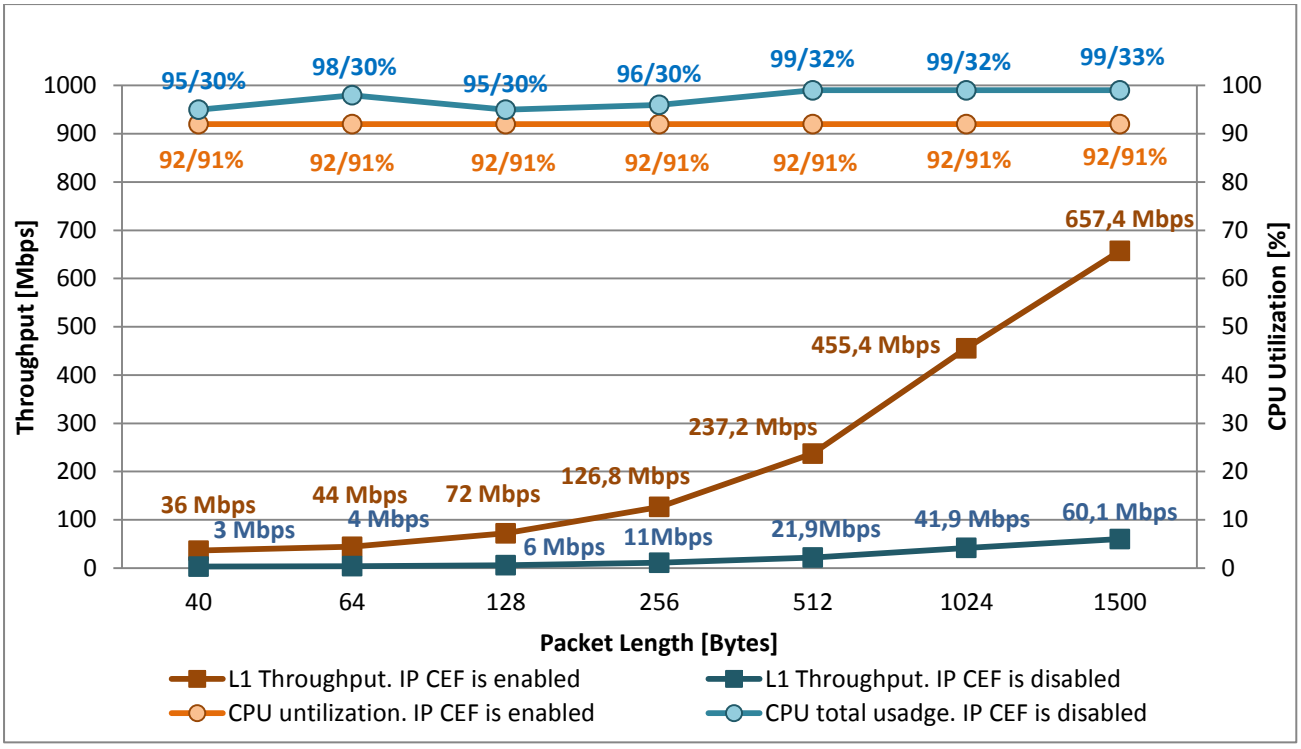
```
interface GigabitEthernet0/1
 ip address 192.168.3.1 255.255.255.0
 ip access-group 100 in
 ip access-group 100 out
interface GigabitEthernet0/0
 ip address 192.168.2.1 255.255.255.0
 ip access-group 100 in
 ip access-group 100 out

access-list 100 permit ip host 192.168.2.2 host 192.168.3.2
access-list 100 permit ip host 192.168.3.2 host 192.168.2.2
```

CPU checks ACL lines 6 times for each packet, 2 times for a forward path and 4 times for a return path. Test results are present in the Table 4 and on the Graph 3.

Packet Length [Bytes]	IP CEF is enabled				2nd variant, IP CEF is disabled			
	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec
40	36,0	92	91	53638	3,0	95	30	4465
64	44,0	92	91	53929	4,0	98	30	4907
128	72,0	92	91	53933	6,0	95	30	4519
256	126,8	92	91	53908	11,0	96	30	4677
512	237,2	92	91	53902	21,9	99	32	4986
1024	455,4	92	91	53597	41,9	99	32	4928
1500	657,4	92	91	53432	60,1	99	33	4884
random	150	69	68		13,0	72	23	

Table 4 Throughput and CPU utilization. Test #3 with 2 ACL lines. Flow Control is OFF.



Graph 3 Throughput and CPU utilization. Test #3 with 2 ACL lines. Flow Control is OFF.

Test #4

Cisco 1921 switching performance in the case of 12 ACL lines,

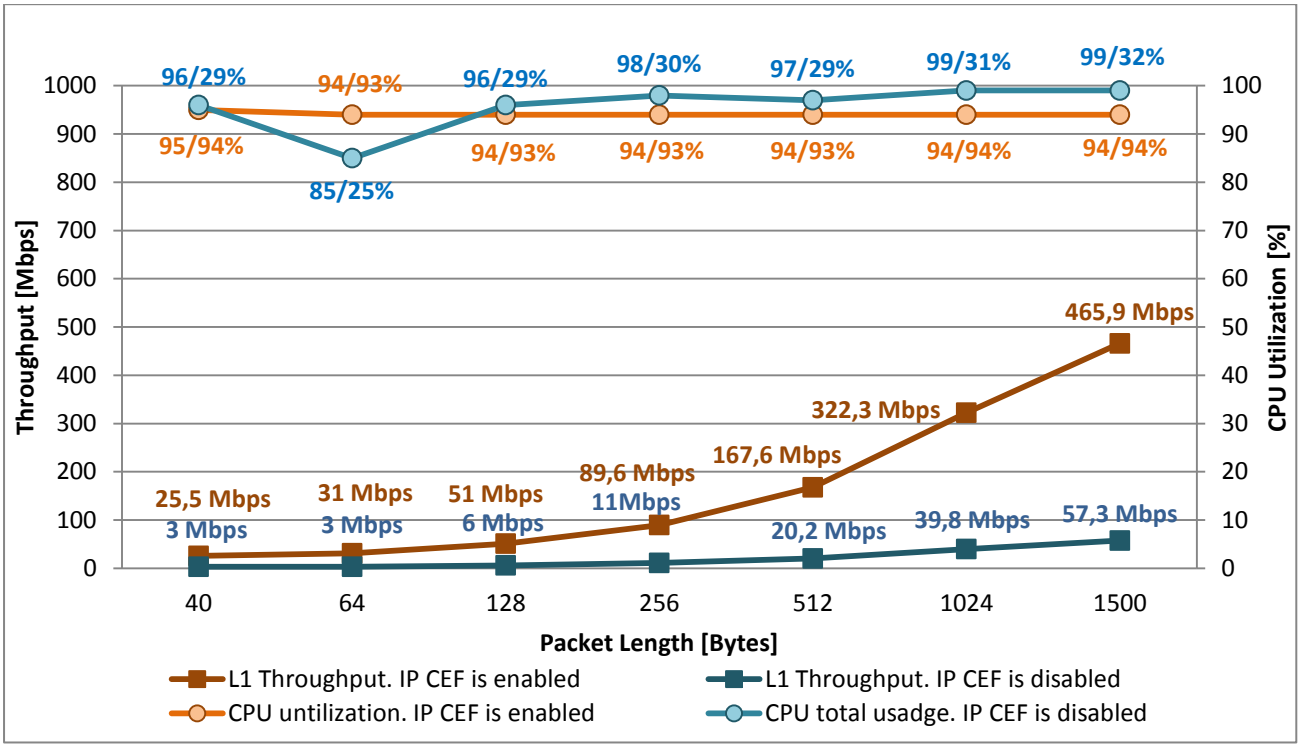
New ACL rules are added into the configuration, Additional 10 lines with non-existent IP address do additional checking for each packet, The CPU checks ACL lines 46 times for each packet, 22 times for a forward path and 24 times for a return path,

```
R1(config)#access-list 100 permit ip host 192.150.2.2 host 192.168.3.2
R1(config)#access-list 100 permit ip host 192.150.2.2 host 192.168.2.2
R1(config)#access-list 100 permit ip host 192.152.2.2 host 192.168.3.2
R1(config)#access-list 100 permit ip host 192.153.3.2 host 192.168.2.2
R1(config)#access-list 100 permit ip host 192.154.2.2 host 192.168.3.2
R1(config)#access-list 100 permit ip host 192.155.3.2 host 192.168.2.2
R1(config)#access-list 100 permit ip host 192.156.2.2 host 192.168.3.2
R1(config)#access-list 100 permit ip host 192.157.3.2 host 192.168.2.2
R1(config)#access-list 100 permit ip host 192.158.2.2 host 192.168.3.2
R1(config)#access-list 100 permit ip host 192.159.3.2 host 192.168.2.2
R1(config)#access-list 100 permit ip host 192.168.2.2 host 192.168.3.2     <----- real IP addresses
R1(config)#access-list 100 permit ip host 192.168.3.2 host 192.168.2.2     <----- real IP addresses
```

Test results are present in the Table 5 and on the Graph 4.

Packet Length [Bytes]	IP CEF is enabled				2nd variant, IP CEF is disabled			
	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec	Measured L1 Rate [Mbps]	CPU total usage [%]	CPU usage caused by traffic [%]	Measured Rate packets/sec
40	25,5	95	94	38004	3,0	96	29	4466
64	31,0	94	93	38006	3,0	85	25	3677
128	51,0	94	93	38111	6,0	96	29	4519
256	89,6	94	93	38103	11,0	98	30	4689
512	167,6	94	93	38090	20,2	97	29	4581
1024	322,3	94	94	37938	39,8	99	31	4682
1500	465,9	94	94	37865	57,3	99	32	4659
random	100	69	67		13,0	74	22	

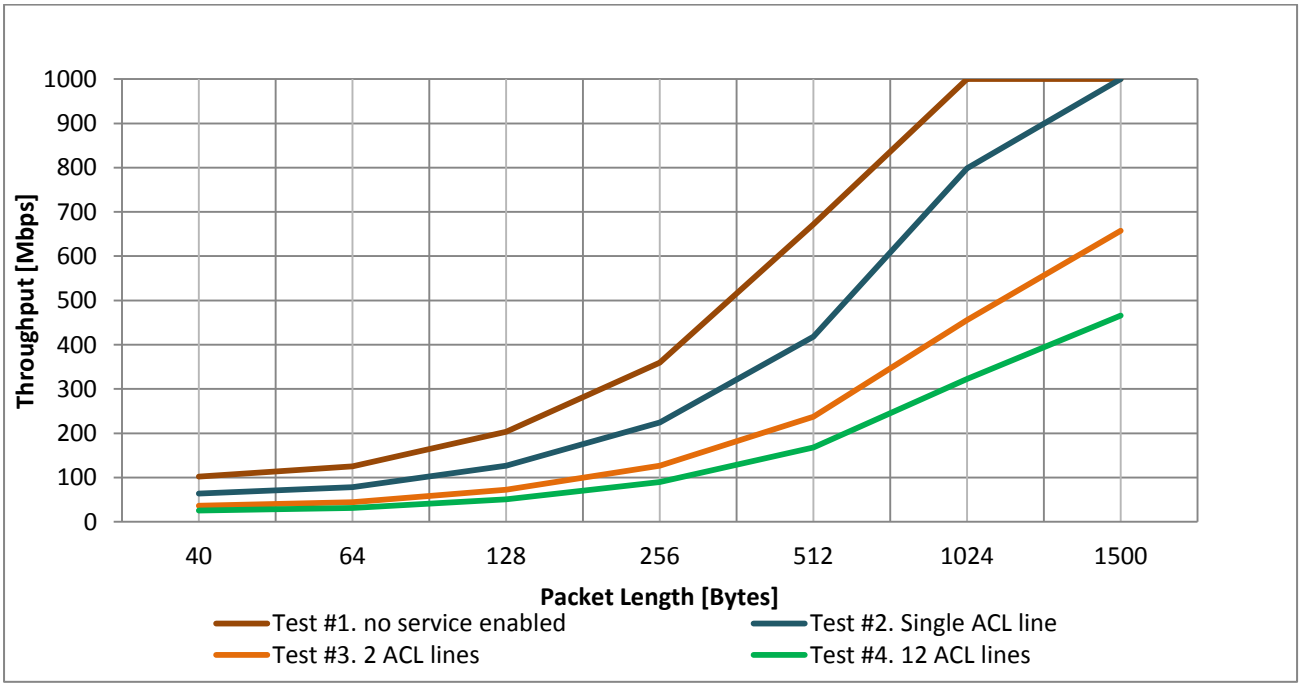
Table 5 Throughput and CPU utilization. Test #4 with 12 ACL lines. Flow Control is OFF



Graph 4 Throughput and CPU utilization. Test #4 with 12 ACL lines. Flow Control is OFF

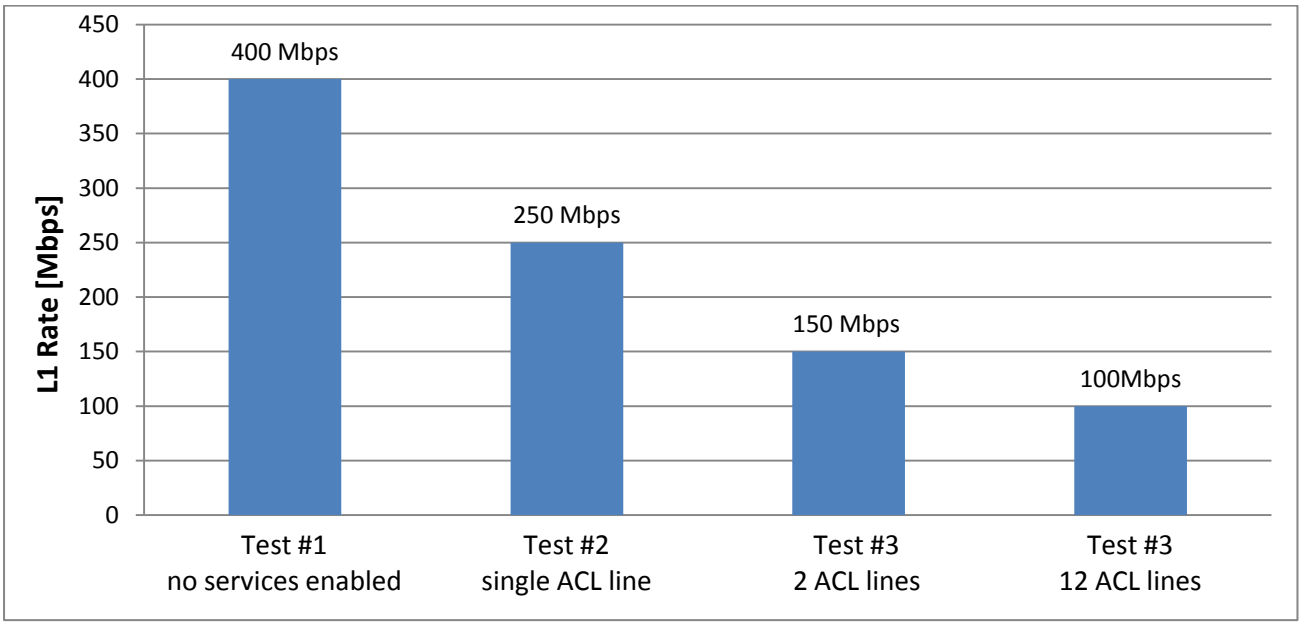
Summary

The Graph 5 is summary graph for different tests. It shows how the Cisco 1921 performance degrades with increasing load on the processor.



Graph 5 Test summary performance graph

The Graph 6 shows router performance for random packets, this gives more close result to a real throughput.



Graph 6 Cisco 1921 switching performance with random packet size.