TCP - Tahoe, Reno, NewReno, SACK

TCP Tahoe

Tahoe variant of TCP consider duplicate ACKs are packet lost event. Once sender receive 3 duplicate ACKs which means 4 ACKs for one packet, Tahoe start fast retransmit (it does not wait to retransmission timer to expire), sets slow start threshold to half of the current congestion window size, reduce the congestion window to 1 and reset to slow start.

Once it rech the slow start threshold, with every ACK received it increase the congestion window size by one.

TCP Reno

Reno variant of TCP use Fast Recovery, Fact Recovery assume that each ACK received represents a single packet sent, using this assumption sender can estimate the amount of outstanding data.

Like Tahoe, Reno also use duplicate ACKs threshold, if sender receive 3 dupliate ACKs, it perform the fast retransmit and unlike Tahoe skip the slow start.

TCP New Reno

TCP New Reno is similar to Reno in case on single packet drop, difference is when multiple packets are dropped from a window. During fast recovery, if partial ack is received for few of the packets, Reno takes out TCP from Fast Recovery mode. However, new reno does not out TCP out from Fast Recovery and treat it as indicator that the packet having sequence after ack is lost. Therefore, new reno retransmit one lost packet per rount trip until all lost packet in that window is delivered.

New Reno is moved out of Fast Recovery, if it receive ack for all the outstanding packets.

TCP SACK

During Fast Recovery, SACK maintain a variable called pipe. Pipe estimates the outstanding number of packets in the path. If the number of packets in the path is less than congestion window size then only sender transmit new or retransmit data. Pipe is incremented by one if sender sent one or retramit a packet. It decrement by one if sender receive duplicate acks.

Simulation

For simulation, I have used ns2 script.

Network Topology

```
Create the following topology:
         node 0
           \
   8Mb,.1ms \
             \
     8Mb,.1ms \       0.8Mb,100ms
node 1 ------node 3 --------- node 4
              /
             /
   8Mb,.1ms /
           /
         node 2
```

As shown in above figure, network has 5 nodes `node0, node1, node2, node3 and node4`

Capacity and delay

- node0 to node3 has 8Mb capacity and 0.1ms of delay
- node1 to node3 has 8Mb capacity and 0.1ms of delay
- node2 to node3 has 8Mb capacity and 0.1ms of delay
- node3 to node4 has 0.8Mb capacity and 100ms of delay

DropTail:

Drop tail is used for queue buffer. Drop tail is the simple queueing mechanis used by the router to determine when to drop packet. In this scenario, each packet is treated as identical and when queue is full to its maximum capacity new packet is dropped, until when queue has enough space for new packet

ns-script

In the script, three methods are implemented to simulate 1 packet drop, 2 packet drop and 3 packet drop scenarios.

Each source is made as FTP source and max packet is defined for the source to simulate packet drop scenarios.

Source-1 starts packet transfer at 1s timestamp and source-2 starts packet transfer at 1.2s timestamp and source-3 starts packet transfer at 1.18s timestamp.

Script will finish the simulation after 6 secs.

Script is identical for all the TCP variant only different is TCP implementation for source node and destination node as follows.

Tahoe

Tahoe is the classic TCP variant, here `Agent/TCP` is used for source and `Agent/TCPSink` is used for the destination nodes.

Reno

For Reno TCP, source is defined as `Agent/TCP/Reno` and destination node is same as Tahoe `Agent/TCPSink`

New Reno

For new reno TCP, source is defined as `Agent/TCP/Newreno` and destination node is same as Tahoe `Agent/TCPSink`

SACK

For SACK TCP, source is defined as `Agent/TCP/Sack1` and destination node is defined as `Agent/TCPSink/Sack1`

Execution

After the script is setup, I have saved 4 scripts based on the source and destination variant of TCP as mentioned above.

- tcp_drop_tahoe.tcl
- tcp_drop_reno.tcl
- tcp_drop_newreno.tcl
- tcp_drop_sack.tcl

To simulate Tahoe 1-packet drop execute the command `ns tcp_drop_tahoe.tcl 1`

To simulate Tahoe 2-packet drop execute the command `ns tcp_drop_tahoe.tcl 2`

To simulate Tahoe 3-packet drop execute the command `ns tcp_drop_tahoe.tcl 3`

To simulate Reno 1-packet drop execute the command `ns tcp_drop_reno.tcl 1`

To simulate Reno 2-packet drop execute the command `ns tcp_drop_reno.tcl 2`

To simulate Reno 3-packet drop execute the command `ns tcp_drop_reno.tcl 3`

To simulate NewReno 1-packet drop execute the command `ns tcp_drop_newreno.tcl 1`

To simulate NewReno 2-packet drop execute the command `ns tcp_drop_newreno.tcl 2`

To simulate NewReno 3-packet drop execute the command `ns tcp_drop_newreno.tcl 3`

To simulate SACK 1-packet drop execute the command `ns tcp_drop_sack.tcl 1`

To simulate SACK 2-packet drop execute the command `ns tcp_drop_sack.tcl 2`

To simulate SACK 3-packet drop execute the command `ns tcp_drop_sack.tcl 3`

After execution of the script, it generates `out.tr` file. This is the trace file contains logs about the packet transmission.

Each line in out.trace contains following information

- state of the packet
  - `r` : receive; packet is received at the destination node
  - `+` : enqueue; packet is enqueue in the queue buffer
  - `-` : dequeue; packet is dequeue from the queue buffer
  - `d` : drop; packet is dropped
- timestamp
- source node
- destination node
- type : if the packet is ***tcp*** or ***ack*** packet
- size : packet size
- flag information
- ip address of source node
- ip address of destination node

- packet sequence number
- packet id

Analysis

Below the script to extract information from the `out.tr` file and analyse the simulation

In [194]:

```
# import necessary libraries
import sys
import matplotlib.pyplot as plt
%matplotlib inline
```

In [195]:

```
# define consts

RECEIVE = 'r'
ENQUEUE = '+'
DEQUEUE = '-'
DROP = 'd'
```

In [196]:

```
# extract the information for the trace line
def process_trace(trace_line):
    tr_map = {}
    tr = trace_line.split(' ')

    tr_map['state'] = tr[0]
    tr_map['ts'] = tr[1]
    tr_map['from'] = tr[2]
    tr_map['to'] = tr[3]
    tr_map['type'] = tr[4]
    tr_map['size'] = tr[5]
    tr_map['from_ip'] = tr[8]
    tr_map['to_ip'] = tr[9]
    tr_map['seq_num'] = tr[10]
    tr_map['pkt_id'] = tr[11]

    return tr_map
```

In [197]:

```
# extract out information from all the log present in out.tr
def get_traces(filename):
    # open trace file
    trace_file = open(filename, "r")
    traces = []
    for trace in trace_file:
        tr = process_trace(trace.rstrip())
        traces.append(tr)
    return traces
```

Analysis

Total time simulation run : Total time the simulation is executed.

Total number of packets recevied by destination node (node-4) : Total number of packets received by destination node.

Packets per sec from node-3 to node-4 : Total number of packets received by destination per second ie total number of packet recieved by destination divided by total time run.

Total Data passed from node-3 to node-4 : Per packet size id 1040, therefore, total data passed is the number of packets multipled by 1040.

Data per sec : like packets per sec, this is total data passed divided by the total time run.

Packets from source (node-0) to destination (node-4) : Total packets through from source to destination.

Packets/sec from source (node-0) to destination (node-4) : Packets through from source to destination per second (divided by total time run).

Data from source (node-0) to destination (node-4) : Data passed through source to destination

Data per sec from source (node-0) to destination (node-4) : Data transmitted from source to destination per second.

Average delay from source (node-0) to destination (node-1) : It the difference between the time packet is enqueue in source node and received at the destination node.

Average Round Trip Time for a packet froms source (node-0) to destination (node-1) : It is the round trip time, time difference between the packet is enqueued in source and ack is received back to source node.

In [198]:

```
def total_through(trace_map):
    rec = {}
    enq = {}
    ack = {}

    for tr in trace_map:
        if (tr['state'] == RECEIVE and
            tr['from'] == '3' and
            tr['to'] == '4' and
            tr['type'] == 'tcp'):
            rec[tr['seq_num']] = float(tr['ts'])

        if (tr['state']==ENQUEUE and
            tr['from'] == '0' and
            tr['to'] == '3' and
            tr['type'] == 'tcp'):
            enq[tr['seq_num']]  = float(tr['ts'])

        if (tr['state']==RECEIVE and
            tr['from'] == '3' and
            tr['to'] == '0' and
            tr['type'] == 'ack'):
            ack[tr['seq_num']] = float(tr['ts'])


    start_time = min(list(enq.values()))
    end_time = max(list(enq.values()) )

    total_time = end_time - start_time
    print('Total time simulation run : ', total_time)

    total_pkts = len(rec)
    print('Total number of packets recevied by destination node (node-4) : ', to
tal_pkts)
    print('Packets per sec from node-3 to node-4 : ', total_pkts/total_time)

    total_data = total_pkts * 1040 #size of one pkt
    print('Total Data passed from node-3 to node-4 : ', total_data)
    print('Data per sec : ', total_data/total_time)

    #totak pkts from node-0 to node-4
    total_pkts_node_0 = 0
    for pkt in enq:
        if pkt in rec:
            total_pkts_node_0 += 1

    print('Packets from source (node-0) to destination (node-4) : ', total_pkts_
node_0)
    print('Packets/sec from source (node-0) to destination (node-4) : ', total_p
kts_node_0/total_time)


    total_data_node_0 = total_pkts_node_0 * 1040
    print('Data from source (node-0) to destination (node-4) : ', total_data_nod
e_0)
    print('Data/sec from source (node-0) to destination (node-4) : ', total_data
_node_0/total_time)

    #avg delay from node-0 to node-4
```

```
    delay = 0
    delay_count = 0
    for pkt in enq:
        if pkt in rec:
            delay = delay + (rec[pkt] - enq[pkt])
            delay_count = delay_count + 1
    avg_delay = delay/delay_count
    print('Average delay from source (node-0) to destination (node-1) : ', avg_d
elay)

    #avg RTT for a packet from node-0 to node-4 and ack back to node-0
    rtt = 0
    rtt_count = 0
    for pkt in enq:
        if pkt in ack:
            rtt = rtt + (ack[pkt] - enq[pkt])
            rtt_count = rtt_count + 1
    avg_rtt = rtt/rtt_count
    print('Average Round Trip Time for a packet froms source (node-0) to destina
tion (node-1) : ', avg_rtt)

    return (total_pkts, total_pkts_node_0, avg_delay, avg_rtt)
```

Plot

Plot the summary of packet delay and packet drop

In [199]:

```
def plot(traces):
    plt.figure(figsize=(20,10))
    enq = {}
    ack = {}
    drop = {}

    for tr in traces:
        if (tr['state']==ENQUEUE and
            tr['from'] == '0' and
            tr['to'] == '3' and
            tr['type'] == 'tcp'):
            enq[tr['seq_num']]  = tr['ts']

        if (tr['state']==RECEIVE and
            tr['from'] == '3' and
            tr['to'] == '0' and
            tr['type'] == 'ack'):
            ack[tr['seq_num']] = tr['ts']

        if (tr['state']==DROP and
            tr['from'] == '3' and
            tr['to'] == '4' and
            tr['type'] == 'tcp'):
            drop[tr['seq_num']] = tr['ts']

    e_seq, e_ts = zip(*sorted(enq.items()))
    e_seq = [float(item)%50 for item in e_seq]
    e_ts = [float(item) for item in e_ts]

    a_seq, a_ts = zip(*sorted(ack.items()))
    a_seq = [float(item)%50 for item in a_seq]
    a_ts = [float(item) for item in a_ts]

    d_seq, d_ts = zip(*sorted(drop.items()))
    d_seq = [float(item)%50 for item in d_seq]
    d_ts = [float(item) for item in d_ts]

    plt.plot(e_ts, e_seq, 's', color='green', label='receive')
    plt.plot(a_ts, a_seq, '.', color='blue', label='ack')
    plt.plot(d_ts, d_seq, 'x', color='red', label='drop')

    plt.legend(loc='upper left')

    plt.show()
```

In [200]:

```
total_pkts = {'t': [0, 0, 0],
              'r' : [0, 0, 0],
              'n' : [0, 0, 0],
              's' : [0, 0, 0]}

pkts_src_dest = {'t': [0, 0, 0],
              'r' : [0, 0, 0],
              'n' : [0, 0, 0],
              's' : [0, 0, 0]}

avg_delay = {'t': [0, 0, 0],
              'r' : [0, 0, 0],
              'n' : [0, 0, 0],
              's' : [0, 0, 0]}

avg_rtt = {'t': [0, 0, 0],
              'r' : [0, 0, 0],
              'n' : [0, 0, 0],
              's' : [0, 0, 0]}
```

In [201]:

```
# read the tahoe one packet drop trace
tahoe_drop_1 = './tahoe/pkt_drop_1/out.tr'
traces_tahoe_drop_1 = get_traces(tahoe_drop_1)
```

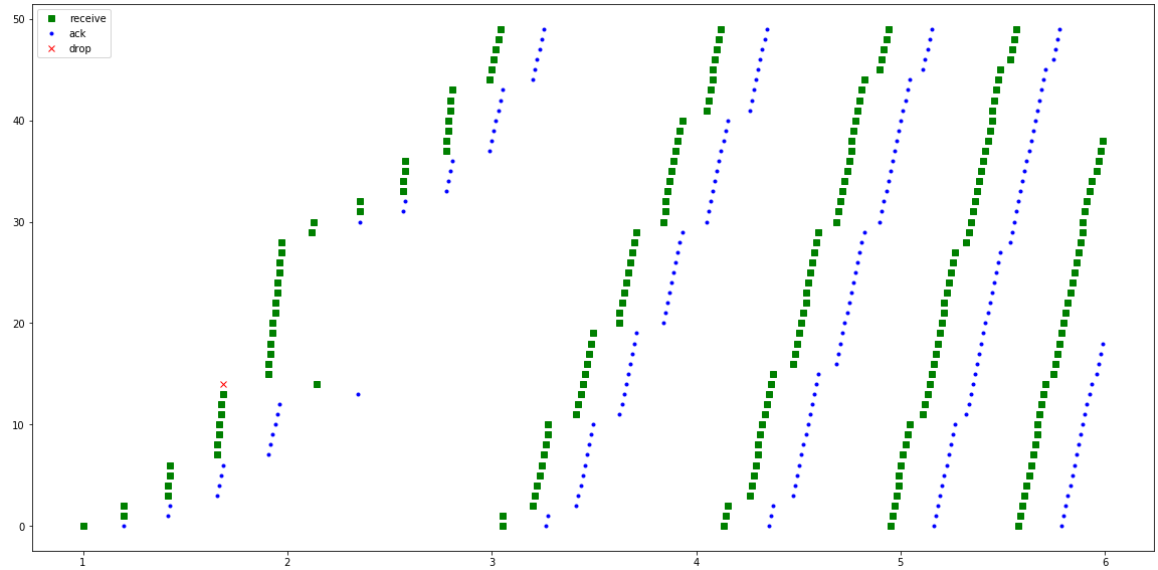
In [202]:

```
total_pkts['t'][0], pkts_src_dest['t'][0], avg_delay['t'][0], avg_rtt['t'][0] =
total_through(traces_tahoe_drop_1)
```

```
Total time simulation run :  4.98996
Total number of packets recevied by destination node (node-4) :  229
Packets per sec from node-3 to node-4 :  45.8921514400917
Total Data passed from node-3 to node-4 :  238160
Data per sec :  47727.83749769537
Packets from source (node-0) to destination (node-4) :  229
Packets/sec from source (node-0) to destination (node-4) :  45.89215
14400917
Data from source (node-0) to destination (node-4) :  238160
Data/sec from source (node-0) to destination (node-4) :  47727.83749
769537
Average delay from source (node-0) to destination (node-1) :  0.1305
211353711791
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.22135704433497547
```

In [203]:

```
plot(traces_tahoe_drop_1)
```



Tahoe two packets drop

In [204]:

```
# read the tahoe one packet drop trace
tahoe_drop_2 = './tahoe/pkt_drop_2/out.tr'
traces_tahoe_drop_2 = get_traces(tahoe_drop_2)
```

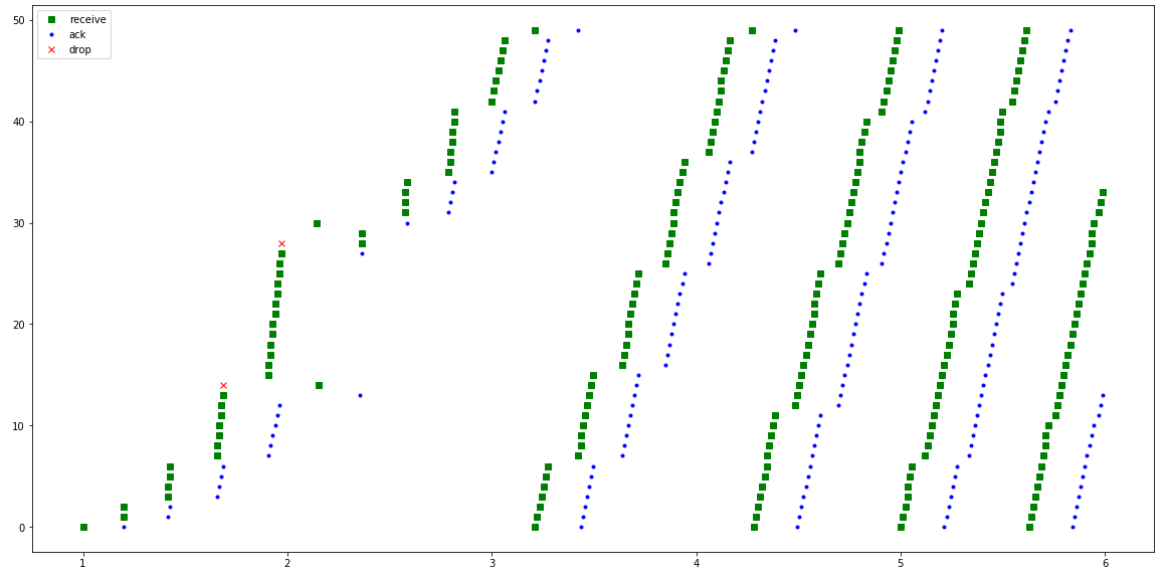
In [205]:

```
total_pkts['t'][1], pkts_src_dest['t'][1], avg_delay['t'][1], avg_rtt['t'][1] =
total_through(traces_tahoe_drop_2)
```

```
Total time simulation run :  4.98996
Total number of packets recevied by destination node (node-4) :  224
Packets per sec from node-3 to node-4 :  44.89013939991503
Total Data passed from node-3 to node-4 :  232960
Data per sec :  46685.74497591163
Packets from source (node-0) to destination (node-4) :  224
Packets/sec from source (node-0) to destination (node-4) :  44.89013
939991503
Data from source (node-0) to destination (node-4) :  232960
Data/sec from source (node-0) to destination (node-4) :  46685.74497
591163
Average delay from source (node-0) to destination (node-1) :  0.1305
7339285714278
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.2225252261306535
```

In [206]:

```
plot(traces_tahoe_drop_2)
```



Tahoe three packet drop

In [207]:

```
# read the tahoe one packet drop trace
tahoe_drop_3 = './tahoe/pkt_drop_3/out.tr'
traces_tahoe_drop_3 = get_traces(tahoe_drop_3)
```

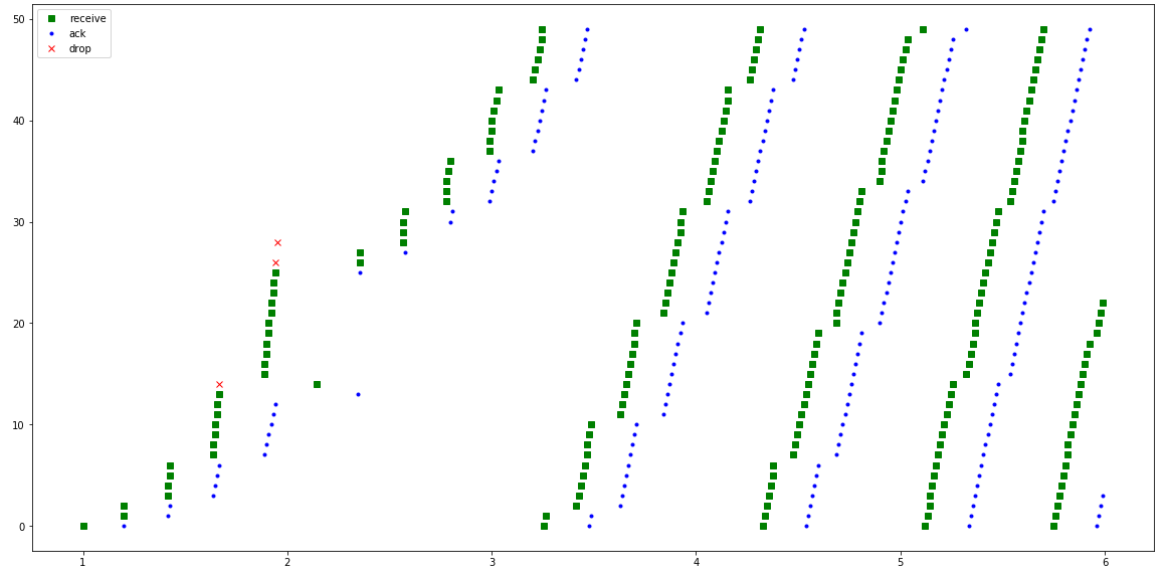
In [208]:

```
total_pkts['t'][2], pkts_src_dest['t'][2], avg_delay['t'][2], avg_rtt['t'][2] =
total_through(traces_tahoe_drop_3)
```

```
Total time simulation run :  4.99076
Total number of packets recevied by destination node (node-4) :  214
Packets per sec from node-3 to node-4 :  42.8792408370669
Total Data passed from node-3 to node-4 :  222560
Data per sec :  44594.41047054958
Packets from source (node-0) to destination (node-4) :  214
Packets/sec from source (node-0) to destination (node-4) :  42.87924
08370669
Data from source (node-0) to destination (node-4) :  222560
Data/sec from source (node-0) to destination (node-4) :  44594.41047
054958
Average delay from source (node-0) to destination (node-1) :  0.1328
927102803738
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.22301536842105252
```

In [209]:

```
plot(traces_tahoe_drop_3)
```



Reno one packet drop

In [210]:

```
# read the tahoe one packet drop trace
reno_drop_1 = './reno/pkt_drop_1/out.tr'
traces_reno_drop_1 = get_traces(reno_drop_1)
```

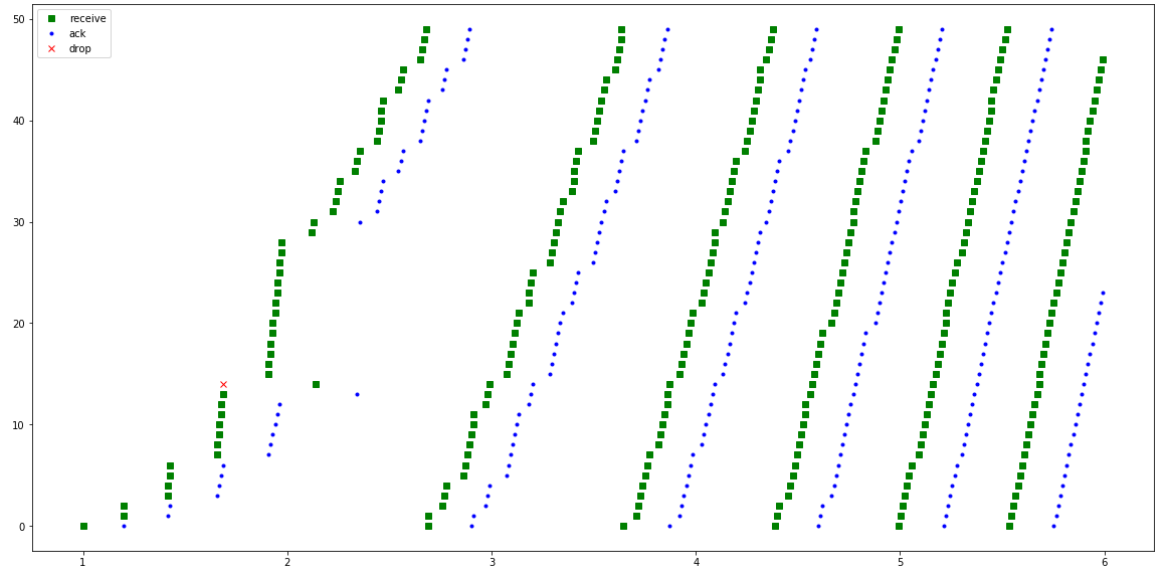
In [211]:

```
total_pkts['r'][0], pkts_src_dest['r'][0], avg_delay['r'][0], avg_rtt['r'][0] =
total_through(traces_reno_drop_1)
```

```
Total time simulation run :  4.9922
Total number of packets recevied by destination node (node-4) :  284
Packets per sec from node-3 to node-4 :  56.88874644445334
Total Data passed from node-3 to node-4 :  295360
Data per sec :  59164.29630223148
Packets from source (node-0) to destination (node-4) :  284
Packets/sec from source (node-0) to destination (node-4) :  56.88874
644445334
Data from source (node-0) to destination (node-4) :  295360
Data/sec from source (node-0) to destination (node-4) :  59164.29630
223148
Average delay from source (node-0) to destination (node-1) :  0.1266
5760563380257
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.21852480620155051
```

In [212]:

```
plot(traces_reno_drop_1)
```



Reno two packets drop

In [213]:

```
# read the tahoe one packet drop trace
reno_drop_2 = './reno/pkt_drop_2/out.tr'
traces_reno_drop_2 = get_traces(reno_drop_2)
```

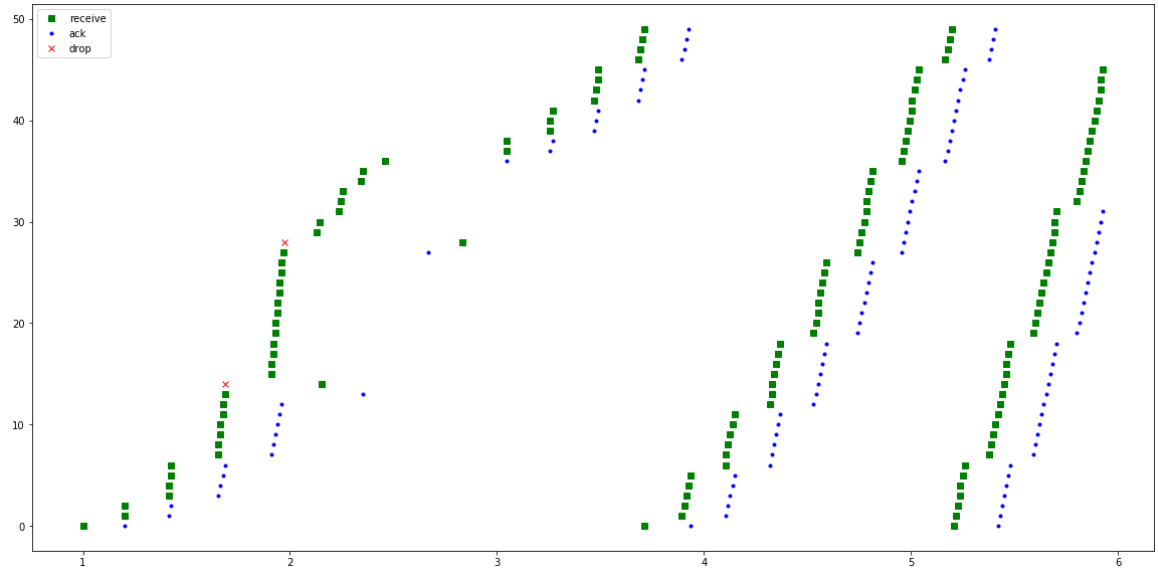
In [214]:

```
total_pkts['r'][1], pkts_src_dest['r'][1], avg_delay['r'][1], avg_rtt['r'][1] =
total_through(traces_reno_drop_2)
```

```
Total time simulation run :  4.92772
Total number of packets recevied by destination node (node-4) :  141
Packets per sec from node-3 to node-4 :  28.613638761942642
Total Data passed from node-3 to node-4 :  146640
Data per sec :  29758.184312420348
Packets from source (node-0) to destination (node-4) :  141
Packets/sec from source (node-0) to destination (node-4) :  28.61363
8761942642
Data from source (node-0) to destination (node-4) :  146640
Data/sec from source (node-0) to destination (node-4) :  29758.18431
2420348
Average delay from source (node-0) to destination (node-1) :  0.1393
4340425531908
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.23185477477477517
```

In [215]:

```
plot(traces_reno_drop_2)
```



Reno three packets drop

In [216]:

```
# read the tahoe one packet drop trace
reno_drop_3 = './reno/pkt_drop_3/out.tr'
traces_reno_drop_3 = get_traces(reno_drop_3)
```

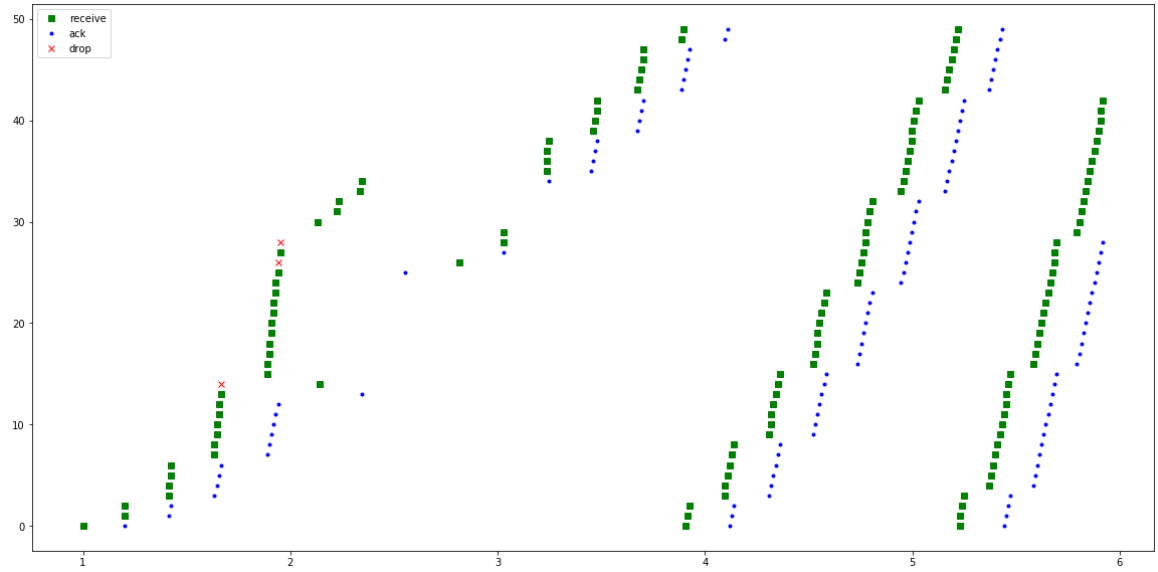
In [217]:

```
total_pkts['r'][2], pkts_src_dest['r'][2], avg_delay['r'][2], avg_rtt['r'][2] =
total_through(traces_reno_drop_3)
```

```
Total time simulation run :  4.91852
Total number of packets recevied by destination node (node-4) :  139
Packets per sec from node-3 to node-4 :  28.260533656465768
Total Data passed from node-3 to node-4 :  144560
Data per sec :  29390.955002724397
Packets from source (node-0) to destination (node-4) :  139
Packets/sec from source (node-0) to destination (node-4) :  28.26053
3656465768
Data from source (node-0) to destination (node-4) :  144560
Data/sec from source (node-0) to destination (node-4) :  29390.95500
2724397
Average delay from source (node-0) to destination (node-1) :  0.1402
240287769783
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.24129477477477515
```

In [218]:

```
plot(traces_reno_drop_3)
```



Newreno one packet drop

In [219]:

```
# read the tahoe one packet drop trace
newreno_drop_1 = './newreno/pkt_drop_1/out.tr'
traces_newreno_drop_1 = get_traces(newreno_drop_1)
```

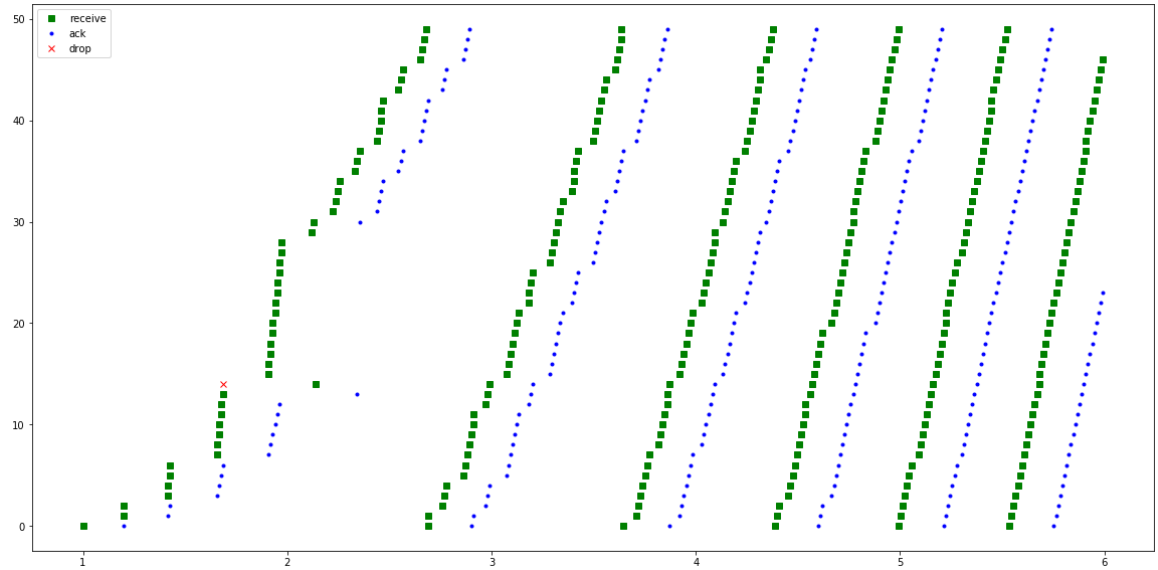
In [220]:

```
total_pkts['n'][0], pkts_src_dest['n'][0], avg_delay['n'][0], avg_rtt['n'][0] =
total_through(traces_newreno_drop_1)
```

```
Total time simulation run :  4.9922
Total number of packets recevied by destination node (node-4) :  284
Packets per sec from node-3 to node-4 :  56.88874644445334
Total Data passed from node-3 to node-4 :  295360
Data per sec :  59164.29630223148
Packets from source (node-0) to destination (node-4) :  284
Packets/sec from source (node-0) to destination (node-4) :  56.88874
644445334
Data from source (node-0) to destination (node-4) :  295360
Data/sec from source (node-0) to destination (node-4) :  59164.29630
223148
Average delay from source (node-0) to destination (node-1) :  0.1266
5760563380257
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.21852480620155051
```

In [221]:

```
plot(traces_newreno_drop_1)
```



Newreno two packets drop

In [222]:

```
# read the tahoe one packet drop trace
newreno_drop_2 = './newreno/pkt_drop_2/out.tr'
traces_newreno_drop_2 = get_traces(newreno_drop_2)
```

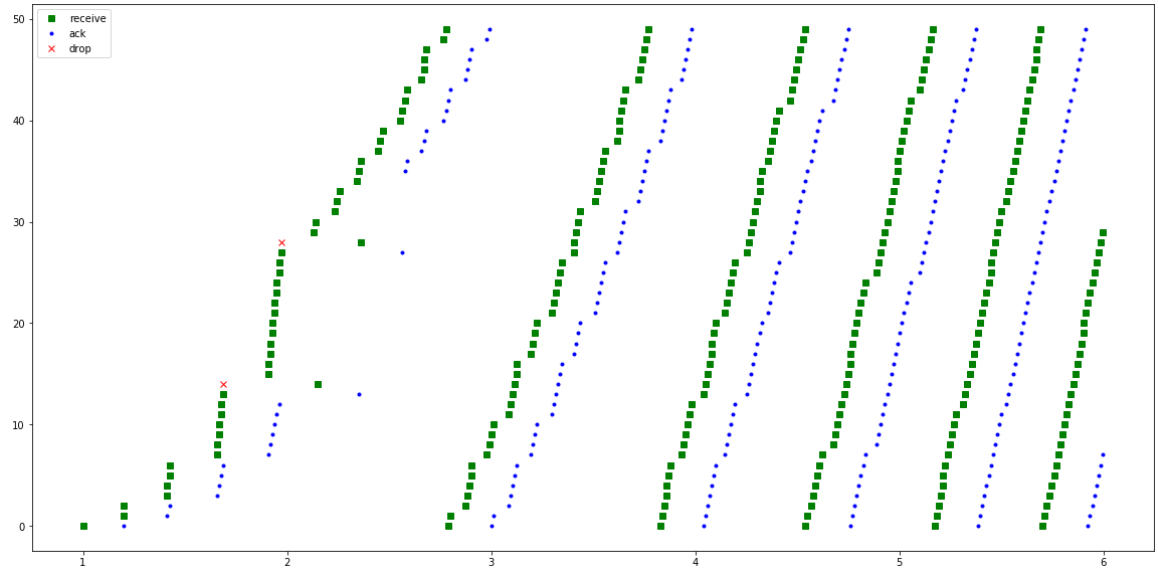
In [223]:

```
total_pkts['n'][1], pkts_src_dest['n'][1], avg_delay['n'][1], avg_rtt['n'][1] =
total_through(traces_newreno_drop_2)
```

```
Total time simulation run :  4.99628
Total number of packets recevied by destination node (node-4) :  268
Packets per sec from node-3 to node-4 :  53.63990809162017
Total Data passed from node-3 to node-4 :  278720
Data per sec :  55785.50441528497
Packets from source (node-0) to destination (node-4) :  268
Packets/sec from source (node-0) to destination (node-4) :  53.63990
809162017
Data from source (node-0) to destination (node-4) :  278720
Data/sec from source (node-0) to destination (node-4) :  55785.50441
528497
Average delay from source (node-0) to destination (node-1) :  0.1273
3656716417913
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.22037831932773103
```

In [224]:

```
plot(traces_newreno_drop_2)
```



Newreno 3 packets drop

In [225]:

```
# read the tahoe one packet drop trace
newreno_drop_3 = './newreno/pkt_drop_3/out.tr'
traces_newreno_drop_3 = get_traces(newreno_drop_3)
```

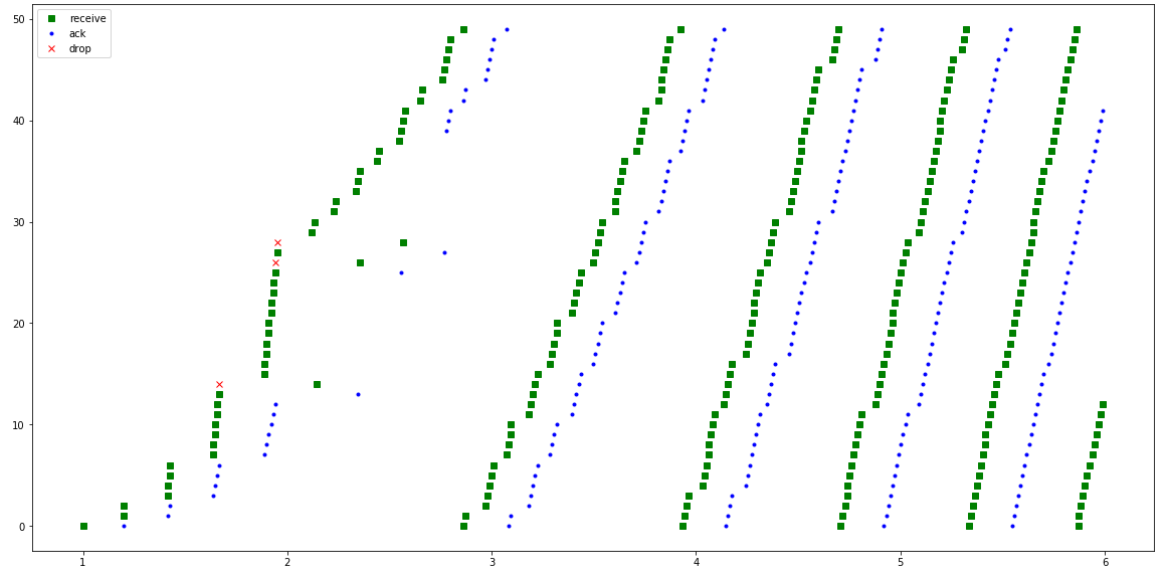
In [226]:

```
total_pkts['n'][2], pkts_src_dest['n'][2], avg_delay['n'][2], avg_rtt['n'][2] =
total_through(traces_newreno_drop_3)
```

```
Total time simulation run :  4.99076
Total number of packets recevied by destination node (node-4) :  252
Packets per sec from node-3 to node-4 :  50.49331163991056
Total Data passed from node-3 to node-4 :  262080
Data per sec :  52513.044105506975
Packets from source (node-0) to destination (node-4) :  252
Packets/sec from source (node-0) to destination (node-4) :  50.49331
163991056
Data from source (node-0) to destination (node-4) :  262080
Data/sec from source (node-0) to destination (node-4) :  52513.04410
5506975
Average delay from source (node-0) to destination (node-1) :  0.1284
3476190476177
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.22377881278538808
```

In [227]:

```
plot(traces_newreno_drop_3)
```



SACK 1 packet drop

In [228]:

```
# read the tahoe one packet drop trace
sack_drop_1 = './sack/pkt_drop_1/out.tr'
traces_sack_drop_1 = get_traces(sack_drop_1)
```

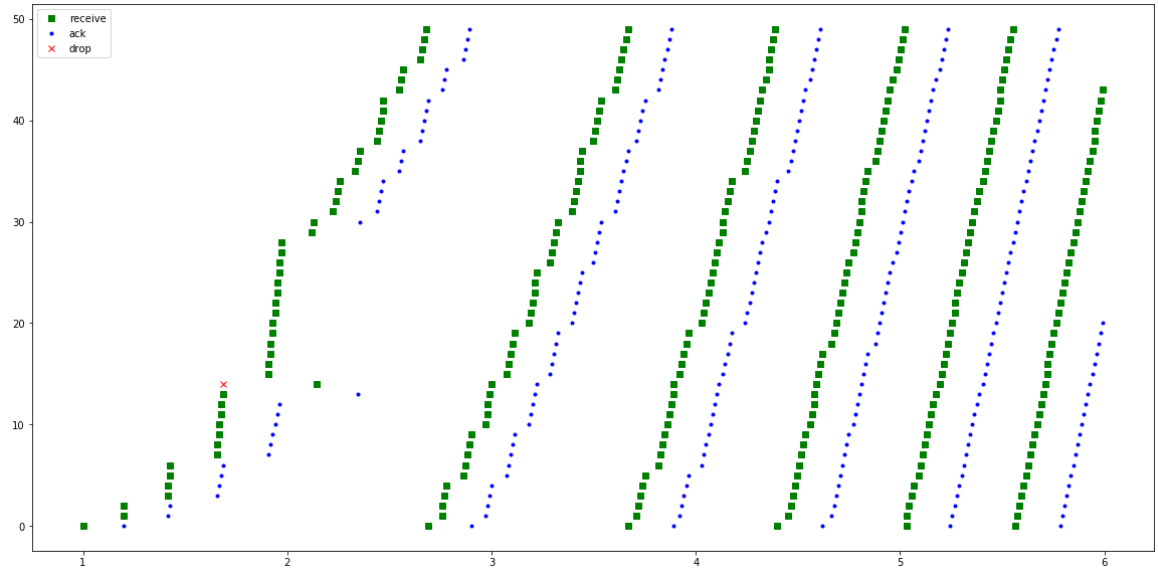
In [229]:

```
total_pkts['s'][0], pkts_src_dest['s'][0], avg_delay['s'][0], avg_rtt['s'][0] =
total_through(traces_sack_drop_1)
```

```
Total time simulation run :  4.992288
Total number of packets recevied by destination node (node-4) :  281
Packets per sec from node-3 to node-4 :  56.28681678621105
Total Data passed from node-3 to node-4 :  292240
Data per sec :  58538.28945765949
Packets from source (node-0) to destination (node-4) :  281
Packets/sec from source (node-0) to destination (node-4) :  56.28681
678621105
Data from source (node-0) to destination (node-4) :  292240
Data/sec from source (node-0) to destination (node-4) :  58538.28945
765949
Average delay from source (node-0) to destination (node-1) :  0.1269
4204982206392
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.21873690980392155
```

In [230]:

```
plot(traces_sack_drop_1)
```



SACK 2-packets drop

In [231]:

```
# read the tahoe one packet drop trace
sack_drop_2 = './sack/pkt_drop_2/out.tr'
traces_sack_drop_2 = get_traces(sack_drop_2)
```

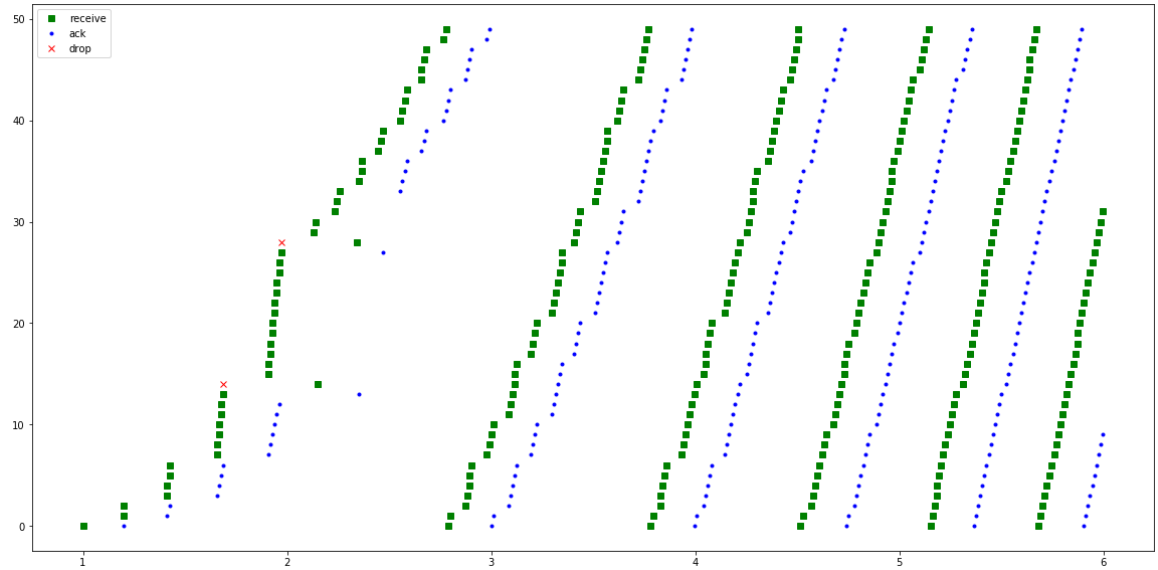
In [232]:

```
total_pkts['s'][1], pkts_src_dest['s'][1], avg_delay['s'][1], avg_rtt['s'][1] =
total_through(traces_sack_drop_2)
```

```
Total time simulation run :  4.996544
Total number of packets recevied by destination node (node-4) :  269
Packets per sec from node-3 to node-4 :  53.837212281128714
Total Data passed from node-3 to node-4 :  279760
Data per sec :  55990.700772373864
Packets from source (node-0) to destination (node-4) :  269
Packets/sec from source (node-0) to destination (node-4) :  53.83721
2281128714
Data from source (node-0) to destination (node-4) :  279760
Data/sec from source (node-0) to destination (node-4) :  55990.70077
2373864
Average delay from source (node-0) to destination (node-1) :  0.1272
5762081784384
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.22016138842975194
```

In [233]:

```
plot(traces_sack_drop_2)
```



SACK 3-packets drop

In [234]:

```
# read the tahoe one packet drop trace
sack_drop_3 = './sack/pkt_drop_3/out.tr'
traces_sack_drop_3 = get_traces(sack_drop_3)
```

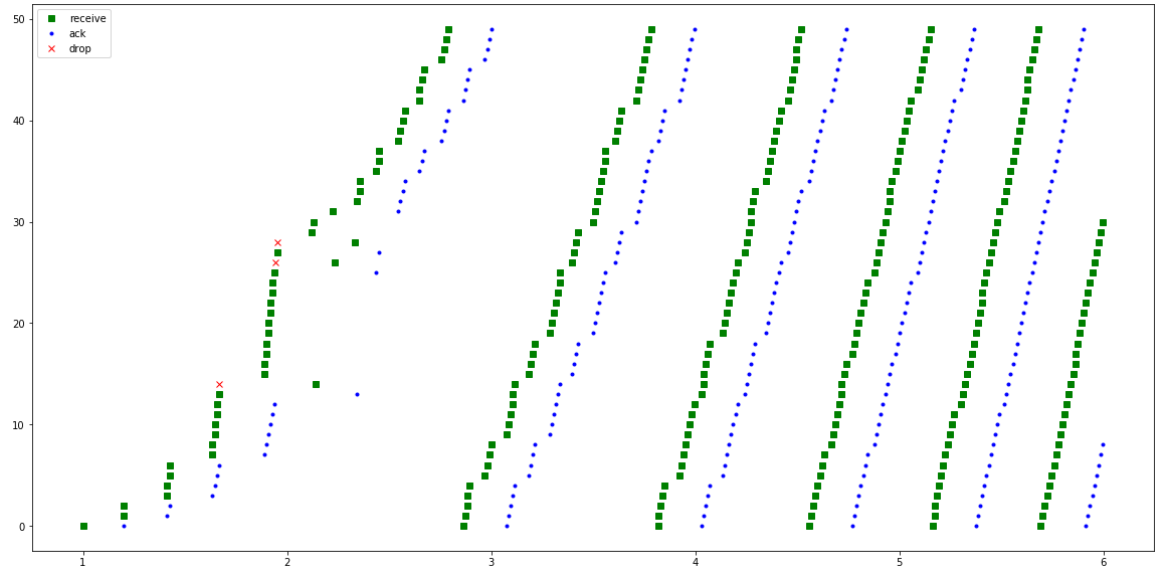
In [235]:

```
total_pkts['s'][2], pkts_src_dest['s'][2], avg_delay['s'][2], avg_rtt['s'][2] =
total_through(traces_sack_drop_3)
```

```
Total time simulation run :  4.997432
Total number of packets recevied by destination node (node-4) :  268
Packets per sec from node-3 to node-4 :  53.62754310613931
Total Data passed from node-3 to node-4 :  278720
Data per sec :  55772.64483038489
Packets from source (node-0) to destination (node-4) :  268
Packets/sec from source (node-0) to destination (node-4) :  53.62754
310613931
Data from source (node-0) to destination (node-4) :  278720
Data/sec from source (node-0) to destination (node-4) :  55772.64483
038489
Average delay from source (node-0) to destination (node-1) :  0.1275
5029850746258
Average Round Trip Time for a packet froms source (node-0) to destin
ation (node-1) :  0.2211333770491802
```

In [236]:

```
plot(traces_sack_drop_3)
```



Summary

Tahoe shows degrading throughput for multiple packet drop.

Reno shows better performance than Tahoe but it show bad performance in case of multiple packet lost

New Reno recovers fast then Reno but in case of partial ACK it shows bad recovery.

SACK performs better in case of partial ack

Total Packets through

Below graph shows the number of packet through for 1-pkt drop, 2-pkt drop and 3-pkt drop scenarios.

As can be seen, Reno does bad job in 2-pkt and 3-pkt drop scenario and sack is doing good for multiple packet lost or parital ack scenario

In [237]:

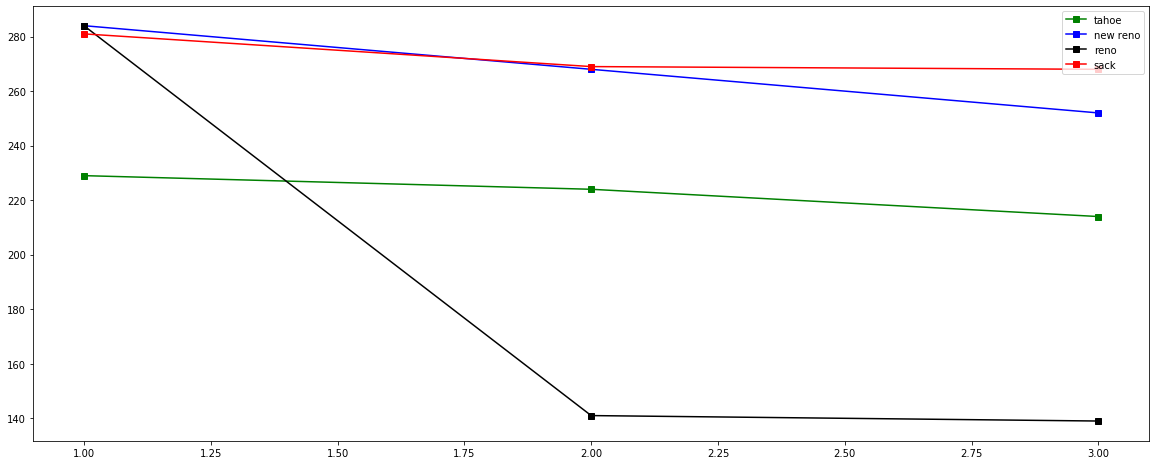
```
plt.figure(figsize=(20,8))

scnearios = [1, 2, 3]

plt.plot(scnearios, pkts_src_dest['t'], '-s', color='green', label='tahoe')
plt.plot(scnearios, pkts_src_dest['n'], '-s', color='blue', label='new reno')
plt.plot(scnearios, pkts_src_dest['r'], '-s', color='black', label='reno')
plt.plot(scnearios, pkts_src_dest['s'], '-s', color='red', label='sack')

plt.legend(loc='upper right')

plt.show()
```



Average delay

Again as can be seen Reno is doing bad in case of partial ack or multiple packets drop. However SACK is doing good beacuse of pipe data structure in case of multiple packets drop, New Reno is also keeping well with SACK but lagged bit in cause of paritial ack.

In [238]:

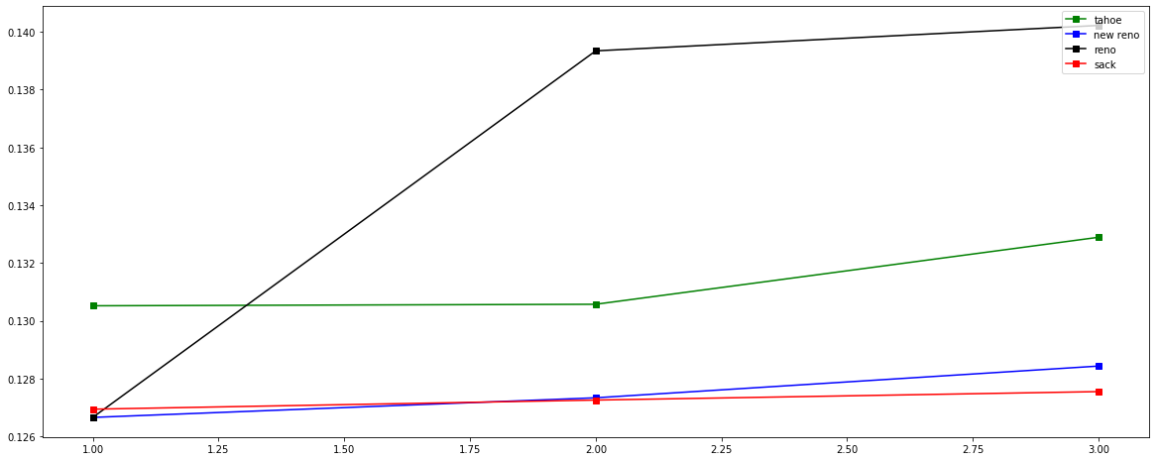
```
plt.figure(figsize=(20,8))

scnearios = [1, 2, 3]

plt.plot(scnearios, avg_delay['t'], '-s', color='green', label='tahoe')
plt.plot(scnearios, avg_delay['n'], '-s', color='blue', label='new reno')
plt.plot(scnearios, avg_delay['r'], '-s', color='black', label='reno')
plt.plot(scnearios, avg_delay['s'], '-s', color='red', label='sack')

plt.legend(loc='upper right')

plt.show()
```



Average round trip time

SACK is doing good in case for 3-pkts drop. Reno is doing bad in average round trip time.

In [239]:

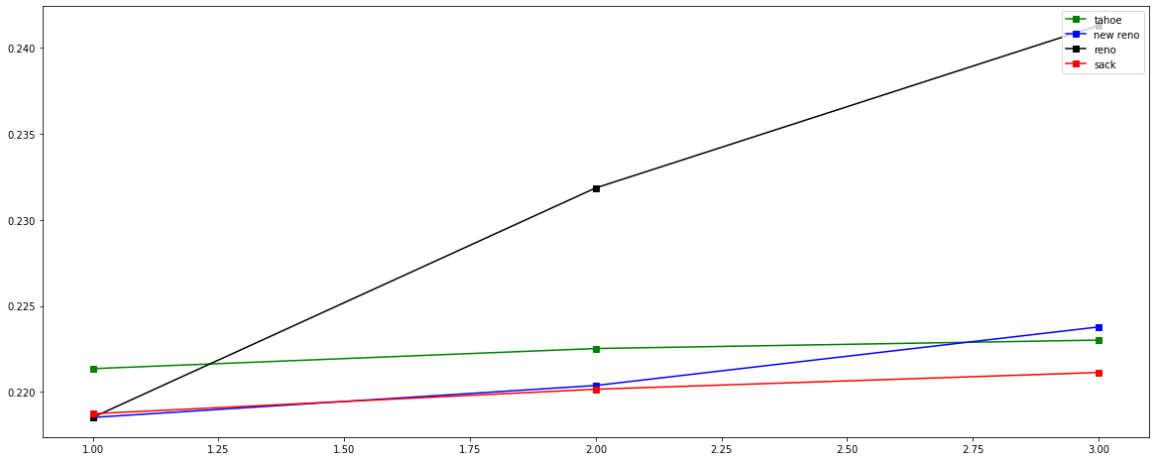
```
plt.figure(figsize=(20,8))

scnearios = [1, 2, 3]

plt.plot(scnearios, avg_rtt['t'], '-s', color='green', label='tahoe')
plt.plot(scnearios, avg_rtt['n'], '-s', color='blue', label='new reno')
plt.plot(scnearios, avg_rtt['r'], '-s', color='black', label='reno')
plt.plot(scnearios, avg_rtt['s'], '-s', color='red', label='sack')

plt.legend(loc='upper right')

plt.show()
```



ref : http://user.it.uu.se/~perg/course/datakom2/it98/tcpsims_lab.html (http://user.it.uu.se/~perg/course/datakom2/it98/tcpsims_lab.html)