MikroTik RouterOS Workshop

Lets talk about QoS

Las Vegas

MUM USA 2011

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About Me

- Jānis Meģis, MikroTik
- Jānis (Tehnical, Trainer, NOT Sales)
  - Support & Training Engineer for almost 7 years
  - Specialization: QoS, PPP, Firewall, Routing
  - Teaching MikroTik RouterOS classes since 2005

Workshop Plan

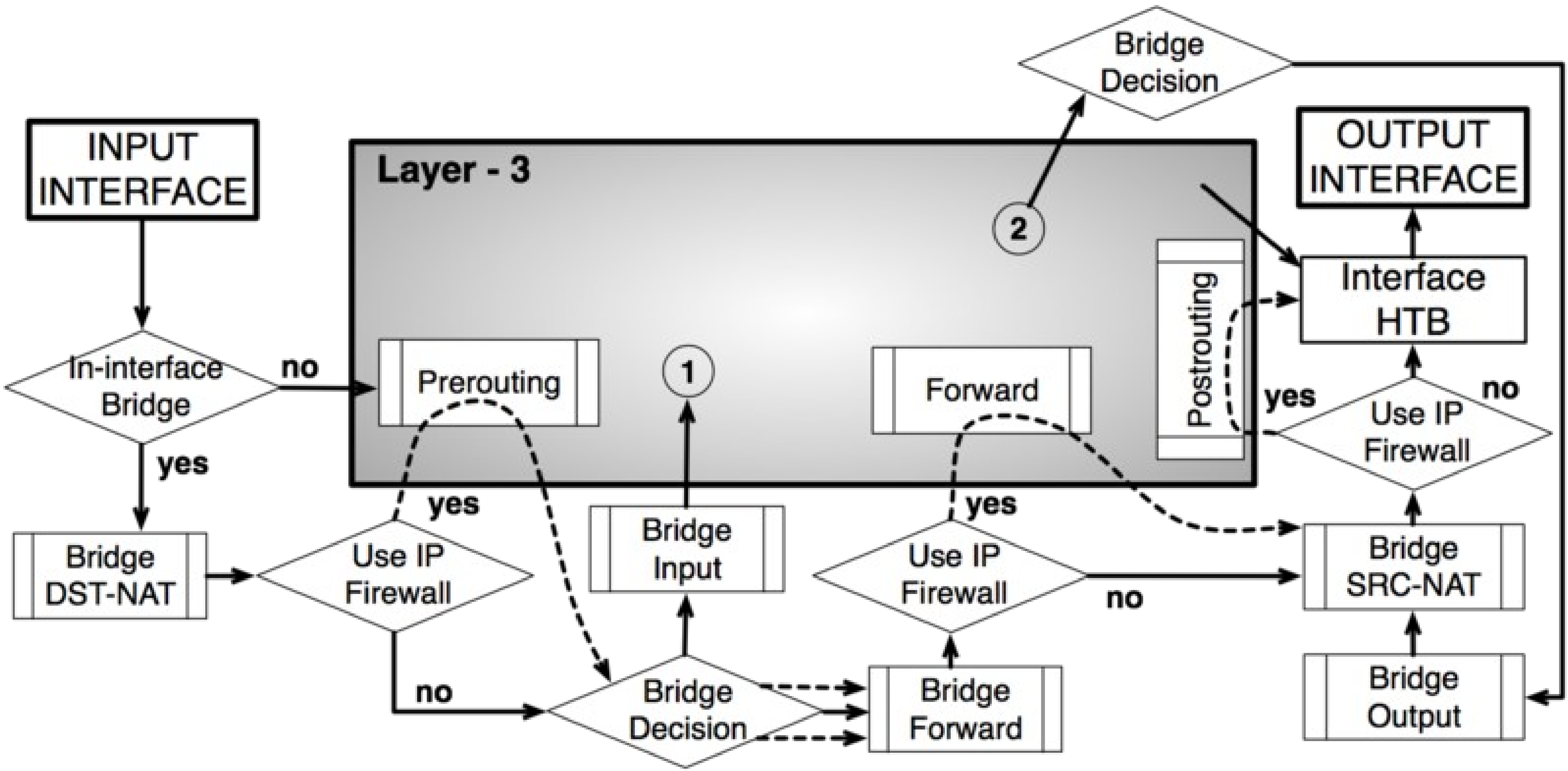
- Packet Flow Diagram
- HTB
- Queue Types (PCQ, multi-queue-fifo)
- Burst
- Queue Size
- Queue tree and Simple queues

Packet Flow Diagram

Packet Flow Diagram

- Packet flow diagram is “The Big Picture” of RouterOS
- It is impossible to properly manage and maintain complex configurations without the knowledge - what happens when and why?
- Packet flow Diagram consist of 2 parts
  - Bridging or Layer-2 (MAC) where Routing part is simplified to one "Layer-3" box
  - Routing or Layer-3 (IP) where Bridging part is simplified to one "Bridging" box

Bridging or Layer-2 (MAC)



Routing or Layer-3 (IP)

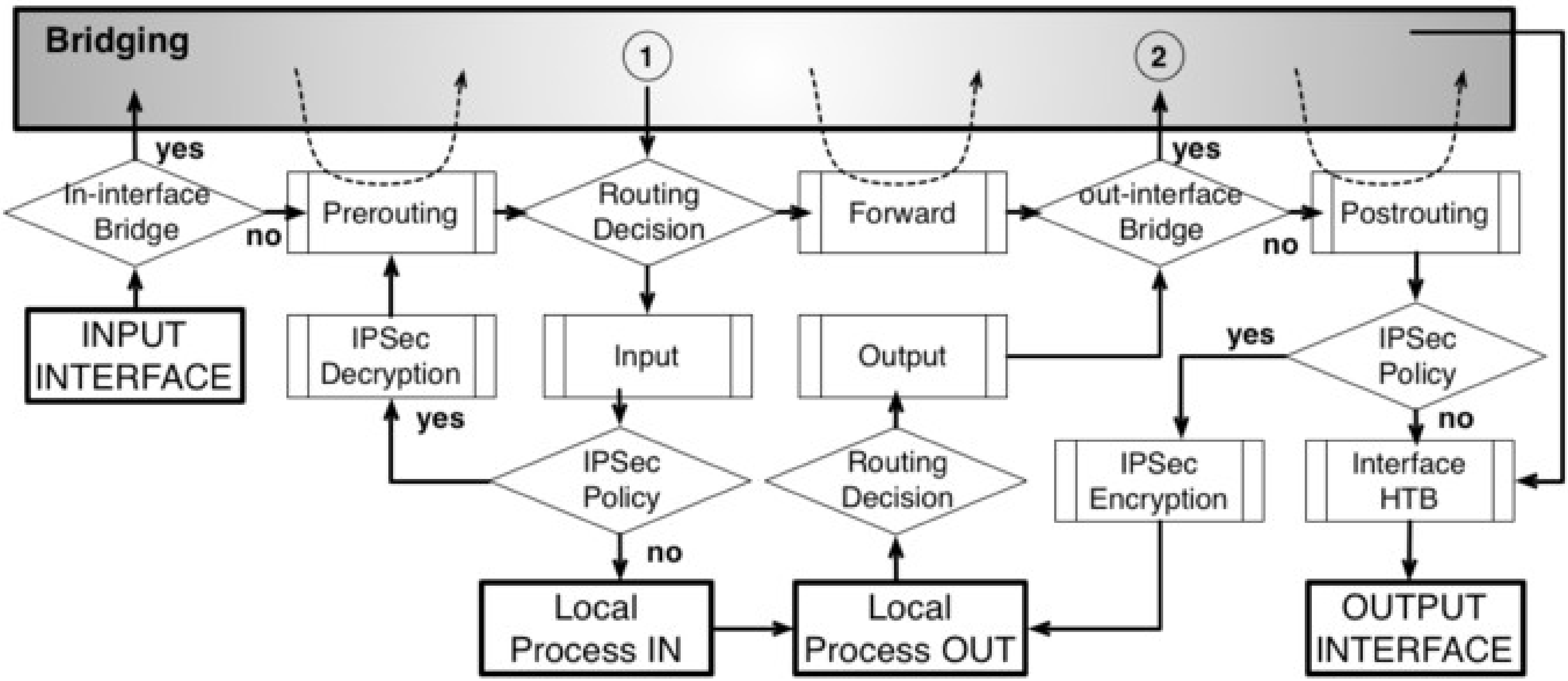
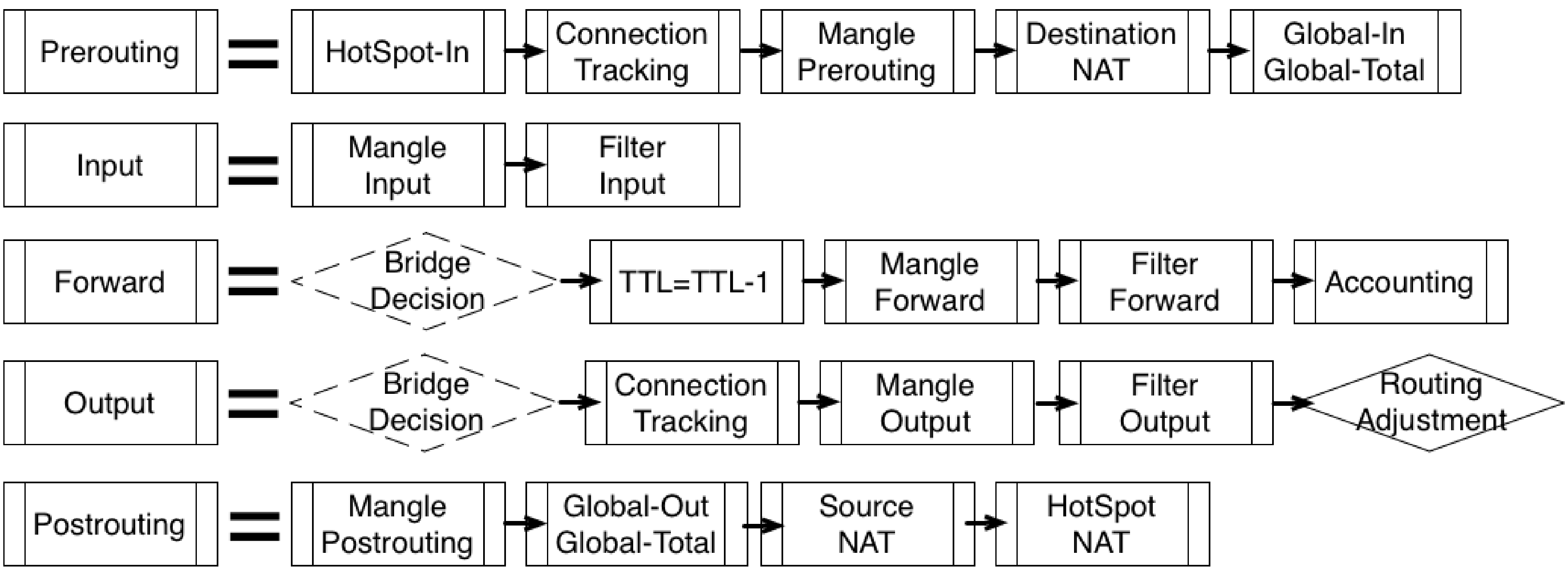


Diagram Abbreviations



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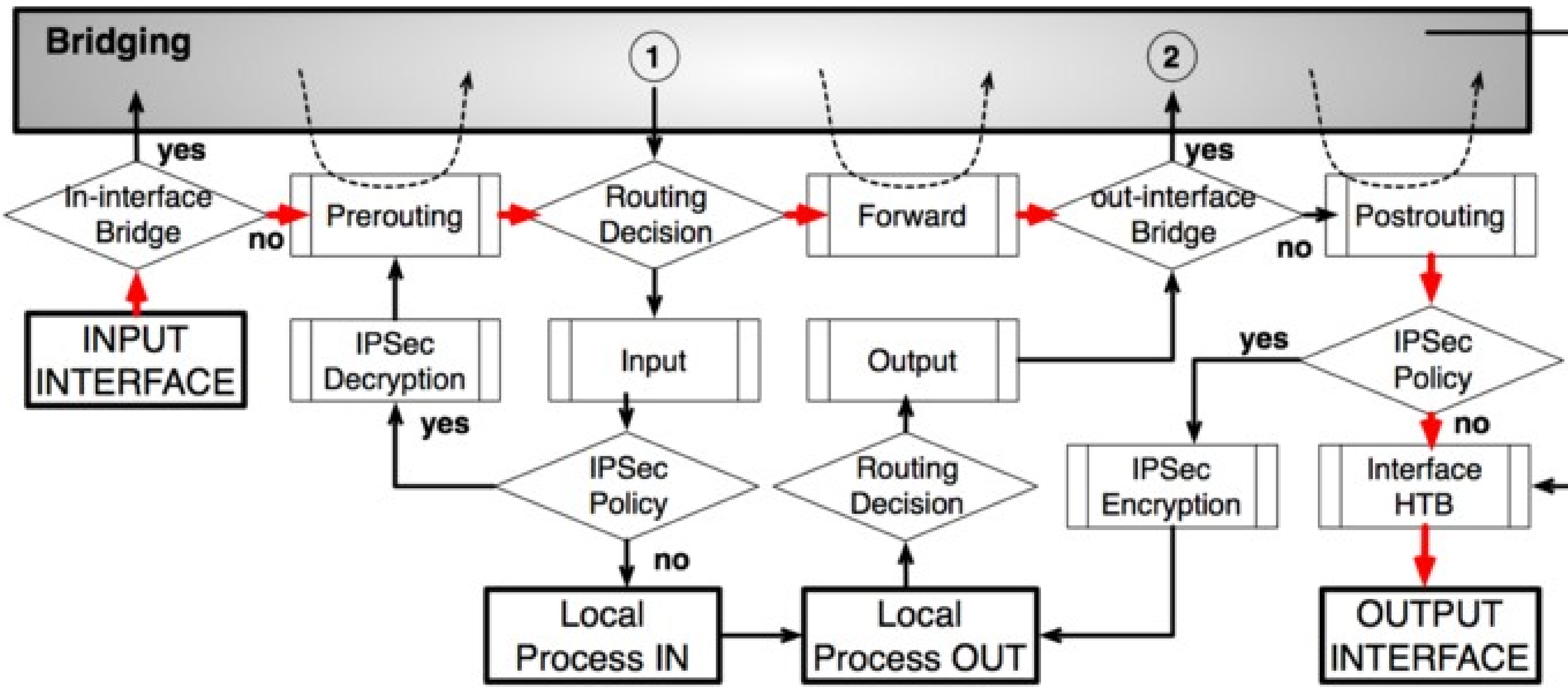
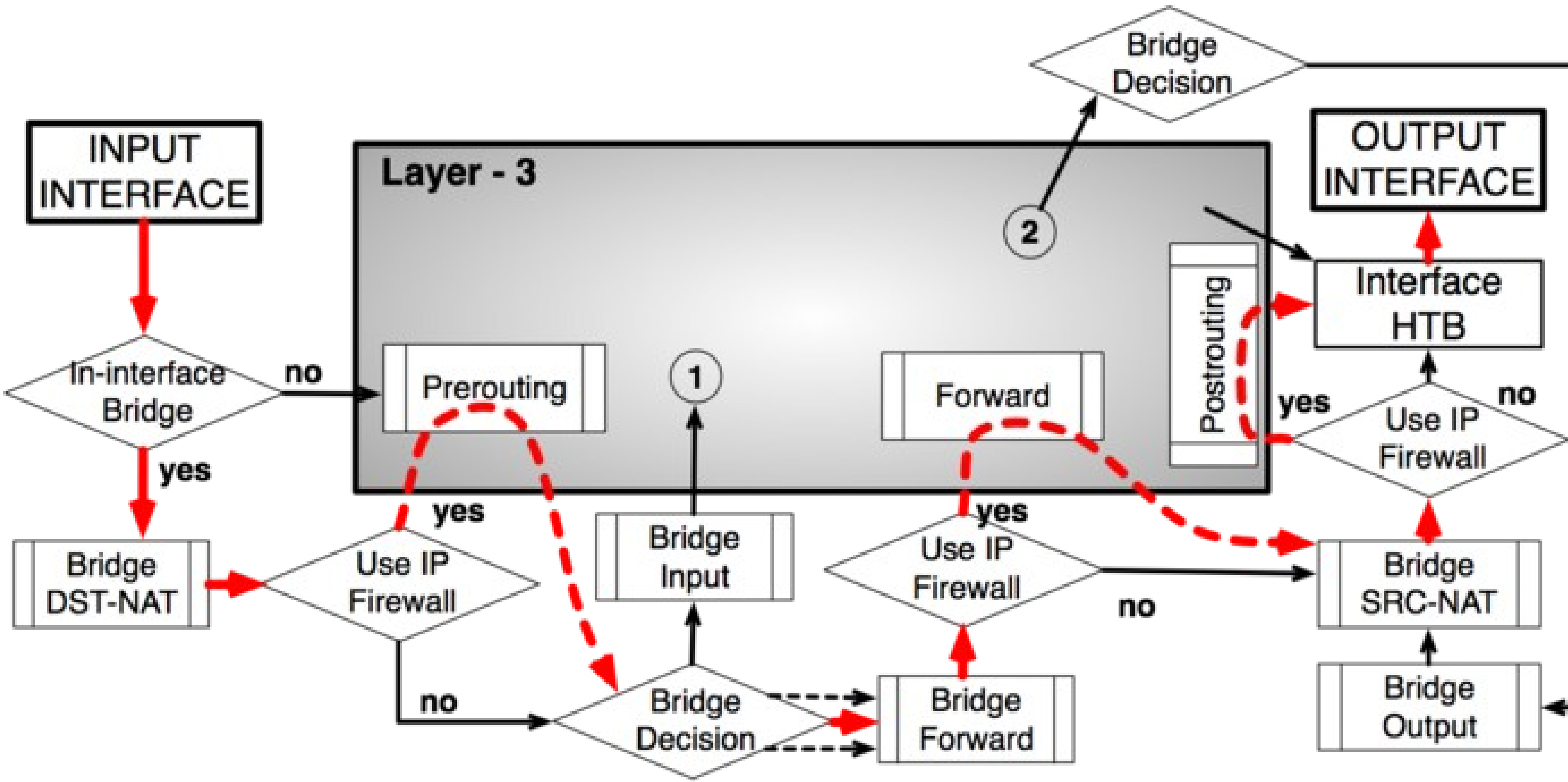
Simple Routing



Bridging with IP firewall



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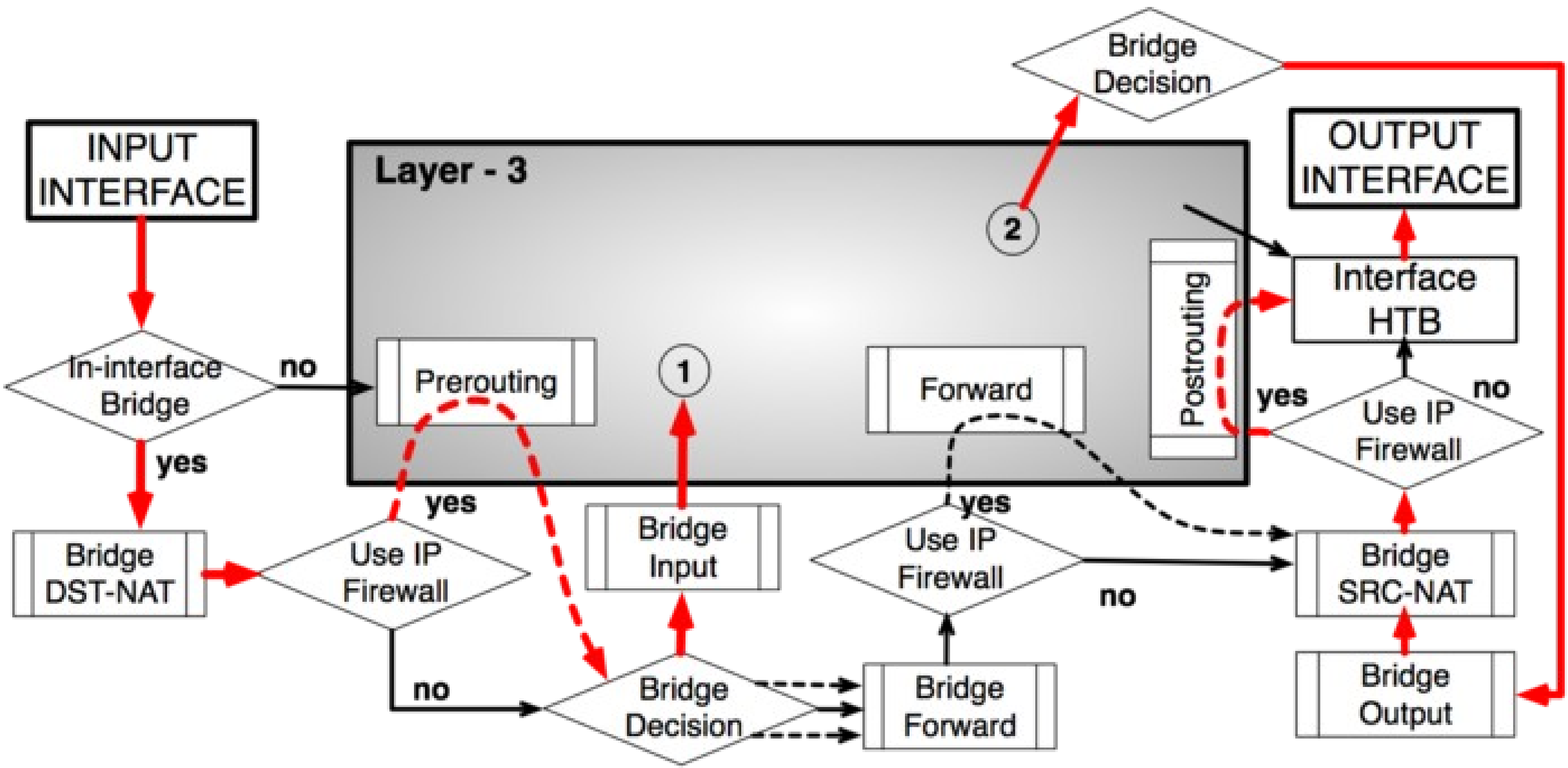
Bridge-to-Bridge Routing (part1)



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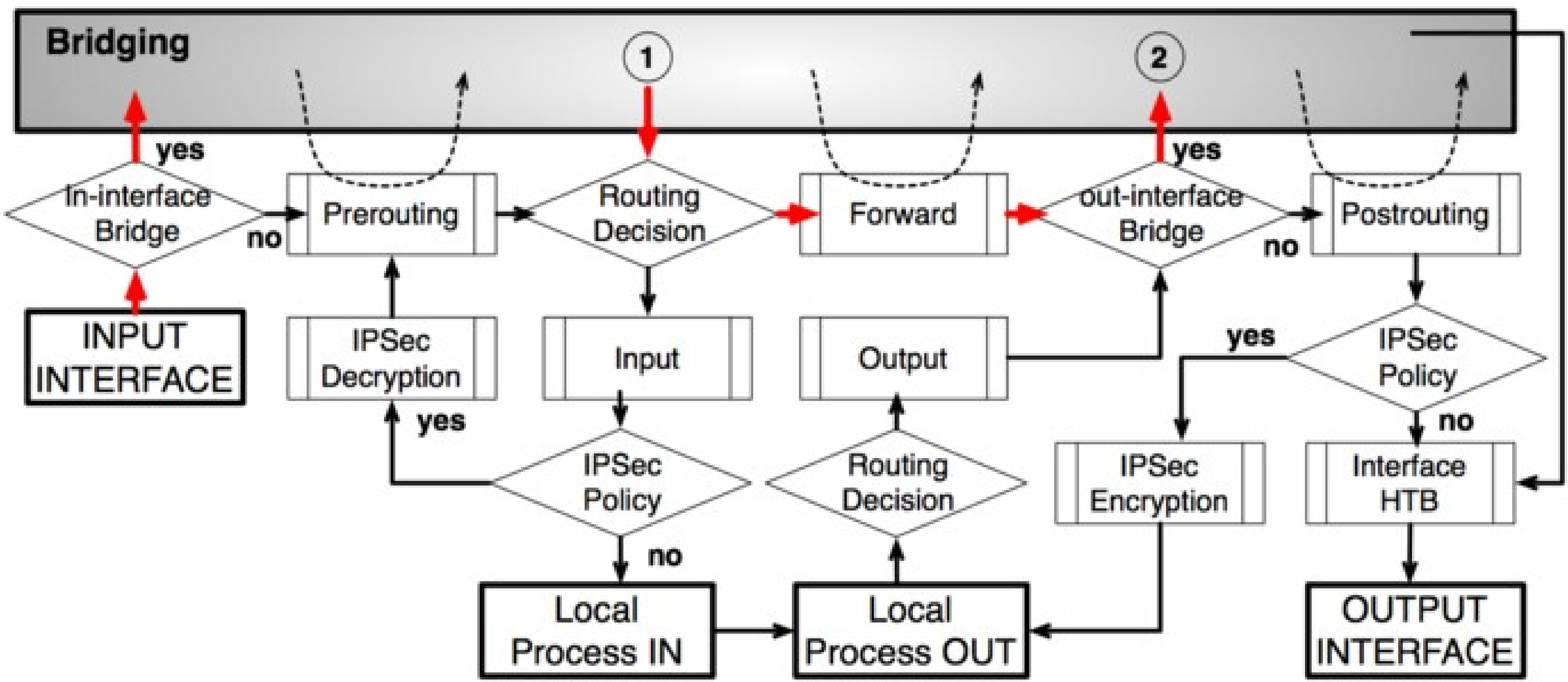
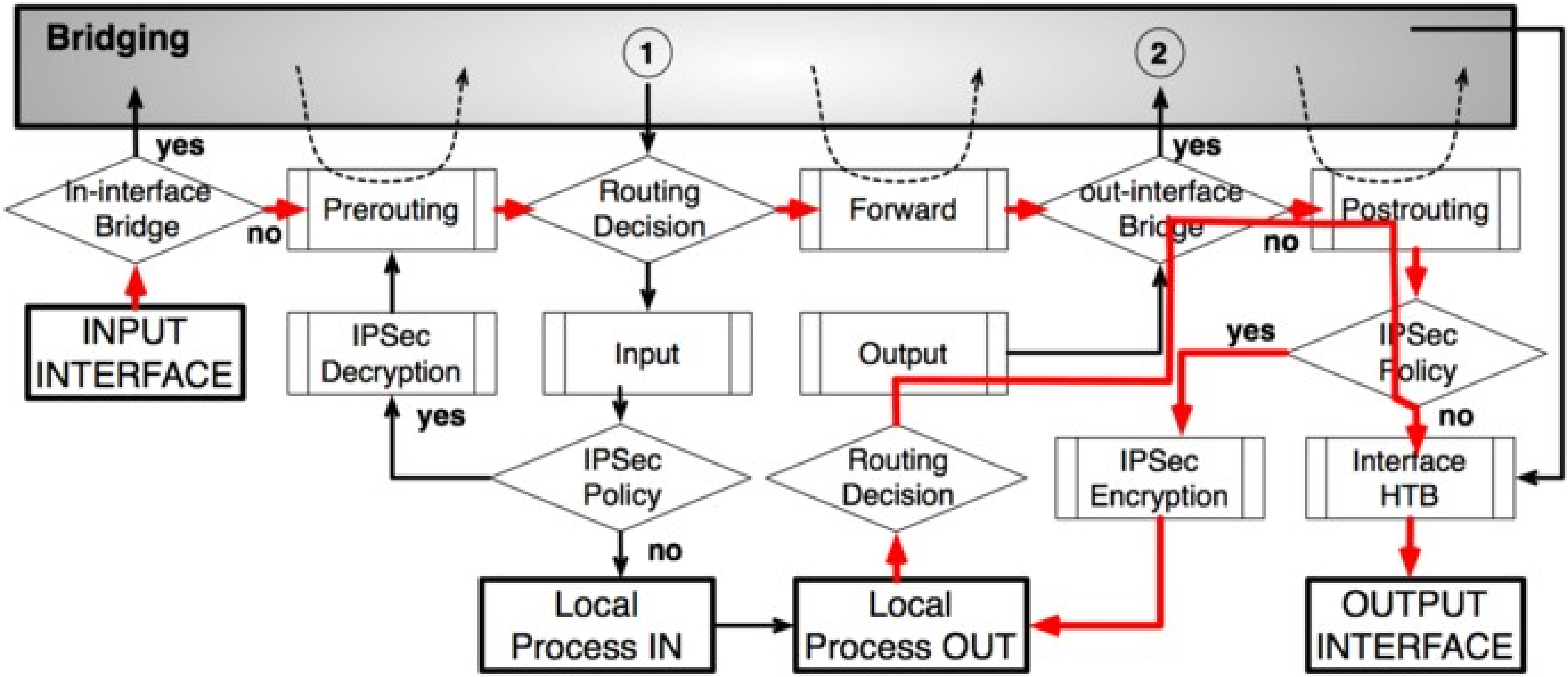
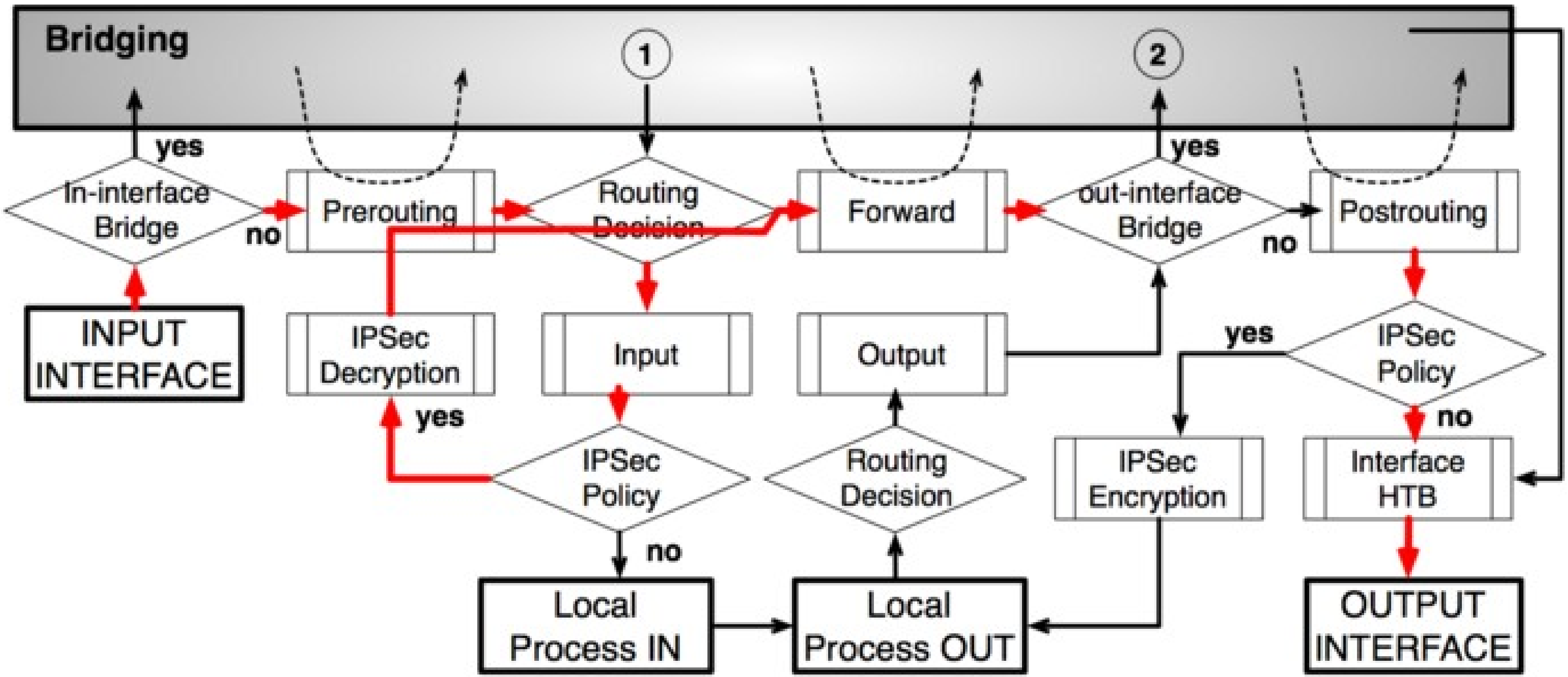
Bridge-to-Bridge Routing (part2)



IPSec Encryption



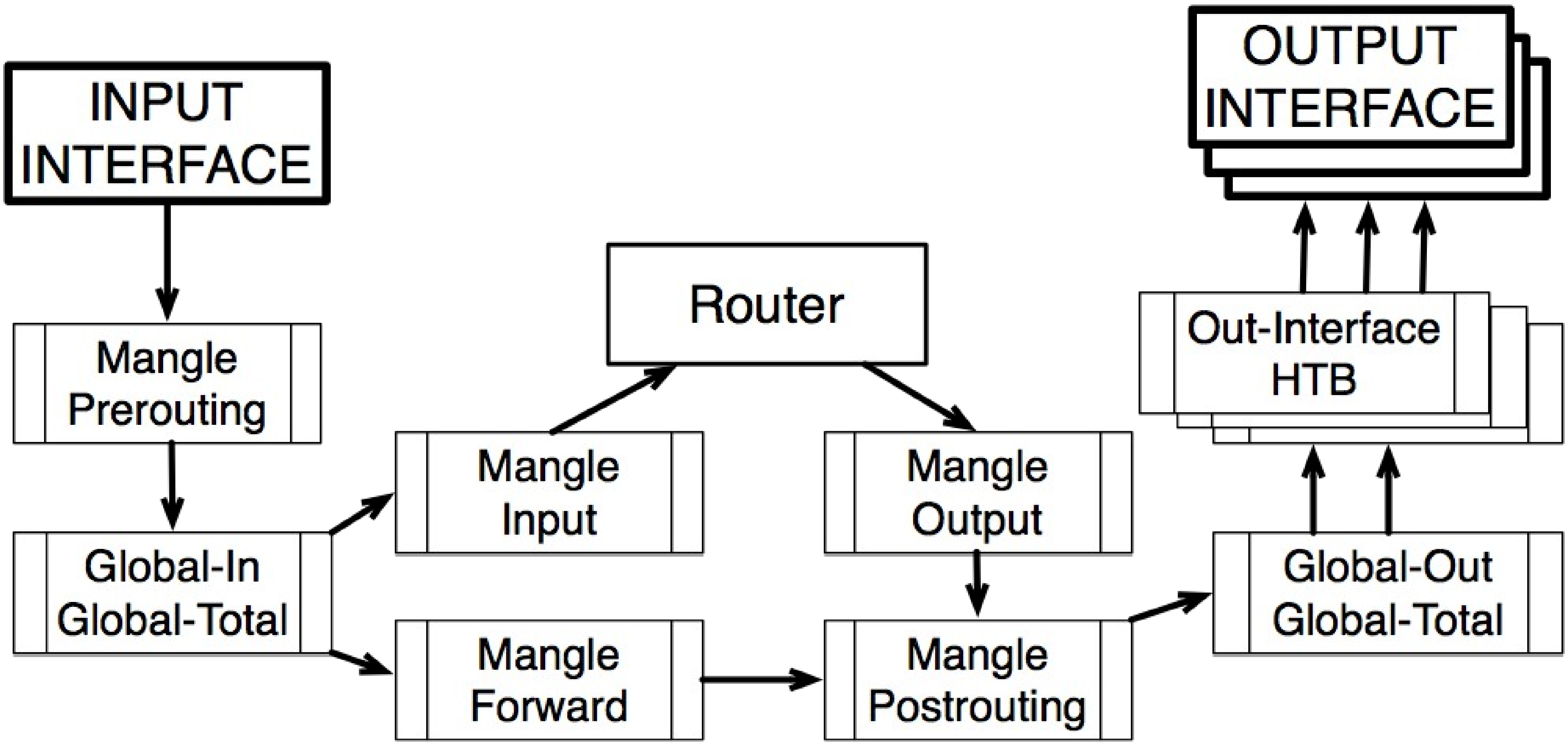
IPSec Decryption



Hierarchical Token Bucket

Lets Simplify!

- QoS Packet Flow Diagram



Global-Out or Interface HTB?

There are two fundamental differences

- In case of SRC-NAT (masquerade) Global-Out will be aware of private client addresses, but Interface HTB will not – Interface HTB is after SRC-NAT

- Each Interface HTB only receives traffic that will be leaving through a particular interface – there is no need for to separate upload and download in mangle

Mangle

- The mangle facility allows you to mark IP packets with special marks.
- These marks are used by other router facilities like routing and bandwidth management to identify the packets.
- Additionally, the mangle facility is used to modify some fields in the IP header, like TOS (DSCP) and TTL fields.

Hierarchical Token Bucket

- All bandwidth management implementation in RouterOS is based on Hierarchical Token Bucket (HTB)
- HTB allows you to create hierarchical queue structure and determine relations between queues
- RouterOS supports 3 virtual HTBs (global-in, global-total, global-out) and one more just before every output interface

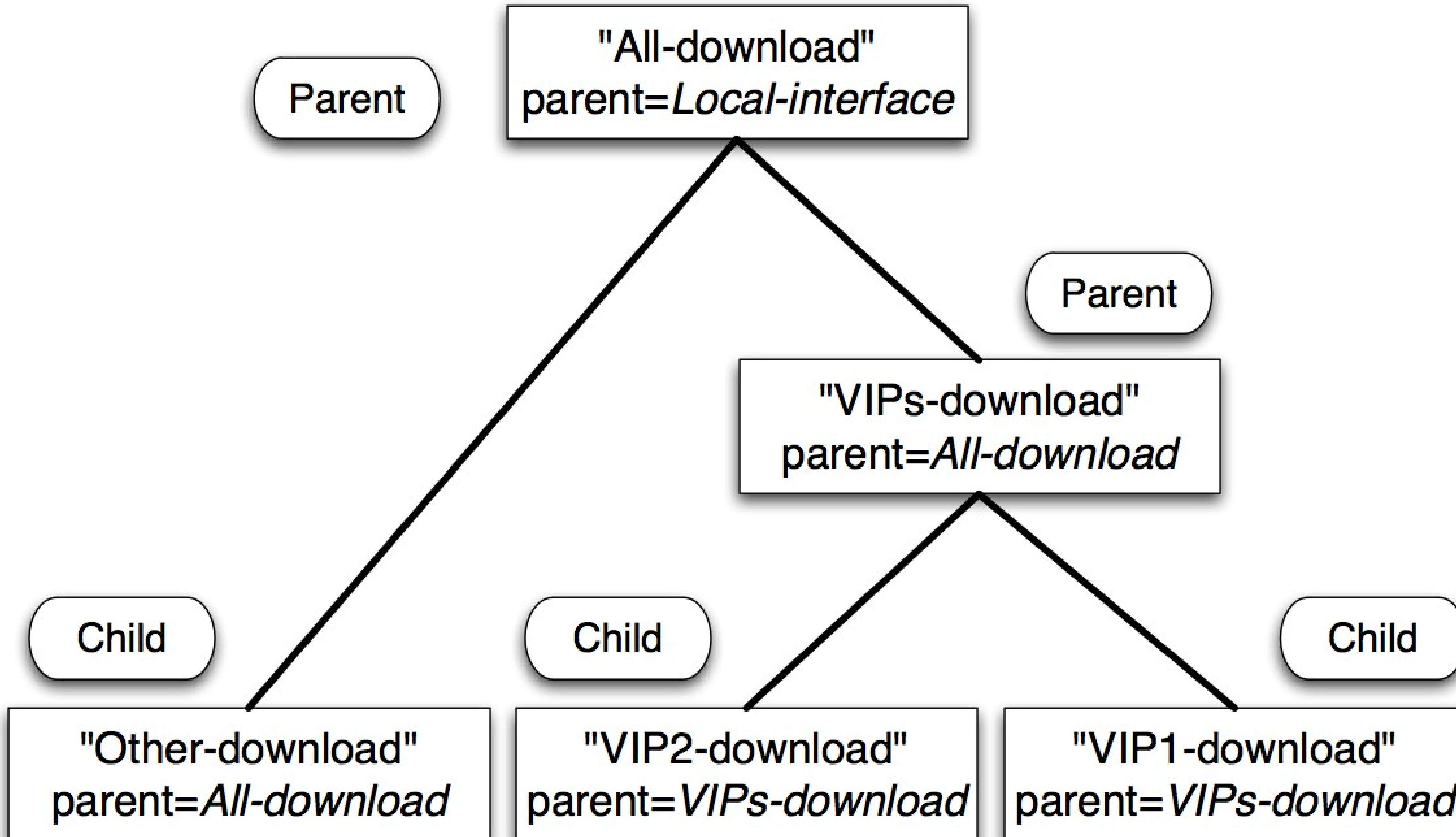
HTB (cont.)

- When packet travels **through** the router, it passes all 4 HTB trees
- When packet travels **to** the router, it passes only global-in and global-total HTB.
- When packet travels **from** the router, it passes global-out, global-total and interface HTB.

HTB Features - Structure

- As soon as queue have at least one child it become parent queue
- All child queues (don't matter how many levels of parents they have) are on the same bottom level of HTB
- Child queues make actual traffic consumption, parent queues are responsible only for traffic distribution
- Child queues will get limit-at first and then rest of the traffic will distributed by parents

HTB Features - Structure



HTB Features – Dual Limitation

- HTB has two rate limits:
  - **CIR (Committed Information Rate) –** (limit-at in RouterOS) worst case scenario, flow will get this amount of traffic no matter what (assuming we can actually send so much data)
  - **MIR (Maximal Information Rate) –** (max-limit in RouterOS) best case scenario, rate that flow can get up to, if there queue's parent has spare bandwidth
- At first HTB will try to satisfy every child queue's **limit-at** – only then it will try to reach **max-limit**

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Dual Limitation

- Maximal rate of the parent should be equal or bigger than sum of committed rates of the children
  - MIR (parent) ≥ CIR(child1) +...+ CIR(childN)
- Maximal rate of any child should be less or equal to maximal rate of the parent
  - MIR (parent) ≥ MIR(child1)
  - MIR (parent) ≥ MIR(child2)
  - MIR (parent) ≥ MIR(childN)

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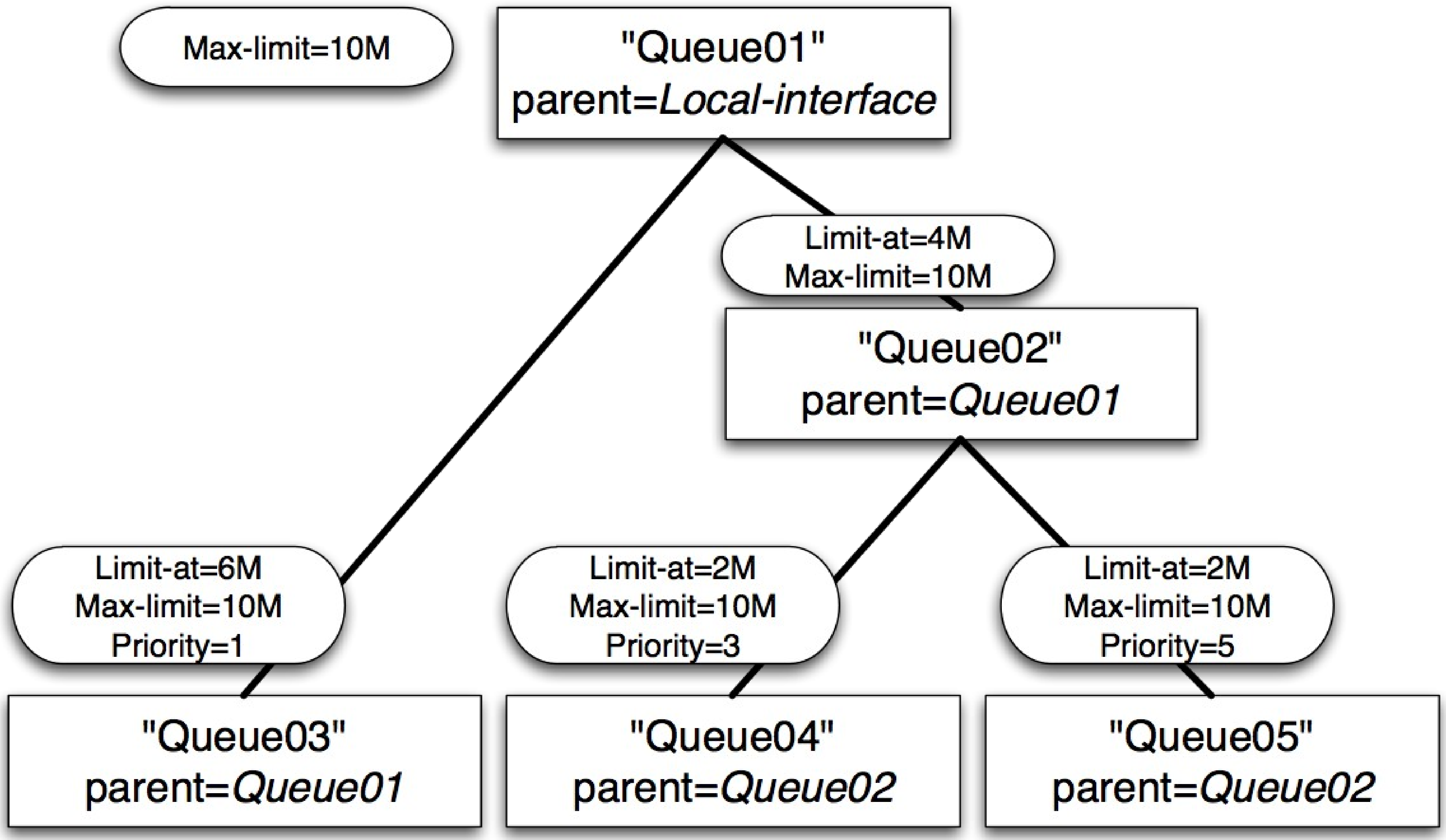
HTB - limit-at



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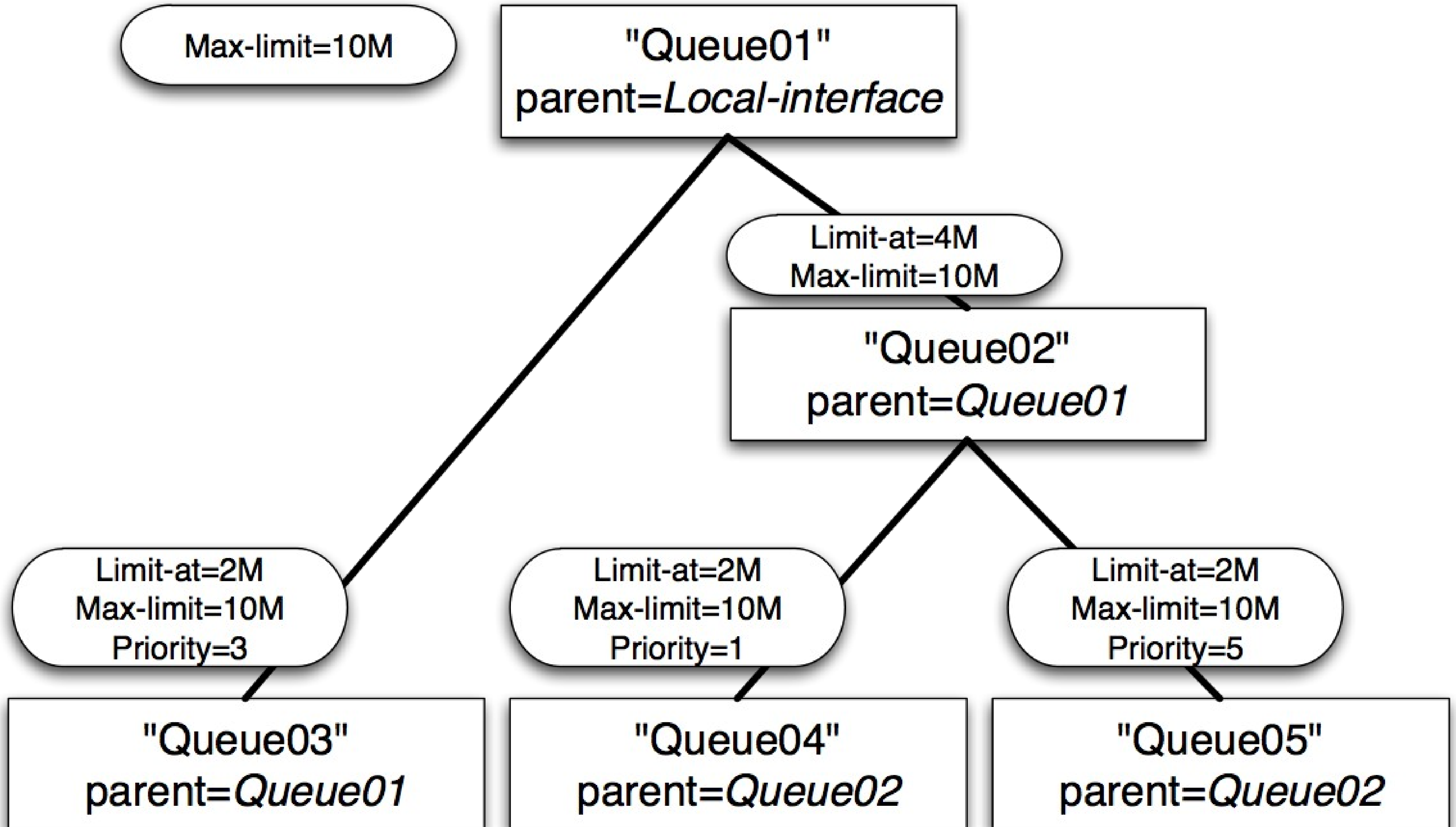
HTB - max-limit



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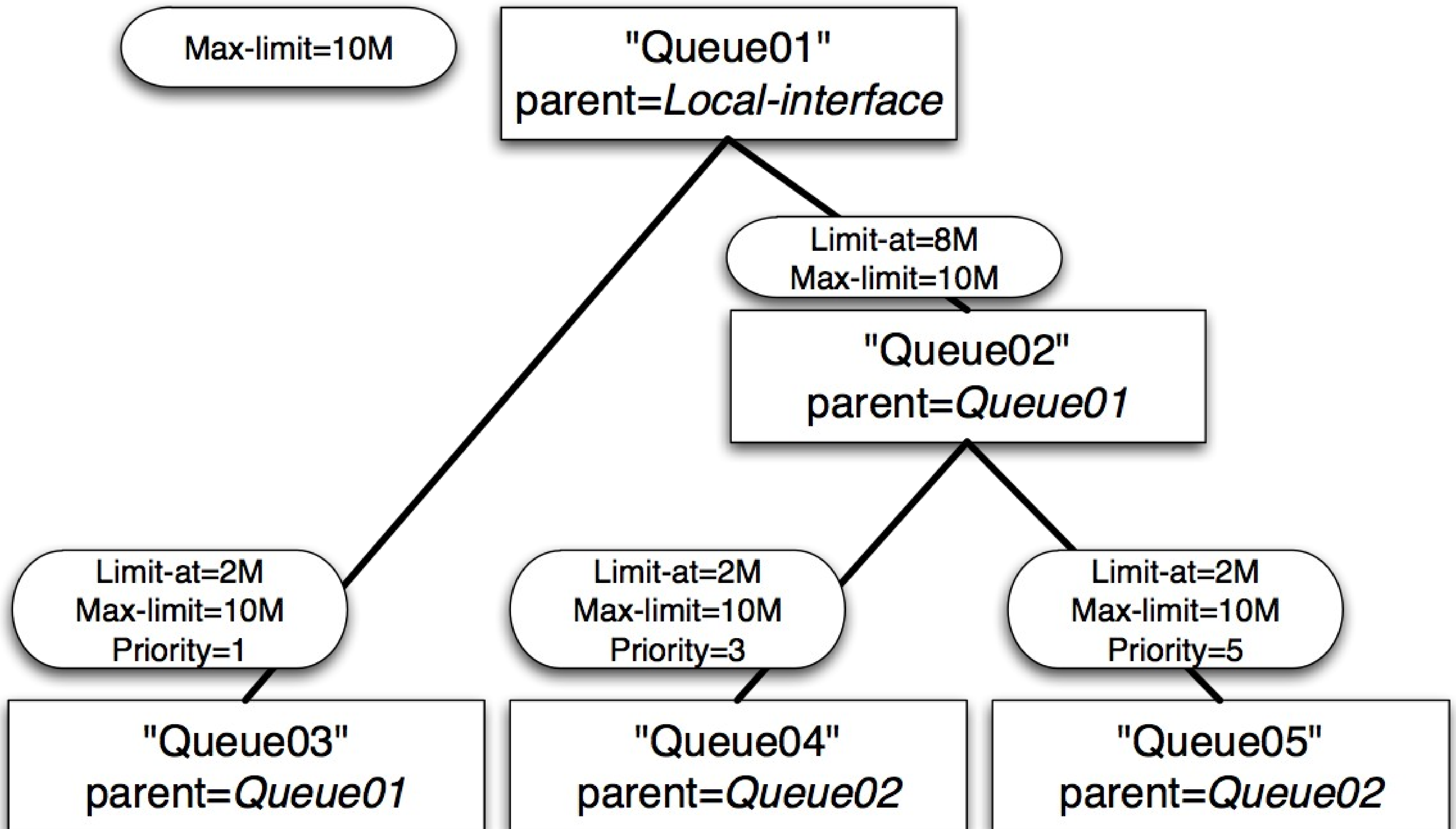
HTB Features - Priority

- Work only for child queues to arrange them
- 8 is the lowest priority, 1 is the highest
- Queue with higher priority will get chance to satisfy its max-limit before other queues
- Actual traffic prioritization will work **only** if limits are specified. Queue without limits will not prioritize anything

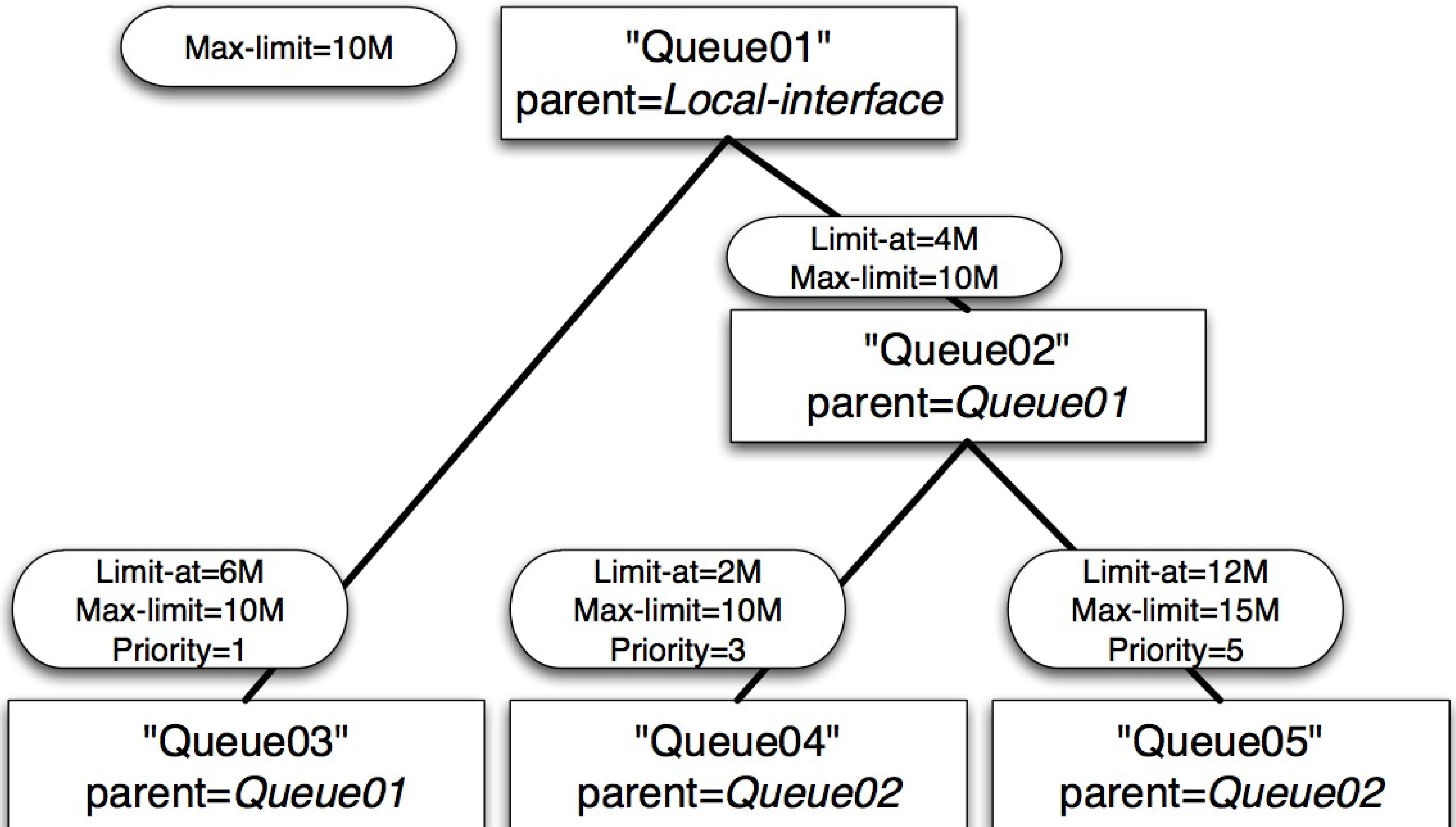
QoS Myth buster

- HTB priority doesn't rearrange packet sequence – it doesn't put some packets before others
  - In HTB “Priority” is an option that helps to decide what packets will pass and what packets will be dropped
  - This drop decision is based on limitations, so if there are no limits there are no need to drop anything, so priority have no effect
  - Priority doesn't affect CIR traffic – it just passes through QoS (even if parent's don't have such amount of traffic)

HTB – limit-at of the Parent



HTB – limit-at > parent's max-limit



QoS Myth Buster

- QoS can't control the amount of received traffic that you see on your interfaces.
  - In Packet Flow diagram global-in is way after Input interface where statistic is registered
  - Effect of traffic slowing down most probably is effect of TCP protocol behaviour
  - If clients PC was able to send out traffic it have to arrive somewhere it can't just disappear

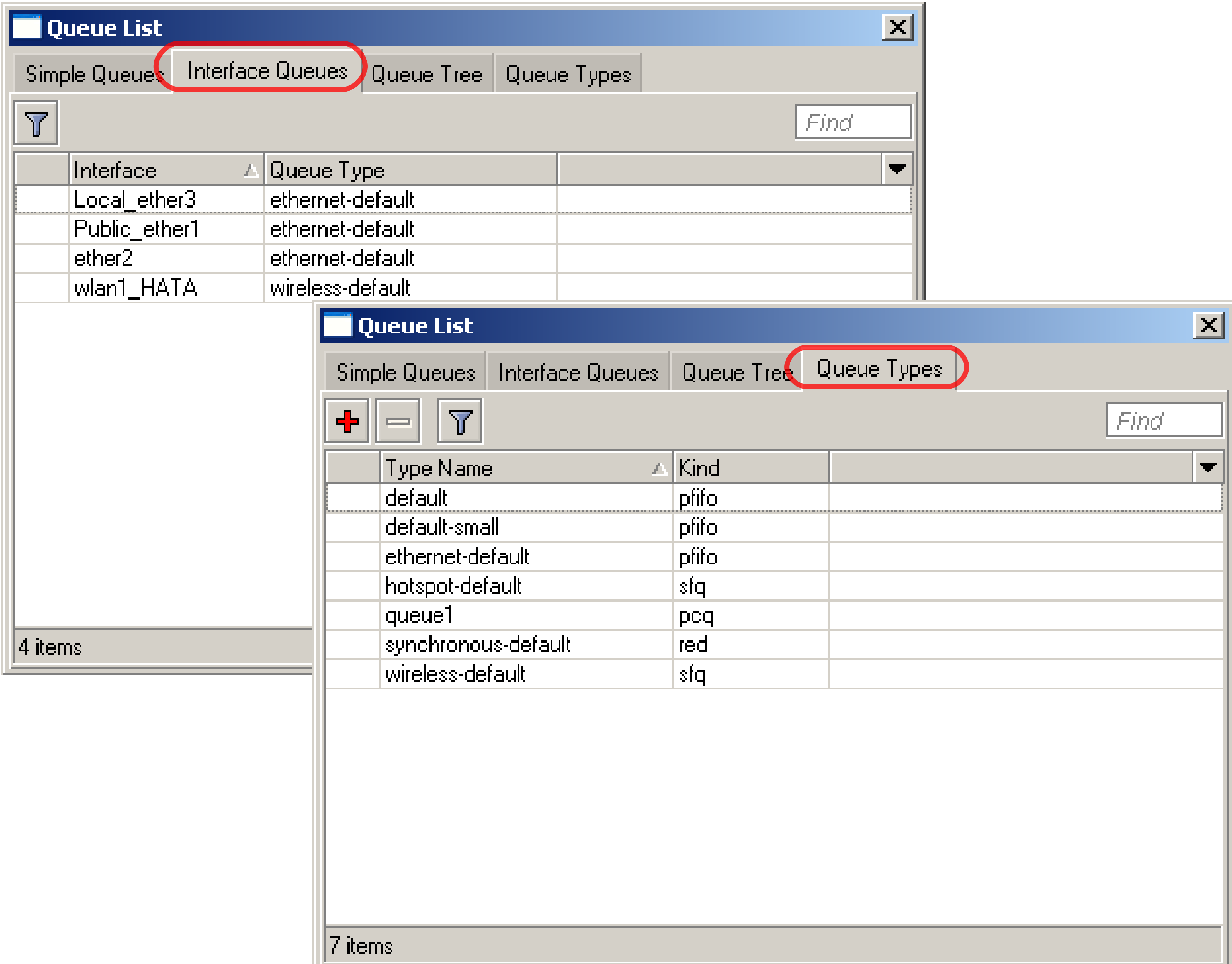
  Only way to see QoS in action is to monitor TX of opposite interface.

QoS Myth Buster

- QoS doesn't know how much actual bandwidth is available
  - In Packet Flow diagram all HTB are before output interface and output interfaces driver is the first one that **might** know how much actual bandwidth you have.
  - Interface driver knows the maximal hardware limitation of your interface, IF actual limitation is smaller, the only way to provide QoS with limitation information is to specify all limits yourself

Queue Types

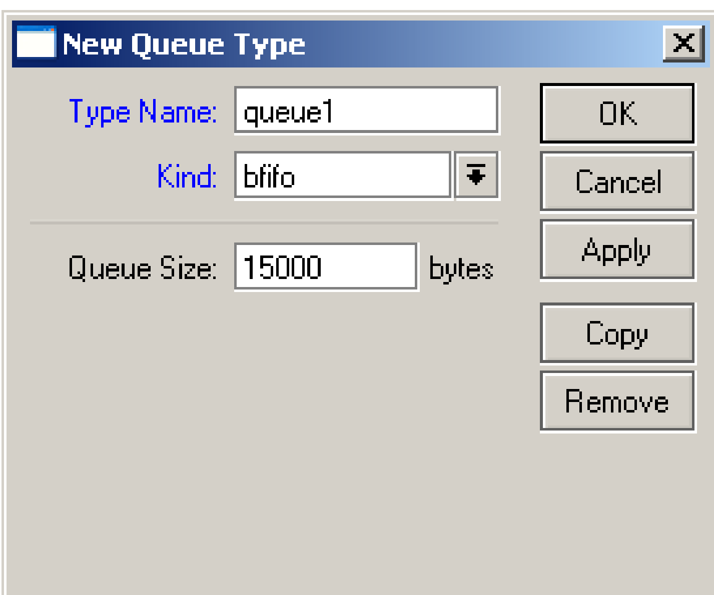
Default Queue Types

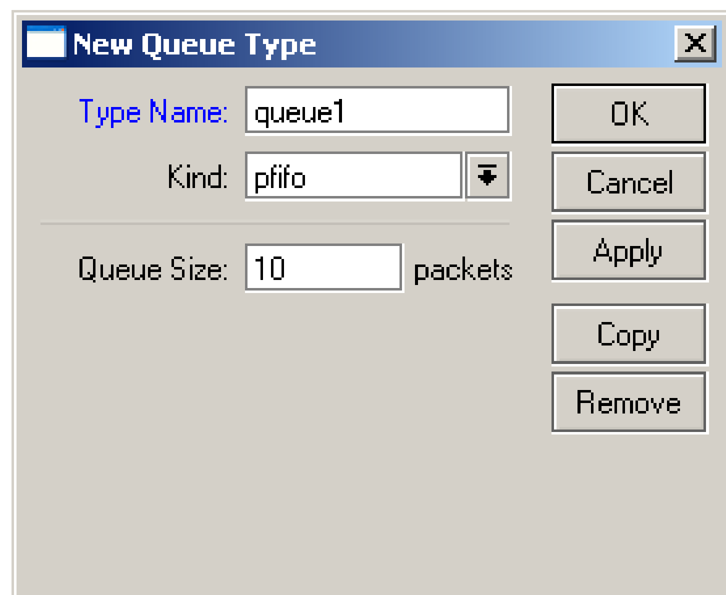


FIFO

Behaviour:

What comes in first is handled first, what comes in next waits until the first is finished. Number of waiting units (Packets or Bytes) is limited by “queue size” option. If queue “is full” next units are dropped





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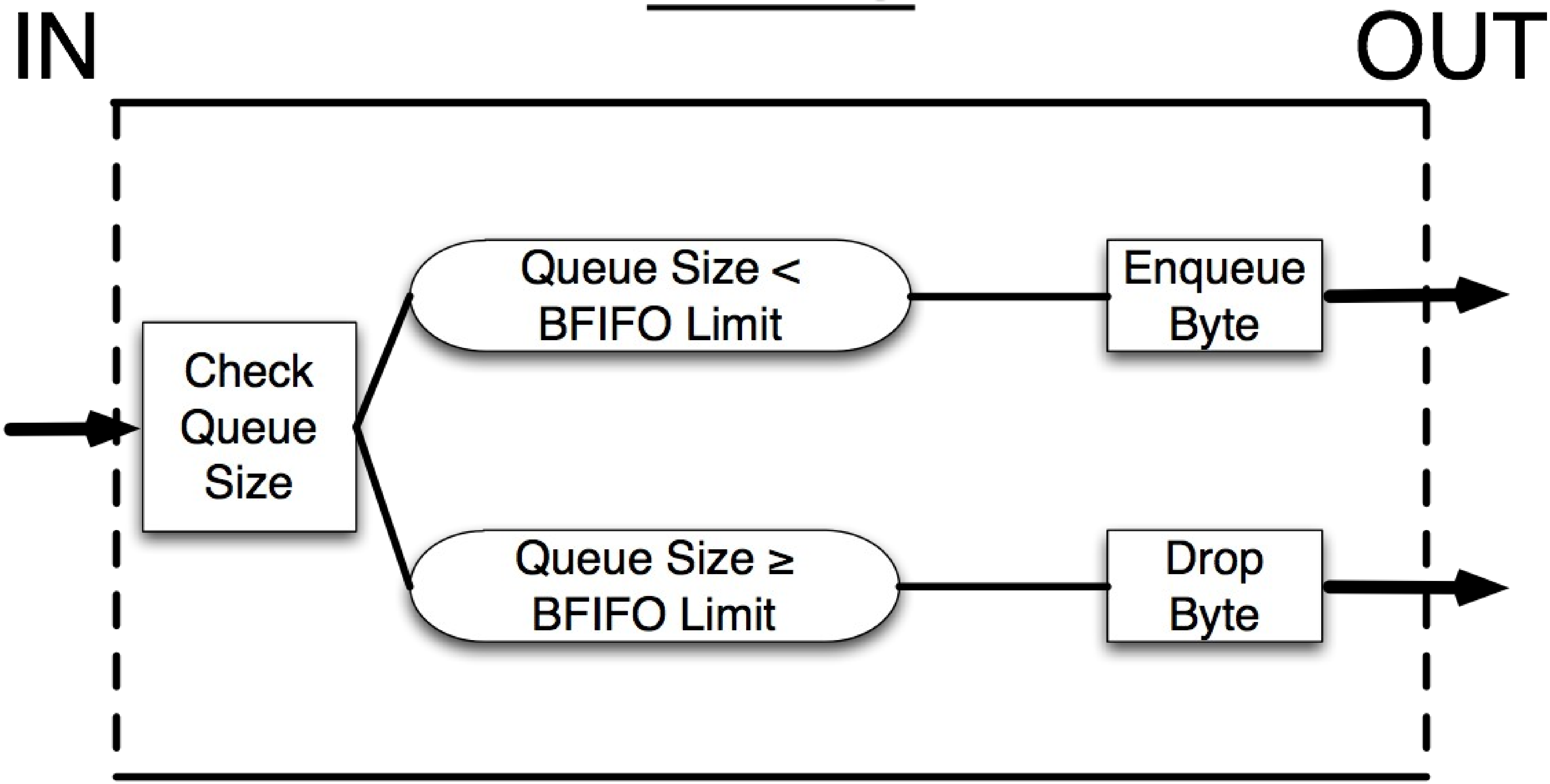
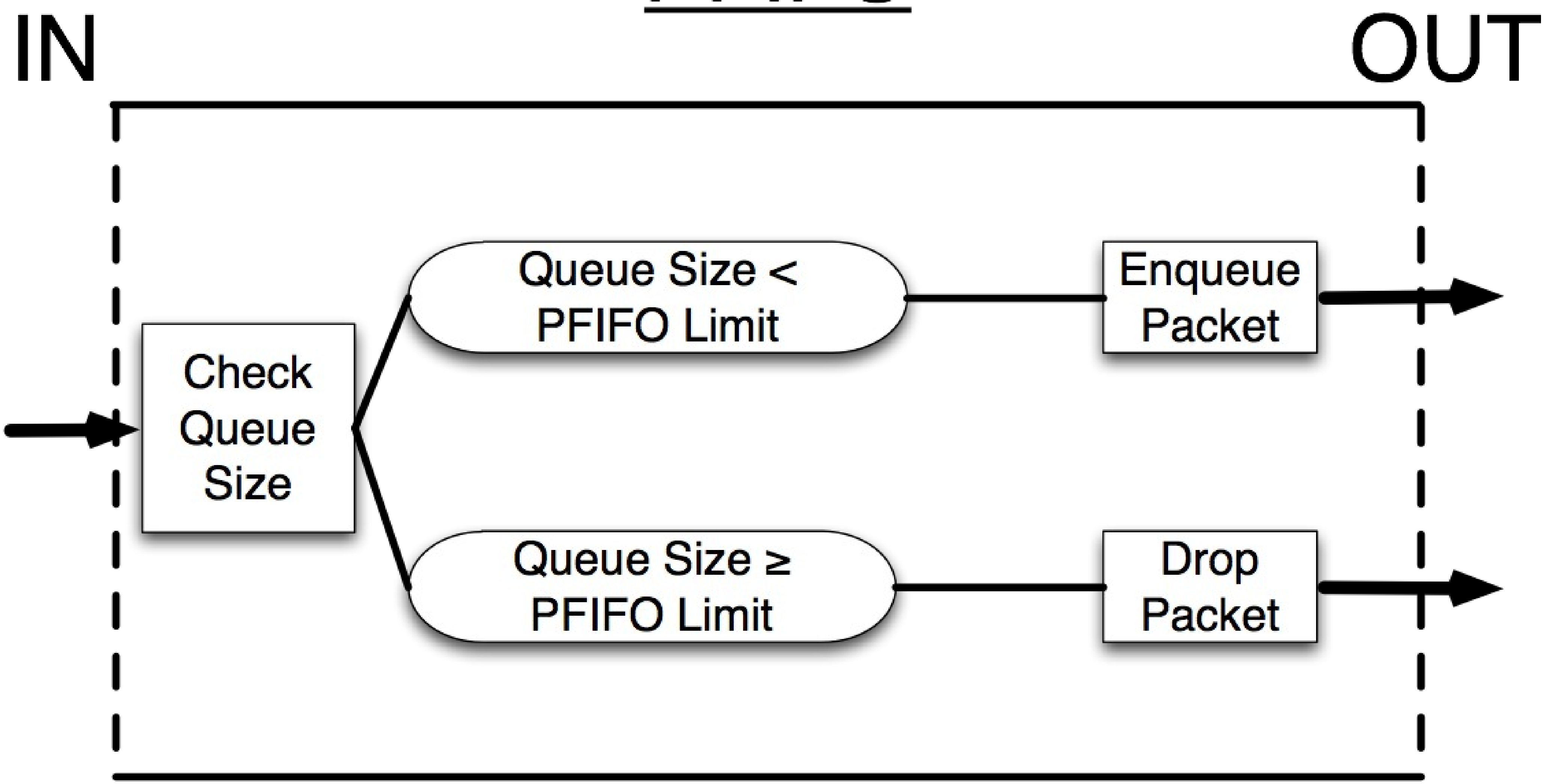
BFIFO


IN
OUT
Check Queue Size
Queue Size < BFIFO Limit
Enqueue Byte
Queue Size ≥ BFIFO Limit
Drop Byte

PFIFO


IN
OUT
Check Queue Size
Queue Size <
PFIFO Limit
Queue Size ≥
PFIFO Limit
Enqueue Packet
Drop Packet

MQ PFIFO

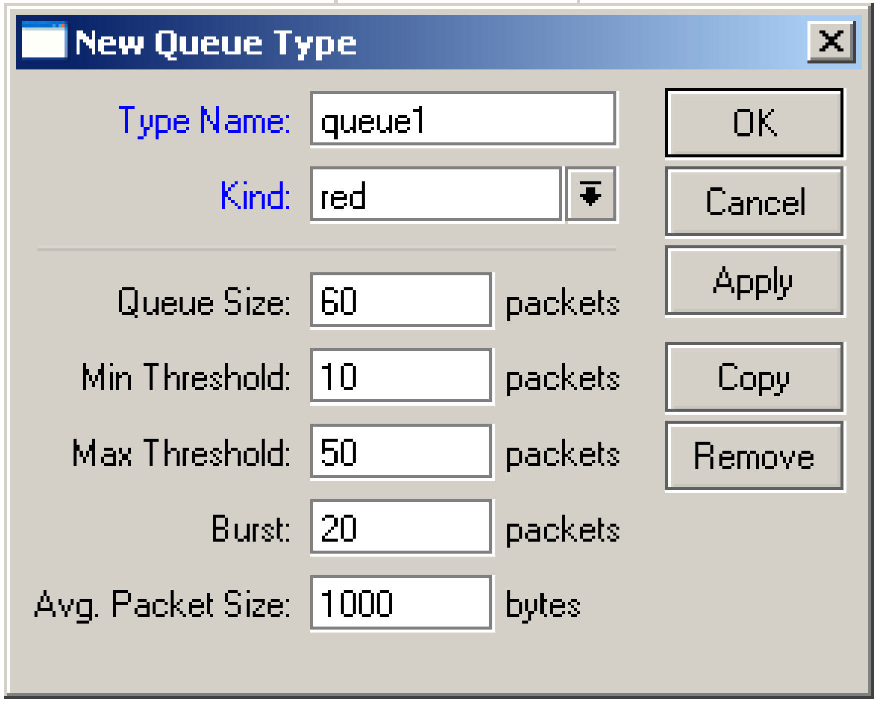
- Multi queue packet FIFO queue was designed multi-core router solutions (RB1100AHx2)
- MQ PFIFO should be used as default interface queue for any Ethernets that have several RX/TX queues (you can check that in /system resources IRQ menu)
- MQ FIFO is alternative to RPS (receive Packet Steering) – so do not use both on same interface it will result in performance loss.

RED

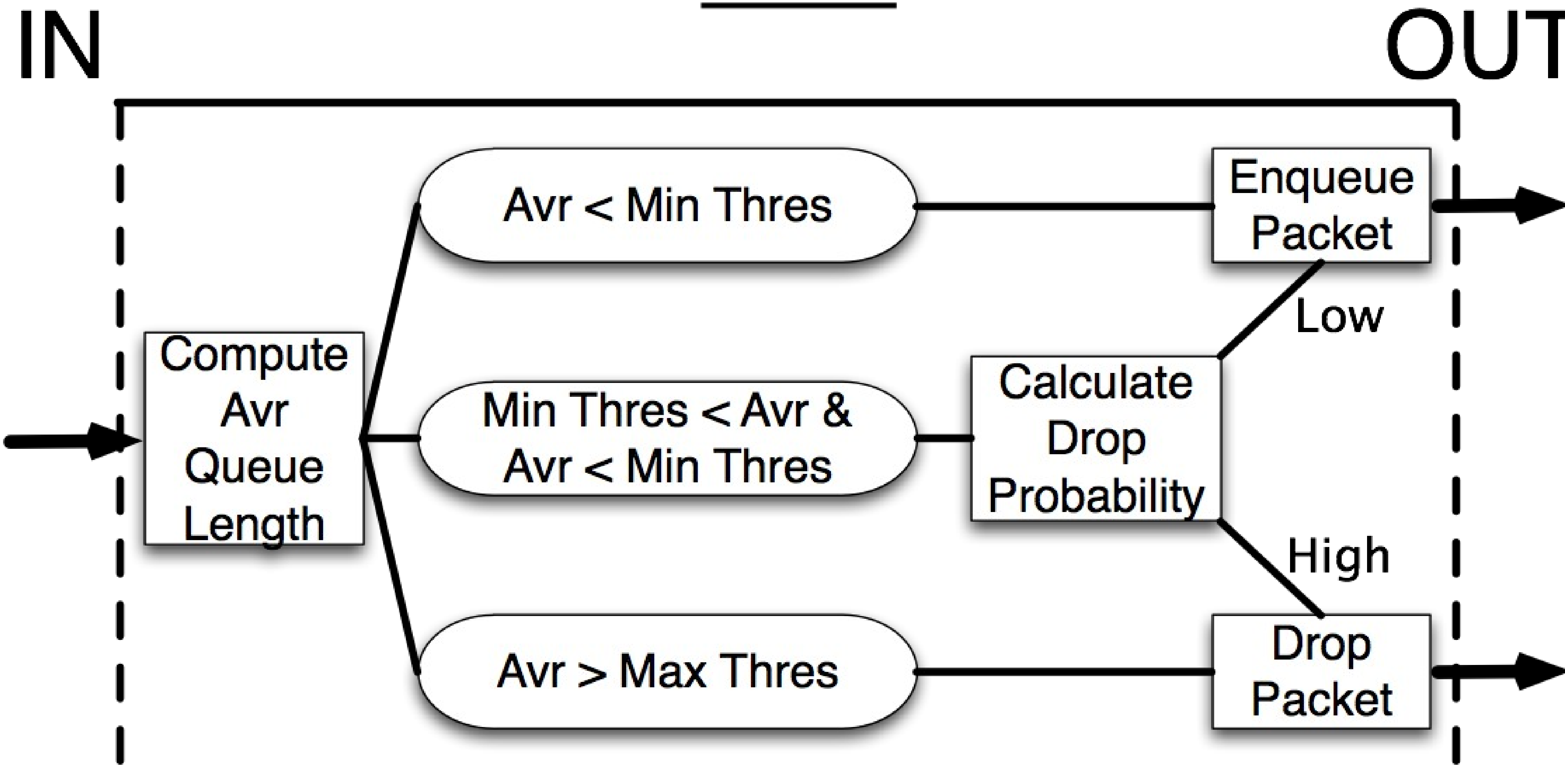
Behaviour:

Same as FIFO with an additional feature – additional drop probability even if queue is not full.

This probability is based on comparison of average queue length over some period of time to minimal and maximal threshold – closer to maximal threshold the bigger the chance of a drop.



RED

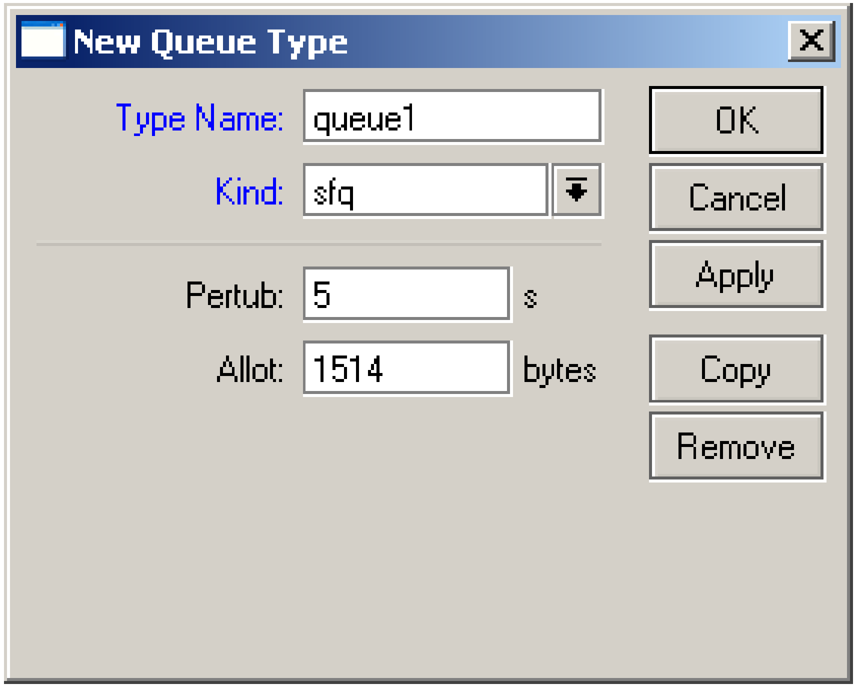

IN
OUT
Compute Avr Queue Length
Avr < Min Thres
Min Thres < Avr & Avr < Min Thres
Avr > Max Thres
Calculate Drop Probability
Low
High
Enqueue Packet
Drop Packet

SFQ

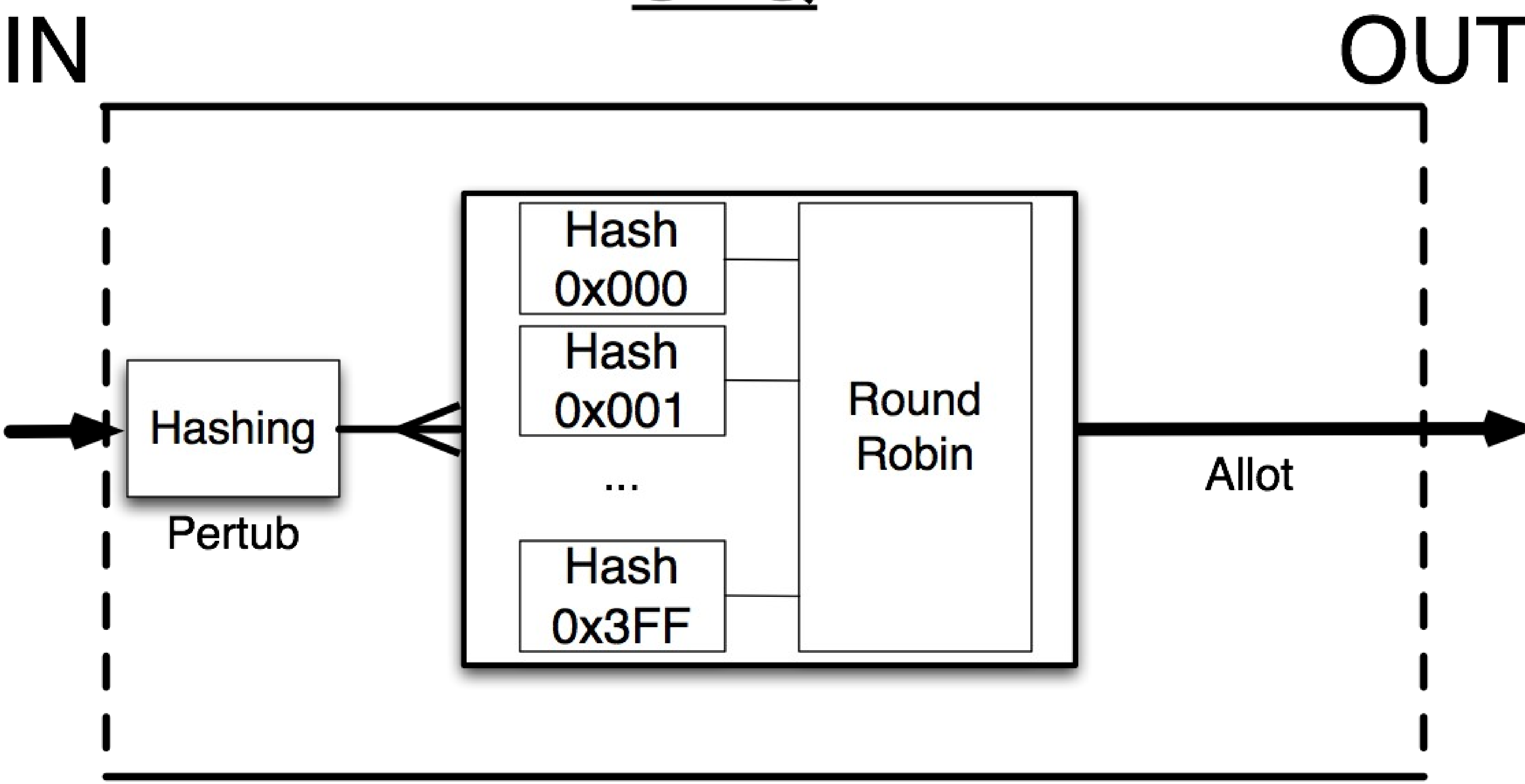
Behaviour:

Based on a hash value from the source and destination address SFQ divides the traffic into 1024 sub-streams

Then the Round Robin algorithm will distribute an equal amount of traffic to each sub-stream



SFQ



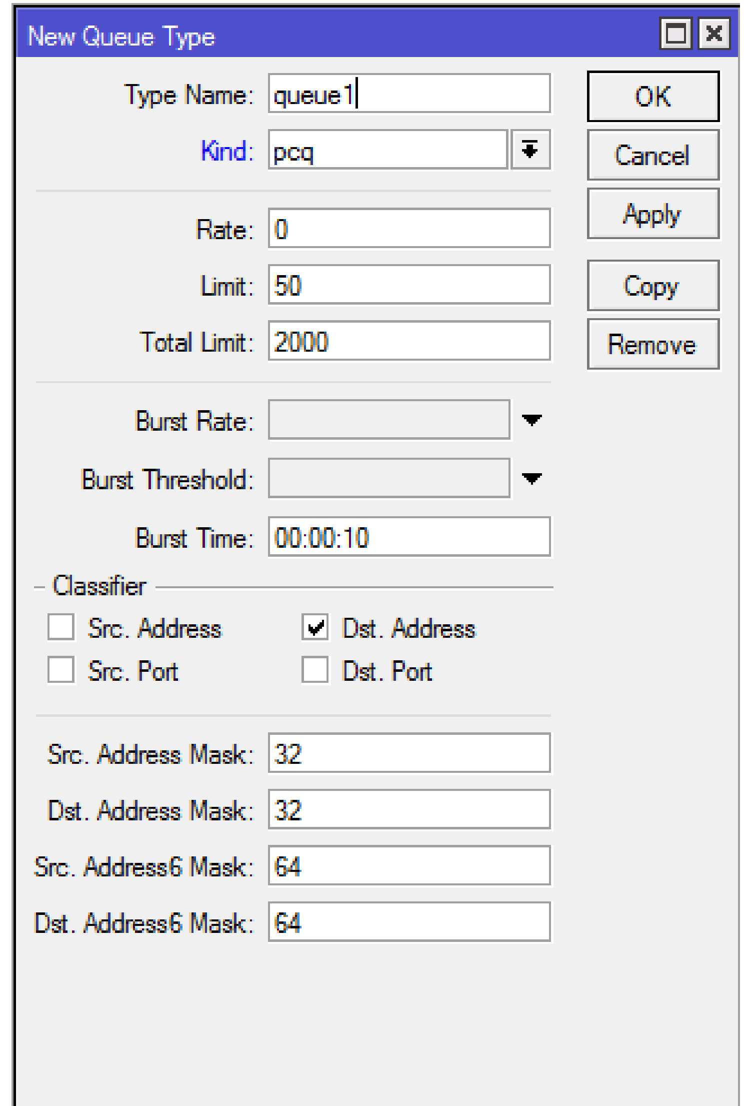
IN
OUT
Hashing
Pertub
Hash
0x000
Hash
0x001
...
Hash
0x3FF
Round
Robin
Allot

SFQ Example

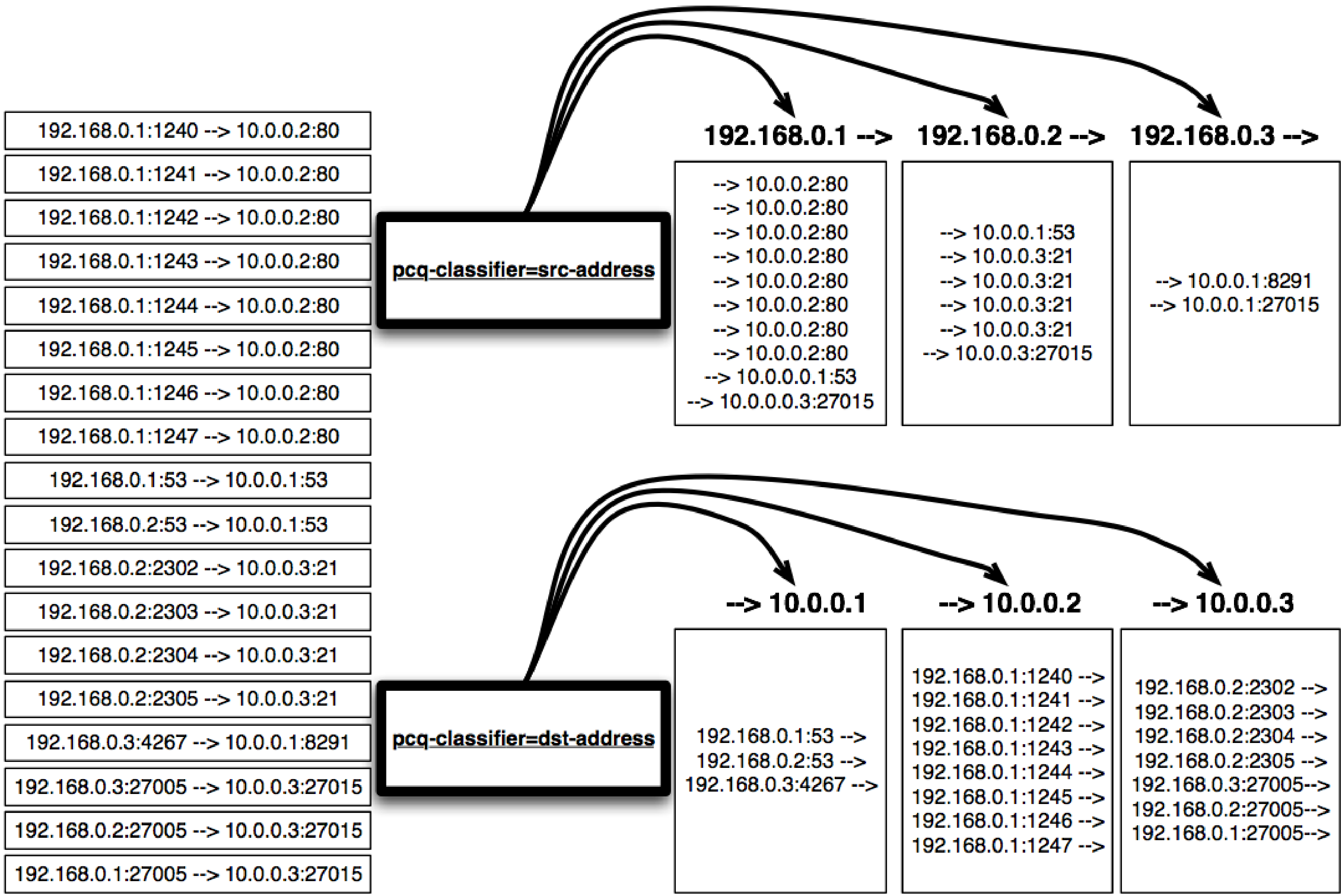
- SFQ should be used for equalizing similar connections
- Usually used to manage information flow to or from the servers, so it can offer services to every customer
- Ideal for p2p limitation, it is possible to place strict limitation without dropping connections,

PCQ

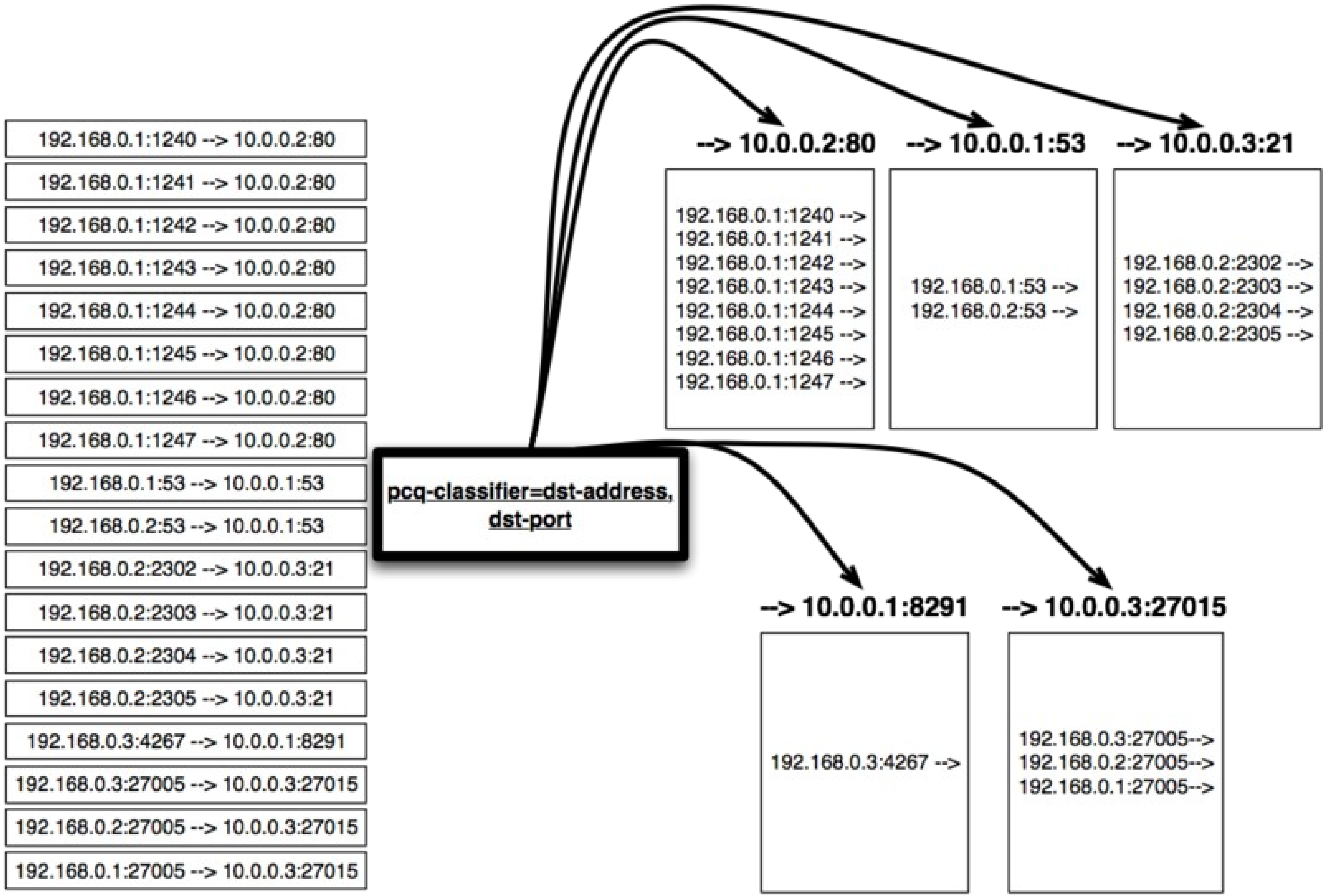
- PCQ was introduced to optimize massive QoS systems, where most of the queues are exactly the same for different sub-streams
- Starting from version 5.0rc5 PCQ have burst support and IPv6 support



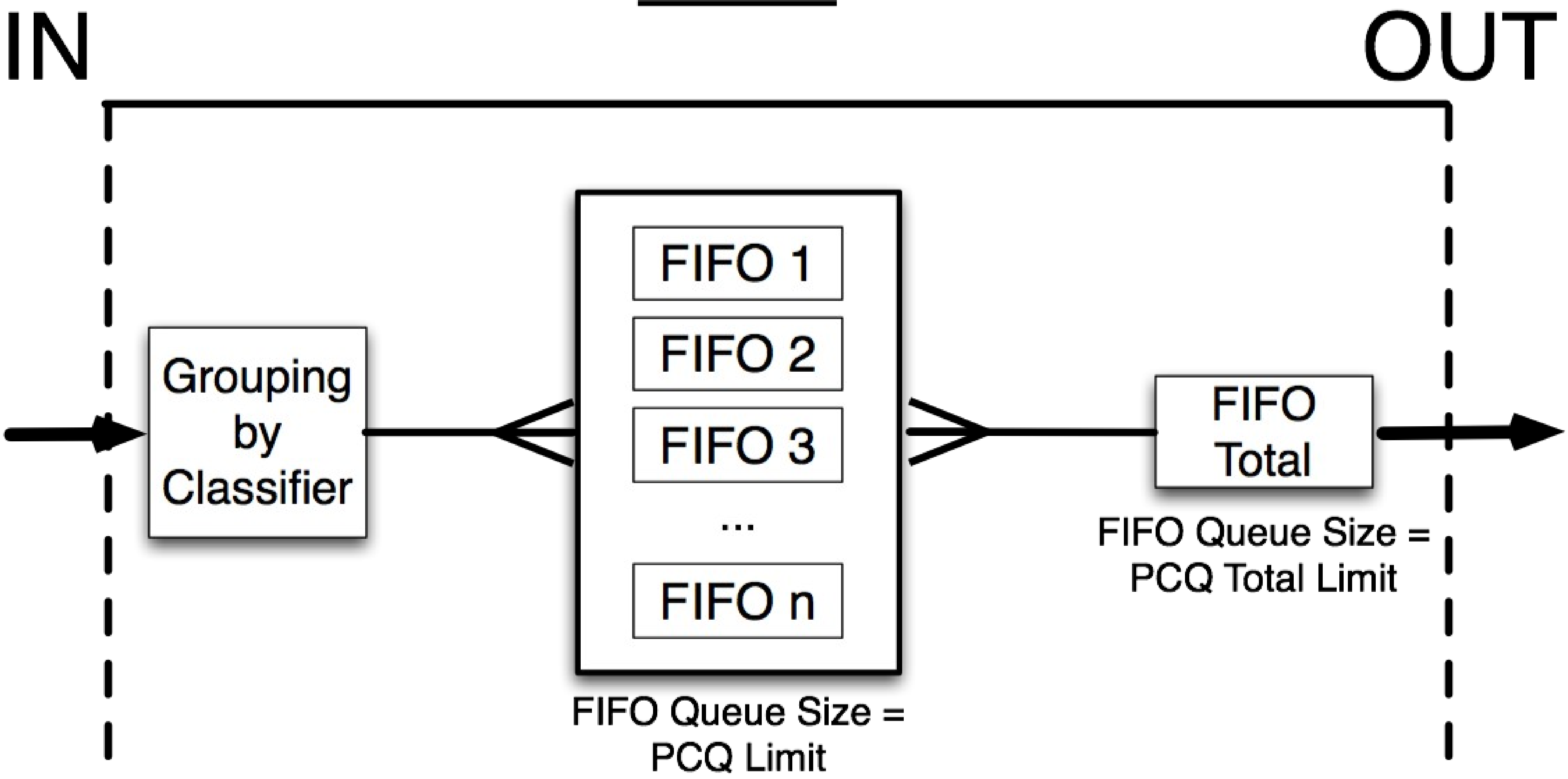
PCQ Classification (1)



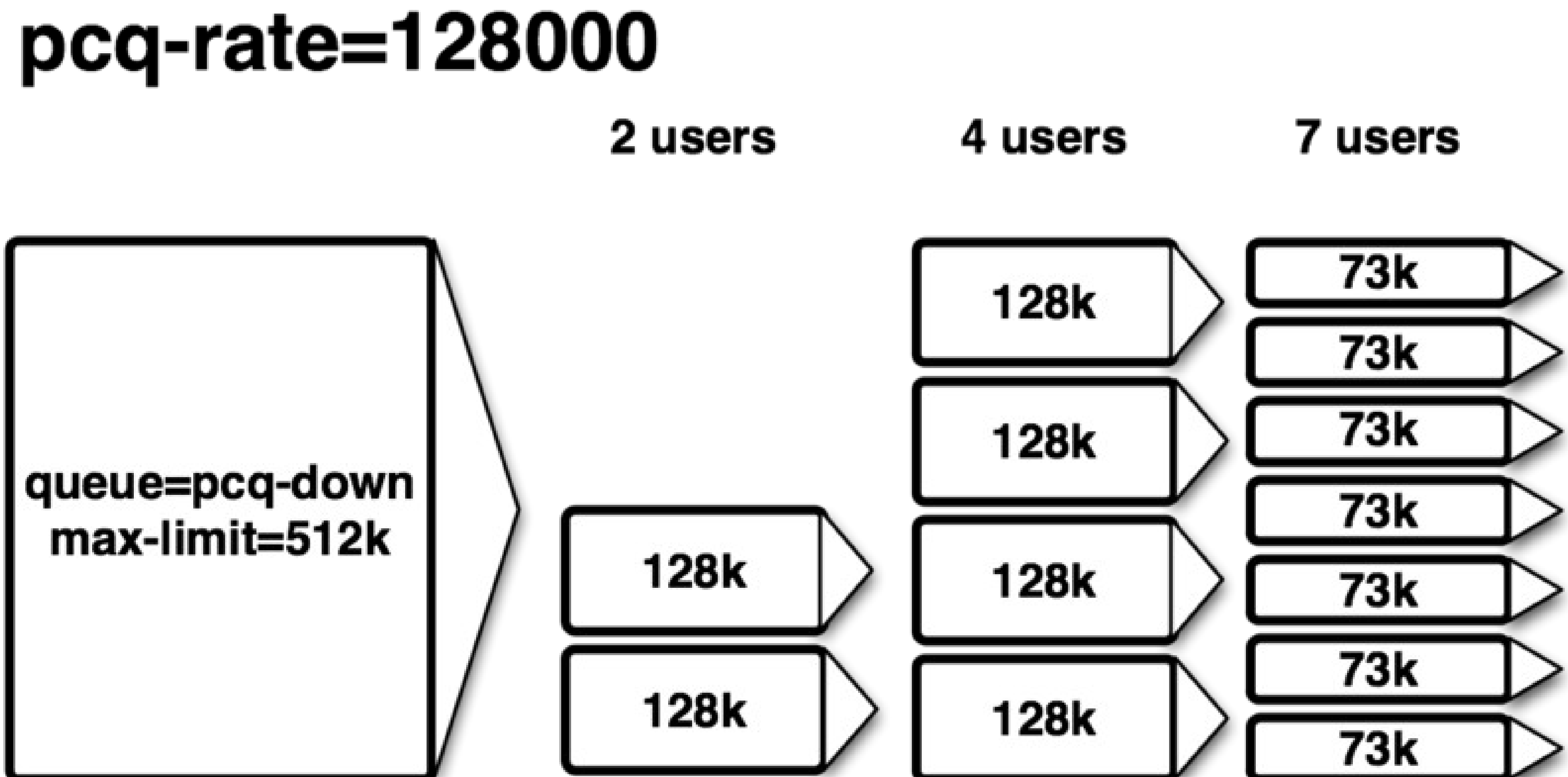
PCQ Classification (2)



PCQ

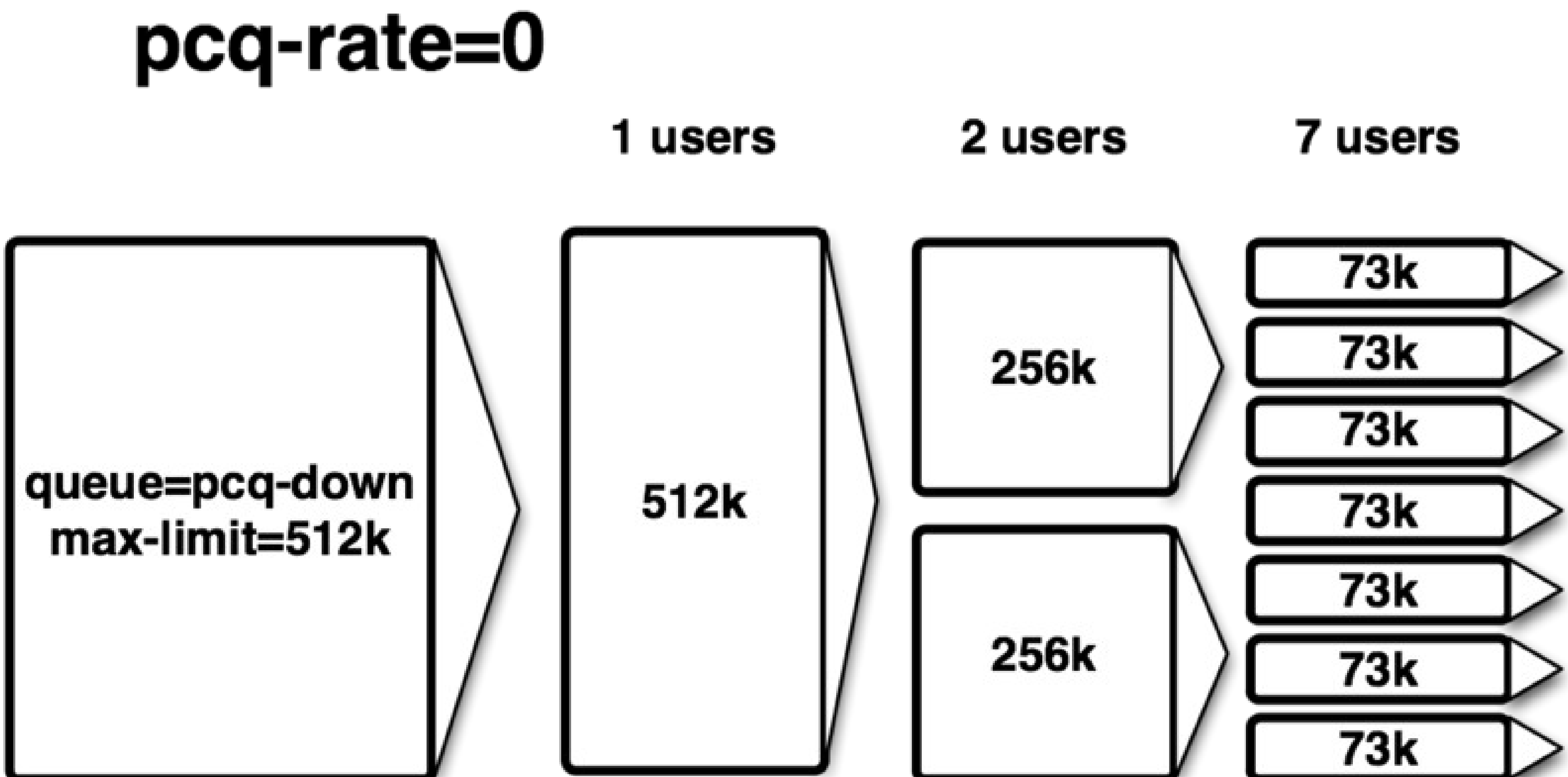

IN
OUT
Grouping by Classifier
FIFO 1
FIFO 2
FIFO 3
...
FIFO n
FIFO Total
FIFO Queue Size = PCQ Total Limit
FIFO Queue Size = PCQ Limit

PCQ Rate (1)



pcq-rate=128000
2 users
4 users
7 users
queue=pcq-down
max-limit=512k
128k
128k
128k
128k
128k
128k
73k
73k
73k
73k
73k
73k
73k

PCQ Rate (2)



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Burst

QoS Feature “Burst”

- Burst is one of the best ways to increase HTTP performance
- Bursts are used to allow higher data rates for a short period of time
- If an _*average data rate*_ is less than **burst-threshold**, burst could be used(_*actual data rate*_ can reach **burst-limit)**
- _A*verage data rate*_ is calculated from the last **burst-time** seconds

Burst - Average Data Rate

- Average data rate is calculated as follows:
  - **burst-time** is being divided into 16 periods
  - router calculates the **average data rate** of each class over these small periods
- Note, that the **actual burst period** is not equal to the burst-time. It can be several times shorter than the burst-time depending on the max-limit, burst-limit, burst-threshold, and actual data rate history (see the graph example on the next slide)

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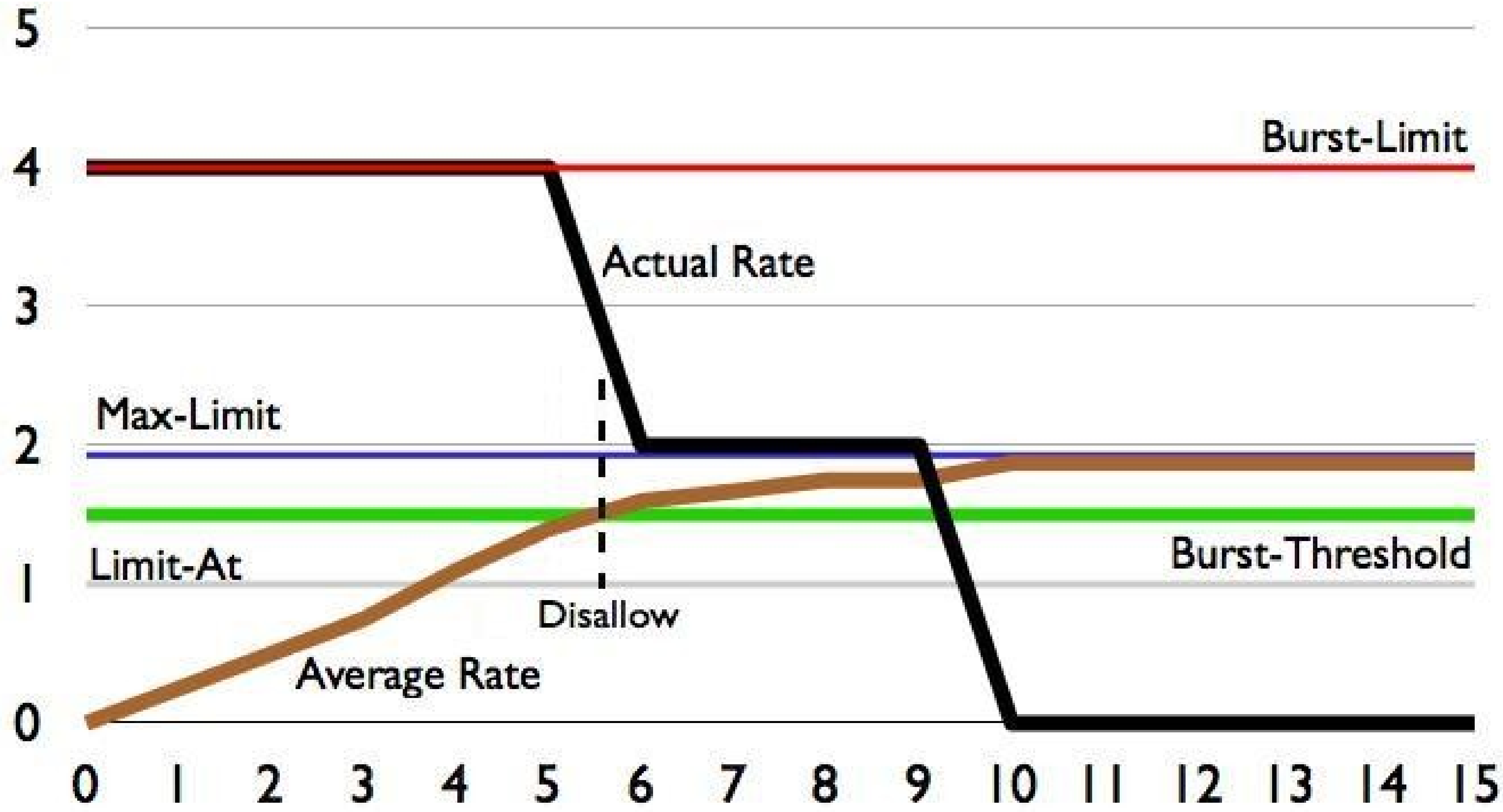
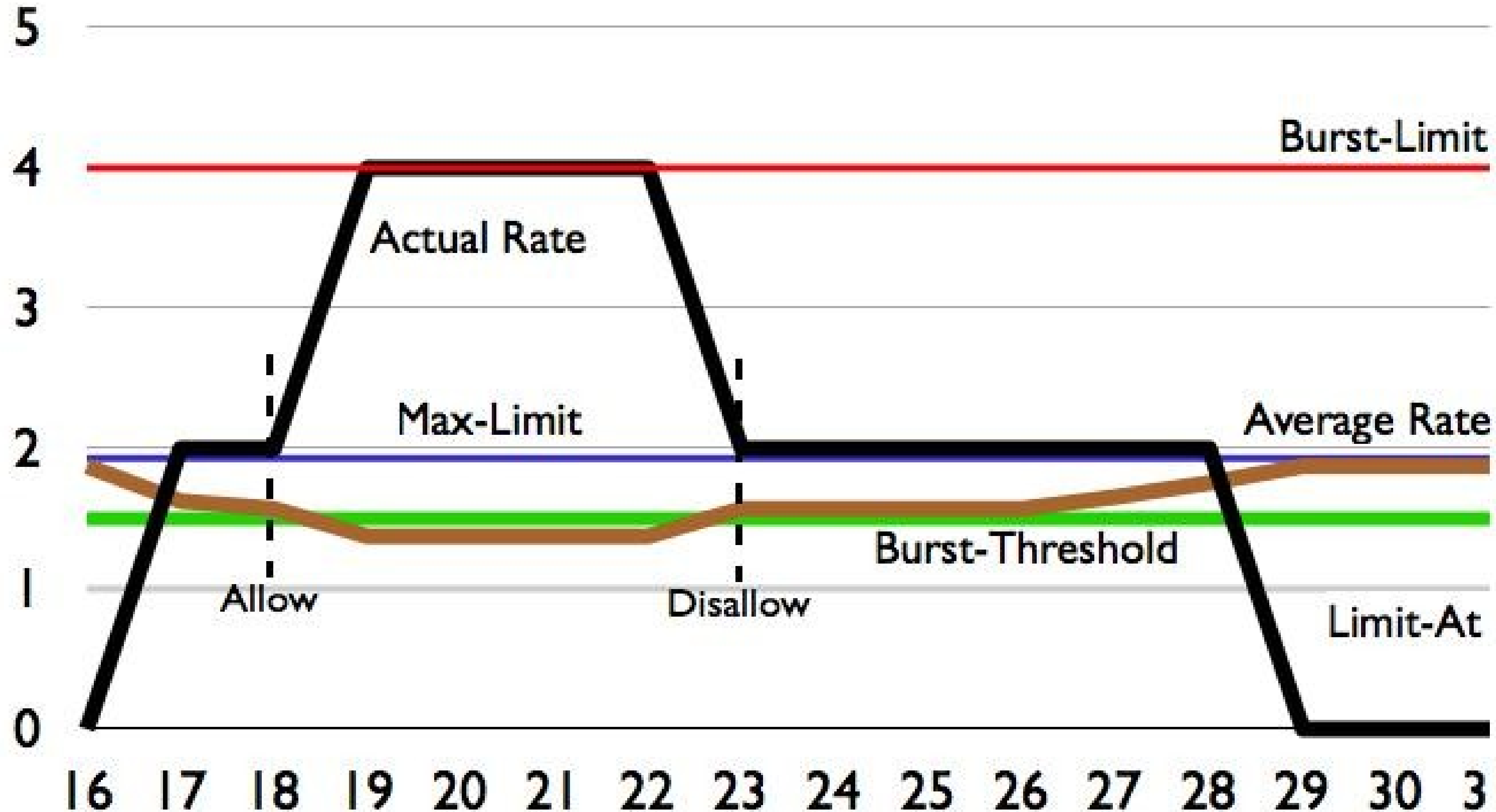
Burst


5
4
3
2
1
0
Burst-Limit
Actual Rate
Max-Limit
Limit-At
Disallow
Burst-Threshold
Average Rate
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Burst (Part 2)

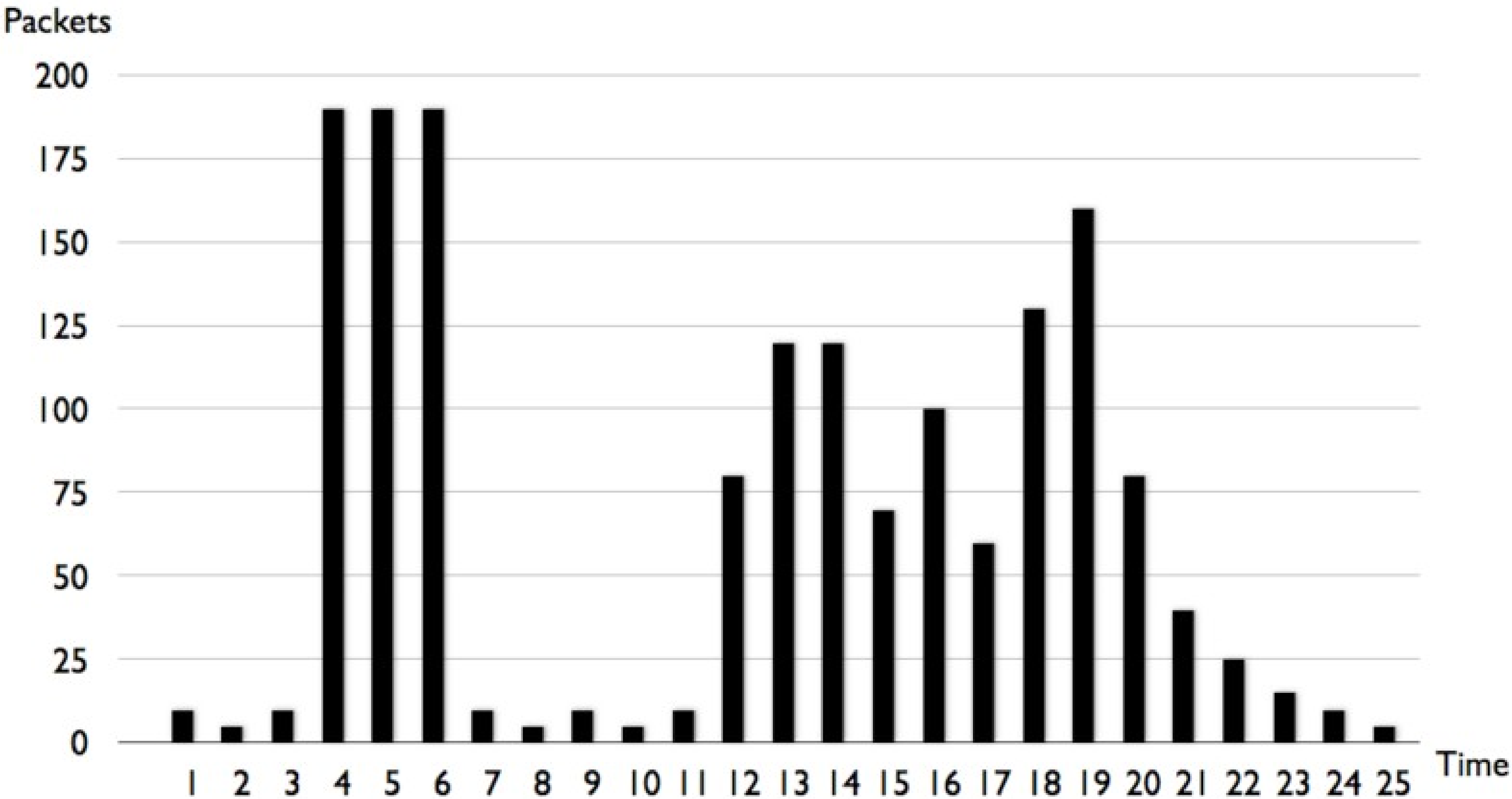


5
4
3
2
1
0
Burst-Limit
Actual Rate
Max-Limit
Average Rate
Burst-Threshold
Allow
Disallow
Limit-At
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Queue Size

Queue Size

- Queue size has a direct impact on the performance of the queue – it is a choice between packet loss and higher latency
- In RouterOS queue sizes are common between the queue types
- To understand Queue size's impact on the traffic we will look at simplified example
  - We will ignore packet retransmits
  - We will assume that process that run continuously can be divided into steps



- There are 25 steps and there are total of 1610 incoming packets over this time frame.

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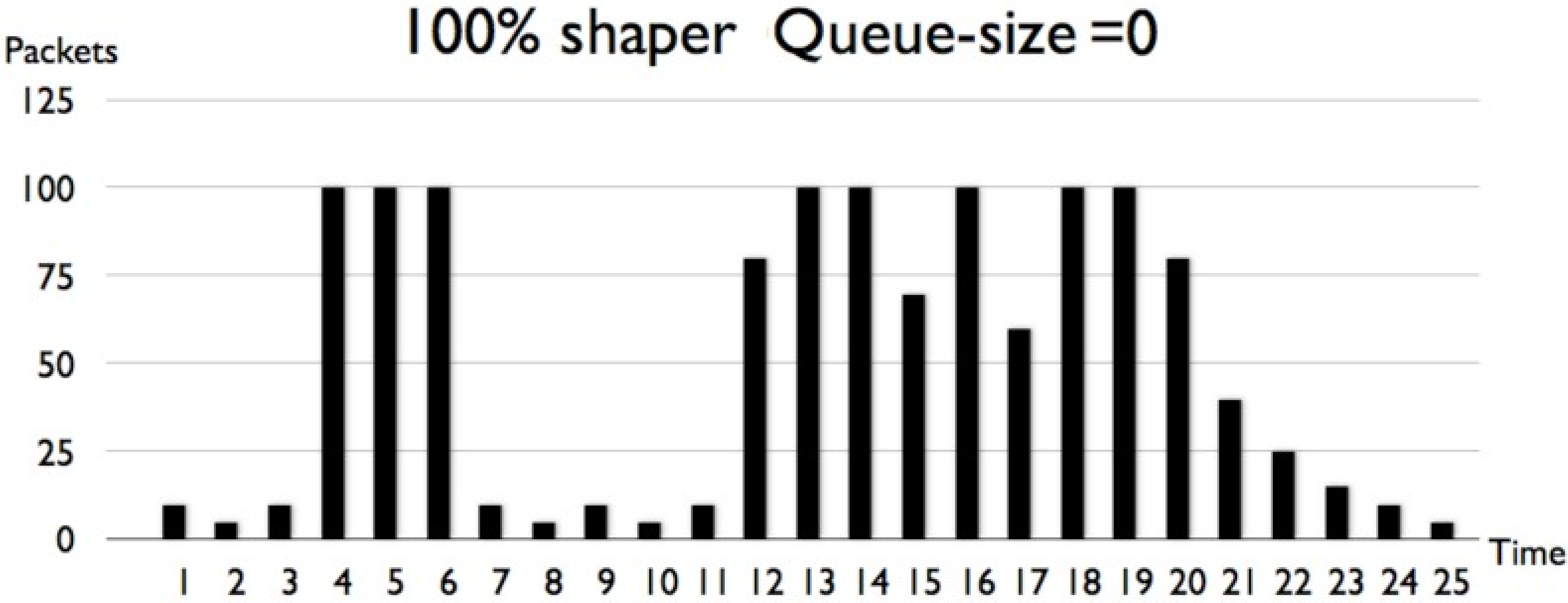
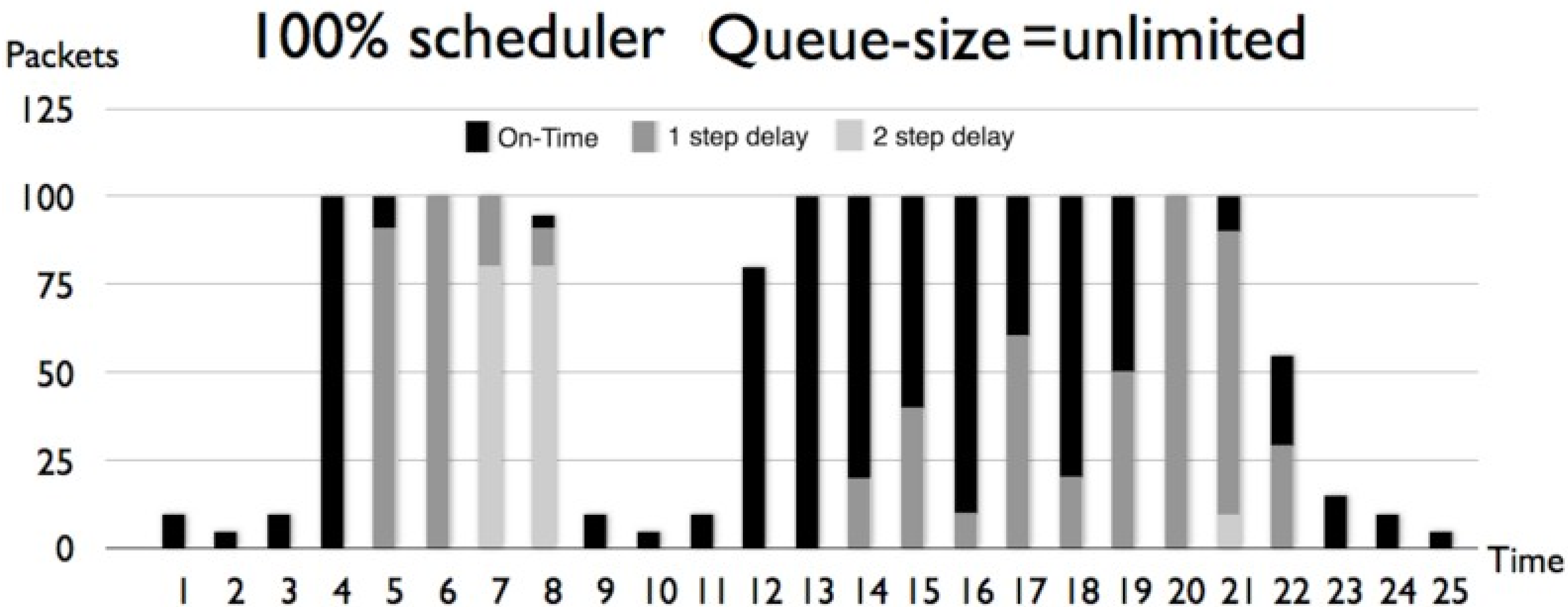
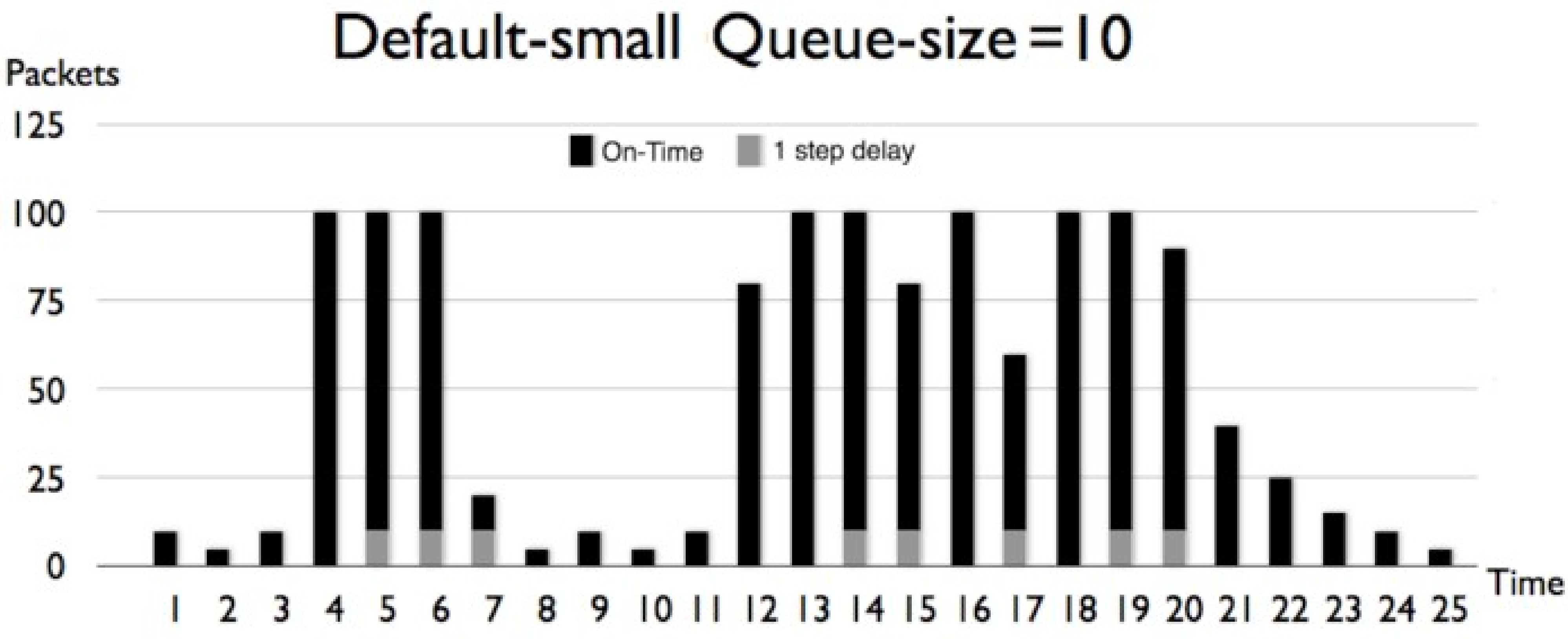


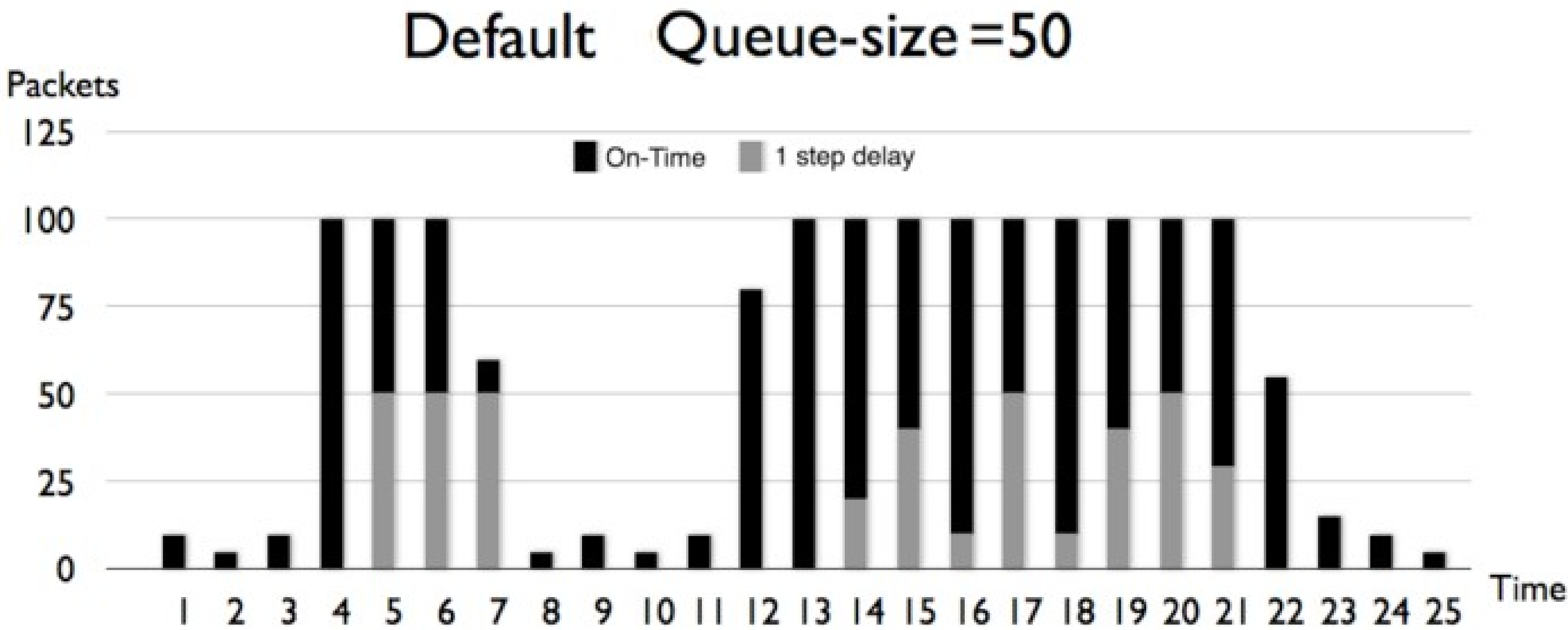
- With this type of limitation only 1250 out of 1610 packets were able to pass the queue (22,4% packet drop), but all packets arrive without delay.



- There was no packet loss, but 630 (39,1%) packets had 1 step delay, and other 170 (10,6%) packets had 2 step delay. (delay = latency)



- There were 320 (19,9%) packets dropped and 80 (5,0%) packets had 1 step delay.

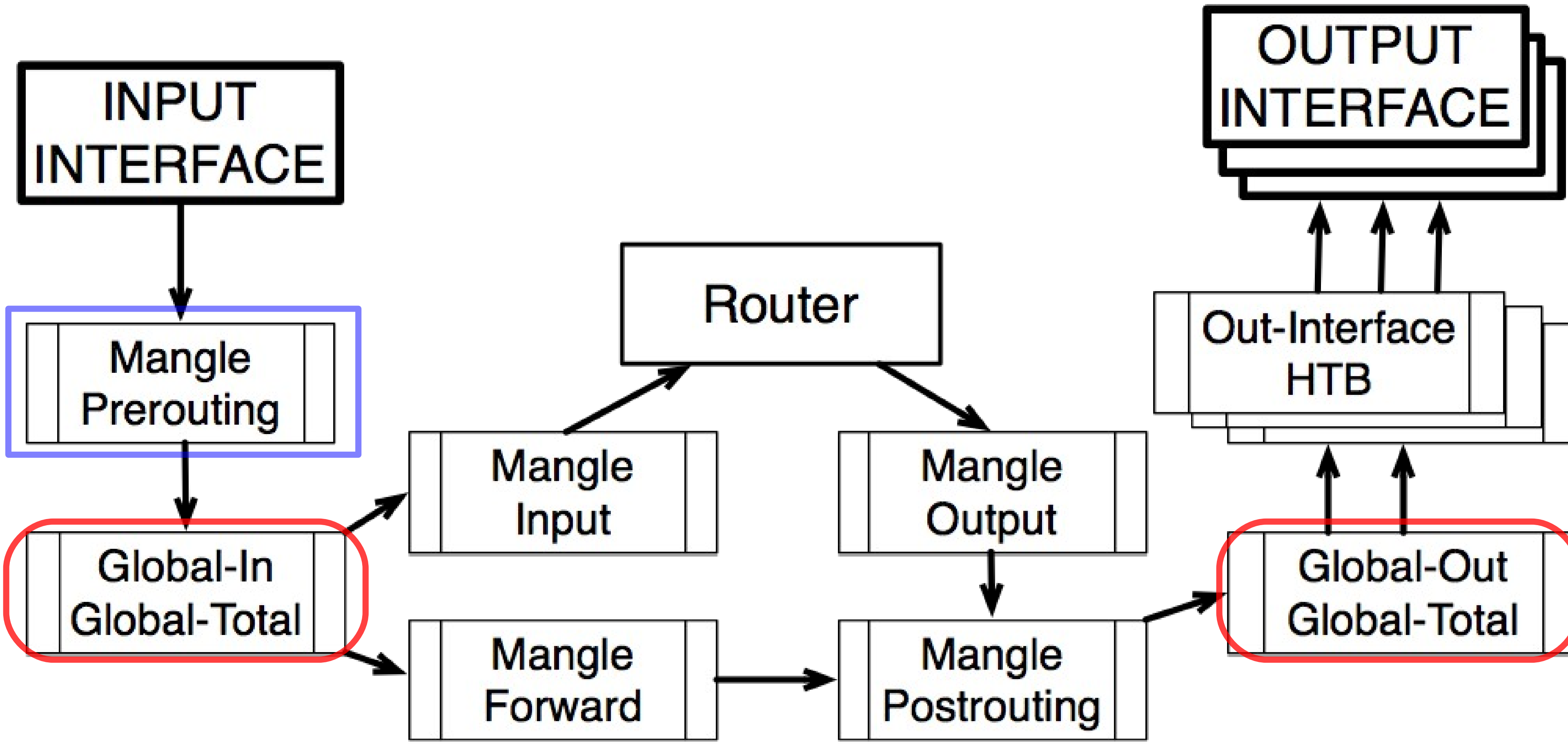


- There were 190 (11,8%) packets dropped and 400 (24,8%) packets had 1 step delay.

Simple Queues

- Simple queues are ordered - similar to firewall rules
  - In order to get to 999th queue packet will have to be checked for match to all 998 previous queues
- Each simple queue **might** stand for 3 separate queues:
  - One in Global-in (“direct” part)
  - One in Global-out (“reverse” part)
  - One in Global-total (“total” part)

Simple Queues and Mangle



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Queue Tree

- Tree queue is one directional only and can be placed in any of the available HTBs
- Queue Tree queues don't have any order – all traffic is processed simultaneously
- All child queues must have packet marks from “/ip firewall mangle” facility assigned to them
- If placed in the same HTB, Simple queue will take all the traffic away from the Queue Tree queue

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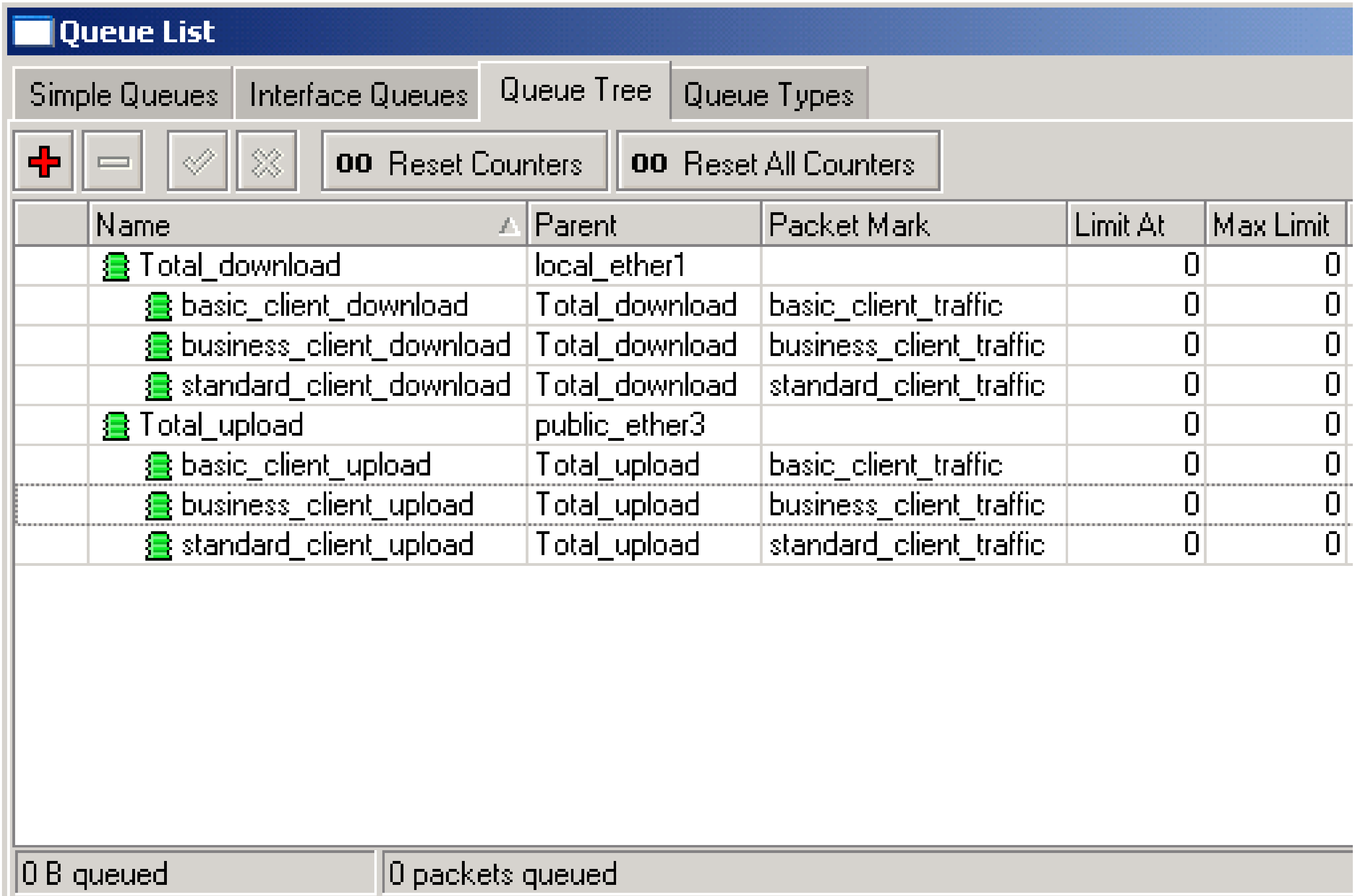
Queue Tree – Winbox View



Simple Queue and Queue Tree (Vegas Style) demonstration

Good luck!