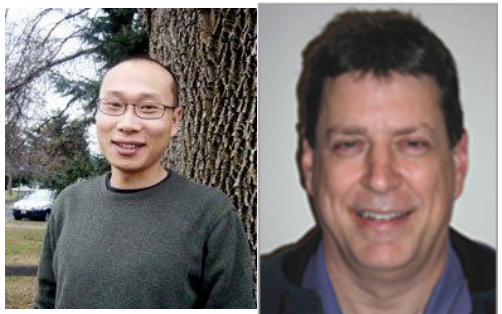
EyeQ
Protecting Network Performance in the Cloud

Vimal

Mohammad Alizadeh
Balaji Prabhakar
David Mazières

Changhoon Kim
Albert Greenberg



Once upon a time…

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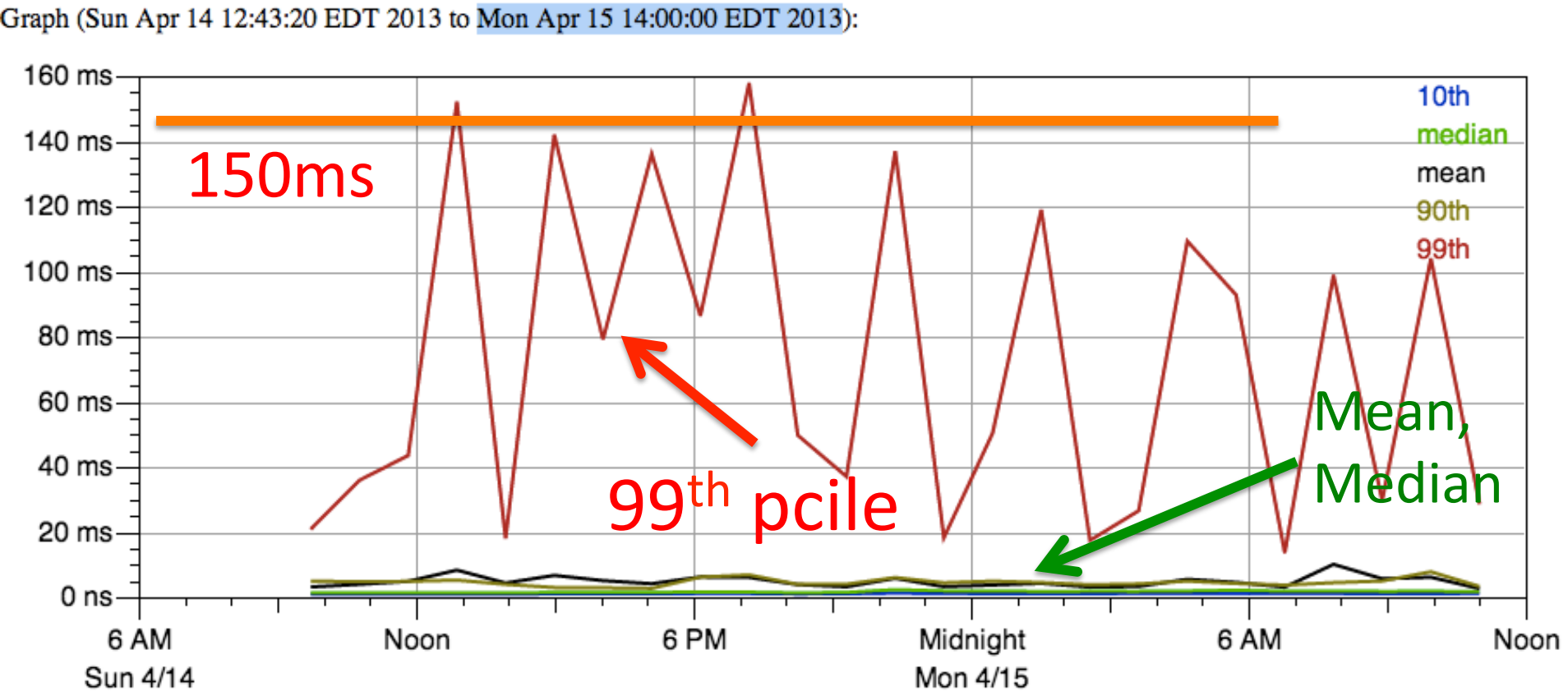
Onc time…

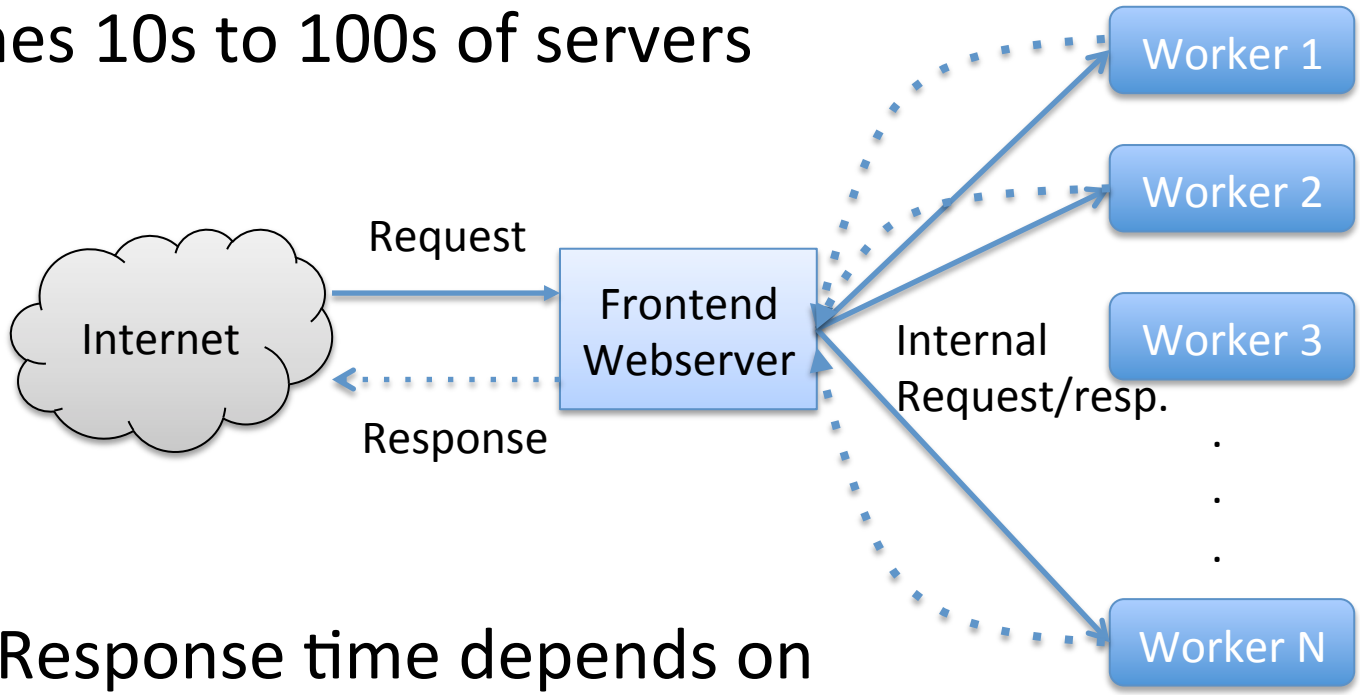
Performance Unpredictability



http://amistrongeryet.com/op_detail.jsp?op=gae_db_readCachedHandles_1&hoursAgo=24

99th percentile latency: Who cares?

Web services: each request touches 10s to 100s of servers



Web Response time depends on the slowest worker.

As N increases, 99th percentile latency really matters

Network Congestion Kills Predictability

Is this how we deal with variability?

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Why We Moved Off The Cloud

The cloud's intractable problem

… is variable — no, highly variable — performance.

`http://code.mixpanel.com/2011/10/27/why-we-moved-off-the-cloud/`

Give up on cloud, move to dedicated

Is this how we deal with variability?

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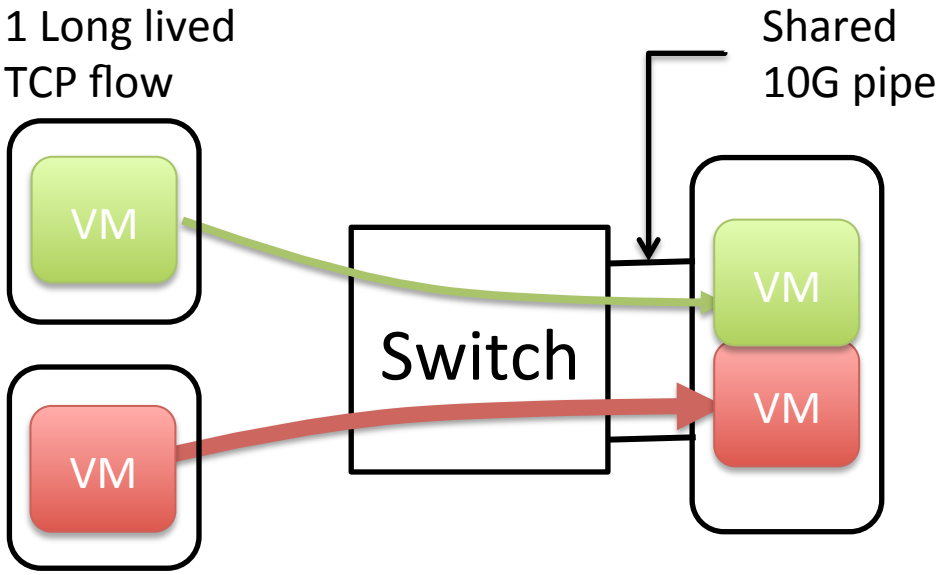
5 Lessons We've Learned Using AWS

… in the Netflix data centers, we have a high capacity, super fast, highly reliable network. This has afforded us the luxury of designing around chatty APIs to remote systems. AWS networking has more variable latency.

`http://techblog.netflix.com/2010/12/5-lessons-weve-learned-using-aws.html`

Overhaul apps to deal with *variability*

Congestion is notorious you when you can't "see" it

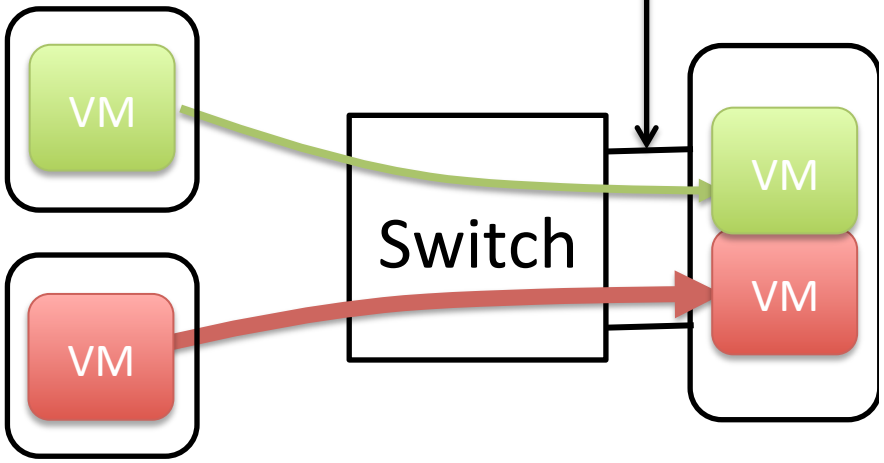


Bursty UDP session:
2.5Gb/s
ON: 5ms
OFF: 15ms

Congestion is notorious you when you can't "see" it

1 Long lived TCP flow

Shared 10G pipe



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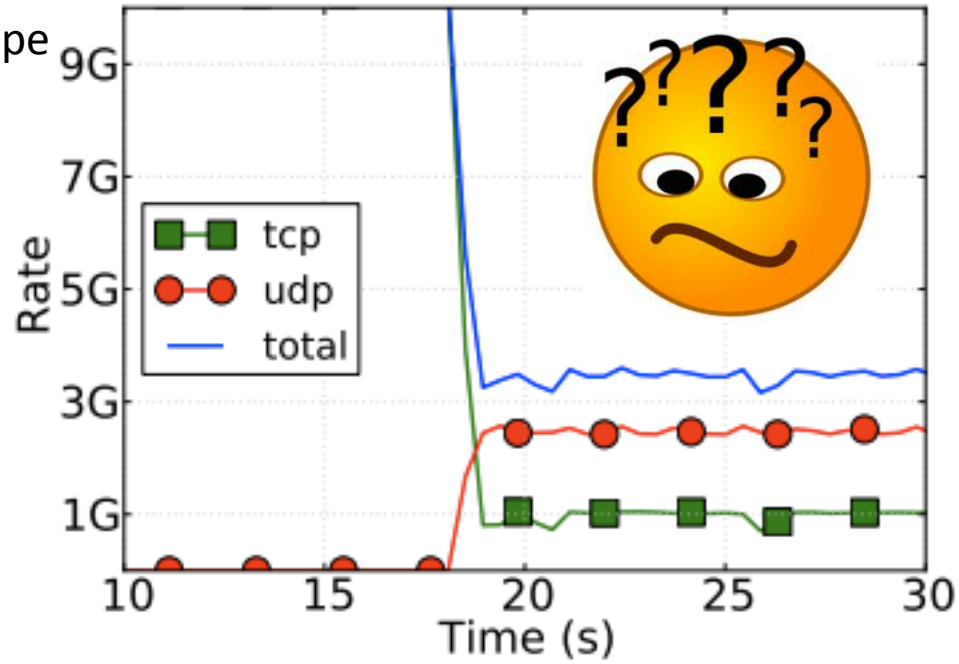

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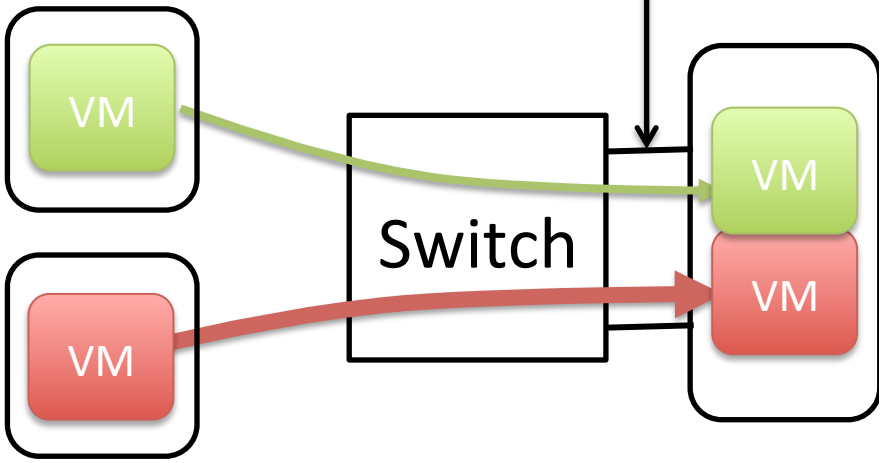

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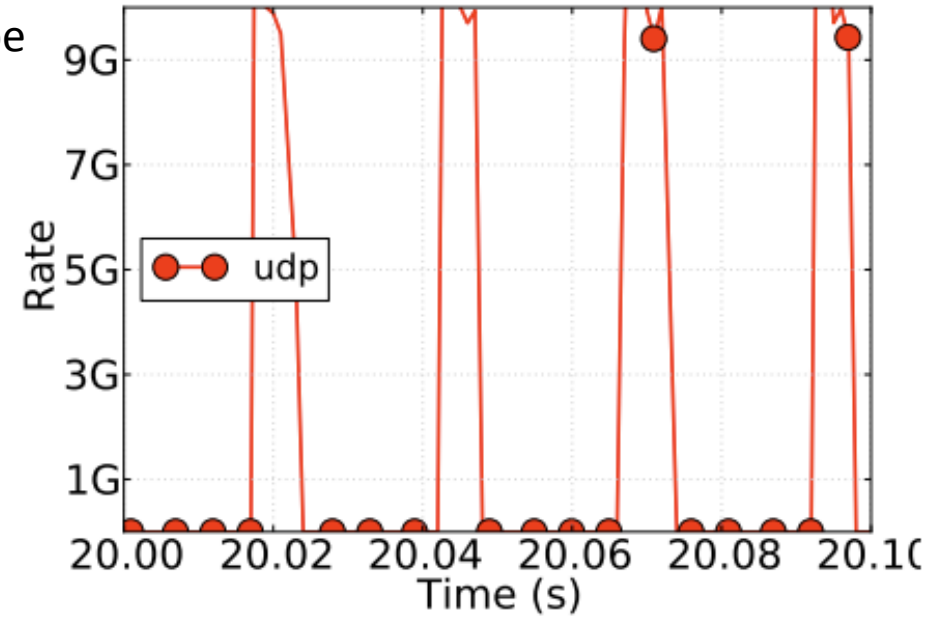
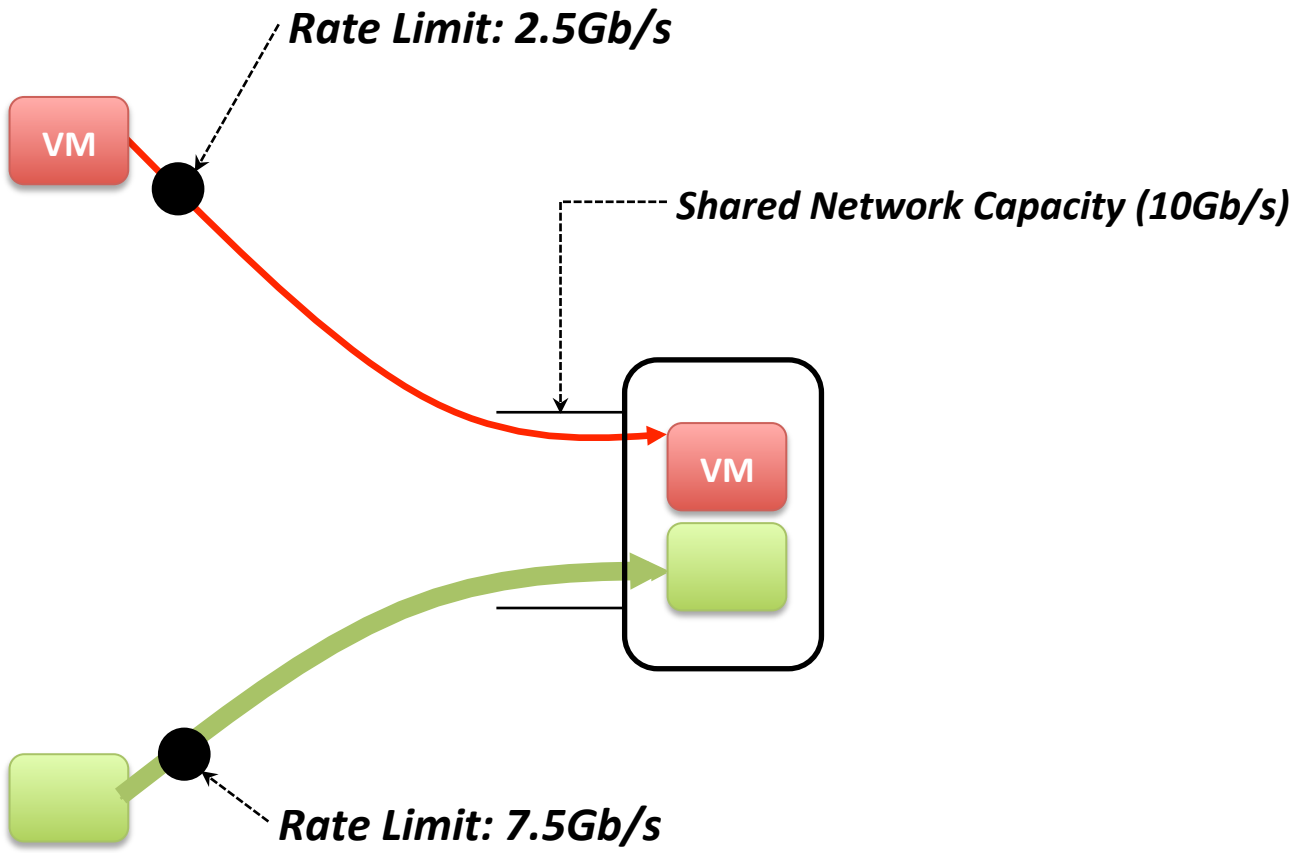


Strawman: Rate Limiting



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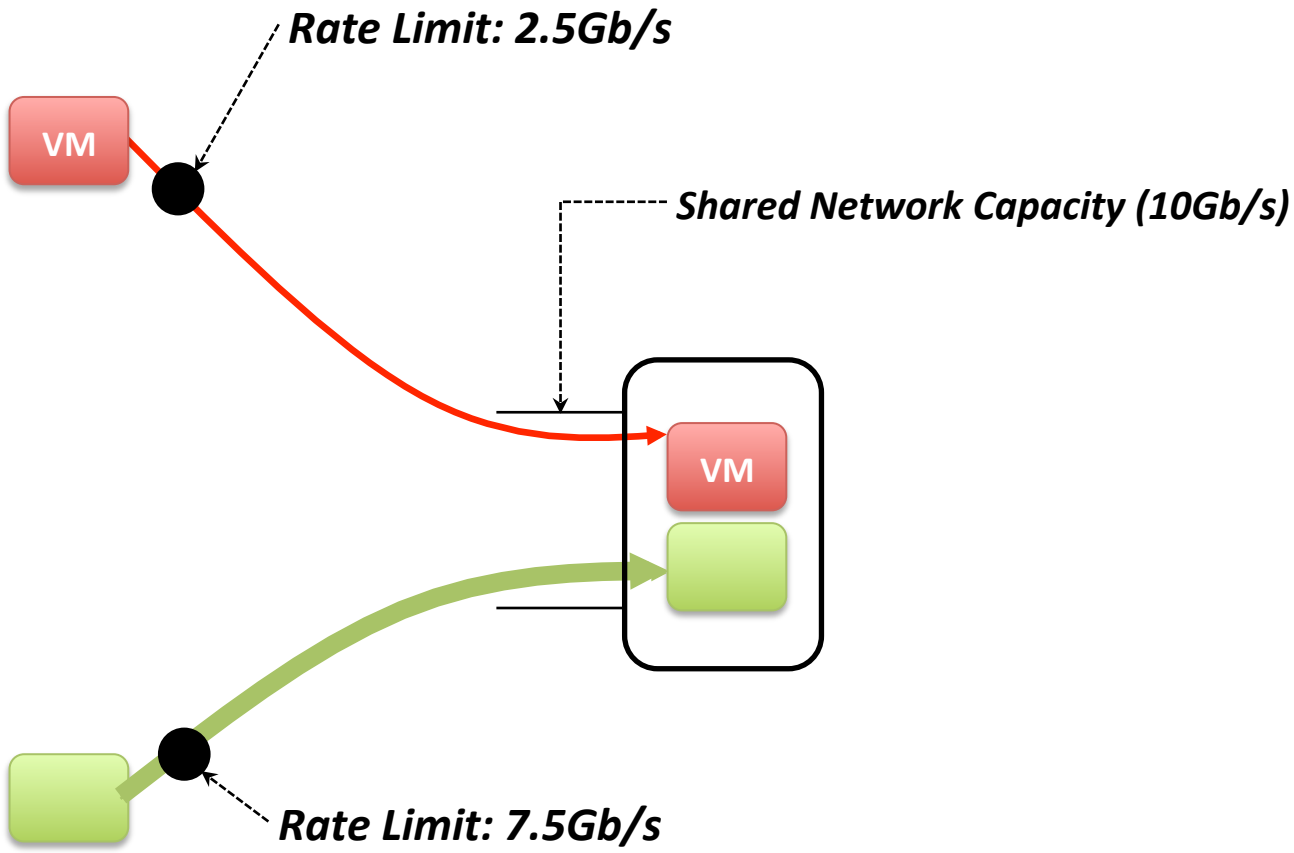

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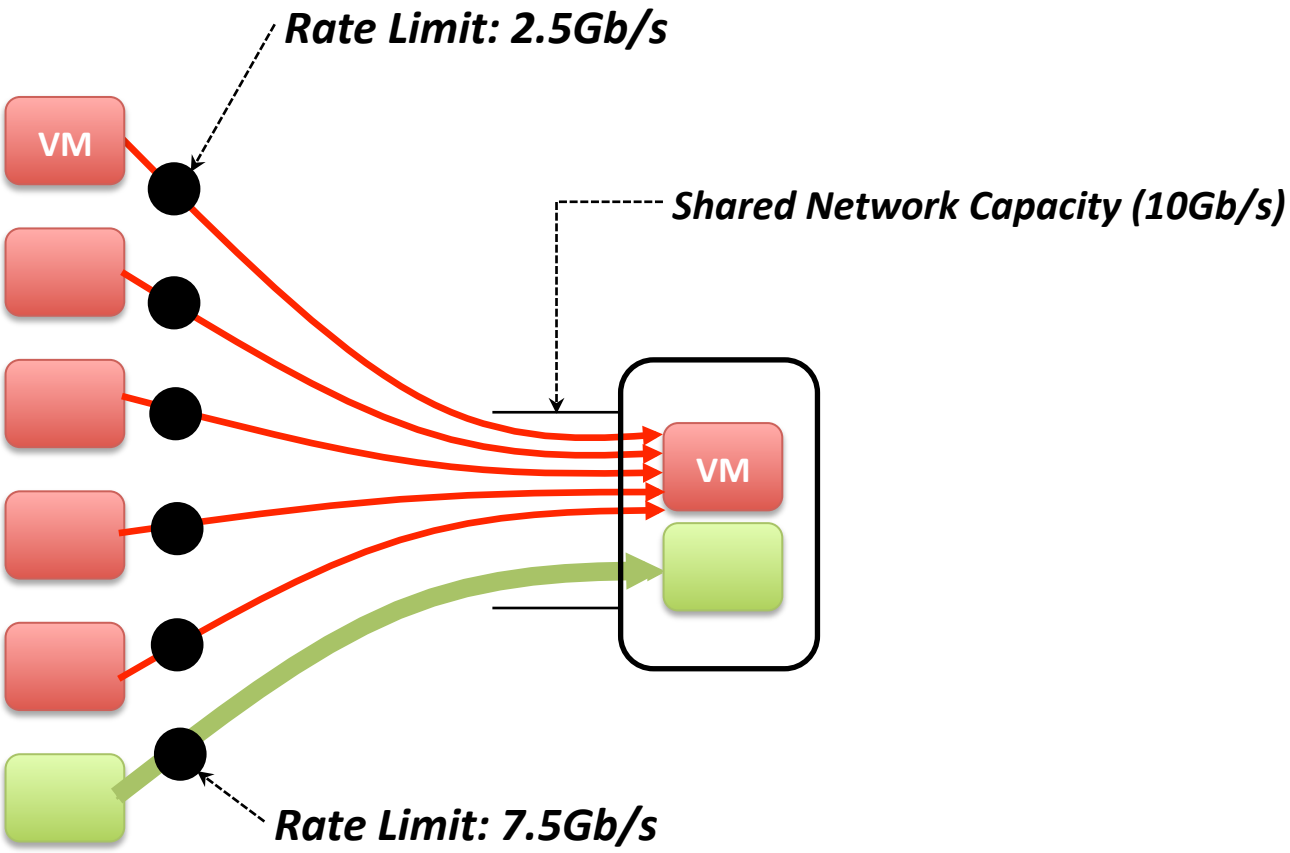
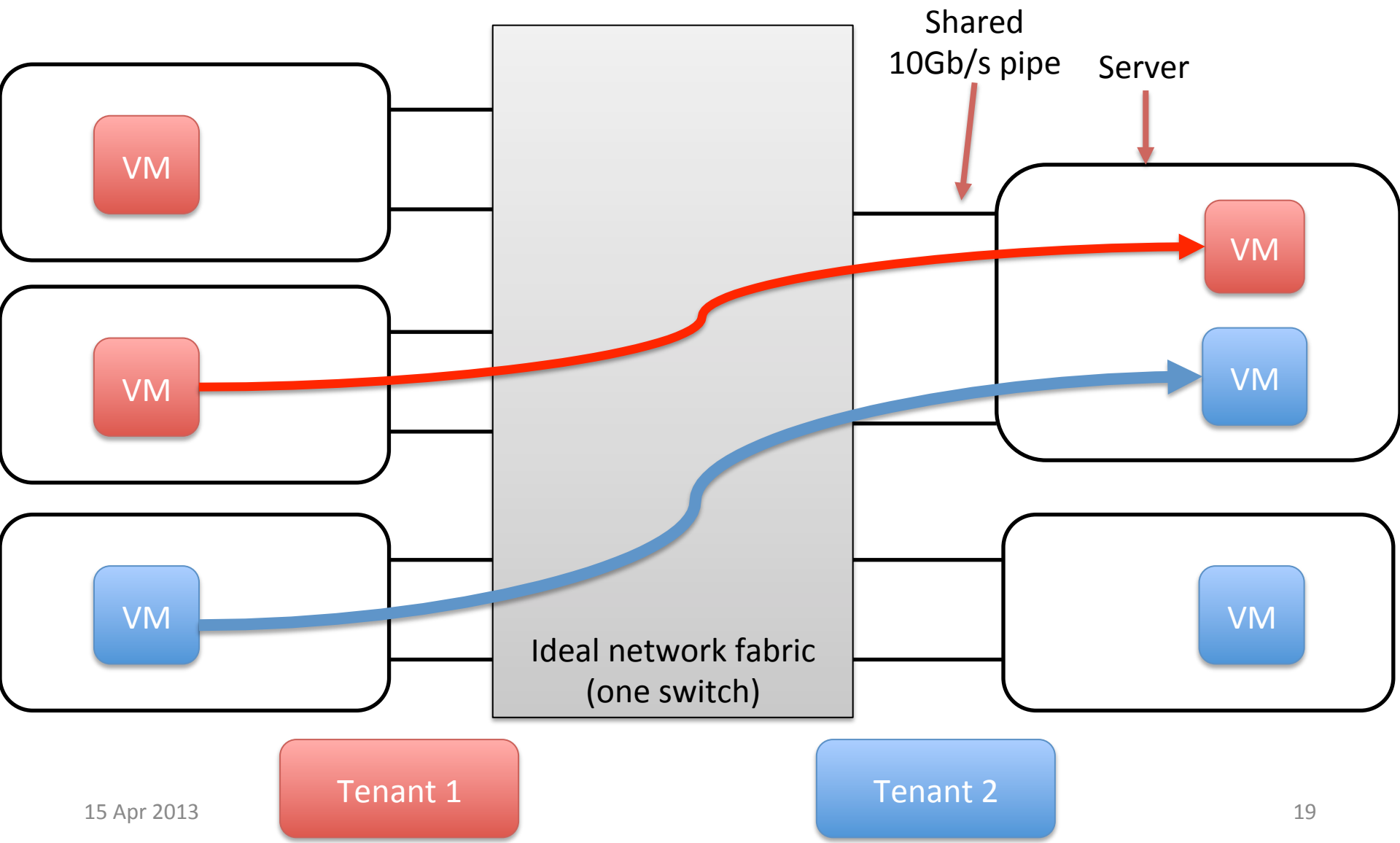


Recap…

- Bandwidth contention
  - Can occur in a few milliseconds!
  - Happens even if tenants don't talk to each other
  - Invisible on 5 minute logs!
- Cannot trust tenants at all
  - Easy to grab more bandwidth simply by blasting traffic (UDP)
- Naïve rate limiting not enough
  - VMs can gang up and blast traffic

Where does Congestion Happen?



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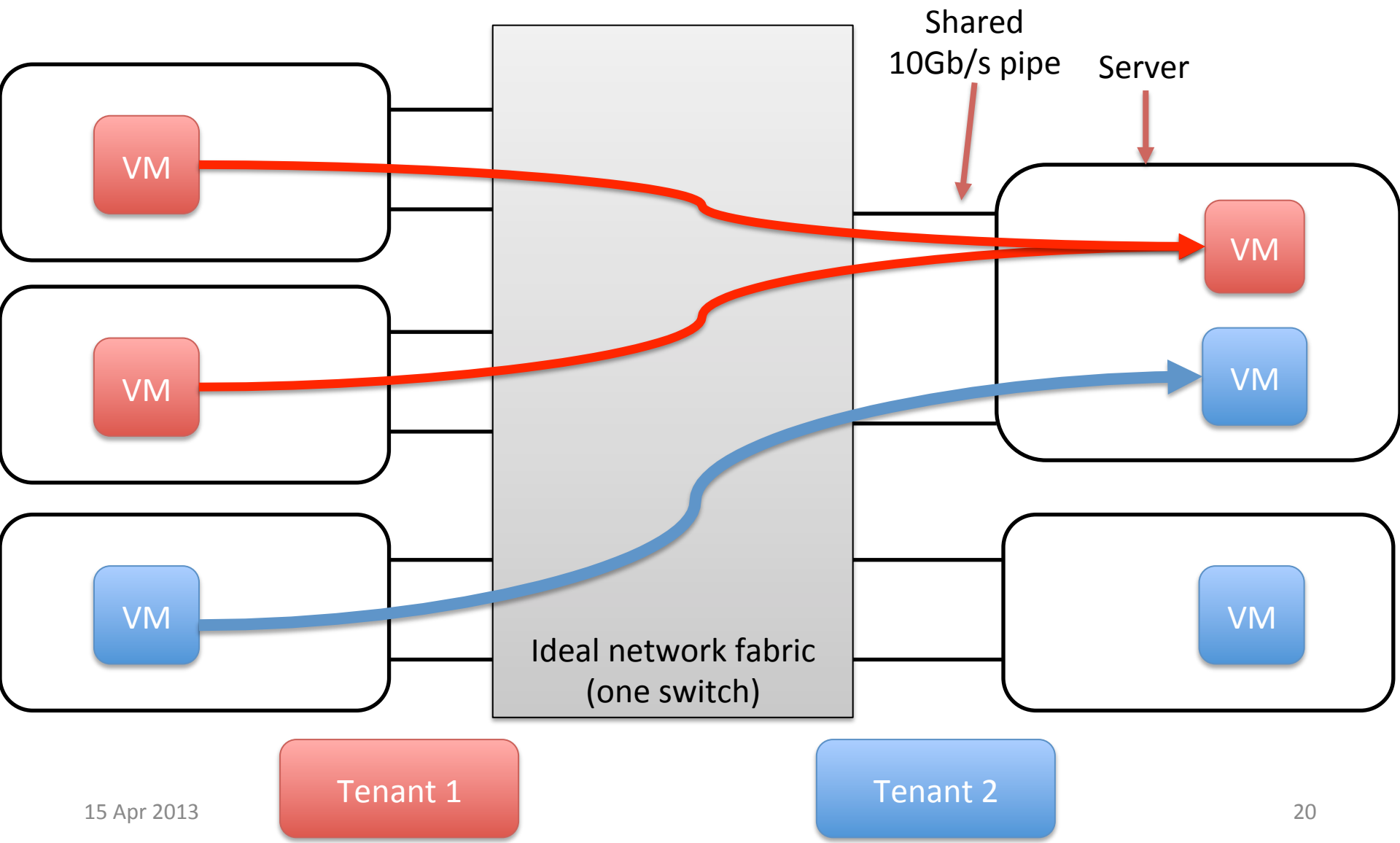

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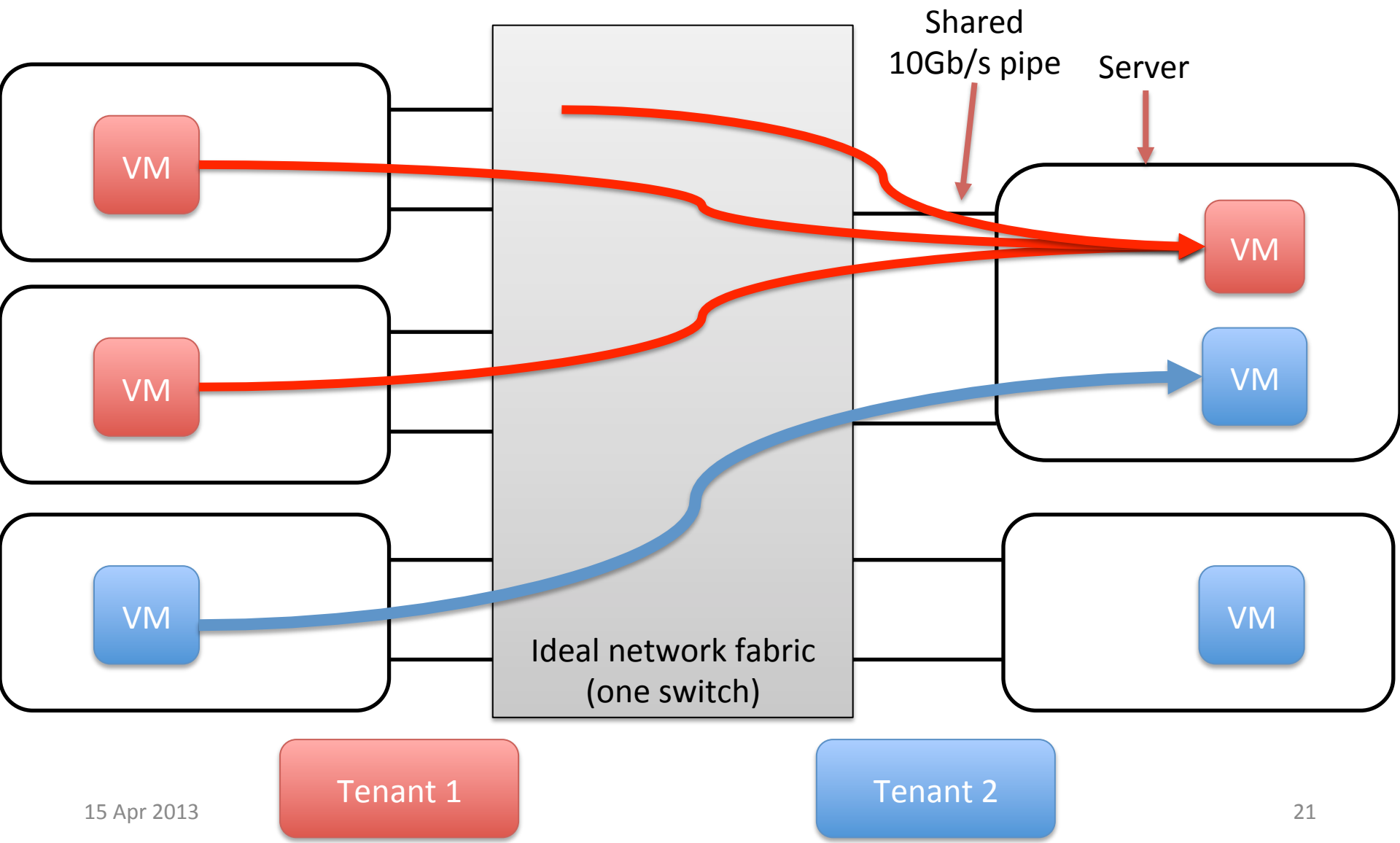

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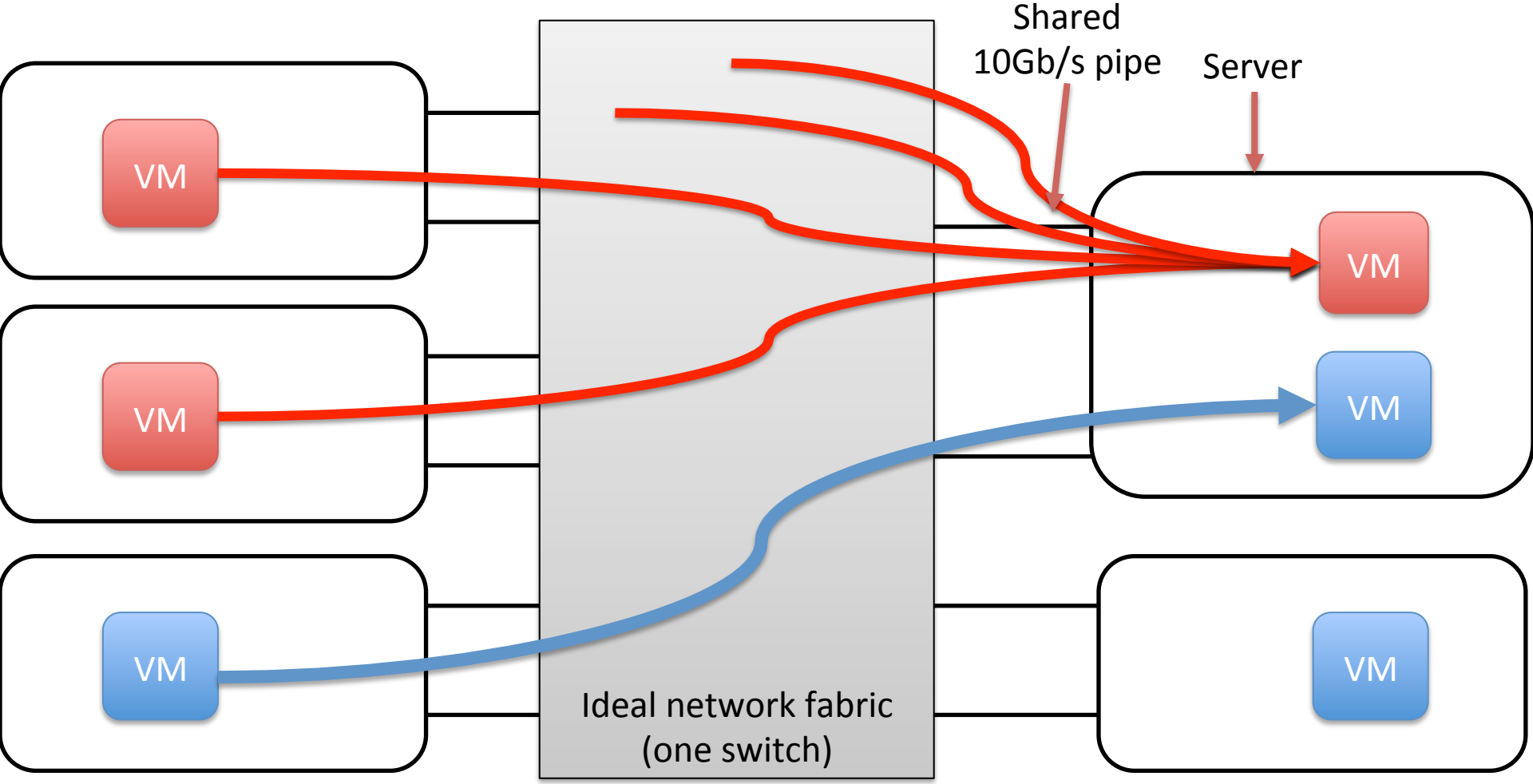

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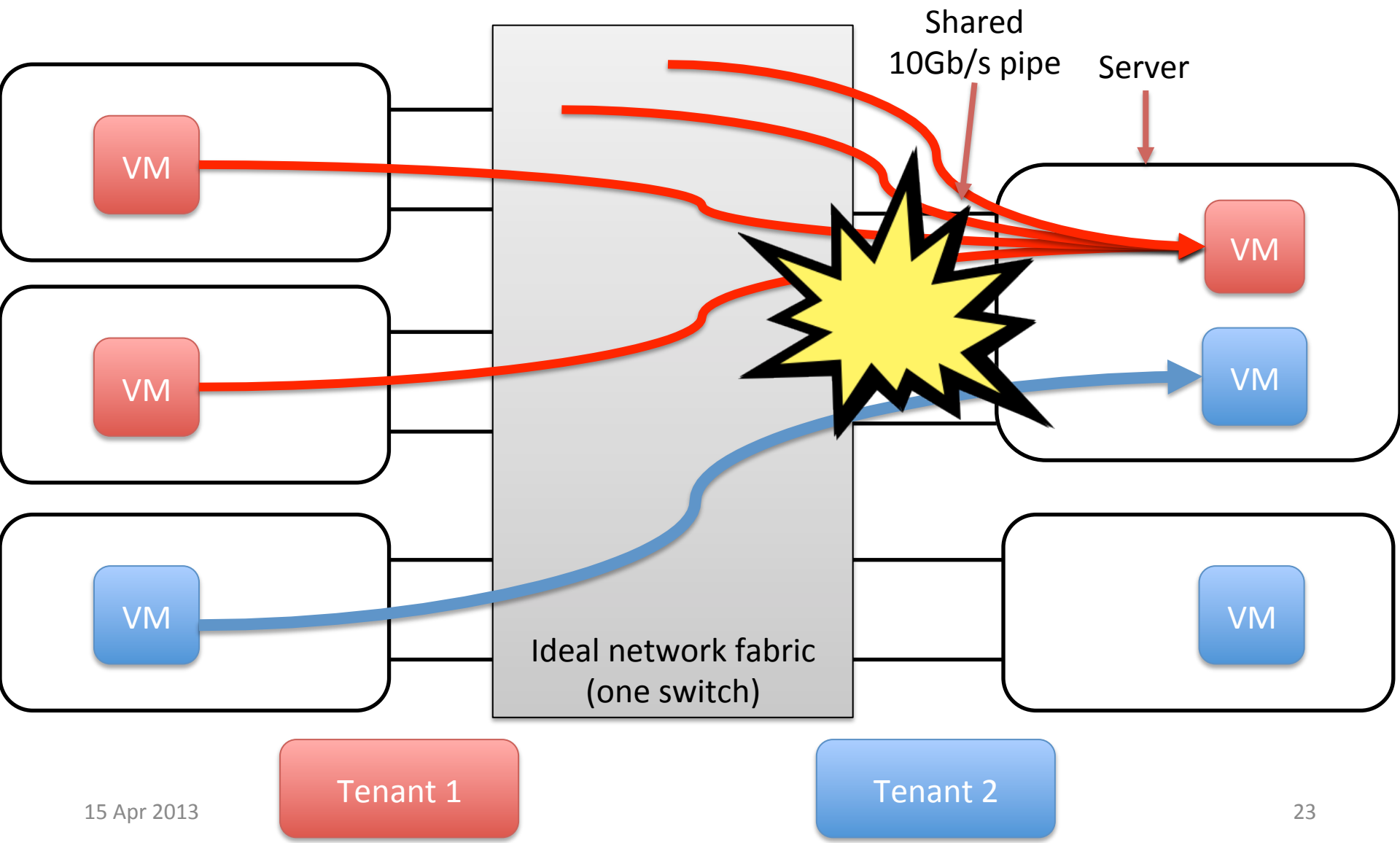
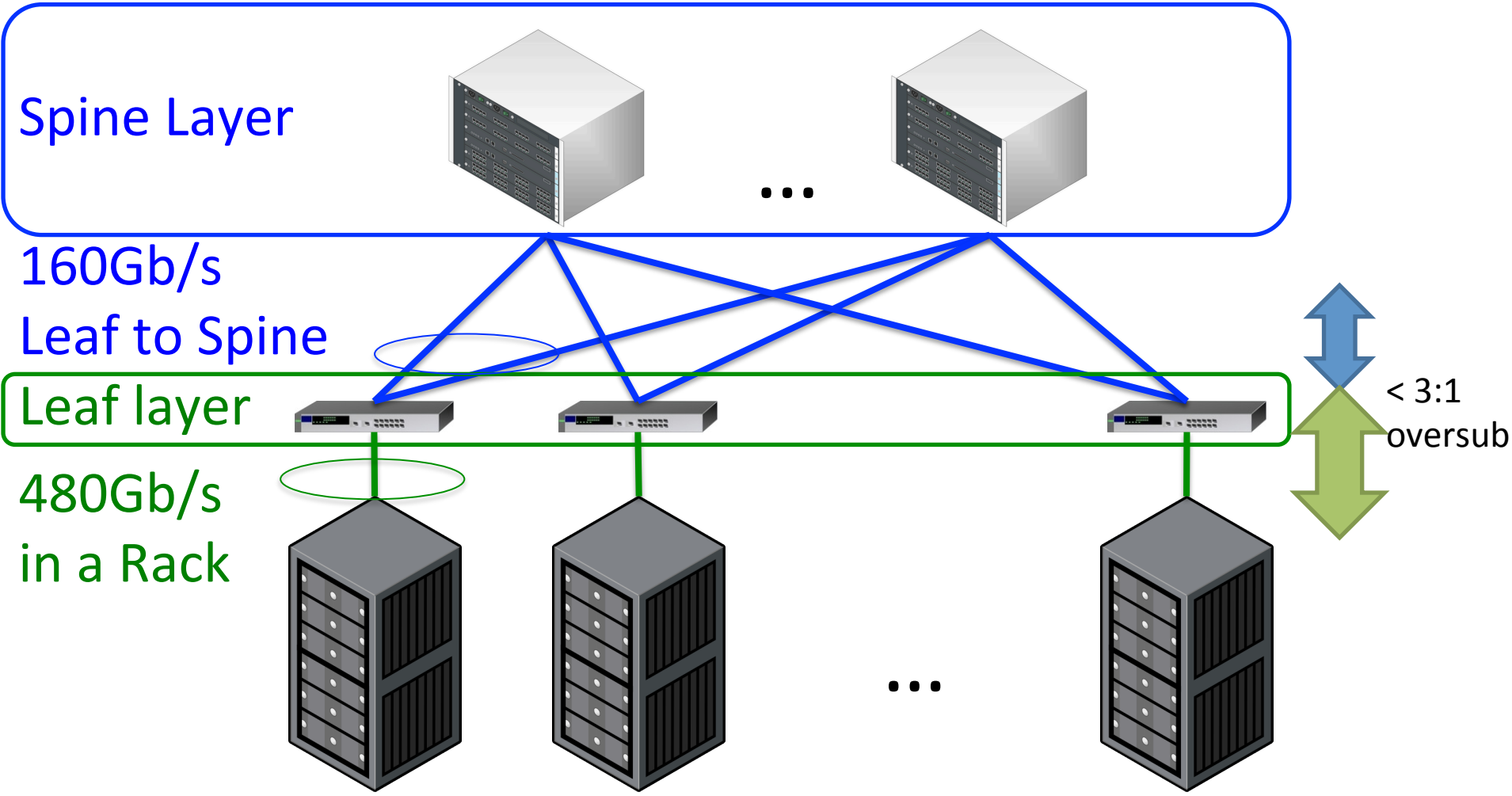
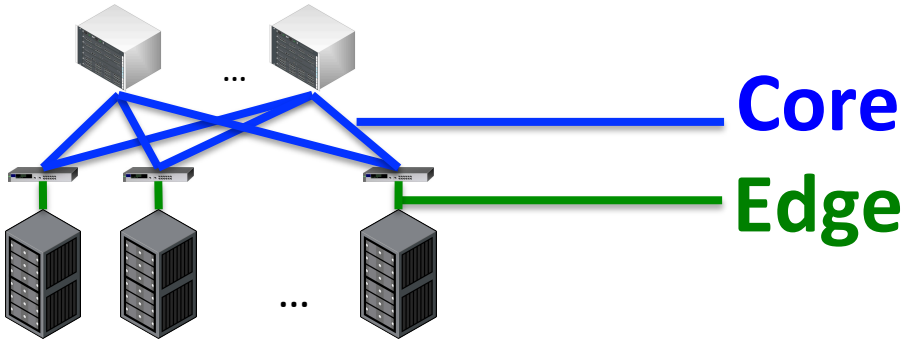
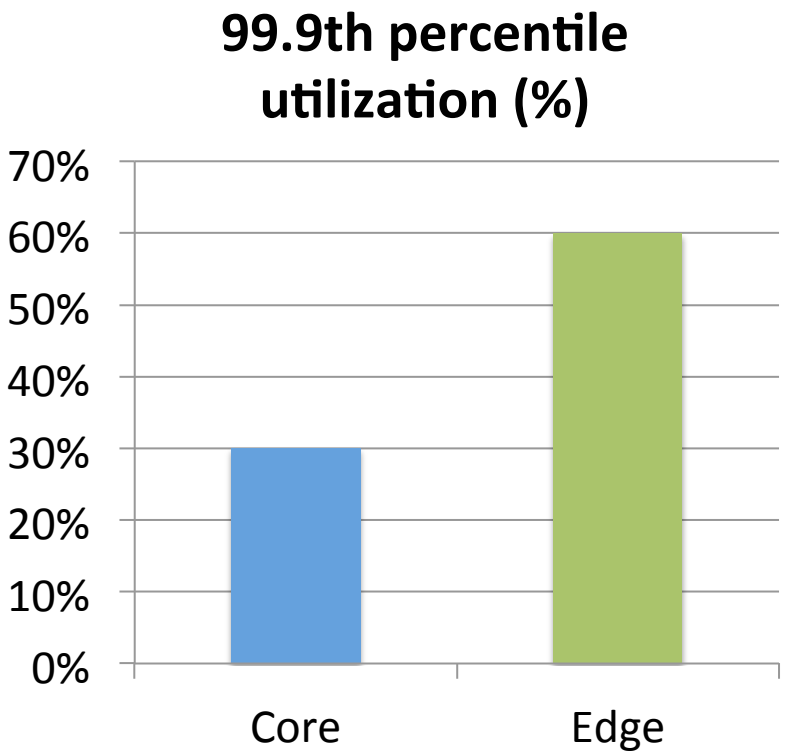


Congestion Study on Windows Azure







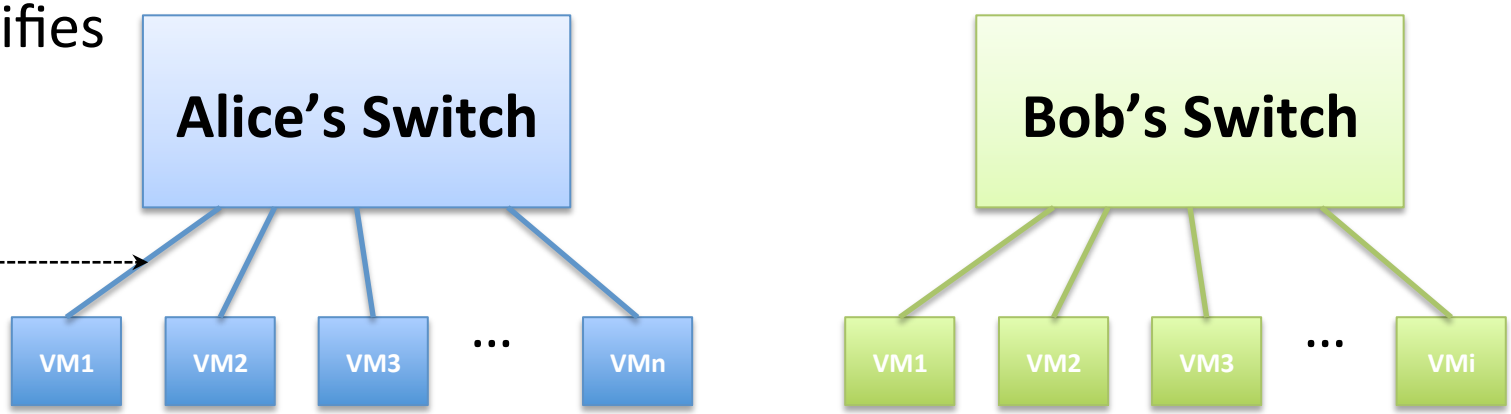
Timescales: over 2 weeks, 99.9th pcile = several minutes

Hottest cluster: 1000x more drops at the Edge, than Core.

16 of 17 clusters: 0 drops in the Core.

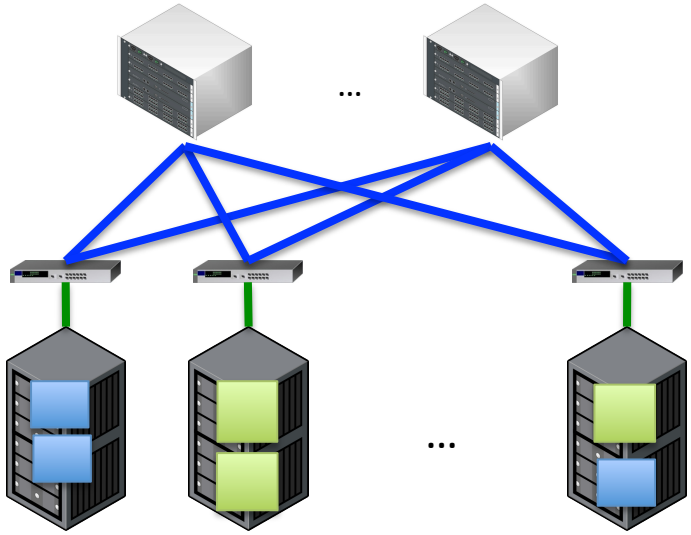
EyeQ's Goal: Rate Guarantees for VMs in the Cloud

Customer specifies capacity of the virtual NIC.

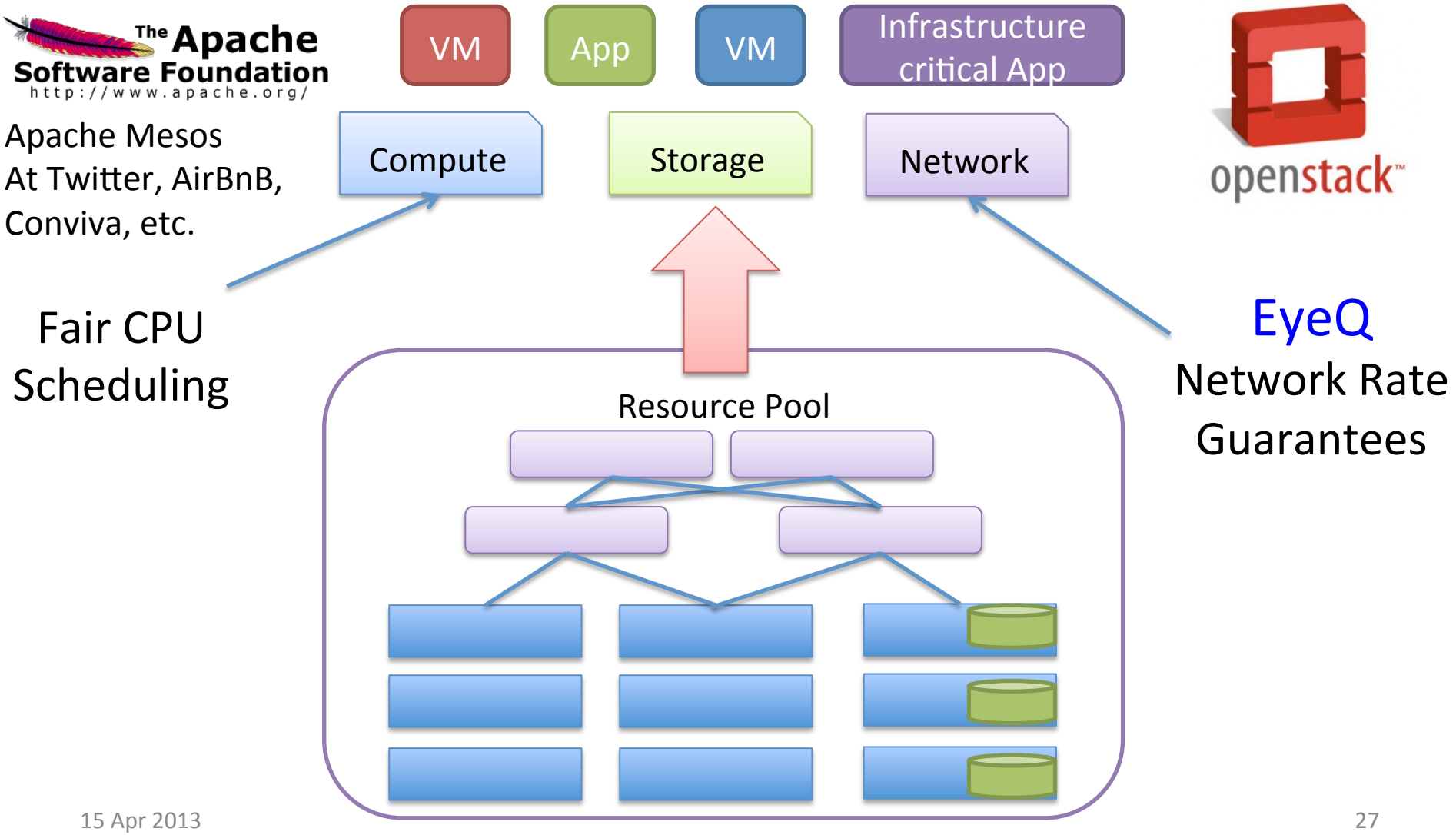


Provider: assures near dedicated performance.

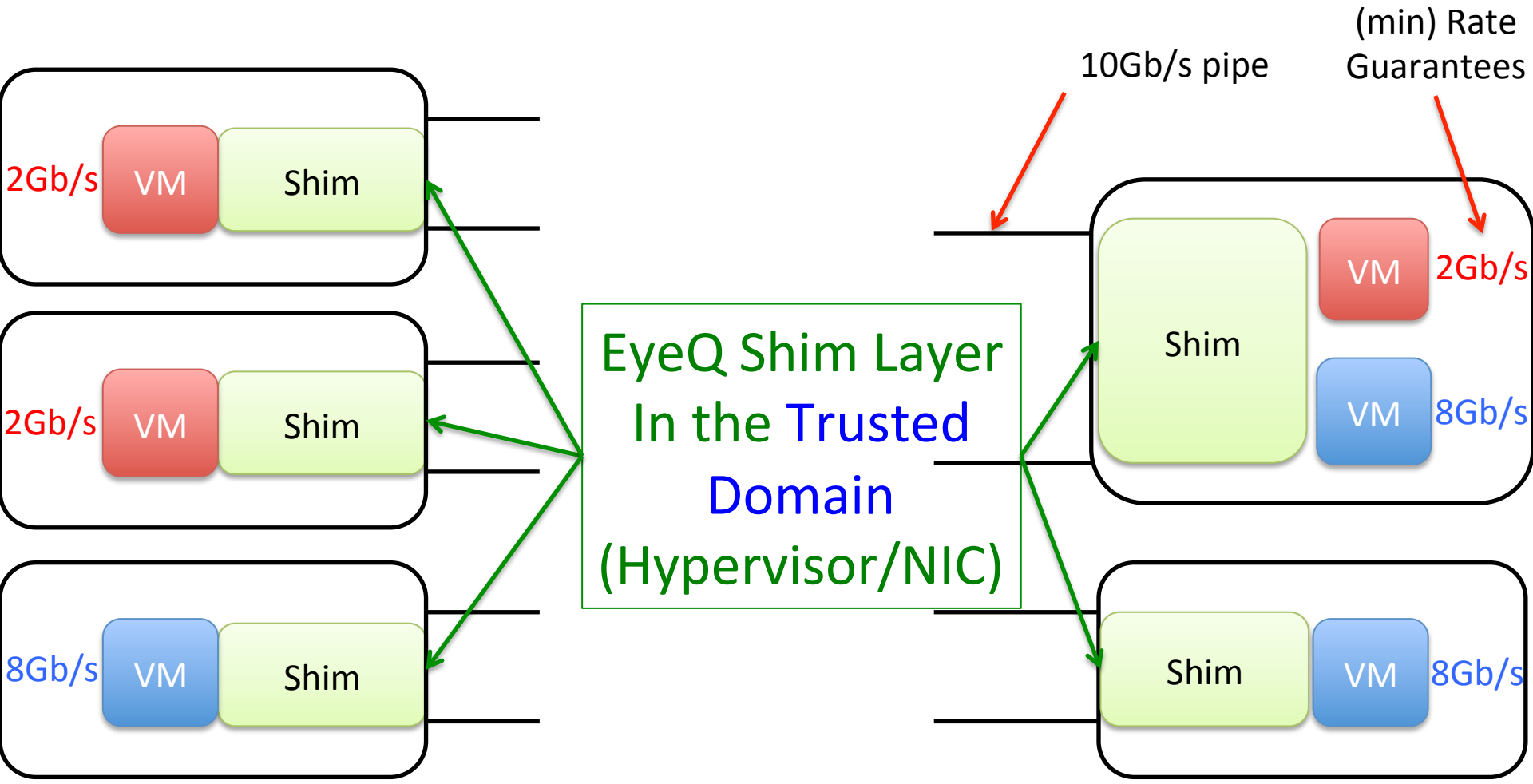
Rate guarantees => Performance isolation



The Big Picture: Resource Management



Decentralized Scheduling



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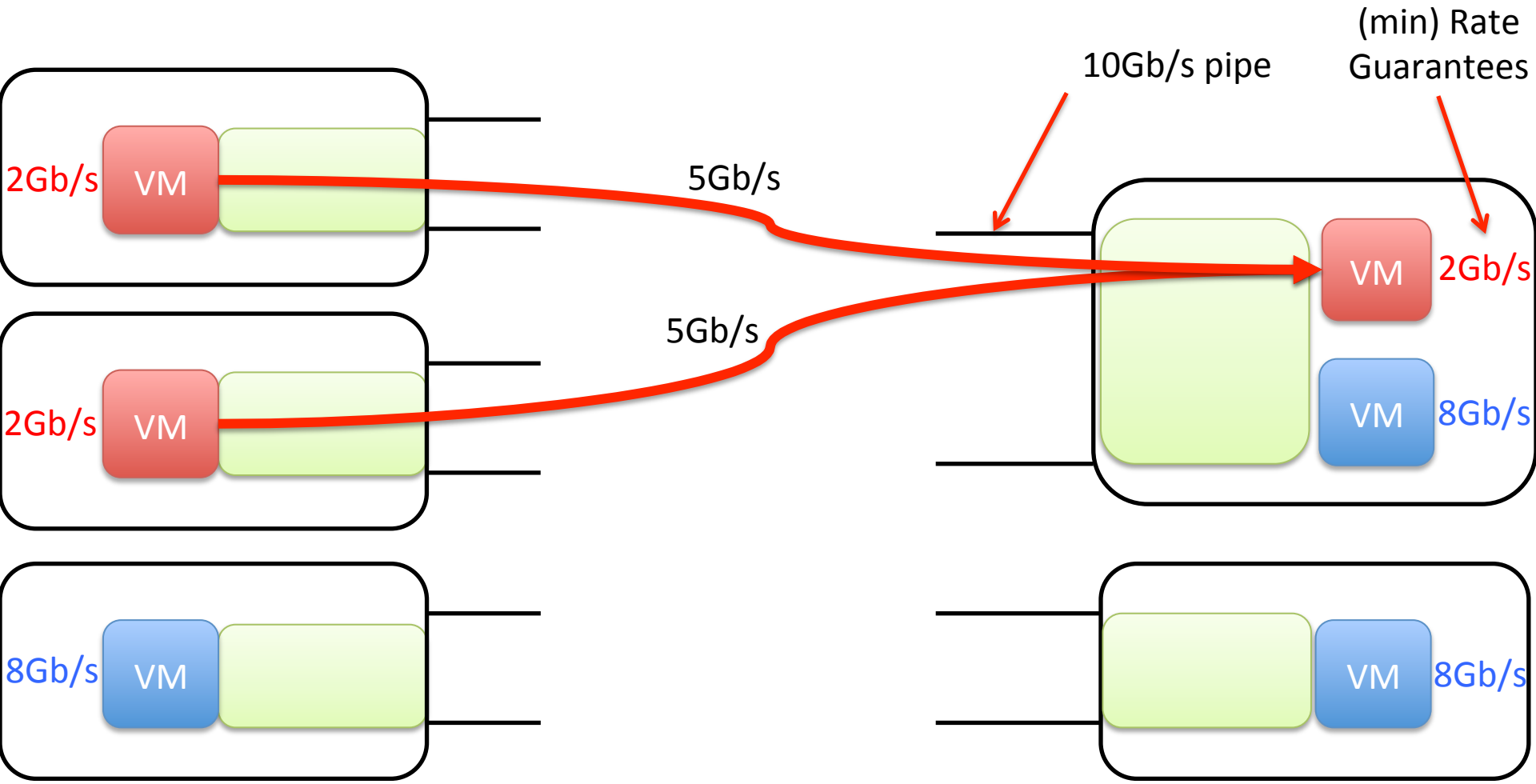

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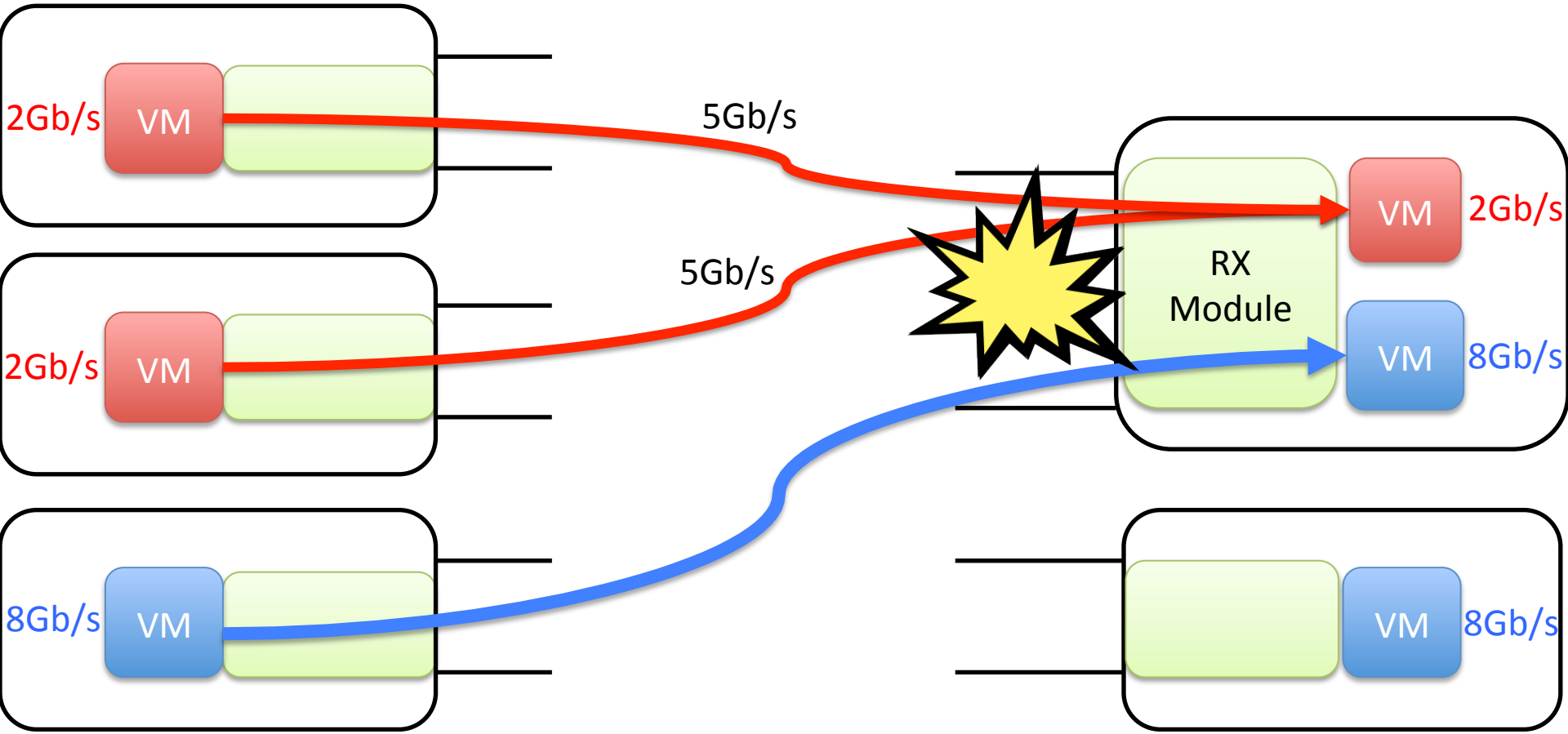

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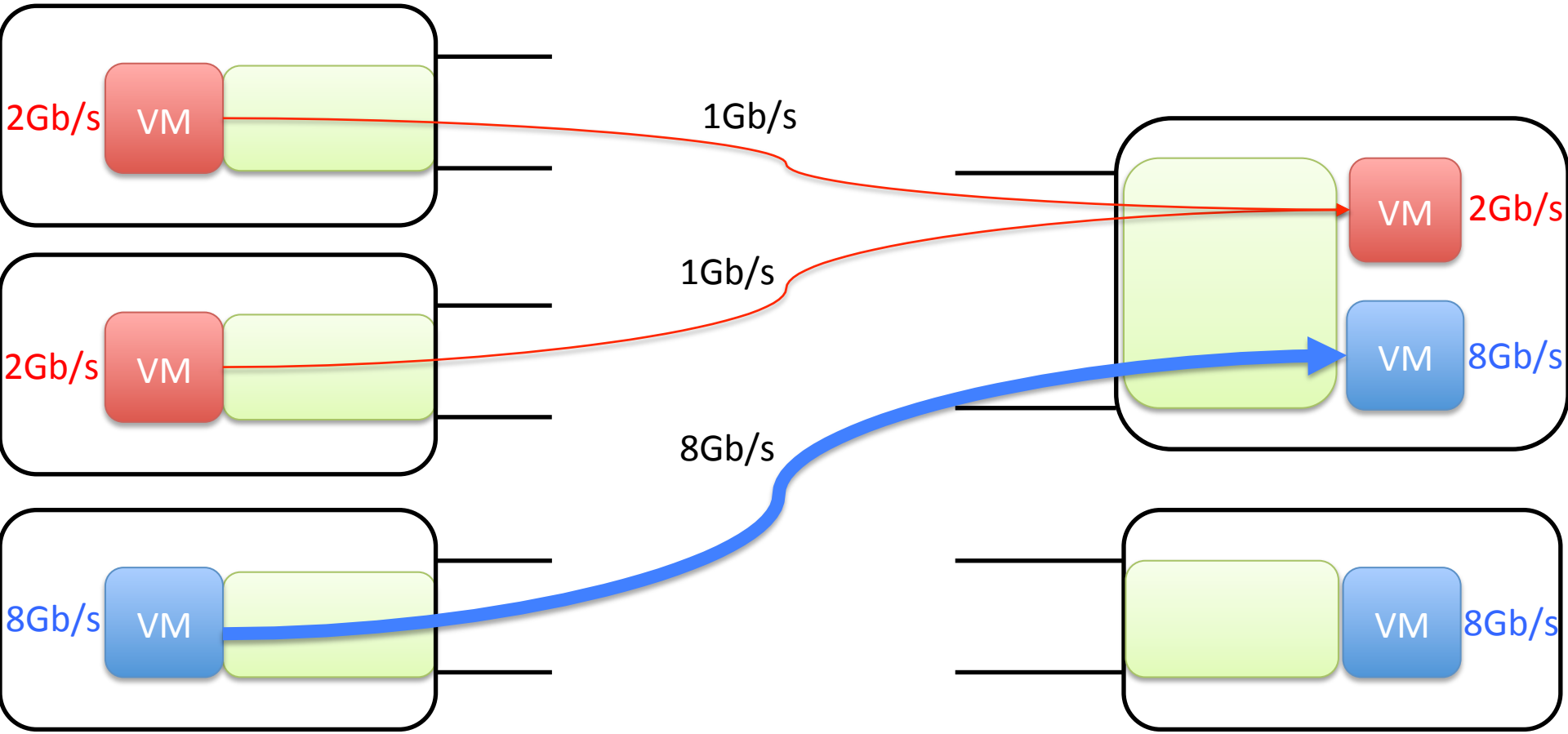

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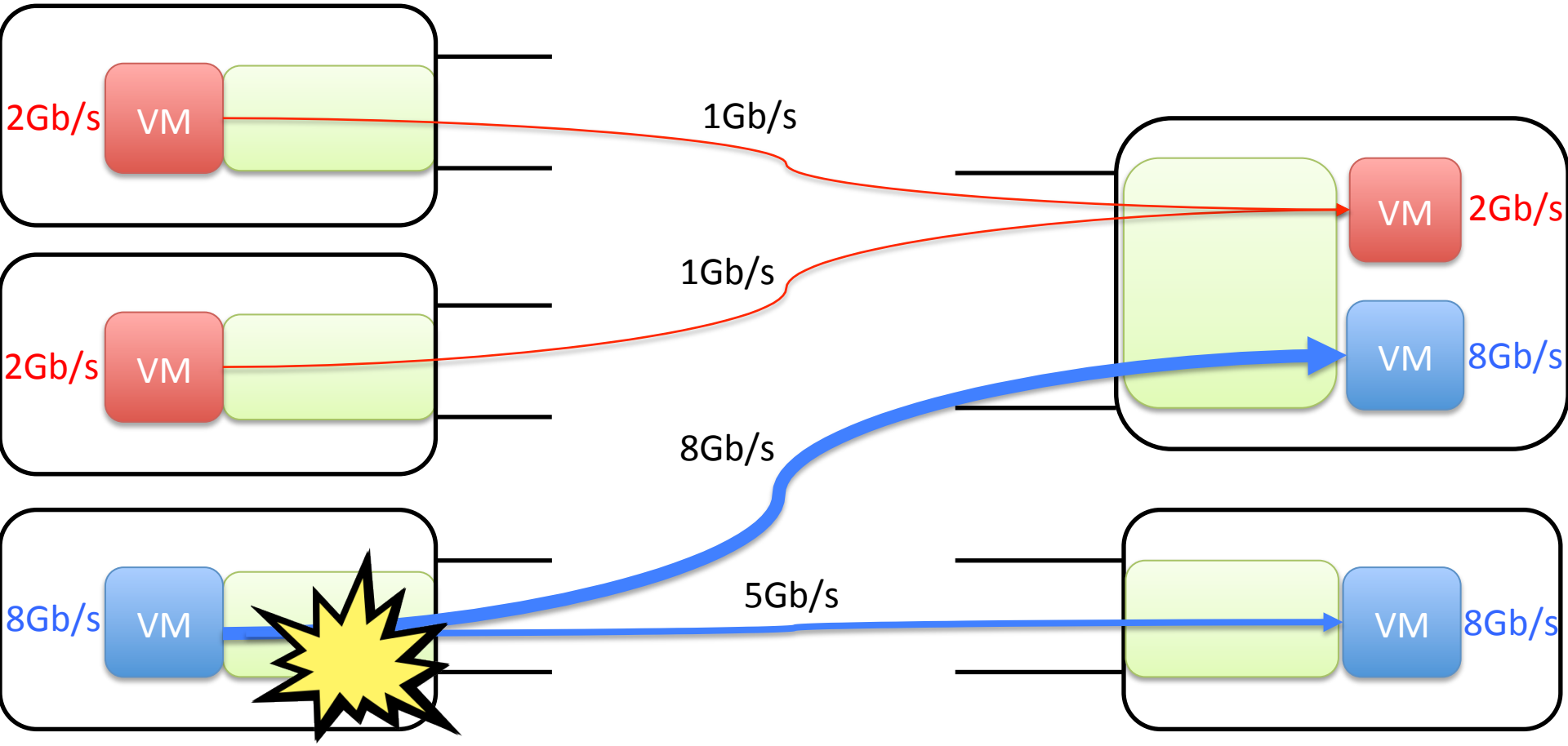
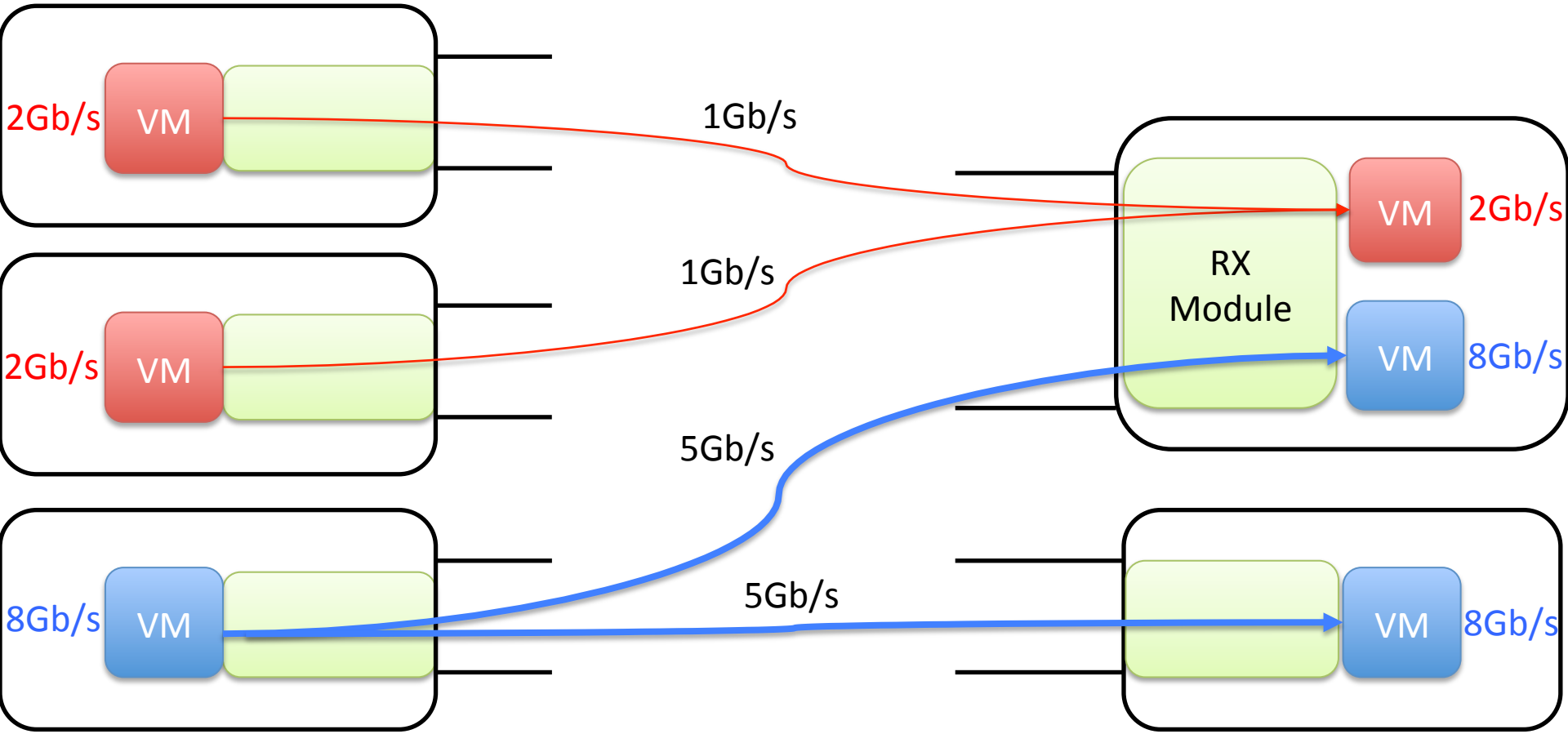


Work Conserving Allocations



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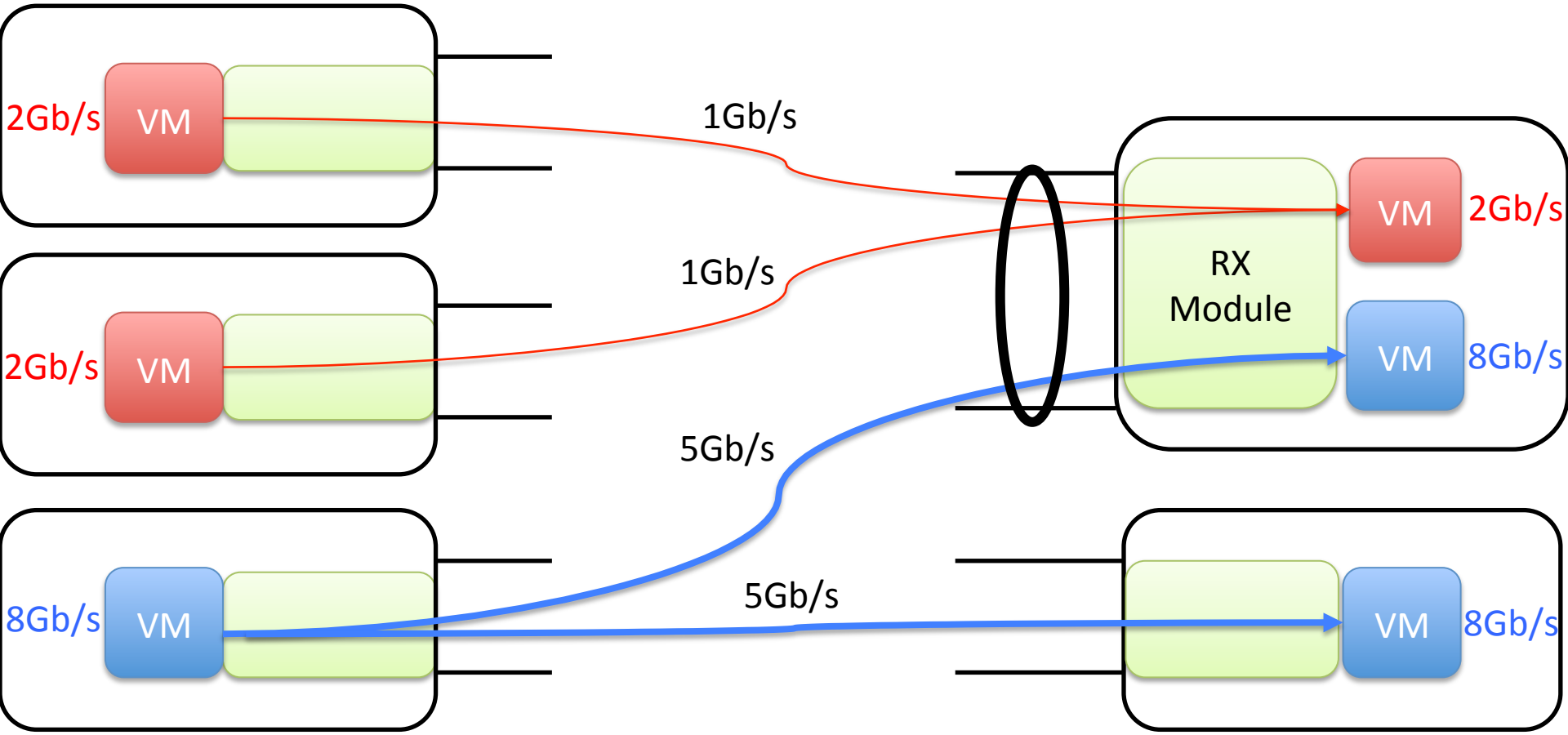

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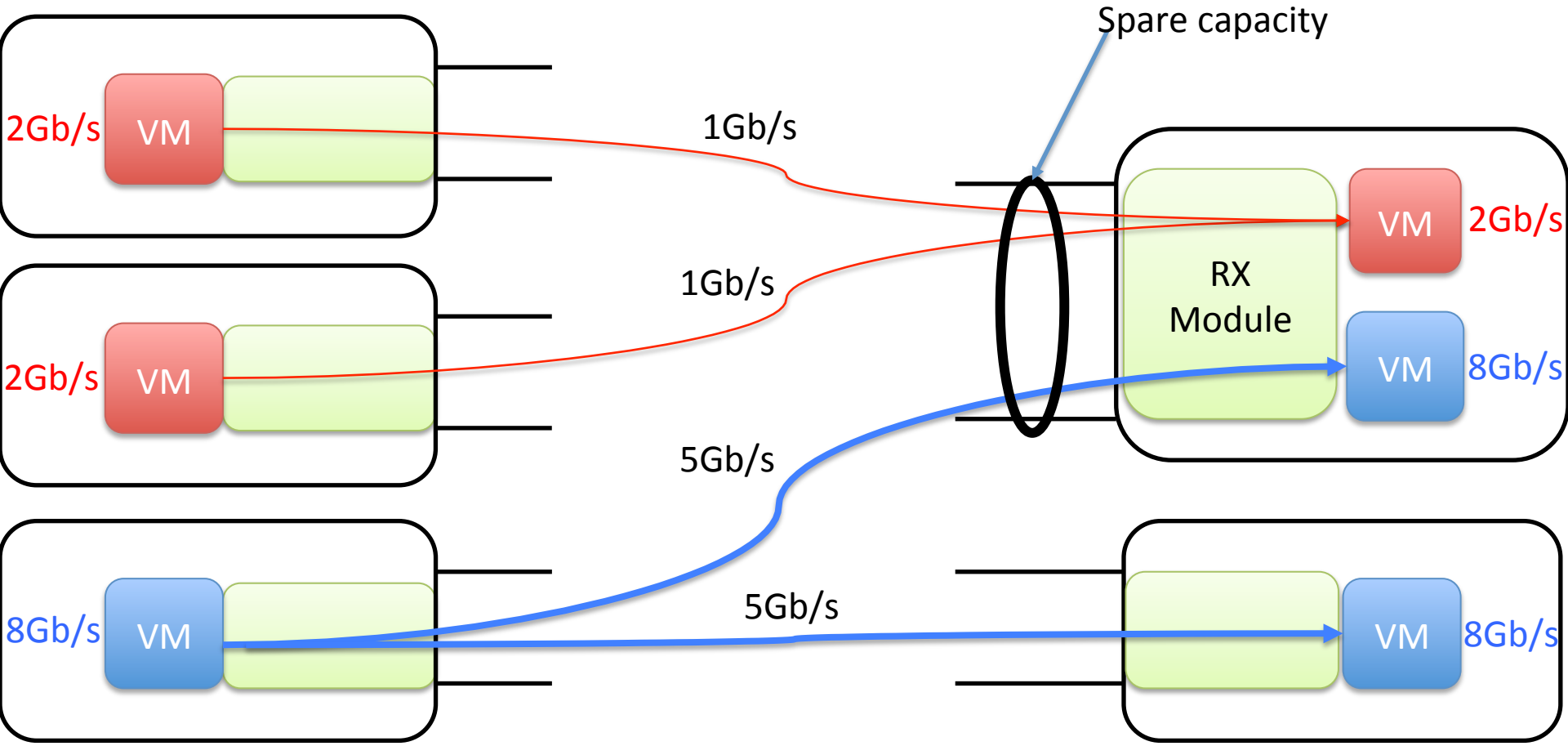

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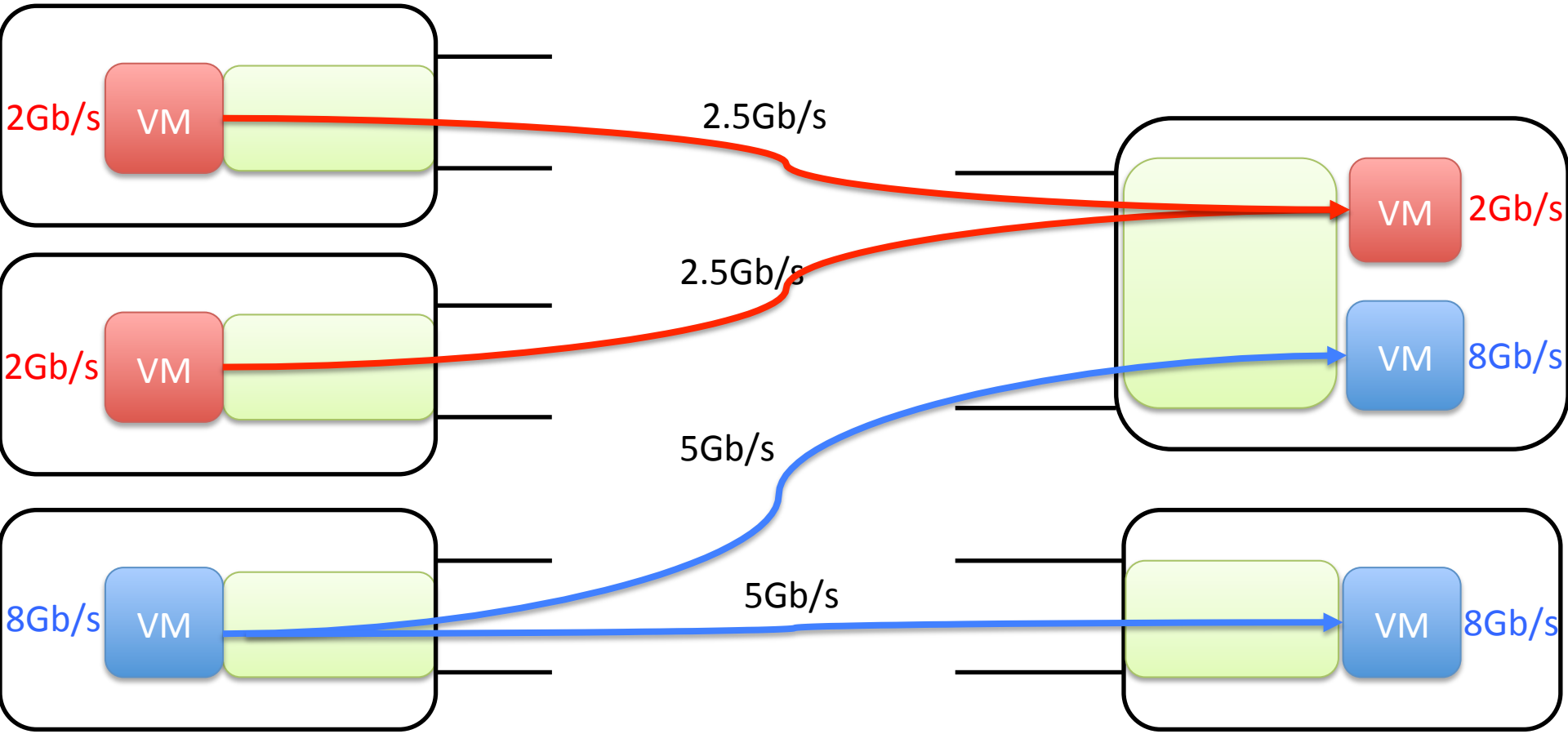
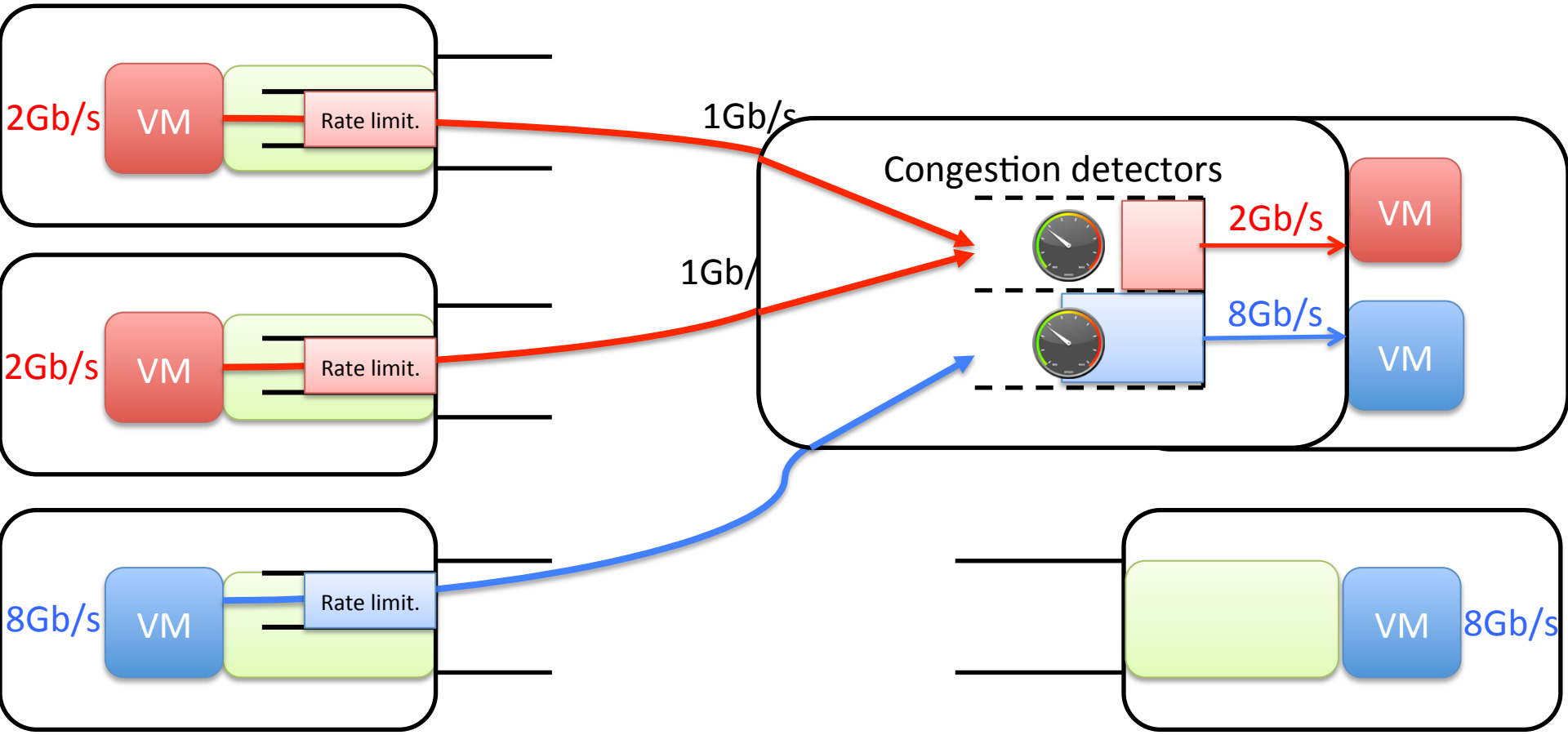
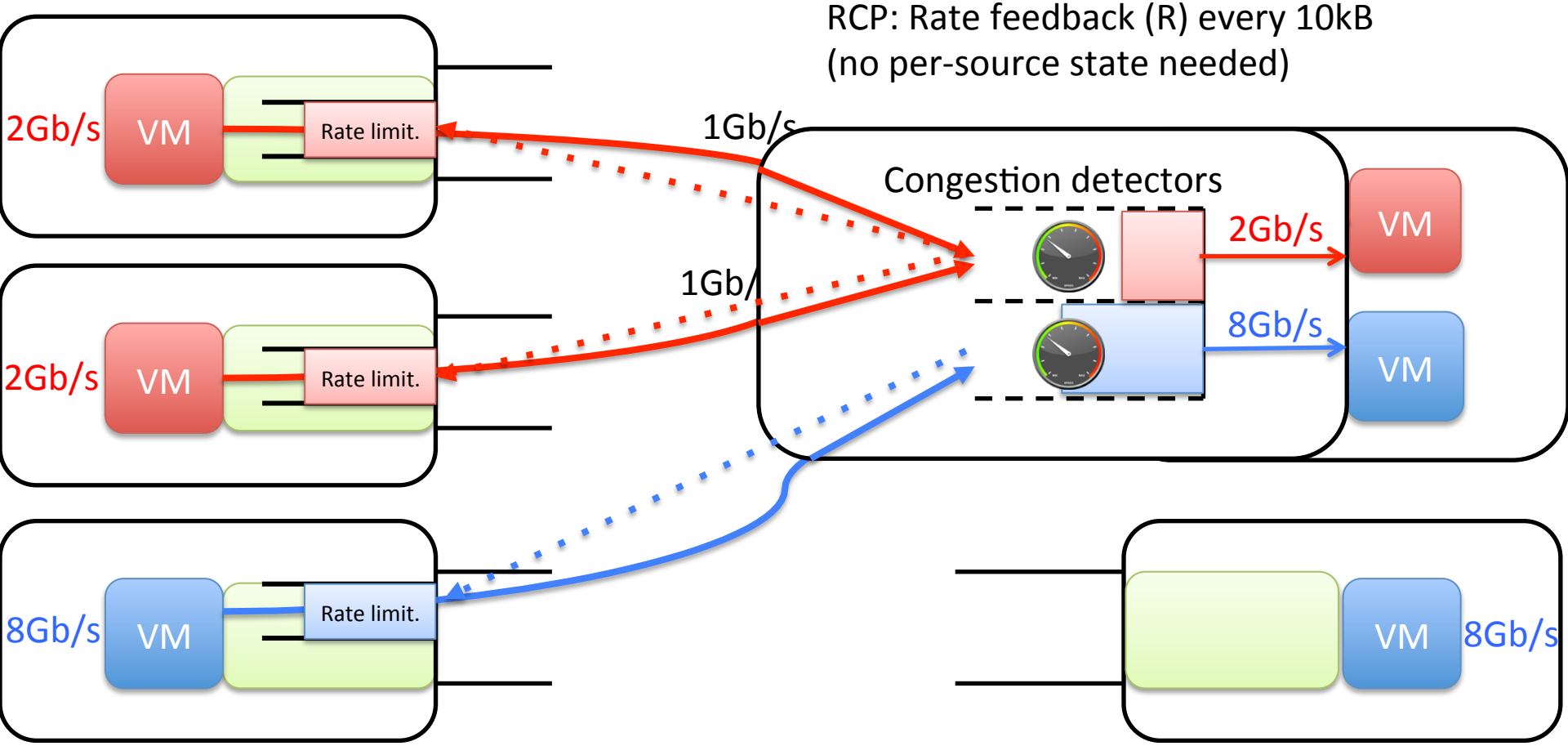


Transmit/Receive Modules



Per-destination rate limiters:
only if dest. is congested… bypass otherwise

Transmit/Receive Modules



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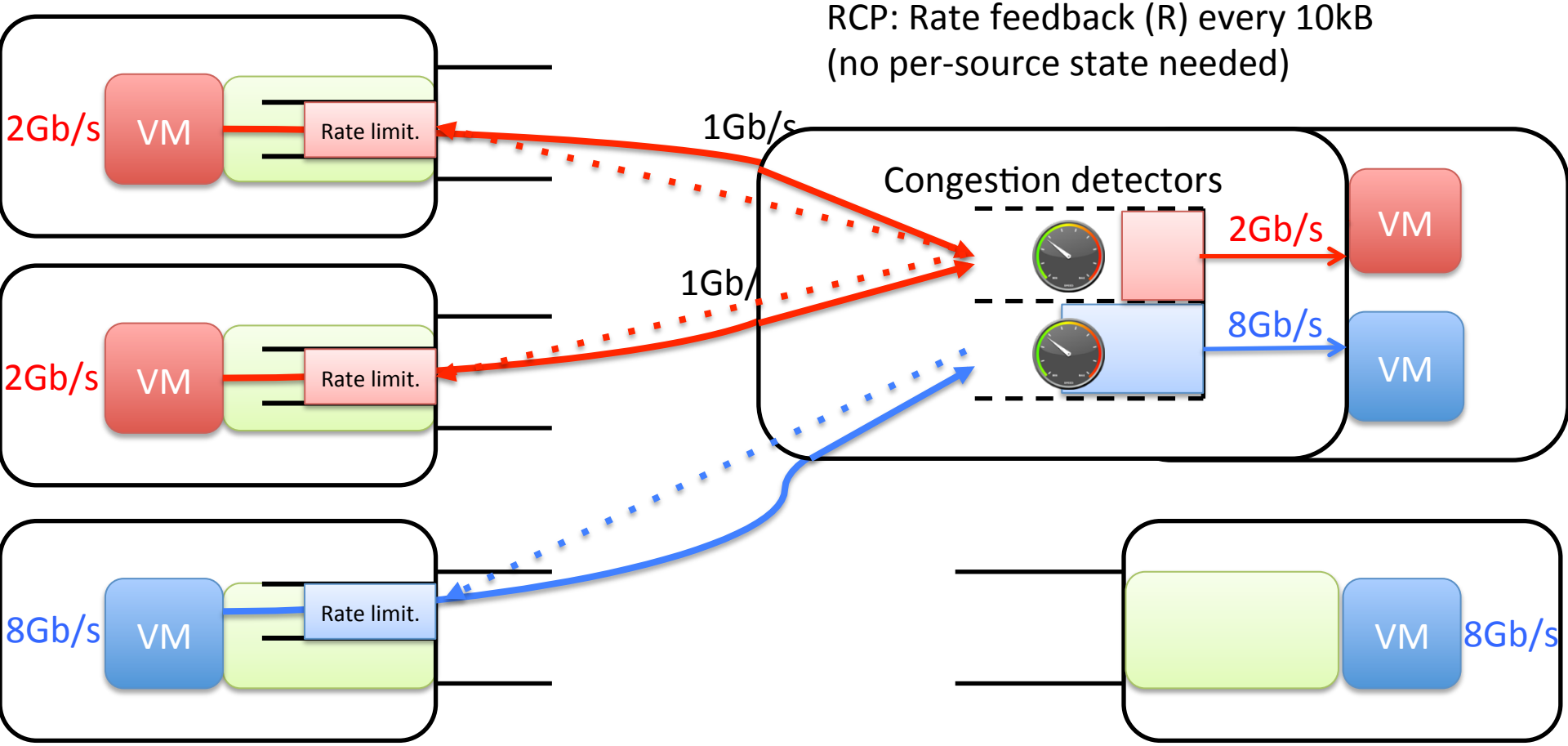

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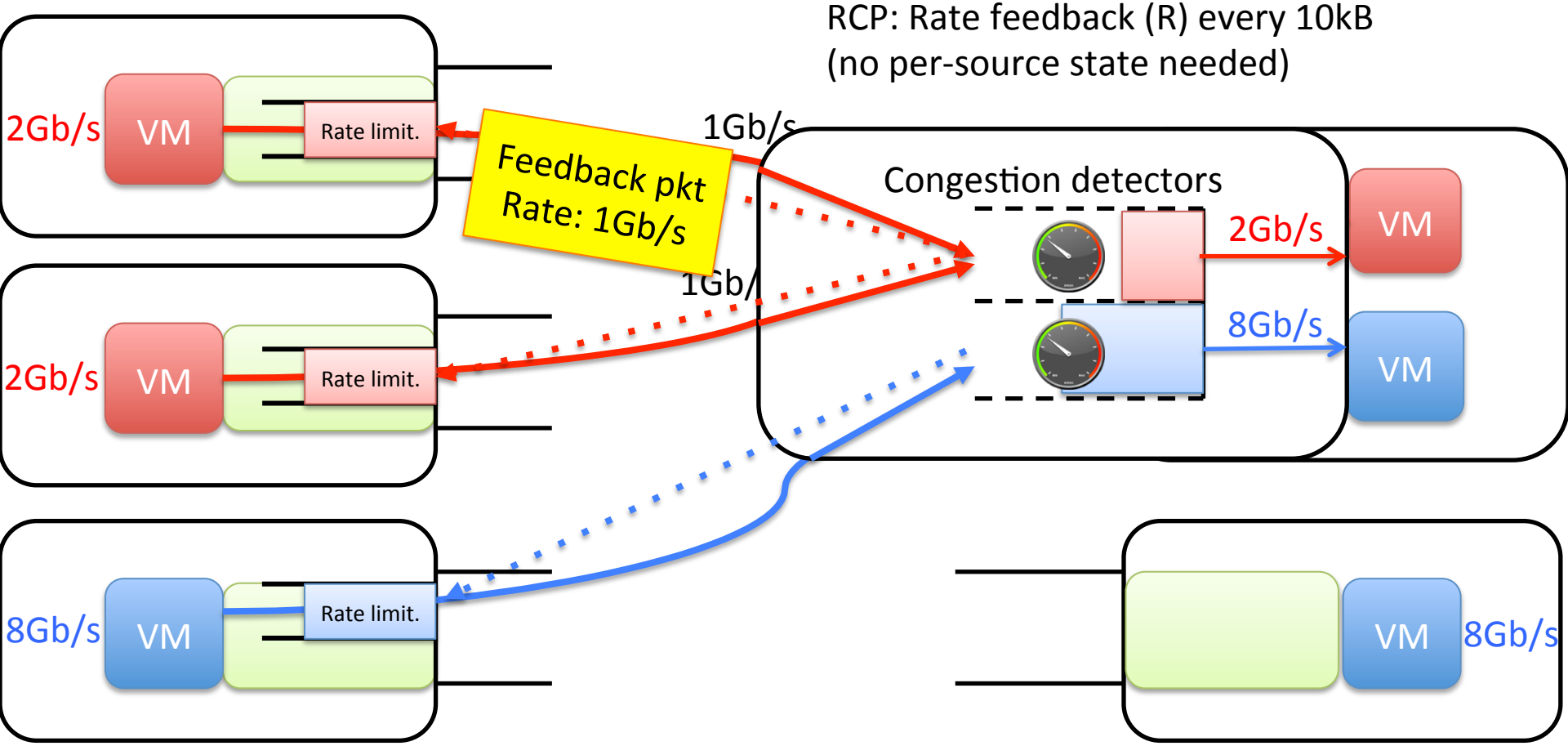

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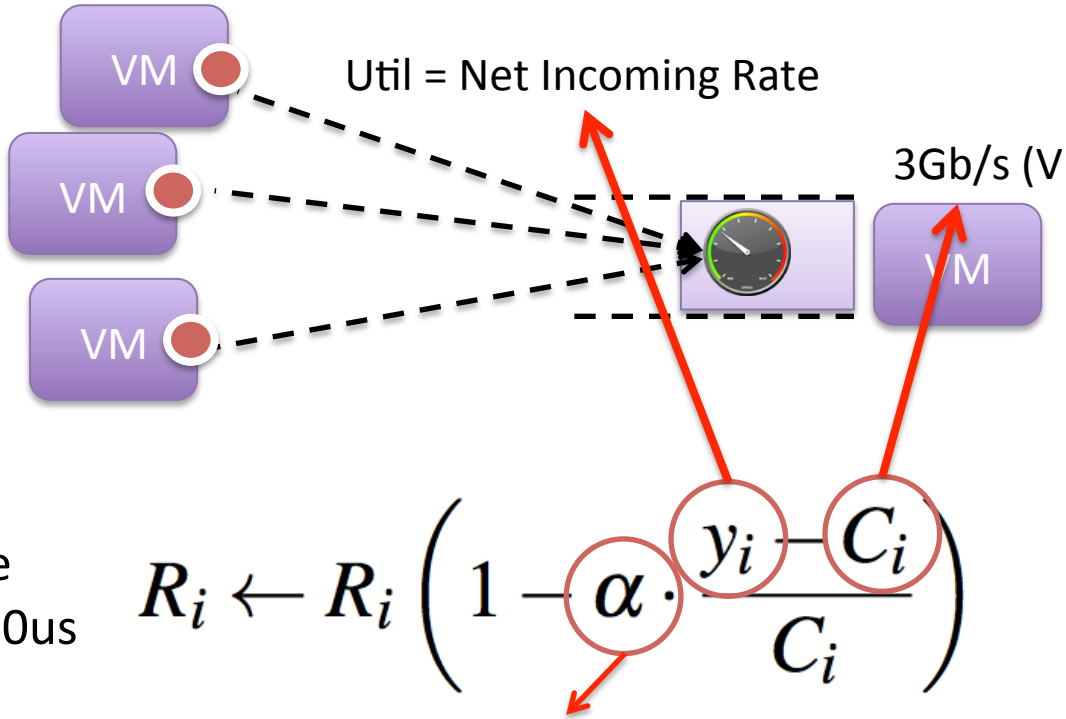
Determining Rate

Determine **one rate Ri** so that utilisation matches allowed limits

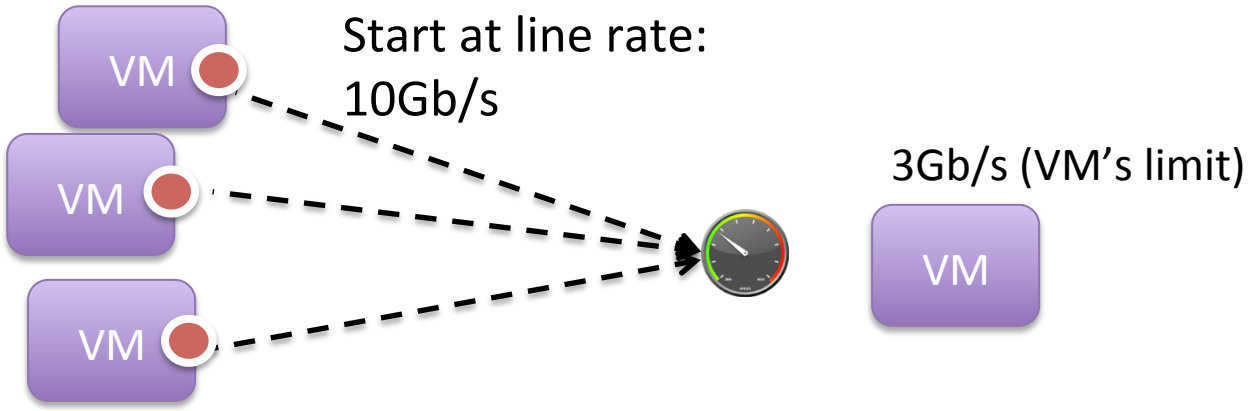


Recompute
Ri every 200us

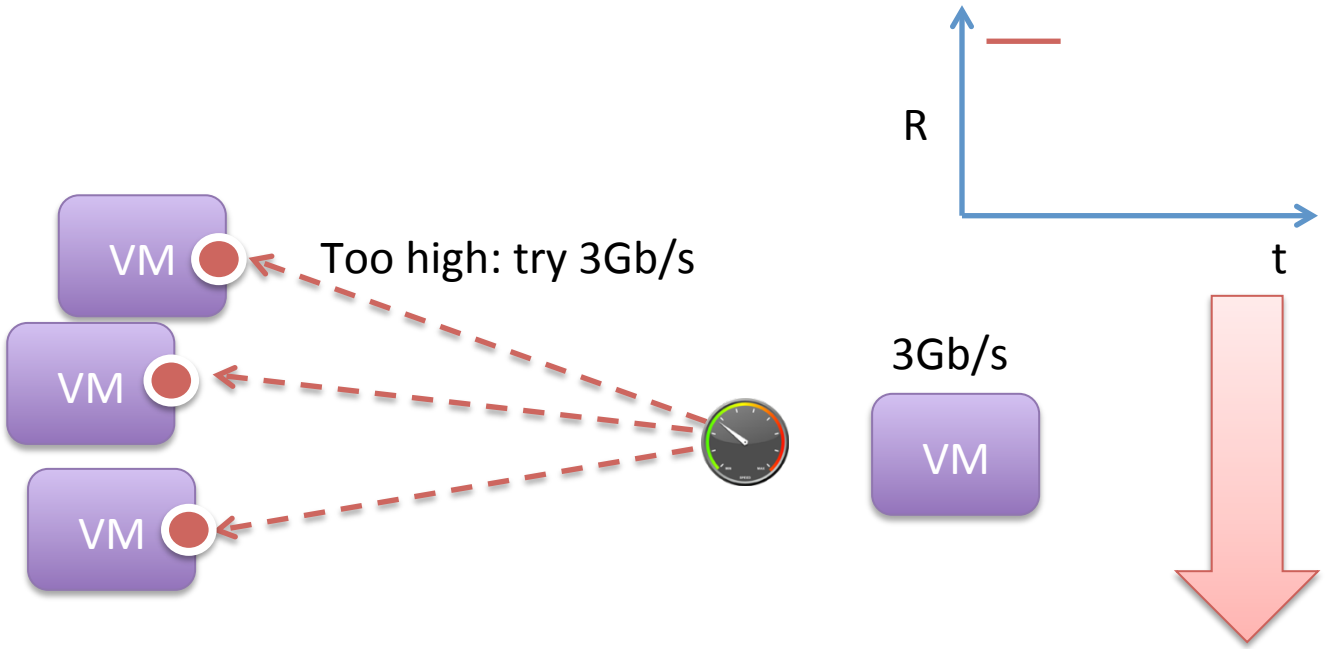
$$R_i \leftarrow R_i \left(1 - \alpha \cdot \frac{y_i - C_i}{C_i}\right)$$

Aggressiveness parameter. Set to 0.5

Determining Rate

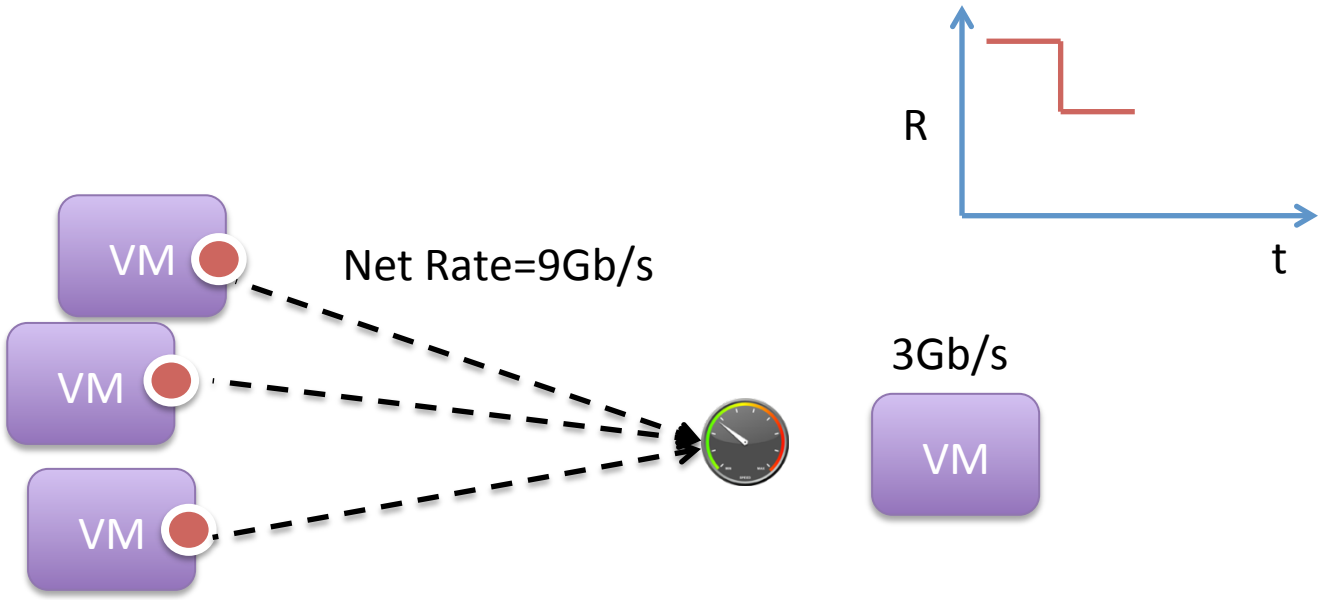


Determining Rate (distributed guessing)

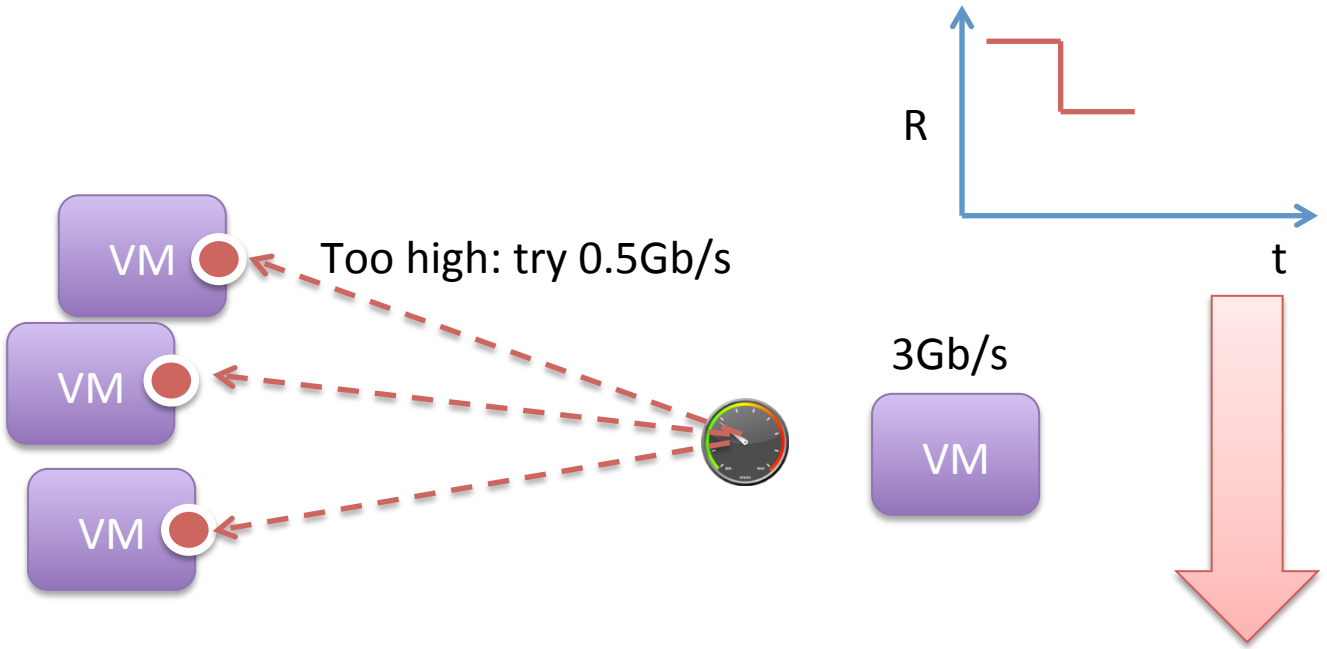


Tiny feedback packets sent to traffic sources

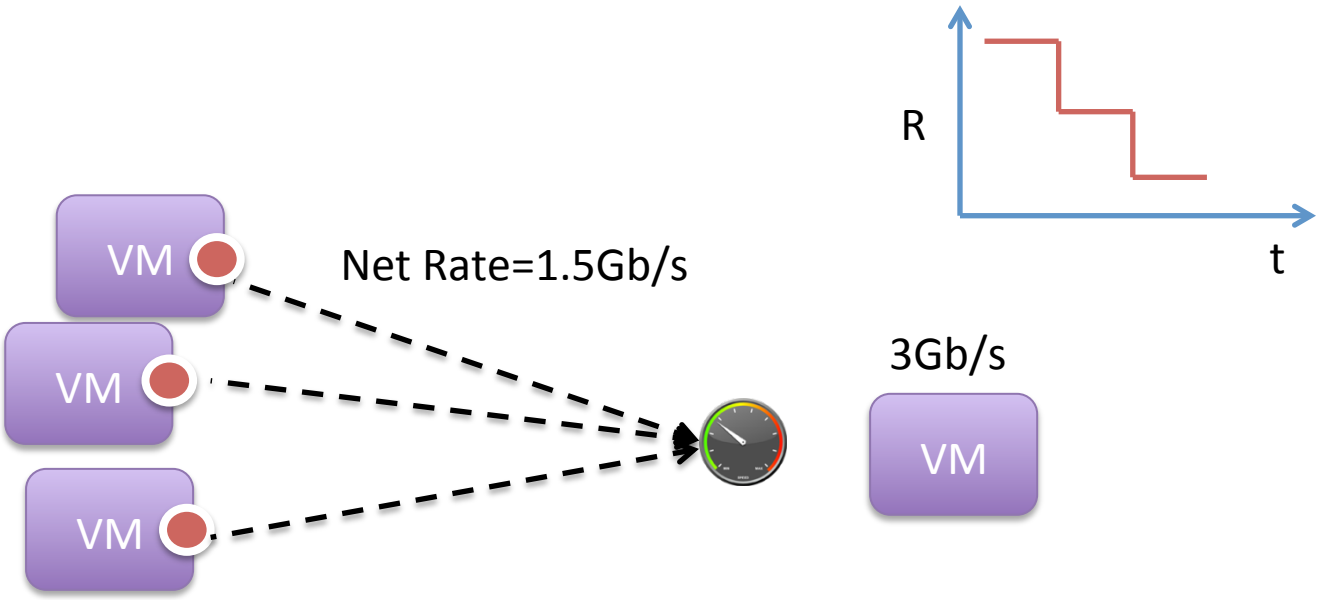
More guessing…



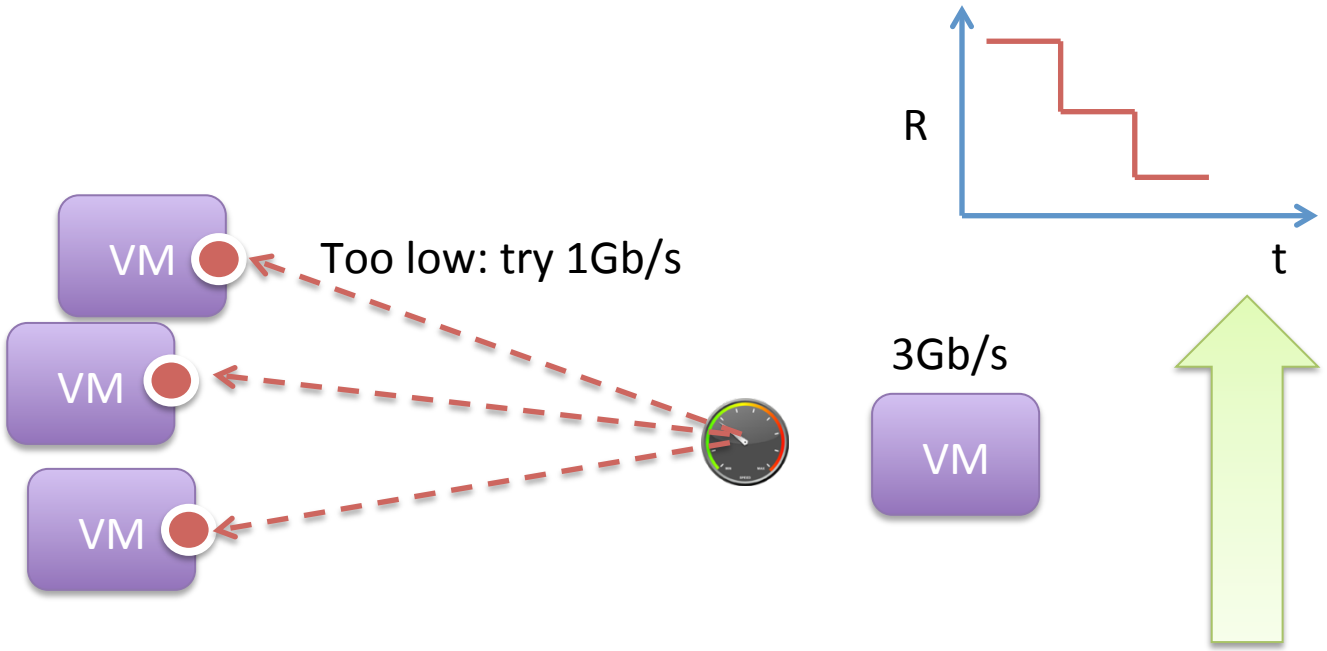
Continue guessing…



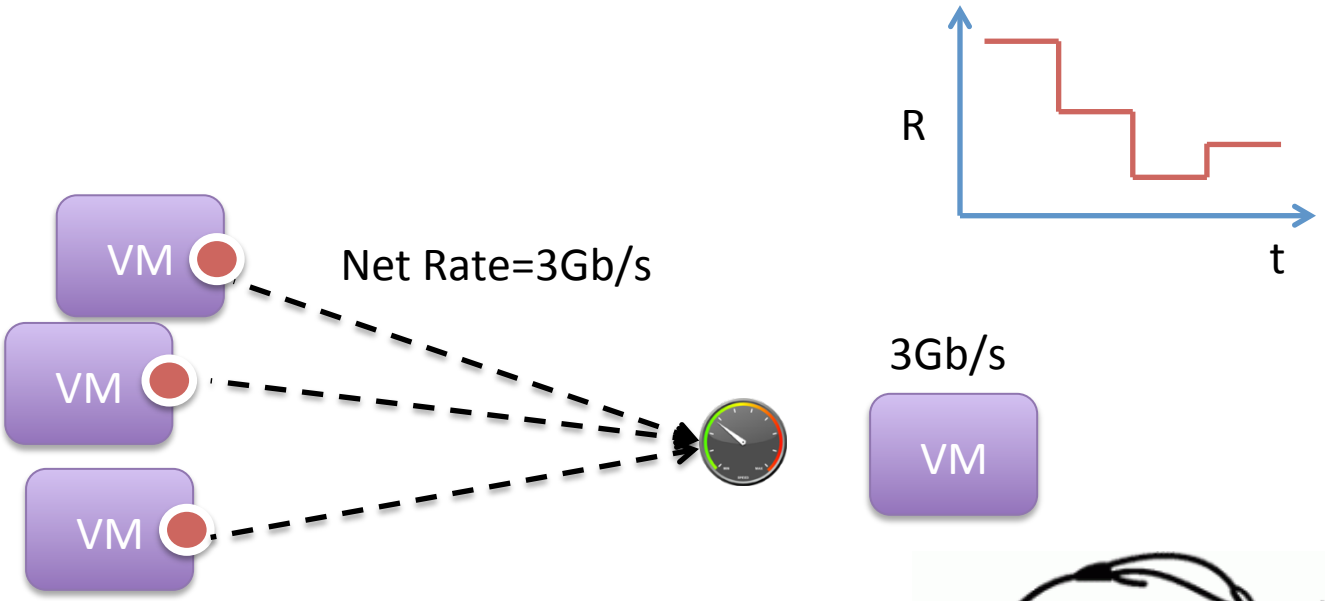
Oops…



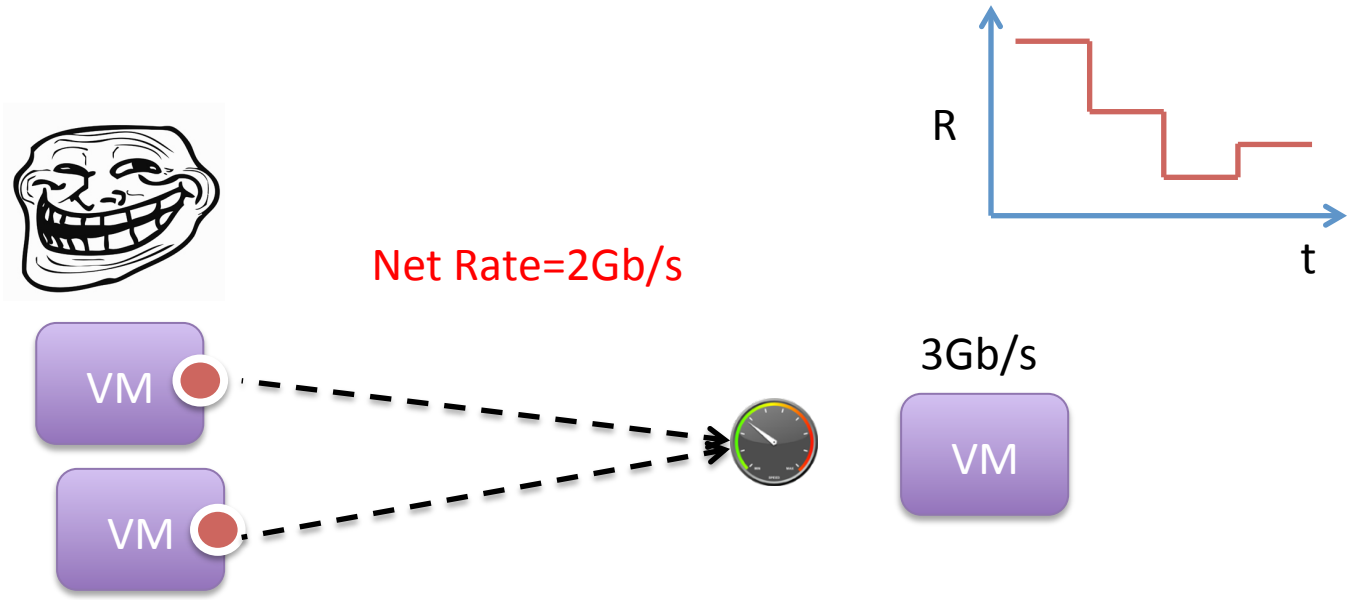
Almost there



Fixed point



Continuous Scheduling



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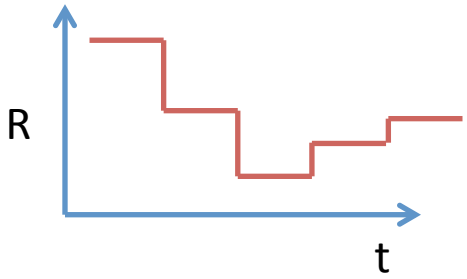
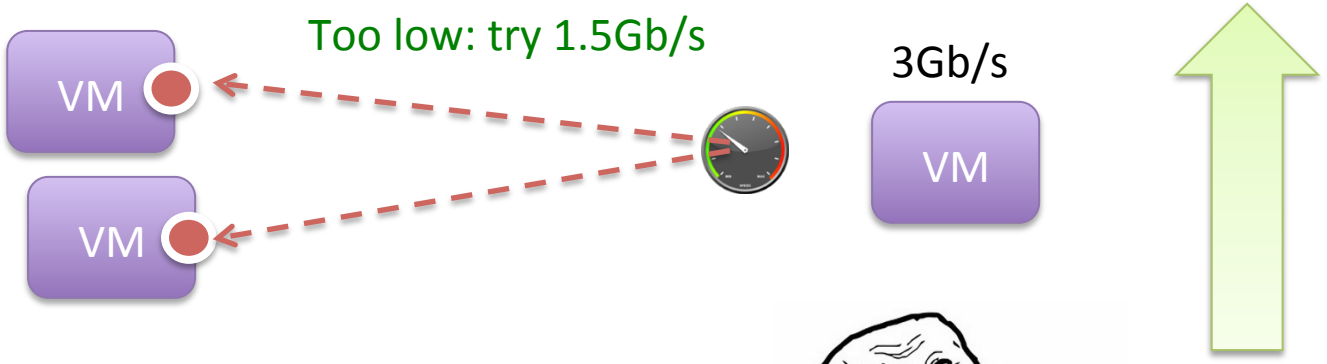




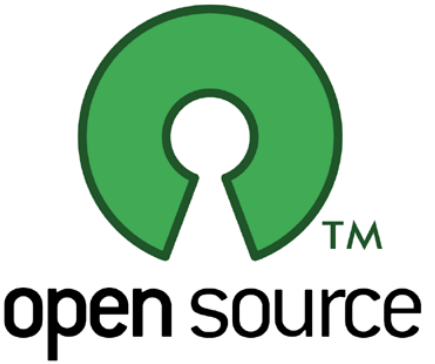
This happens every 200us.

Software Prototype

Linux Kernel Module (qdisc)

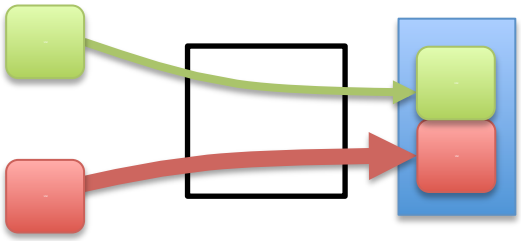
Windows Filter Driver (in VMSwitch)

- Non-intrusive: no changes to applications or existing network stack. Works even with UDP!
- ~1700 lines of code



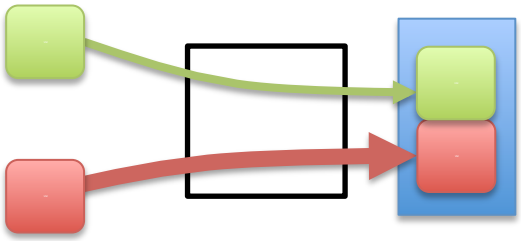
Linux Kernel Module is Open-Source

- Full system and documentation at http://jvimal.github.com/eyeq
- EyeQ's rate limiters more efficient than today's rate limiters in Linux/Windows



Does it work?

TCP: 6Gb/s
UDP: 3Gb/s



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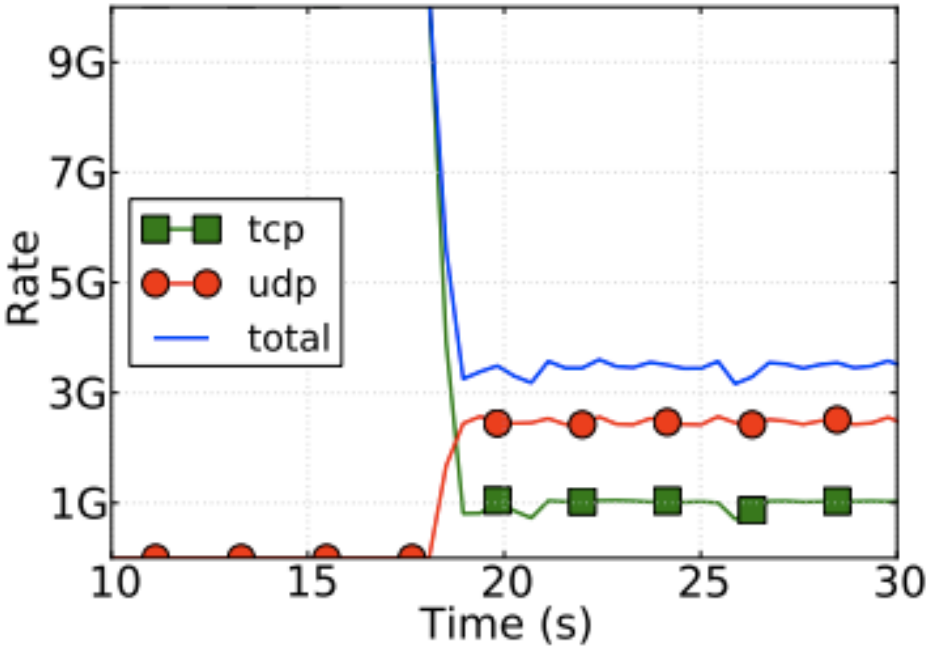
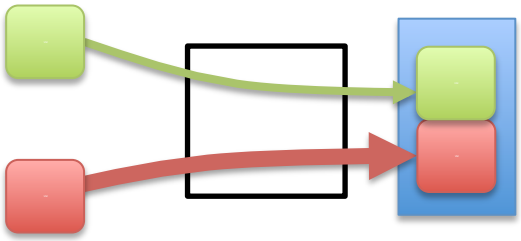


Without EyeQ



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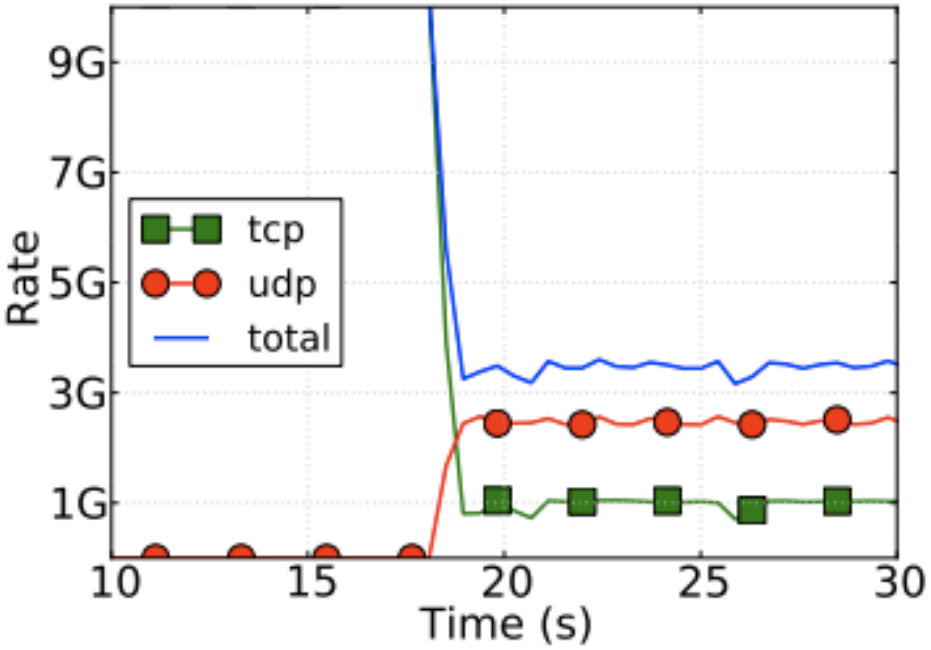
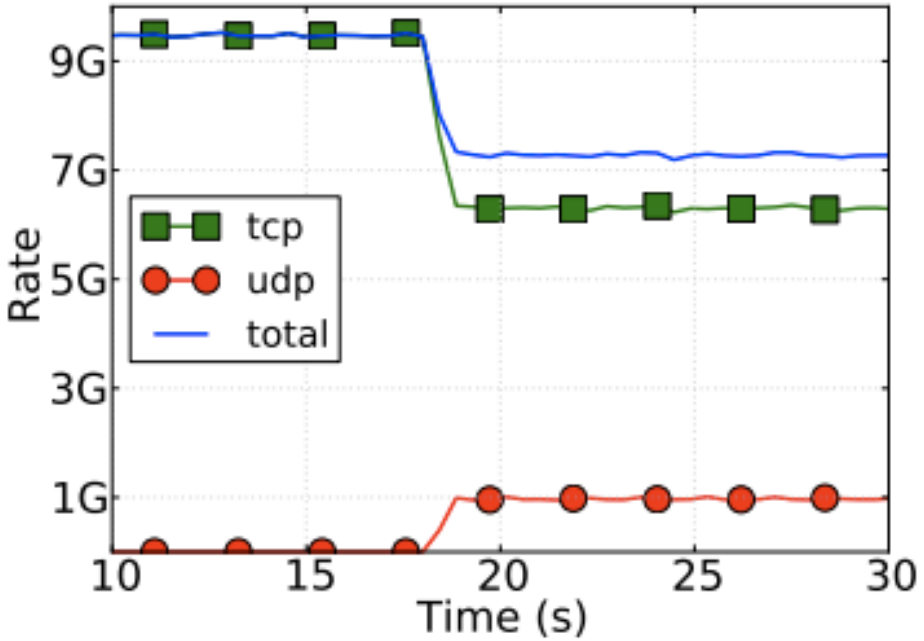
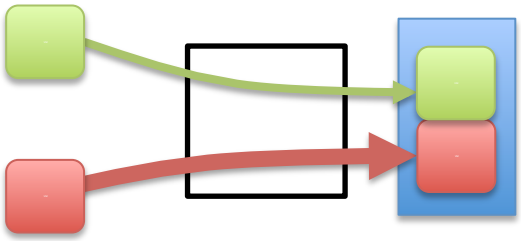


Without EyeQ

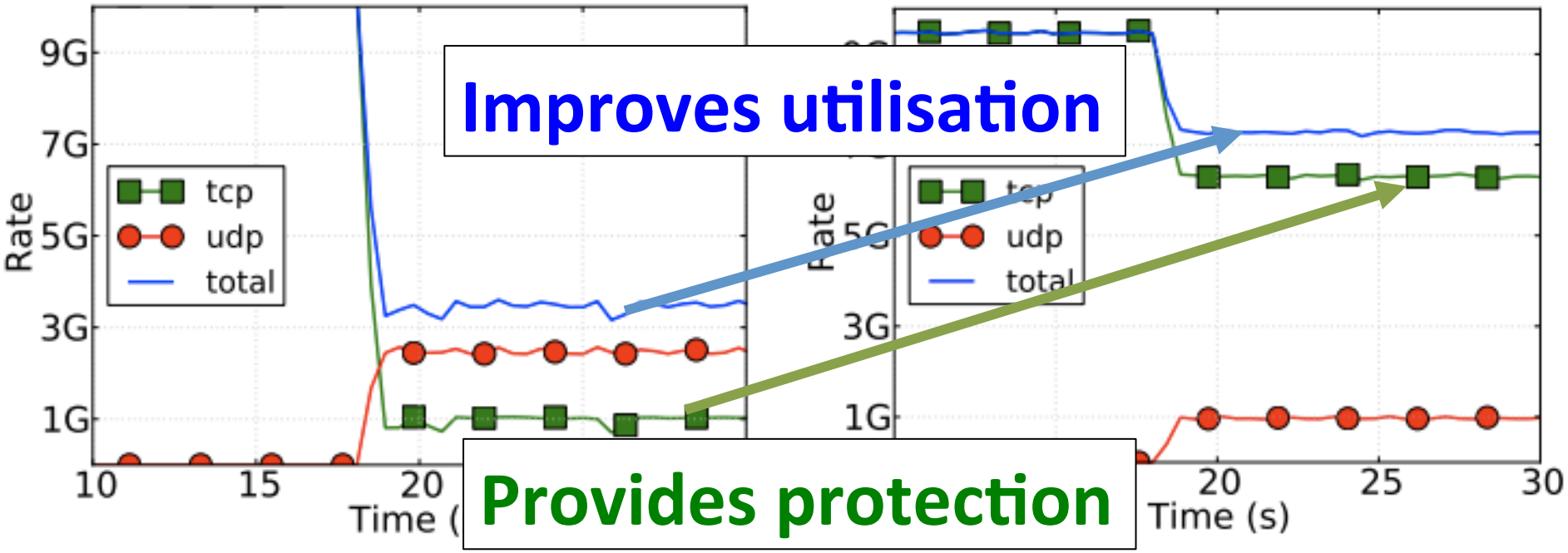


With EyeQ



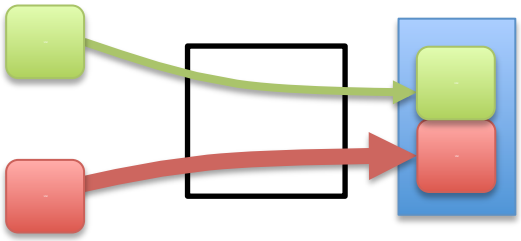
Does it work?

TCP: 6Gb/s
UDP: 3Gb/s



Without EyeQ

With EyeQ



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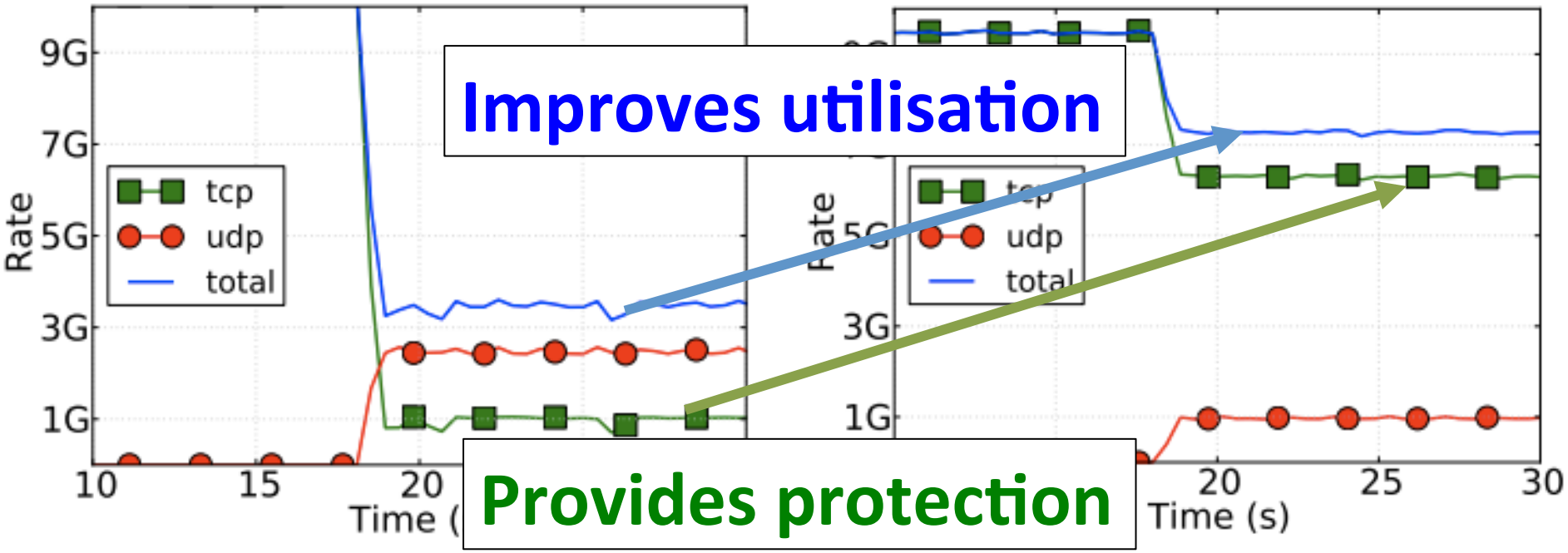
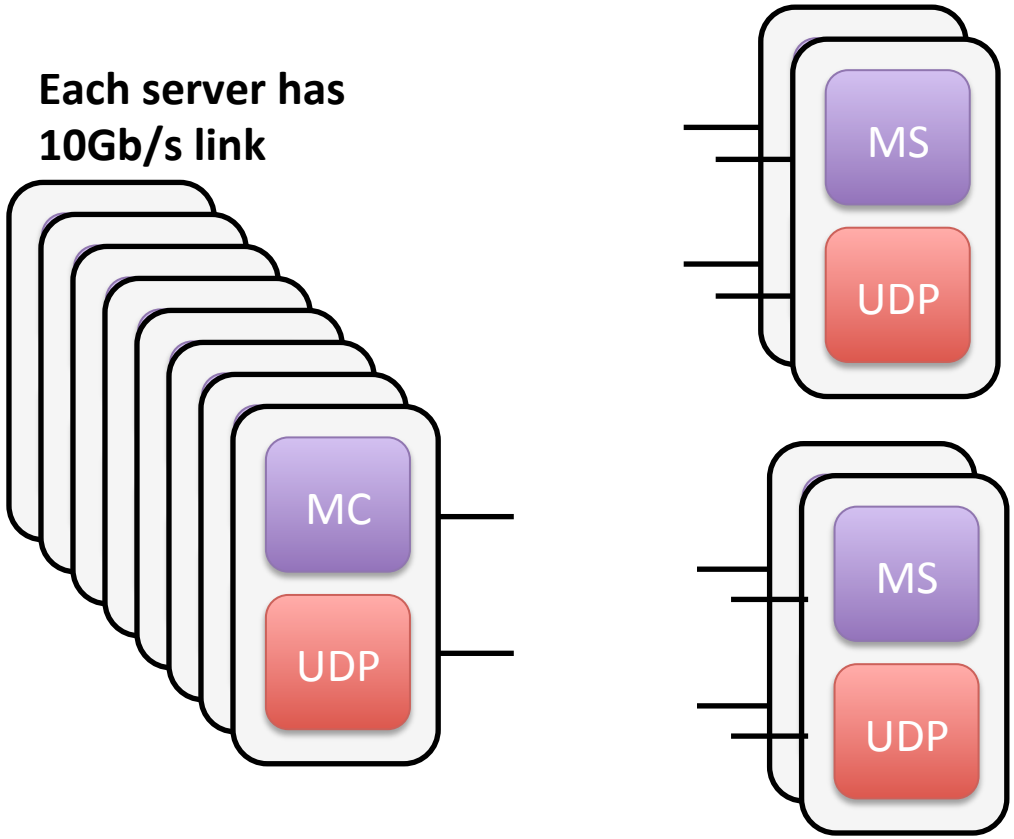


Without EyeQ

With EyeQ

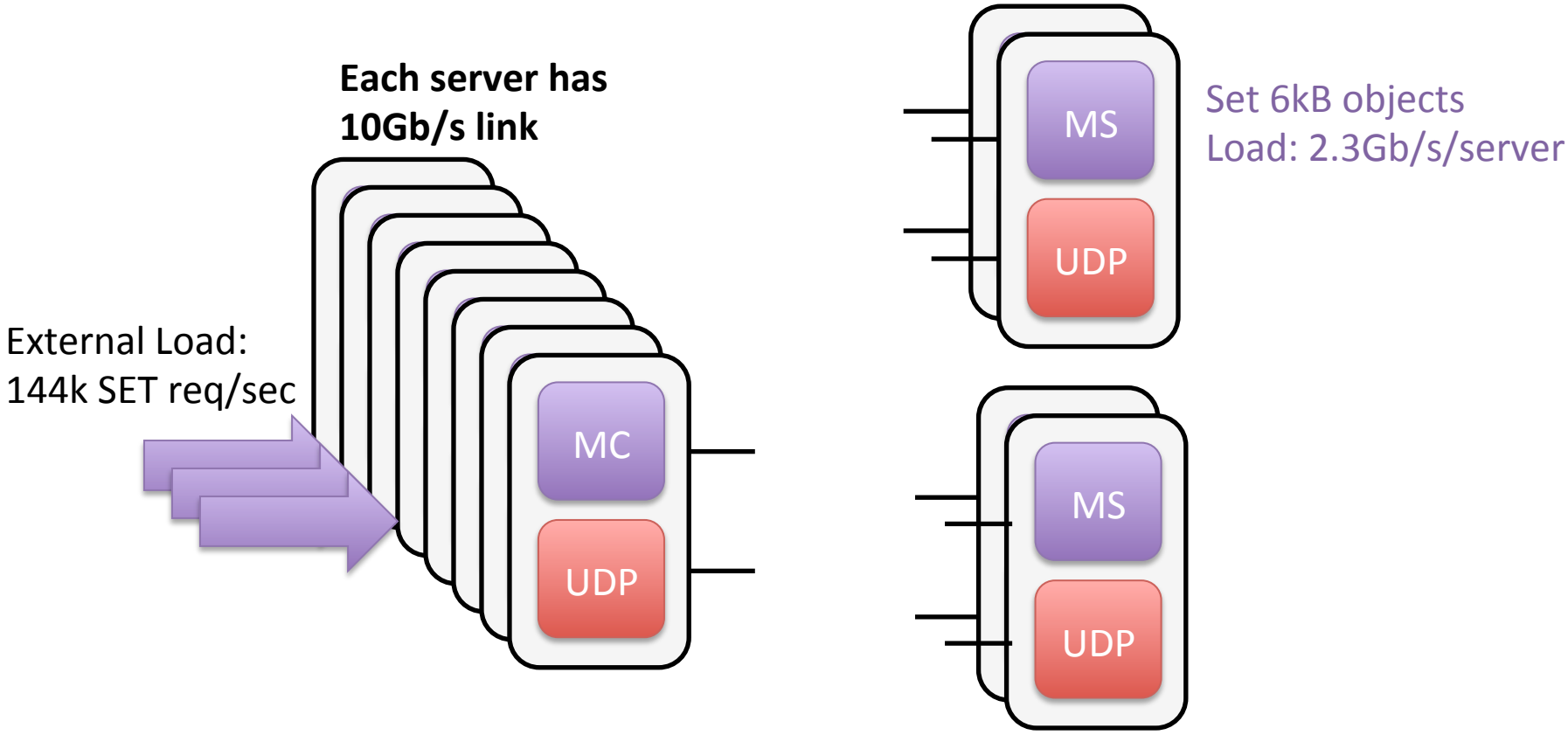
Close to Bare-Metal Latency?



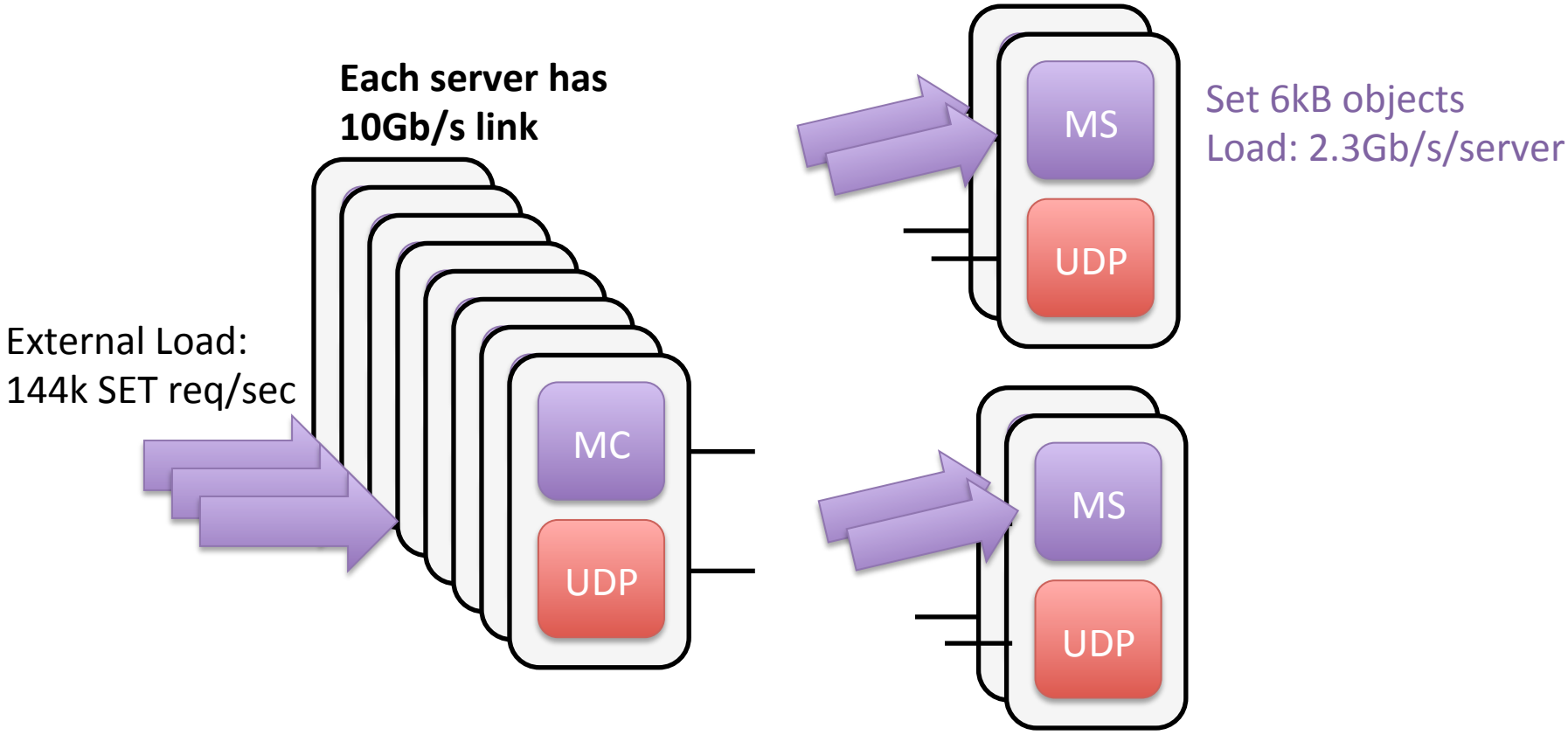
12 Client Pool

4 Server Pool

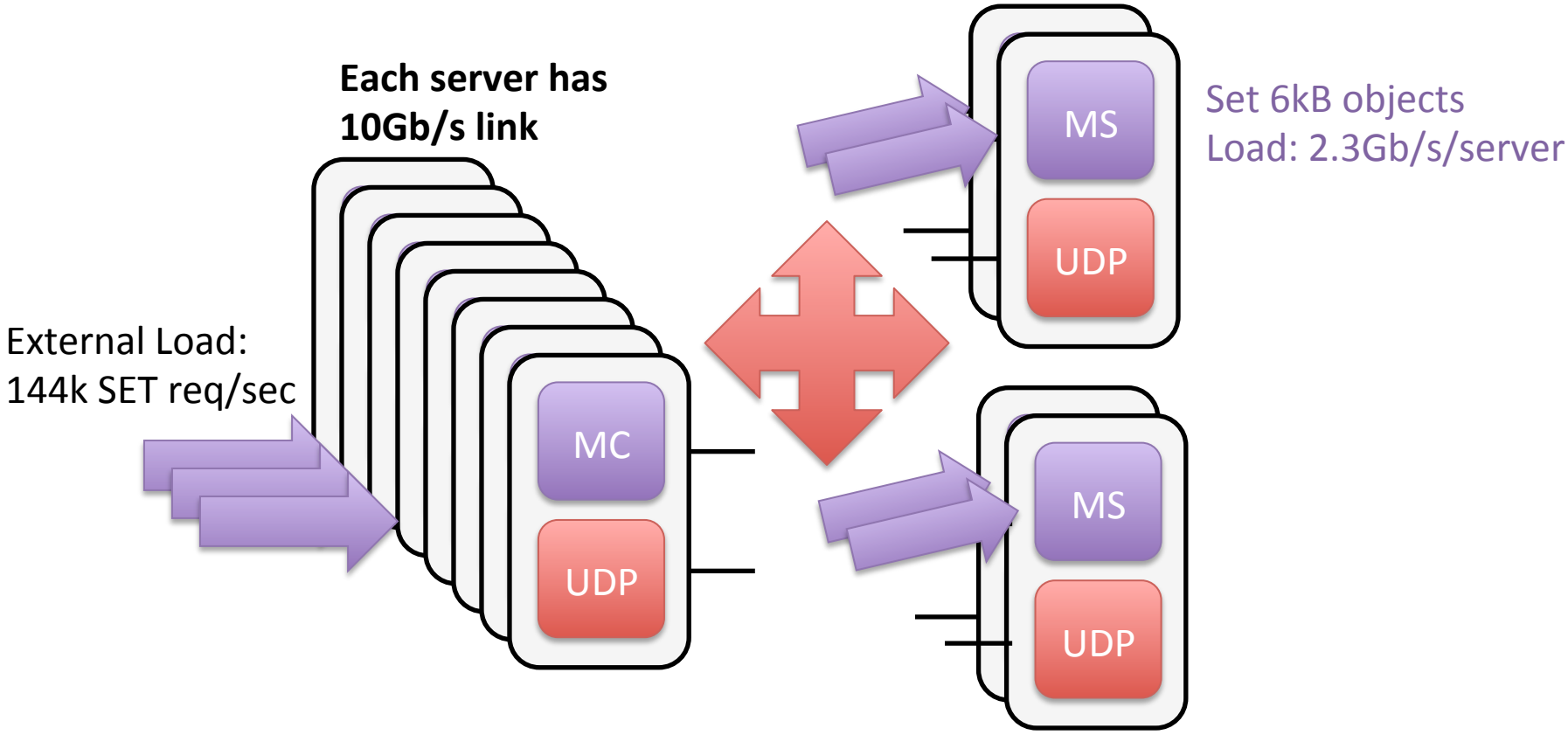
Close to Bare-Metal Latency?



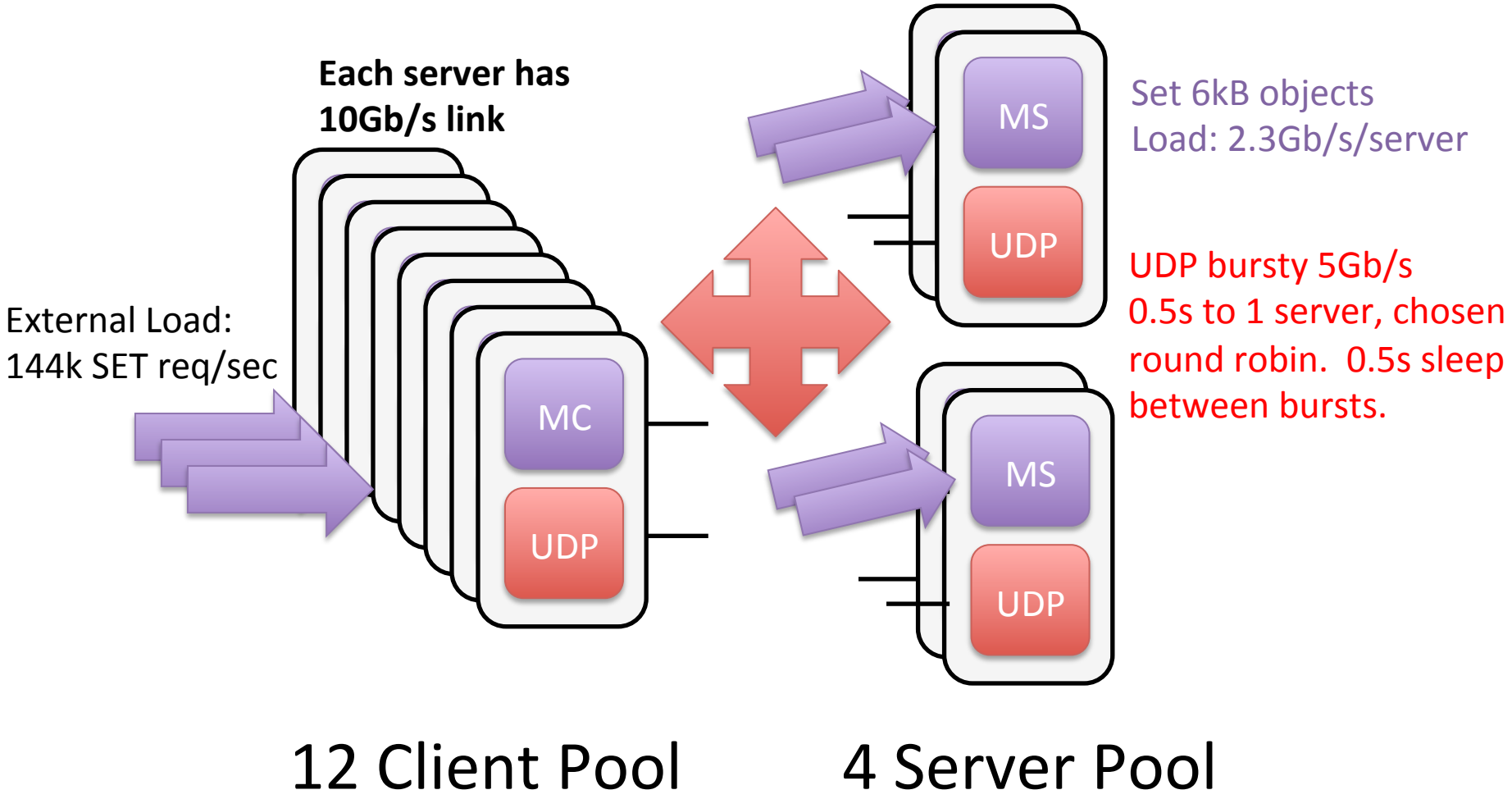
Close to Bare-Metal Latency?



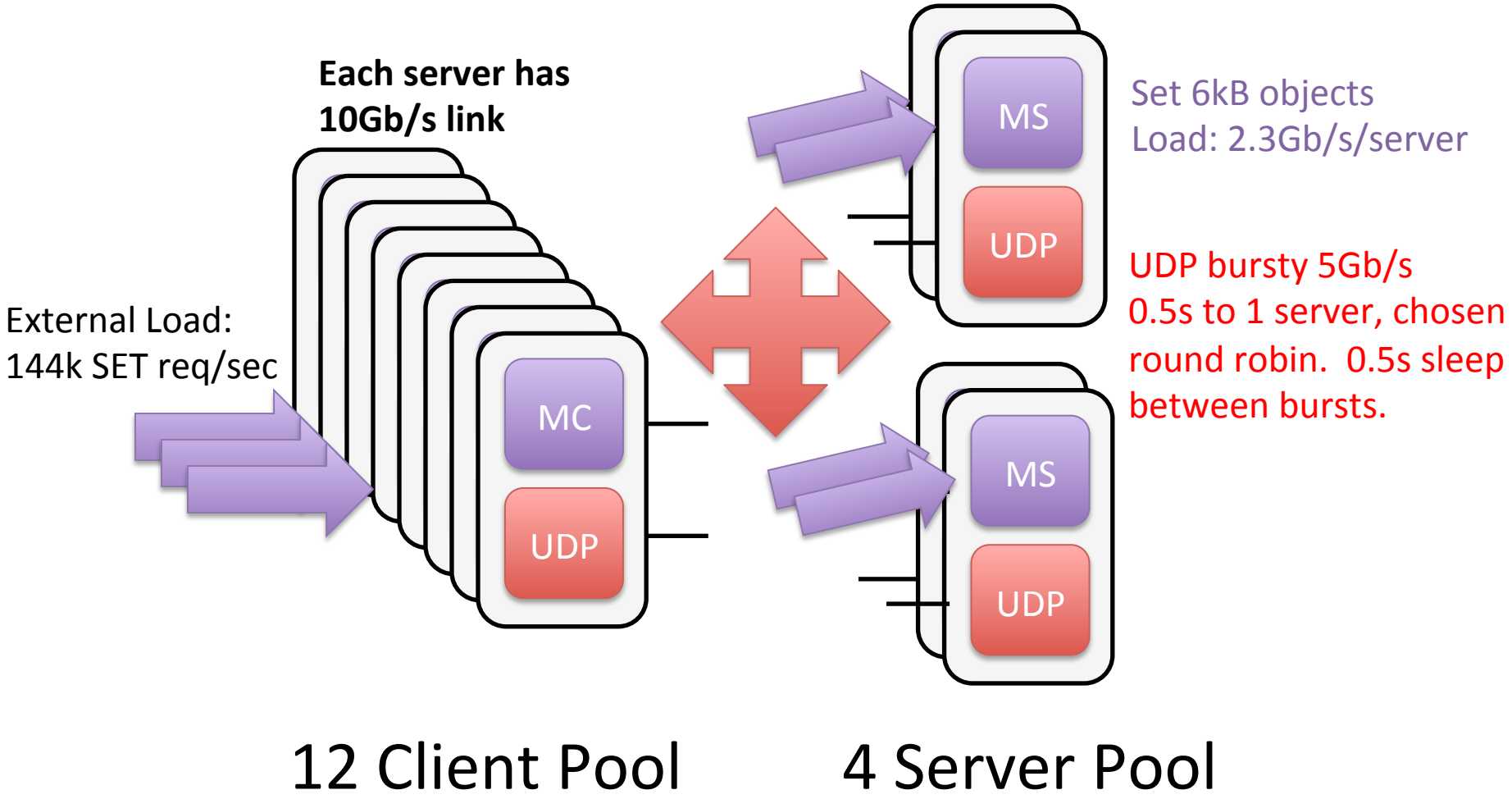
Close to Bare-Metal Latency?



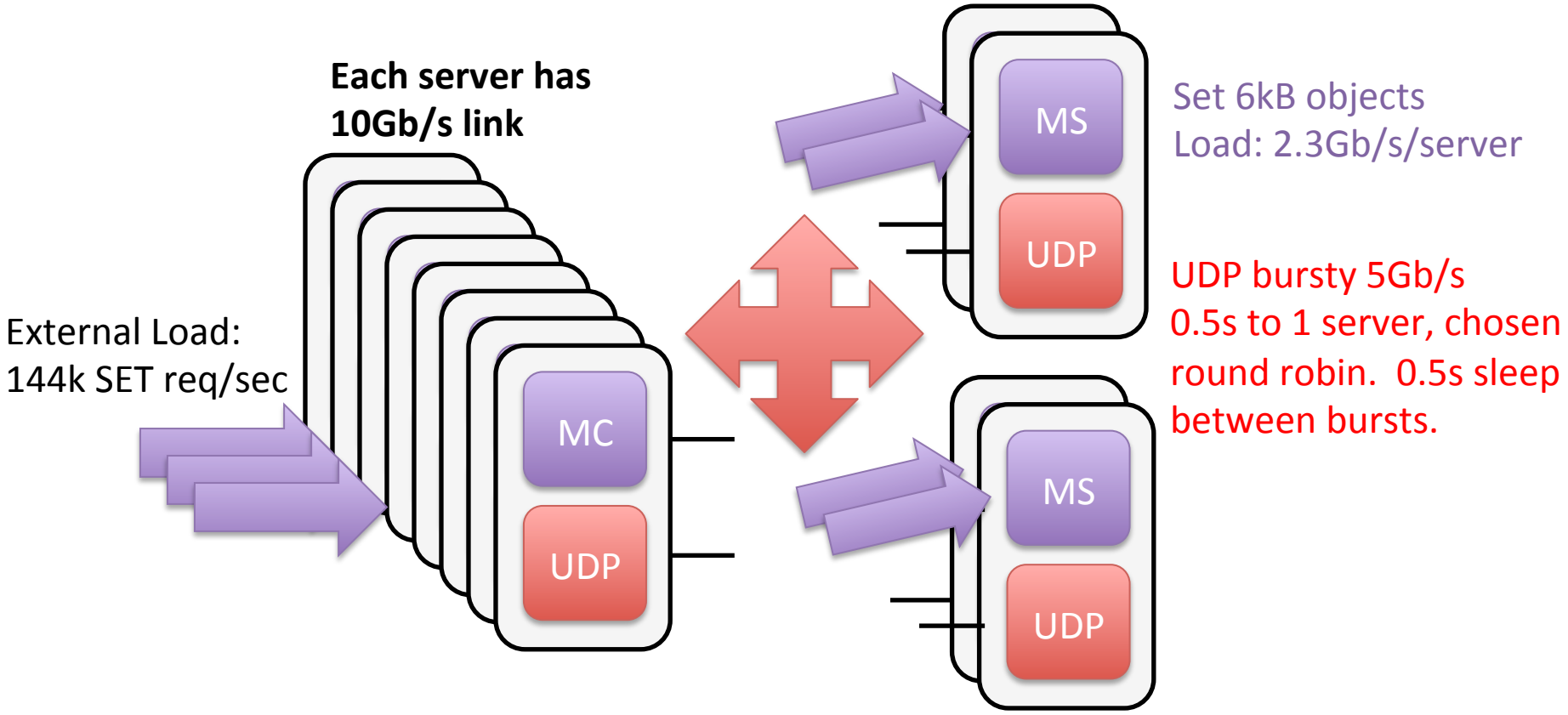
Close to Bare-Metal Latency?



Close to Bare-Metal Latency?



Close to Bare-Metal Latency?



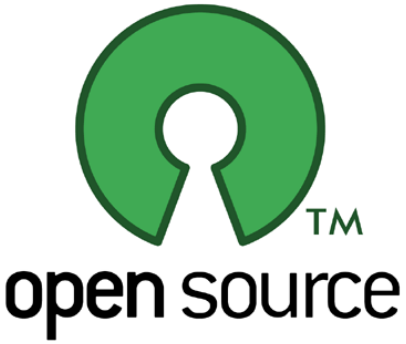
Close to Bare-Metal Latency?

Scenario	50th	99.9th	Throughput
Baseline (Linux 3.4)	98us	666us	144kreq/s
Without Interference + EyeQ	100us	**630**us	144kreq/s
With Interference	**4127**us	**>10^6**us	144kreq/s
With Interference + EyeQ	102us	**750**us	144kreq/s

12 Client Pool 4 Server Pool

Thank you!

EyeQ: a system to partition bandwidth within a data center in a simple and predictable way



http://jvimal.github.com/eyeq

jvimal@stanford.edu

Rate Limiter Memory Overhead

112B + NCUPS * 104B

- 8 CPUs: ~0.9kB
- 16 CPUs: ~1.8kB
- Scales linearly with number of IP destinations, not connections (struct sock: 648B)