Self-healing Network or The Magic of Flow Label

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Yandex

Facts and figures from some of the intelligent products and services in the Yandex ecosystem

Yandex.Music

AI-powered streaming platform serving over 20 million users in 12 countries

Yandex.Direct

Ad platform serving 53% of the Russian digital advertising market

Yandex Zen

Personalized, AI-powered content feed with 40 million monthly users

Yandex.Taxi

Ride-hailing in 17 countries with over 1 billion rides

Alice

Russian-speaking intelligent assistant with 35 million monthly users

Yandex.Drive

Carsharing with a fleet of 11,500 vehicles

Yandex.Eats

Food delivery from over 10,000 restaurants across 30+ cities

Search

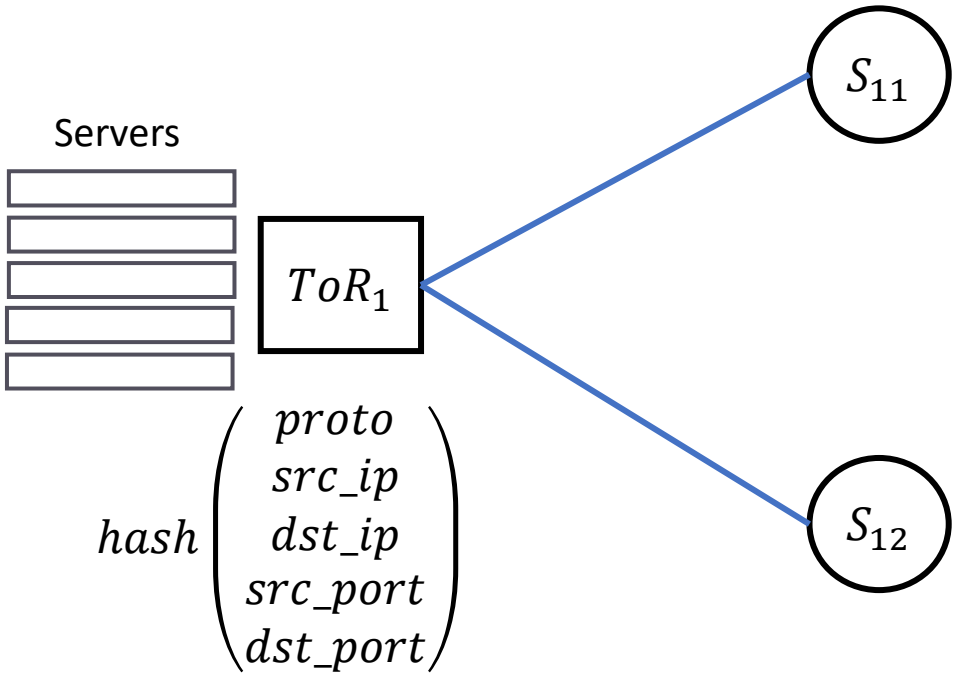
56.3% search share in Russia
67.7% desktop, 50% mobile

Self-Driving Car

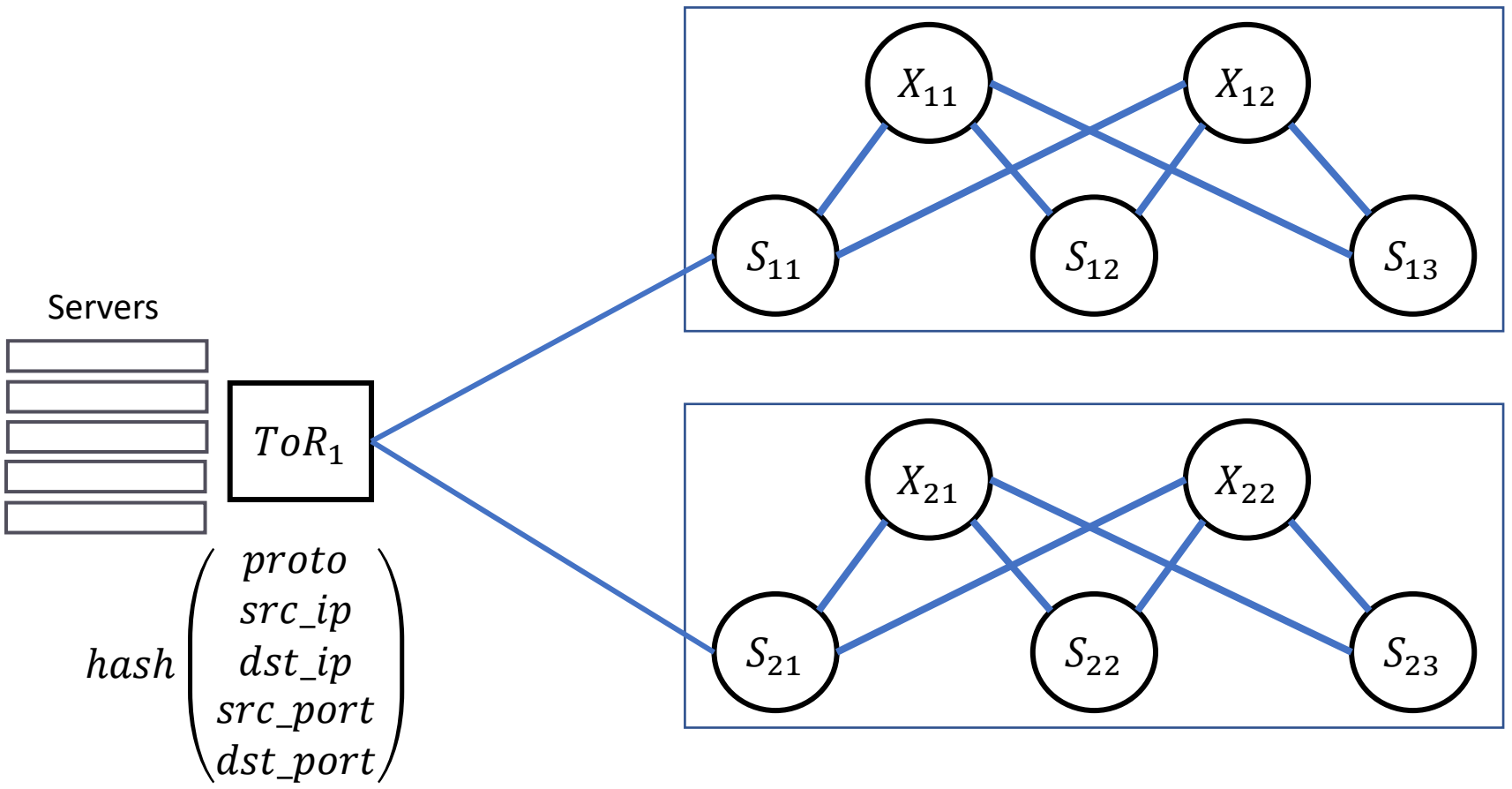
Tested on public roads in Russia, Israel, and the US
Robotaxi service with 3,000+ rides

All figures as of August 2019

Just a Top of Rack Switch (ToR)

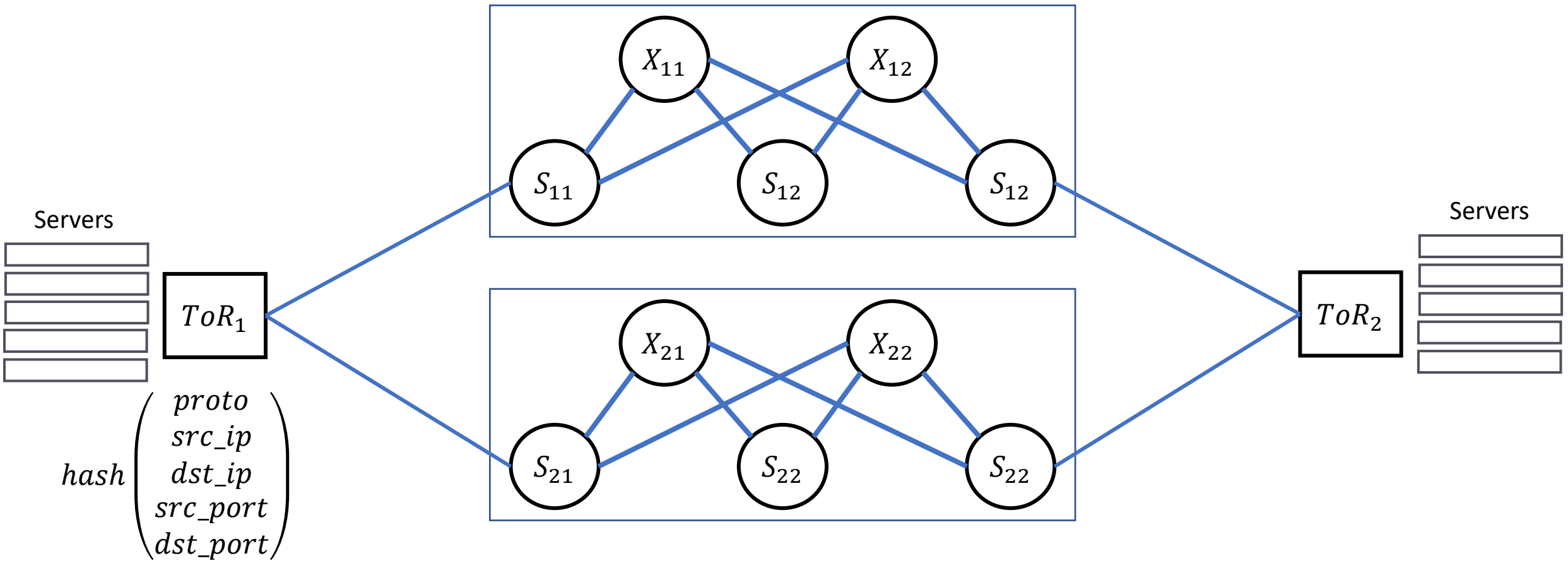


ToR + 2xPlanes

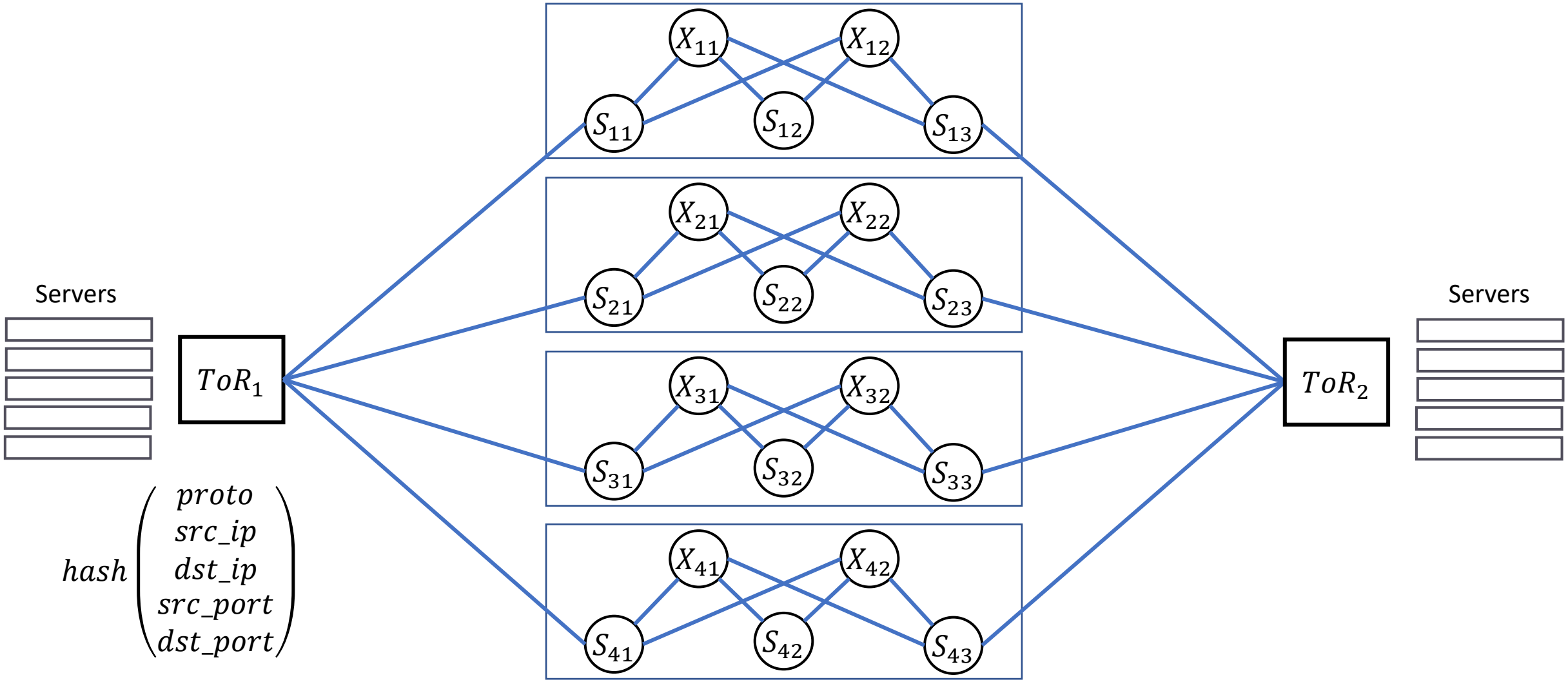


S – spine;
X – super spine;

ToR + 2xPlanes + ToR



ToR + 4xPlanes + ToR



Many-Many Paths

N_PLANES: Number of planes in DC;

N_X_SPINES: Number of super spines (X) in each plane;

- Inside ToR: 1
- Inside Pod: N_PLANES
- Between Pods: N_PLANES x N_X_SPINES

Many-Many Paths

N_PLANES: Number of planes in DC; (8)

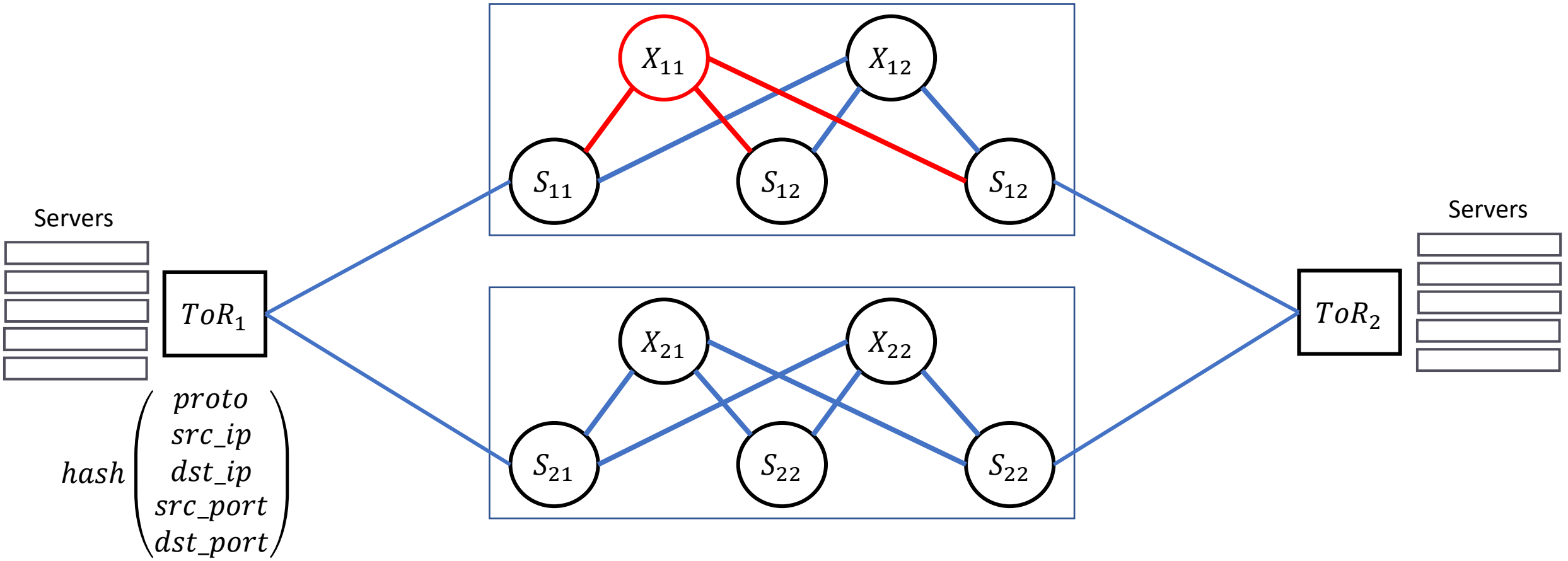
N_X_SPINES: Number of super spines (X) in each plane; (32)

- Inside ToR: 1
- Inside Pod: N_PLANES = 8
- Between Pods: N_PLANES x N_X_SPINES = 256

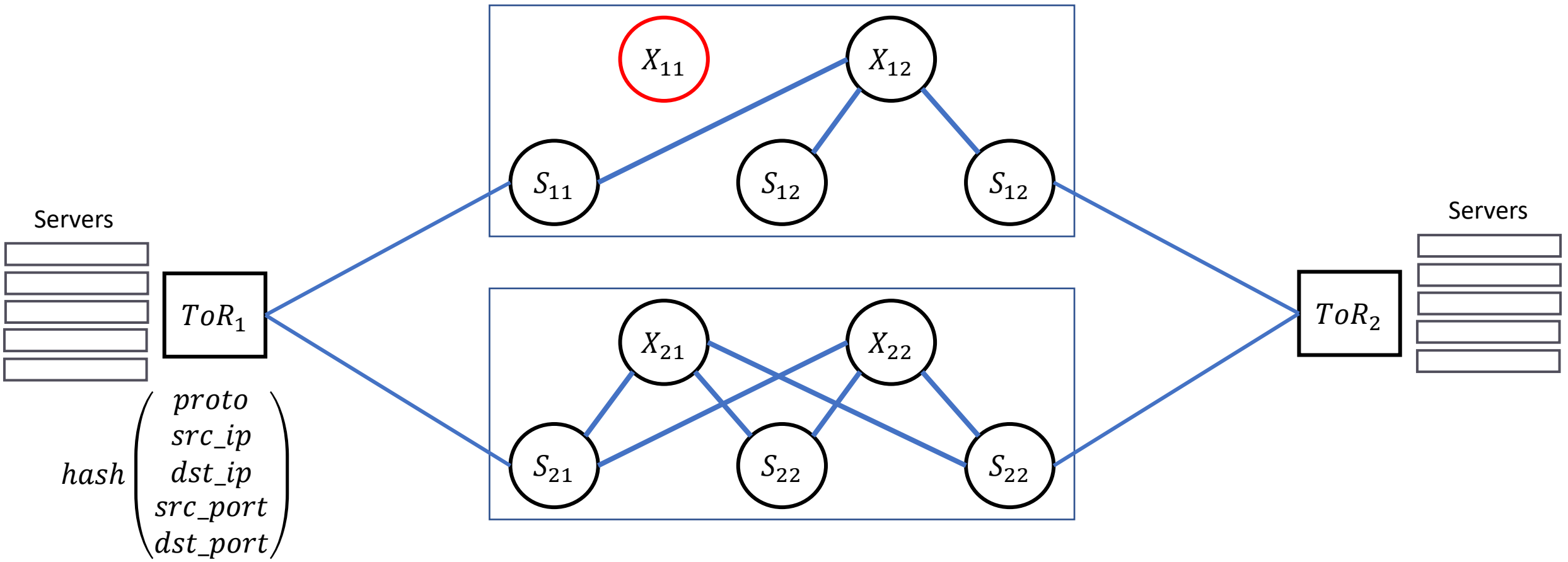
Self-healing Datacenter: Cookbook

- Does it scale? **Yes!**
- Does it have many paths? **Yes!**
- Does it have fault tolerance?

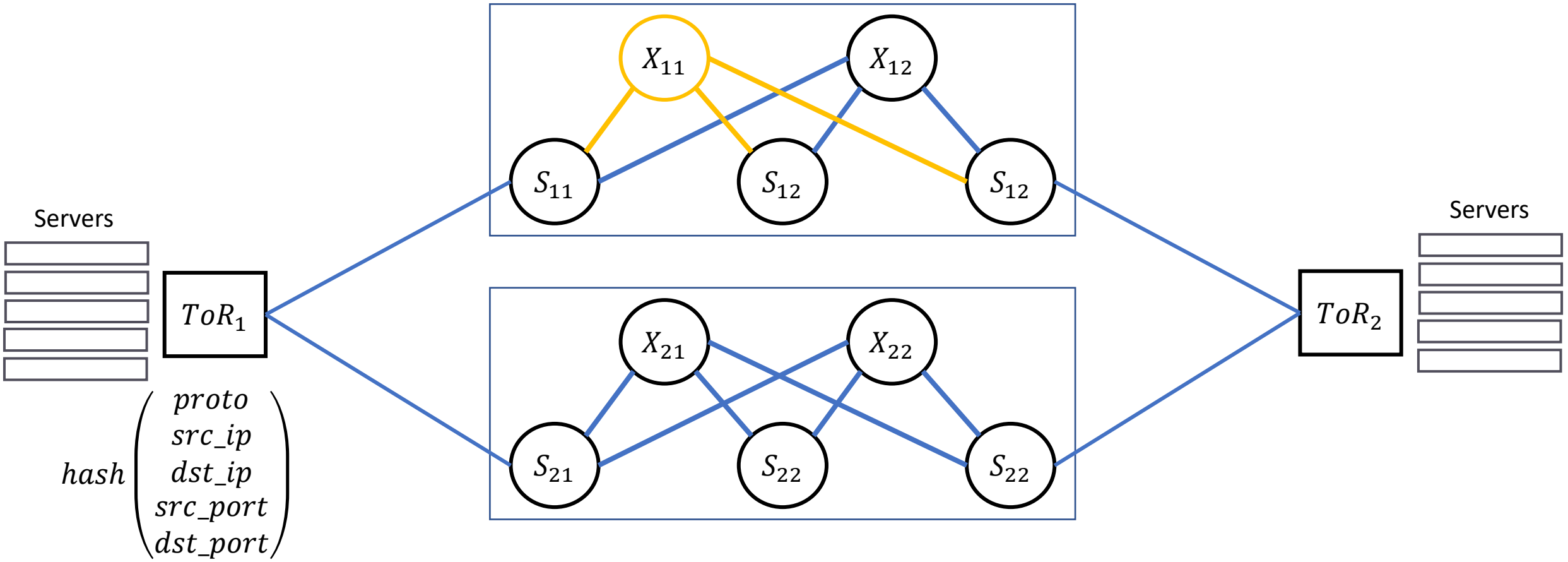
X_{11} is Broken



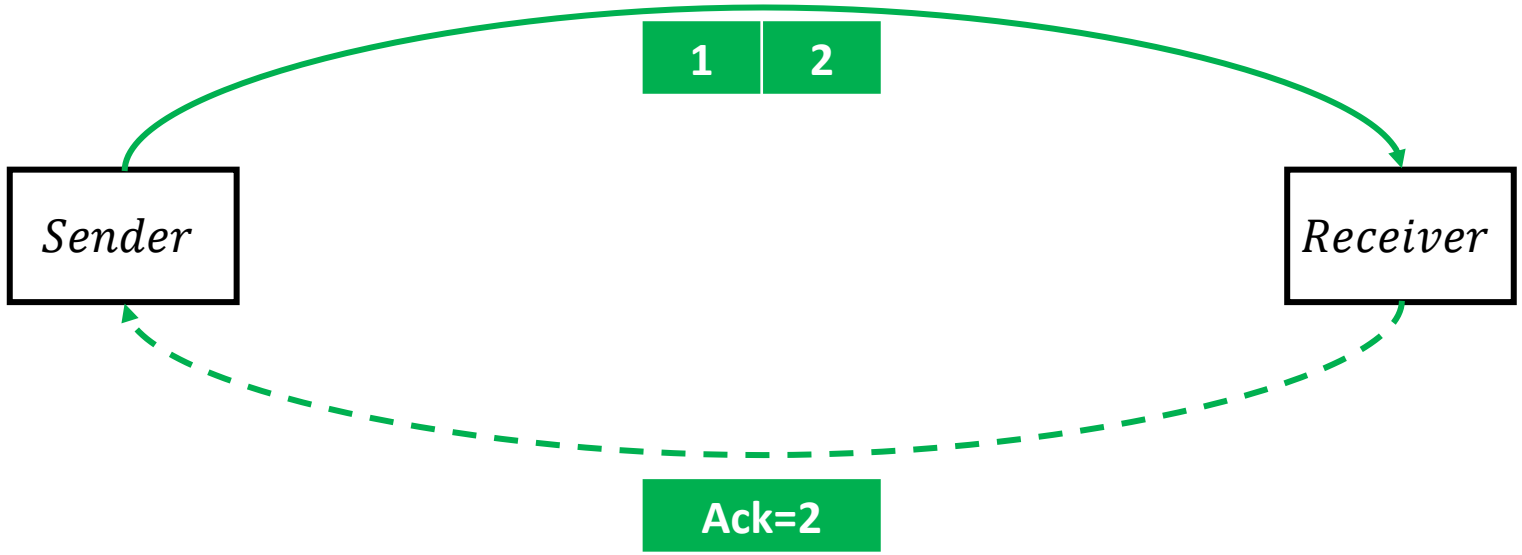
X_{11} is Broken: No link, No Problem



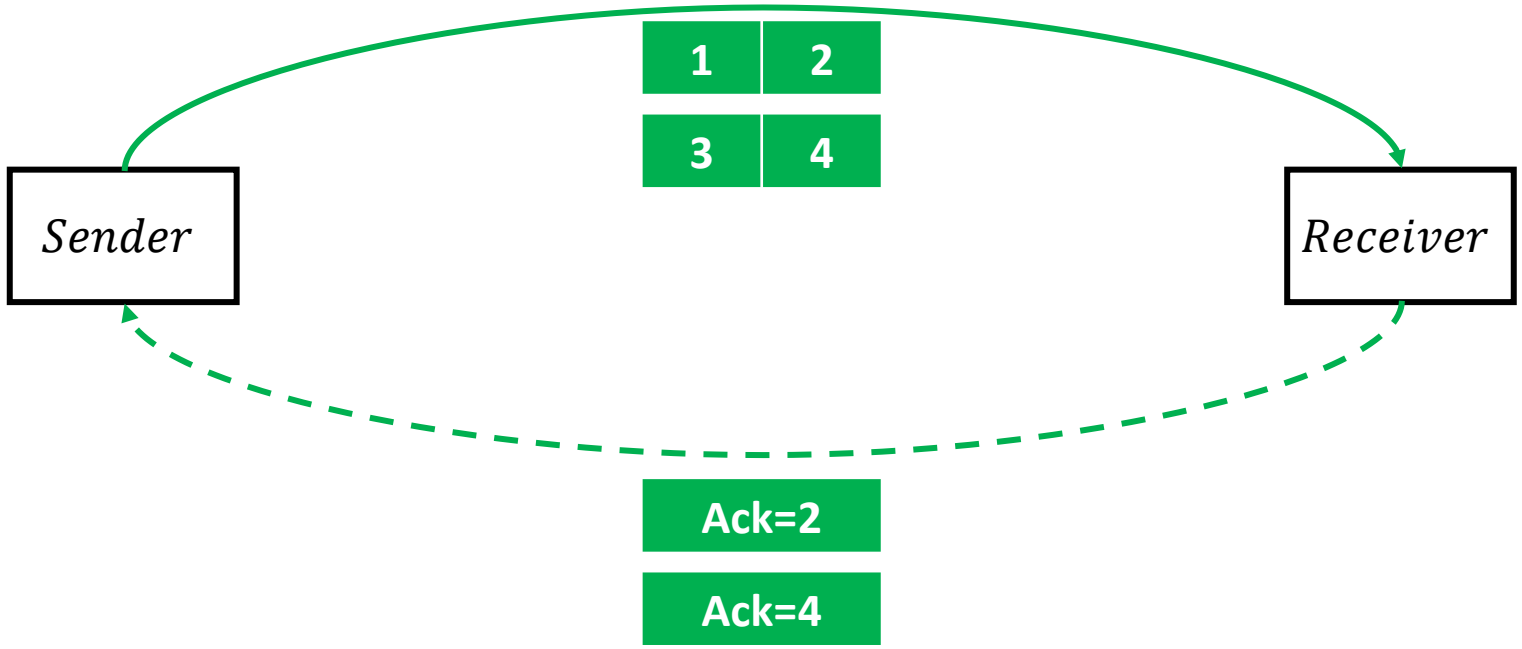
X_{11} is Broken: Constant Loss



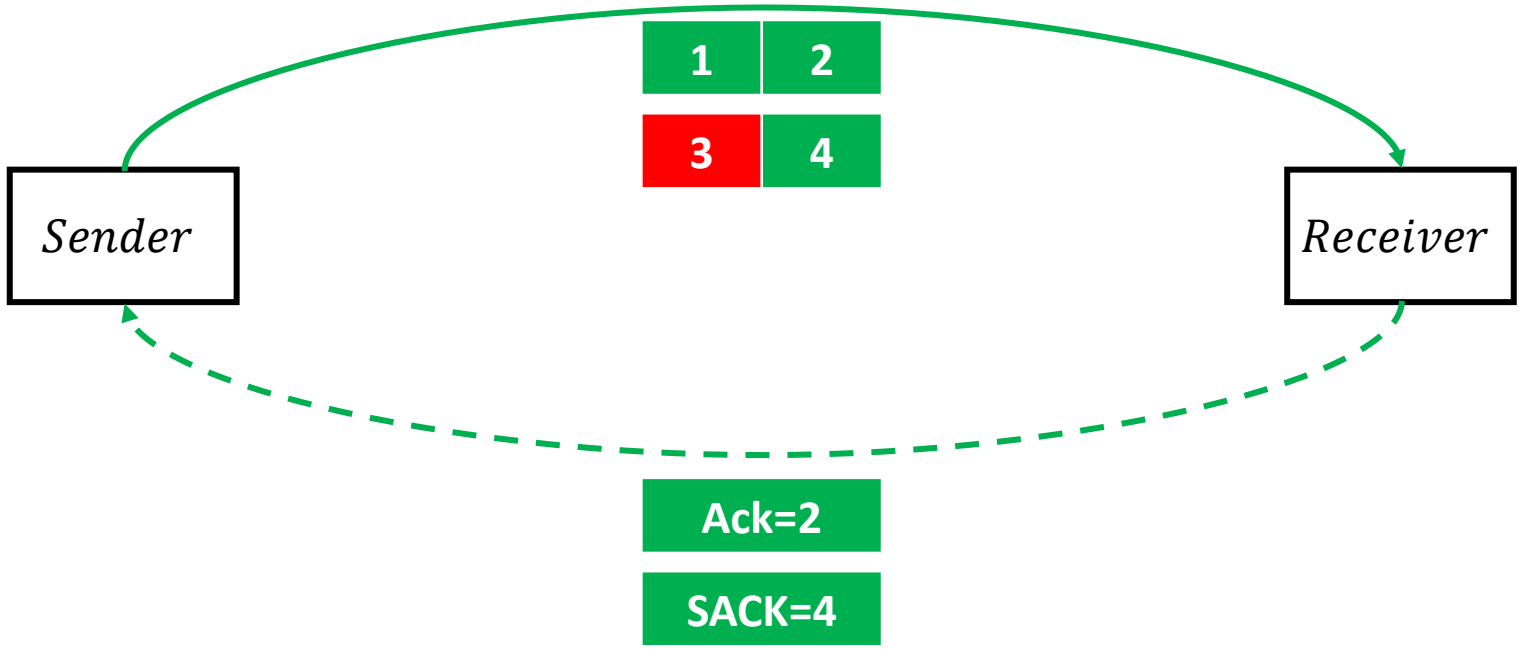
TCP Acknowledgment



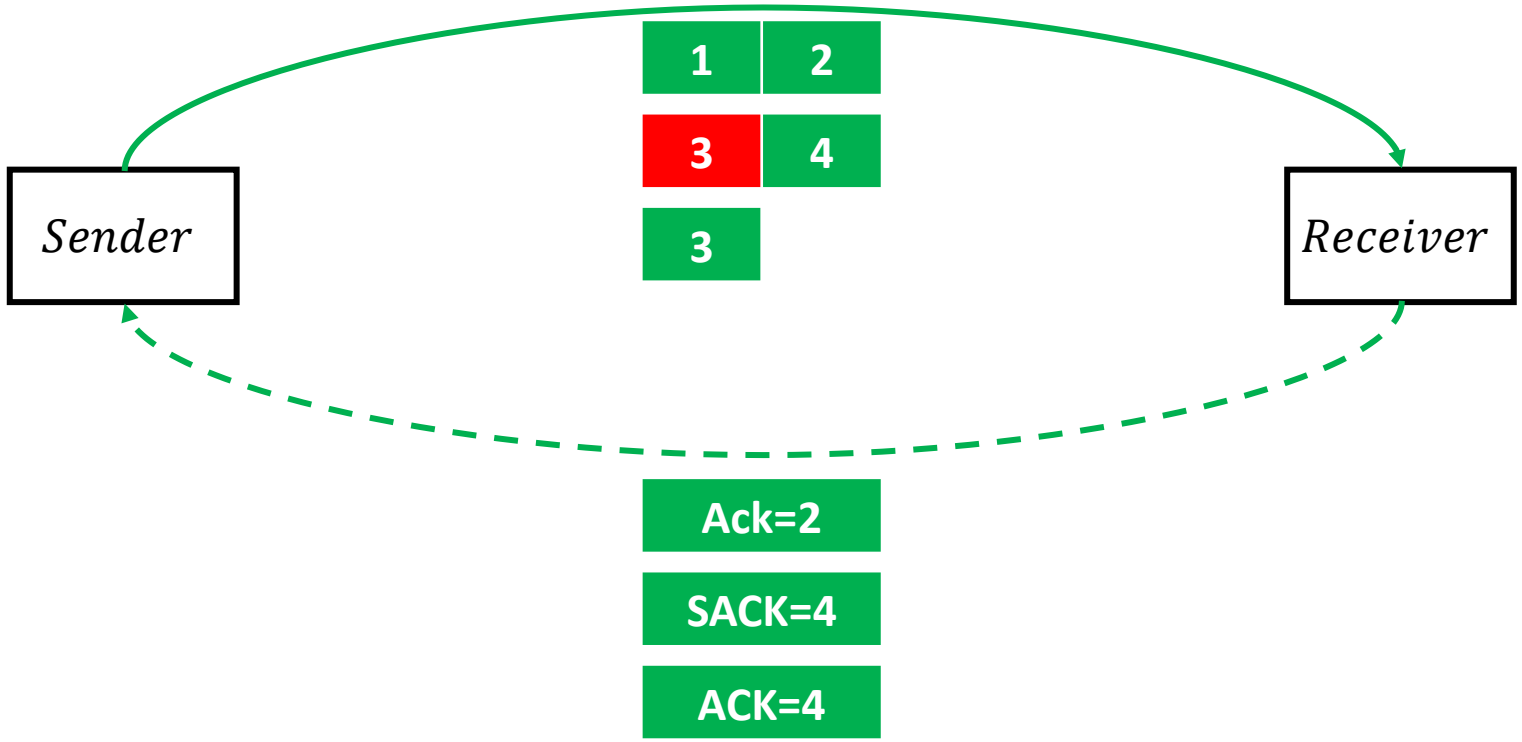
TCP Acknowledgment



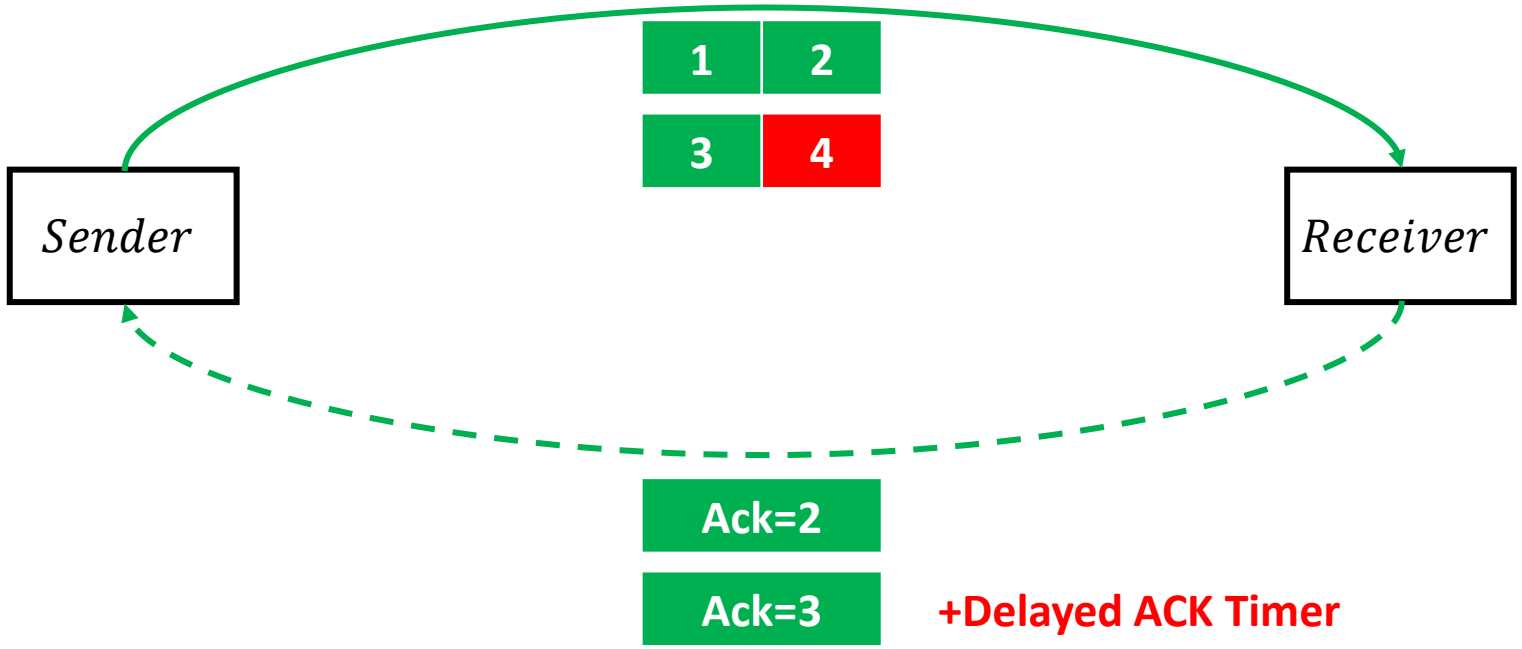
TCP Retransmits: SACK



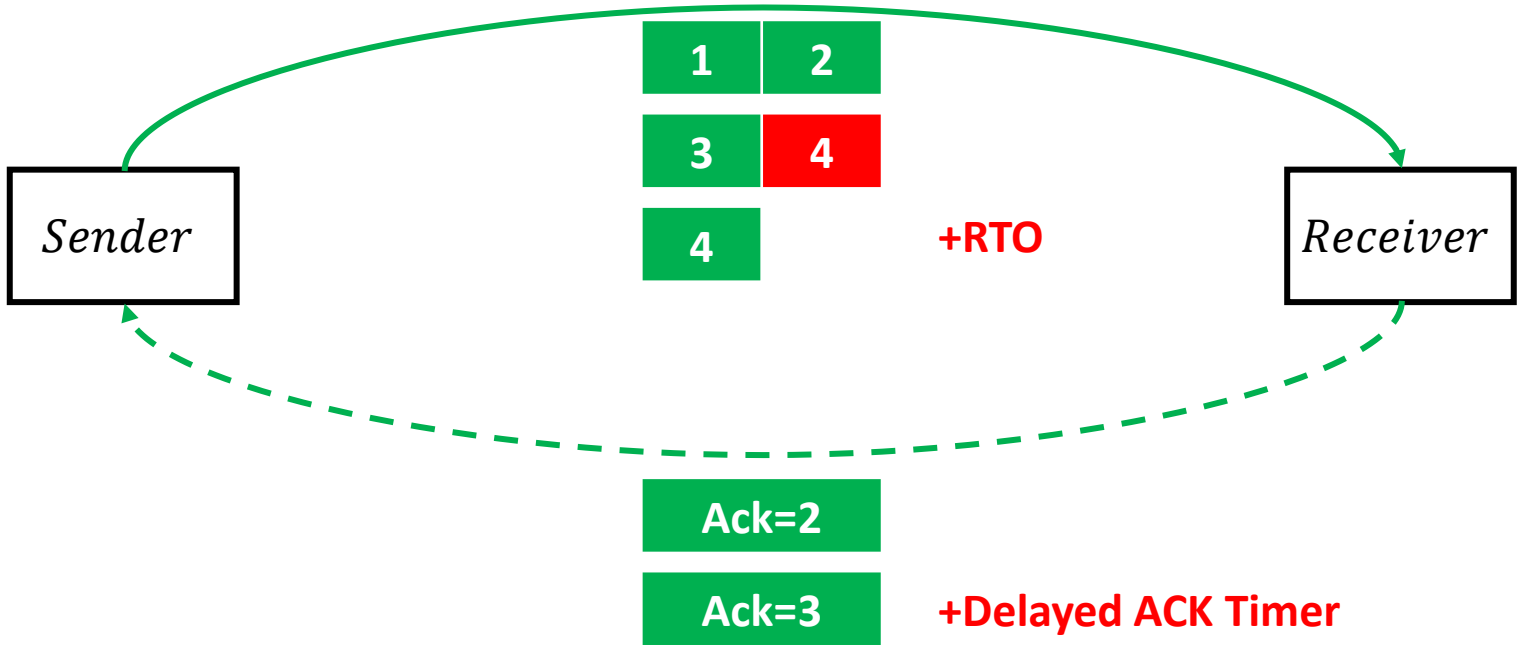
TCP Retransmits: SACK



TCP Retransmits: RTO

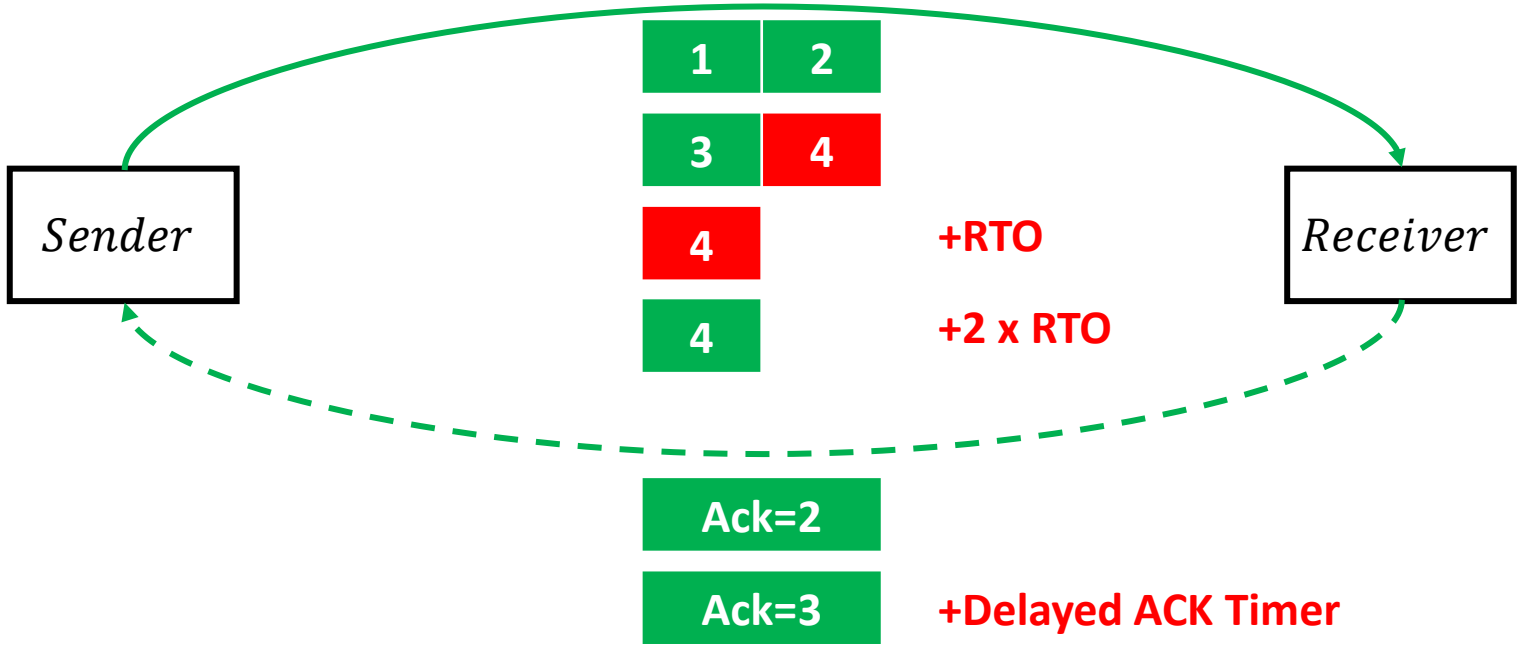


TCP Retransmits: RTO



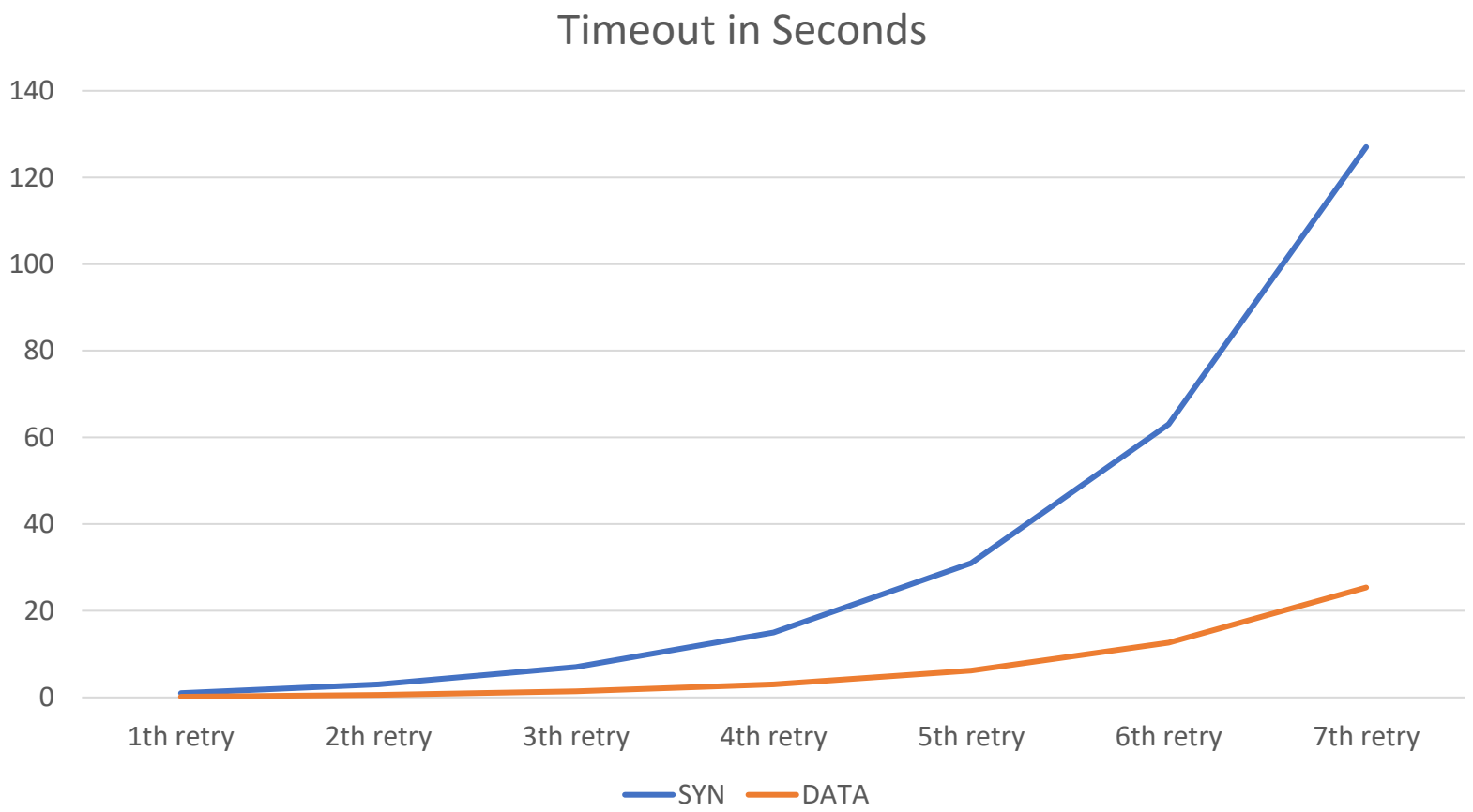
RTO = MAX(RTO_MIN, RTT)

TCP Retransmits: RTO



RTO = MAX(RTO_MIN, RTT)

RTO & SYN_RTO Timeouts



Timeouts

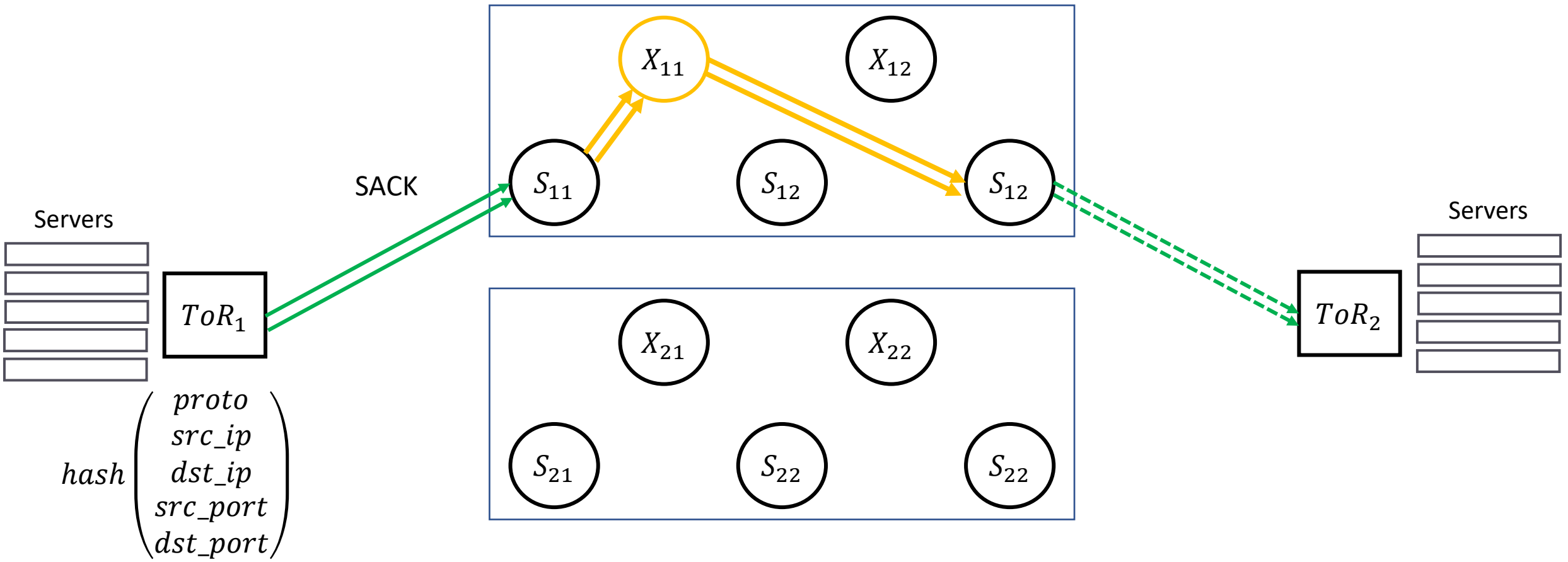
RTO_MIN	SYN_RTO
200ms	1s

Real RTT

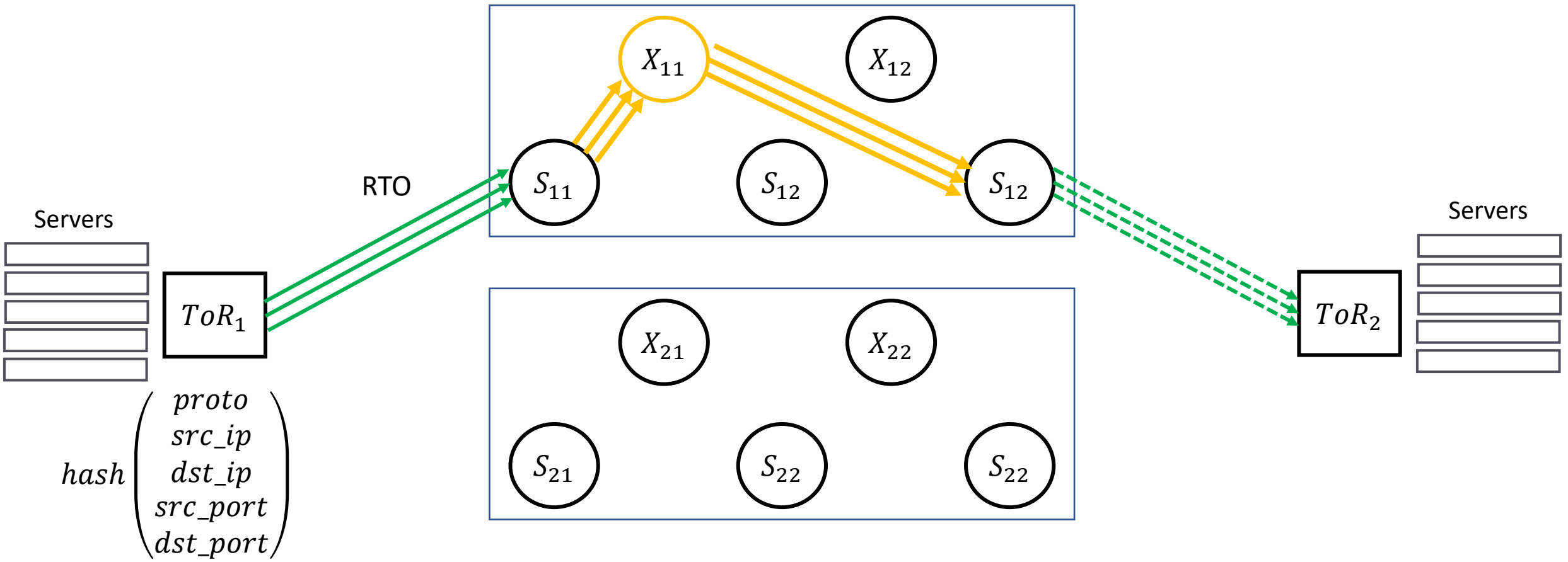
1ms

RTO = MAX(RTO_MIN, RTT)

Unhappy TCP Flow



Unhappy TCP Flow



The Old Way: Services

- Configure TCP options using sysctl;
- Configure application timeouts;
- TCP sessions reuse with software defined health checks;
- None of these methods are properly evaluated;

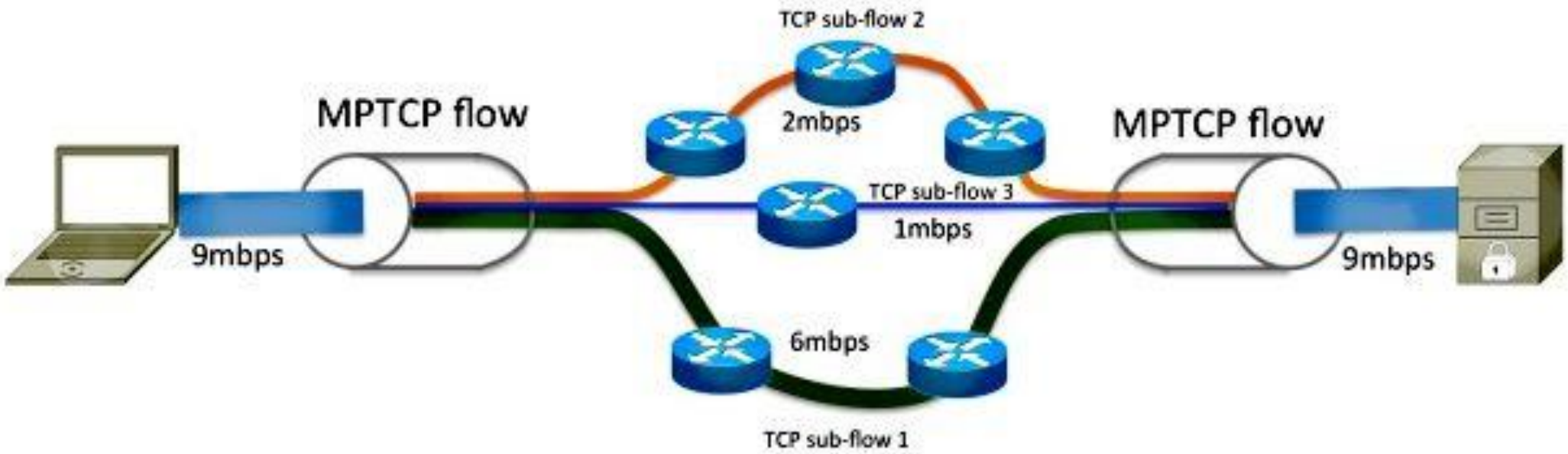
The Old Way: NOC

The Old Way: NOC

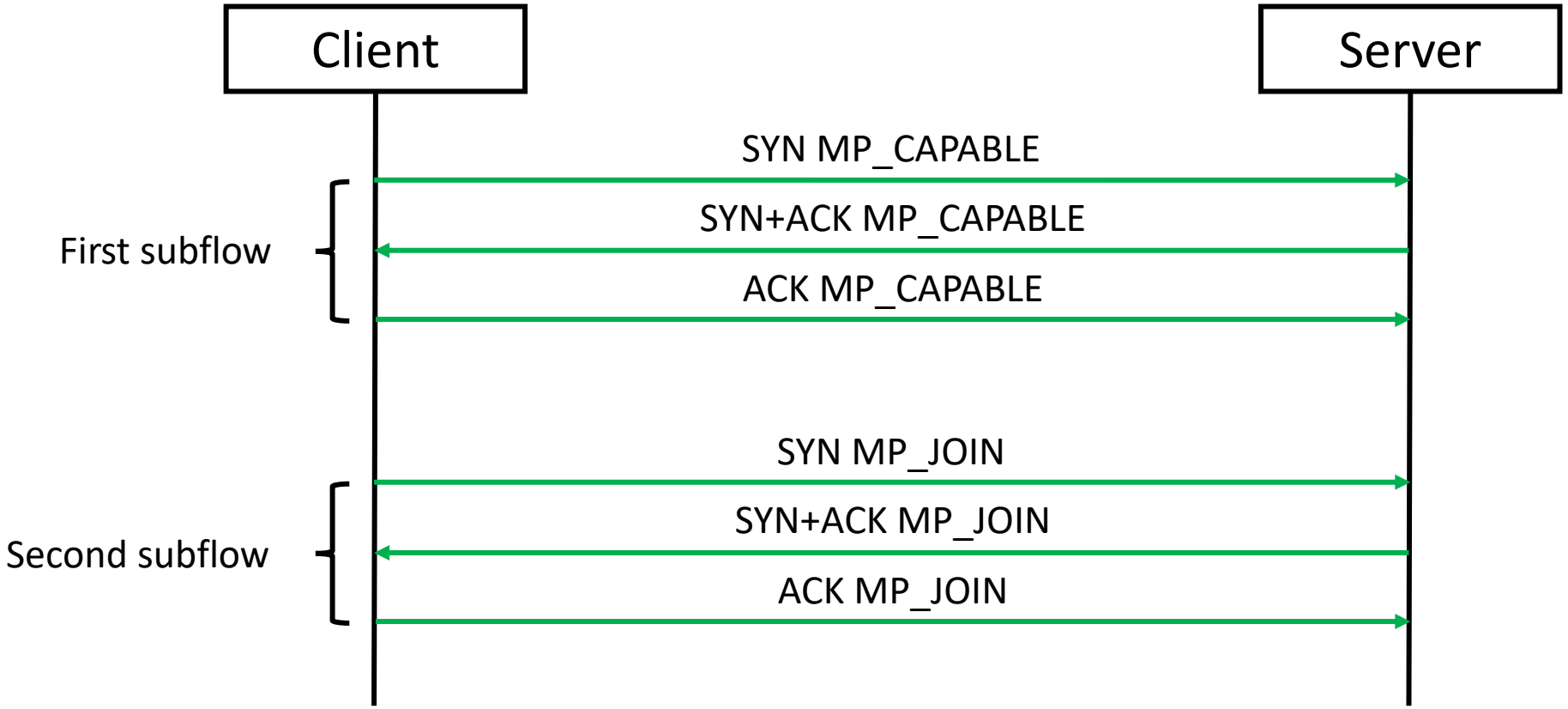
- Outage!
- Detection (1-5 minutes);
- Isolation (5-15 minutes);

Total: 5-20 minutes of service degradation.

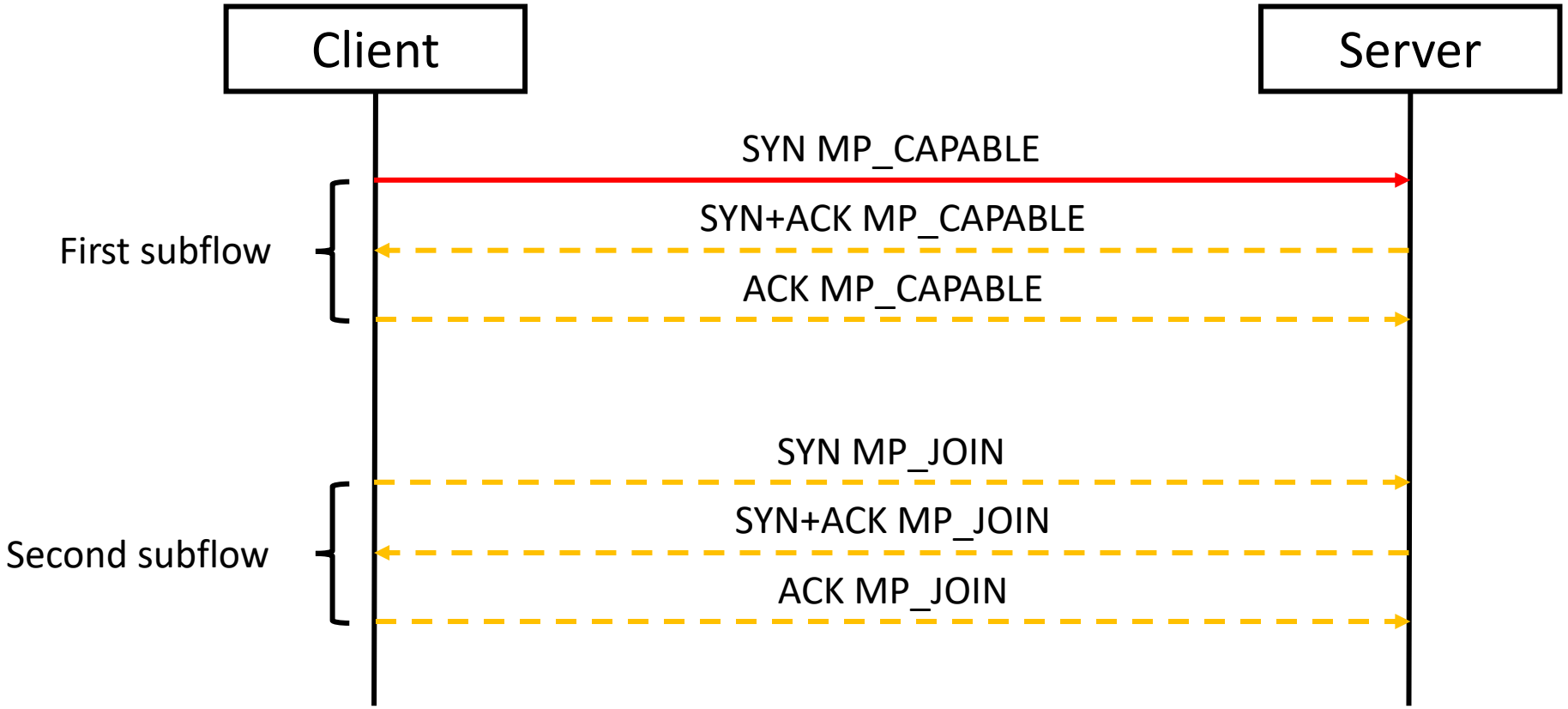
Can Single TCP Flow Use Multiple Paths?



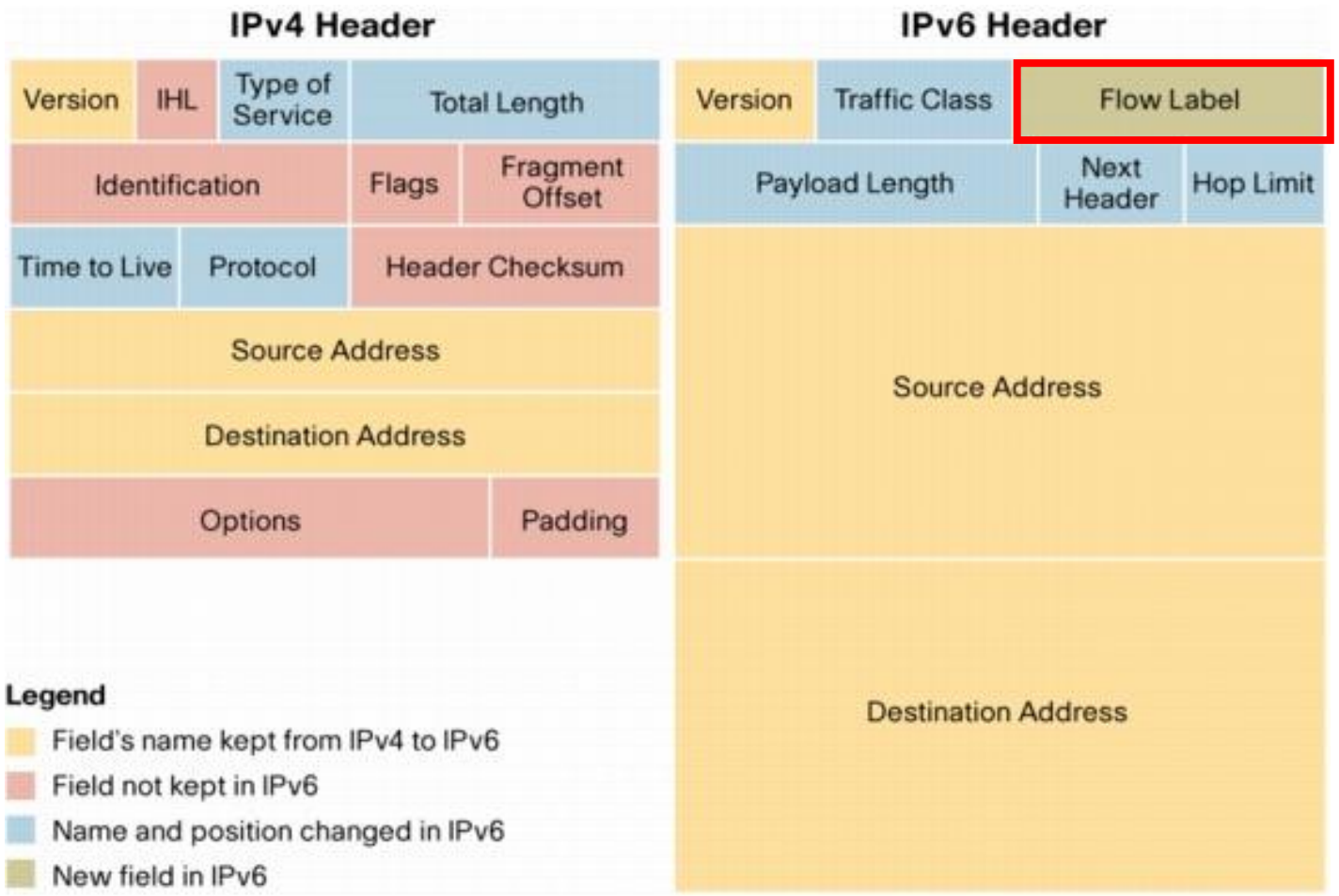
MPTCP – Ordered Subflows



MPTCP – Doesn’t Give False Tolerance



IP Headers


IPv4 Header
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding
IPv6 Header
Version
Traffic Class
Flow Label
Payload Length
Next Header
Hop Limit
Source Address
Destination Address
Legend
Field's name kept from IPv4 to IPv6
Field not kept in IPv6
Name and position changed in IPv6
New field in IPv6

Flow Label

Linux Kernel

2014

From: Tom Herbert @ 2014-07-02 4:33 UTC (permalink / raw)
To: davem, netdev

Automatically generate flow labels for IPv6 packets on transmit.
The flow label is computed based on skb_get_hash. The flow label will
only automatically be set when it is zero otherwise (i.e. flow label
manager hasn't set one). This supports the transmit side functionality
of RFC 6438.

Added an IPv6 sysctl auto_flowlabels to enable/disable this behavior
system wide, and added IPV6_AUTOFLOWLABEL socket option to enable this
functionality per socket.

By default, auto flowlabels are disabled to avoid possible conflicts
with flow label manager, however if this feature proves useful we
may want to enable it by default.

It should also be noted that FreeBSD has already implemented automatic
flow labels (including the sysctl and socket option). In FreeBSD,
automatic flow labels default to enabled.

Linux Kernel

2015

From: Tom Herbert <tom@herbertland.com>
To: <davem@davemloft.net>, <netdev@vger.kernel.org>
Cc: <kernel-team@fb.com>
Subject: [PATCH net-next 0/2] net: Initialize sk_hash to random value and res
Date: Tue, 28 Jul 2015 16:02:04 -0700
Message-ID: <1438124526-2129341-1-git-send-email-tom@herbertland.com> (raw)

This patch set implements a common function to simply set sk_txhash to
a random number instead of going through the trouble to call flow
dissector. From dst_negative_advice we now reset the sk_txhash in hopes
of finding a better ECMP path through the network. Changing sk_txhash
affects:
  - IPv6 flow label and UDP source port which affect ECMP in the network
  - Local EMCP route selection (pending changes to use sk_txhash)

Tom Herbert (2):
  net: Set sk_txhash from a random number
  net: Recompute sk_txhash on negative routing advice

Linux Kernel

2016

From: Lawrence Brakmo <brakmo@fb.com>
To: netdev <netdev@vger.kernel.org>
Cc: Kernel Team <kernel-team@fb.com>,
        Eric Dumazet <eric.dumazet@gmail.com>,
        Yuchung Cheng <ycheng@google.com>,
        Neal Cardwell <ncardwell@google.com>
Subject: [PATCH v4 net-next] tcp: Change txhash on every SYN and RTO retransmit
Date: Tue, 27 Sep 2016 19:03:37 -0700
Message-ID: <20160928020337.3057238-1-brakmo@fb.com> (raw)

The current code changes txhash (flowlables) on every retransmitted
SYN/ACK, but only after the 2nd retransmitted SYN and only after
tcp_retries1 RTO retransmits.

With this patch:
1) txhash is changed with every SYN retransmits
2) txhash is changed with every RTO.

The result is that we can start re-routing around failed (or very
congested paths) as soon as possible. Otherwise application health
checks may fail and the connection may be terminated before we start
to change txhash.

v4: Removed sysctl, txhash is changed for all RTOs
v3: Removed text saying default value of sysctl is 0 (it is 100)

net.ipv6.auto_flowlabels

0: automatic flow labels are completely disabled

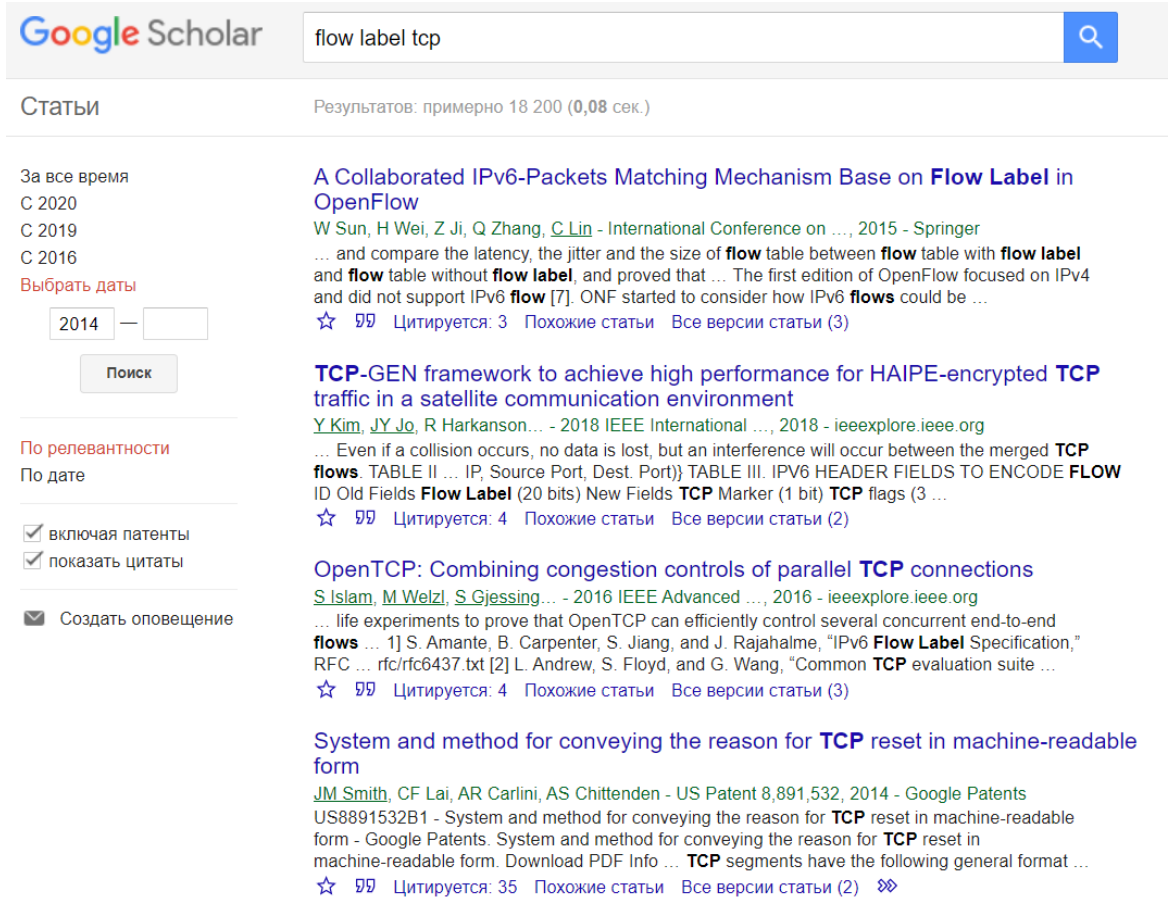
1: automatic flow labels are enabled by default, they can be disabled on a per socket basis using the IPV6_AUTOFLOWLABEL socket option

2: automatic flow labels are allowed, they may be enabled on a per socket basis using the IPV6_AUTOFLOWLABEL socket option

3: automatic flow labels are enabled and enforced, they cannot be disabled by the socket option

Default: 1

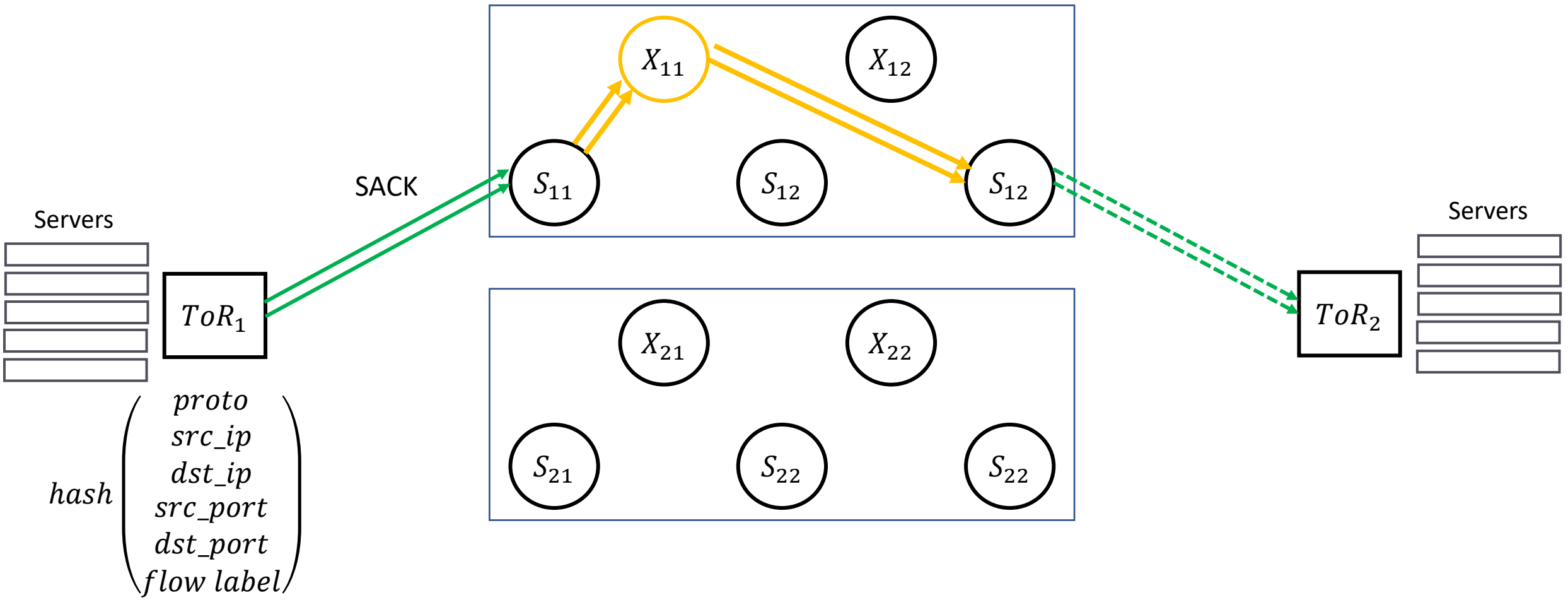
Flow Label: Yet Some Search Engine



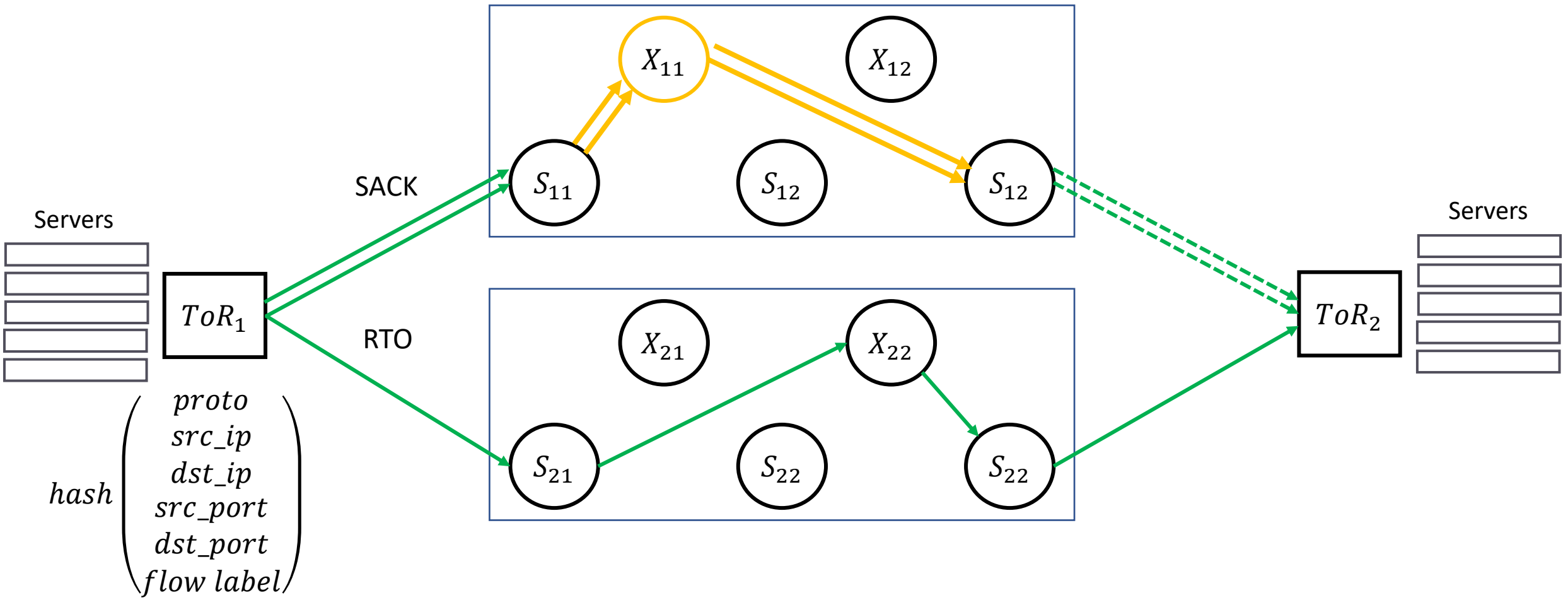
There is nothing…


I KNOW WHAT YOU
ATE LAST SUMMER

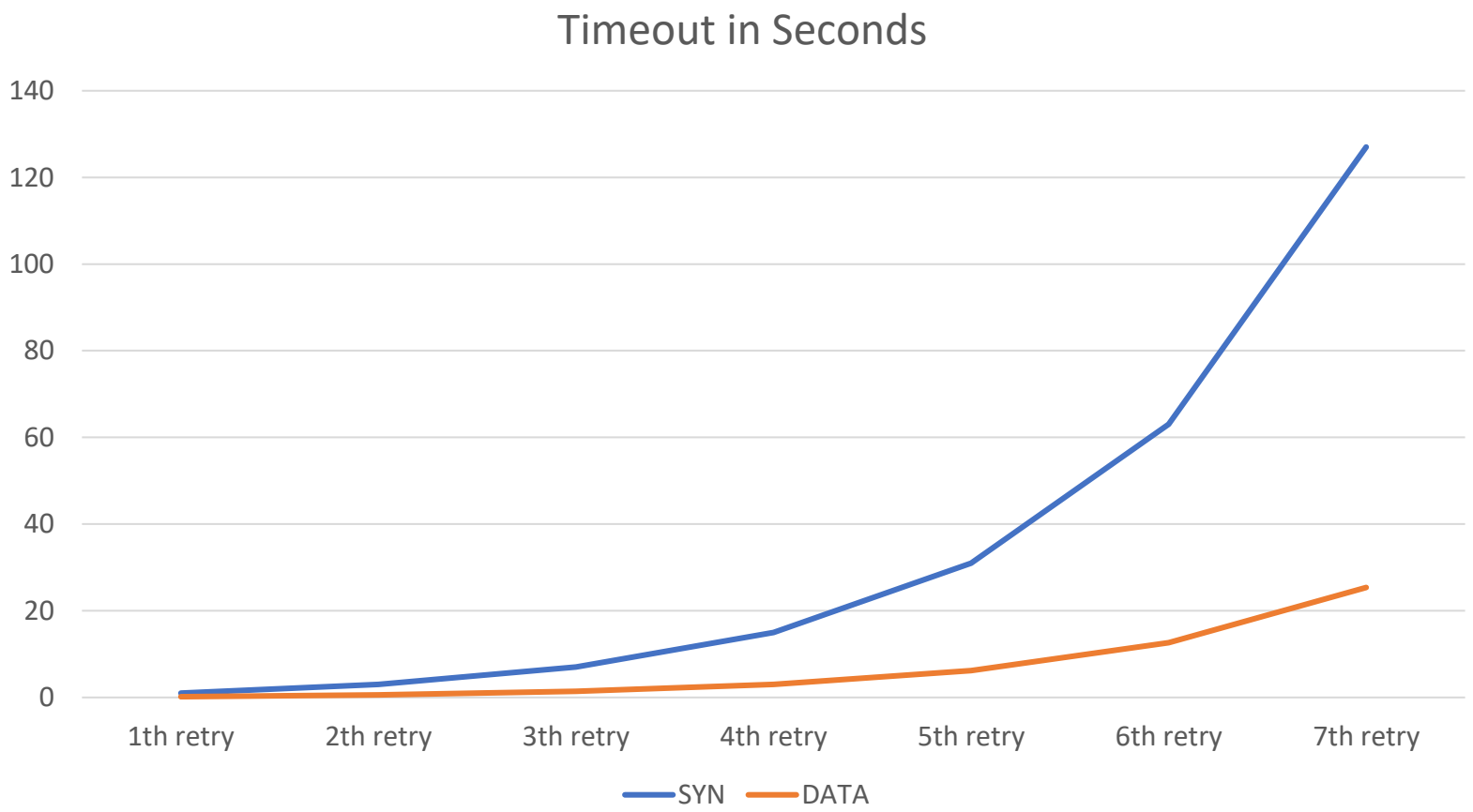
Unhappy TCP Flow



Unhappy TCP Flow Becomes Happier



RTO & SYN_RTO Timeouts



Timeouts

RTO_MIN	SYN_RTO
200ms	1s

Real RTT

1ms

RTO = MAX(RTO_MIN, RTT)

How to Reduce RTO Timeouts?

ip route get *ADDRESS* [**from** *ADDRESS* **iif** *STRING*] [**oif** *STRING*] [**tos** *TOS*]

ip route { **add** | **del** | **change** | **append** | **replace** | **monitor** } *ROUTE*

SELECTOR := [**root** *PREFIX*] [**match** *PREFIX*] [**exact** *PREFIX*] [**table** *TABLE_ID*] [**proto** *RTPROTO*] [**type** *TYPE*] [**scope** *SCOPE*]

ROUTE := *NODE_SPEC* [*INFO_SPEC*]

NODE_SPEC := [*TYPE*] *PREFIX* [**tos** *TOS*] [**table** *TABLE_ID*] [**proto** *RTPROTO*] [**scope** *SCOPE*] [**metric** *METRIC*]

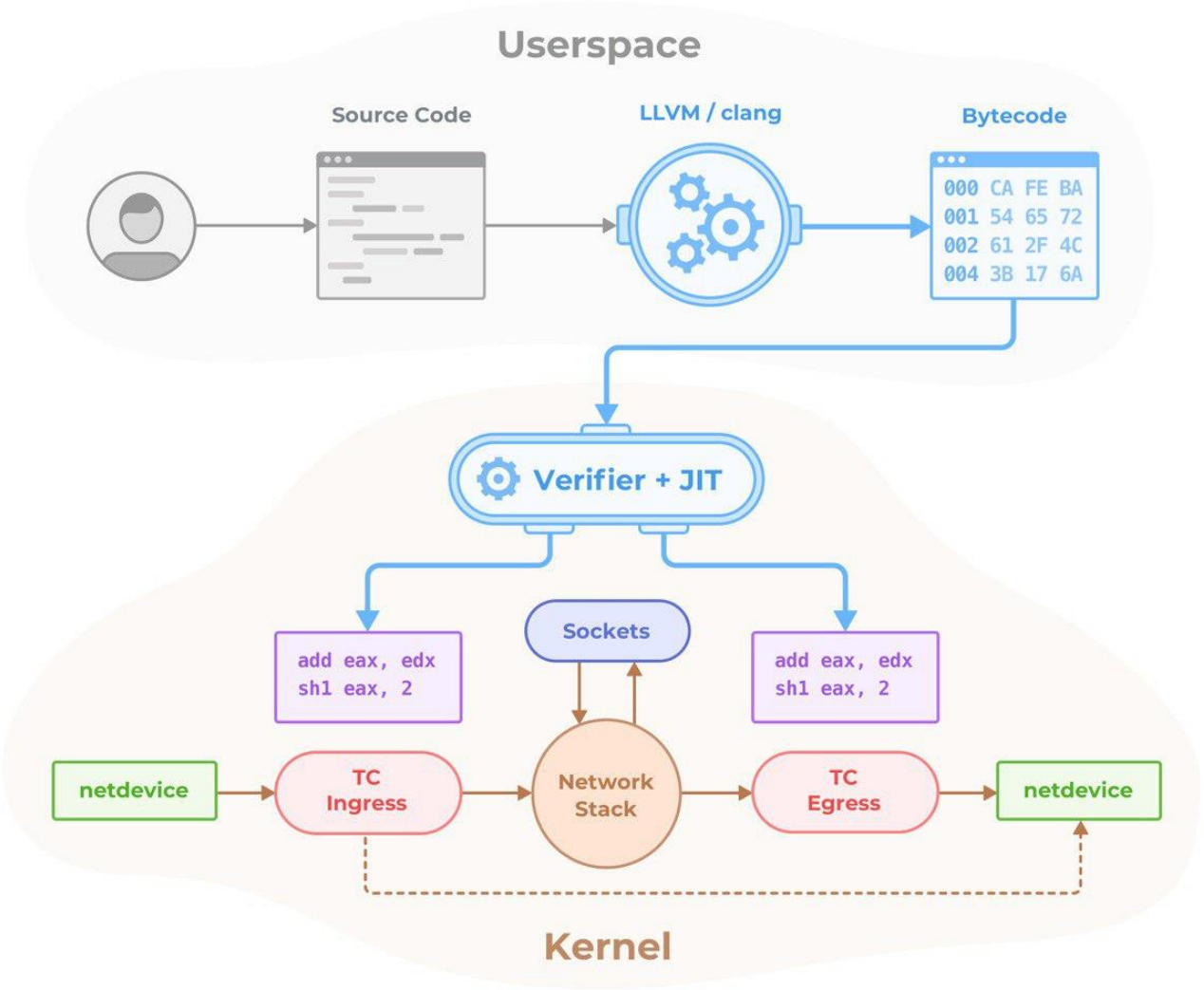
INFO_SPEC := *NH OPTIONS FLAGS* [**nexthop** *NH*] ...

NH := [**via** *ADDRESS*] [**dev** *STRING*] [**weight** *NUMBER*] *NHFLAGS*

OPTIONS := *FLAGS* [**mtu** *NUMBER*] [**advmss** *NUMBER*] [**rtt** *TIME*] [**rttvar** *TIME*] [**window** *NUMBER*] [**cwnd** *NUMBER*] [**initcwnd** *NUMBER*] [**ssthresh** *REALM*] [**realms** *REALM*] [**rto_min** *TIME*] [**initrwnd** *NUMBER*]

SYN_RTO is Different

eBPF

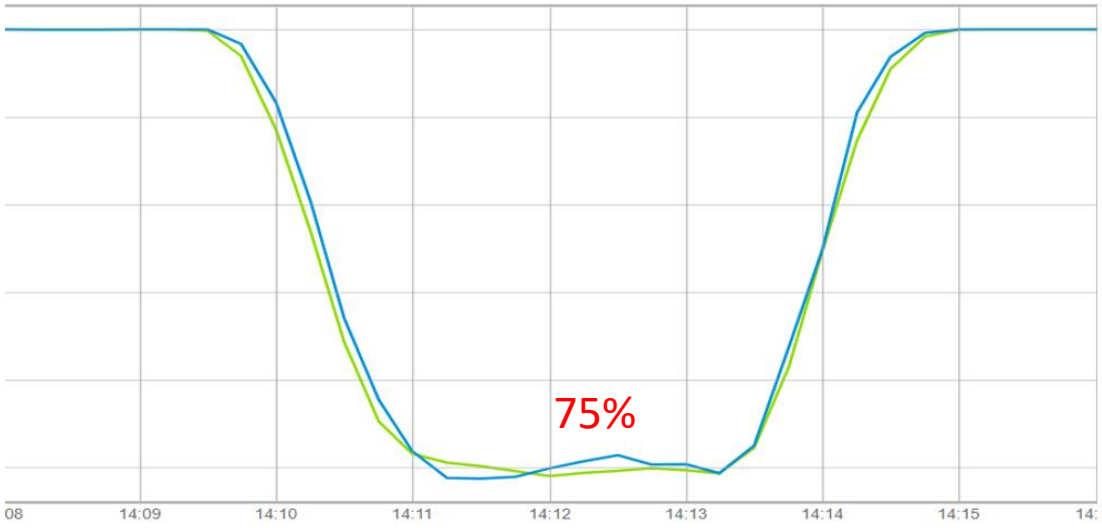

Userspace
Source Code
LLVM / clang
Bytecode
000 CA FE BA
001 54 65 72
002 61 2F 4C
004 3B 17 6A
Verifier + JIT
Sockets
add eax, edx
sh1 eax, 2
add eax, edx
sh1 eax, 2
netdevice
TC
Ingress
Network
Stack
TC
Egress
netdevice
Kernel

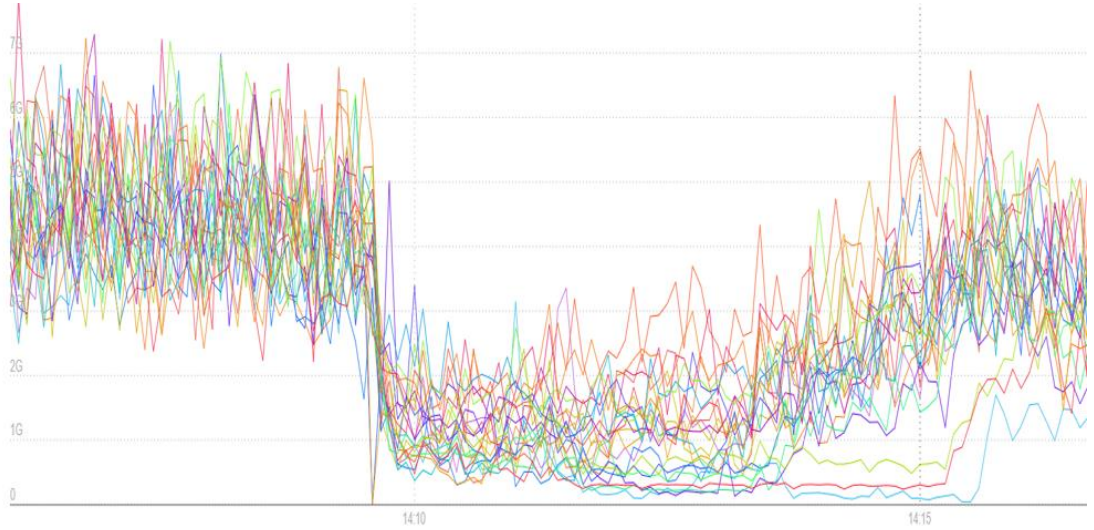
```
/* Check for TIMEOUT INIT operation and IPv6 addresses */
if (op == BPF_SOCK_OPS_TIMEOUT_INIT &&
        skops->family == AF_INET6) {

        /* If the first 5.5 bytes of the IPv6 address are the same
         * then both hosts are in the same datacenter
         * so use an RTO of 10ms
         */
        if (skops->local_ip6[0] == skops->remote_ip6[0] &&
            (bpf_ntohl(skops->local_ip6[1]) & 0xfff00000) ==
            (bpf_ntohl(skops->remote_ip6[1]) & 0xfff00000))
                rv = 10;
```

Changing SYN RTO

https://elixir.bootlin.com/linux/latest/source/samples/bpf/tcp_synrto_kern.c

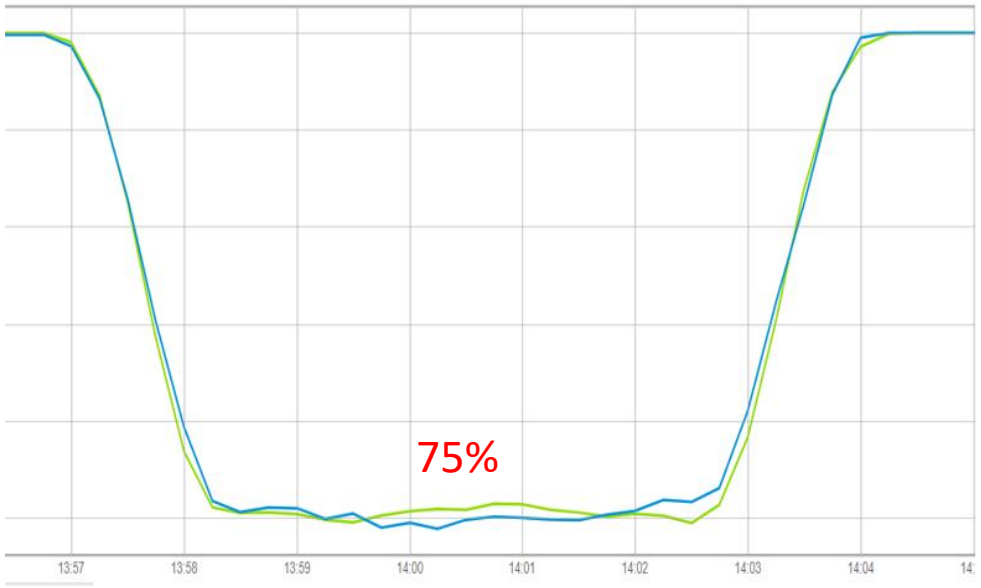
Evaluation: Without Flow Label

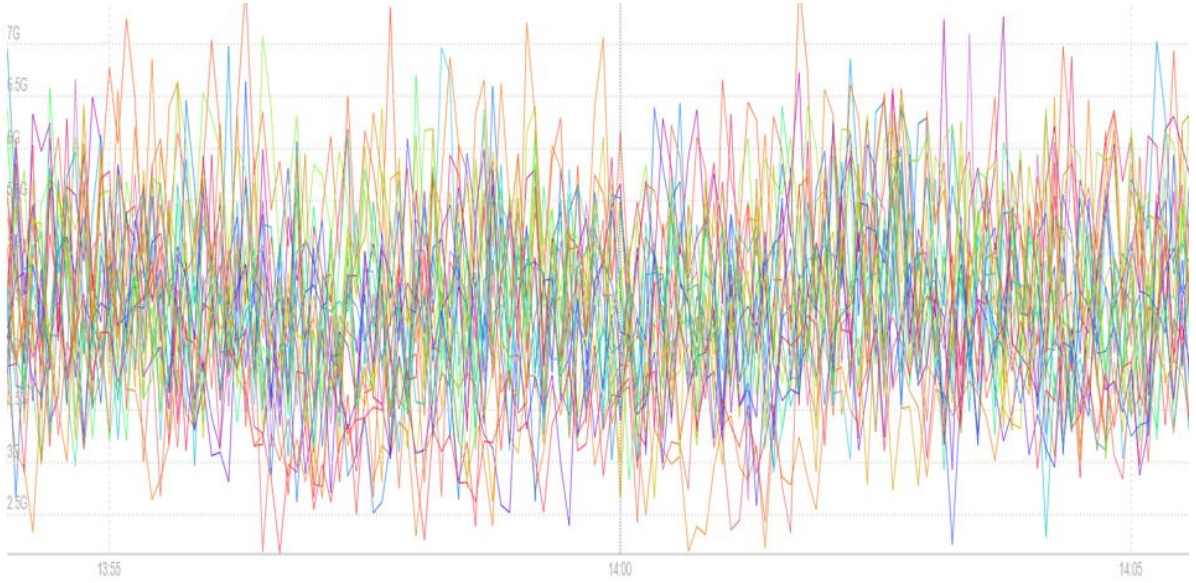




One of four ToR uplinks drops packets, significant service degradation

Evaluation: Flow Label + eBPF



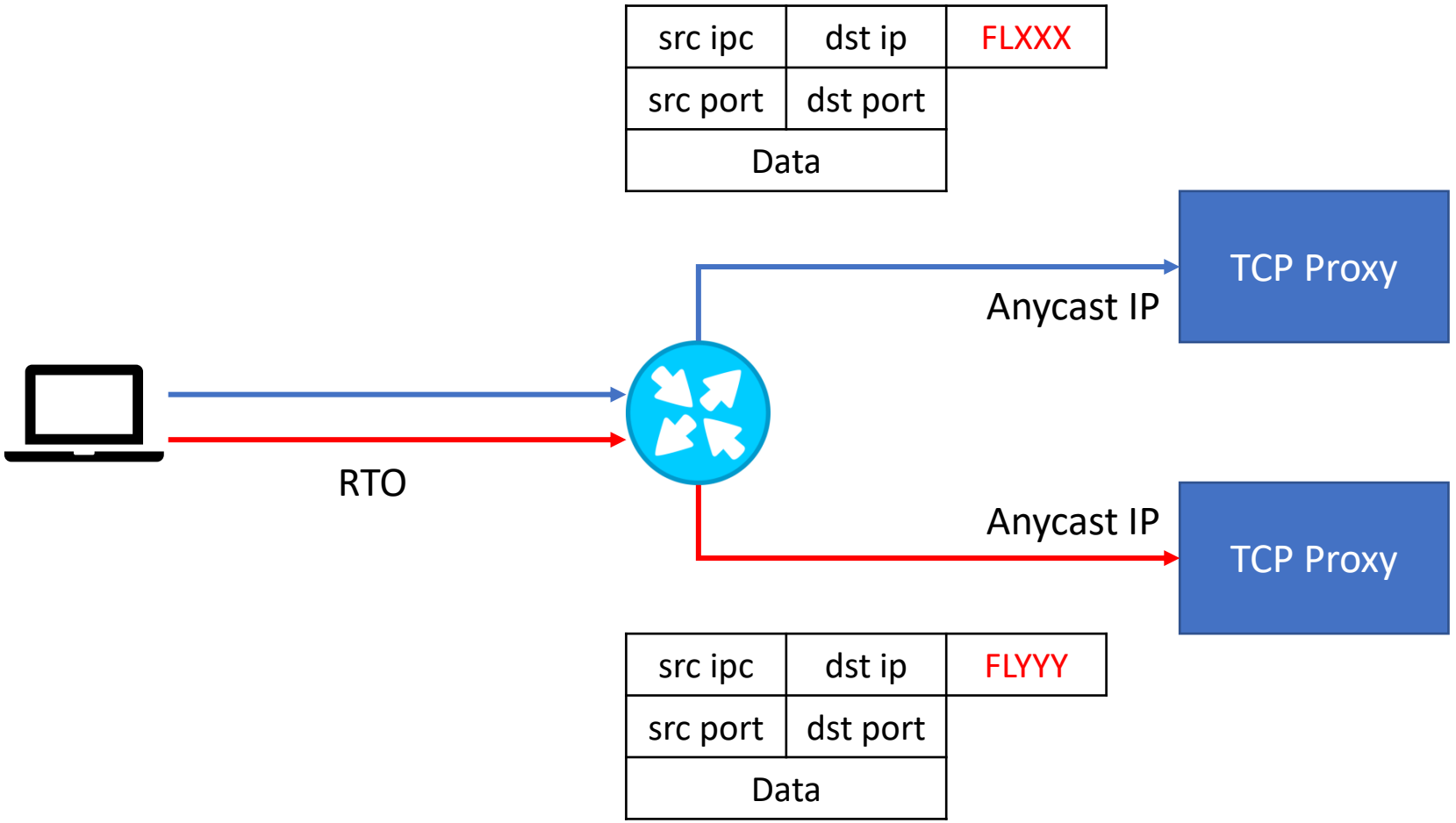


One of four ToR uplink drops packets, no effect on the service!

Self-healing Datacenter: Cookbook

- Does it scale? **Yes!**
- Does it have many paths? **Yes!**
- Does it have fault tolerance? **Use IPv6! Use flow label!**
- How do I change RTO? **eBPF is the answer!**
- Without documentation!

Side Effect


src ipc
dst ip
FLXXX
src port
dst port
Data
TCP Proxy
Anycast IP
RTO
Anycast IP
TCP Proxy
src ipc
dst ip
FLYYY
src port
dst port
Data

Flow Label: Safe Mode

Client – sends SYN, Server – responds with SYN&ACK

- In case of SYN_RTO or RTO events Server SHOULD recalculate its TCP socket hash, thus change Flow Label. This behavior MAY be switched on by default;
- In case of SYN_RTO or RTO events Client MAY recalculate its TCP socket hash, thus change Flow Label. This behavior MUST be switched off by default;

Self-healing ~~Datacenter~~ TCP: Cookbook

- Flow label provides is a way to ‘jump’ from a failing path;
- Already works in controlled environment;
- Can disrupt TCP connection for stateful anycast services;
- We need to change Linux defaults!
- This time we need to document it!