Orchestrating a brighter world

NEC

Cloud Federation

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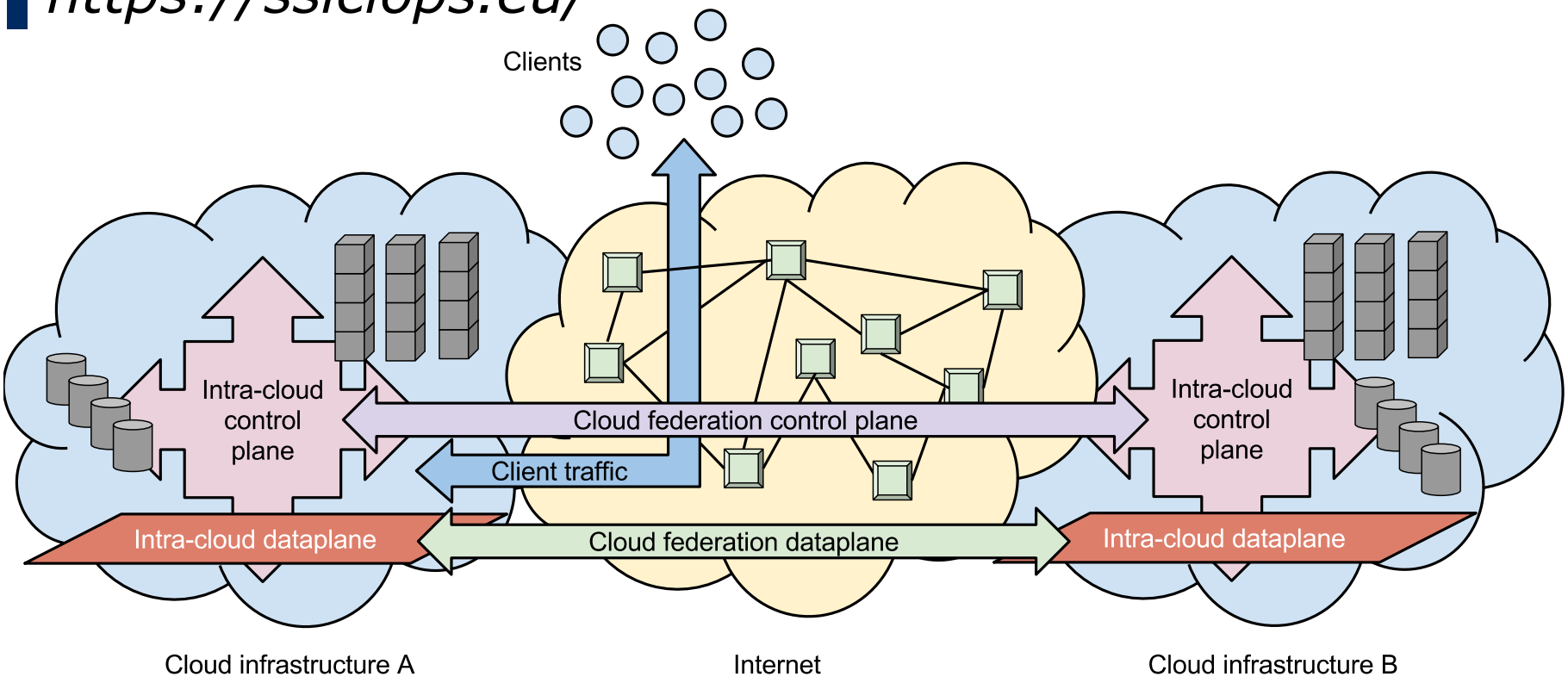
SSICLOPS H2020 Project

- "Scalable and Secure Infrastructures for Cloud Operations"
- Optimizing and securing packet transport in and across data centers
- *https://ssiclops.eu/*

SSICLOPS



Cloud Computing

- Trend towards migrating applications to the cloud
  - public vs. private
- Create VM
- Upload to Cloud
- Run VM
- Use VM
- → Perfect!

Cloud Computing – Issues

Single point of failure

- Application is hosted on remote server
- If cloud fails, application, data, ... becomes unavailable
- Same thing for the connection to the cloud

Latency

- Application is hosted remotely
- Farther away than hosted locally
- Depending on client location, latency will vary

Load bursts

- (Private) cloud infrastructure might not be able to handle large bursts in application usage

Can we do better?

Multi-Site Deployment – Solution?

Deploy application in multiple locations

- different private clouds
- different availability zones

Impact

- improves resilience against outages
- decreases latency
- increases resource pool

Drawback: Instances are separate islands

- No data sharing between instances
- Inconsistent data across locations
- No coordinated load-balancing across locations

Can we do better?

Multi-Site Deployment – Connectivity?

- Application instances need to be connected to share load and data
- Could be done with WAN and public IP addresses
- Most applications expect being used on private networks, though
  - assumes trust and attack protection
  - no traffic encryption
  - no traffic filtering and firewalling between components
- Solution: tunnels, VPNs, ...
  - to securely extend private networks across locations
  - to avoid applications needing to be extended for public network environments

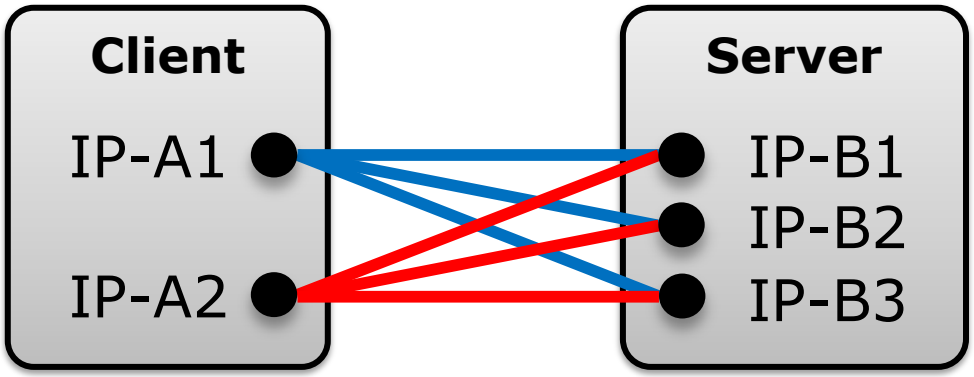
Federated Cloud Networks

- Deployment on multiple sites increases resilience
- Connecting the sites ensures data consistency
- But: connectivity between sites is still single point of failure
- Typically, data centers have multiple uplinks
- Fail-over mechanism in place
- Issues
  - Fail-over mechanism needs to be engineered specifically
  - No aggregation of bandwidth of uplinks
  - Maybe assigning flows to uplinks
    - on a flow basis, not individual packets
    - worst case: all (large) flows end up on same link
  - When private traffic is put into tunnels, tunnel will hide IP/port diversity (single source, single destination → single uplink)

Can we do better?

Digression: MPTCP

- MPTCP: MultiPath TCP
- Splits up TCP connections into multiple subflows
- Each subflow behaves like a separate TCP flow
- Client initiates subflows
  - by default in mesh-like fashion across all local and all remote IP addresses
- Server tells client about additional IP addresses



MPTCP Benefits for Cloud Interconnection

- Can make use of multiple paths
- Spreads packets to path on individual basis
- Automatically adjusts to current capacity of paths
  - including reduction to zero if path becomes unavailable
- Nicely coexists with regular TCP traffic
- Nicely coexists with existing middleboxes (routers, firewalls, DPIs, ...)

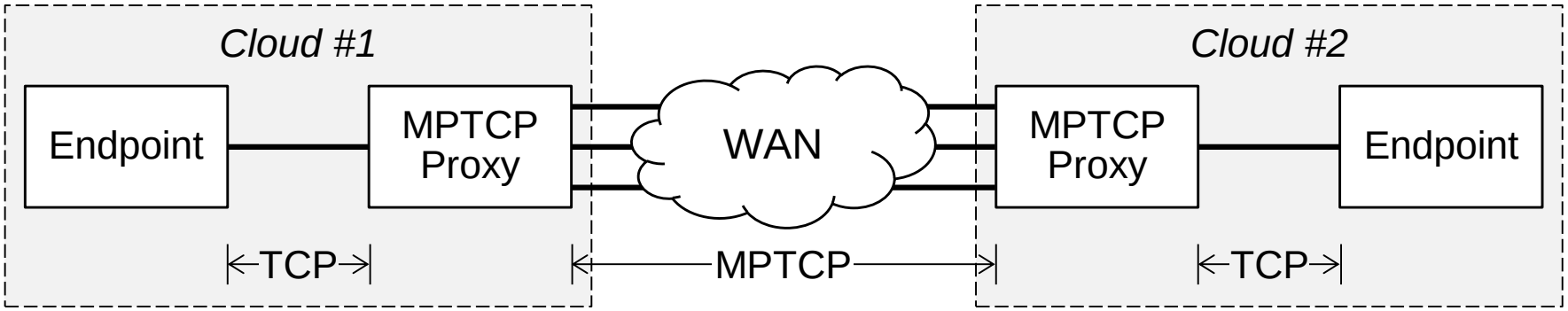
→ ***How to implement?***

MPTCP Use by Cloud Applications

- Extend applications with MPTCP and we're done?
- Endpoints (client/server) need MPTCP-capable kernel
  - not part of standard distributions
  - for Linux, kernel needs to be patched and compiled
  - difficult for already existing applications/VMs
- VMs in cloud do not know about multiple uplinks
  - typically have single virtual NIC connected to "the network"
  - only have single IP address

MPTCP Proxy

- Leave applications alone and introduce MPTCP at infrastructure level
  - like a tunnel, but with different capabilities
- Idea: add component which transforms TCP streams into (multiple) MPTCP ones
- Infrastructure knows about multiple uplinks



MPTCP Proxy: Direct Mapping

Take each TCP packet and transform into MPTCP one

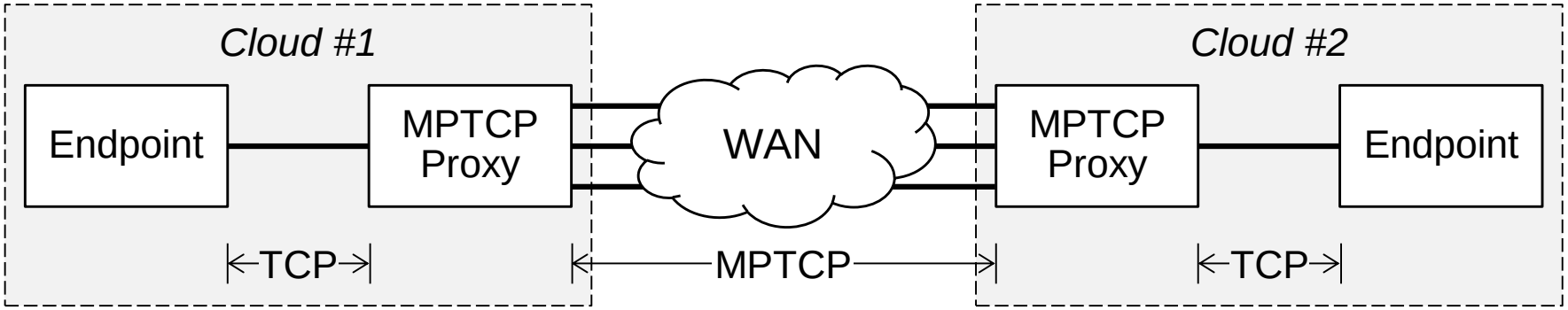
- add an MPTCP header option
- transform TCP header fields (IP addresses, TCP ports, sequence numbers)

Advantages

- direct mapping of packets
- no need to touch data (e.g., split packets and reassemble data)

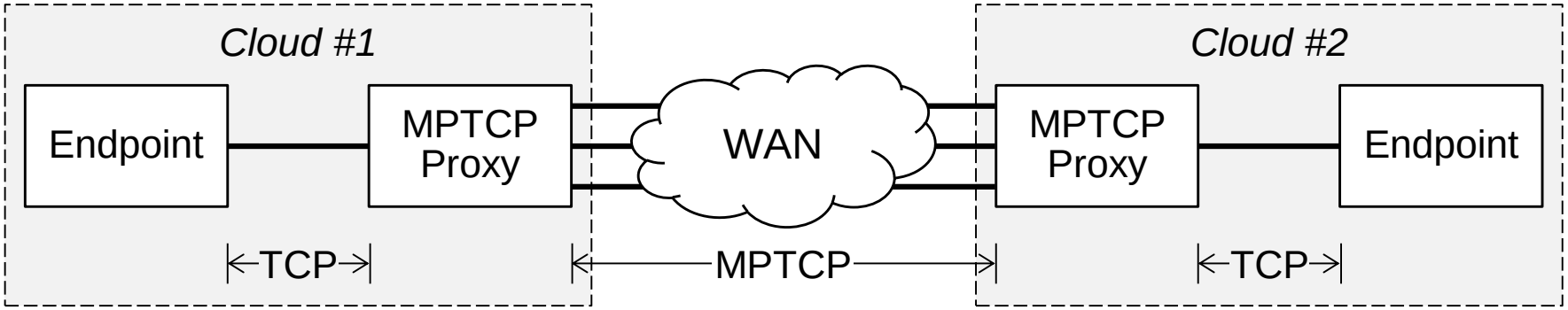
Disadvantages

- Packets get larger (added header option!)
  - Need to configure/tell endpoints to reduce packet size
- TCP behaviour for subflows needs to be implemented



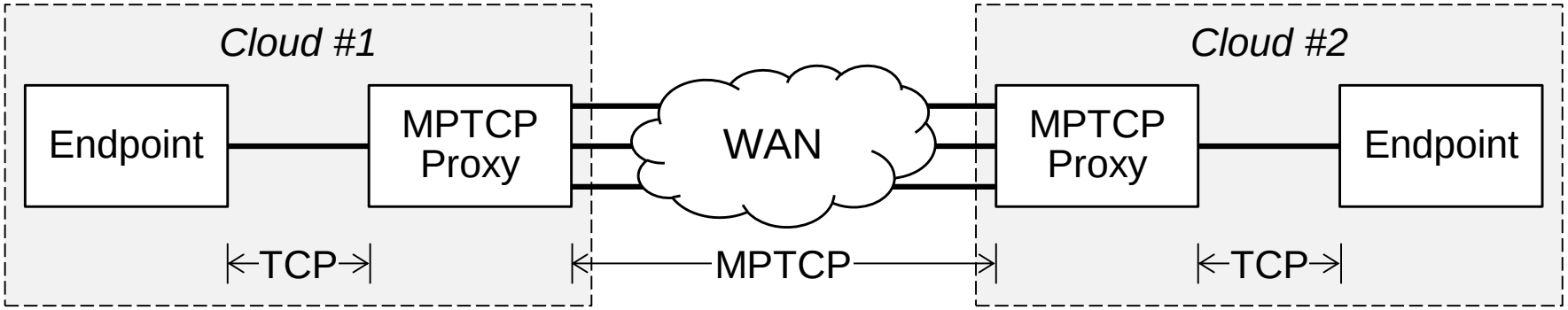
MPTCP Proxy: Decoupled Connections

- TCP and MPTCP connections terminated at both sides of the proxy
- No direct mapping/coupling of packets
  - works on TCP's stream abstraction
- Advantages
  - no need to explicitly fiddle around with individual packets
  - no need to re-implement TCP
- Disadvantages
  - buffering of data required at proxy
  - has impact on congestion control, latency ("buffer bloat")



MPTCP Proxy: Implementation

- Another advantage of decoupled connections: proxies that do this already exist!
- SOCKS is doing exactly this (w/o MPTCP)
- Stable proxies exist
- Implementation: run a SOCKS proxy on top of an MPTCP-capable kernel!
- Traffic needs to be steered to proxies, as applications do not know about them

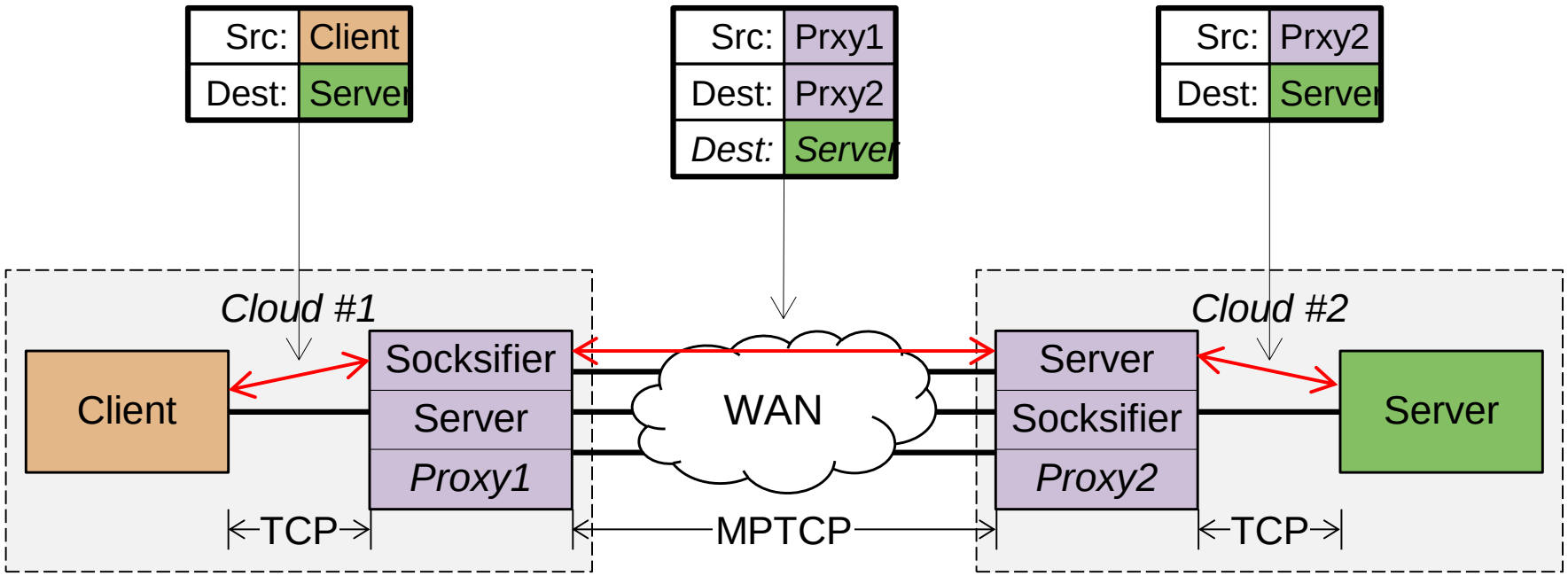


MPTCP Proxy: Peer-to-Peer

- SOCKS is designed for client-server operation
- For transparent operation, two components are needed: Socksifier, SOCKS server
- Still, only client-server
- Cloud federation is a peer-to-peer application
  - connections can be initiated from both sides
- Double instantiation of Socksifier – SOCKS server in opposite directions work
  - traffic needs to be isolated and steered appropriately, depending on direction of connection establishment

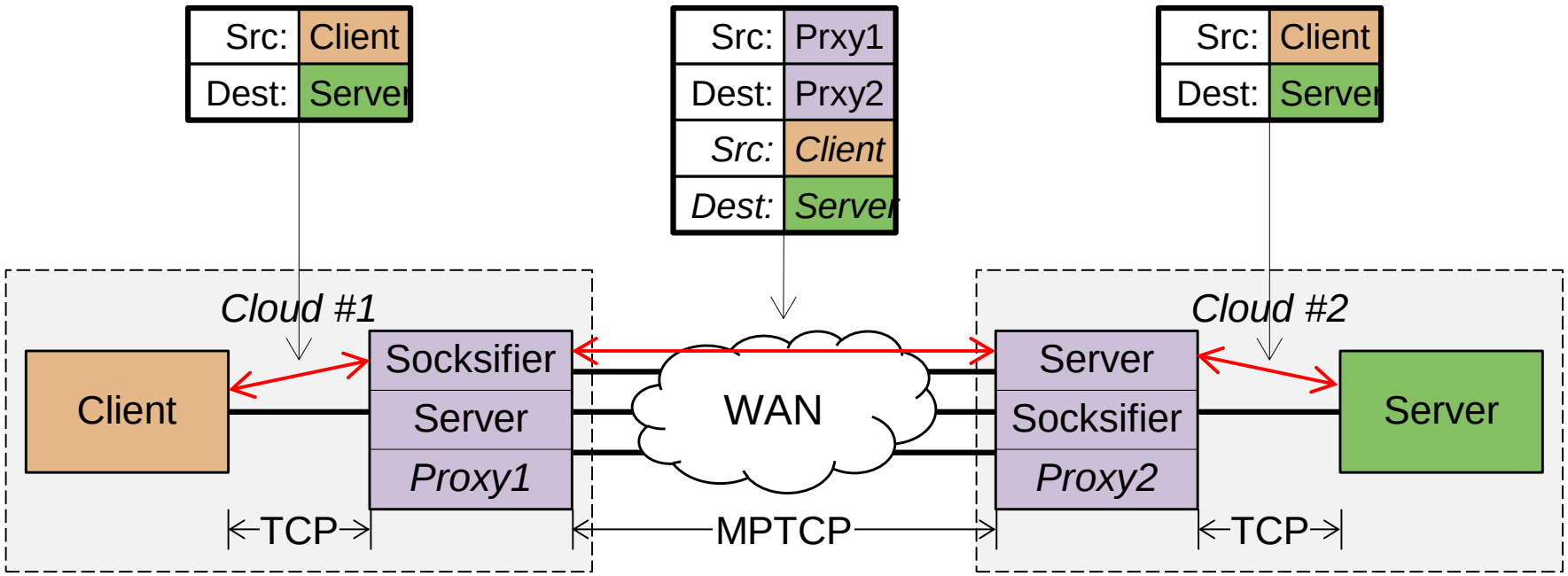
MPTCP Proxy: IP Addresses

- Proxy uses its own address for establishing connections to destination
- Might affect access restrictions / content selection on server

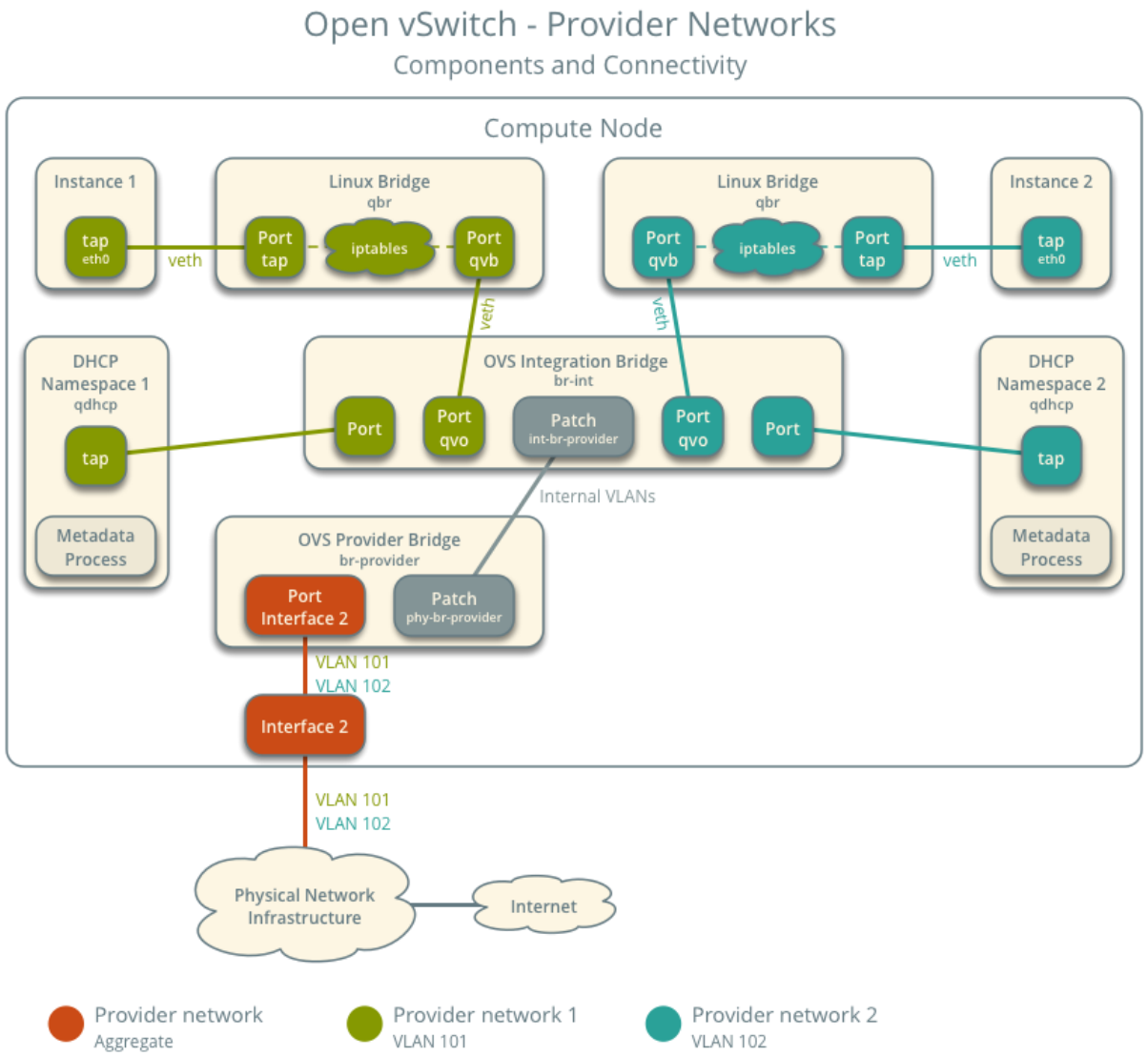


MPTCP Proxy: IP Address Fixing

- Extended SOCKS protocol to also communicate Client address
- Rewrite source address at destination proxy

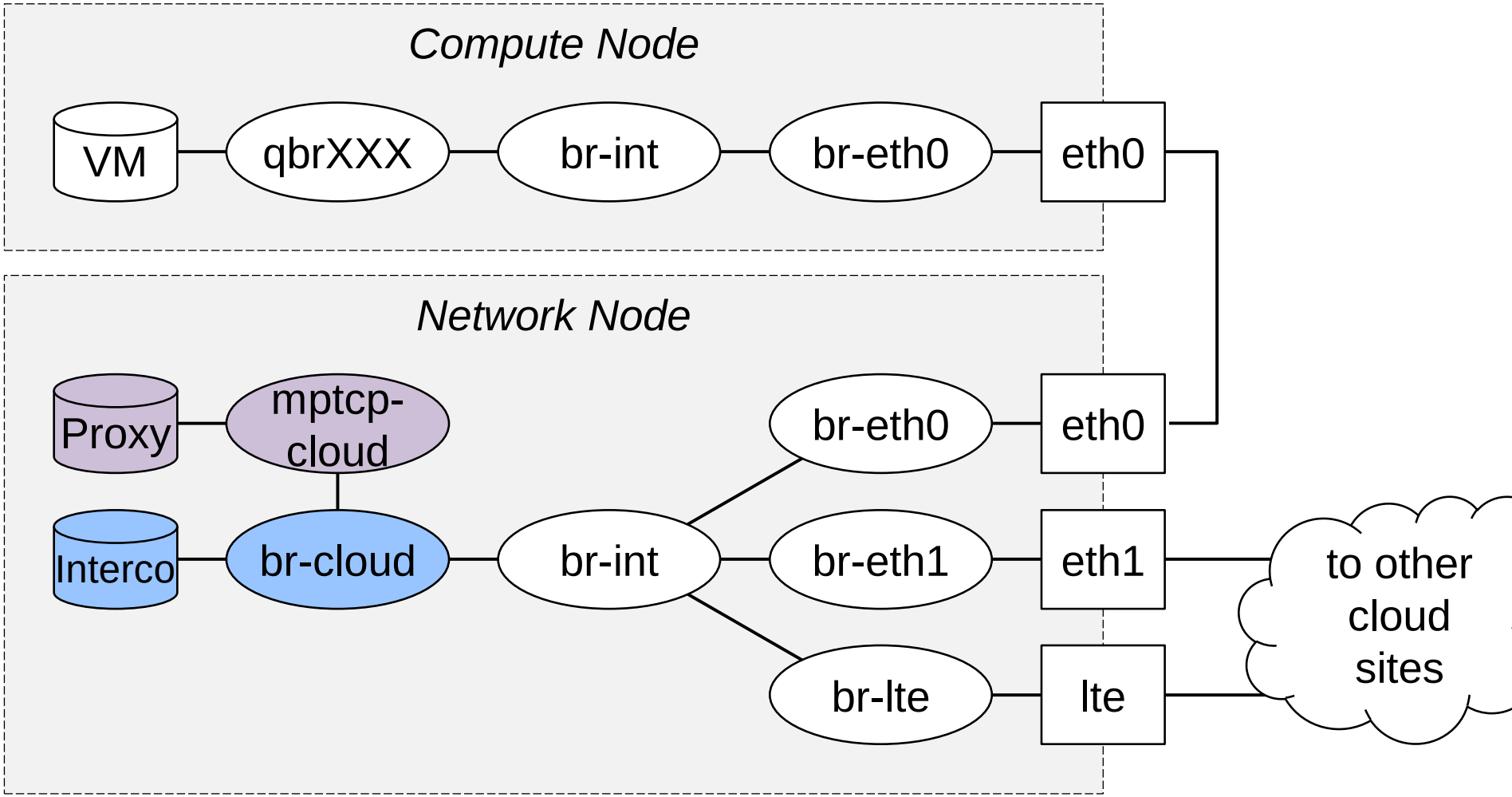


Digression: OpenStack Networking

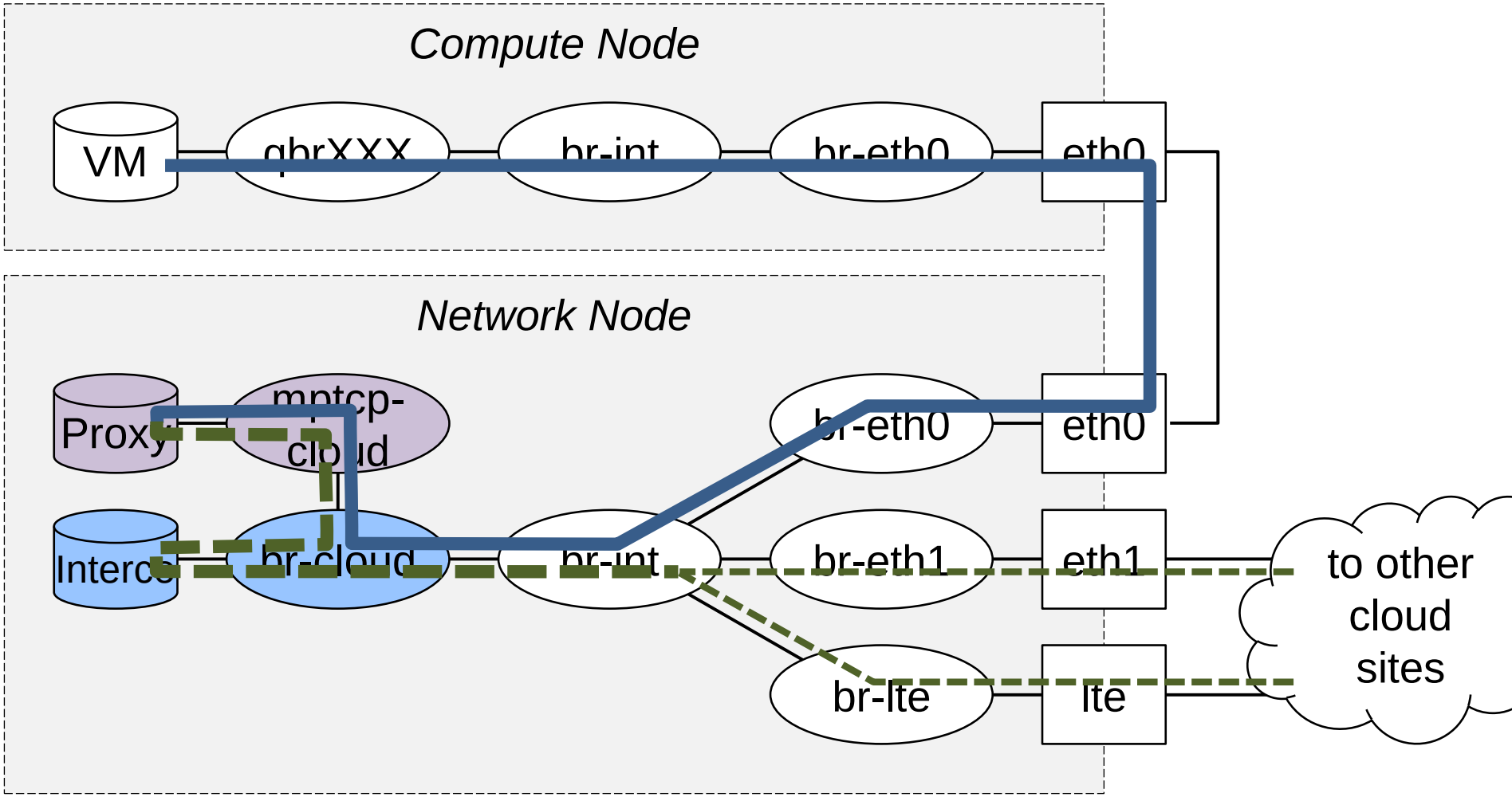


Source: https://docs.openstack.org/ocata/networking-guide/deploy-ovs-provider.html

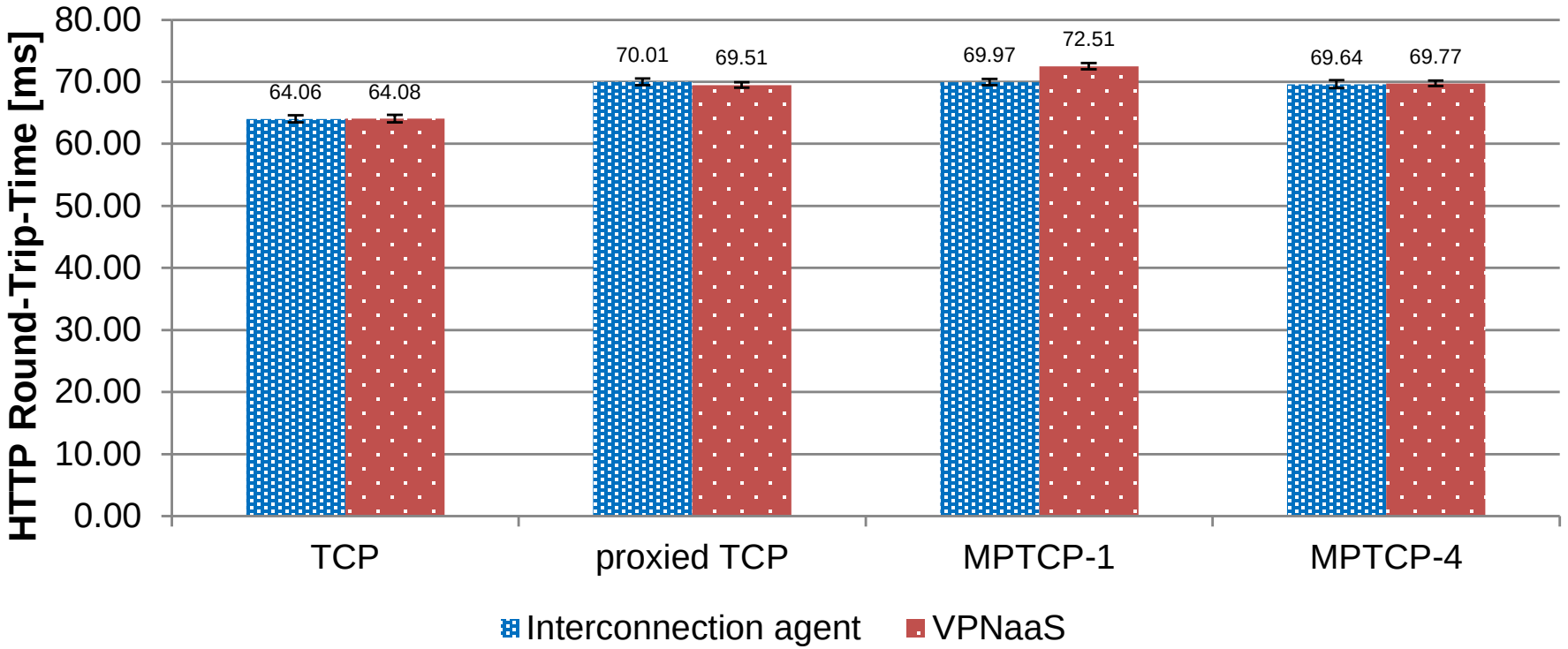
MPTCP Proxy & OpenStack: Components



MPTCP Proxy & OpenStack: Traffic Flow

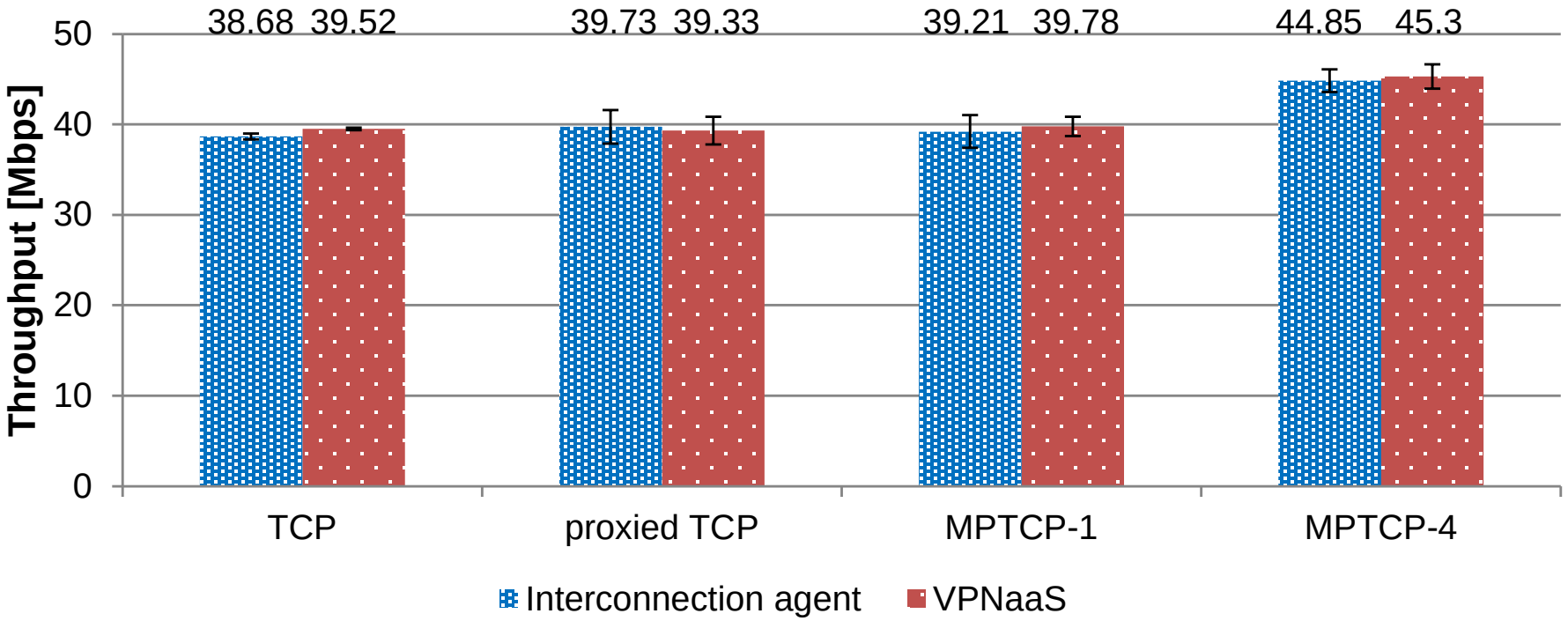


Cloud Federation Results: Latency



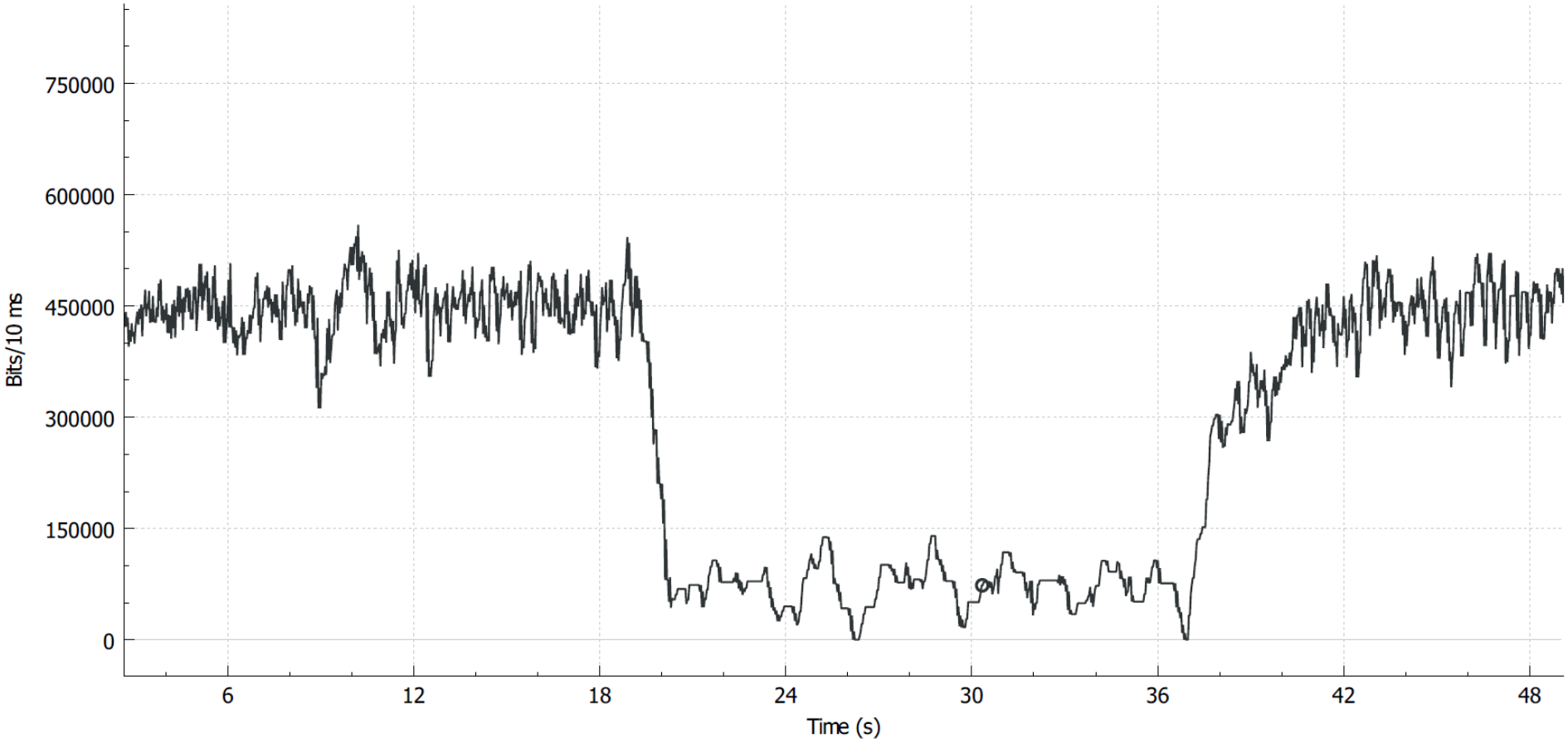
Connection between Heidelberg, Germany and Helsinki, Finland

Cloud Federation Results: Throughput



Connection between Heidelberg, Germany and Helsinki, Finland

Cloud Federation Results: Link Down/Up



Summary

- **Cloud federation** can **improve resilience** and **latency**
  - independent failure
  - multiple locations
- **Multipath** interconnection further **improves resilience** and **throughput** for inter-cloud traffic
  - independence of network paths
- **MPTCP** is a **viable technology** for interconnection
- MPTCP proxy makes **benefits** of multiple paths **available** to all cloud applications **transparently**
  - no changes to applications needed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