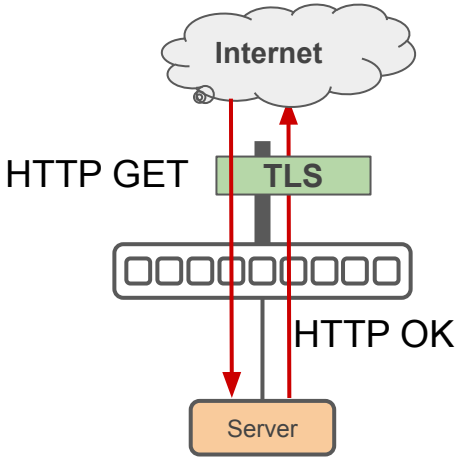
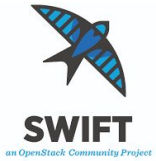
Prism: Proxies without the Pain

Yutaro Hayakawa (LINE Corporation)
Michio Honda (University of Edinburgh)
Douglas Santry (Apple Inc.)
Lars Eggert (NetApp)

Object Storage Systems





Protocol

S3 Protocol, HTTP/HTTPS etc...

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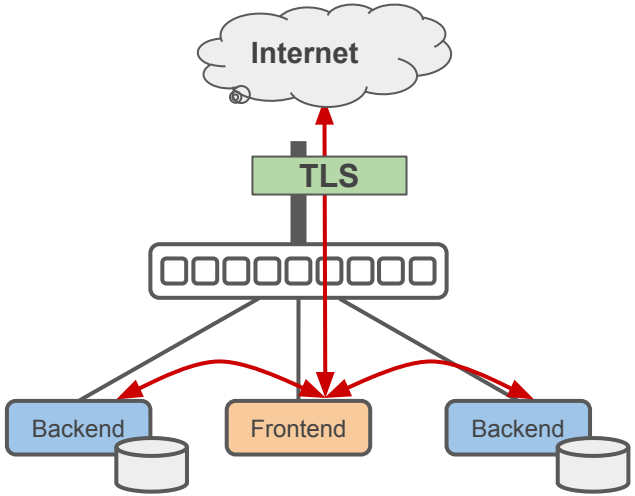


Protocol

S3 Protocol, HTTP/HTTPS etc...

Frontend servers

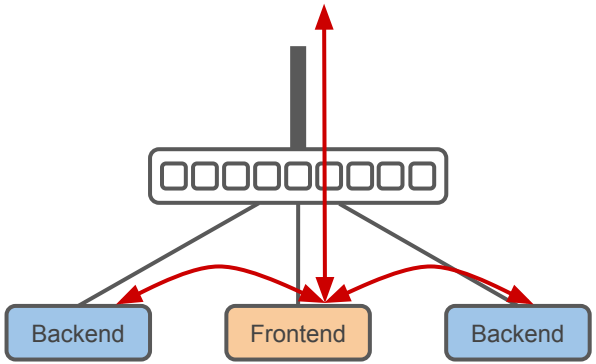
Proxy servers for load balacing, caching, filtering etc…

Backend servers

Storage servers

Object Storage Scale-out Architectures

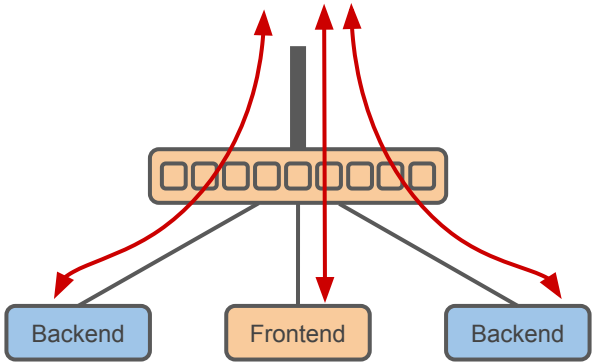
Frontend Proxy



OpenStack Swift, Minio, Mos [HPDC'16], Crystal [FAST'17], etc...

- ✔ Standard protocols (e.g. S3 / HTTP)
- ✔ TLS (Encryption / Authentication)
- ✖ Frontend becomes bottleneck

Content-based Routing



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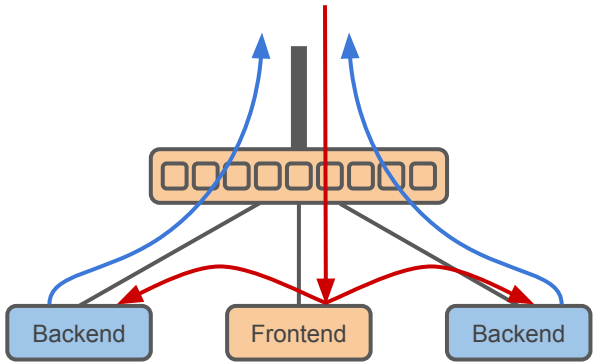

Our proposal

- ✔ Can use standard protocols
- ✔ TLS
- ✔ No intermediate servers (for return path)

Object Storage Scale-out Architectures

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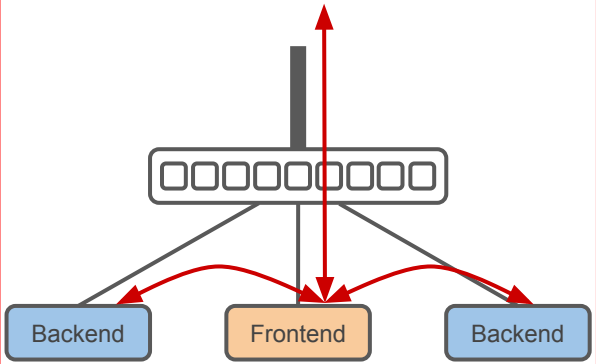

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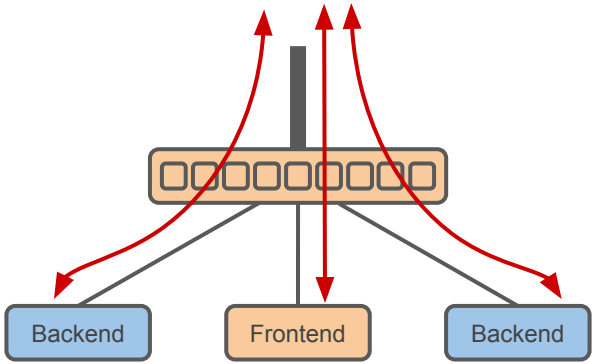

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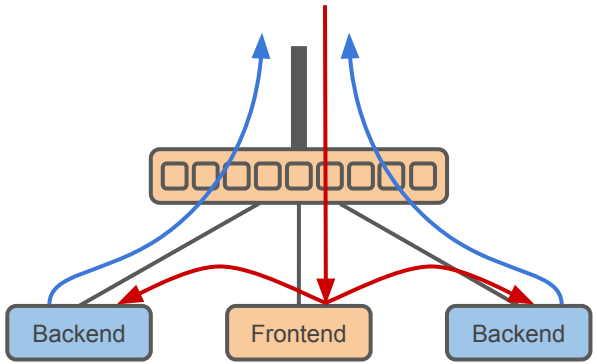

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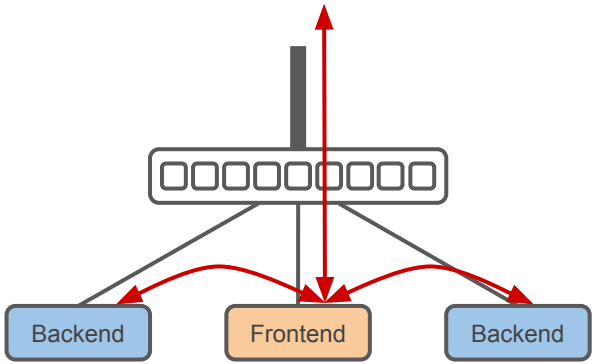

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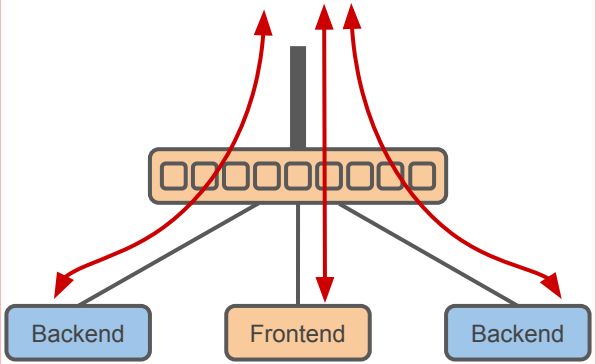

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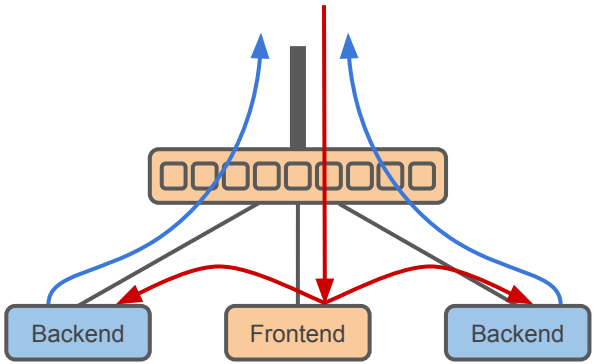

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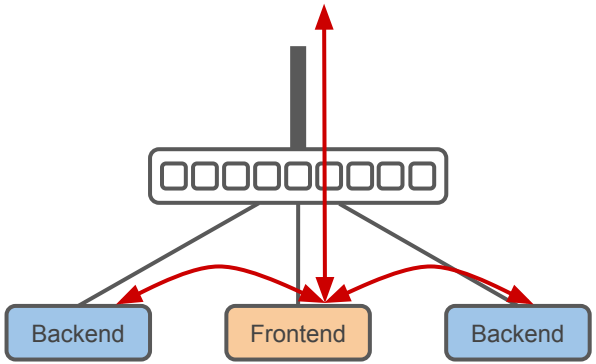

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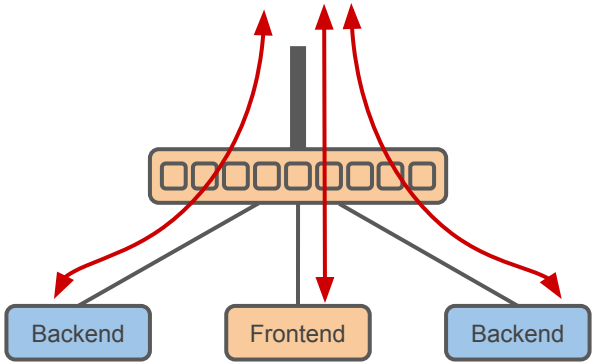

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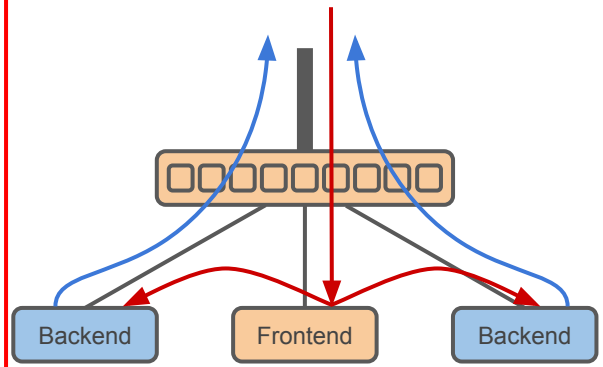

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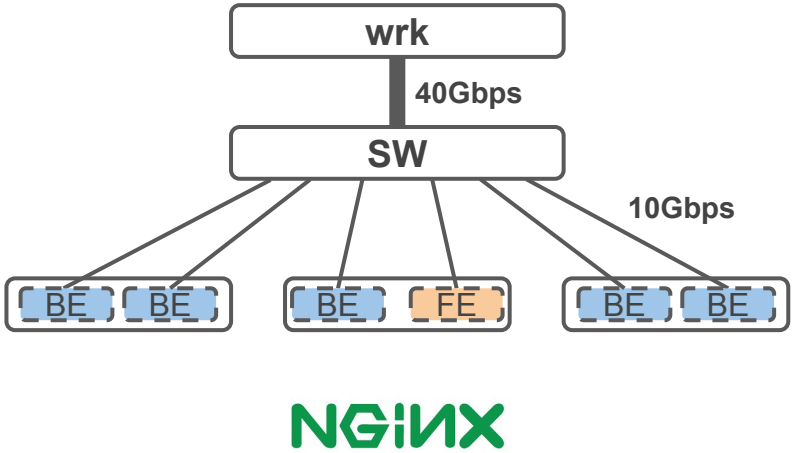
Performance Characterization of Frontend Proxy Architecture



Setup

- Physical Server (4 core, Dual Port 10G NIC)
- BE — Logical Backend Server (Nginx, 2 core, 1 NIC Port)
- FE — Logical Frontend Server (Nginx, 2 core, 1 NIC Port)
- SW — Software L2 switch (Netmap based)
- wrk — Benchmark client (wrk)

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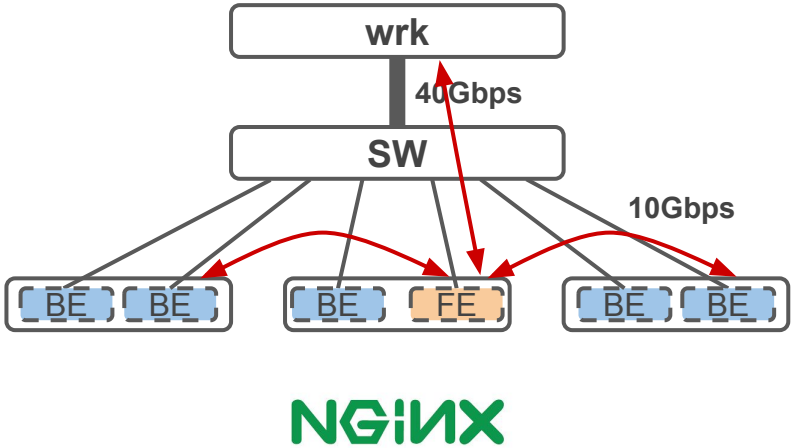

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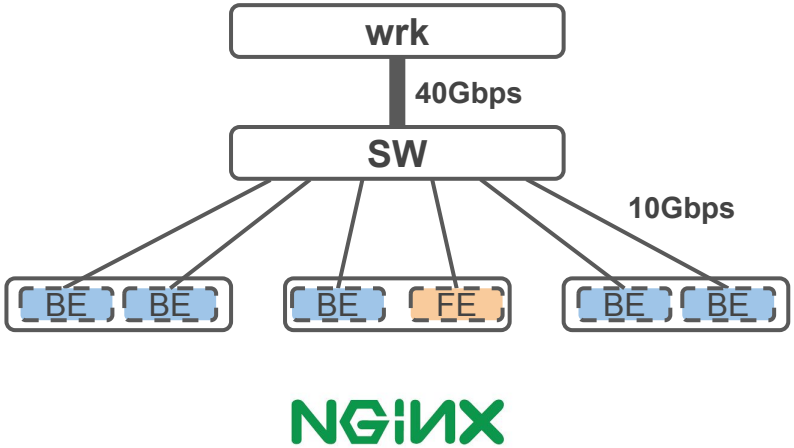
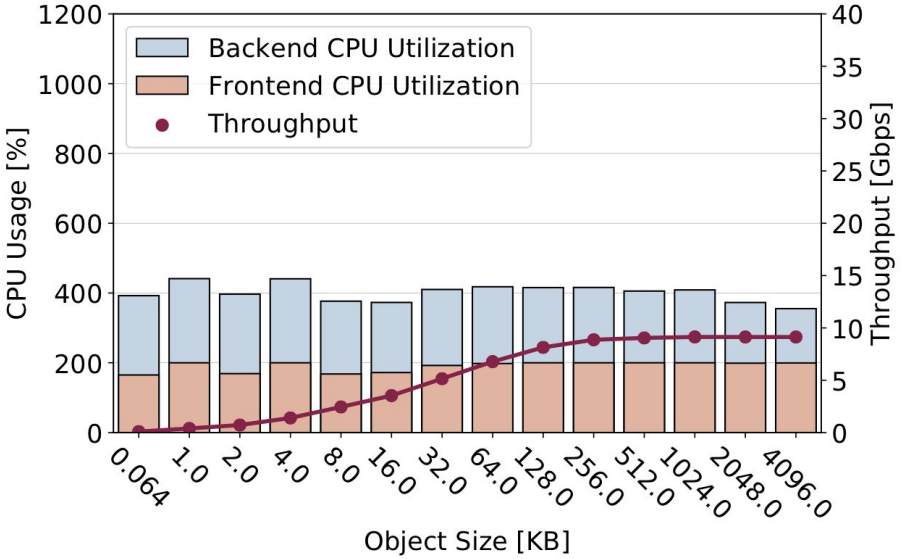




Performance Characterization of Frontend Proxy Architecture

Left Y-Axis: Cluster CPU Utilization

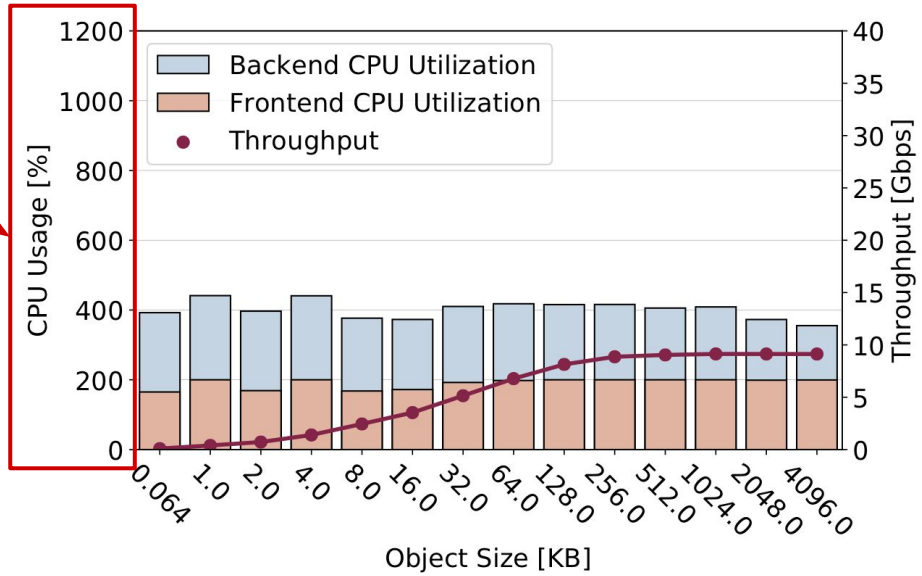
1200% = 2cores (200%) * 5 backends
+ 2cores (200%) * 1 frontend

Right Y-Axis: Throughput observed at client

Max 40Gbps (attached bandwidth of the client)

X-Axis: Object size with KB

0.064 => 64bytes



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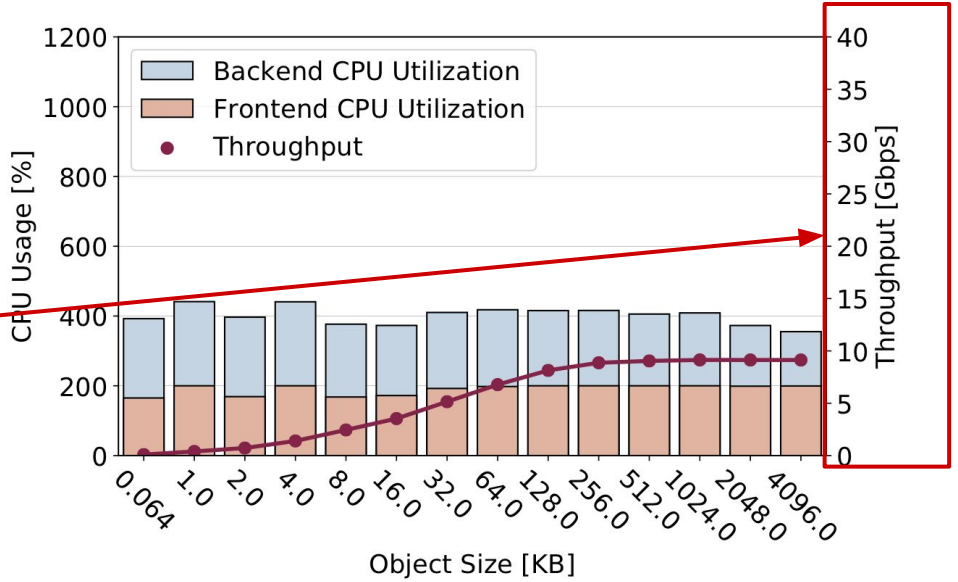

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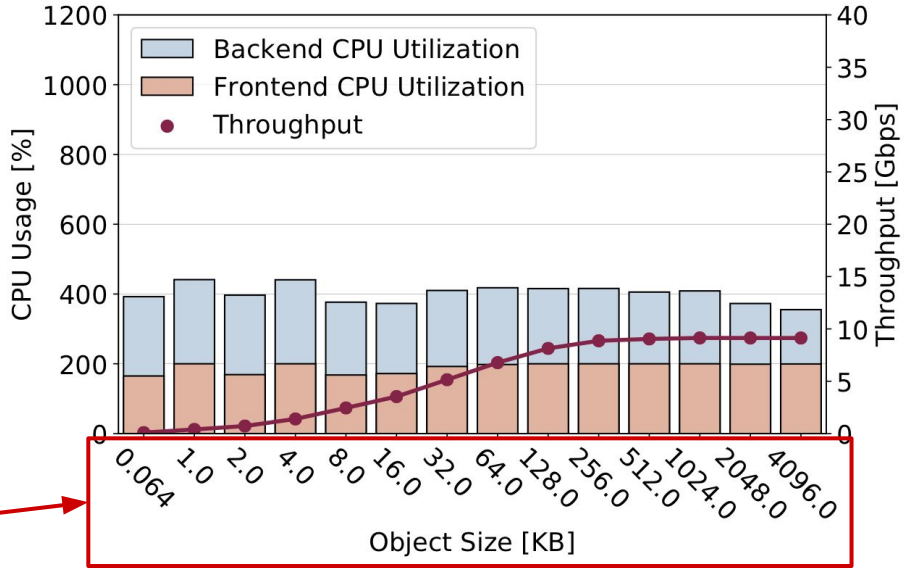
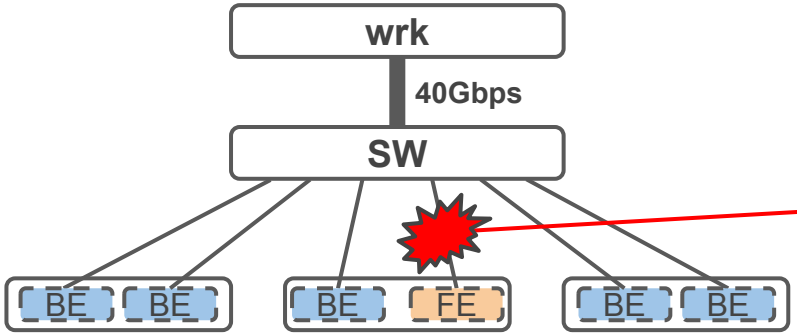
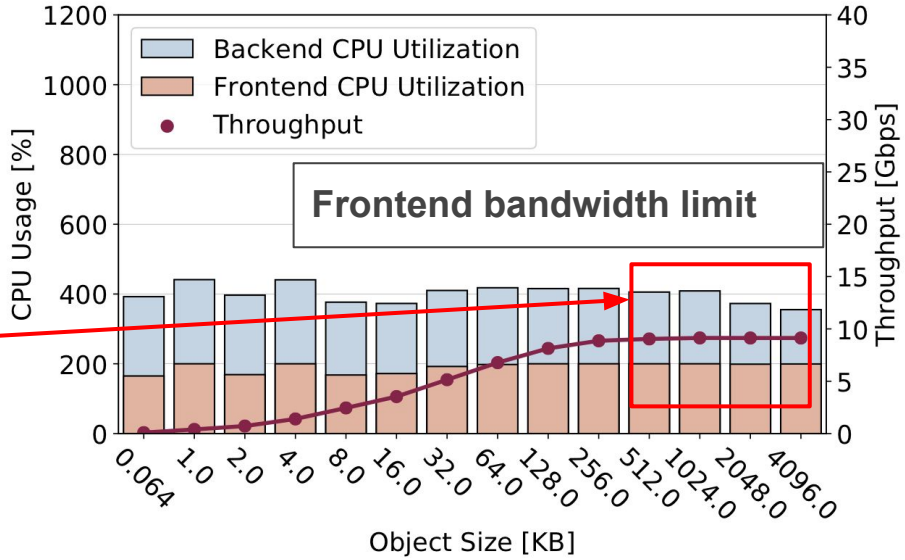


Underutilized Uplink Bandwidth

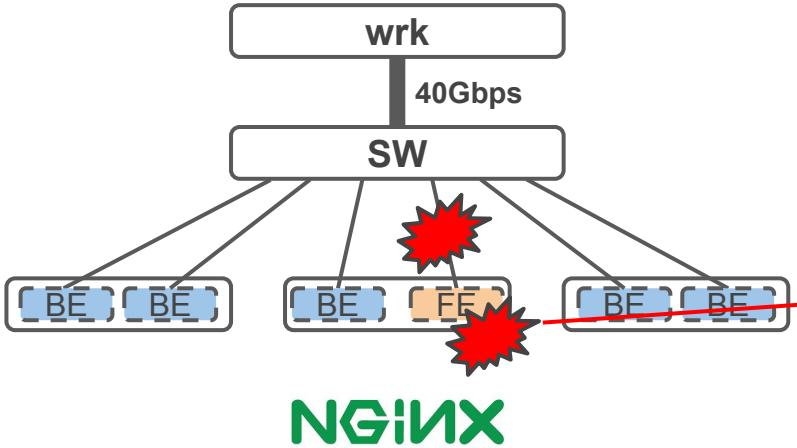
30Gbps out of 40Gbps uplink bandwidth is unsed

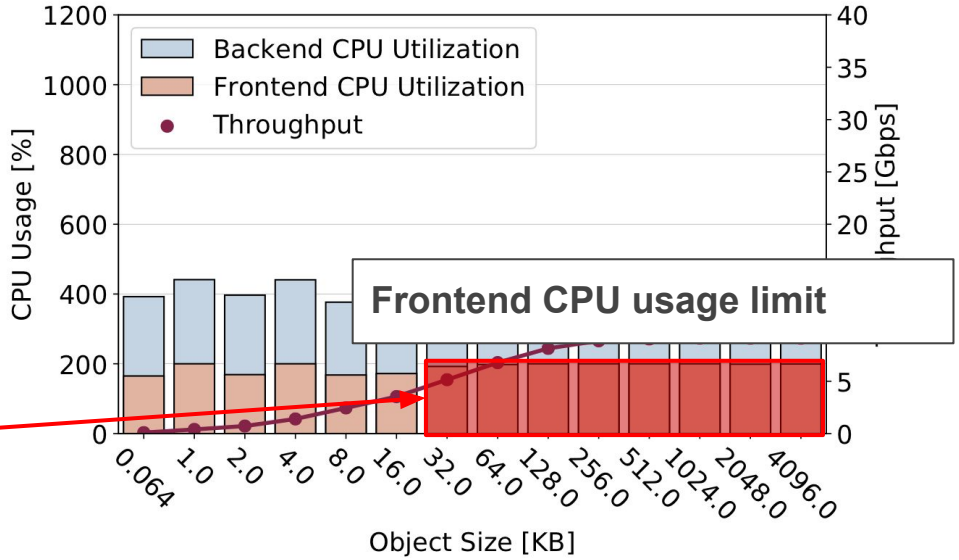




Overutilized Frontend CPU Resources

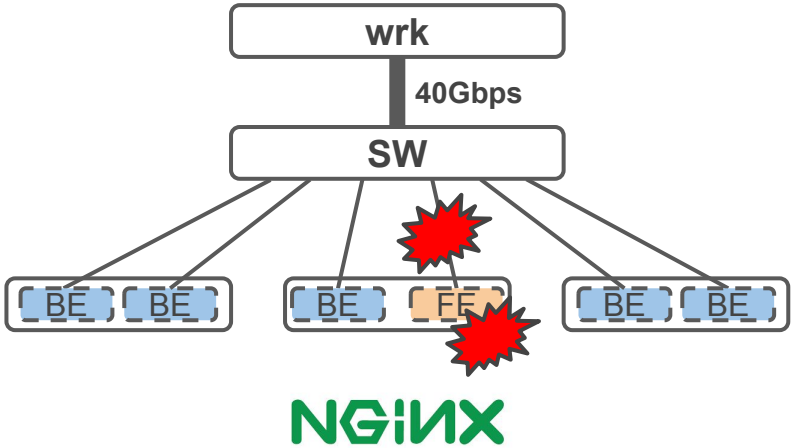
Frontend CPU is fully utilized in most of the cases

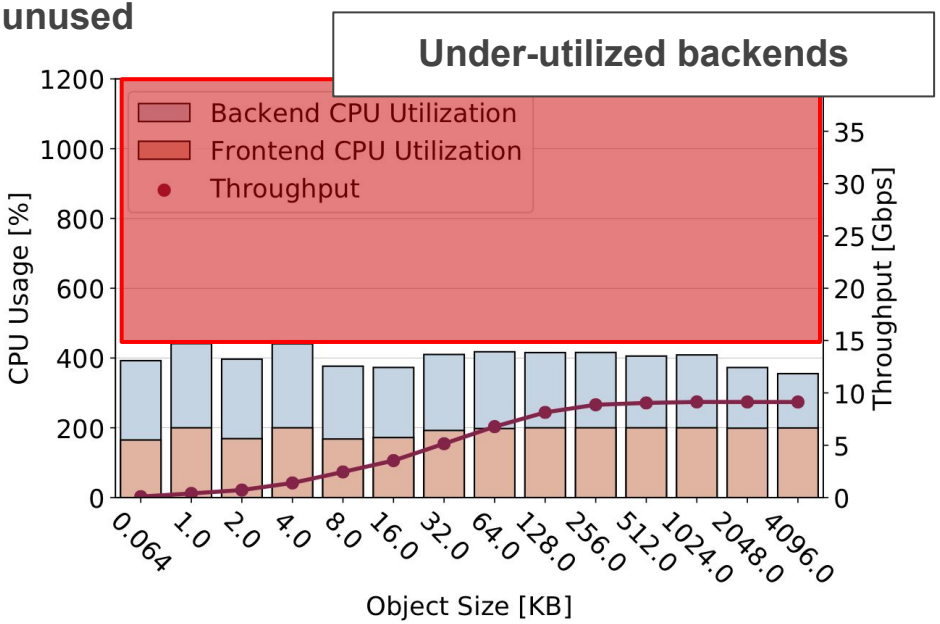




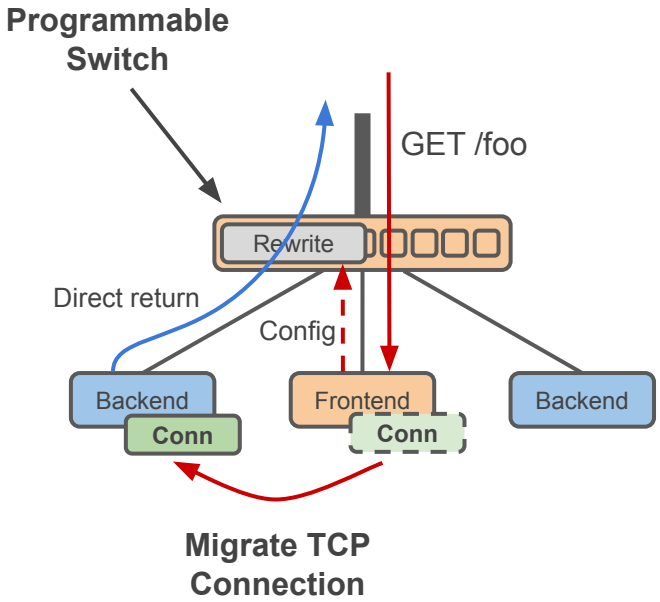
Underutilized Backend CPU Resources

800% out of 1000% backend CPU resources are unused





Motivation: TCP Hand-off [ASPLOS'98]



Benefit

1. Don't need special protocol on client
2. Effectively utilizes the uplink bandwidth
3. Effectively utilizes the backend CPU resource

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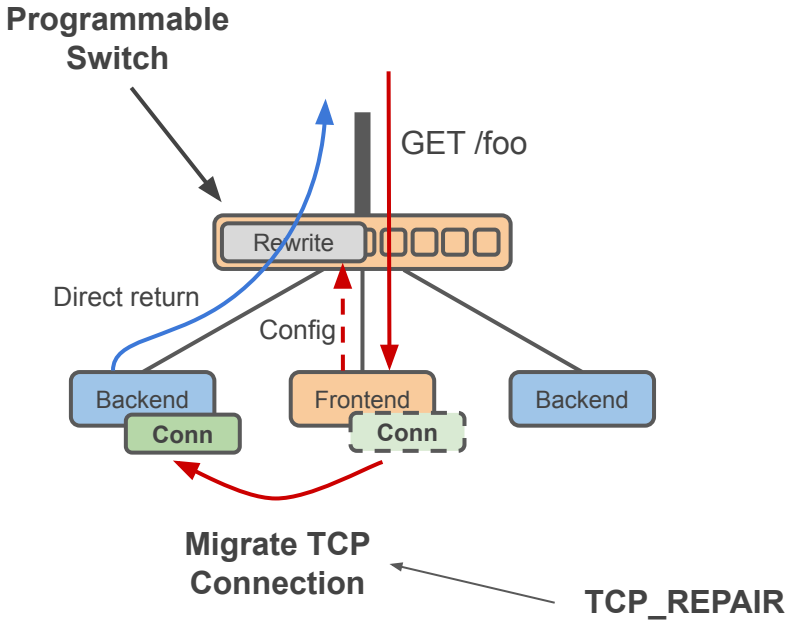
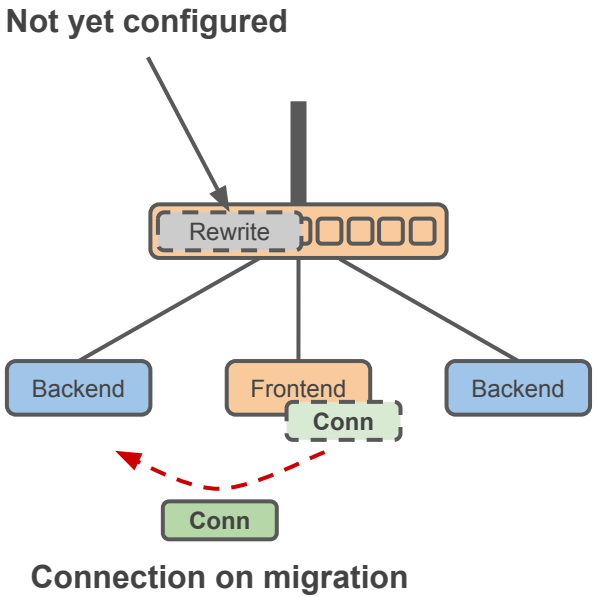


Now it is more feasible than as of 1998

1. Linux TCP_REPAIR
2. Programmable DPlane eco-system (P4, eBPF...)

TCP Hand-off is Non-trivial



Example: "Leaked" packet problem

Connection state shouldn't progress during migration

Unexpected packet from client may changes it

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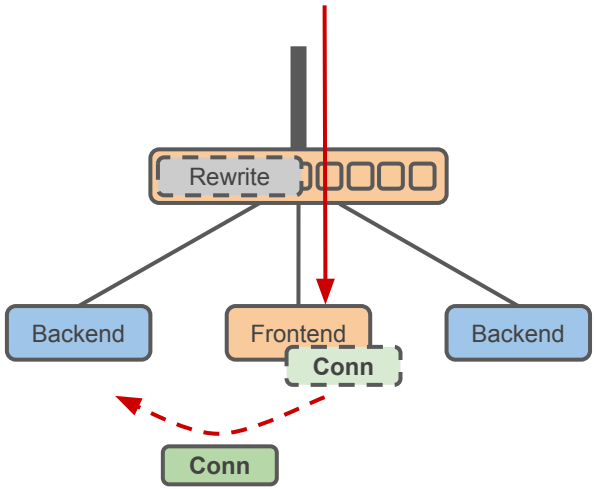

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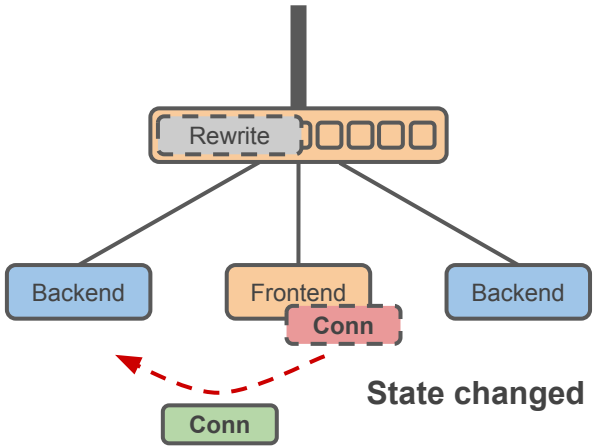

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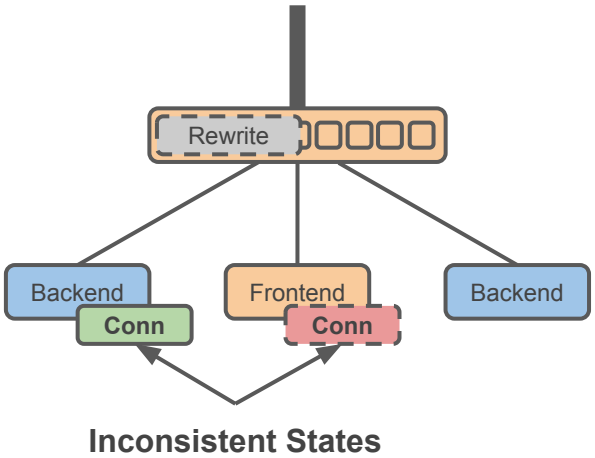

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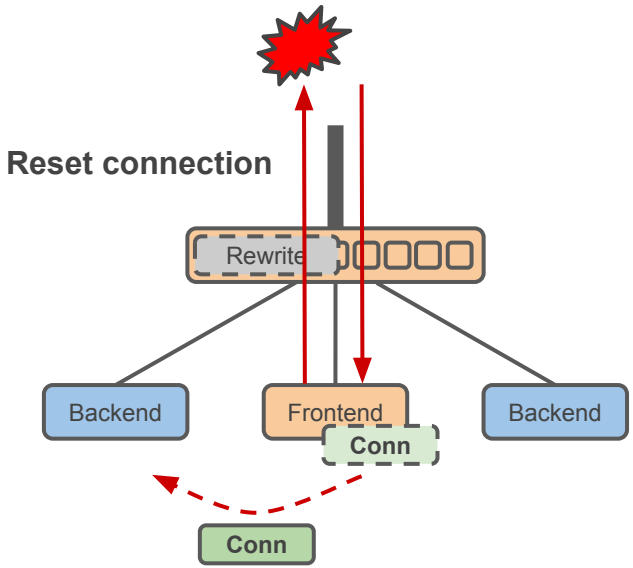
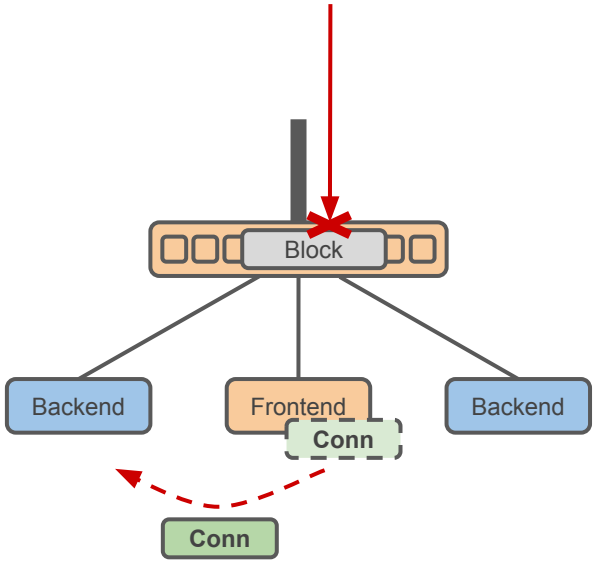


TCP_REPAIR sends RST when it get packet in "REPAIR" state

=> Breaks the client

TCP Hand-off is Non-trivial



Need "lock" in network to prevent the "leak"

Original TCP Hand-off paper doesn't cover this issue

Our Contributions

1. Robust hand-off protocol which overcomes correctness issues

Two Phase Hand-off Protocol,

2. Prism switch

Efficient switch interaction / inline switch coniguration protocol

3. Prism stack

Event loop based software stack to integrate TCP Hand-off to the applications,

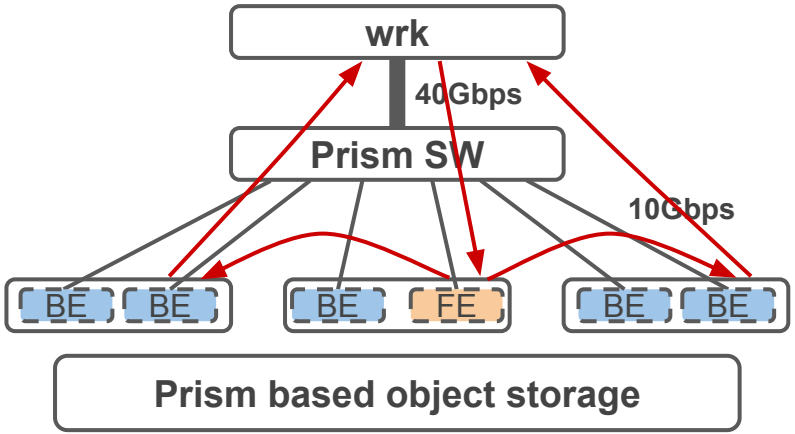
FIN_WAIT1/CLOSE_WAIT handling

4. Evaluation with realistic use cases

Replicated / Partitioned object storage

And more in our paper

Prism Performance



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Same as baseline, but using Prism

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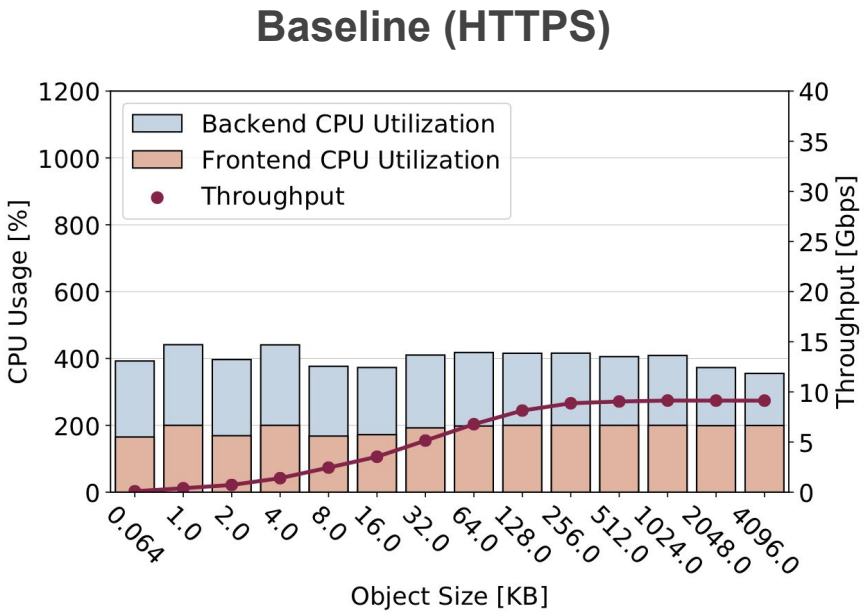
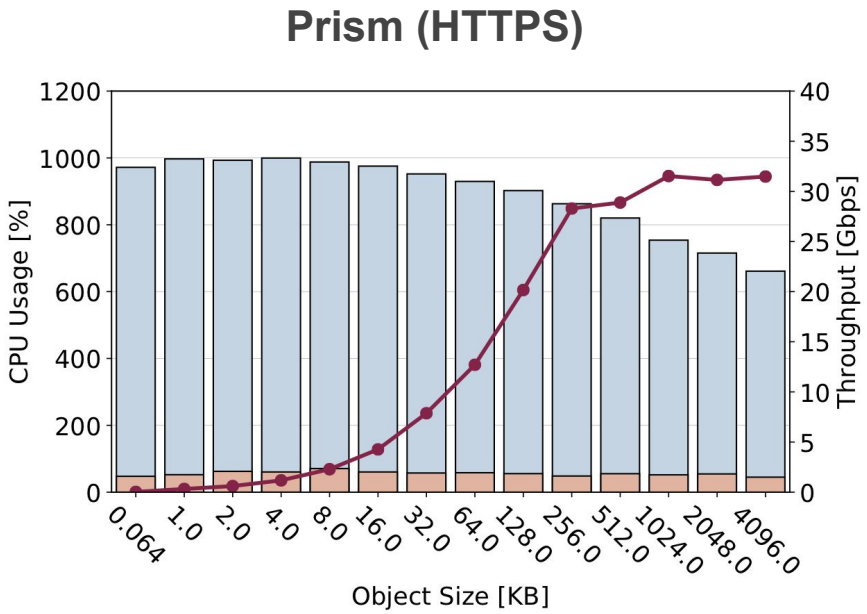
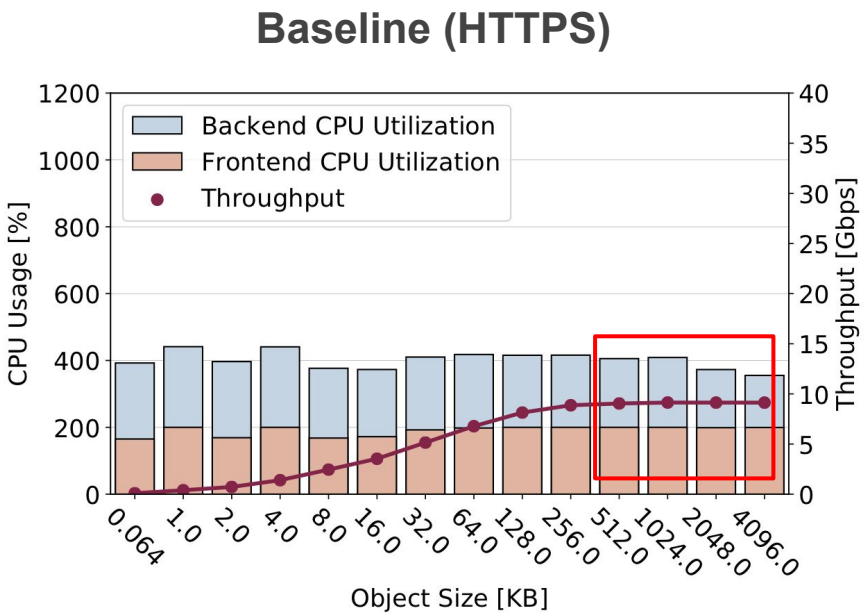
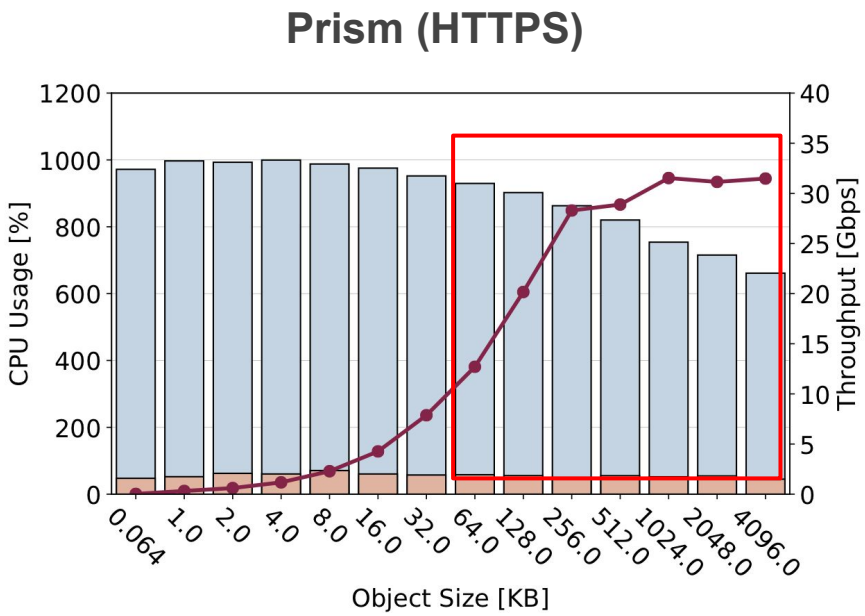


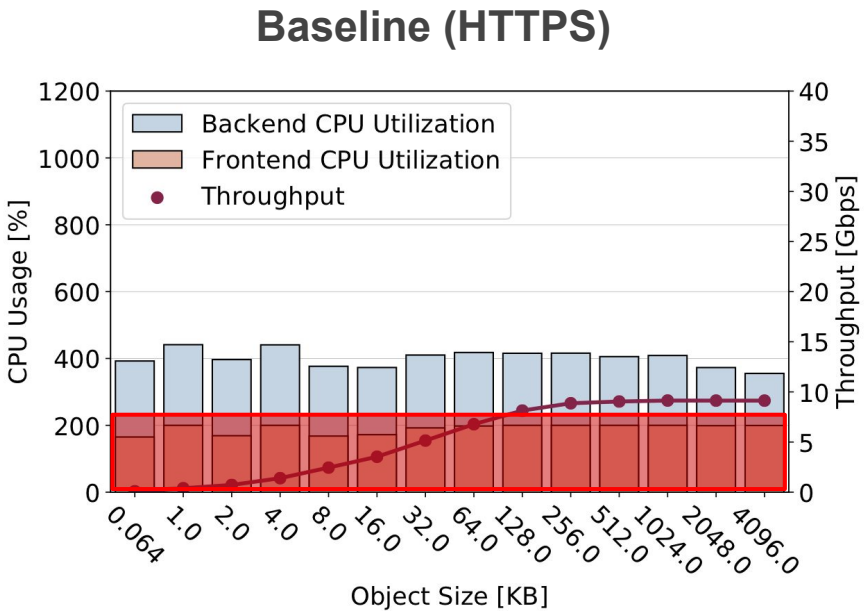


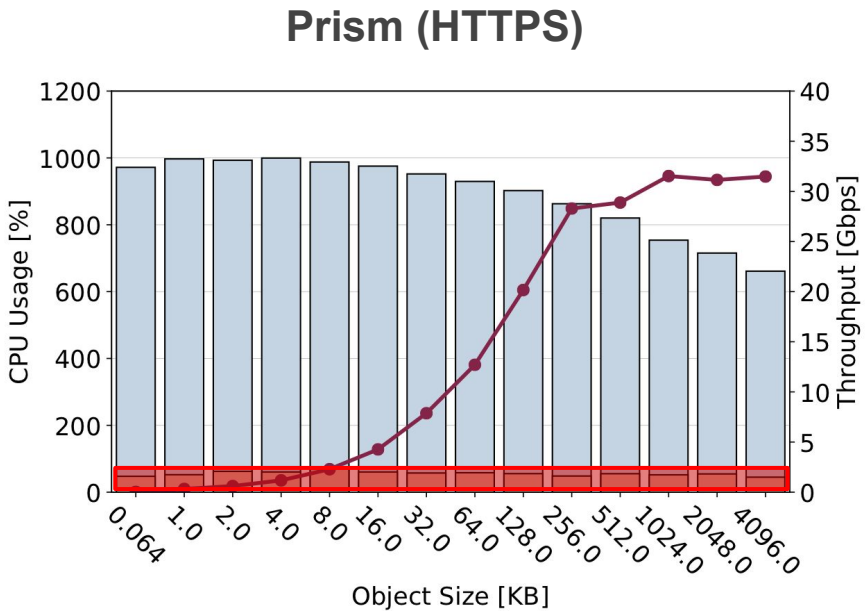
Prism Effectively Utilizes Uplink Bandwidth





Prism Effectively Reduces Frontend CPU Utilization





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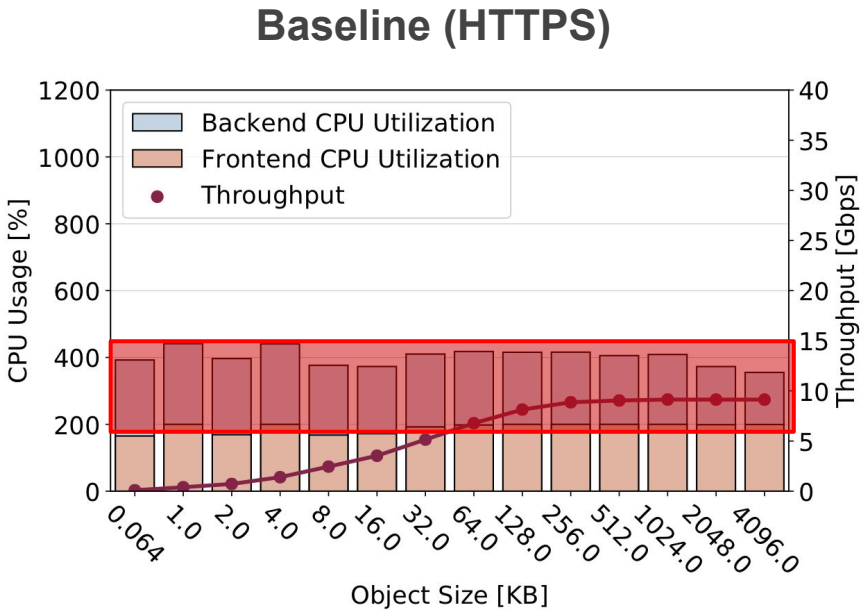
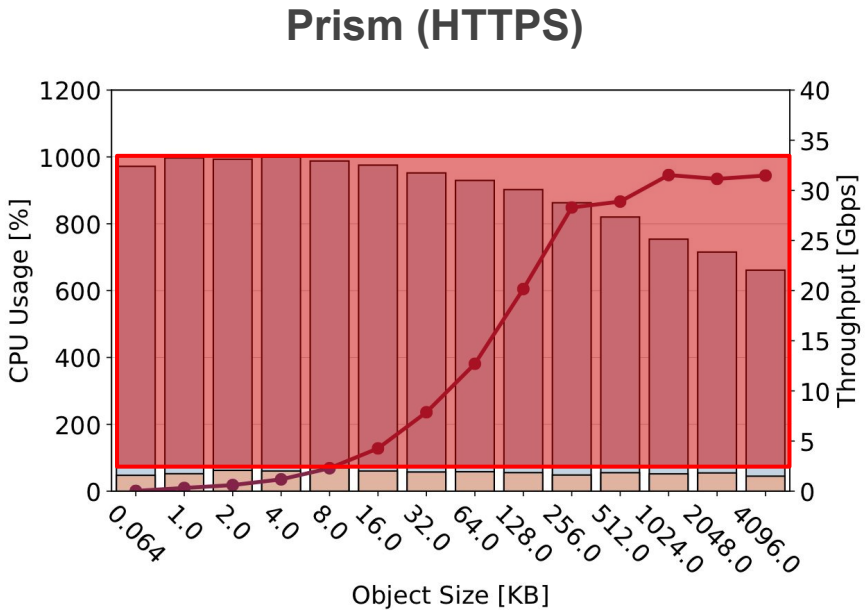




Hand-off Latency

Operation	Latency (μs)
Block all traffic (switch config)	22
Serialize protocol states	14
Send states	51
Deserialize protocol states	123
Configure rewrite (switch config)	22
Total	**232**

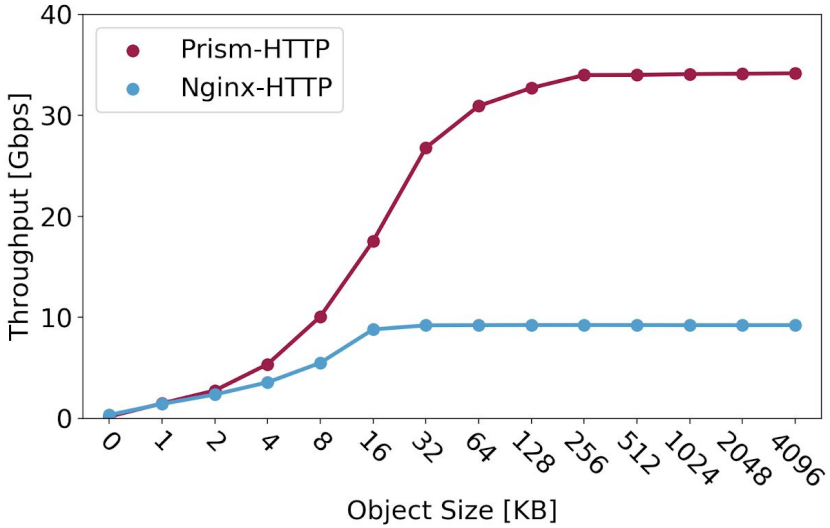
Extra latency for hand-off

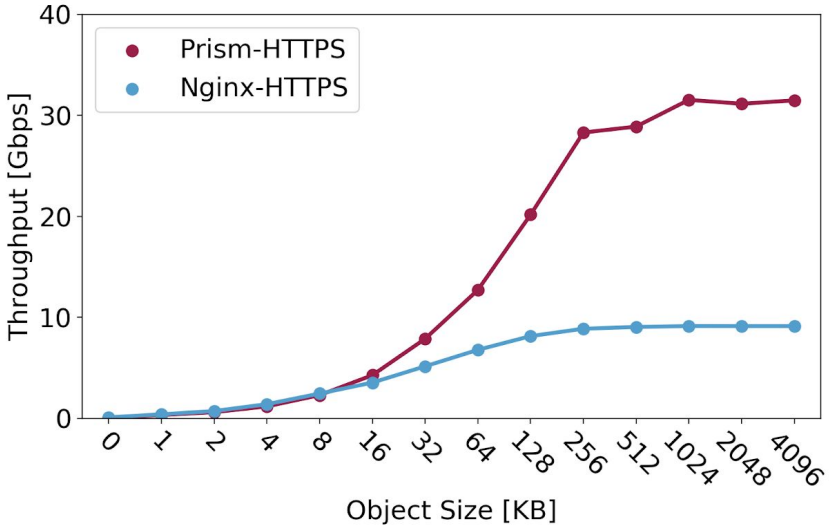
Time takes for hand-off is **fixed** for read

How it costs depends on the **object size**

Cost of Hand-off Latency

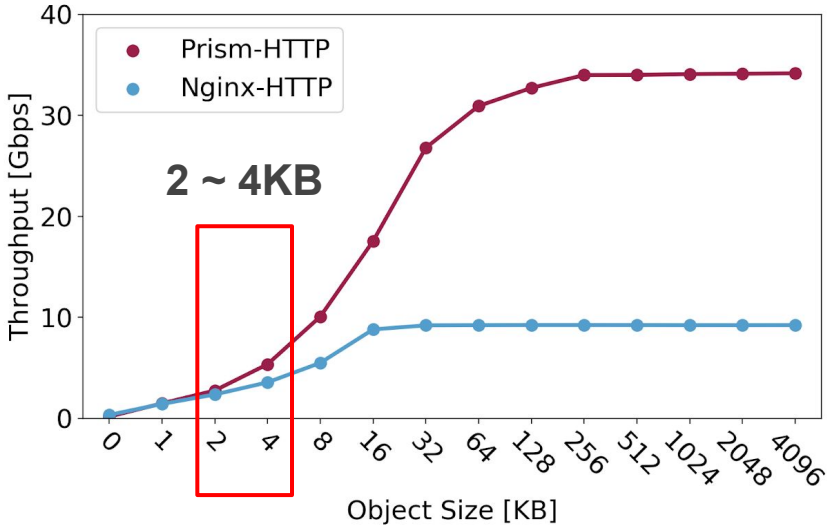
How large does the object size need to be to amortize the connection hand-off cost?

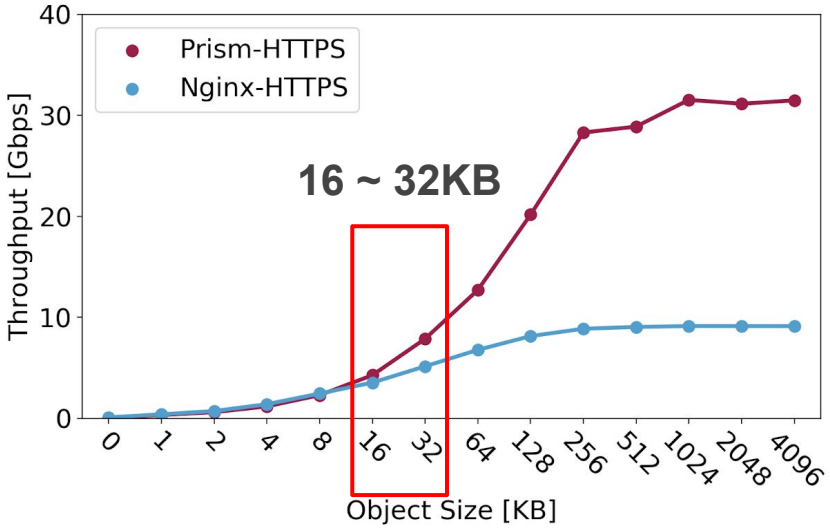




Cost of Hand-off Latency

How large does the object size need to be to amortize the connection hand-off cost?





Recap

Object storage performance is capped by the frontend intermedeates all traffic

Limitation of attached bandwidth, high CPU usage due to relaying large traffic

TCP hand-off based solution is fairly feasible in these days, but non-trivial

Need to take many "correctness" issues into account (e.g. "leaked" packet problem)

Prism is a framework to integrate TCP hand-off approach into the applications

Robust connection hand-off mechanism, switch implementation, software stack, etc…

Source is available: https://github.com/YutaroHayakawa/Prism-HTTP