Sincronia:
Near-Optimal Network Design for Coflows

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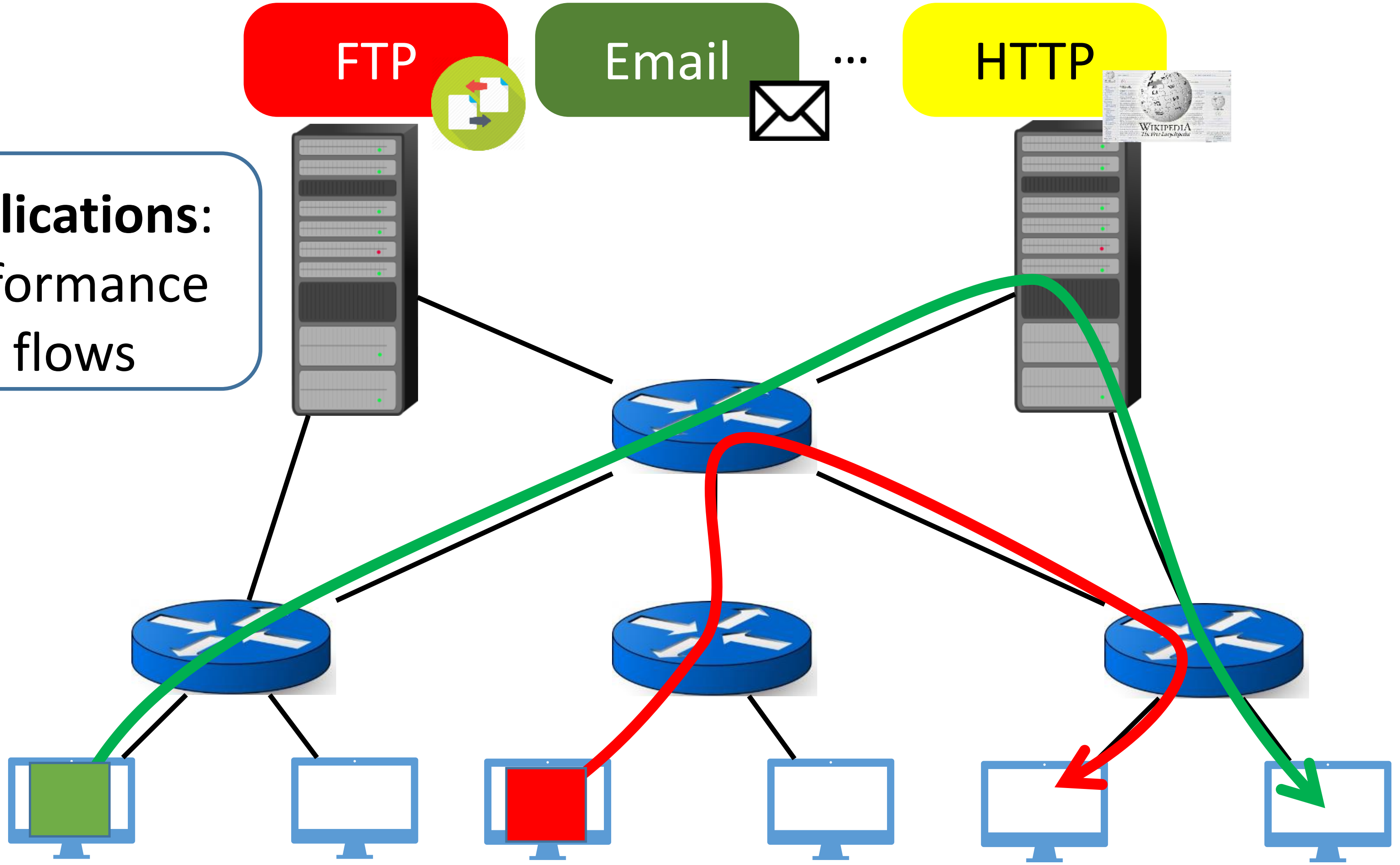
The *Flow* Abstraction

Traditional Applications: Care about performance of individual flows



Good Match

Optimized for **Flow-level** performance

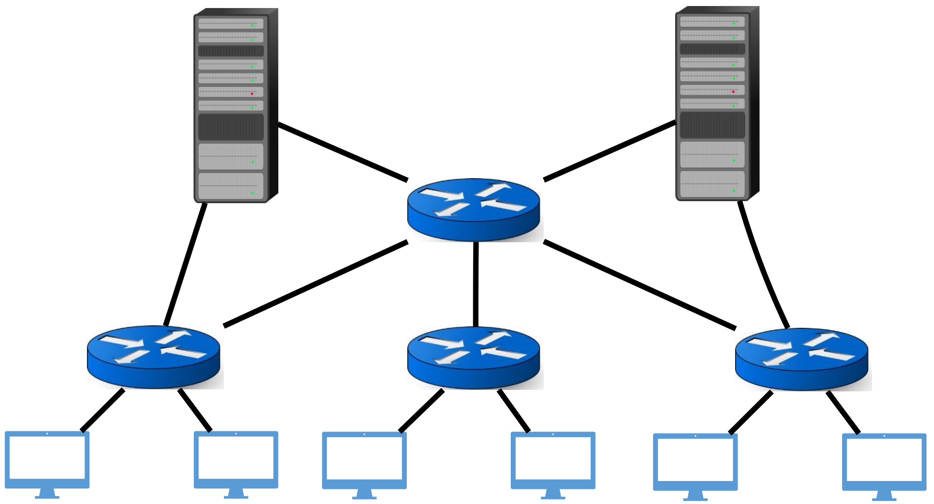
Is Flow Still the Right Abstraction?

FTP | Email | … | HTTP

Traditional Applications:
Care about performance
of individual flows

Hadoop | Apache Spark | … | Dryad

Distributed Applications:
Care about performance
for a group of flows

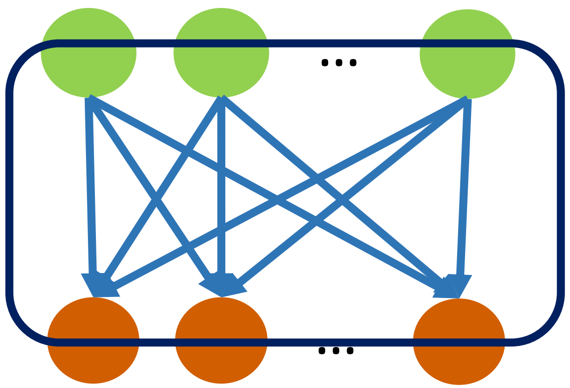


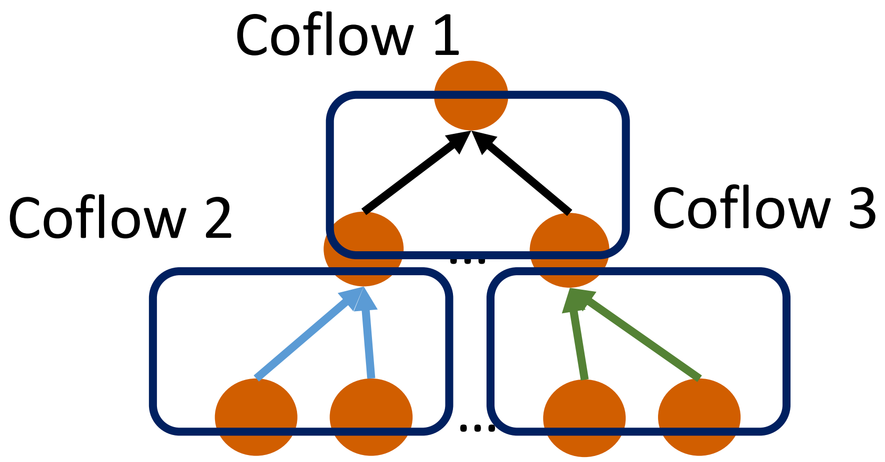
Mismatch

Optimized for **Flow-level** performance

The *Coflow* abstraction

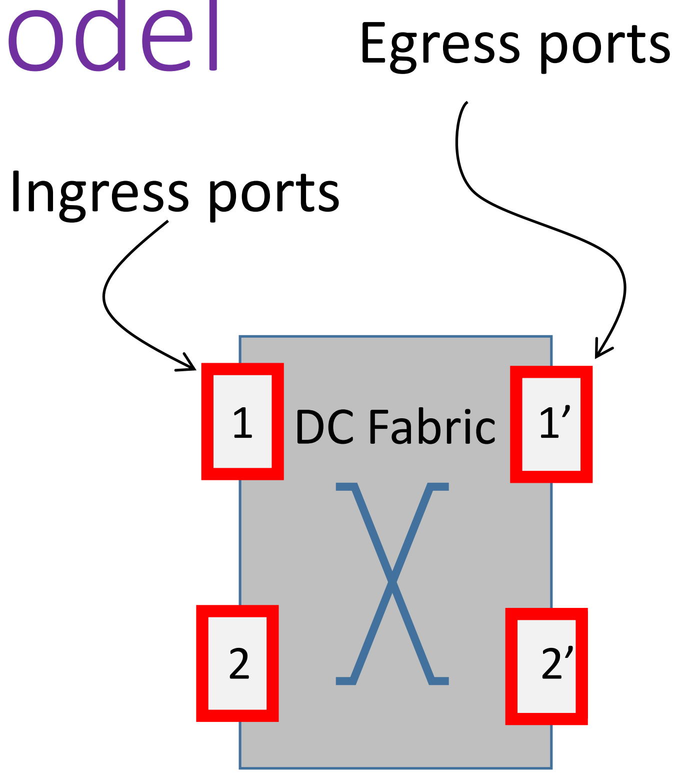
Collection of semantically related **flows** [Chowdhury & Stoica, 2012]





Allows applications to more precisely express their performance goals

Network and Coflow Model



- Big-switch model
- Clairvoyant scheduler
  - Coflow details known at arrival time:
    - Source-destination for each flow
    - Size of each flow
    - Coflow weight
- Metric – coflow completion time: Time when **all** flows complete

Goal: Minimize Average Weighted Coflow Completion Time (CCT)

Prior Results

Impossibility Results

- NP-hard
- <2x approximation hard

Systems/ Theory	State-of-the-art	Performance Guarantees	Runs on Existing Transport	Work Conserving	Starvation Avoiding
Systems	**Varys** [SIGCOMM '14]	✗	✗	✓	✓
Theory	**On Scheduling Coflows** [IPCO '17]	✓ (4-apx)	✗	✗	✗

Practical, Near-Optimal Network Design for Coflows?

Sincronia:
Two key results

#1

Guarantees 4-approximation for (weighted) average CCT

#2

Given a set of coflows and a "right" ordering,
ANY per-flow rate allocation mechanism that is
work-conserving & order-preserving
produces average CCT within 4x of optimal

- Per-flow rate allocation **irrelevant**
- Transport layer agnostic

Sincronia – Near-Optimal Network Design

Systems/ Theory	Name	Performance Guarantees	Runs on Existing Transport	Work Conserving	Starvation Avoiding
Systems	**Varys**	✖	✖	✔	✔
Theory	**On Scheduling Coflows**	✔ (4-apx)	✖	✖	✖
Systems	**Sincronia**	✔ (4-apx)	✔	✔	✔

Also outperforms state-of-the-art across evaluated workloads

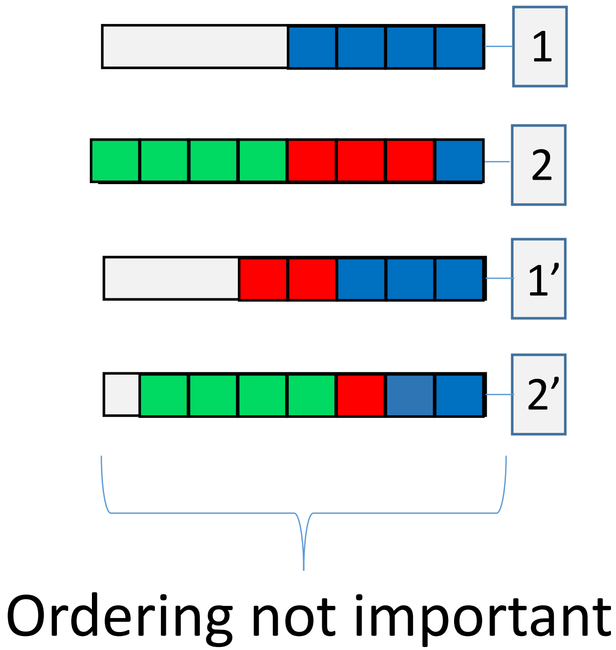
Sincronia Design

- Algorithm – BSSI
  - Bottleneck, Select, Scale, Iterate
  - SRPT-first style algorithm

- Priorities set from order
- Flows offloaded to transport layer
- No explicit per-flow rate allocation

Bottleneck-Select-Scale-Iterate (BSSI)

- Find **BOTTLENECK** port
- **SELECT** (weighted) largest job
  - Ordered last
- **SCALE** weights of remaining jobs
- **ITERATE** on unscheduled jobs



BSSI in Action

- Bottleneck
- Select
  - Ordered Last
- Scale
- Iterate

$\text{Size}/\text{Weight} = 8$

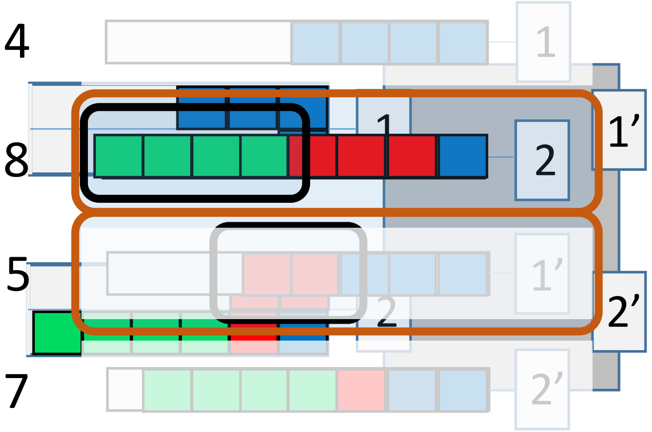
$\text{Weight} \leftarrow \text{Weight} \times (1 - \frac{\text{Size}/\text{Weight}}{\text{Size}/\text{Weight}})$

$\text{Size}/\text{Weight} = 4$

$\text{Size}/\text{Weight} = 4$

$\text{Weight} \leftarrow \text{Weight}(1 - \frac{\text{Size}/\text{Weight}}{\text{Size}/\text{Weight}})$

$\text{Size}/\text{Weight} = 1$



Weights: 1 1 1

¼ 0 ¾

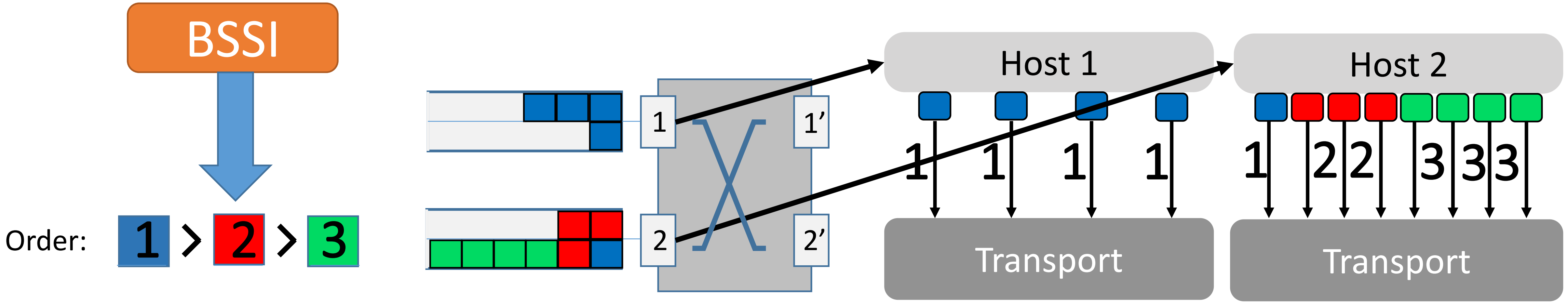
0 0 ⅜

Order: ■ > ■ > ■

Scale weights of each flow

(unscheduled coflows)

End-to-End Design(Offline)



- Each host knows ordering
- Flows get priority of coflow
- Offloads to priority enabled transport layer

Per-flow Rate Allocation is Irrelevant

- Intuition: Sharing bandwidth does not help CCT
- **Order-preserving schedule**:

  Flow blocked **iff** ingress or egress port serving higher-ordered flow

Given the BSSI ordering,
ANY per-flow rate allocation mechanism that is
work conserving & order-preserving
produces average CCT within **4x of optimal**

Avoiding per-flow rate allocation: Implications

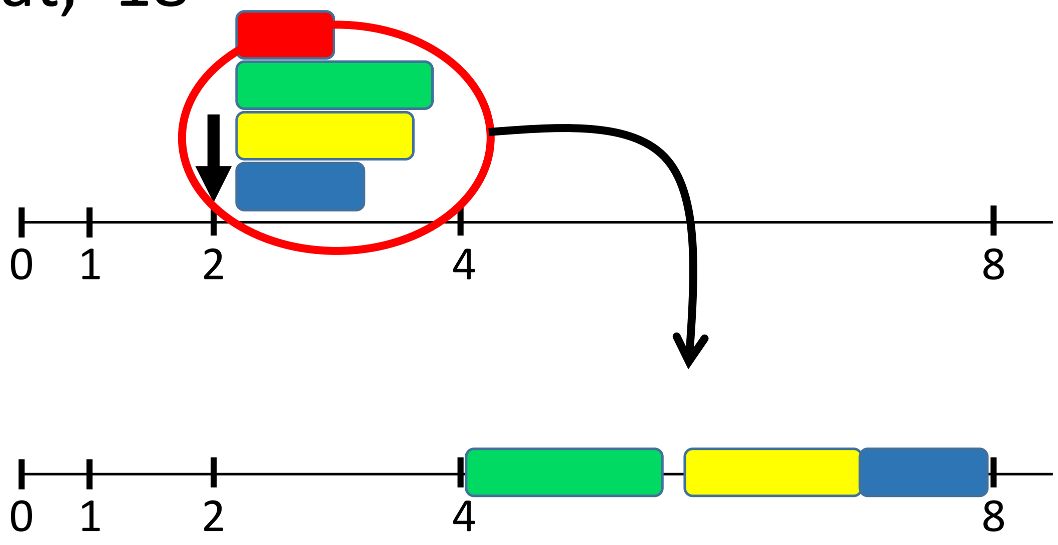
- Implement on top of any transport layer
  - E.g. pFabric, pHost, TCP
- Design and implementation independent of
  - Network Topology
  - Location of Congestion
  - Paths of Coflows

Details in paper

- More scalable
  - No reallocations upon coflow arrivals/departures

Handling Arbitrary Arrival Times

- Framework: Khuller, Li, Sturmfels, Sun, Venkat, ‘18
- Time divided into epochs
- In each epoch
  - Choose subset of unscheduled jobs
  - Schedule in next epoch using offline alg.



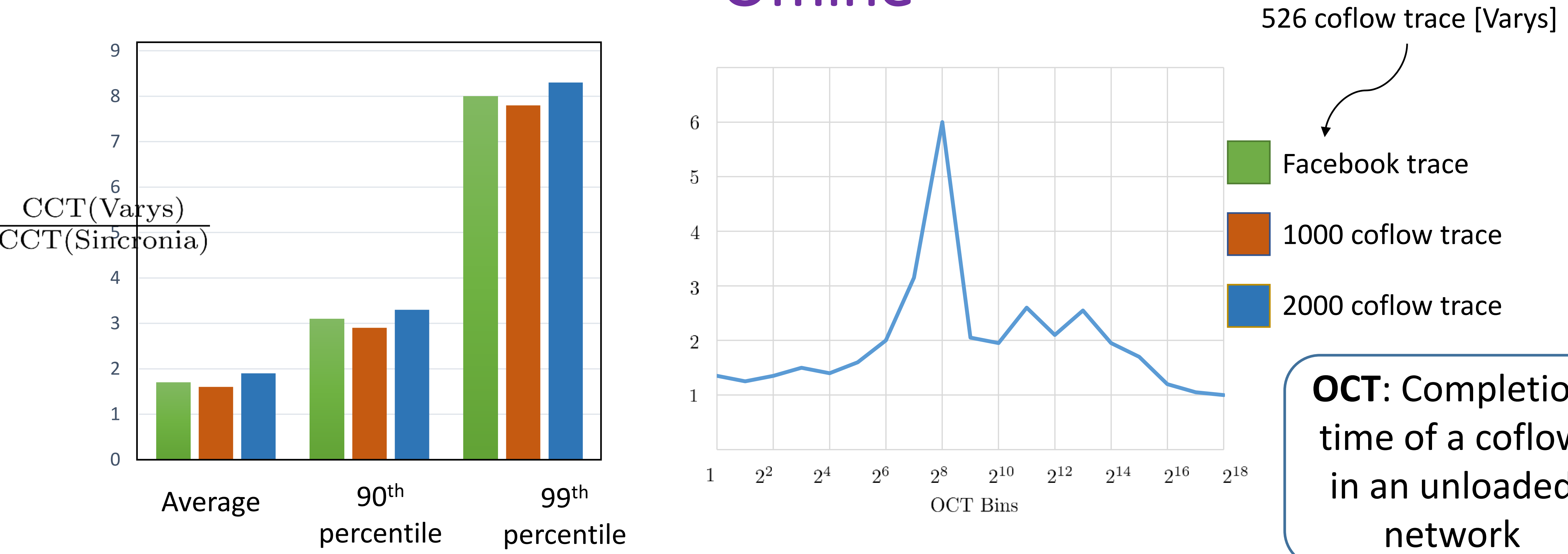
Provides 12-competitive performance
(details in paper)

Evaluation Overview

- **Testbed implementation on top of TCP**
  - Evaluate impact of in-network congestion, and hardware constraints
- **Simulations**
  - **Coflows arrive at time 0**
  - **Coflows arrive at arbitrary times**
  - Sensitivity analysis
    - Coflow sizes, structure, # of coflows
    - Network topologies, Oversubscription ratios, Network load
    - …

All simulations, workloads, and implementations are open-sourced on Sincronia website

Simulation Results
Offline

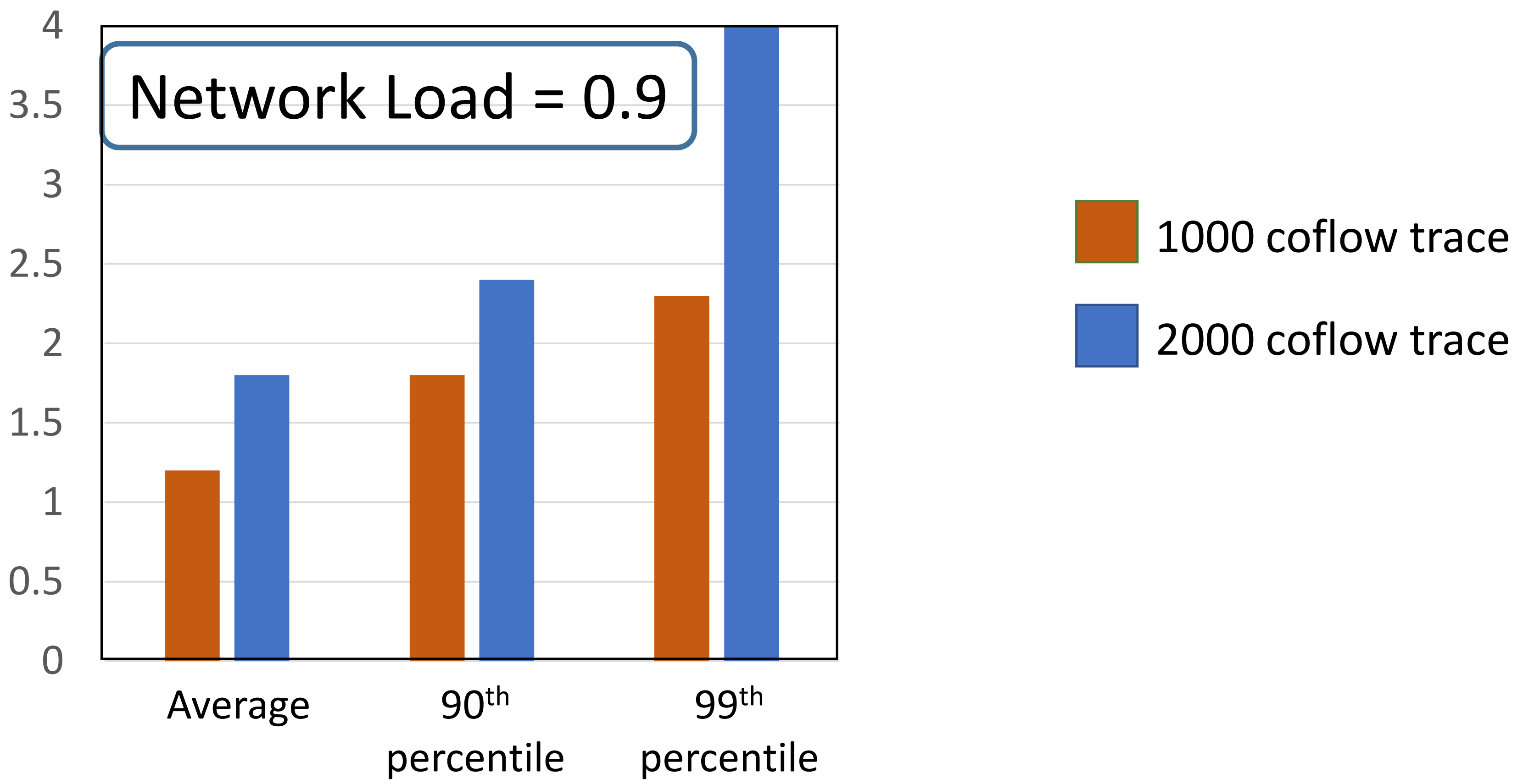


OCT: Completion time of a coflow in an unloaded network

Sincronia not only provides near-optimal guarantees, but also improves upon state-of-the-art design in practice

Simulation Results
Online

$$\frac{\text{CCT}}{\text{OCT}} = \text{Slowdown}$$

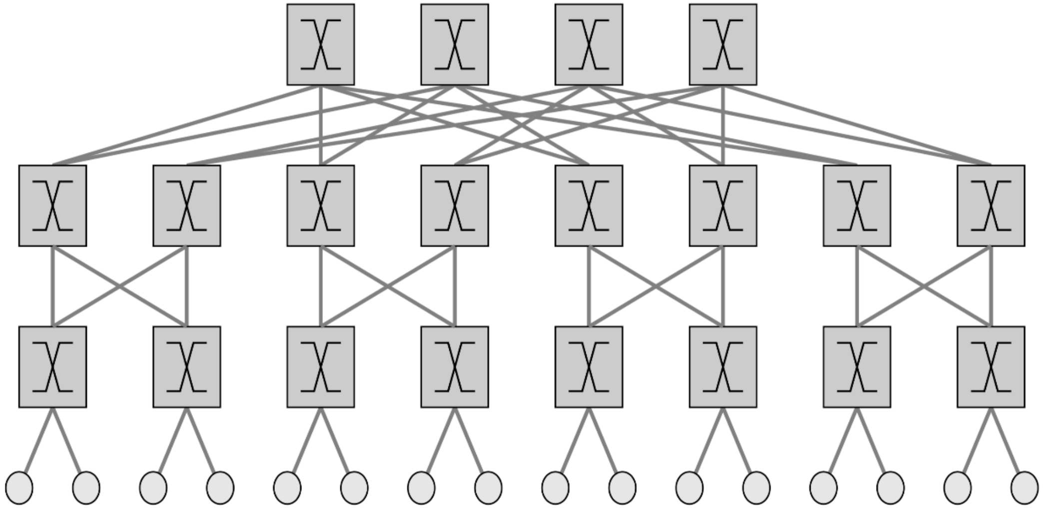


Even at such high network loads,
Sincronia achieves CCT close to that of an unloaded network

Implementation Results

Implemented on top of TCP

- 16-server Fat tree topology
  - Full bisection bandwidth
  - 20 PICA8 switches
    - Supports 8 priority levels
- DiffServ for priority scheduling



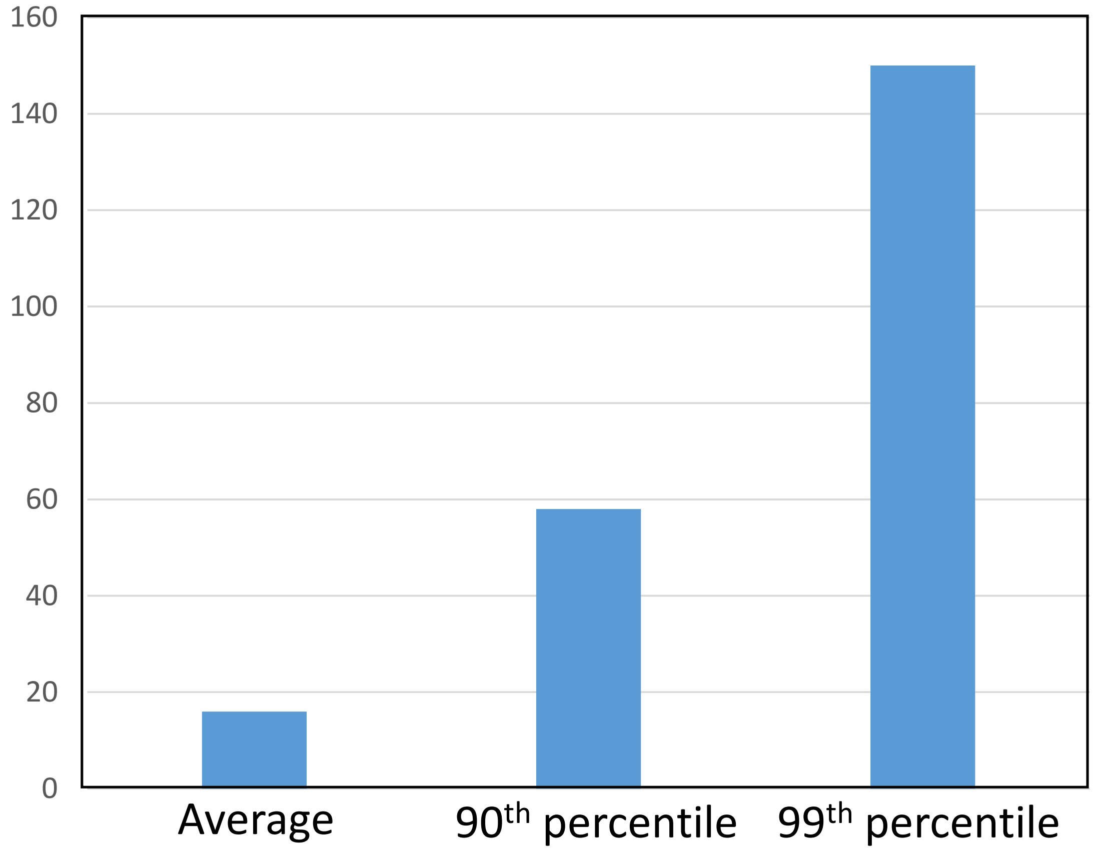
Implementation Results

- Unfair Evaluation

  - TCP not designed for coflows
  - TCP not designed to minimize CT

+ Compare against existing designs

  - E.g. Varys reports 1.85x improvement
    at mean and at tails



Sincronia achieves significant improvements over existing network designs even with a small number of priority levels

Summary

- Sincronia – a network design for coflows
  - 4x within optimal
  - No per-flow rate allocation

Name	Performance Guarantees	Run on existing Transport	Work Conserving	Starvation Avoiding
Varys	✗	✗	✓	✓
On Scheduling Coflows	✓ (4-apx)	✗	✗	✗
Sincronia	✓ (4-apx)	✓	✓	✓

- Paper discusses number of open problems

Thanks!