Varys

Efficient Coflow Scheduling

Mosharaf Chowdhury,
Yuan Zhong, Ion Stoica

amplab
UC Berkeley

Communication is Crucial

Performance

Facebook analytics jobs spend **33%** of their runtime in communication[1]

As in-memory systems proliferate,
the network is likely to become the ***primary bottleneck***

1. *Managing Data Transfers in Computer Clusters with Orchestra, SIGCOMM'2011*

Flow

A sequence of packets between two endpoints

Independent unit of allocation, sharing, load balancing, and/or prioritization

Optimizing Communication Performance: Networking Approach

"Let systems figure it out"

Optimizing Communication Performance: Systems Approach

"Let users figure it out"

	# Comm. Params*
Spark 1.0.1	6
Hadoop 1.0.4	10
YARN 2.3.0	20

*Lower bound. Does not include *many* parameters that can indirectly impact communication; e.g., number of reducers etc. Also excludes control-plane communication/RPC parameters.

Optimizing Communication Performance: Systems Approach

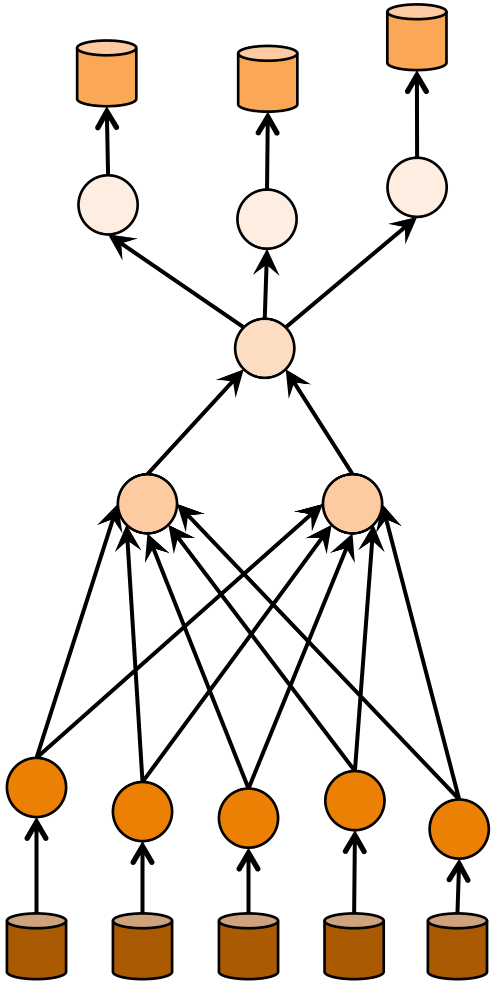
"Let users figure it out"

Optimizing Communication Performance: Networking Approach

"Let systems figure it out"

Optimizing Communication Performance: Systems Approach

"Let users figure it out"



Optimizing Communication Performance: Networking Approach

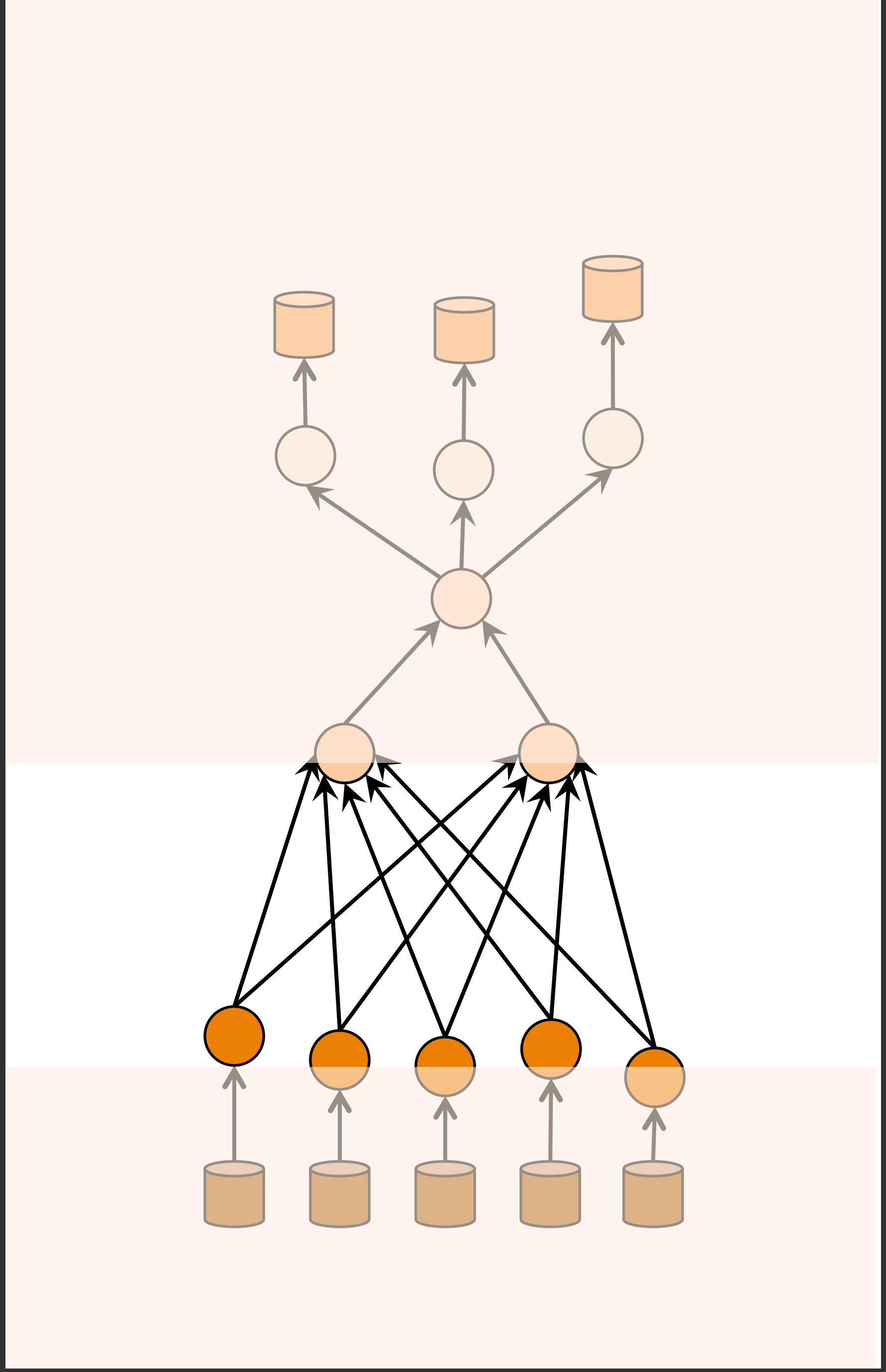
"Let systems figure it out"

Coflow[1]

A collection of parallel flows

Distributed endpoints

Each flow is independent



Completion time depends on *the last flow* to complete

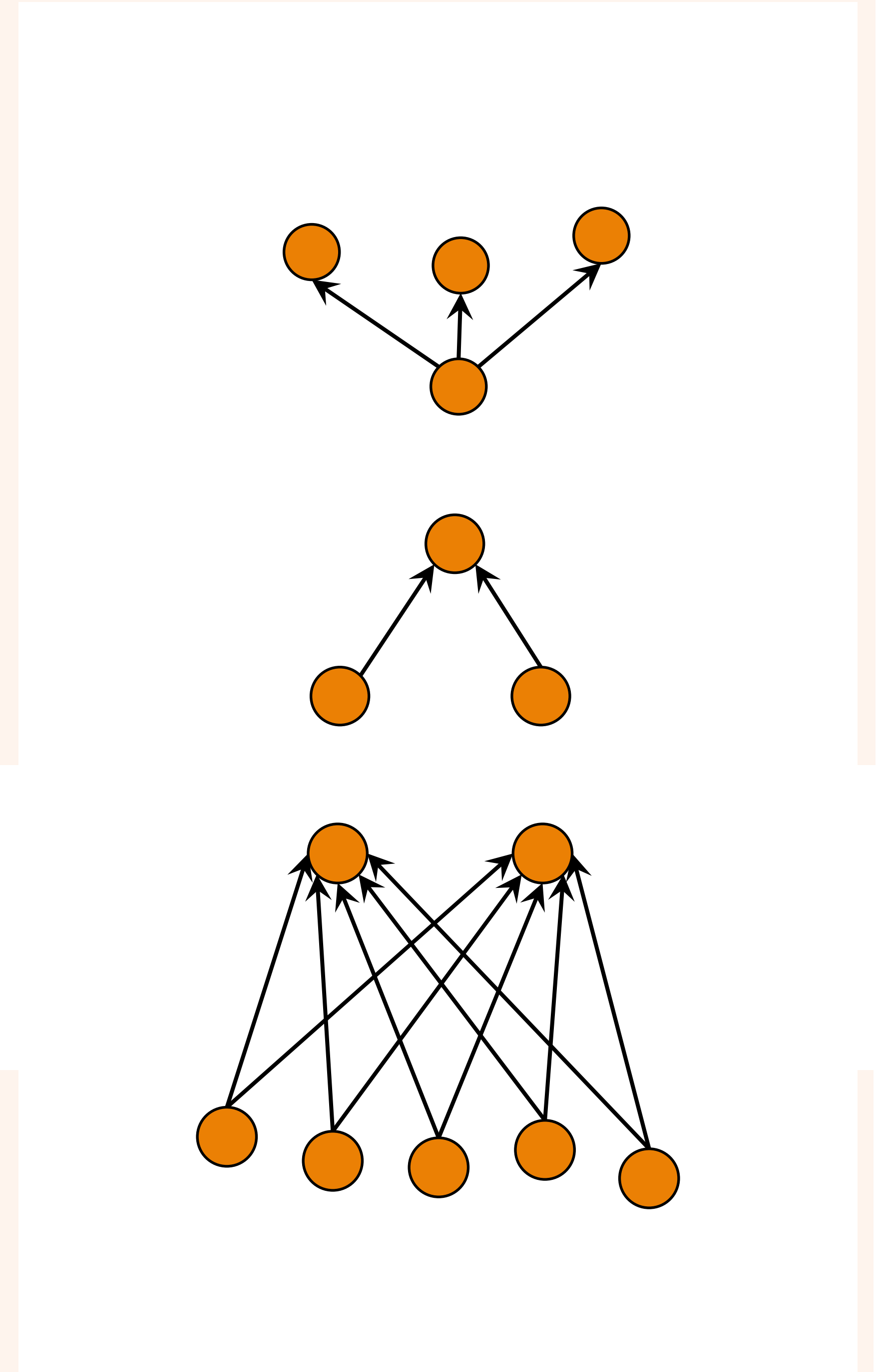
1. *Coflow: A Networking Abstraction for Cluster Applications, HotNets'2012*

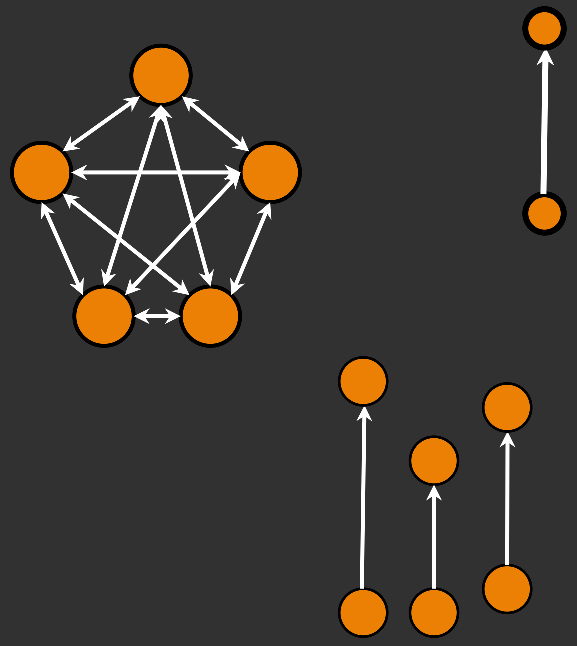
Coflow[1]

A collection of parallel flows

Distributed endpoints

Each flow is independent

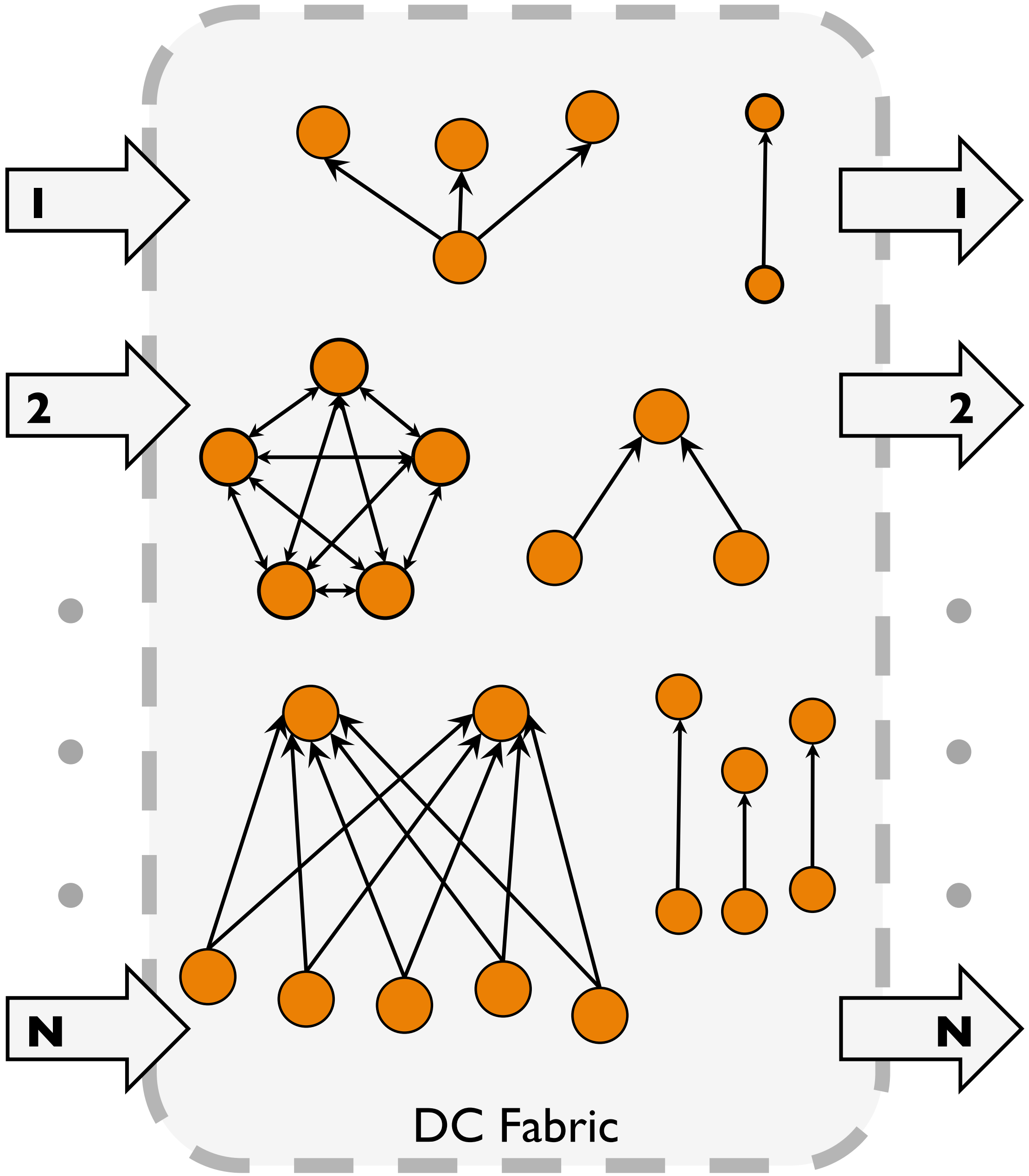




Completion time depends on *the last flow* to complete

1. Coflow: A Networking Abstraction for Cluster Applications, HotNets'2012

How to schedule coflows ...



... for faster
#1 completion of coflows?

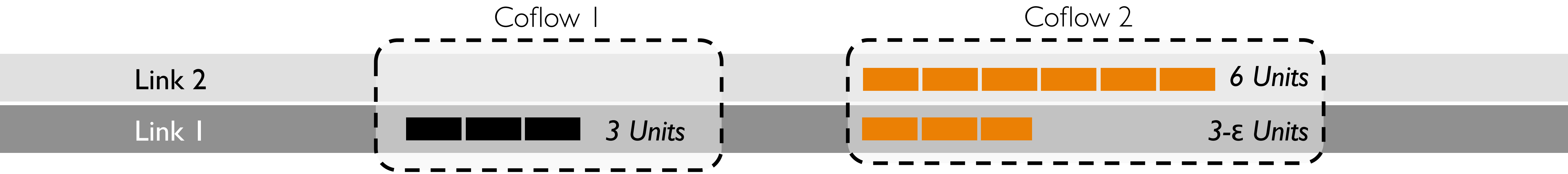
... to meet
#2 more deadlines?

Varys

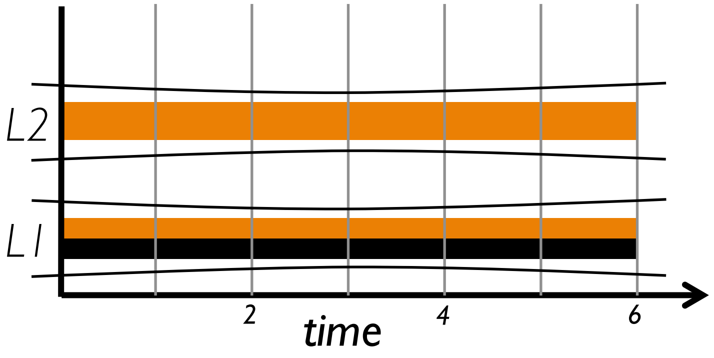
Enables coflows in data-intensive clusters

1. **Simpler Frameworks** — *Zero user-side configuration using a simple coflow API*
2. **Better performance** — *Faster and more predictable transfers through coflow scheduling*

Benefits of Inter-Coflow Scheduling

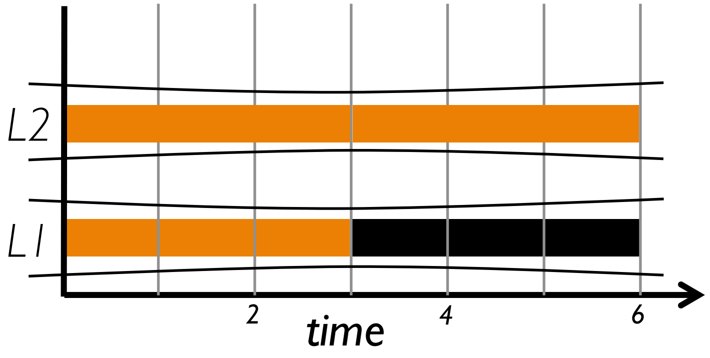


Fair Sharing



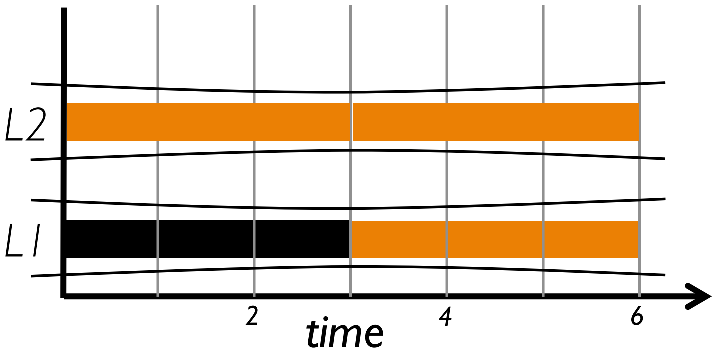
Coflow1 comp. time = 6
Coflow2 comp. time = 6

Flow-level Prioritization[1,2]



Coflow1 comp. time = ***6***
Coflow2 comp. time = ***6***

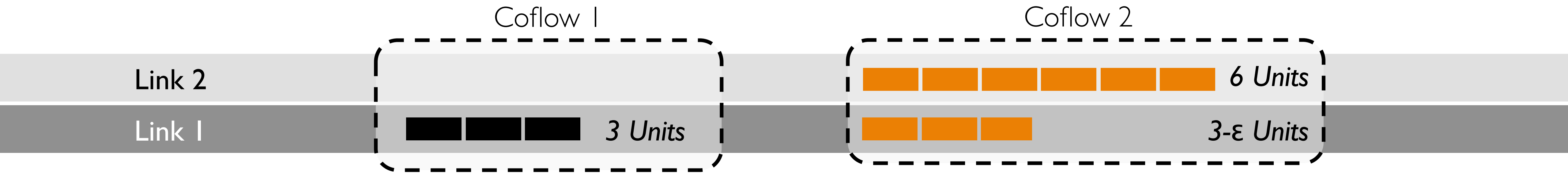
The Optimal



Coflow1 comp. time = ***3***
Coflow2 comp. time = ***6***

1. Finishing Flows Quickly with Preemptive Scheduling, SIGCOMM'2012.
2. pFabric: Minimal Near-Optimal Datacenter Transport, SIGCOMM'2013.

Inter-Coflow Scheduling

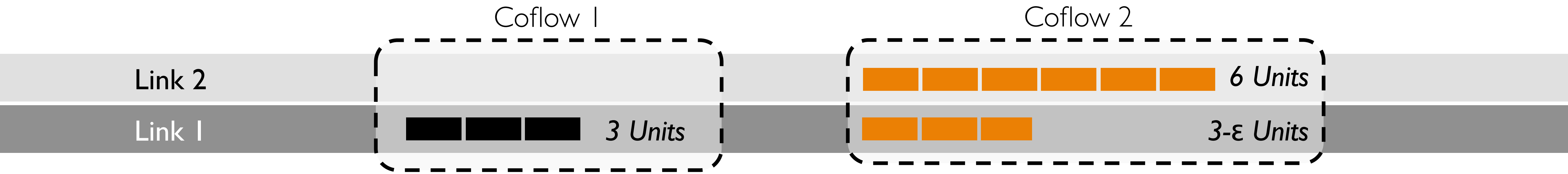


Concurrent Open Shop Scheduling[1]

- Tasks on independent machines
- Examples include job scheduling and caching blocks
- Use a **ordering** heuristic

1. *A note on the complexity of the concurrent open shop problem, Journal of Scheduling, 9(4):389–396, 2006*

Inter-Coflow Scheduling is **NP-Hard**



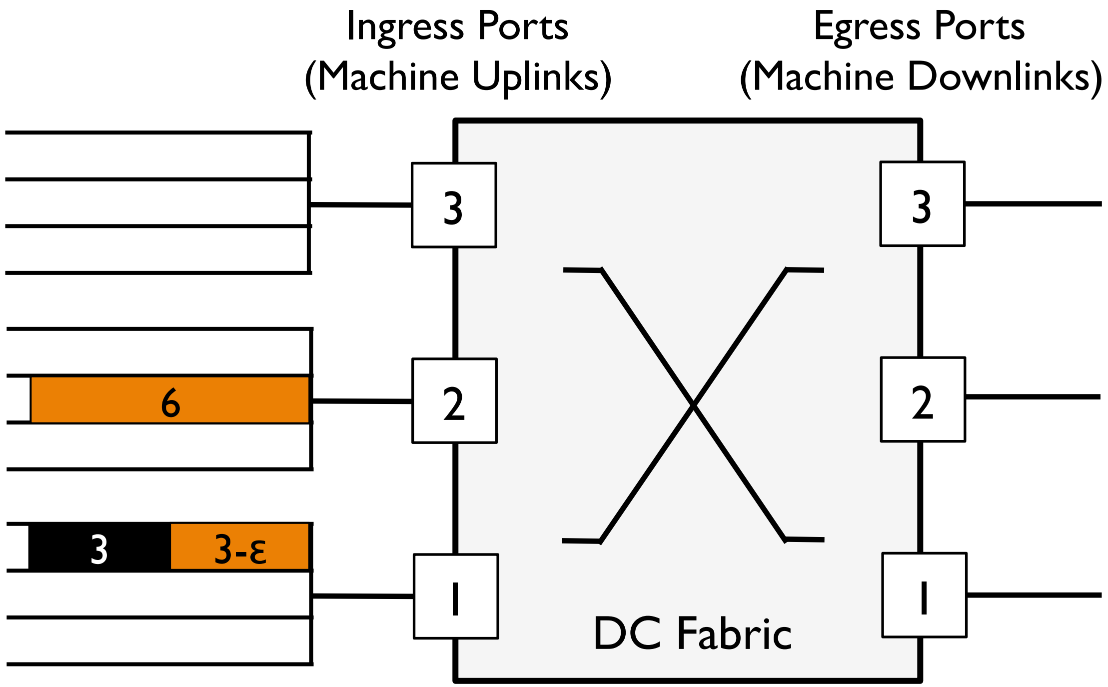
with coupled resources

Concurrent Open Shop Scheduling ^

- Flows on dependent links
- Consider **ordering** and **matching** constraints

Characterized COSS-CR

Proved that list scheduling might not result in optimal solution

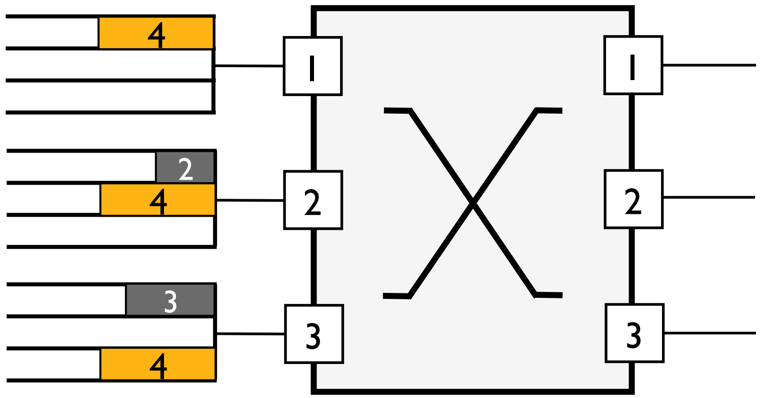


Varys

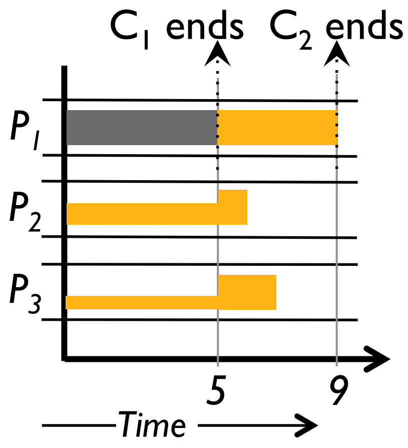
Employs a two-step algorithm to minimize coflow completion times

1. **Ordering heuristic** — *Keeps an ordered list of coflows to be scheduled, preempting if needed*
2. **Allocation algorithm** — *Allocates minimum required resources to each coflow to finish in minimum time*

Ordering Heuristic: **SEBF**



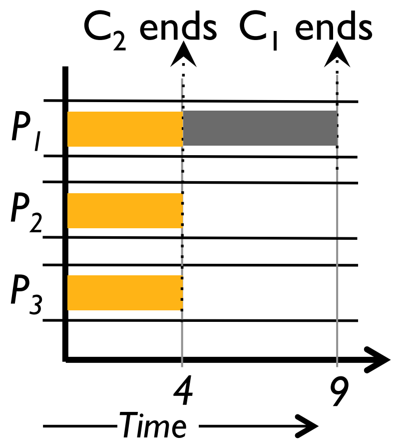
	C_1	C_2
Length	3	4
Width	2	3
Size	5	12
Bottleneck	**5**	4



Shortest-First

Narrowest-First

Smallest-First



Smallest-Effective-Bottleneck-First

Allocation Algorithm

MADD

A coflow cannot finish before its very last flow

→

Finishing flows faster than the bottleneck cannot decrease a coflow's completion time

→

Ensure minimum allocation to each flow for it to finish at the desired duration;

for example,
at bottleneck's completion, or
at the deadline.

Varys

Enables frameworks to take advantage of coflow scheduling

1. Exposes the coflow API
2. Enforces through a centralized scheduler

Evaluation

A 3000-node trace-driven simulation matched against a 100-node EC2 deployment

1. Does it improve performance?
2. Can it beat non-preemptive solutions?

YES

Faster Jobs

	Comm. Improv.	Job Improv.
Avg.	**1.85X**	**1.25X**
95th	**1.74X**	**1.15X**

Faster Jobs

	Comm. Heavy[1]	
	Comm. Improv.	Job Improv.
Avg.	3.16X	2.50X
95th	3.84X	2.94X

1. 26% jobs spend at least 50% of their duration in communication stages.

Better than Non-Preemptive Solutions

	w.r.t. FIFO[1]
Avg.	**5.65X**
95th	**7.70X**

NO

Perpetual Starvation?

1. *Managing Data Transfers in Computer Clusters with Orchestra, SIGCOMM'2011*

#1

Coflow Dependencies

#2

Unknown Flow Information

#3

Decentralized Varys

in the Context of *Multipoint-to-Multipoint* Coflows

#4

Theory Behind
"Concurrent Open Shop Scheduling *with* Coupled Resources"

Varys

Greedily schedules coflows without worrying about flow-level metrics

- Consolidates network optimization of data-intensive frameworks
- Improves job performance by addressing the COSS-CR problem
- Increases predictability through informed admission control

http://varys.net/