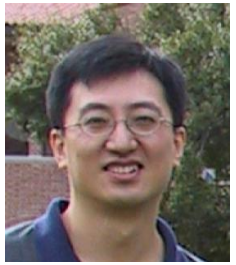
Saath: Speeding up CoFlows by Exploiting the Spatial Dimension



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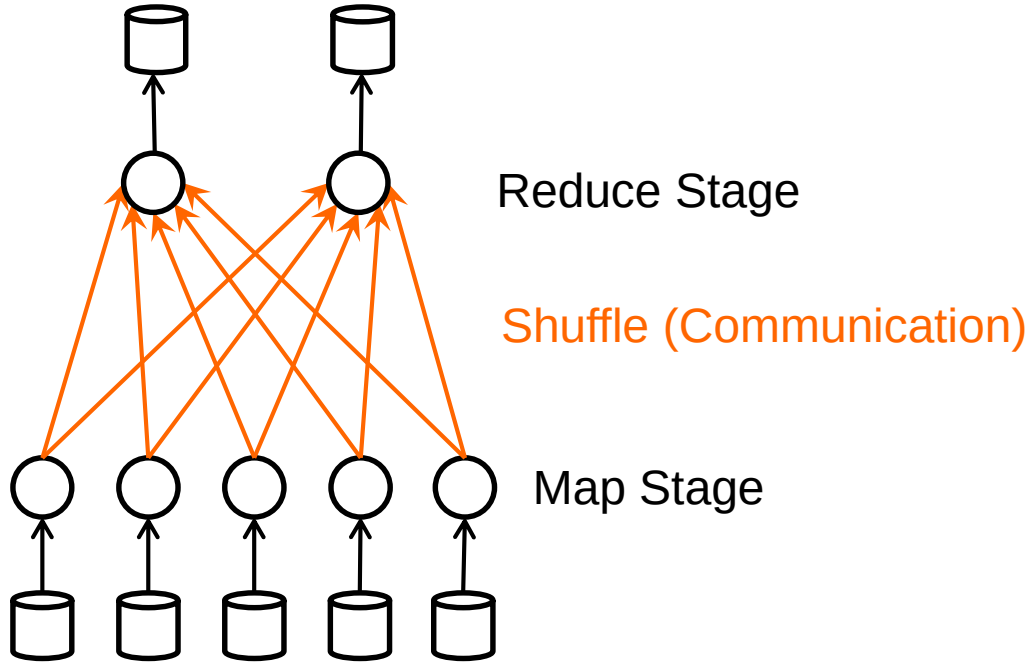
Analytics Jobs in Big Data

- Analytics jobs in data-centers
  - Process huge amount of data
  - Distributed in nature
  - Have multiple stages that communicate with each other

Example – Map Reduce Jobs

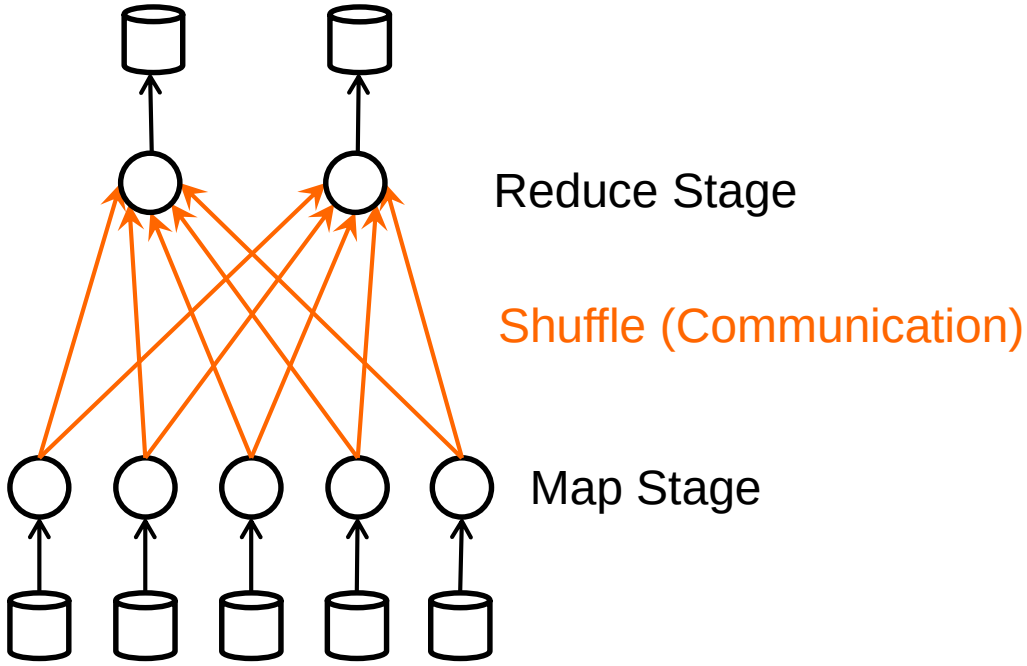
Two compute stages:
Map and Reduce

Map communicates with reduce in shuffle phase



Impact of communication on job performance

Facebook jobs spend 25% time in communication![1]



[1] Based on information from full facebook trace used in Aalo. Aalo slides.

CoFlow abstraction

CoFlow:

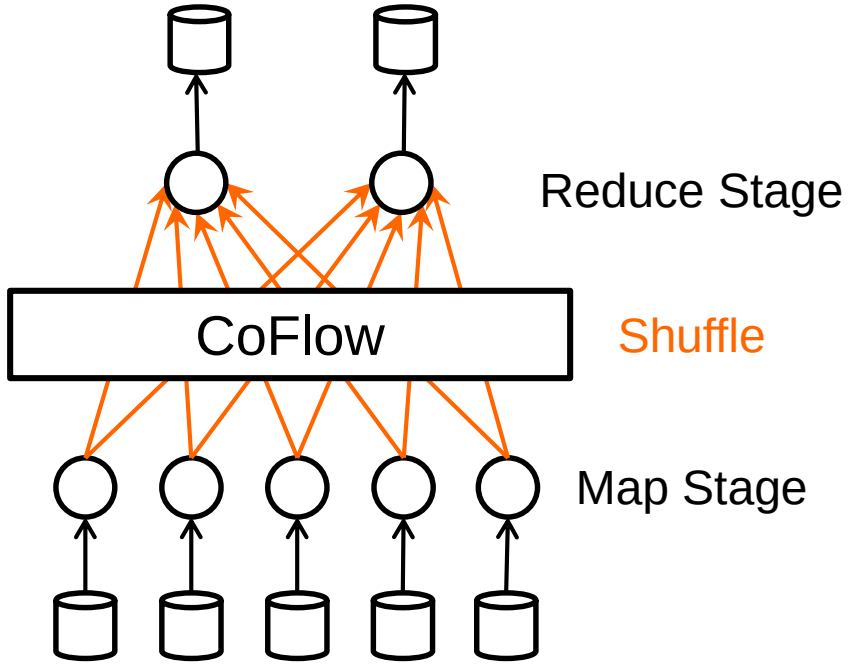
Collection of all flows that share same goal

Implication:

CoFlow finishes when all its flows are over

CoFlow Completion Time (CCT):

Completion time of its last flow



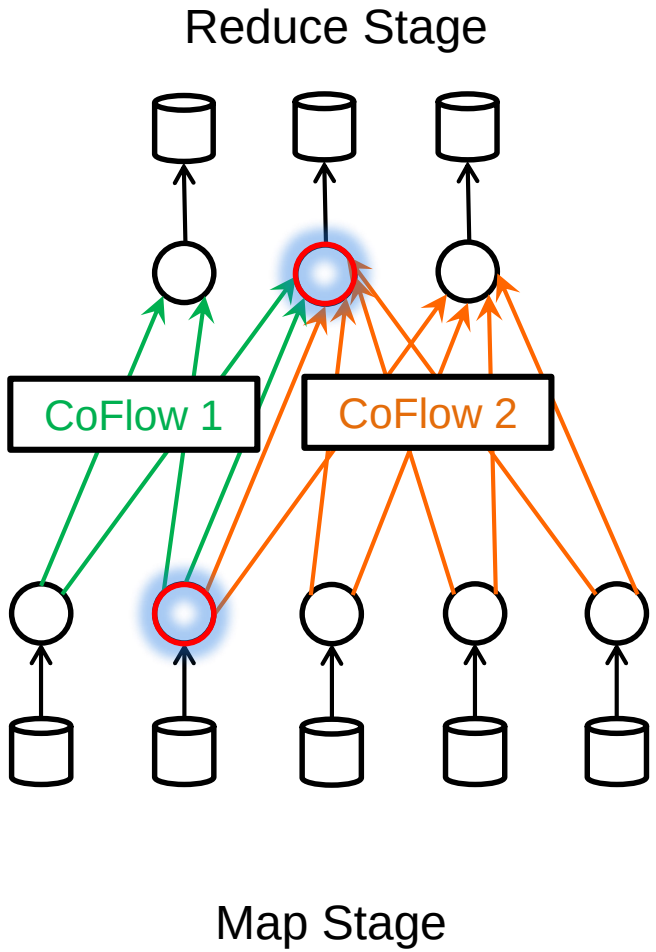
CoFlow Scheduling Problem

Green Job 2 mappers and 2 reducers

Orange Job 4 mappers and 2 reducers

They share datacenter network

Goal: minimize **average** CoFlow completion time (CCT) of all CoFlows



CoFlow Scheduling Problem

- CoFlow scheduling problem
  - Minimize average CoFlow Completion Time (CCT)
- CoFlows have 2-dimensions
  - Time – Length of individual flows
  - Space – Many flows or ports
- CoFlow scheduling problem is NP Hard [3]

[3] M. Chowdhury, Y. Zhong, and I. Stoica. Efficient coflow scheduling with Varys. In SIGCOMM, 2014.

Outline

- Background of *Aalo* (State-of-the-art CoFlow scheduler)
- Limitations of *Aalo*
- Design of *Saath*
- Evaluation

Background of *Aalo* (State-of-the-art CoFlow scheduler)

- Shortest job first for sequential jobs
- Online approximation of SJF
- Aalo: Online SJF + Spatial dimension (many distributed tasks)

Scheduling 101

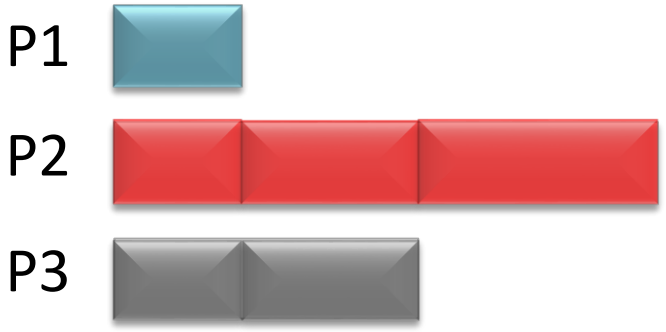
Shortest-Job-First (SJF): optimal in minimizing average completion time

Outline

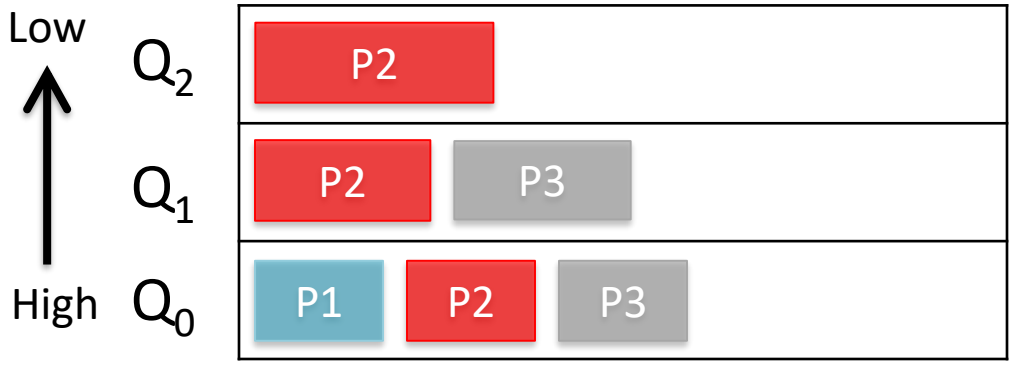
- Background of *Aalo* (State-of-the-art CoFlow scheduler)
  - Shortest job first for sequential jobs
  - Online approximation of SJF
  - Aalo: Online SJF + Spatial dimension (many distributed tasks)

Online Approximation to SJF using Priority queues

Process durations - Unknown



Priority queues
(Higher Priority = more CPU time)



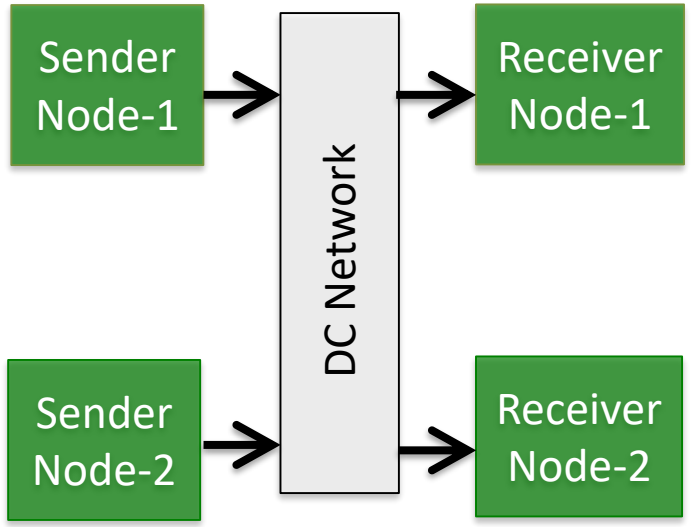
Shorter processes finish in High priority queues

Outline

- Background of *Aalo* (State-of-the-art CoFlow scheduler)
  - Shortest job first for sequential jobs
  - Online approximation of SJF
  - Aalo: Online SJF + Spatial dimension (many distributed tasks)

Datacenter Network abstraction: Non-blocking switch

- The entire datacenter fabric is one non-blocking switch
  - Makes analysis simple
  - Recent works like CONGA[Sigcomm' 14], VL2 [Sigcomm'09] make the abstraction practical
- Only source of contention are end-hosts
- Implication: The CoFlow scheduling problem boils down to ordering them at sending hosts/ports

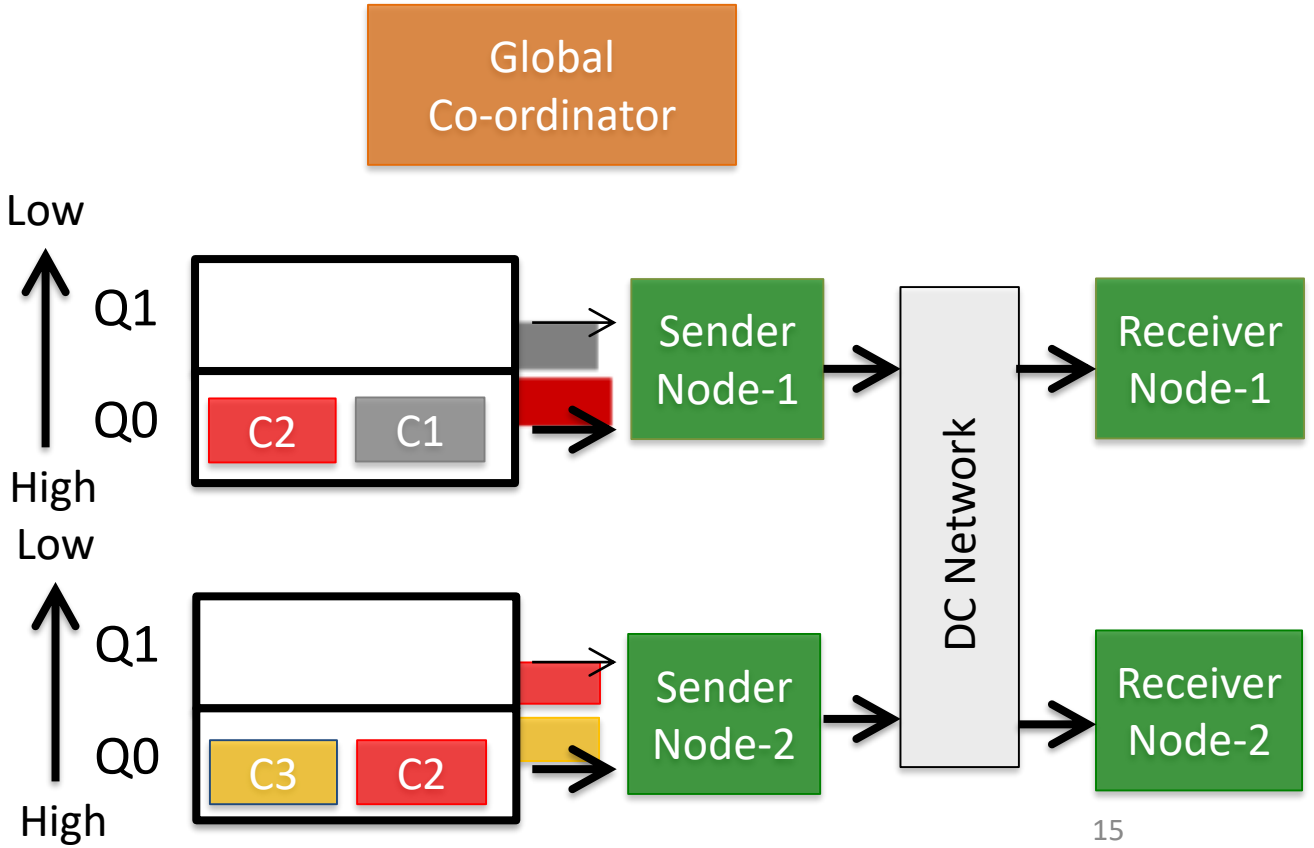


[4] Sigcomm 2014, CONGA, M. Alizadeh et.al ;[5] Sigcomm 2009, VL2, A Greenberg et.al

Aalo: Online CoFlow Scheduler

A CoFlow has many flows -- How to approximate SJF?

1. Replicates priority queues at each node
2. A CoFlow moved across priority queues based on total bytes sent at all its ports
3. Different ports send independently
4. Intra-queue: Use FIFO



[6] Sigcomm 2015, Aalo, Choudhary et.al.

Outline

- Background of *Aalo* (State-of-the-art CoFlow scheduler
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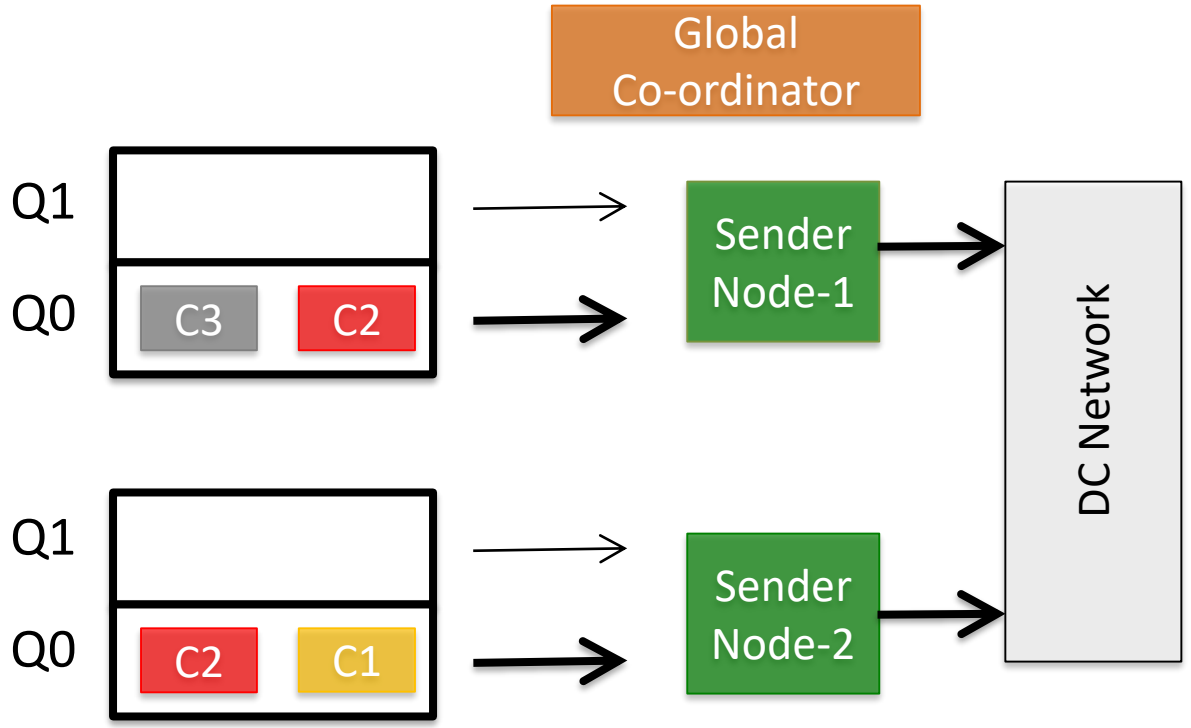
Aalo Drawback 1: Out-of-Sync

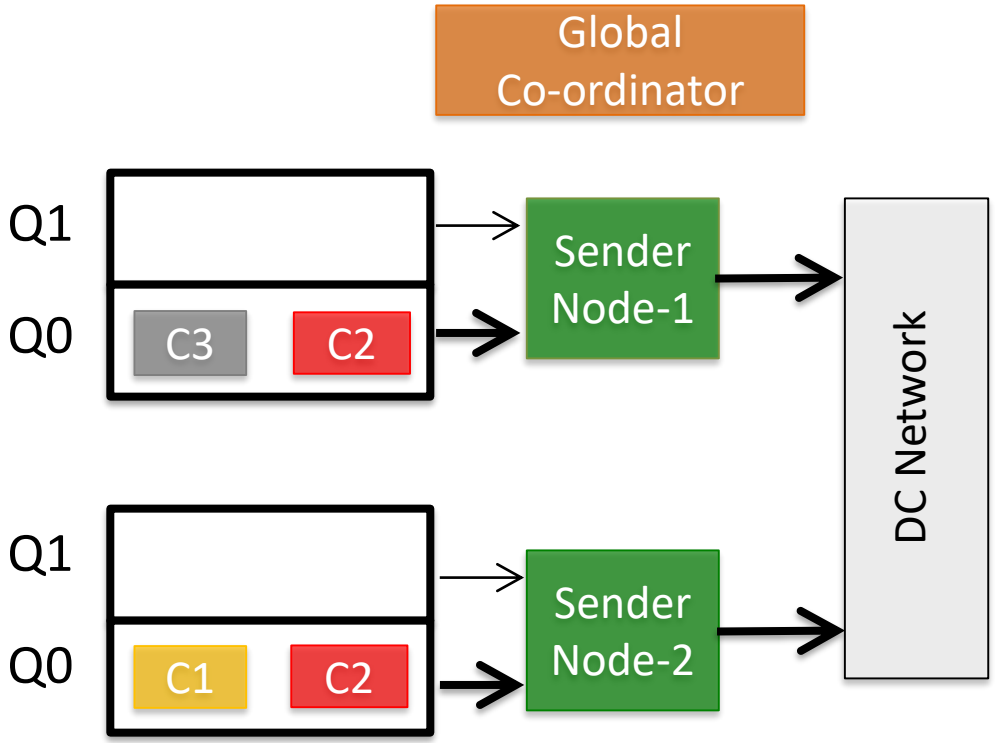
Ports schedule independent of each other

Flows of a CoFlow may get scheduled at different times at different ports

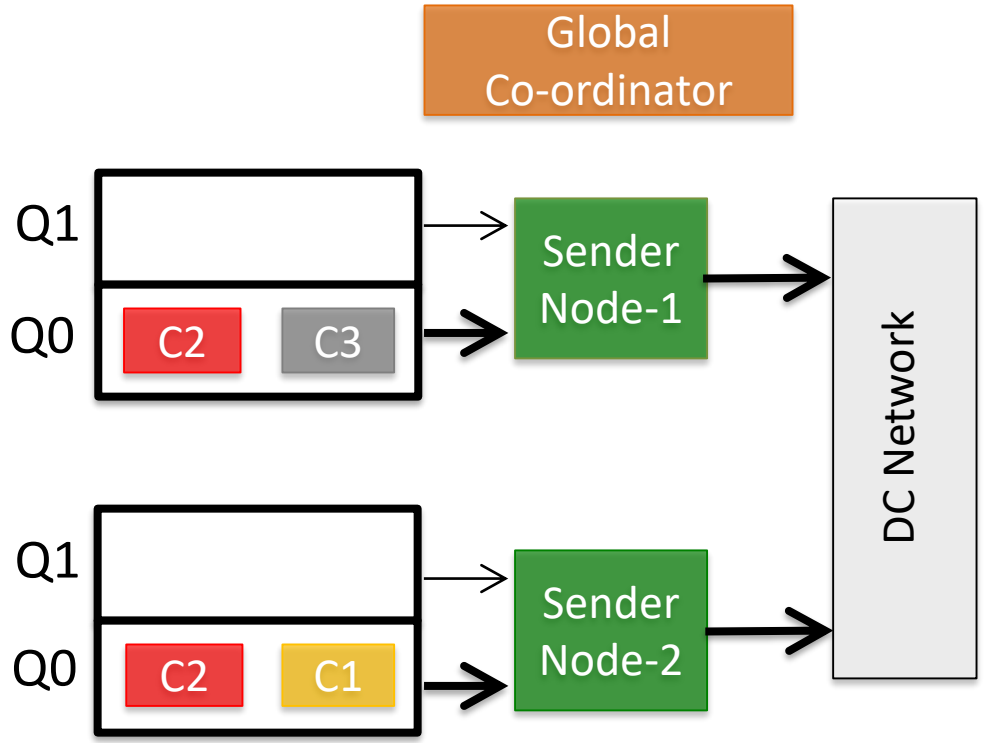


Aalo Drawback 2: Contention Oblivion

Contention of a CoFlow – Number of other CoFlows it blocks



- C1 – 1 – C2
- C2 – 2 – C1 & C3
- C3 – 1 – C2



Average CCT = (2+1+2)/3= 5/3

Average CCT =(1+2+1)/3 = 4/3

Aalo is not taking arrangement of CoFlows across Space into account

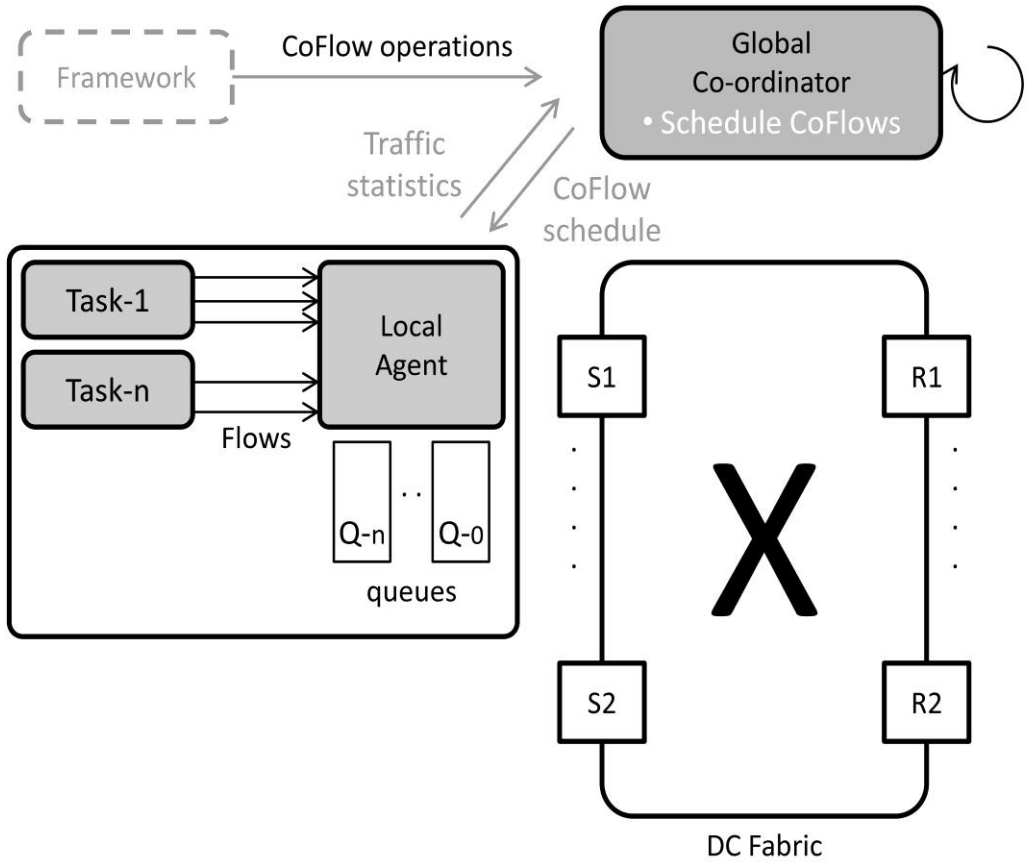
Outline

- State-of-the-art CoFlow scheduler - *Aalo*
- Limitations of *Aalo*
- Design of *Saath*
- Evaluation

Saath:
Speeding up CoFlows by exploiting the Spatial Dimension

Saath

- Saath is an online scheduler.
- Takes spatial dimension into account while scheduling CoFlows.
- Spatial dimension: Arrangement of flows of CoFlows across ports



Saath Key Ideas

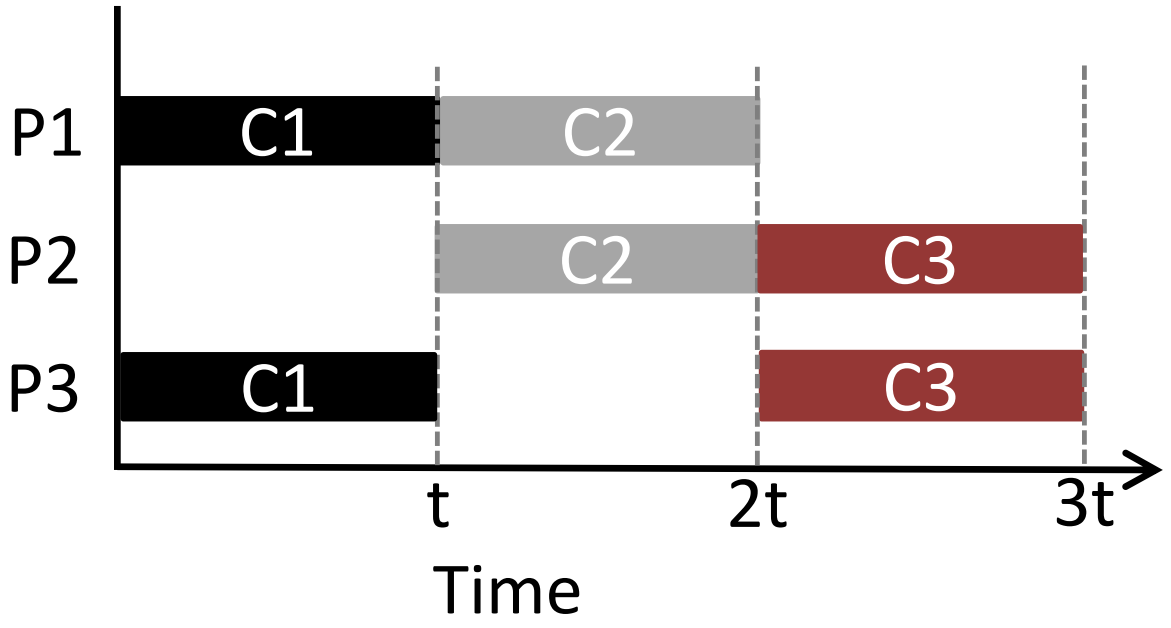
- All-or-none
- Least-Contention-First within a queue
- Faster CoFlow-queue transition

Key idea 1: All-or-none

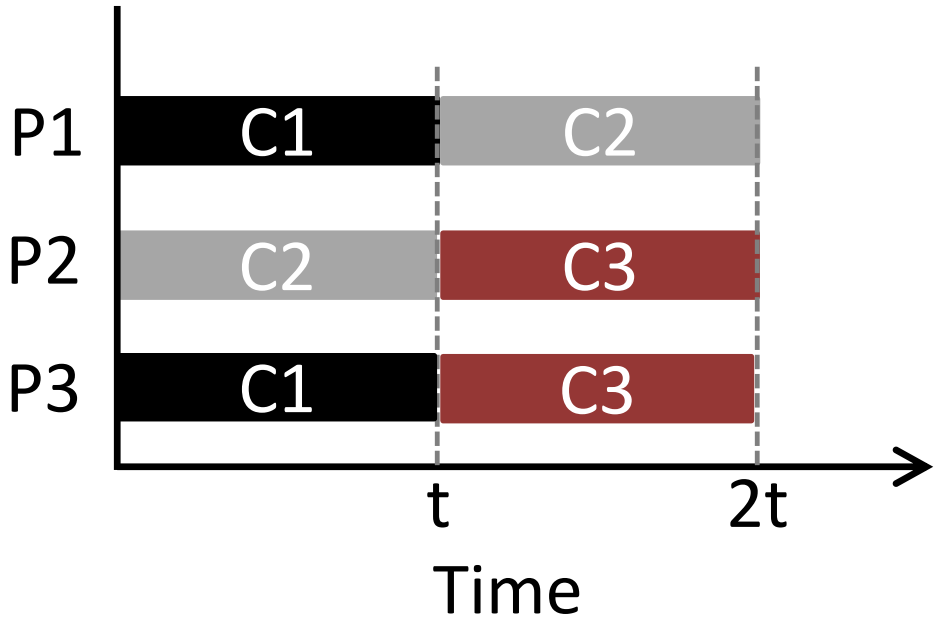
- Either schedule all flows of a CoFlow or schedule none.
  - Not scheduling a CoFlow for which a subset of flow was being scheduled has no effect on CCT.
  - By freeing up some ports we potentially improve CCT for others

Challenges in All-or-none

CCT:
C1 = t , C2 = 2t, C3 = C4 = t



CCT:
C1 = t , C2 = 2t, C3 = C4 = t



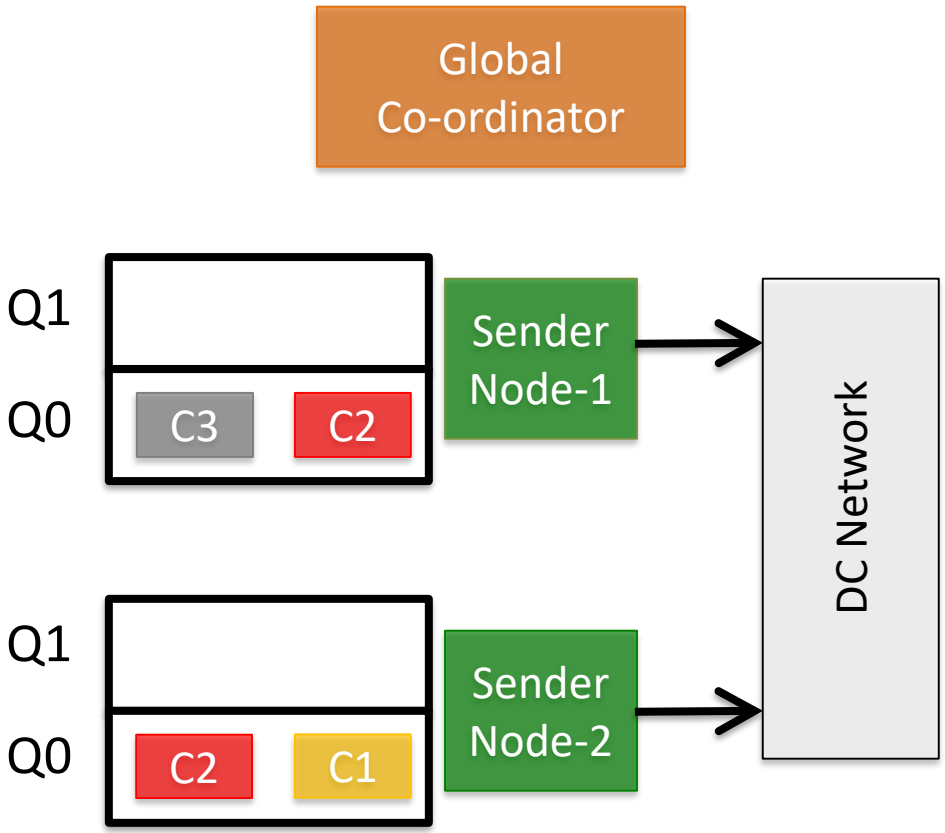
Saath handles low port utilization by carefully designed work conservation

Key idea 2: Least-Contention-First within a queue

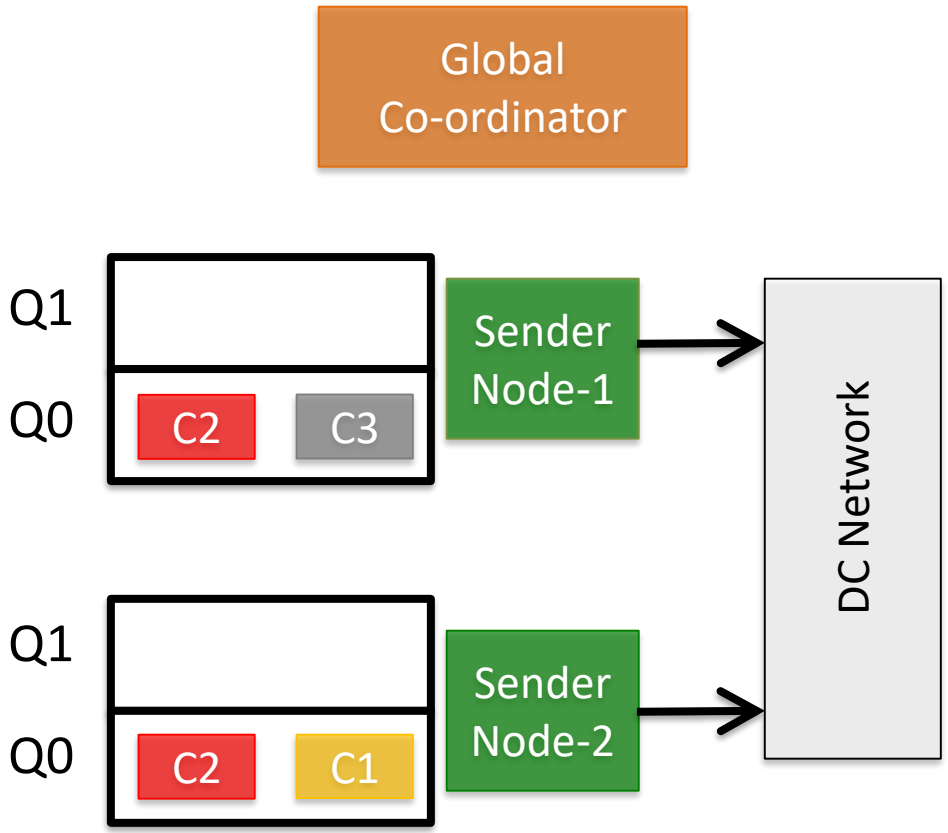
- *Contention* of a CoFlow – Number of other CoFlows it blocks
- Saath sorts CoFlows in each queue in increasing order of *Contention*
- Allows more CoFlows to be scheduled in parallel.

Key idea 2: Least-Contention-First within a queue

Contention of a CoFlow – Number of other CoFlows it blocks



- C1 – 1 – C2
- C2 – 2 – C1 and C3
- C3 – 1 – C2



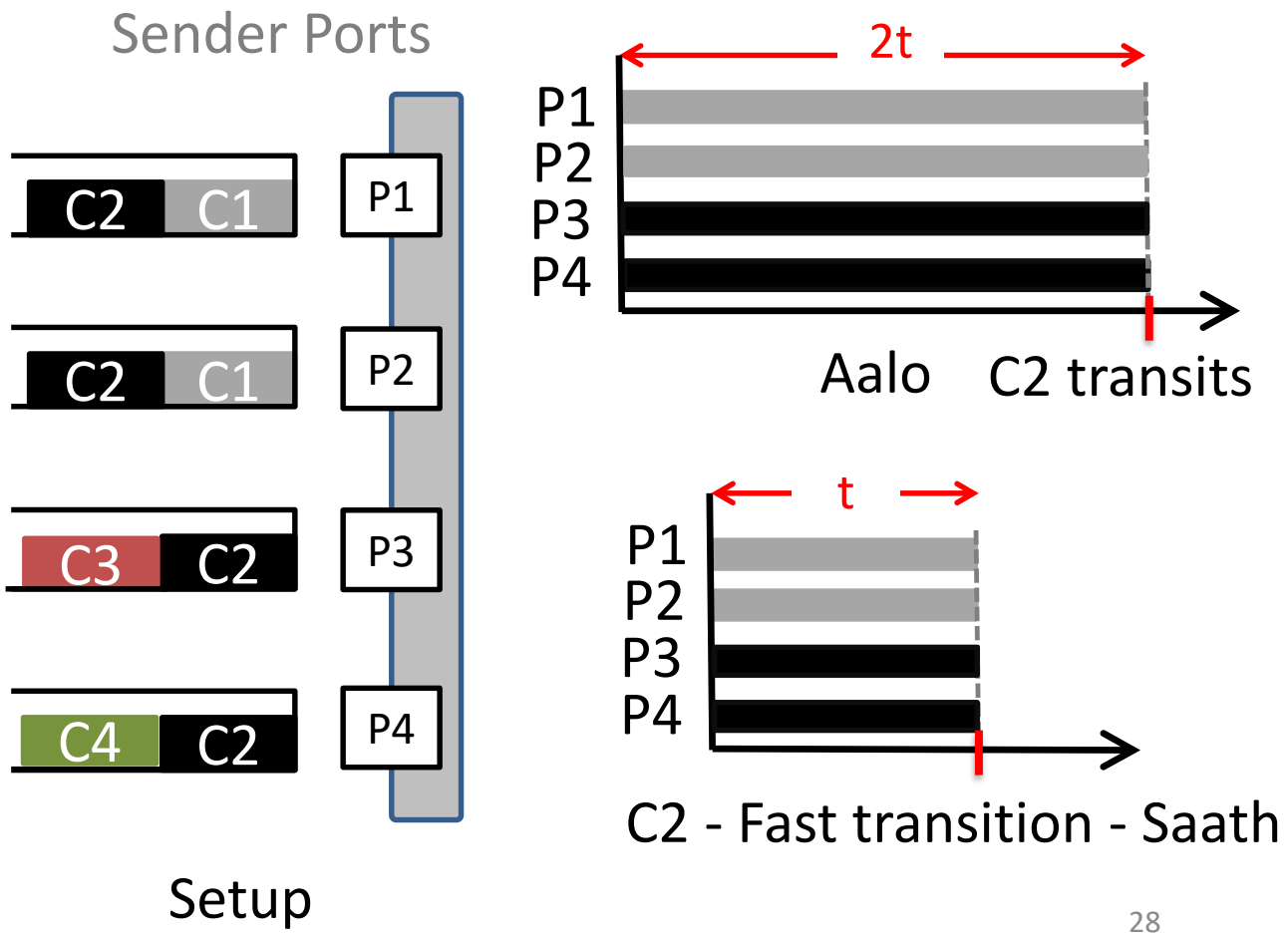
Average CCT = (1+2+2)/3 = 5/3

Average CCT = (1+2+1)/3 = 4/3

Key idea 3: Faster CoFlow-queue transition

- Both Aalo and Saath use priority-queue structure to move CoFlows across queues
- Aalo uses total bytes by all flows
- Saath uses bytes per flow
- Saath has fast transition of longer CoFlows to lower priority queue

Assume queue transition threshold for Aalo is portBandwidth × 4t



Recap: Saath Scheduling Ideas

- All-or-none
- Least-Contention-First within a queue
- Faster CoFlow-queue transition

Outline

- State-of-the-art CoFlow scheduler - *Aalo*
- Limitations of *Aalo*
- Design of *Saath*
- Evaluation

Evaluation Methodology

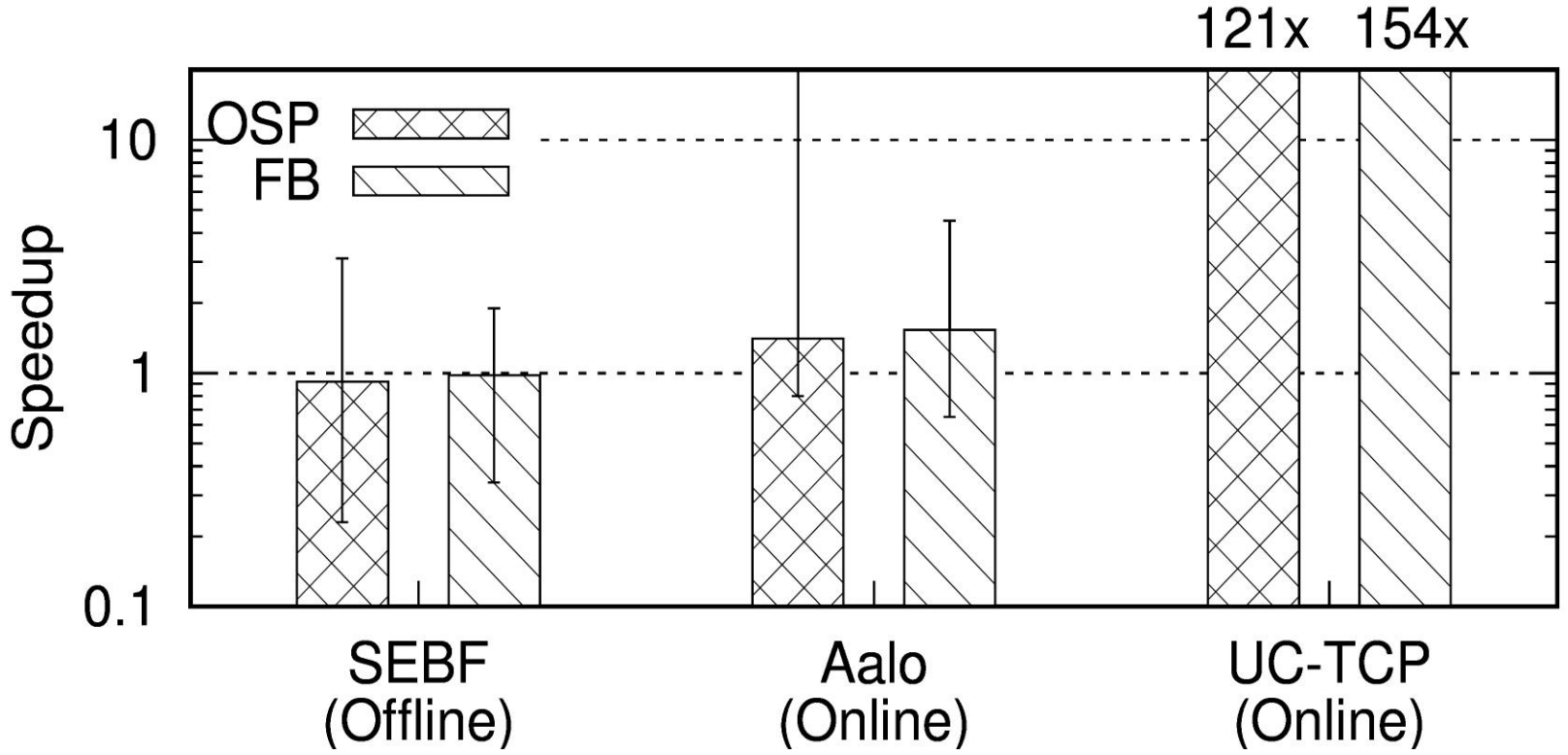
1. Large scale trace driven simulations
2. Large scale testbed evaluation - 150 nodes
3. Implemented Saath in 5.2 KLoC in C++

Trace

1. FB Trace[7]
    1. Collected from Facebook's cluster.
    2. 526 CoFlows, 150 ports
2. OSP
    1. Collected from Microsoft's cluster.
    2. O(1000) CoFlows, O(100) ports

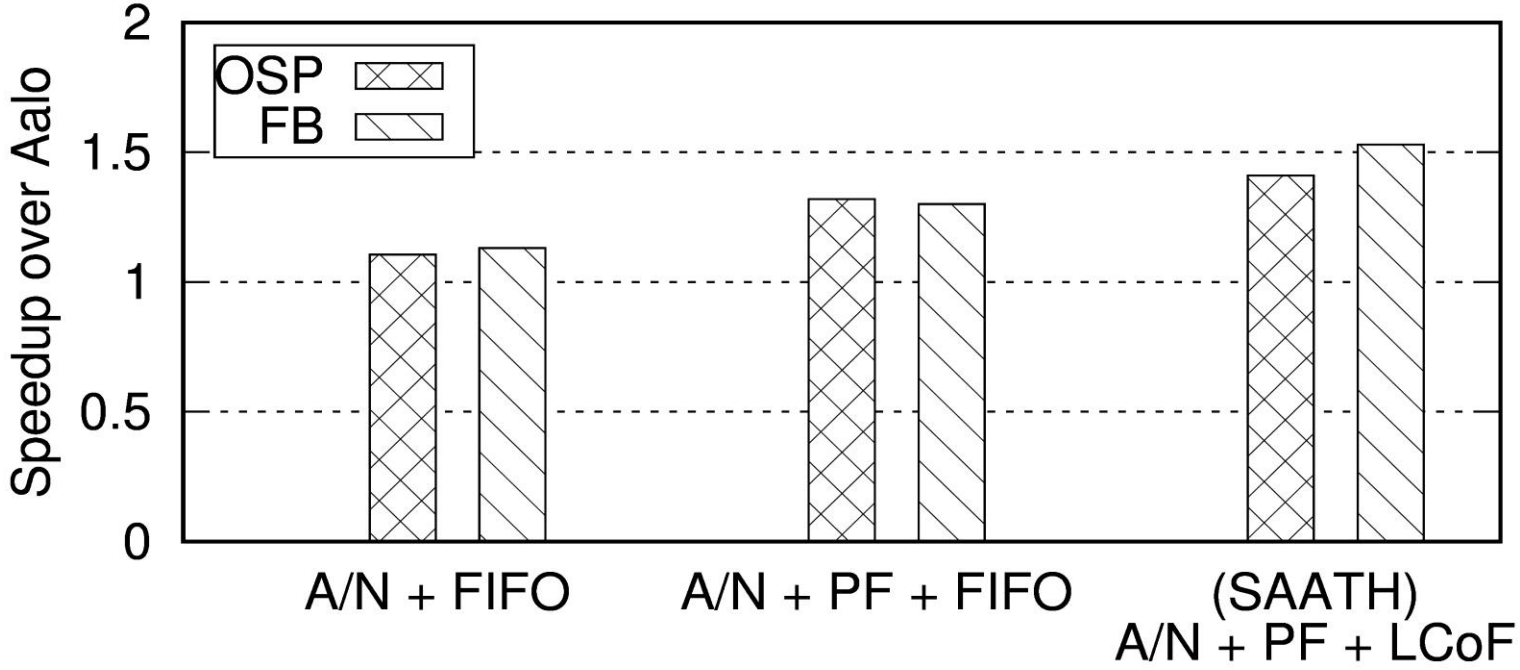
[7] : https://github.com/coflow/coflow-benchmark

Overall CCT improvement



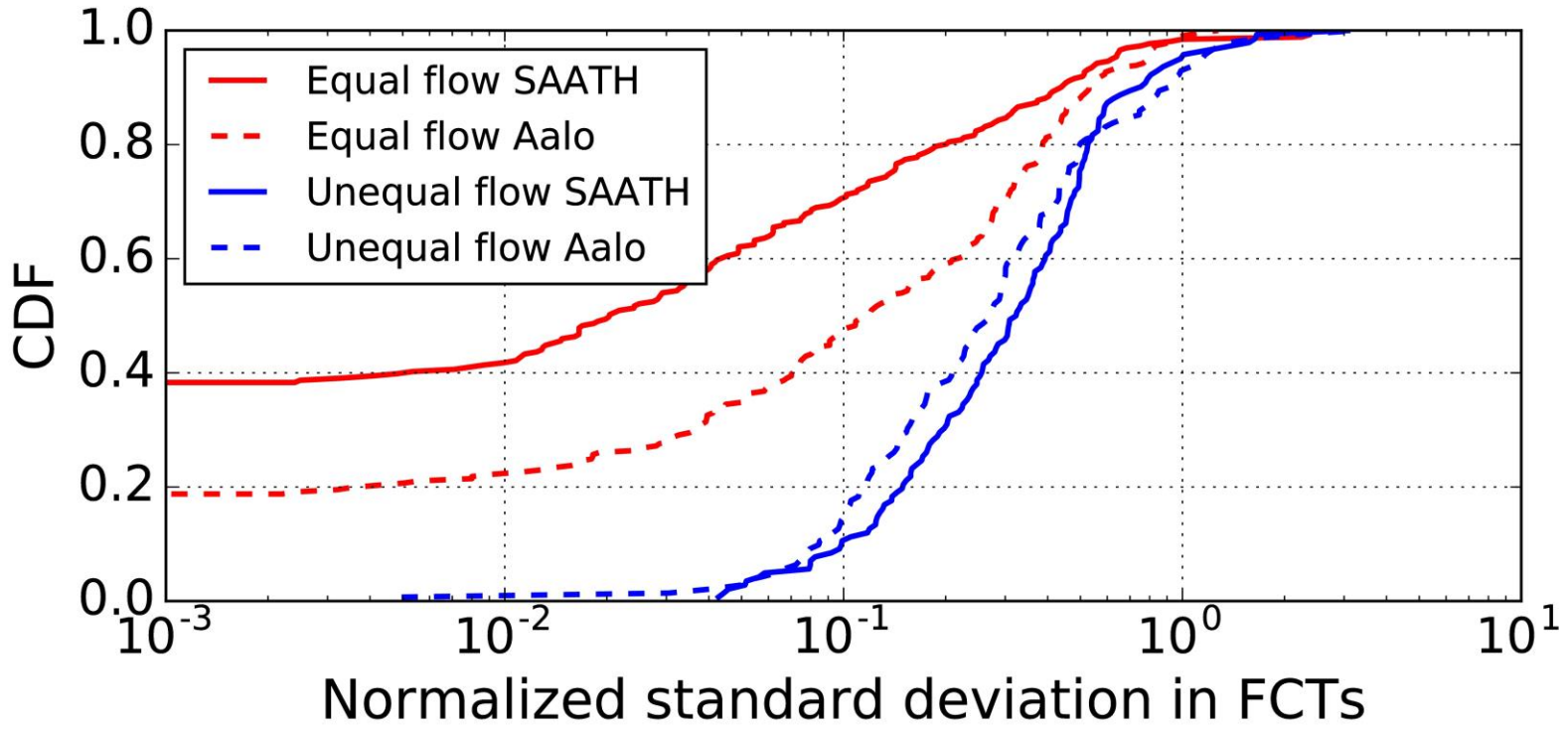
- Saath approaches offline SEBF
- 1.53x for FB and 1.42x for OSP median speedup as compared to Aalo

CCT improvement – Design Components



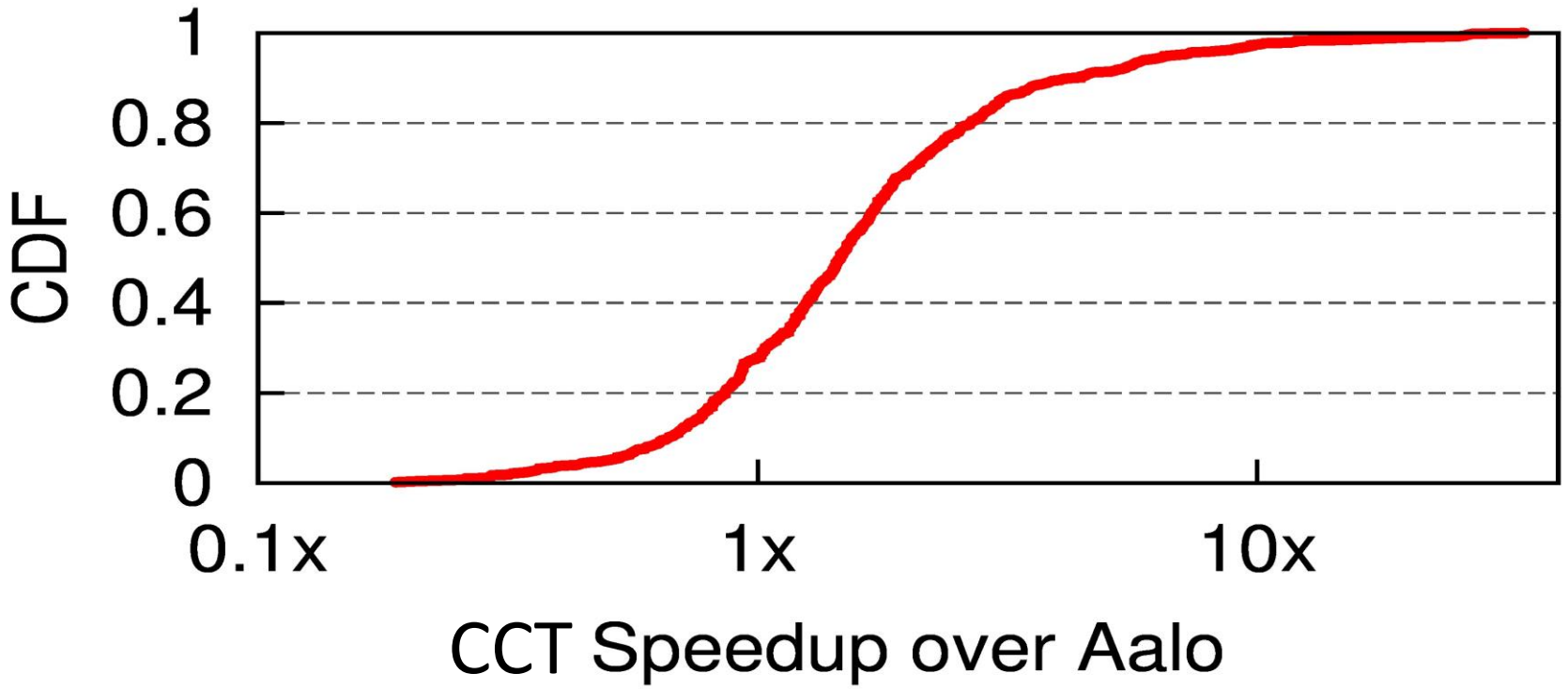
- Each design component has considerable contribution in CCT improvement.

Things are In-Sync now



- Most of the equal flow coflow now have very small deviation in FCTs

Testbed



CCT Speedup 1.88x on Average and 1.43x P50

Scheduling Overhead

		SAATH		Aalo	
		Average	**P90**	**Average**	**P90**
Global Coordinator	**CPU %**	37.8	42.7	33.5	35.5
	Memory(MB)	229	284	267	374
	Total time (msec)	0.57	2.85	0.1	0.2
	(LCoF/All-or-none) (msec)	(0.02/0.24)	(0.03/0.7)		
Local Node	**CPU %**	5.6	5.7	5.5	5.7
	Memory(MB)	1.68	1.7	1.75	1.78

Conclusion

- CoFlow sheduling holds promise to optimize communication in Big Data jobs
- Limitation of prior-art Aalo:
  - Ignores spatial arrangement
  - Has no coordination across ports
    - Flows can be out of sync
    - CoFlow contention oblivious
- Saath:
  - Fuses spatial dimension in CoFlow scheduling
  - Coordination across ports
  - Evaluation: CCT improvement: 1.53x (P50) and 4.5x (P90) for FB trace and 1.42x (P50) and 37x (P90)

Thank you!