

Yosemite: Efficient Scheduling of Weighted Coflows in Data Centers

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Abstract—Recently, coflow has been proposed as a new abstraction to capture the communication patterns in a rich set of data parallel applications in data centers. Coflows effectively model the application-level semantics of network resource usage, so high-level optimization goals, such as reducing the transfer latency of applications, can be better achieved by taking coflows as the basic elements in network resource allocation or scheduling. Although efficient coflow scheduling methods have been studied, in this paper, we propose to schedule *weighted coflows* as a further step in this direction, where weights are used to express the emergences or priorities of different coflows or their corresponding applications. We design an information-agnostic online algorithm to dynamically schedule coflows according to their weights and the instantaneous network condition. Then We implement the algorithm in a scheduling system named Yosemite. Our evaluation results show that, compared to the latest information-agnostic coflow scheduling algorithms, Yosemite can reduce more than 40% of the WCCT (Weighted Coflow Completion Time), and more than 30% of the completion time for coflows with above-the-average level of emergence. It even outperforms the most efficient clairvoyant coflow scheduling method by reducing around 30% WCCT, and 25%~30% of the completion time for coflows with above-the-average emergence, respectively.

I. INTRODUCTION

Recently, coflow has been proposed as a new abstraction to capture the communication patterns in a rich set of data parallel applications. According to [3], a coflow is *a collection of flows between two groups of machines with associated semantics and a collective objective*. The collection of flows share a common performance goal, e.g., minimizing the completion time of the latest flow in the collection, or ensuring that flows in the collection meet a common deadline. Coflows effectively model the application-level semantics of network resource usage, so high-level optimization goals, such as reducing the transfer latency of applications, can be better achieved by taking coflows as the basic elements in network resource allocation or scheduling. Efficient coflow scheduling methods targeting minimizing Coflow Completion Time (CCT) have been studied. Varys [3] proposes the *Smallest-Effective-Bottleneck-First* (SEBF) heuristic to determine the scheduling order of coflows and uses *Minimum-Allocation-for-Desired-Duration* (MADD) to compute the bandwidth to be allocated. However, Varys is a clairvoyant method in the sense that it depends on flow information, such as flow size or

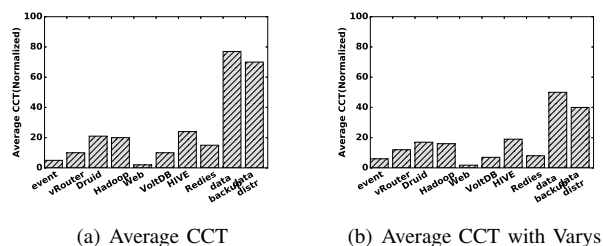


Fig. 1: Normalized Coflow Completion Time, grouped by the level of emergence

flow arrival time, to determine how to scheduling coflows. This may limit its application to scenarios where such information cannot be provided a priori. To solve this problem, non-clairvoyant methods that are flow information agnostic, such as Aalo [2], Barrat [4], and CODA [5], have also been studied. In this paper, we propose to schedule *weighted coflows* as a further step in this direction, where weights are assigned to coflows to express the emergences or priorities of different coflows or their corresponding applications. We design an information-agnostic online algorithm to dynamically schedule coflows according to their weights and the instantaneous network condition.

II. MOTIVATION

We now use real network traffic from a medium-sized data center, where more than 100 applications run on about 3000 servers simultaneously. After talking with the network operators and software development engineers about the emergence of different applications, we make an in-depth analysis of the traffic collected from 720 servers deployed in 60 racks. The traffic lasts about one month, and the basic statistics of the top ten network-demanding applications are summarized in Table I. There are typically five emergence levels, i.e., significant, important, normal, unimportant and lax. For example, the event application and the vRoute application are responsible for communication of critical components, and are of the highest level of emergence, while data-backup and data-dist are applications running in the background and are of the lowest level of emergence. To illustrate the ineffectiveness of existing coflow scheduling methods, we plot the average

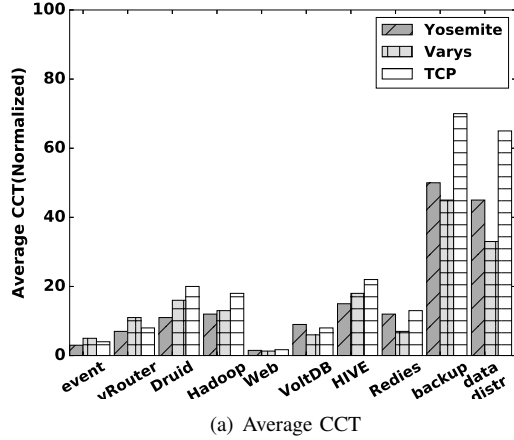


Fig. 2: [Simulation] Average CCT (Normalized) and Average WCCT for all applications

Coflow Completion Time (CCT) of different coflows, grouped by their levels of emergence, in Fig.1. Fig.1(a) shows the direct measurement result of all applications, while Fig.1(b) shows the simulation result when Varys is used to schedule them. Comparing the two plots, we can see that Varys clearly reduces the completion time of less emergent coflows, such as Redies, data-backup and data-dist, at the expenses of the same of even longer completion time of more emergent coflows, such as Event and vRouter. This motivates us to optimize the Weighted Coflow Completion Time (WCCT), where weight denotes the emergence of coflows, and the more emergent the coflow, the higher the weight. Coflow scheduling algorithms should take coflow weight into consideration, and optimizing CCT becomes just a special case of optimizing WCCT.

TABLE I: Applications and their levels of emergence

App Name	Type	width	length (MB)	Emergence Level
Event	communication	20	5	significant
vRouter	communication	8	3	significant
Druid	interactive	6	18	important
Hadoop	computation	5	42	normal
Web	interactive	3	5	normal
VoltDB	background	4	21	normal
Hive	background	7	32	unimportant
Redies	background	2	30	unimportant
data-backup	background	3	124	lax
data-dist	background	5	93	lax

III. ALGORITHM

Efficient algorithm is needed to schedule coflows according to the network condition and emergence level. Algorithm 1 prioritizes coflows according to the heuristics explained above (line 1 ~ 13) and allocates bandwidth to each flow (line 14 ~ 22). At last, it distributes the unallocated bandwidth equally among all unfinished flows to provide resource conservation. Algorithm 1 is an information-agnostic online algorithm that dynamically schedule coflows according to their weights and the instantaneous network condition.

Algorithm 1 Information-agnostic Online scheduling to minimize WCCT

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1: if a new coflow arrives then
2:   update the coflow list  $\mathcal{F} = \{F^{(k)}\}$ 
3:    $n = |\mathcal{F}|$ 
4:   for  $1 \leq k \leq n$  do
5:     update  $s_{i,j}^{(k)}$ , the cumulative volume of the traffic sent
       by coflow  $F^{(k)}$ , for  $1 \leq i, j \leq m$ 
6:      $L_i^{(k)} = \sum_{j=1}^m s_{i,j}^{(k)}$  for  $1 \leq i \leq m$ 
7:      $L_{j+m}^{(k)} = \sum_{i=1}^m s_{i,j}^{(k)}$  for  $1 \leq j \leq m$ 
8:      $l^{(k)} = \min_{1 \leq i \leq 2m} L_i^{(k)}$ 
9:      $\alpha^{(k)} = l^{(k)} / w_k$ 
10:  end for
11:   $\omega = \text{sort the list of } \{\alpha^{(k)}\} \text{ in nondecreasing order}$ 
12:   $\gamma = \text{index set of } \omega$ 
13: end if
14: initialize the bandwidth to be allocated on each ingress
    and egress port:  $I_p = O_p = \text{port physical bandwidth}$ , for
     $1 \leq p \leq m$ 
15: for  $\ell$  from 1 to  $n$  do
16:   schedule coflow  $F = F^{\gamma[\ell]}$ 
17:    $r = \min \{I_p, O_q\}$ , subject to  $F$  still need to send traffic
       to port  $p$  or receive traffic from port  $q$ 
18:   for each unfinished flow  $F_{i,j}$  in  $F$  do
19:     allocate bandwidth of  $r$  to  $F_{i,j}$ 
20:     update  $I_i$  and  $O_j$  by deducting  $r$  from them
21:   end for
22: end for
23: allocate remaining bandwidth equally to all flows

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To test the performance of this. We set 5 level of emergence in our data center and use 5, 4, 3, 2, 1 to present the Significant, Important, Normal, Unimportant and Lax level of emergence, then Fig. 2 shows the result. We can see that for vRouter and event which own significant level emergence, Varys performs almost to TCP, while Yosemite performs about 20% better than TCP. For Hadoop and Druid (Important), Yosemite performs about 30% better than Varys. While other unimportant applications Varys perform about 10%~20% better than Yosemite.

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