Developing Communication-aware Service Placement Frameworks in the Cloud Economy

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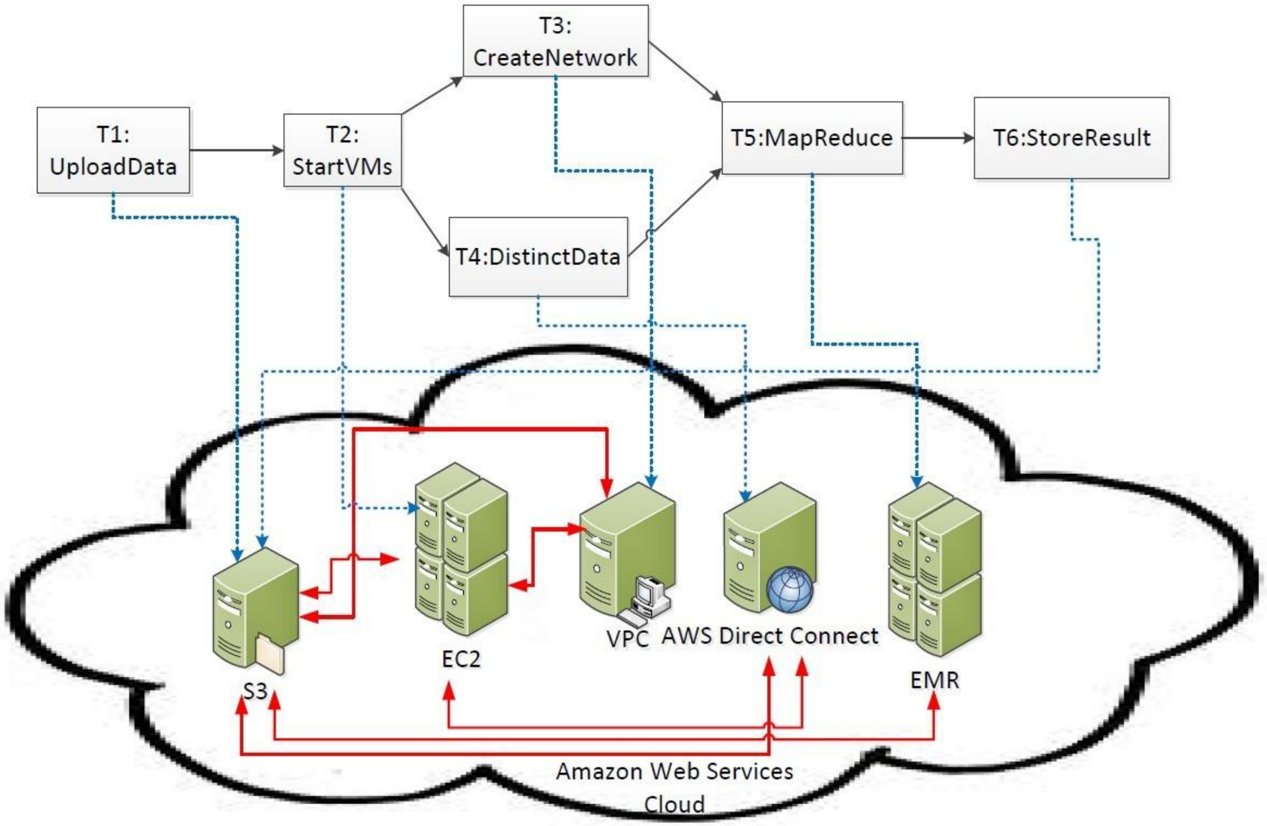
Multitenant cloud system

- Cloud system with multiple tenants and services
  - Cloud Tenants: Users renting services and virtual machines.
  - Cloud system(Datacenter)
    - Cloud providers: deliver a level of QoS(Quality-of-Service), such as: Amazon Web Services, Microsoft Azure, Google Cloud Platform, etc,
    - Cloud Services: hosted by a collection of virtual machines running different jobs: data analysis, web servers, etc.

Example: NASDAQ OMX



S3:
Amazon simple Storage Service

EC2:
Amazon Elastic Compute

VPC:
Amazon Virtual Private Cloud

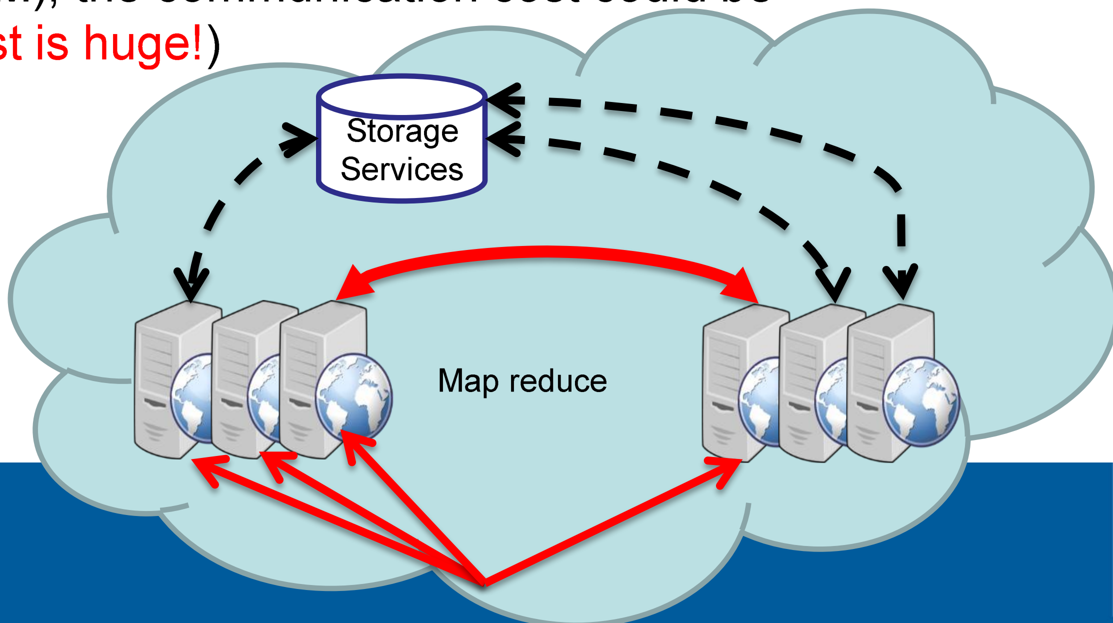
Direct Connect:
Amazon Direct Connect

EMR:
Amazon Elastic MapReduce

Challenges

1. Task/Service invocations may vary according to dynamic system information, and it may be difficult to know the full picture of the tasks/workflows in the Cloud. This work is *service-oriented*, which does not focus on allocating resources for *a set of specific tasks or workflows*, but aim to allocate resources based on *the interaction patterns between services*.

2. When the services interact with each other, data might be(cached) communicated between them. If the Virtual machine(VMs) that host the services with frequent communications among themselves can be placed to the same Physical Machine(PM), the communication cost could be significantly reduced. (The cost is huge!)



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Leontief Input-Output Model in economy

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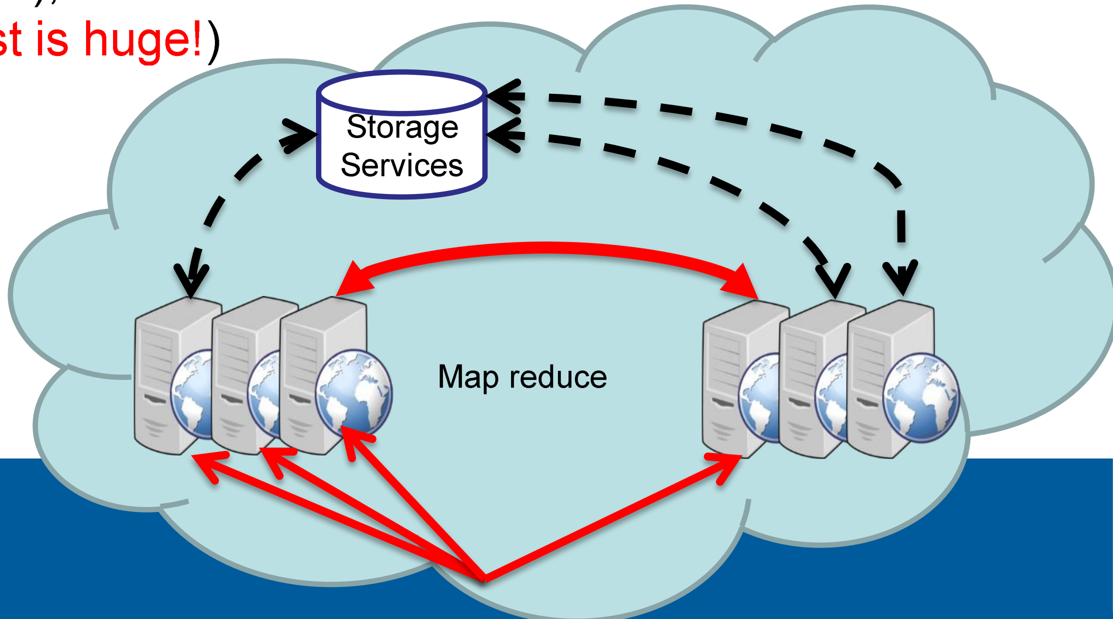
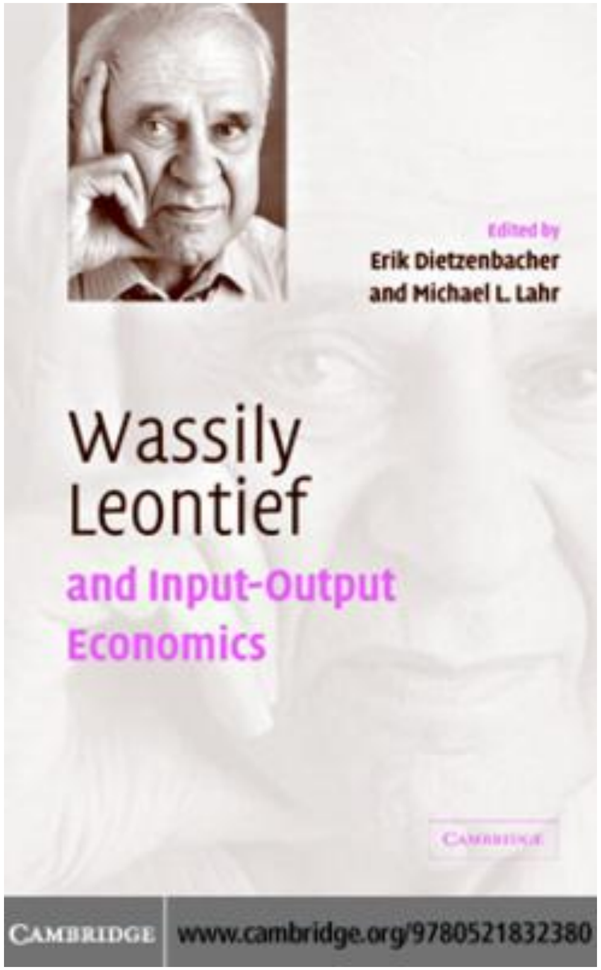
Genetic algorithm to find out the "optimal" solution



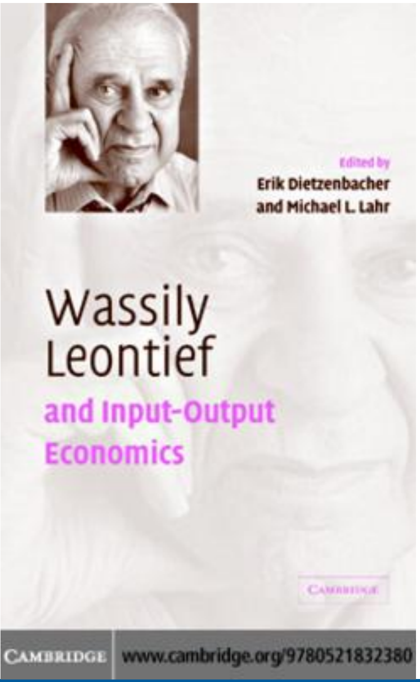
Leontief Input-Output Model



Leontief Input-Output Model

Exchange of Goods and Services in the U.S. for 1947 (in billions of 1947 dollars)

	Agriculture	Manufacturing	Services	Open Sector
Agriculture	34.69	4.92	5.62	39.24
Manufacturing	5.28	61.82	22.99	60.02
Services	10.45	25.95	42.03	130.65
Total Gross Output	84.56	163.43	219.03	



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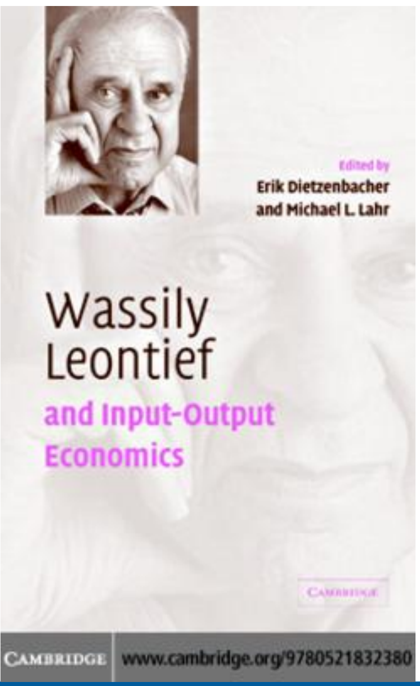

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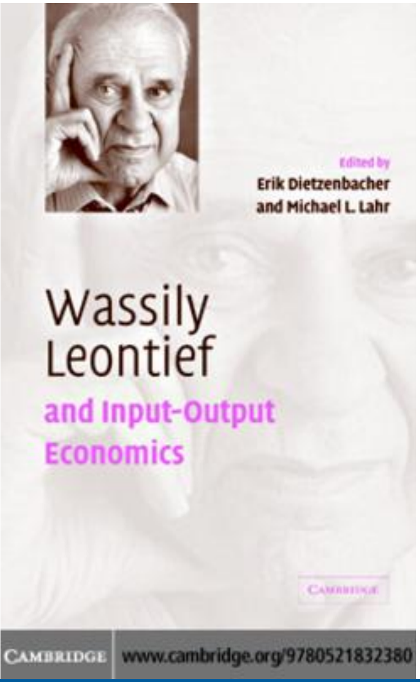
consumption matrix

demand vector

$$C = \begin{bmatrix} .4102 & .0301 & .0257 \\ .0624 & .3783 & .1050 \\ .1236 & .1588 & .1919 \end{bmatrix} \quad \mathbf{d} = \begin{bmatrix} 39.24 \\ 60.02 \\ 130.65 \end{bmatrix}$$



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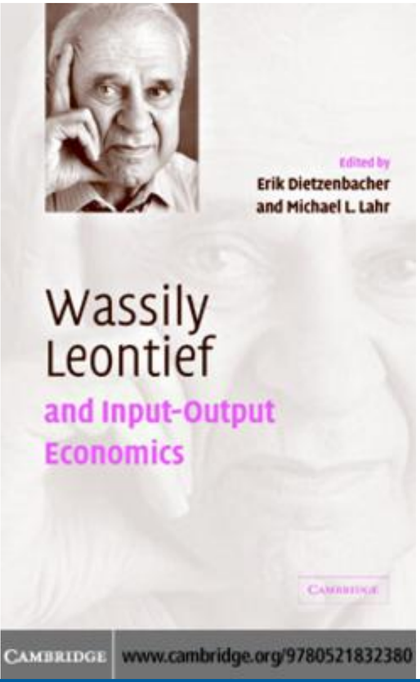

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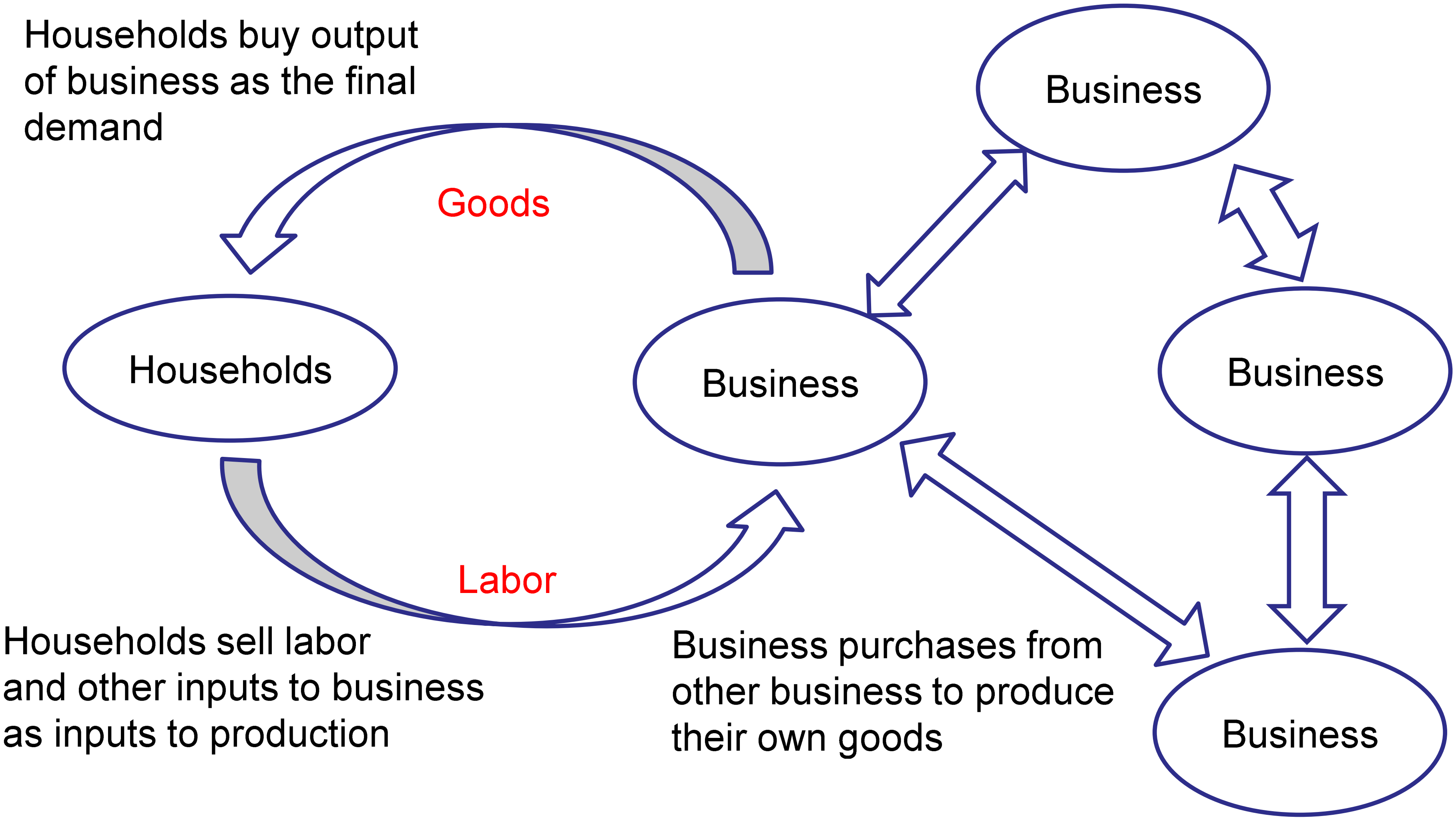
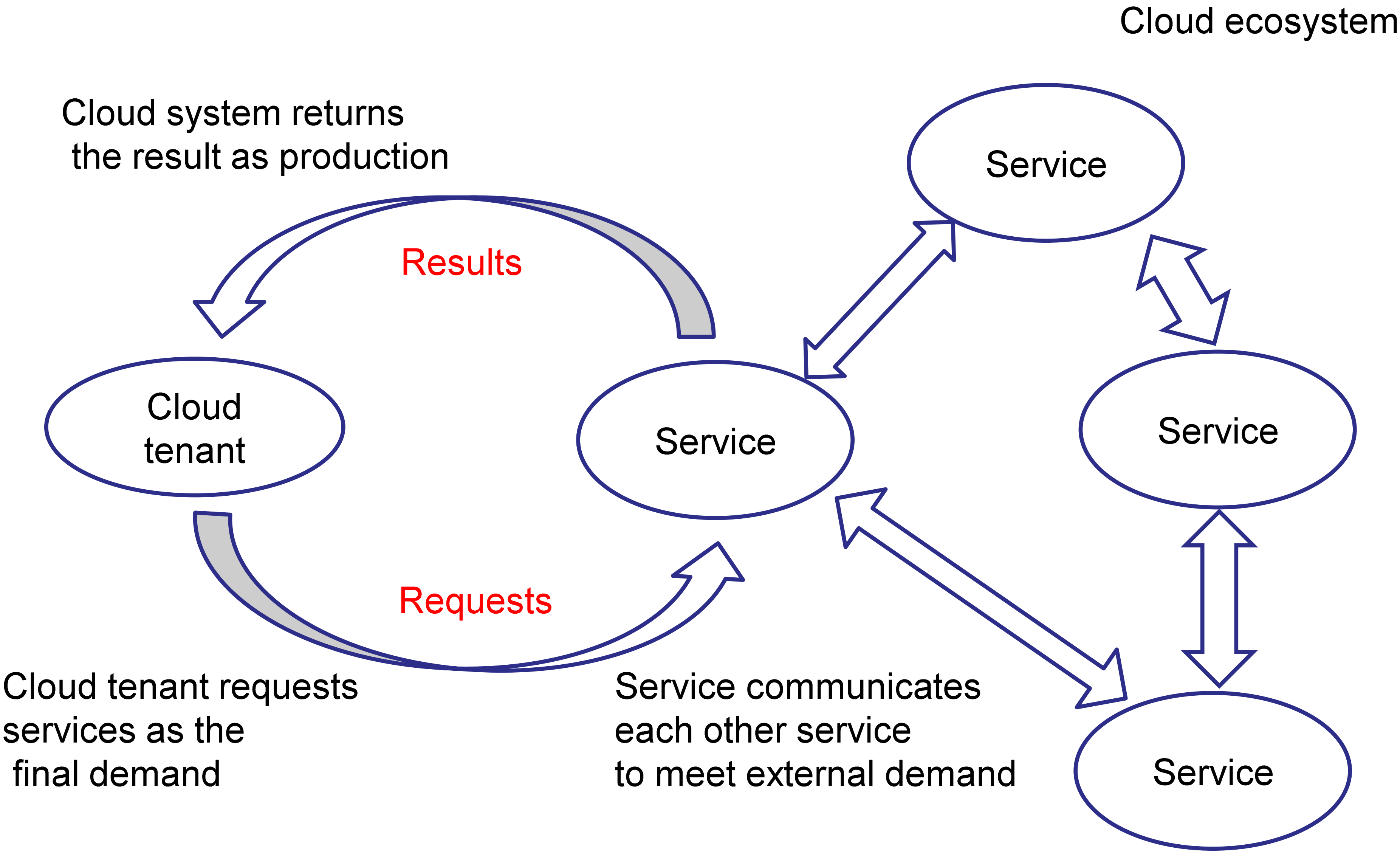
x - Equilibrium Production Level $\mathbf{x} = C\mathbf{x} + \mathbf{d}$

$$\mathbf{x} = (I - C)^{-1}\mathbf{d} = \begin{bmatrix} 82.40 \\ 138.85 \\ 201.57 \end{bmatrix}$$

Modern industry ecosystem



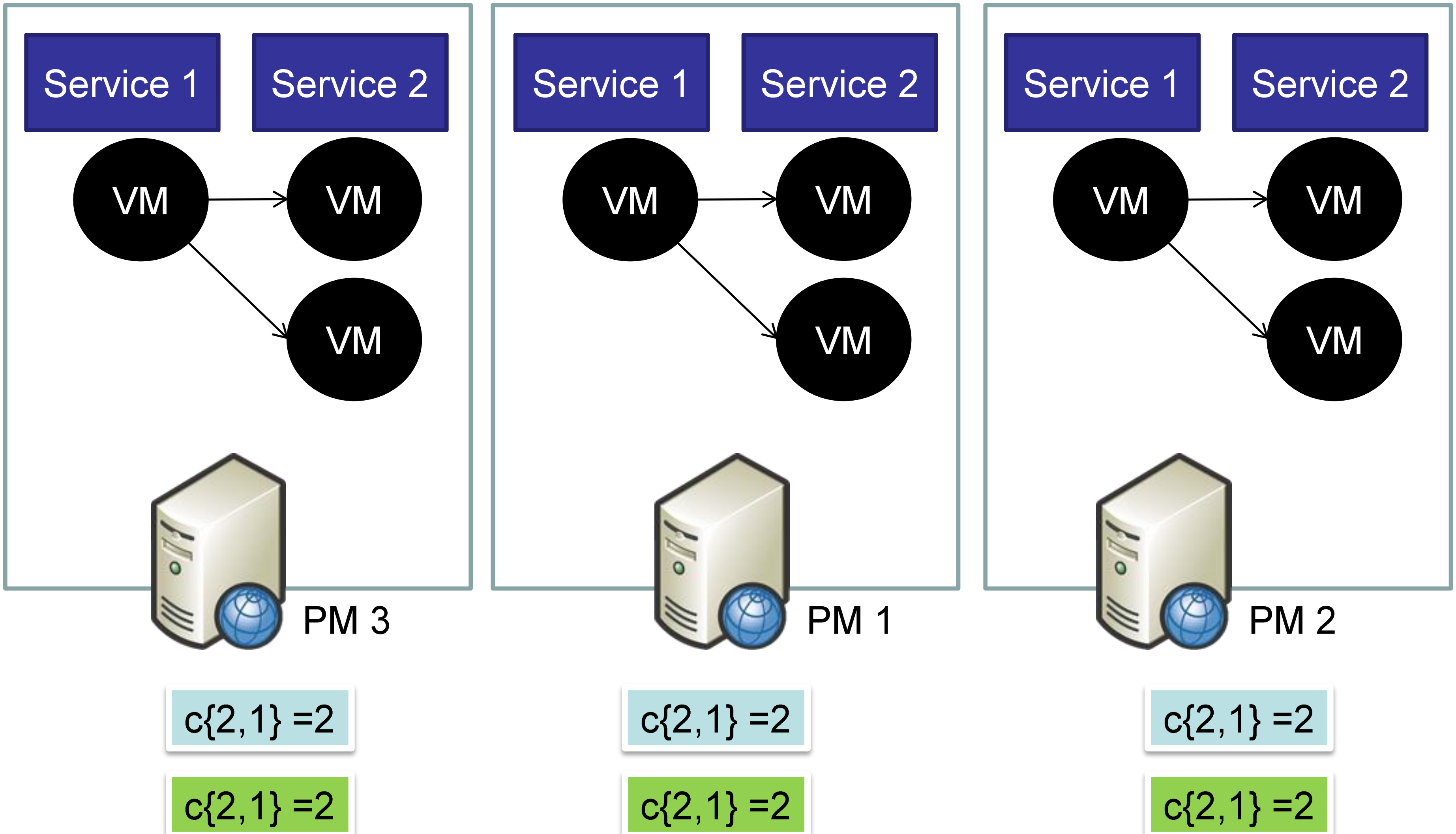

Cloud ecosystem
Cloud system returns
the result as production
Results
Service
Cloud
tenant
Service
Service
Requests
Cloud tenant requests
services as the
final demand
Service communicates
each other service
to meet external demand
Service

Consumption Matrix

	Service 0	Service 1	Service 2	Service 3	Service 4	External demand
Service 0	c{0,0}	c{0,1}	c{0,2}	c{0,3}	c{0,4}	λ0
Service 1	c{1,0}	c{1,1}	c{1,2}	c{1,3}	c{1,4}	λ1
Service 2	c{2,0}	c{2,1}	c{2,2}	c{2,3}	c{2,4}	λ2
Service 3	c{3,0}	c{3,1}	c{3,2}	c{3,3}	c{3,4}	λ3
Service 4	c{4,0}	c{4,1}	c{4,2}	c{4,3}	c{4,4}	λ4

c{2,1} =2

Consumption relation



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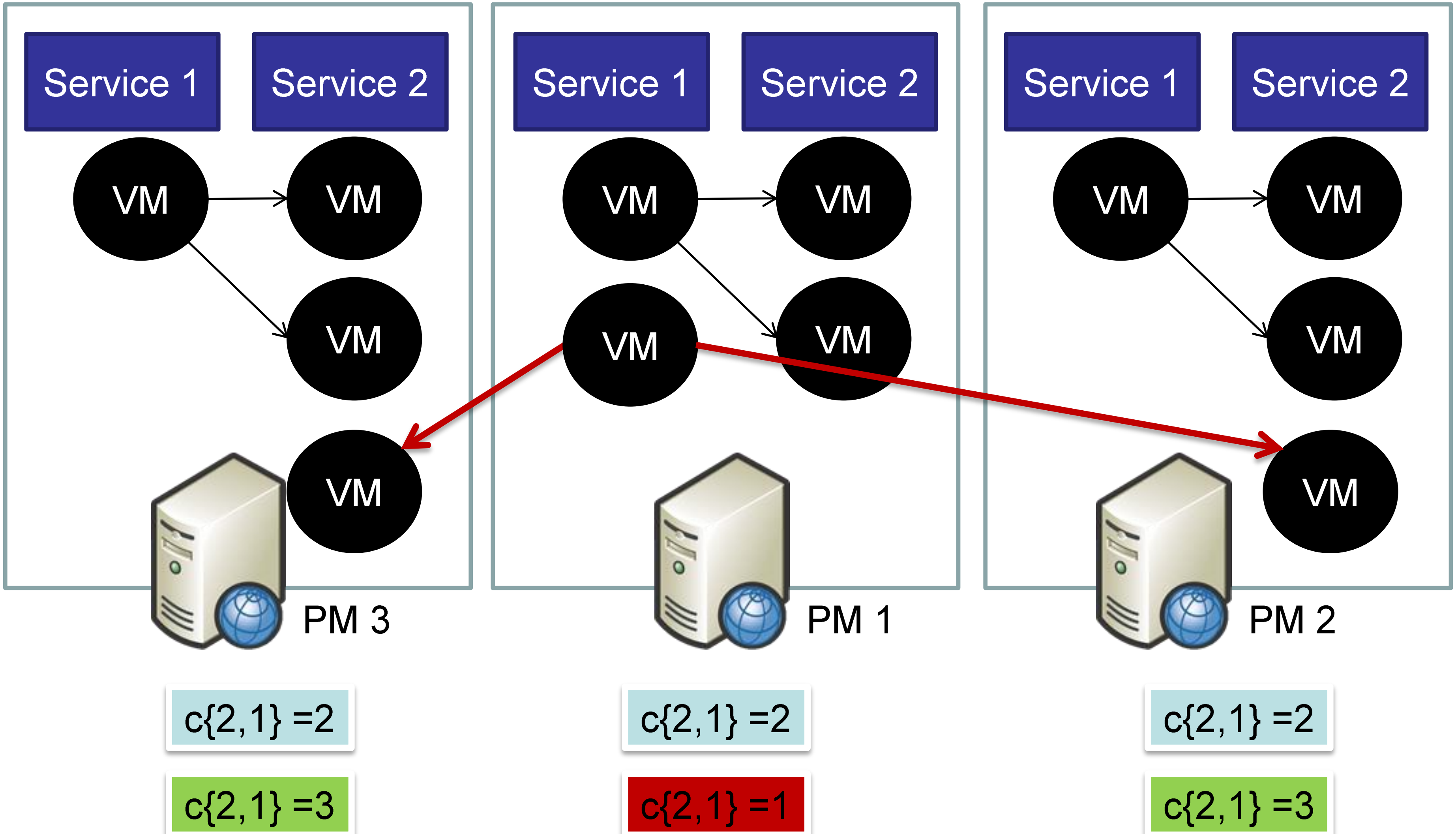

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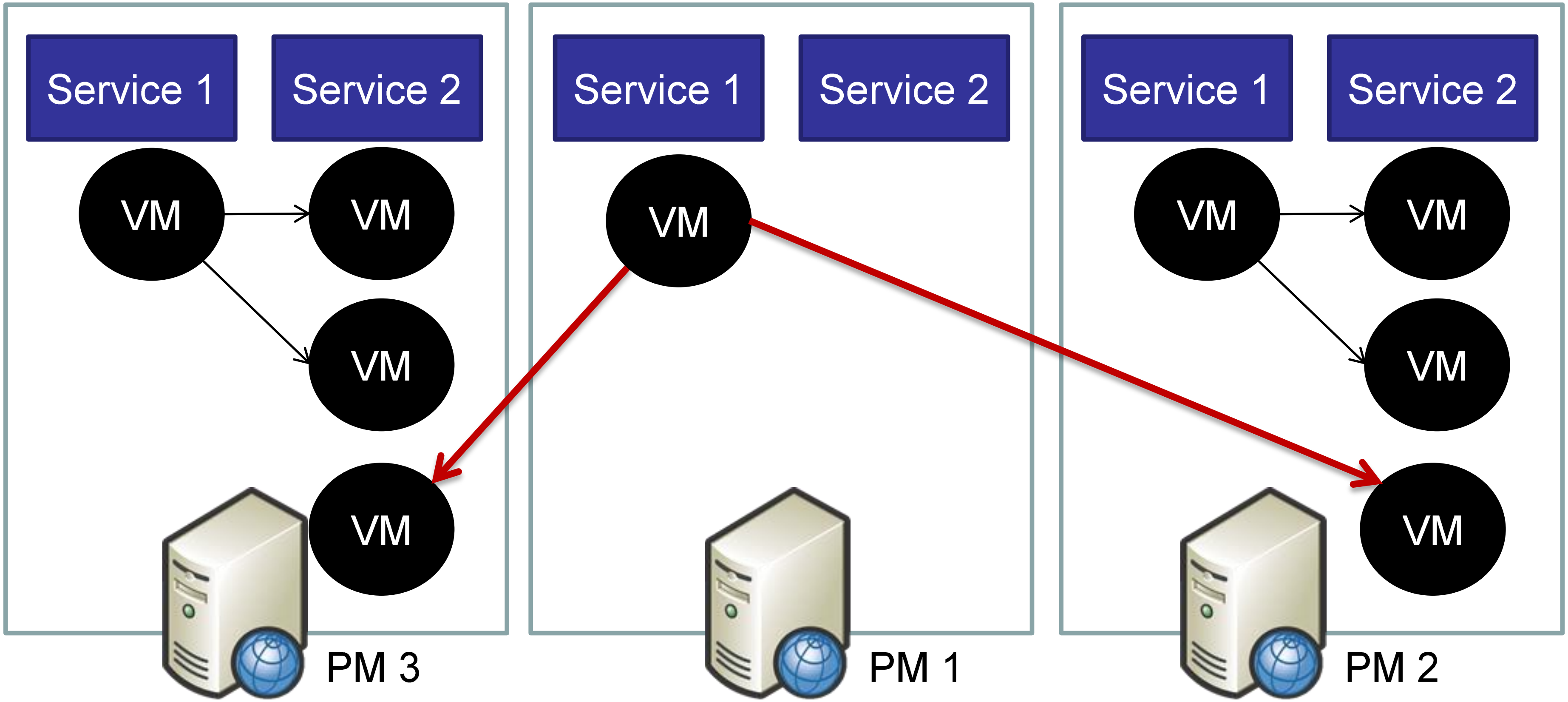


c{2,1} =2	c{2,1} =2	c{2,1} =2
c{2,1} =3	c{2,1} =0	c{2,1} =3

Communication Cost

$$\mathcal{C}(\mathcal{M}) = \sum_{k=1}^{N}\sum_{j=1}^{M}\sum_{i=1}^{M}\beta_{ijk} \qquad (6)$$

calculates that the amount of requests that are sent from S{ *j* } in PM n{ *k* } to S{ *i* } in a time unit, but cannot handled by VM{ *i* } in n{ *k* } in order to maintain the QoS. Therefore, these requests have to be sent to be processed by VM{*i*} in a different PM.

$$\beta_{ijk} = \begin{cases} e_{ji} \times (f(j, R_j, v_{jk}) \times p_{ji} - f(i, R_i, v_{ik})) & \text{if } \alpha_{ijk} < c_{ij} \\ 0 & \text{otherwise} \end{cases} \qquad (7)$$

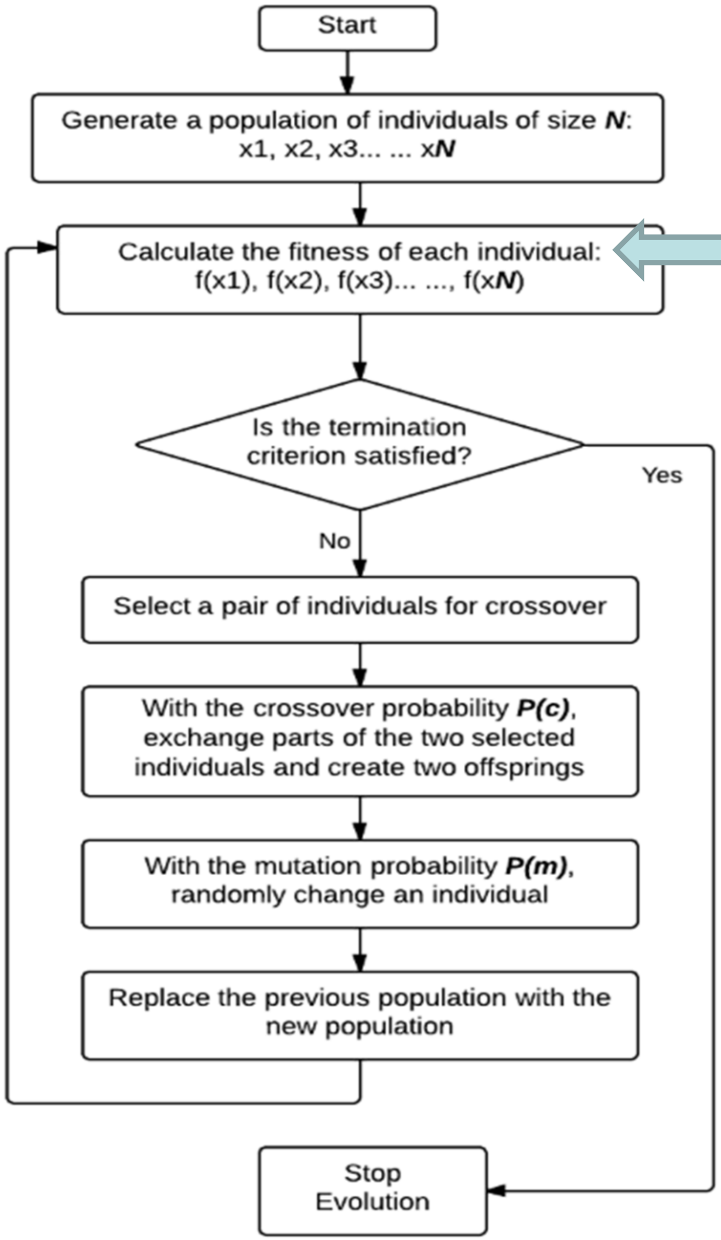
The ratio of the number of VM{ *i* } to the number of VM{ *j* } in the PM n{ *k* }

The total amount of data that have to be communicated in the Cloud caused by the inadequate resource capacity of S{ *j* } in PM n{ *k* } comparing with that of S{ *j* } in the same PM.

The objective is to find a VM-to-PM mapping such that $\mathcal{C}(\mathcal{M})$ is minimized, subject to certain constraints. This can be formalized as Eq. 8, where x_i is the number of VM^is

$$\begin{aligned} \text{miminize} \quad & \mathcal{C}(\mathcal{M}), \\ \text{subject to:} \quad & \forall i: 1 \le i \le M, \sum_{k=1}^{N} v_{ik} = x_i \\ & v_{ik} \ge 0 \end{aligned} \qquad (8)$$

Designing Genetic Algorithm for VMs Allocation Problem



Calculate it via Eq. 5

$$\mathcal{C}(\mathcal{M}) = \sum_{k=1}^{N} \sum_{j=1}^{M} \sum_{i=1}^{M} \beta_{ijk}$$

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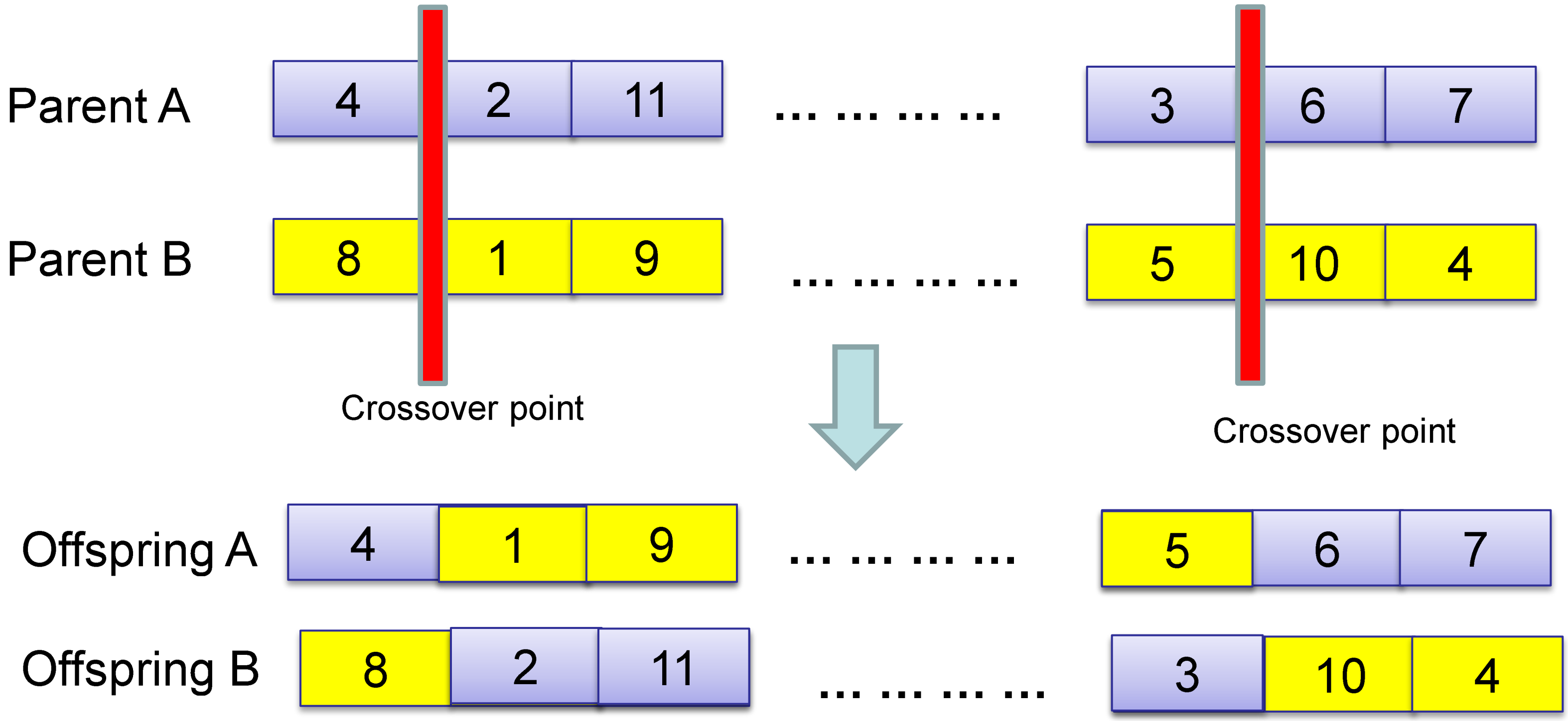
Genetic Algorithm : two points Crossover



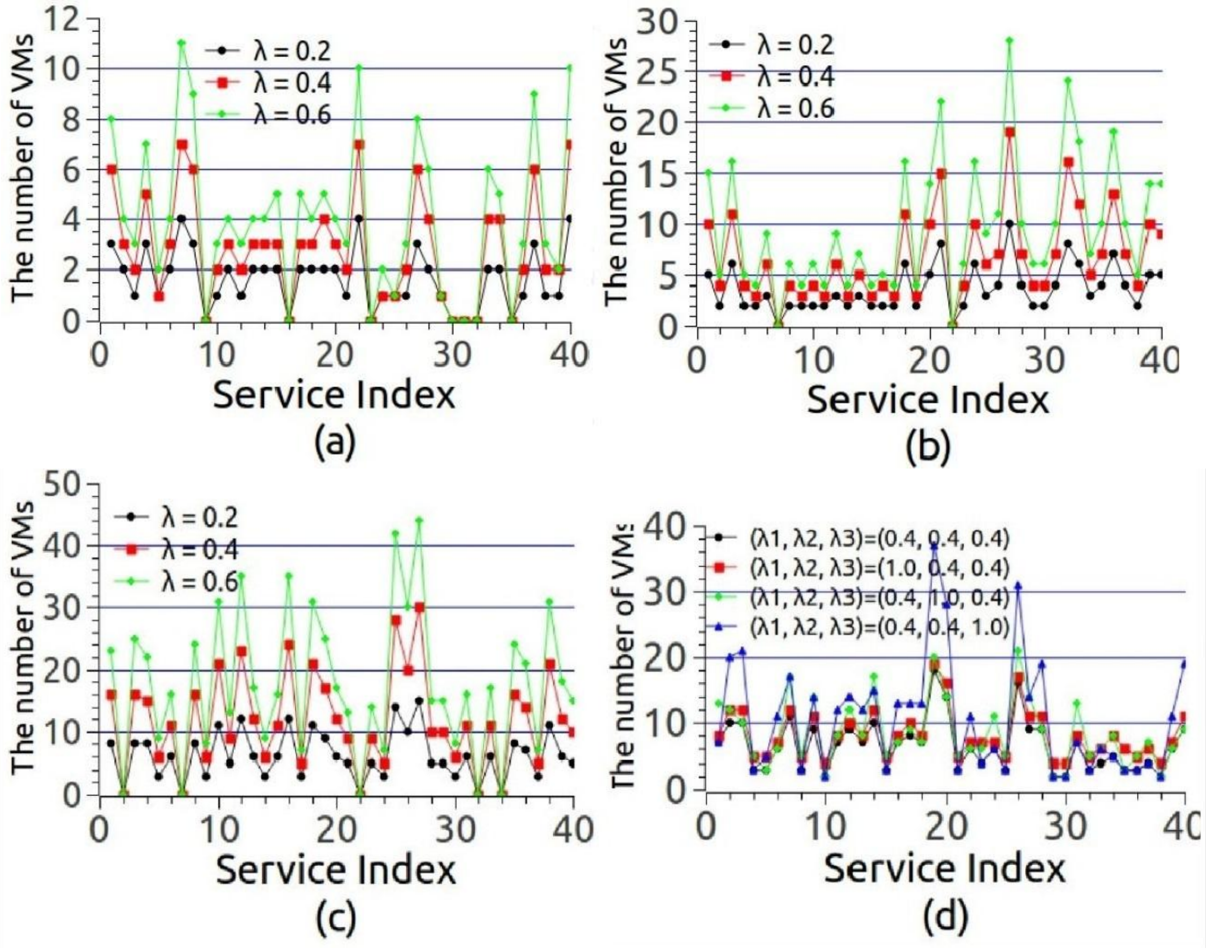
Impact of the increase in external demands

a: computation-intensive workflow

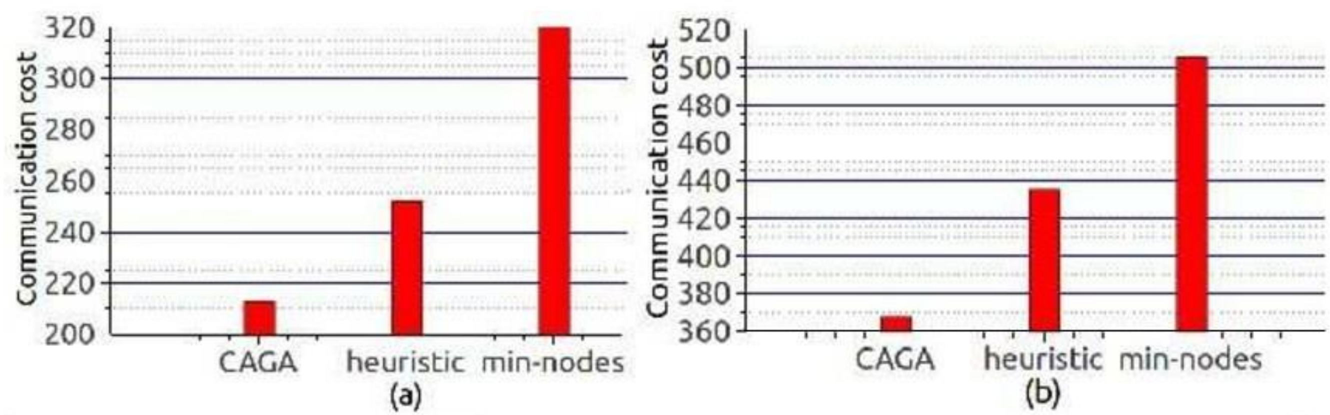
b: general workflow

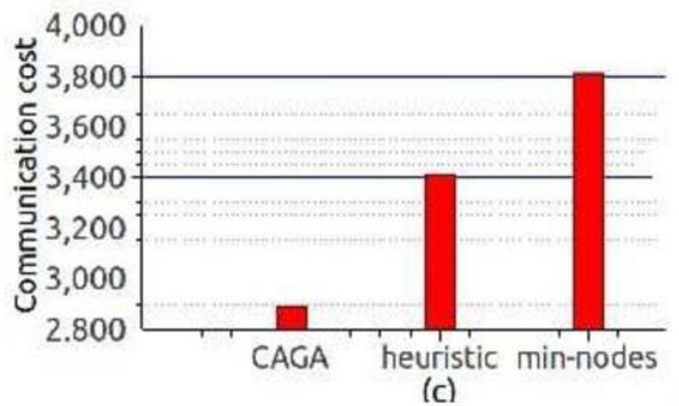
c: communication-intensive workflow

d: the three types of workflow combined



Comparing CAGA with mini-nodes and the round-robin heuristic in terms of communication cost



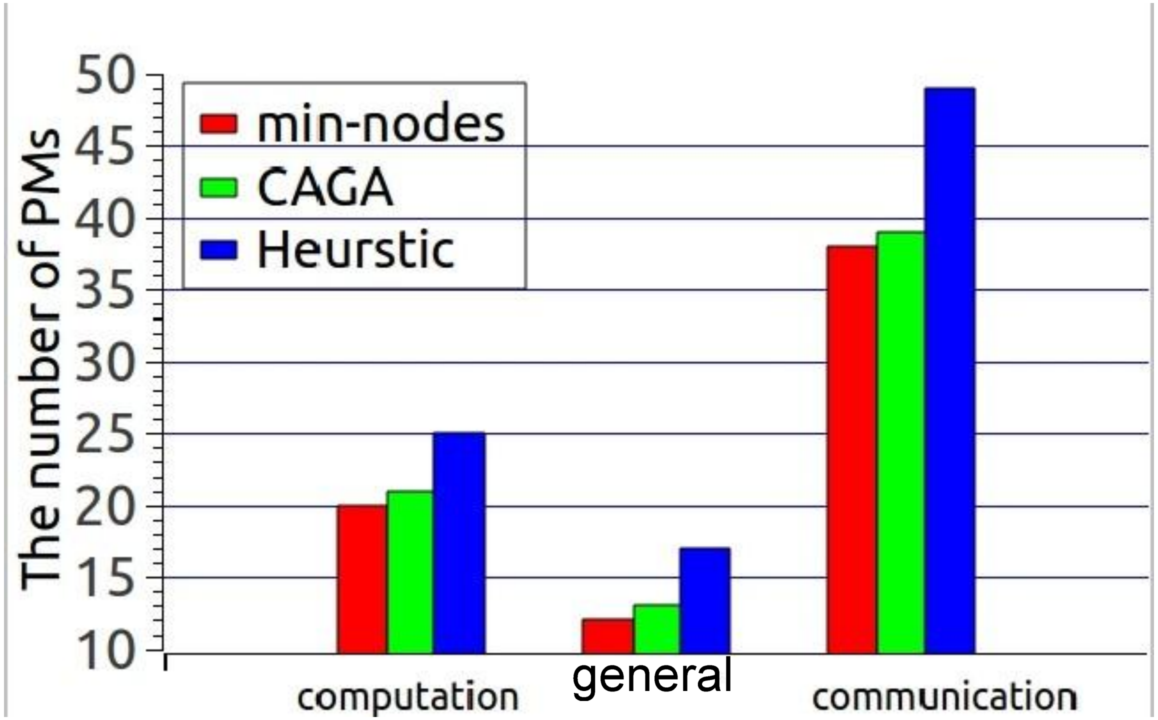


a: computation-intensive workflow

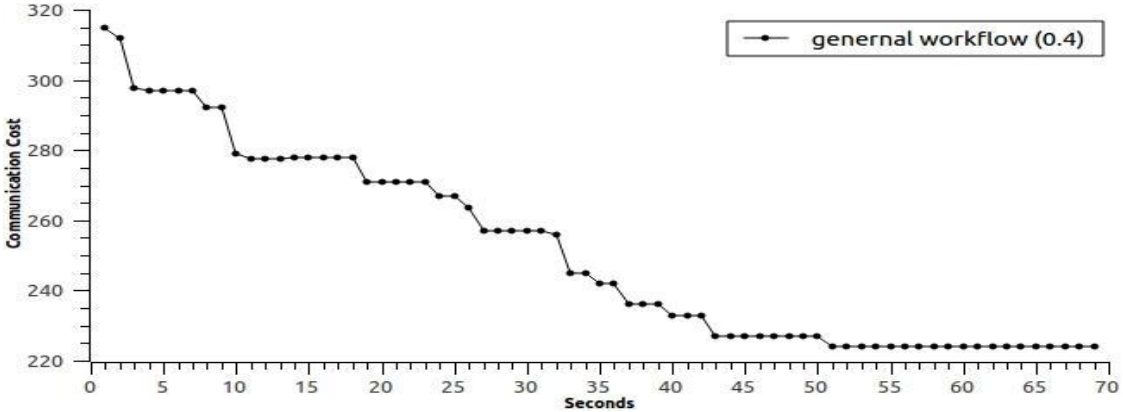
b: general workflow

c: communication-intensive workflow

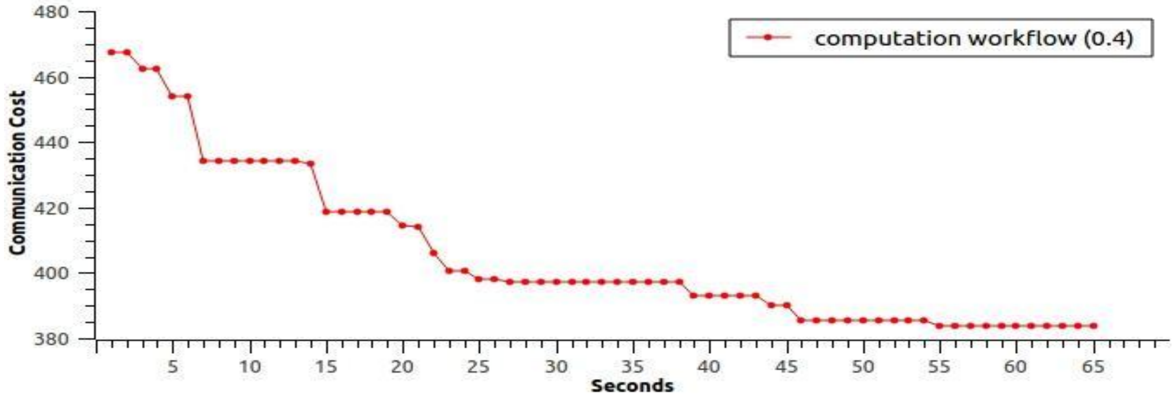
Comparing CAGA with mini-nodes and the round-robin heuristic in terms of number of used PMs



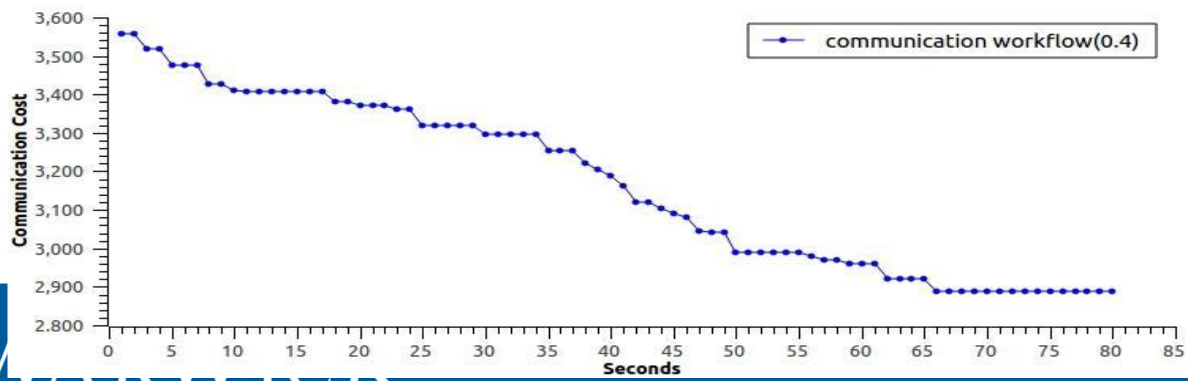
Convergence speed of CAGA



a: general workflow



b: computation-intensive workflow



c: communication-intensive workflow

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Question?