How Hard Can It Be?

Understanding the Complexity of Replica Aware Virtual Cluster Embeddings

Carlo Fuerst (TU Berlin, Germany), Maciek Pacut (University of Wroclaw, Poland)
Paolo Costa (Microsoft Research, UK), Stefan Schmid (TU Berlin & T-Labs, Germany)

Today‘s Cloud Computing

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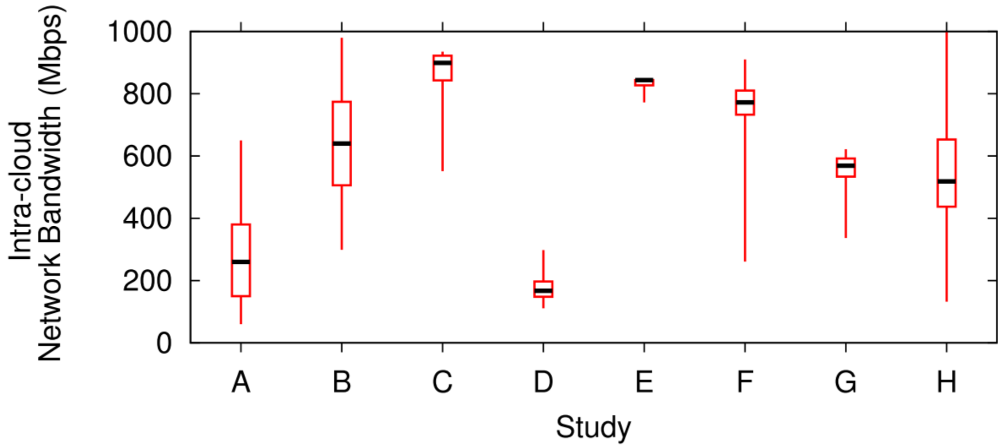

Figure 1: Percentiles (1-25-50-75-99th) for intra-cloud network bandwidth observed by past studies.

Source: Ballani et al. [1] in Sigcomm‘11

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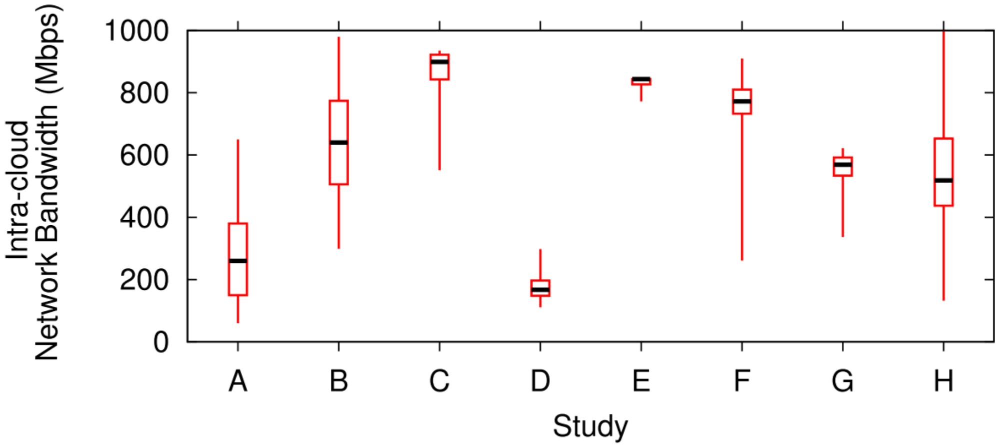

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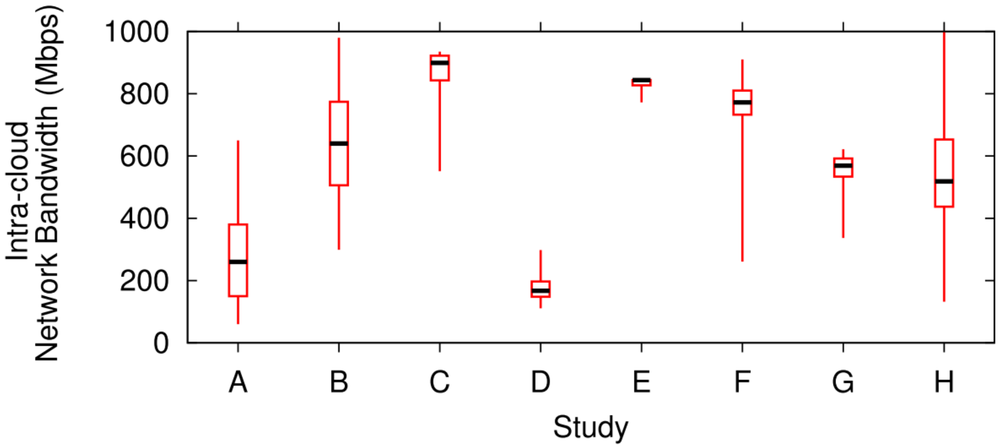

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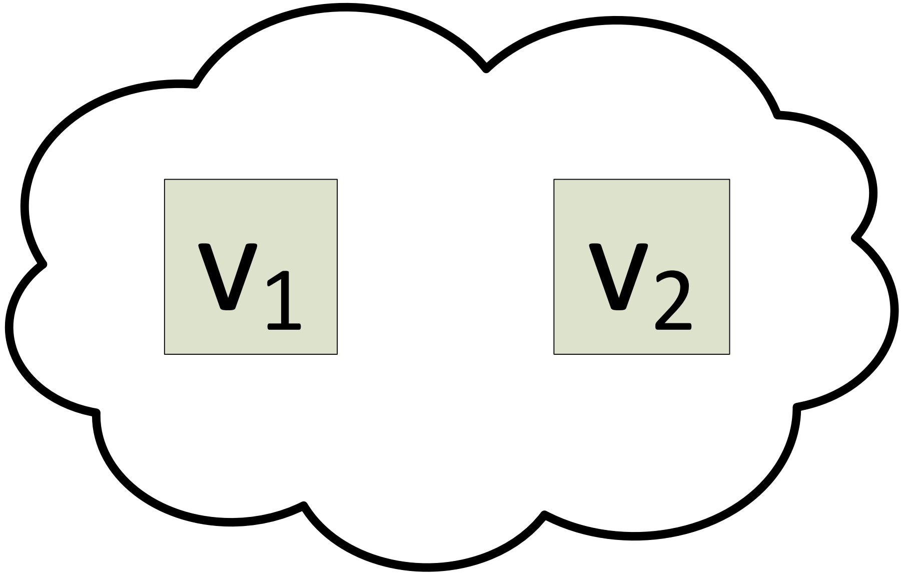
Costs for the tenats become unpredictable

Proposed Solutions: Virtual Clusters



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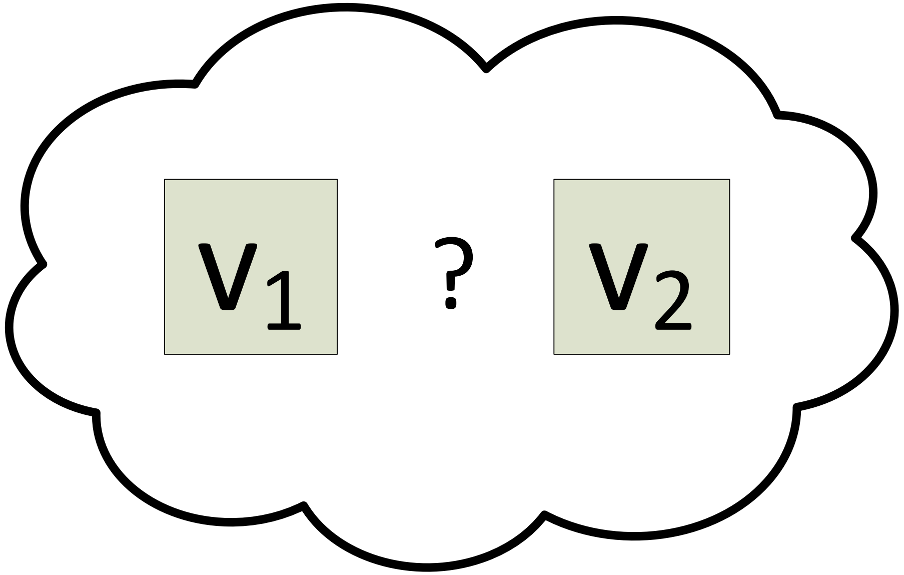

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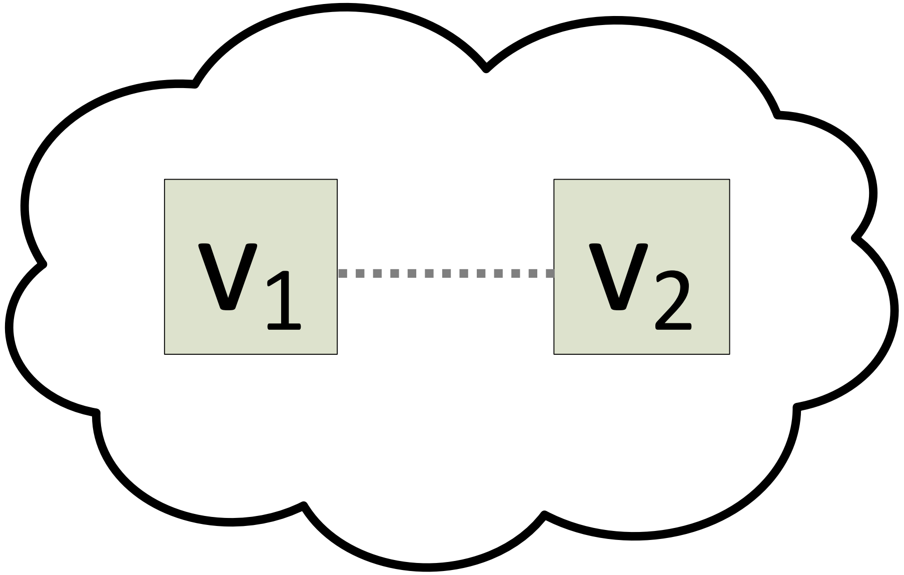


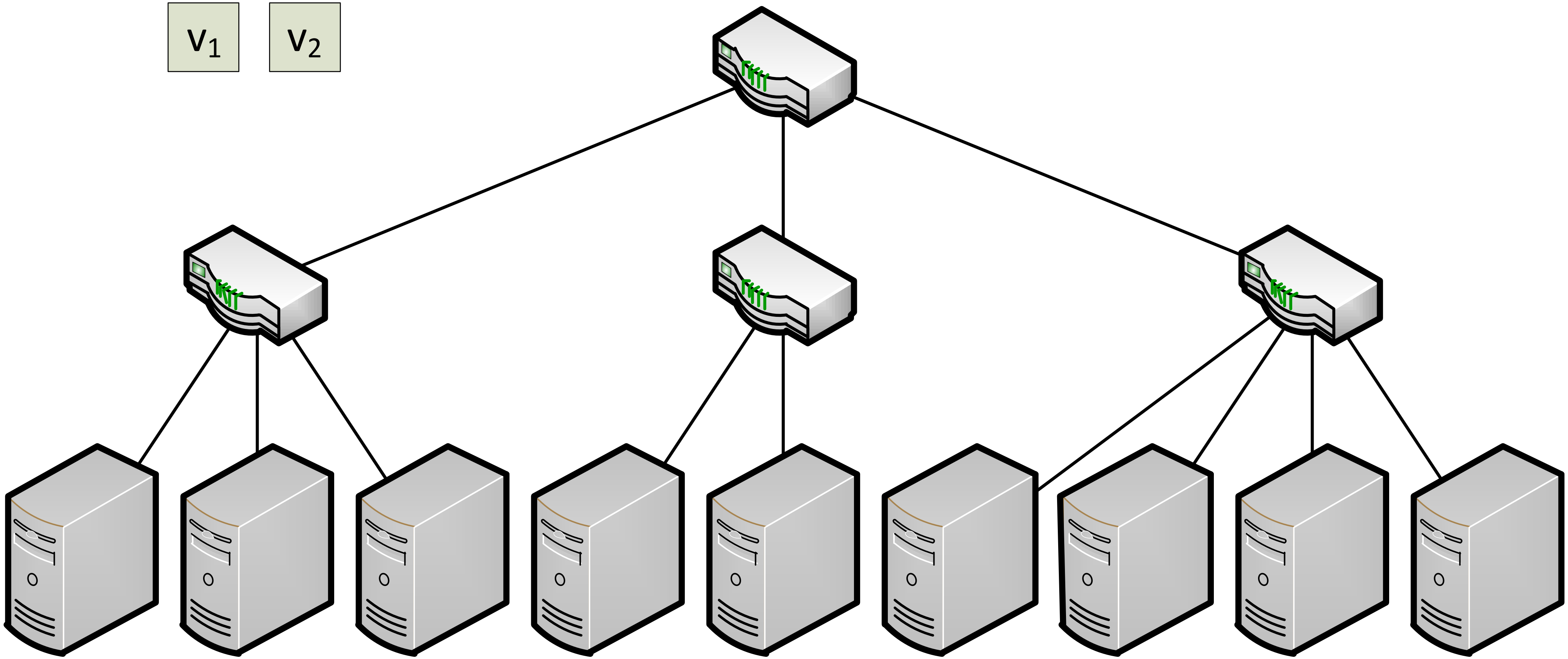
Remove the uncertainty by specifiying the bandwidth connecting the VMs

Proposed Solutions: Virtual Clusters

- Introduced by Ballani et al. [1]
- Provides absolute guarantees on VMs and network perfomance
- Specified by two parameters:
  - N the number of VMs
  - B the available bandwidth between VMs.

Embedding

v_1 v_2



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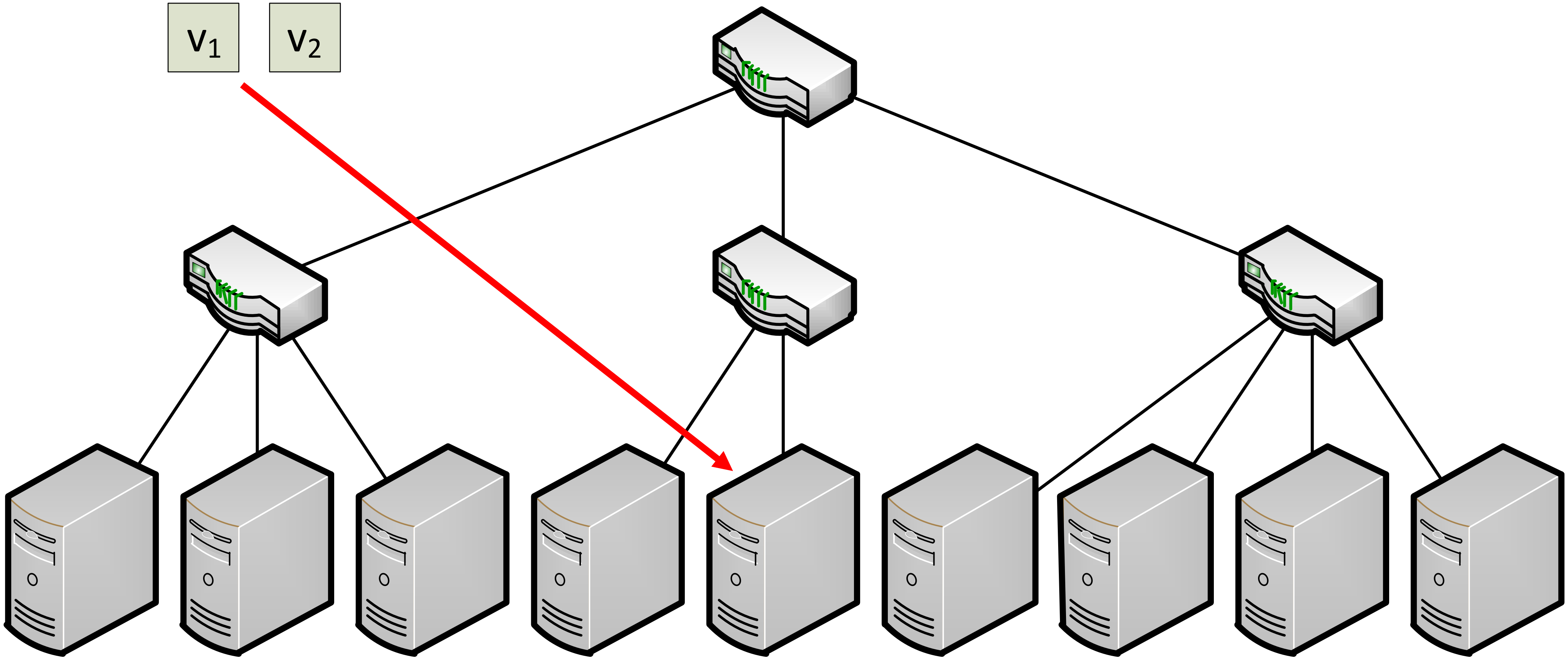

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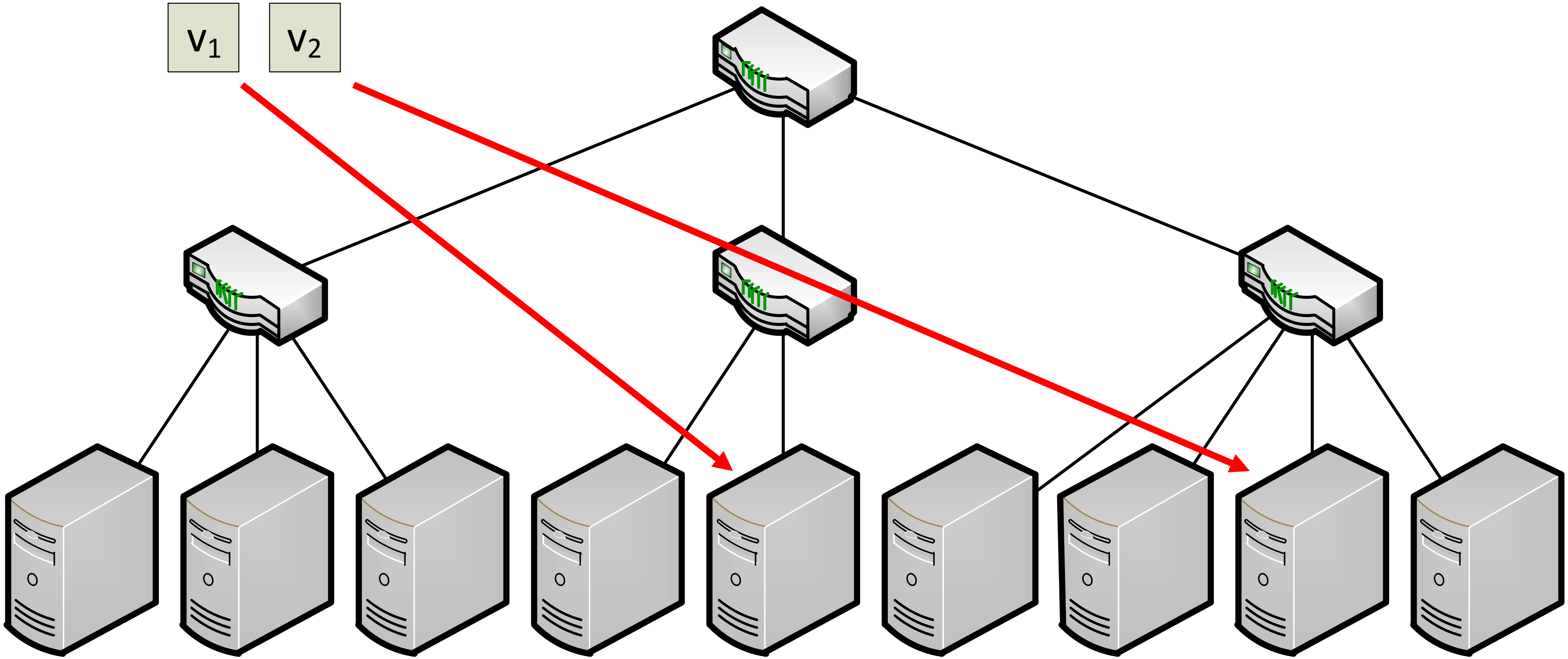

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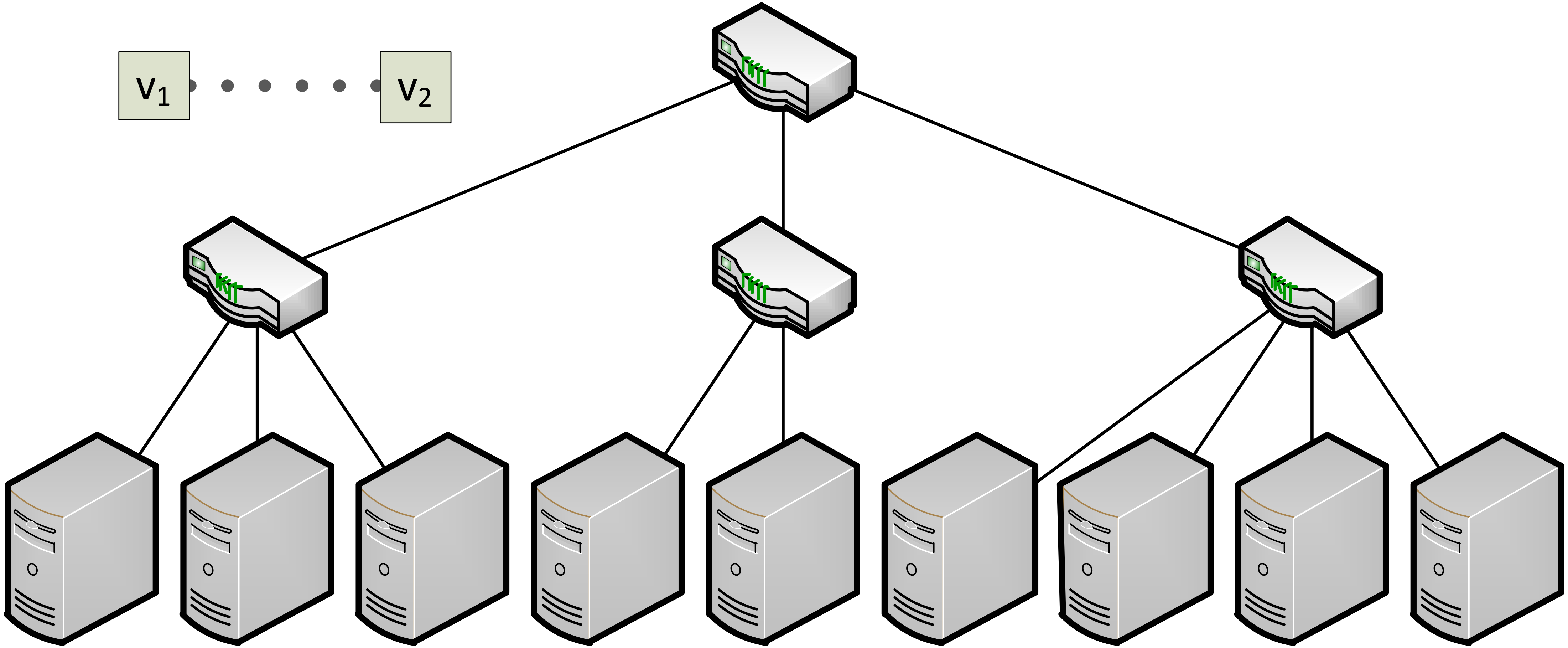

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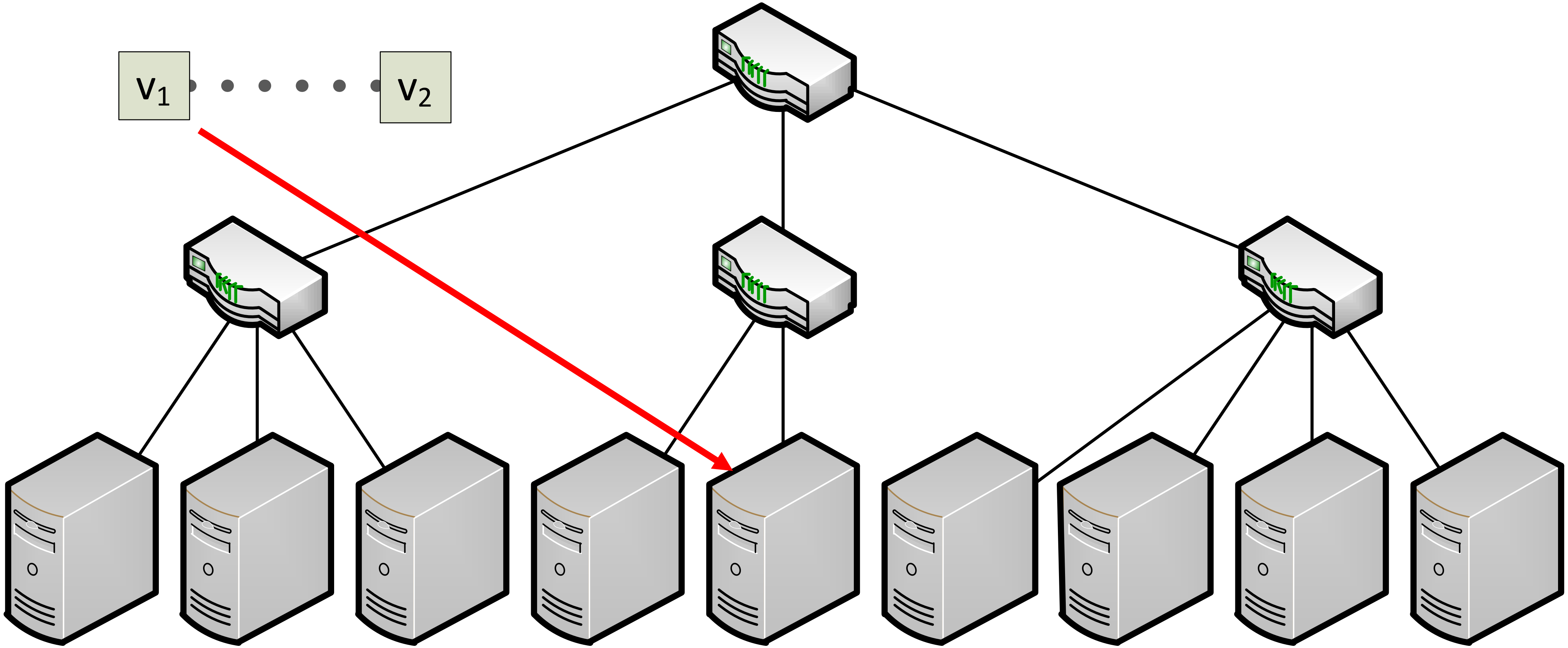

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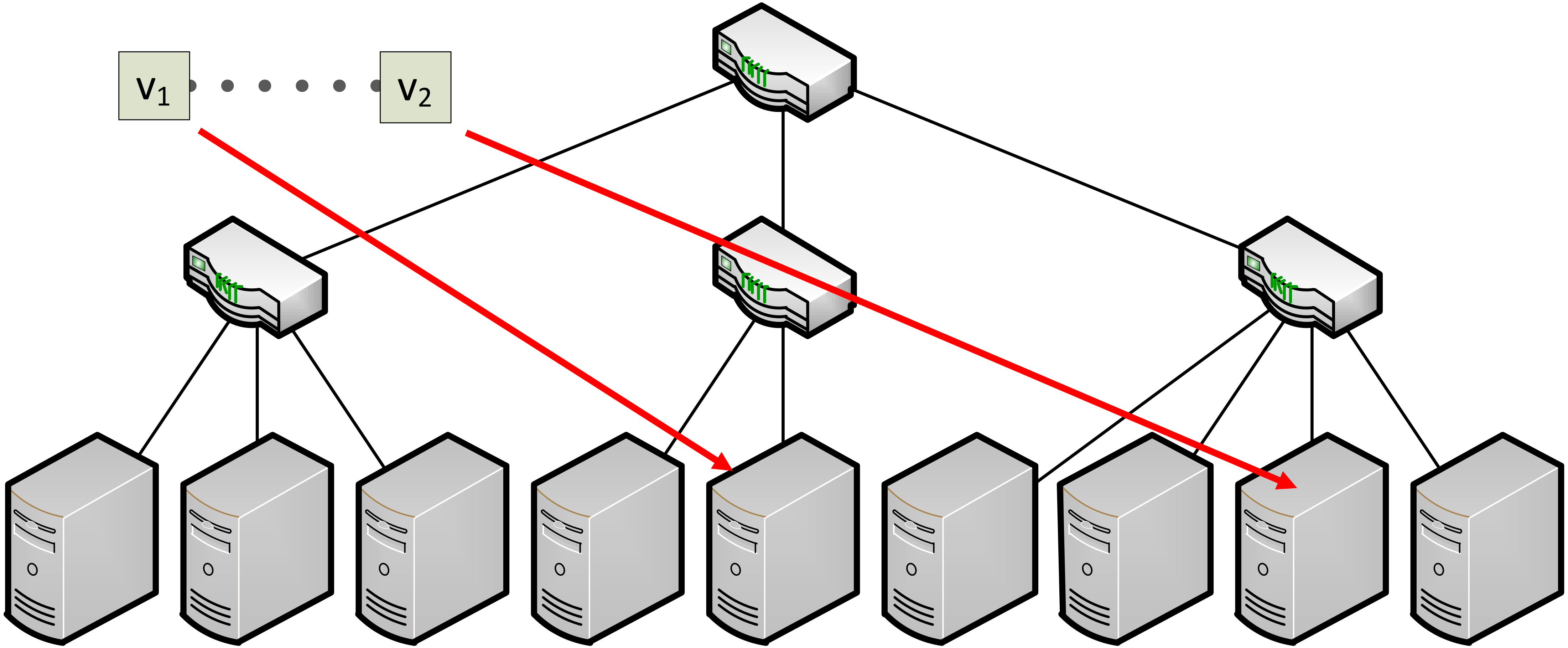

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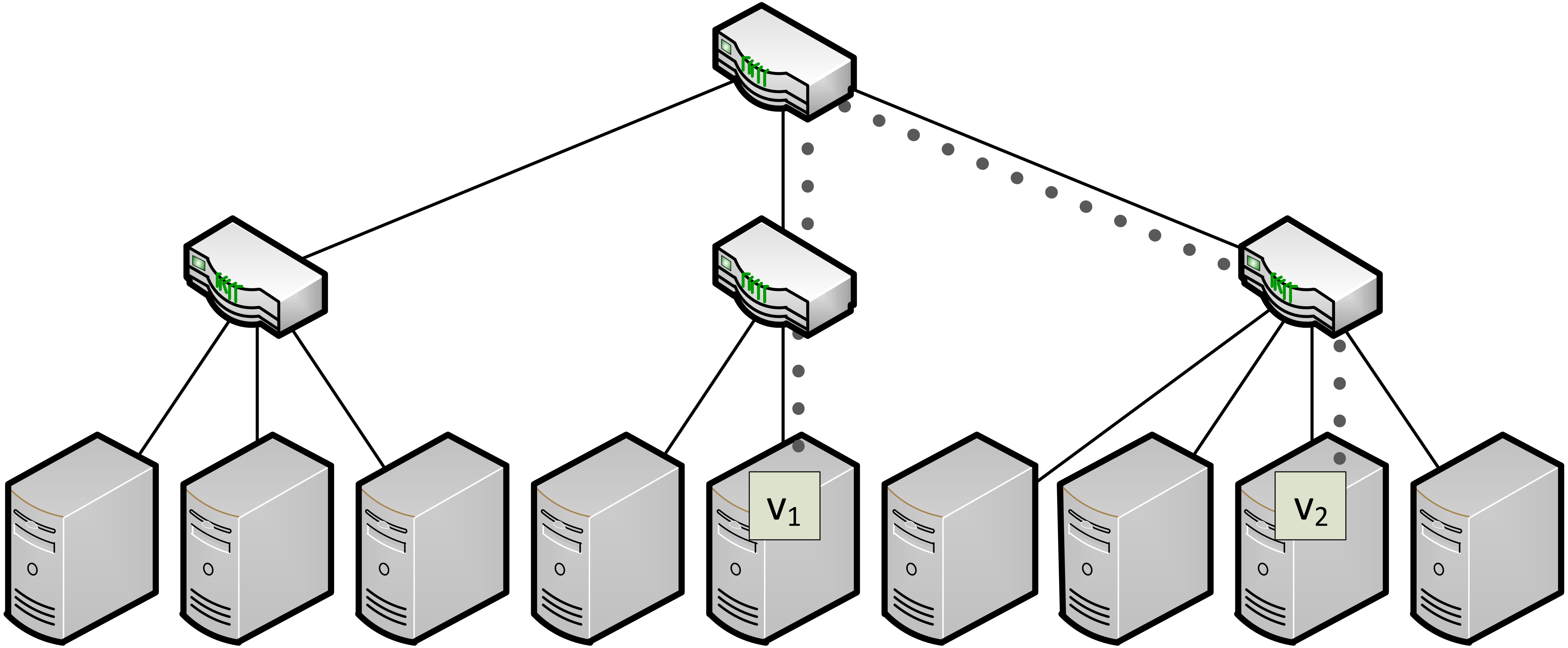

Virtual Cluster Embedding Problem

- Subproblem of the NP-hard virtual network embeddding problem
- Good heuristics available
  - Ballani et al. [1] in Sigcomm’11
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but…

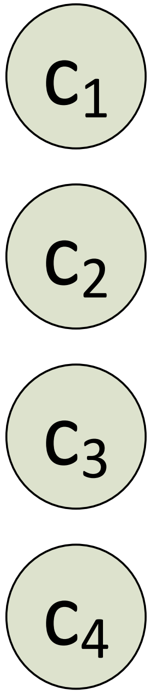
The virtual cluster embedding problem is *not* NP-hard.[4]

Can the problem be solved efficiently with additional properties?

Cloud Application: Batch processing

Example: MapReduce

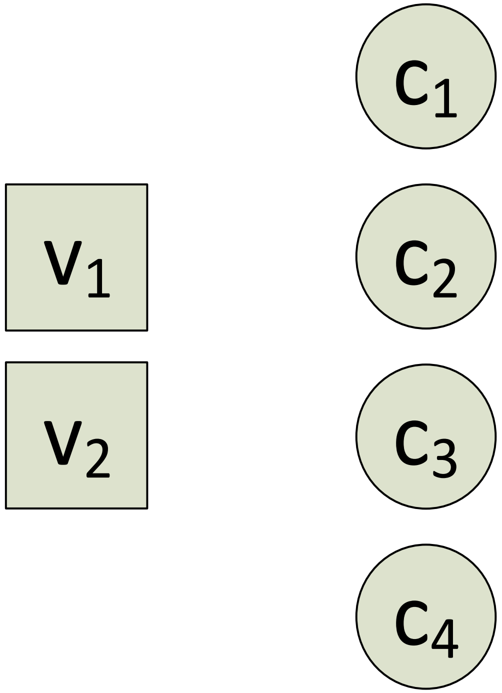
1. Input is given by a set of atomic chunks



Cloud Application: Batch processing

Example: MapReduce

1. Input is given by a set of atomic chunks
2. Every chunk is processed by a map task



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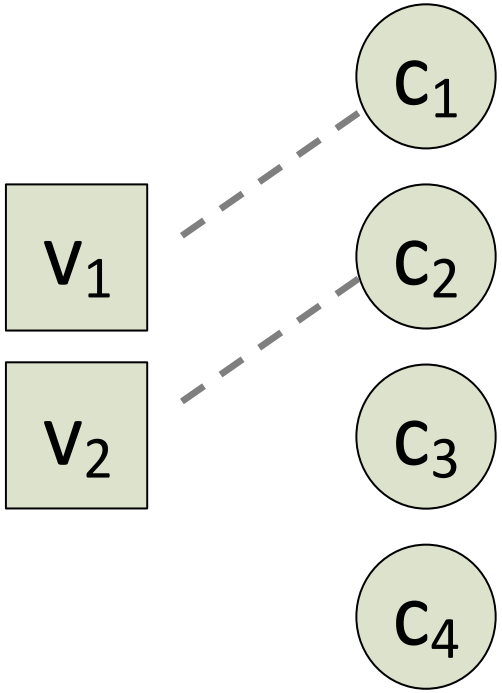

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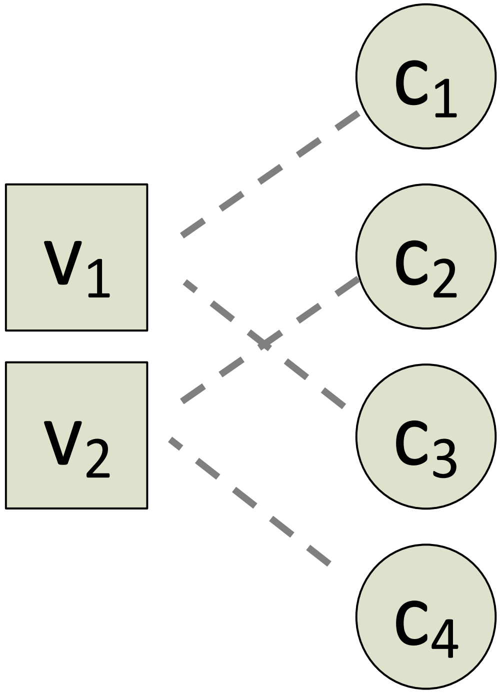

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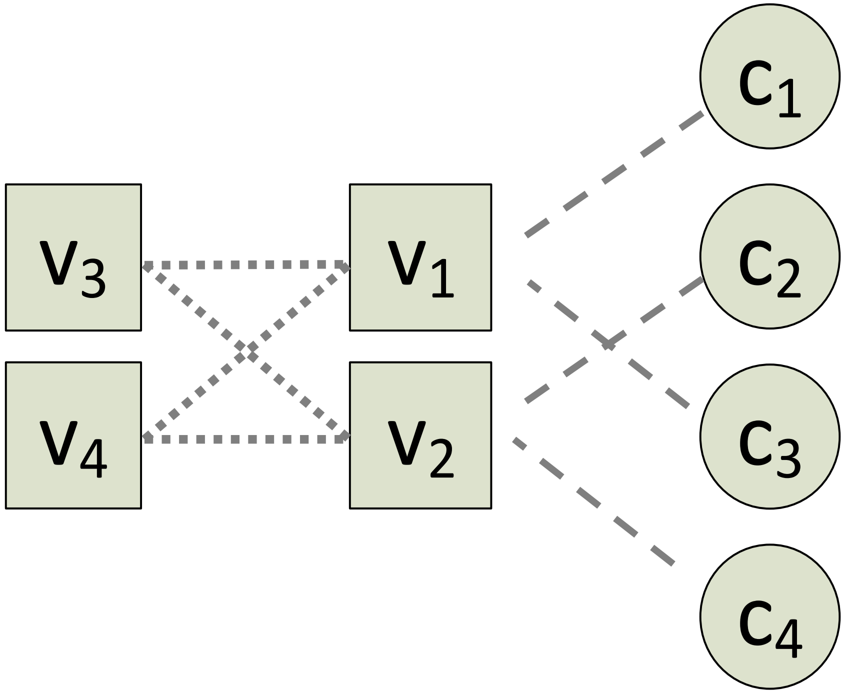

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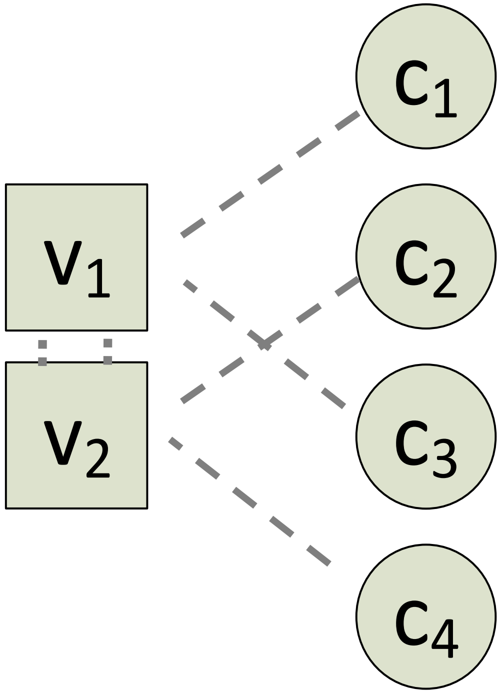

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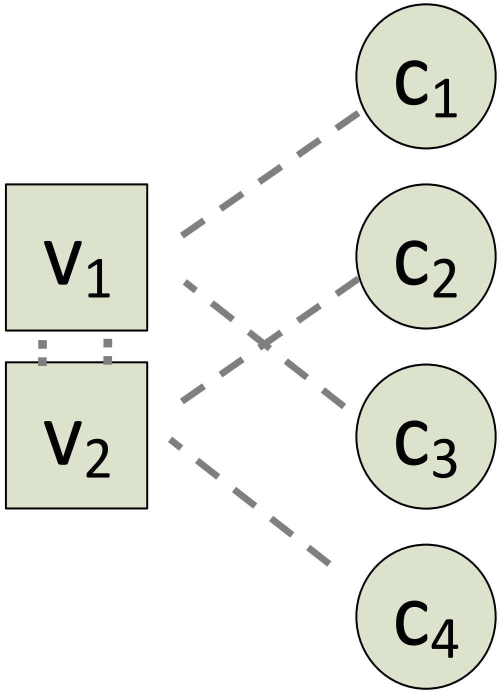

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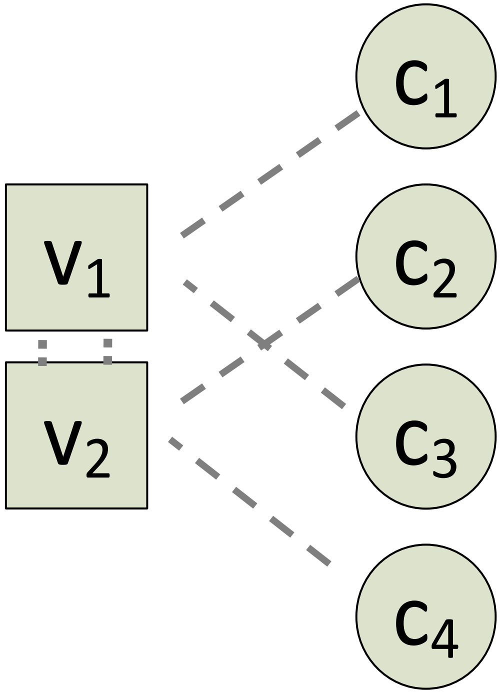

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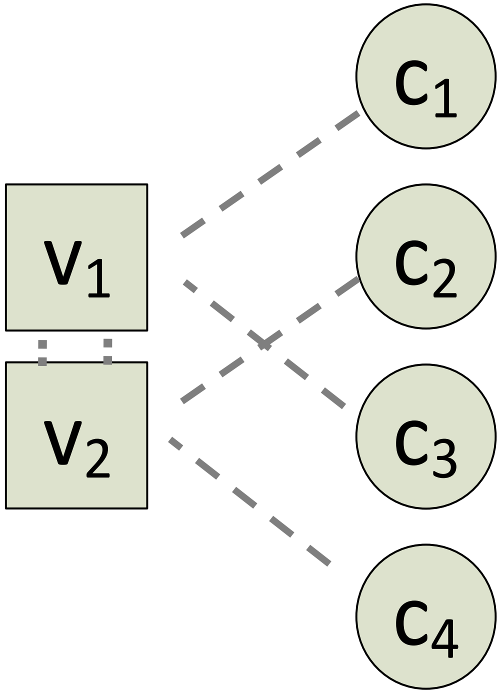
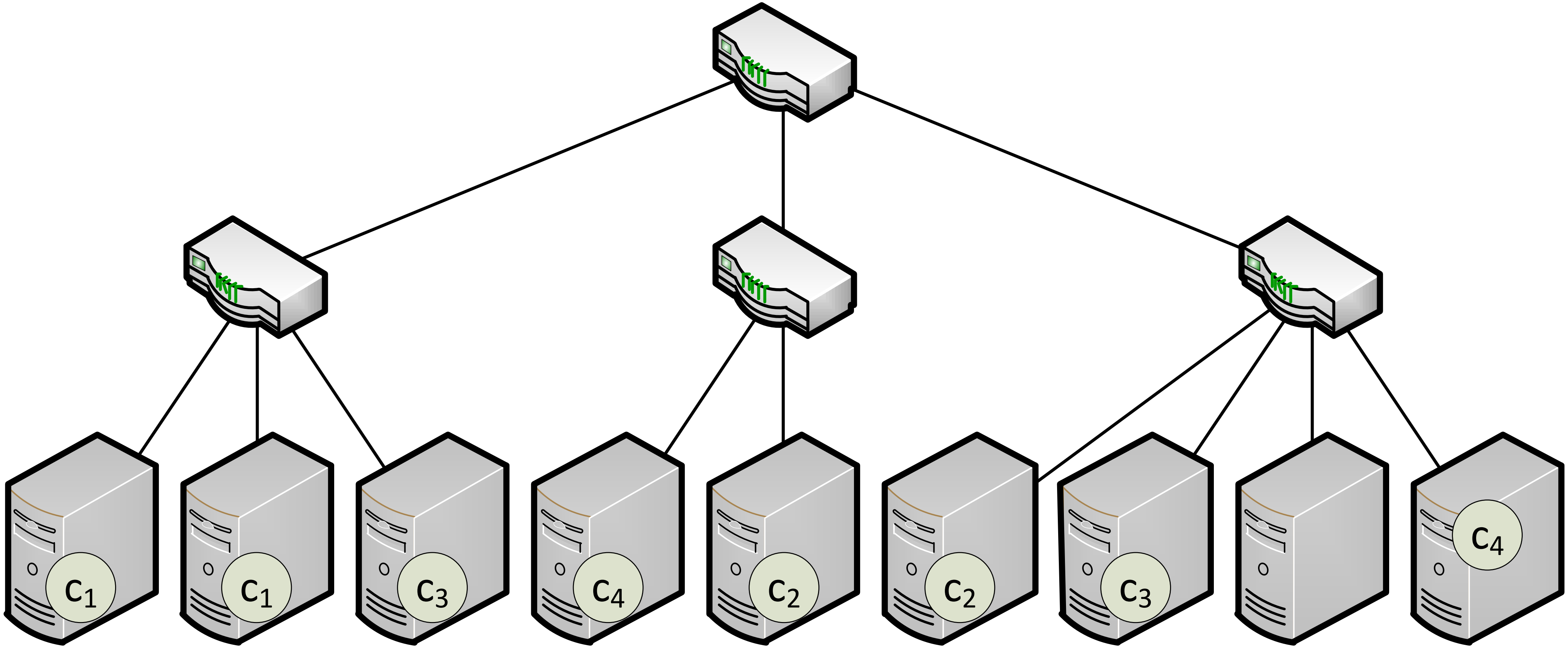


Shortcoming of Virtual Clusters



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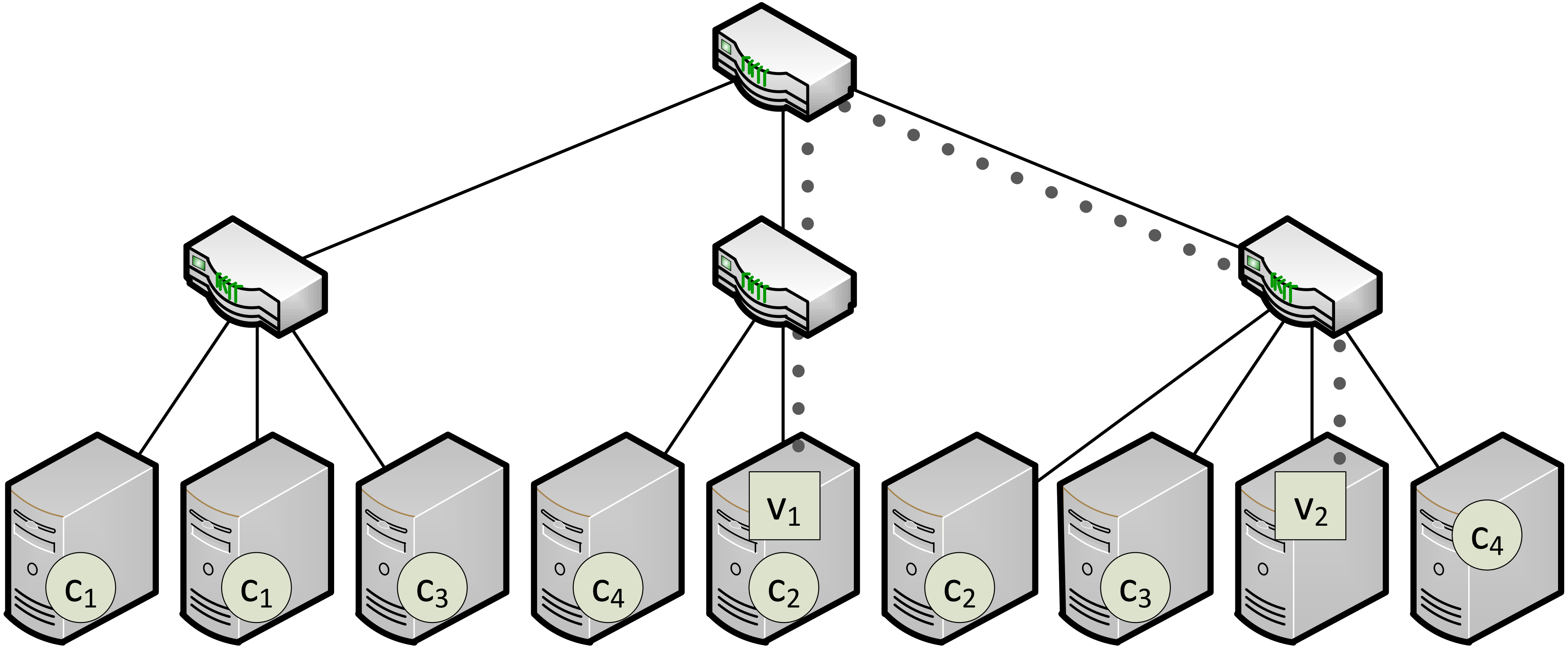

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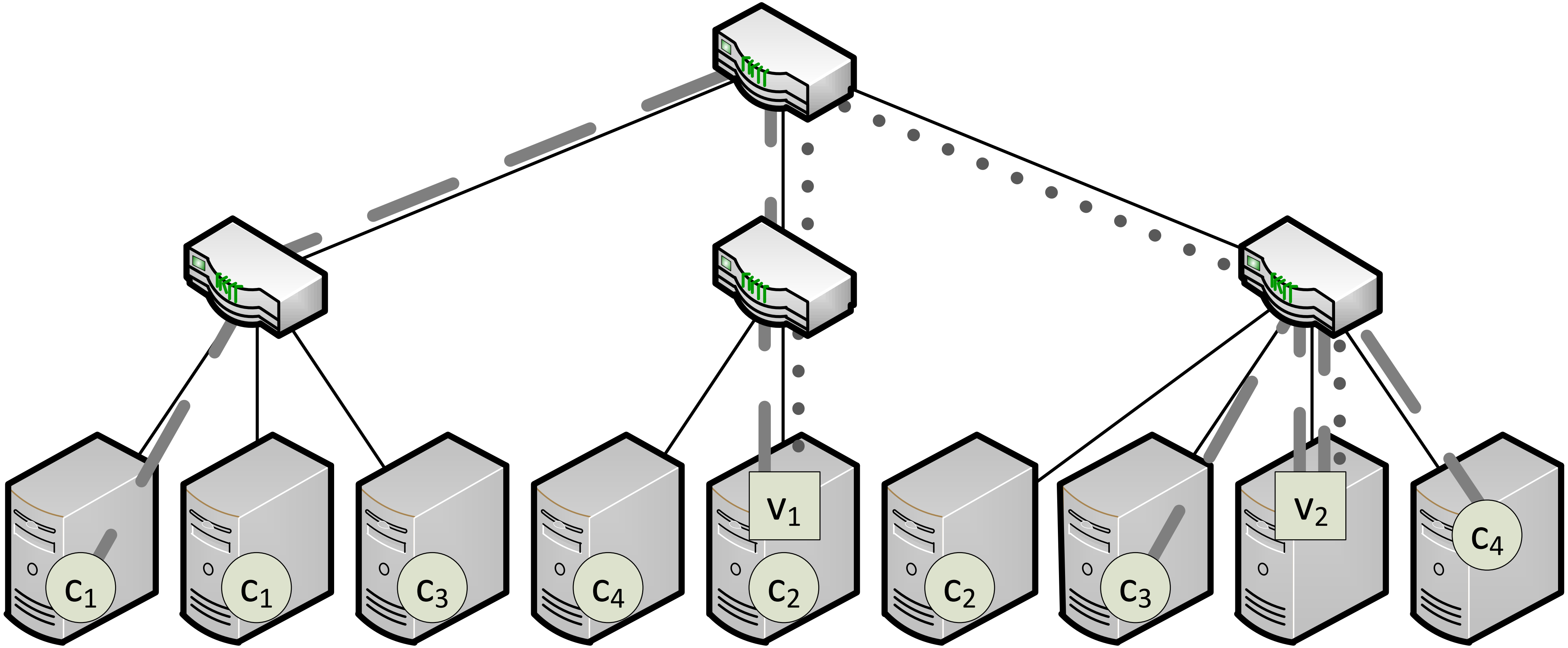

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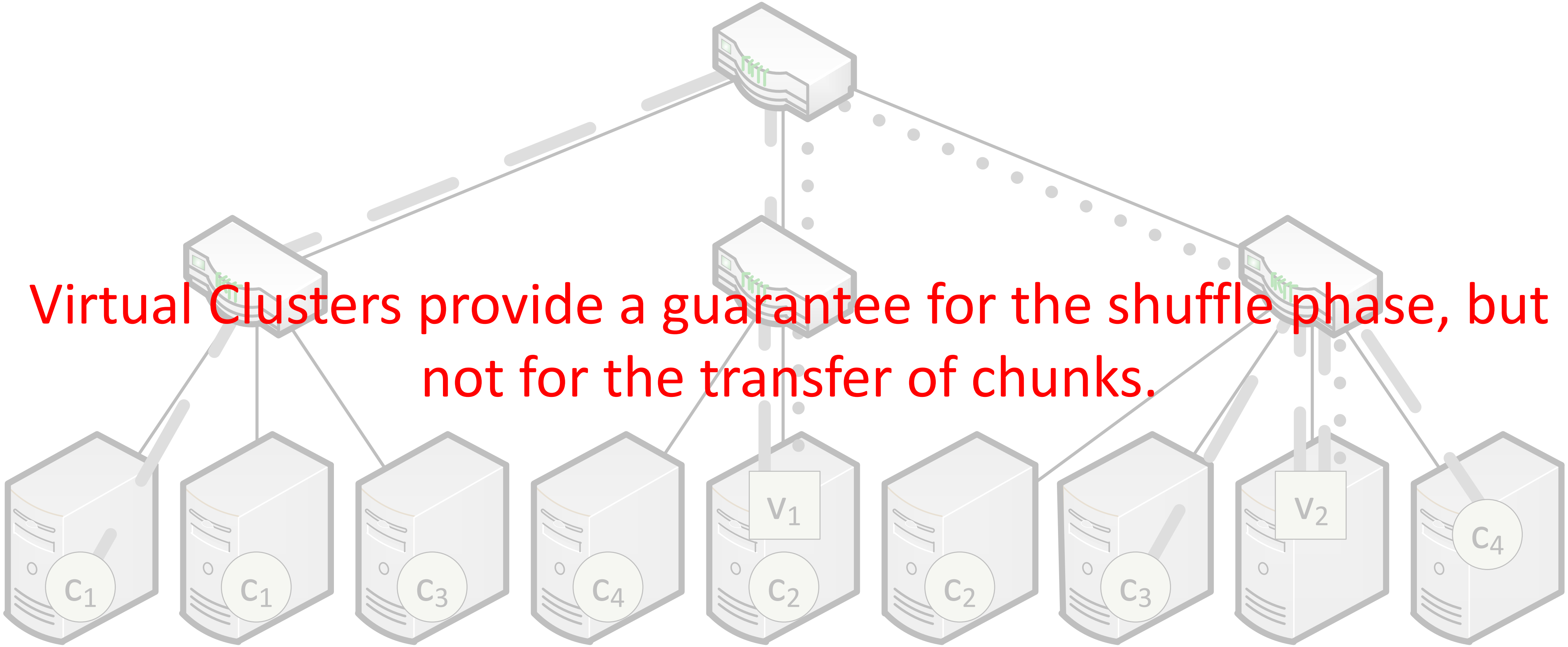
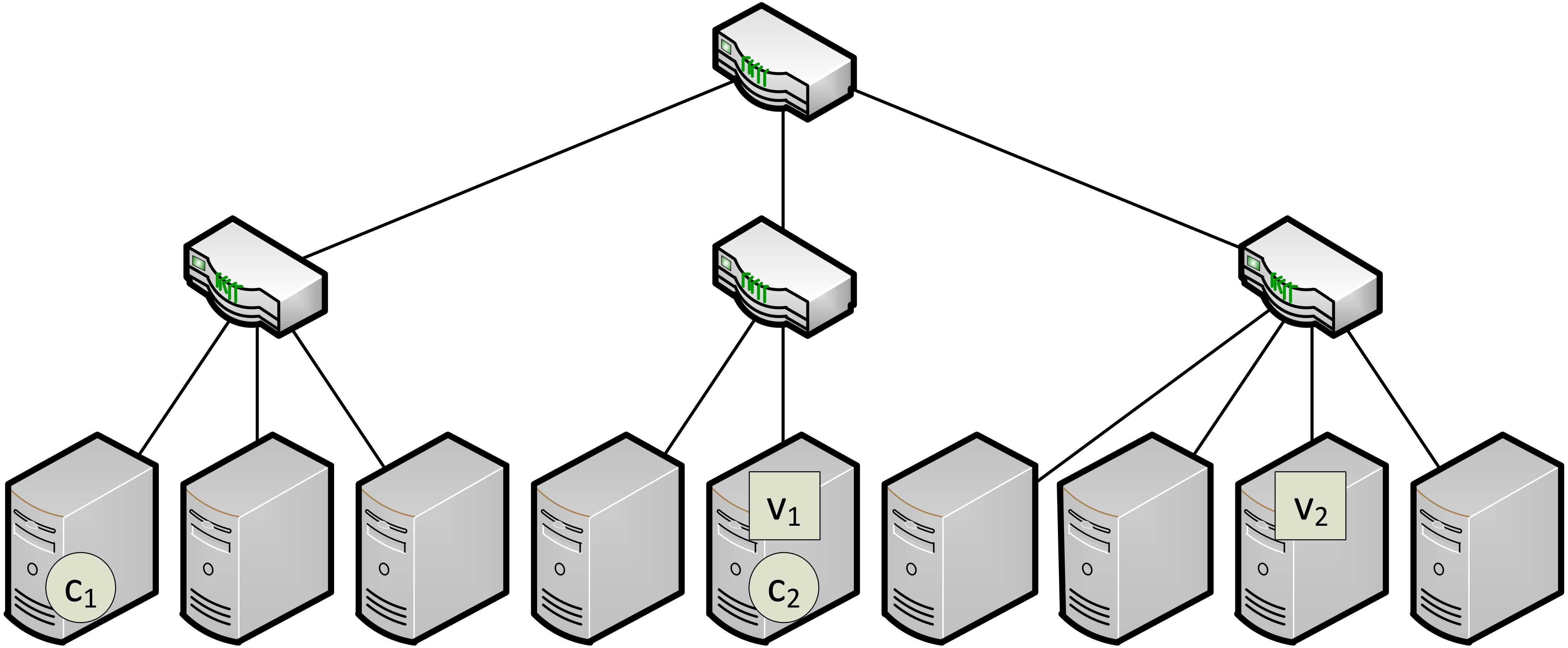
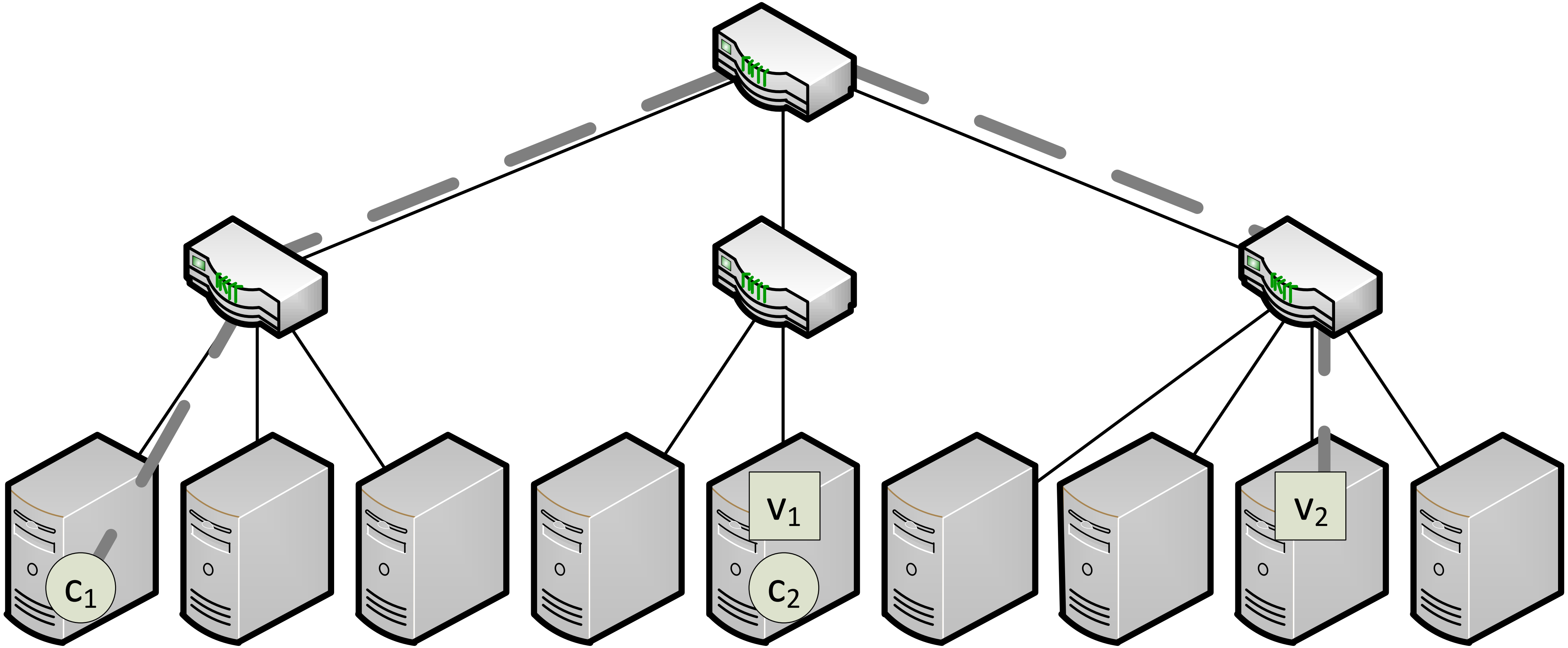


Virtual Clusters provide a guarantee for the shuffle phase, but not for the transfer of chunks.

Basic Problem



Basic Solution



Problem Decomposition

The basic problem can be extended with:

- VM interconnect (**NI**)

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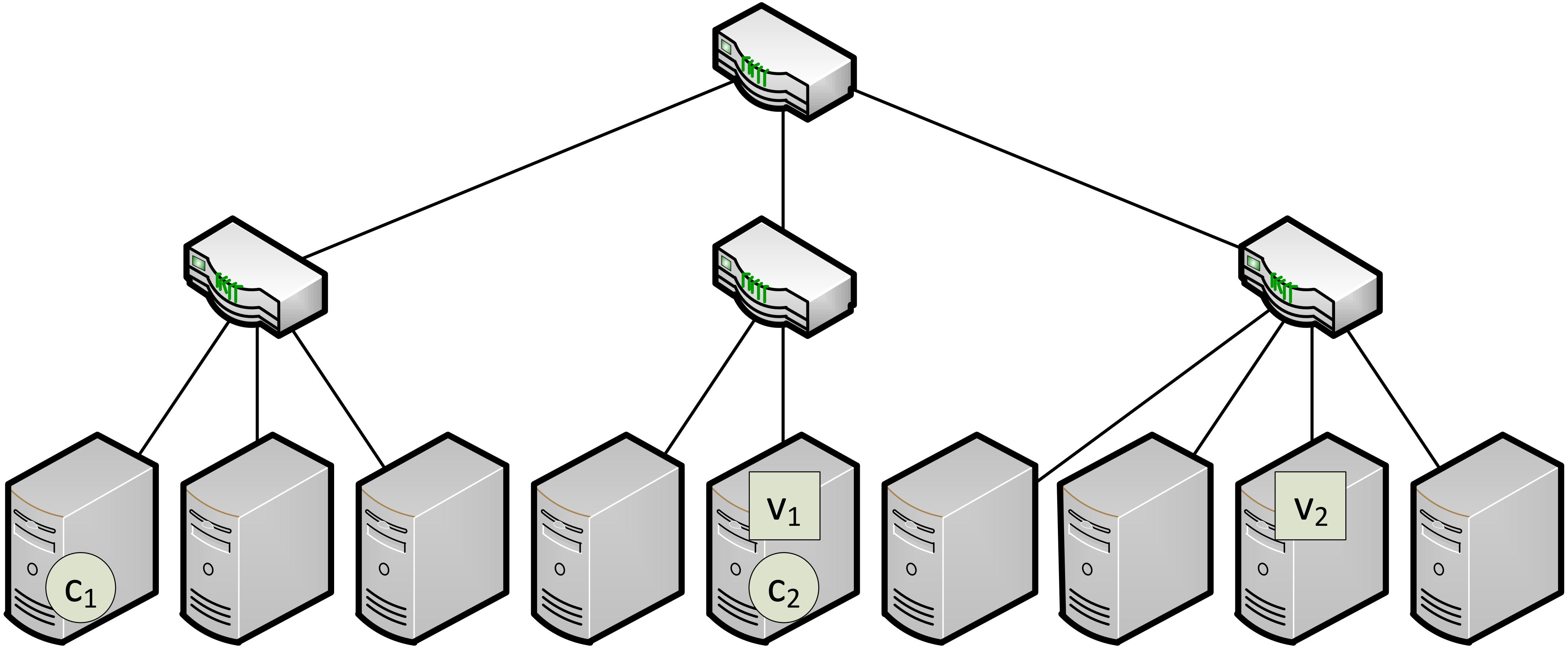

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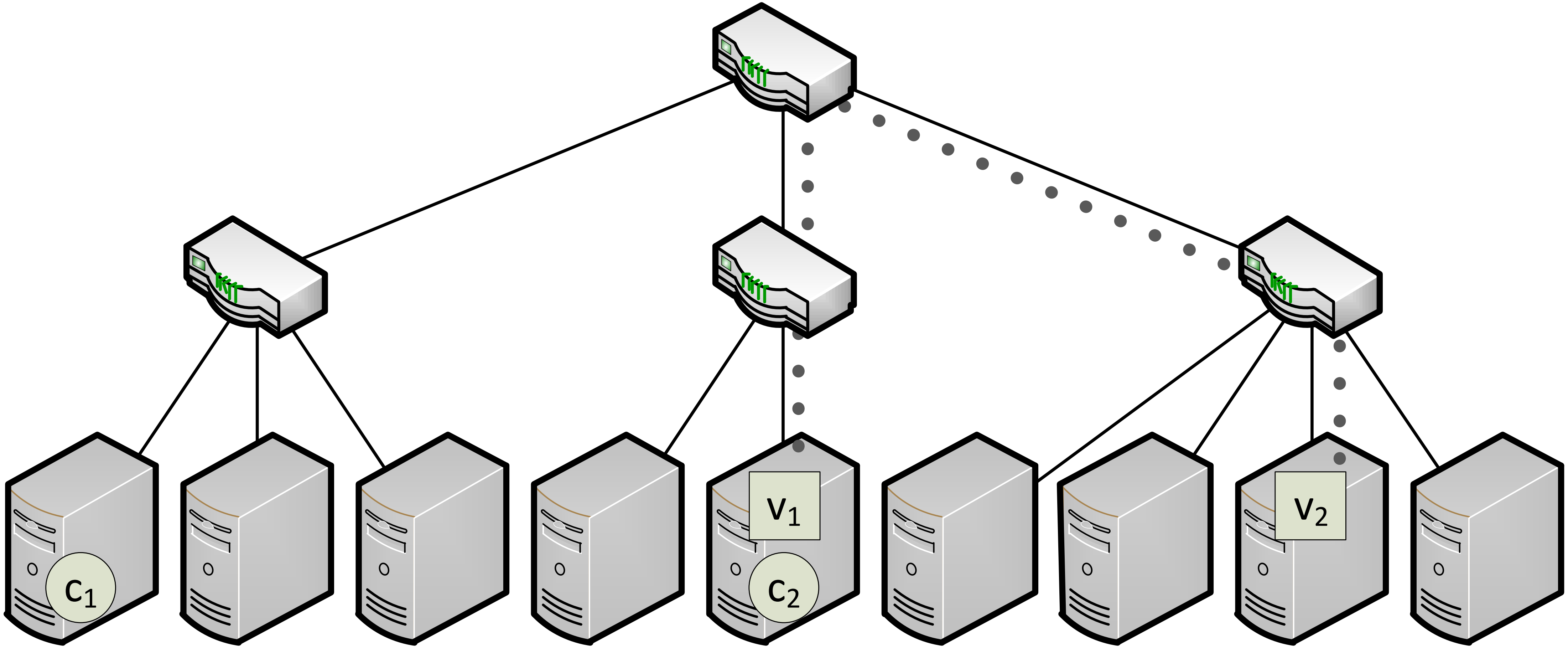

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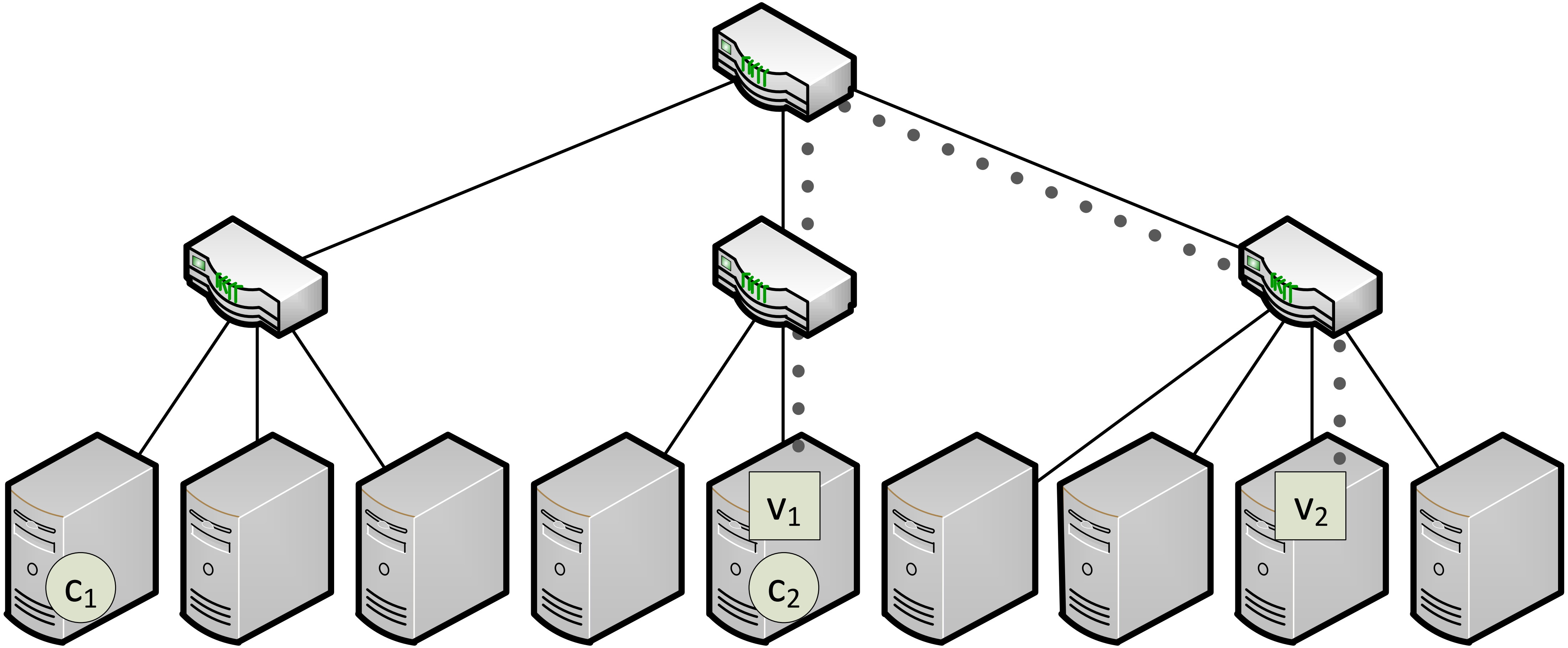

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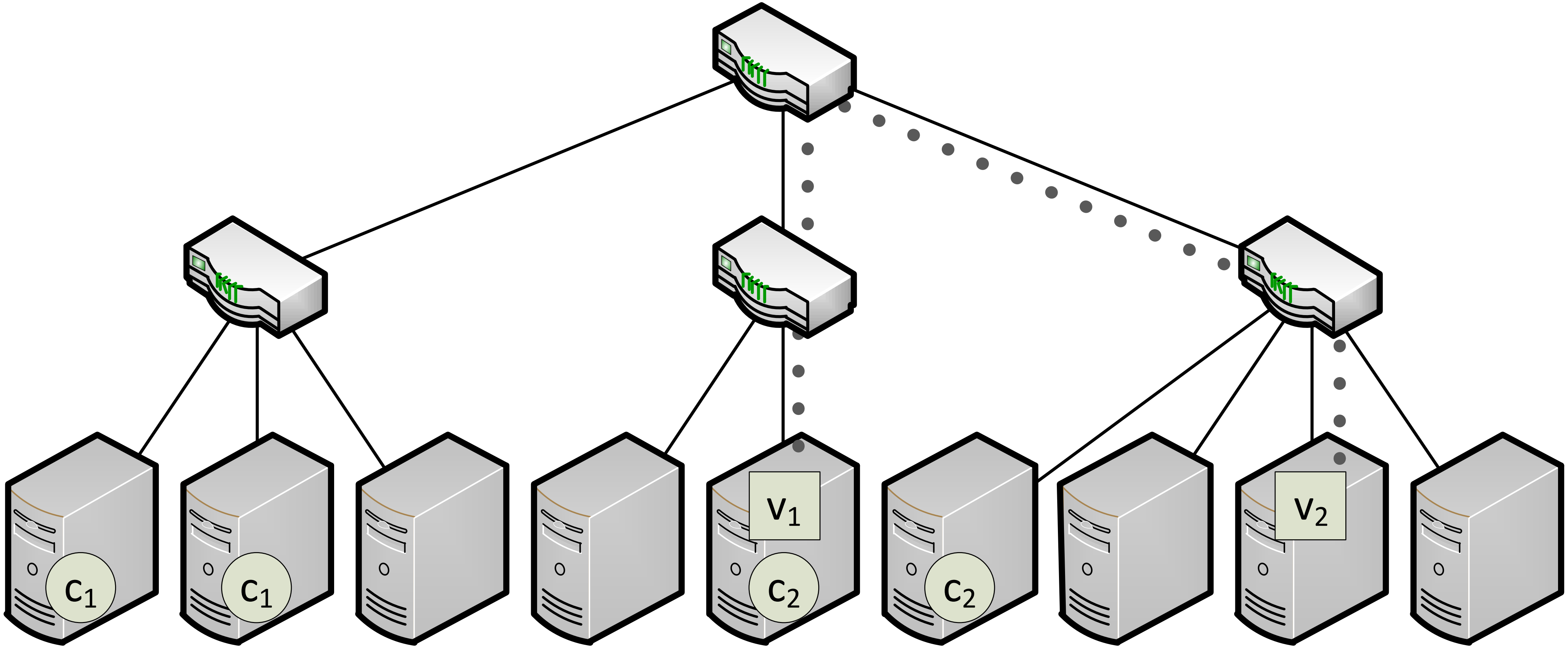

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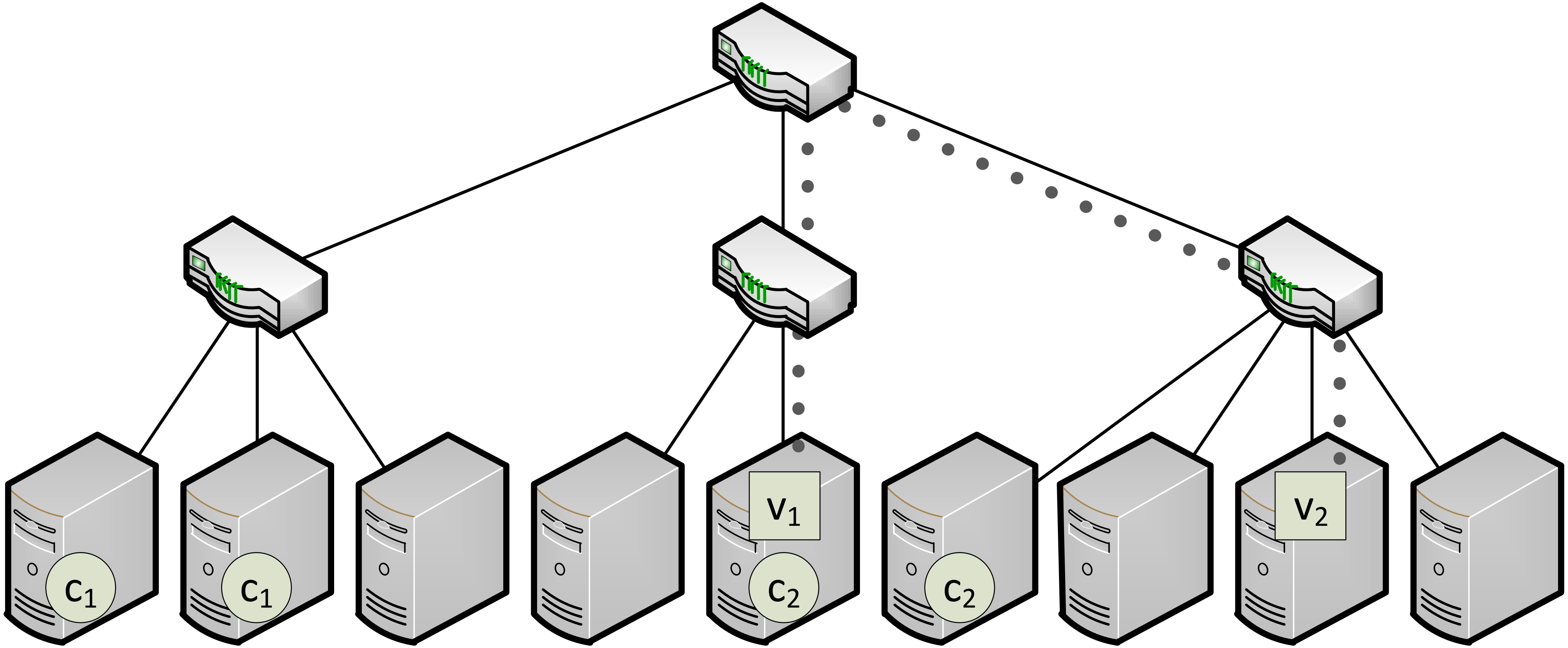

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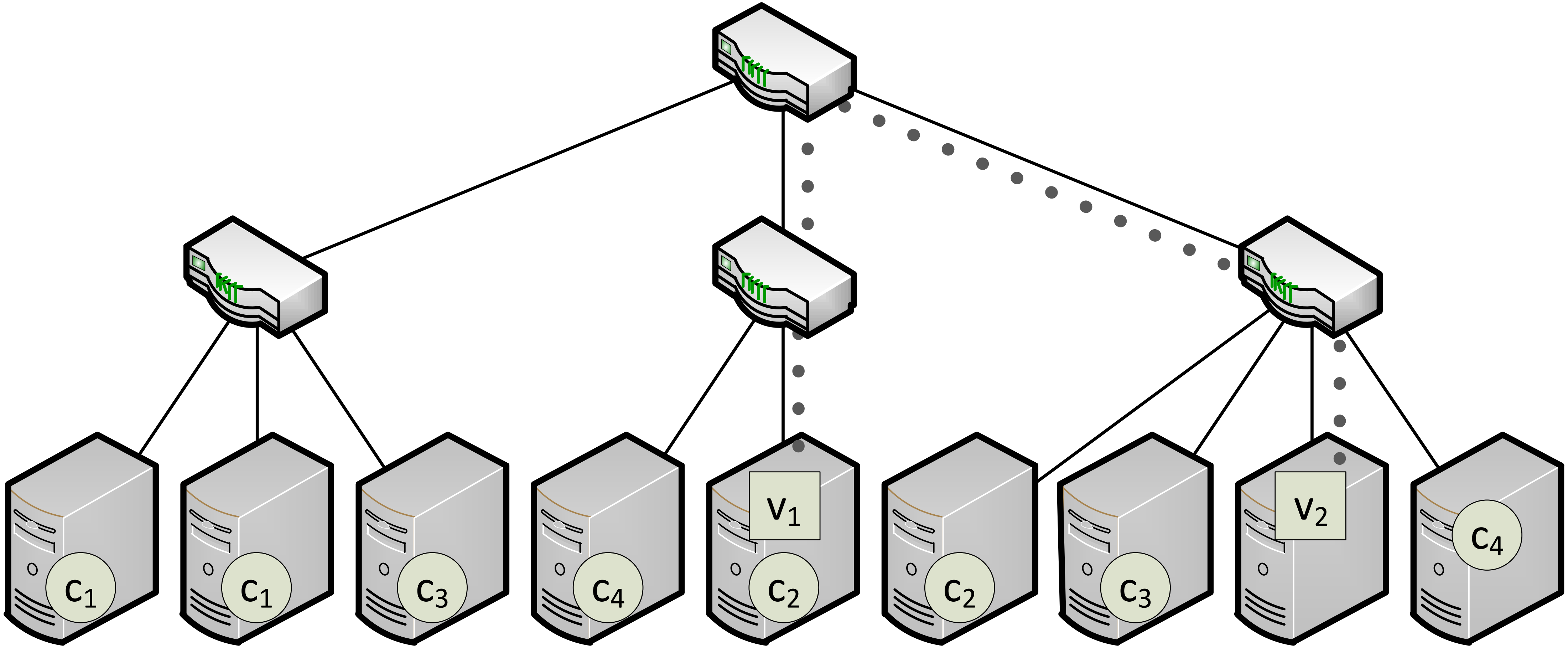

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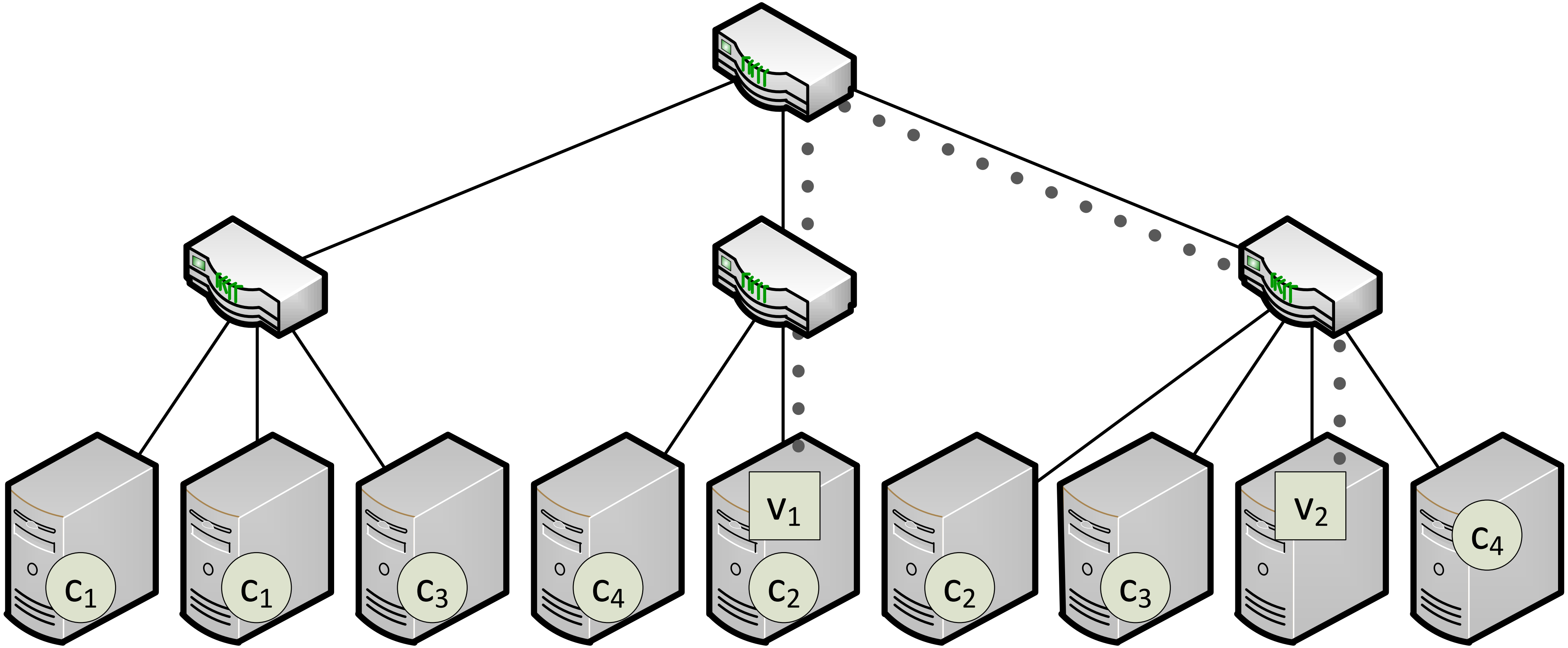

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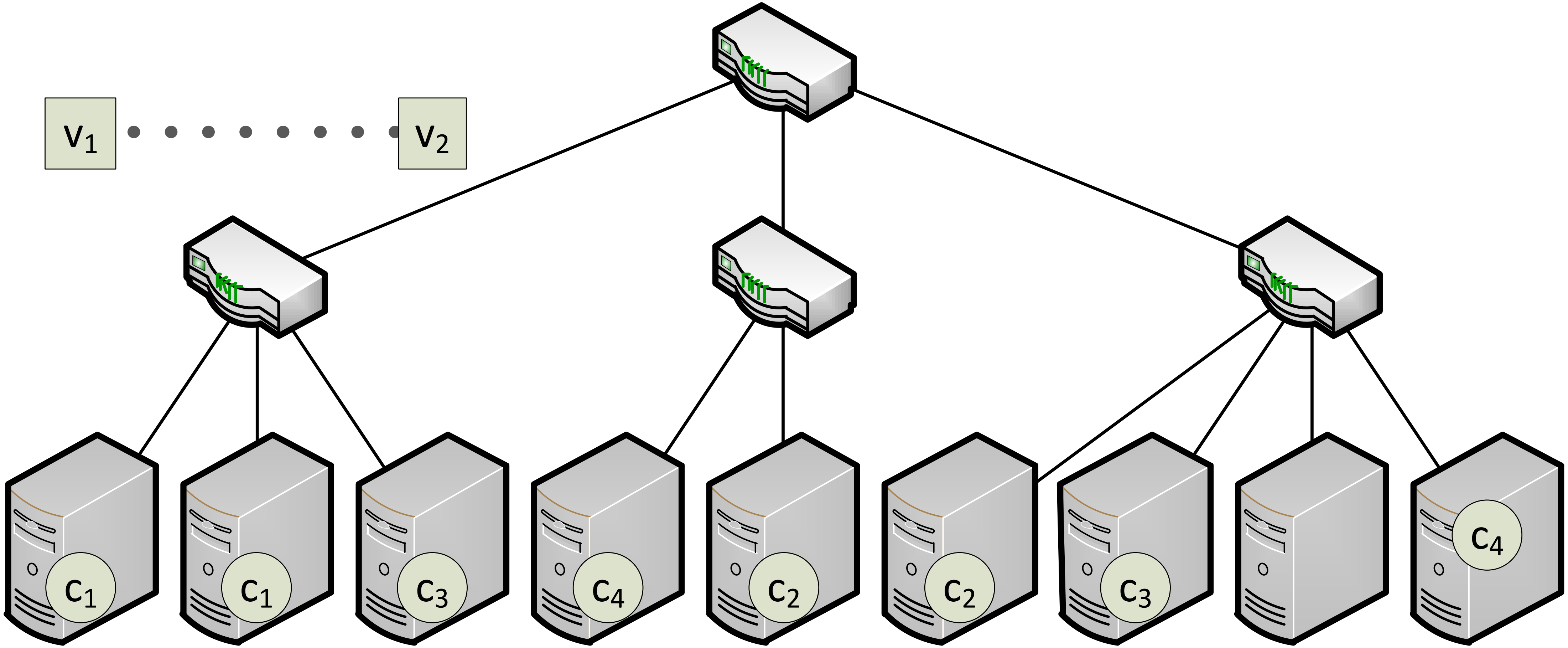

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- Bandwidth Constraints (**BW**)

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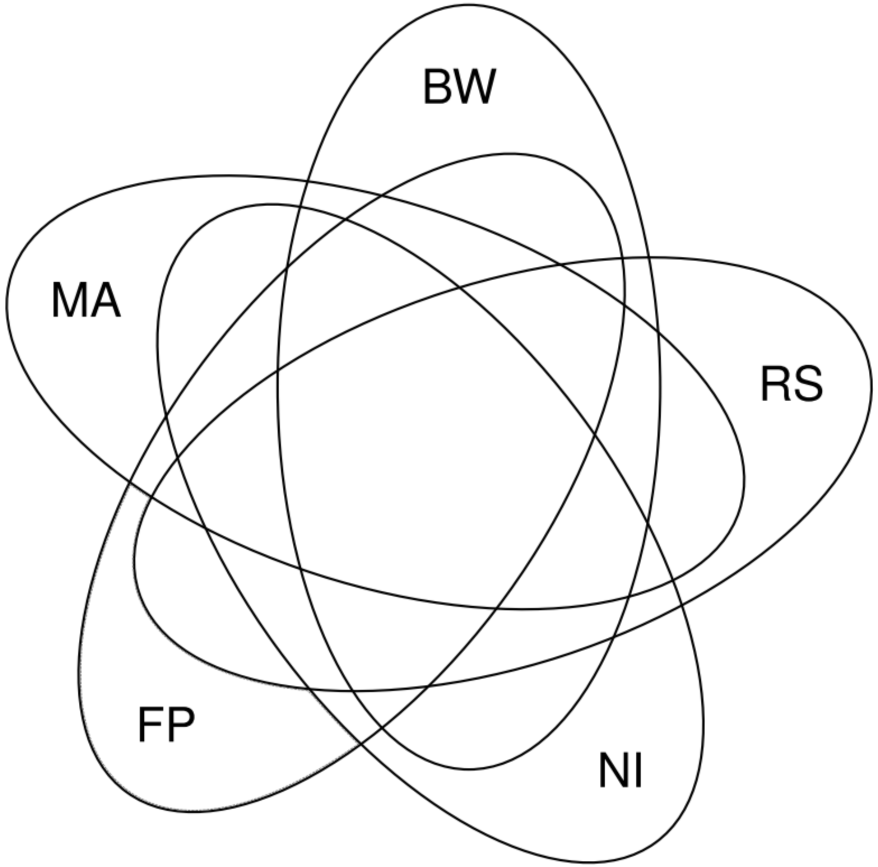

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- Trivial problem identification

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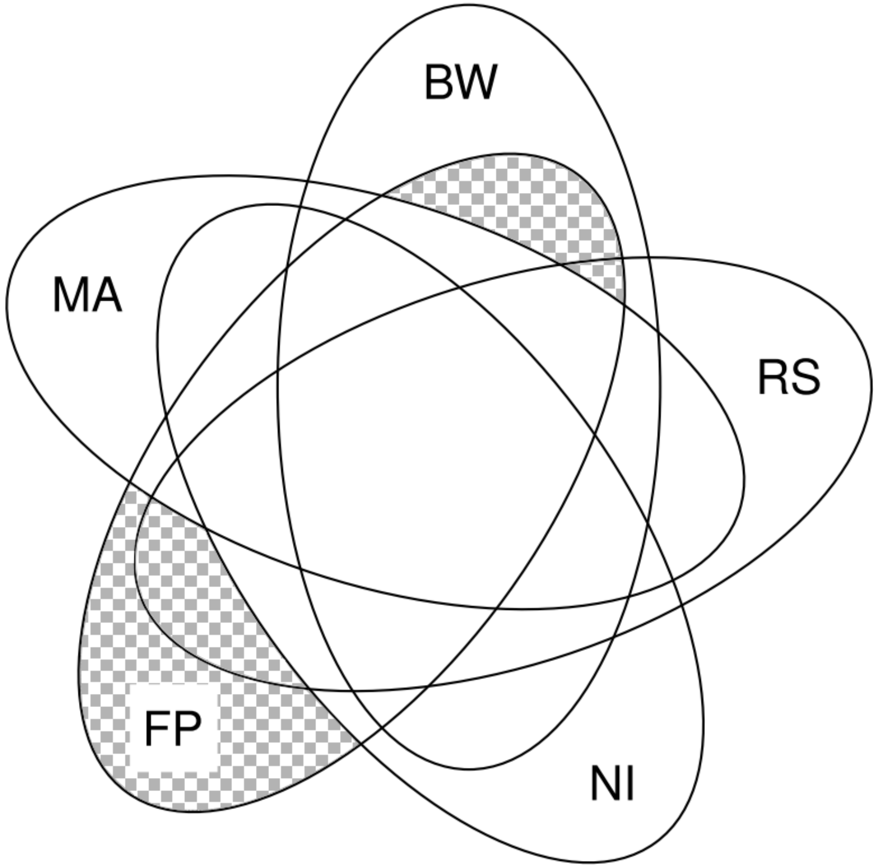

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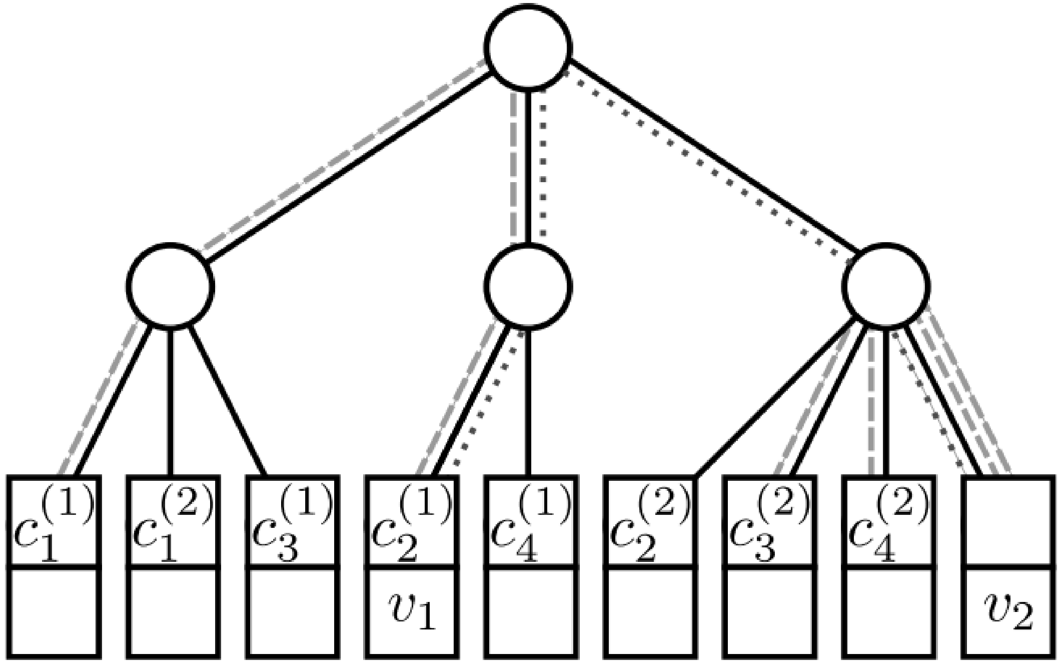

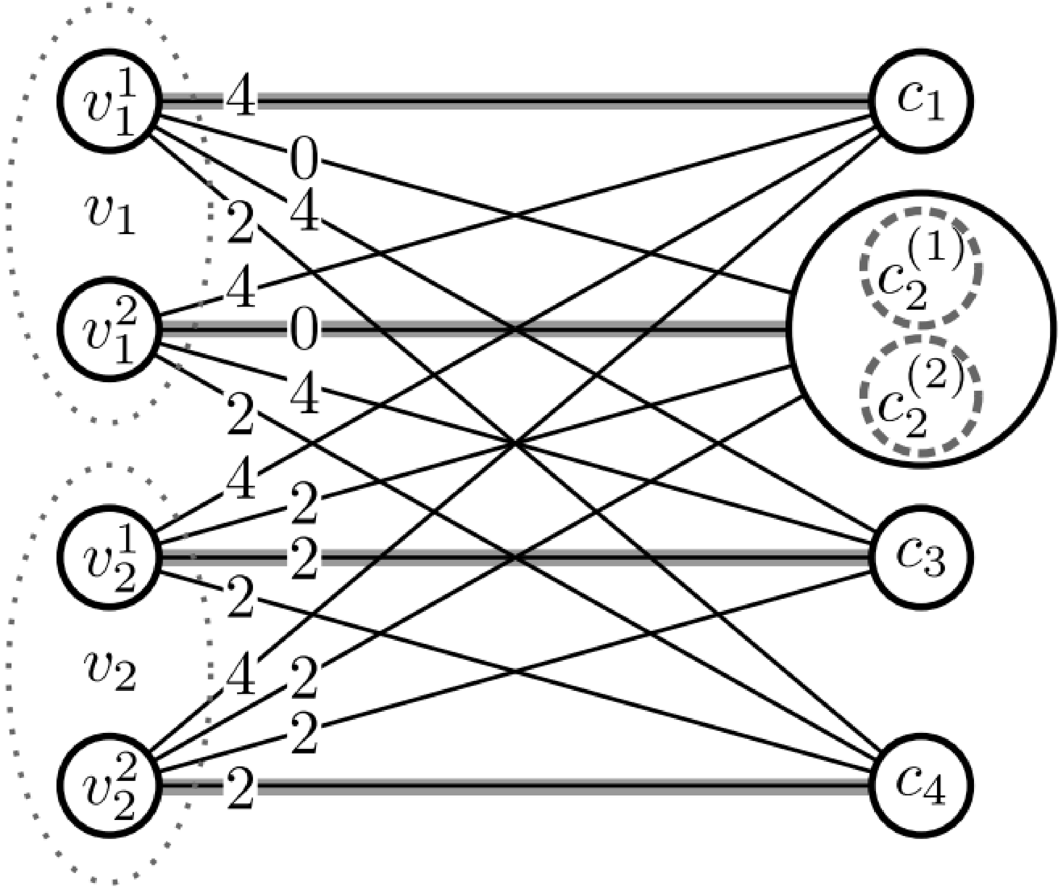

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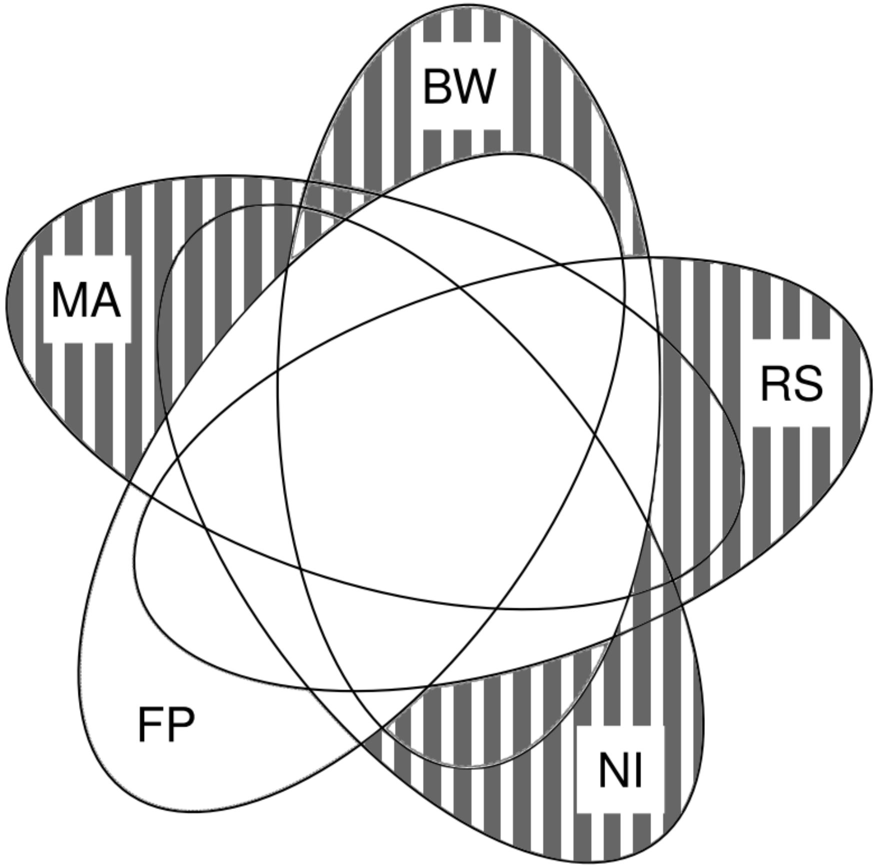

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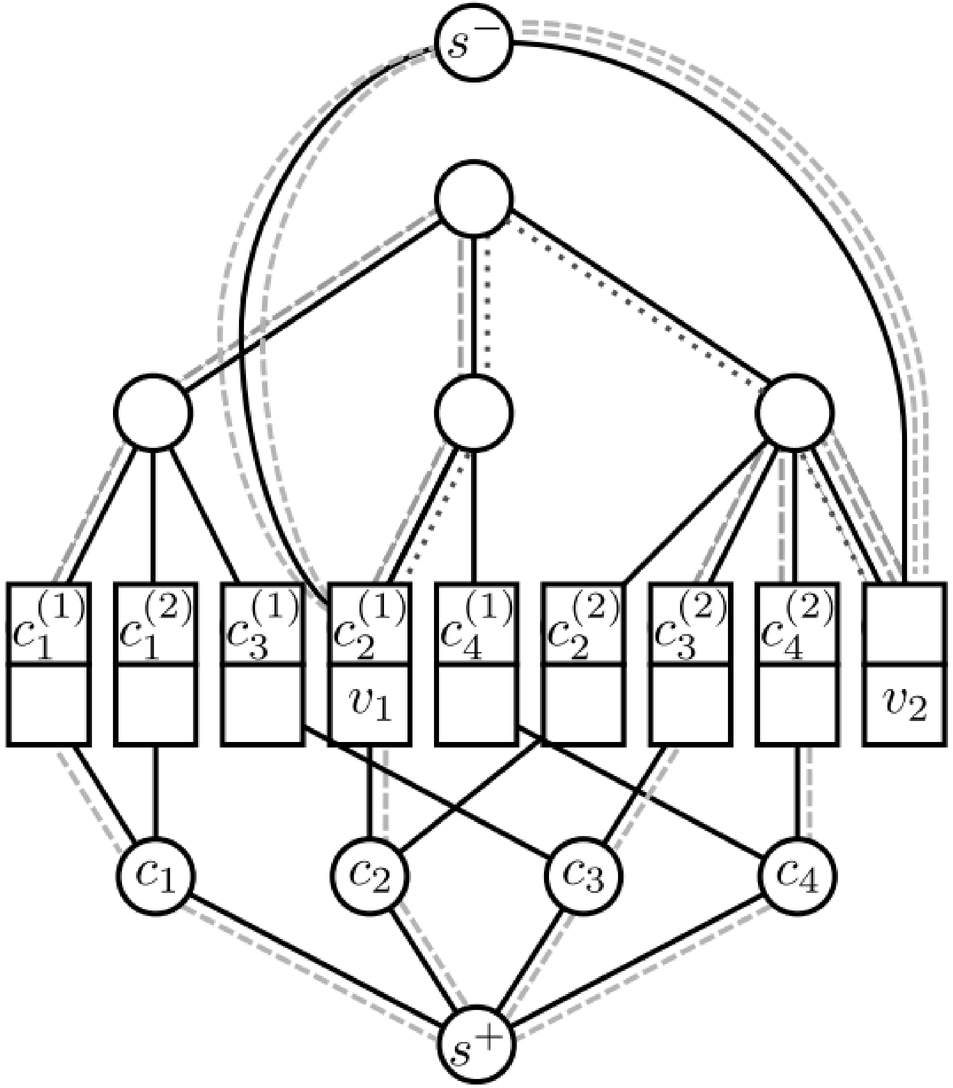

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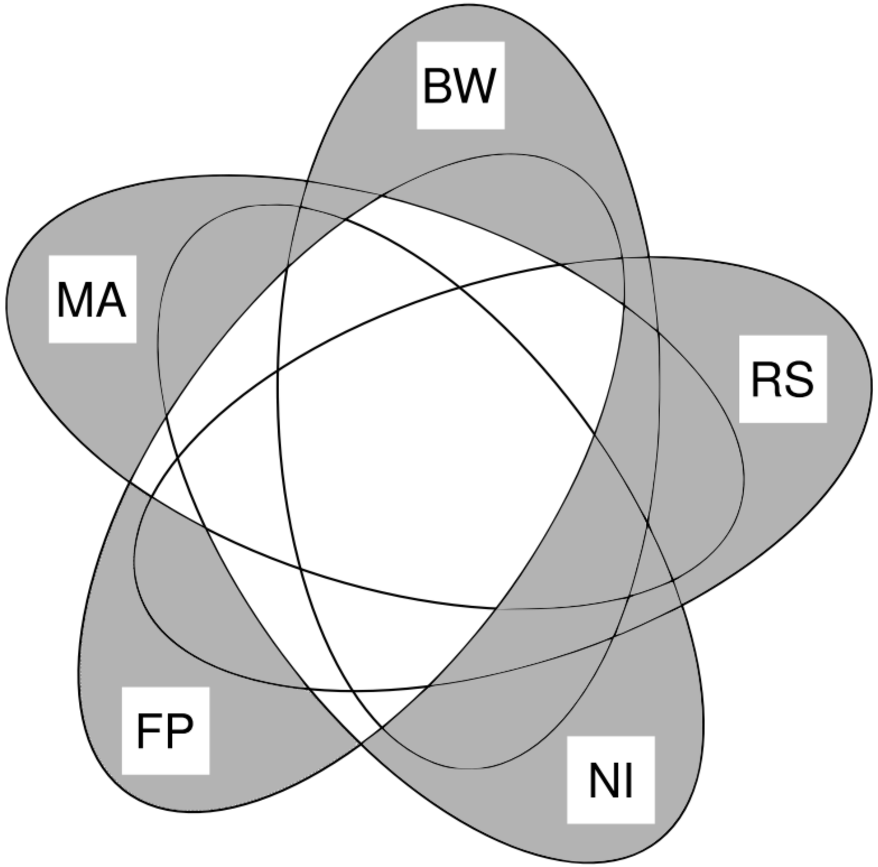

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- Hardness results

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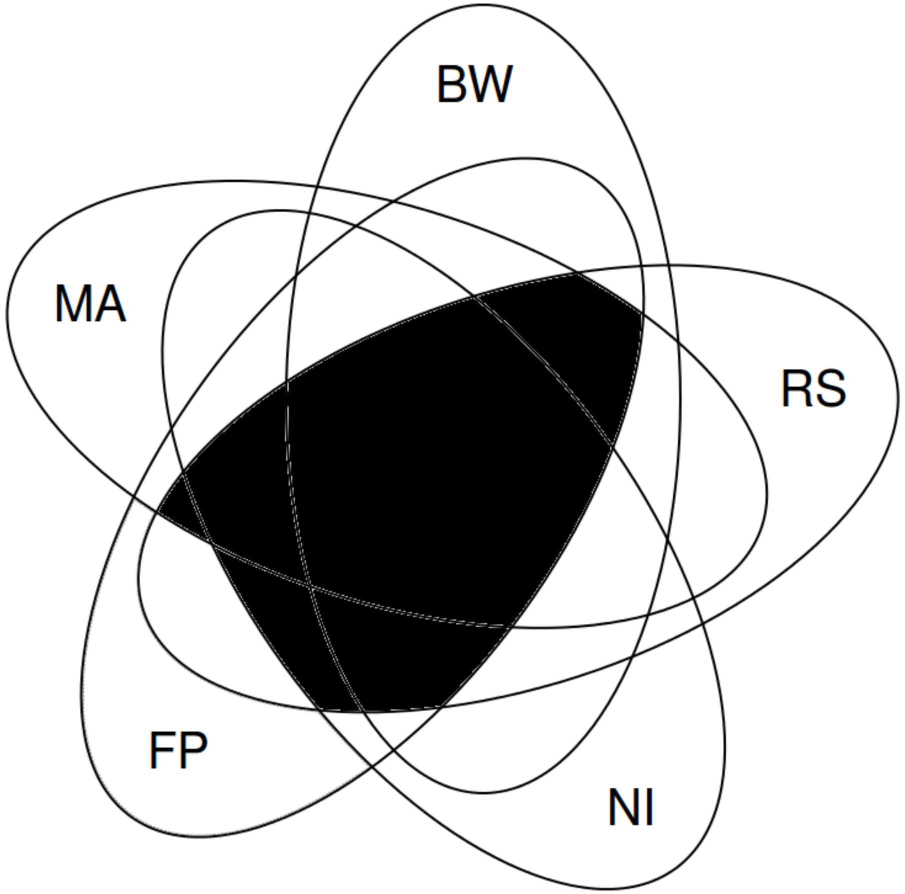
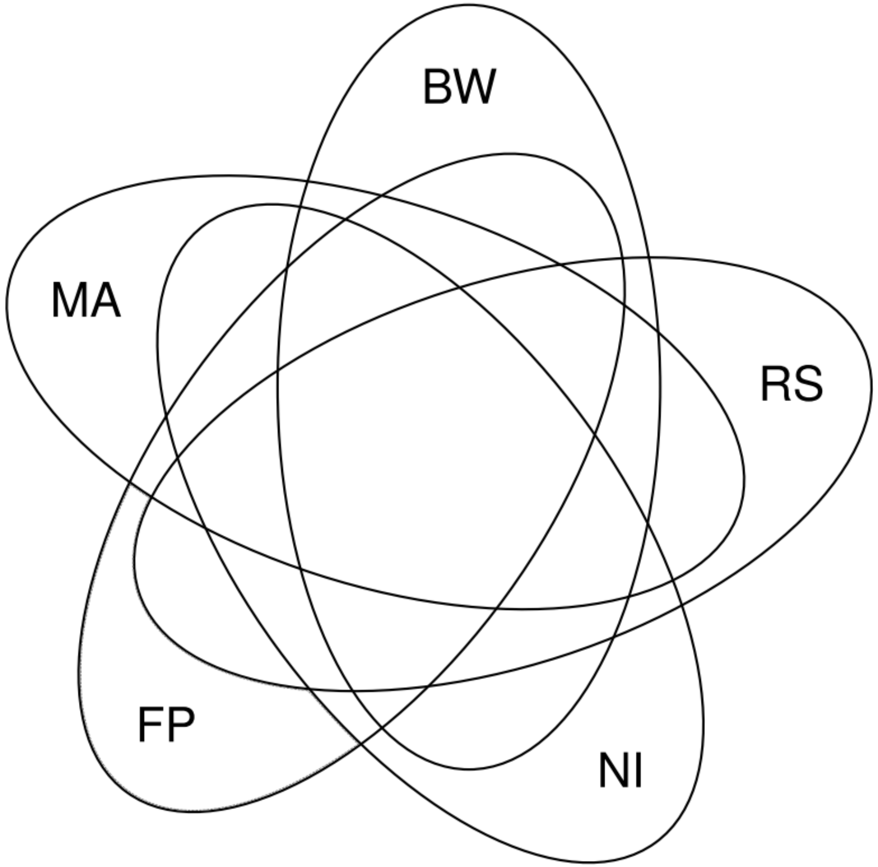


Everything but Replicas (MA + NI + FP + BW)



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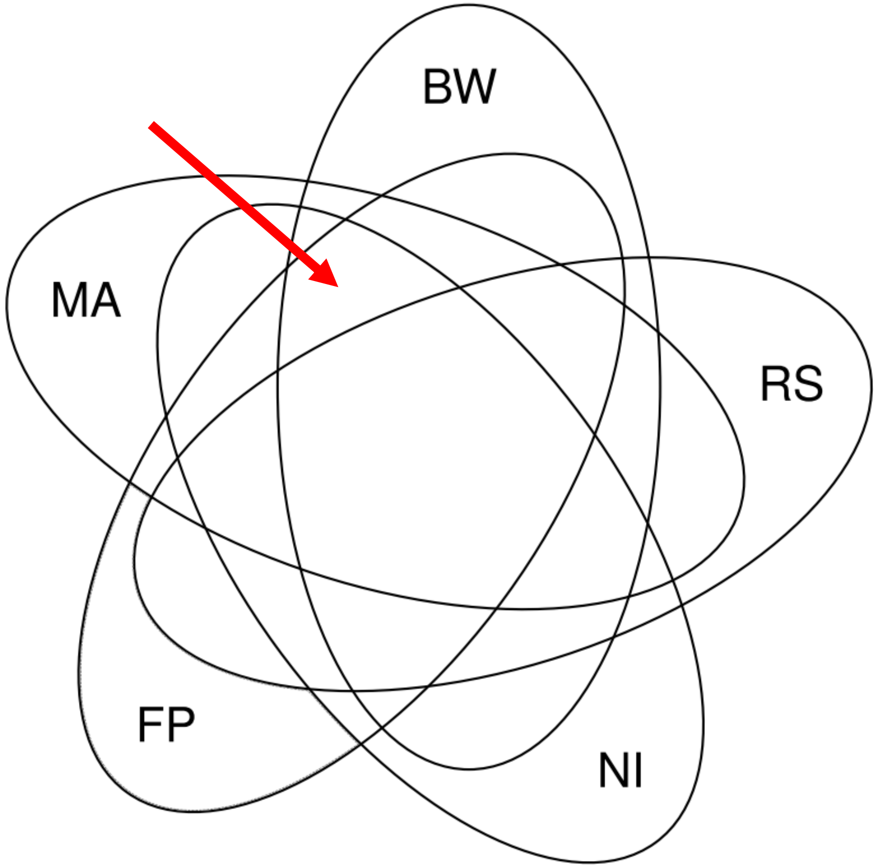
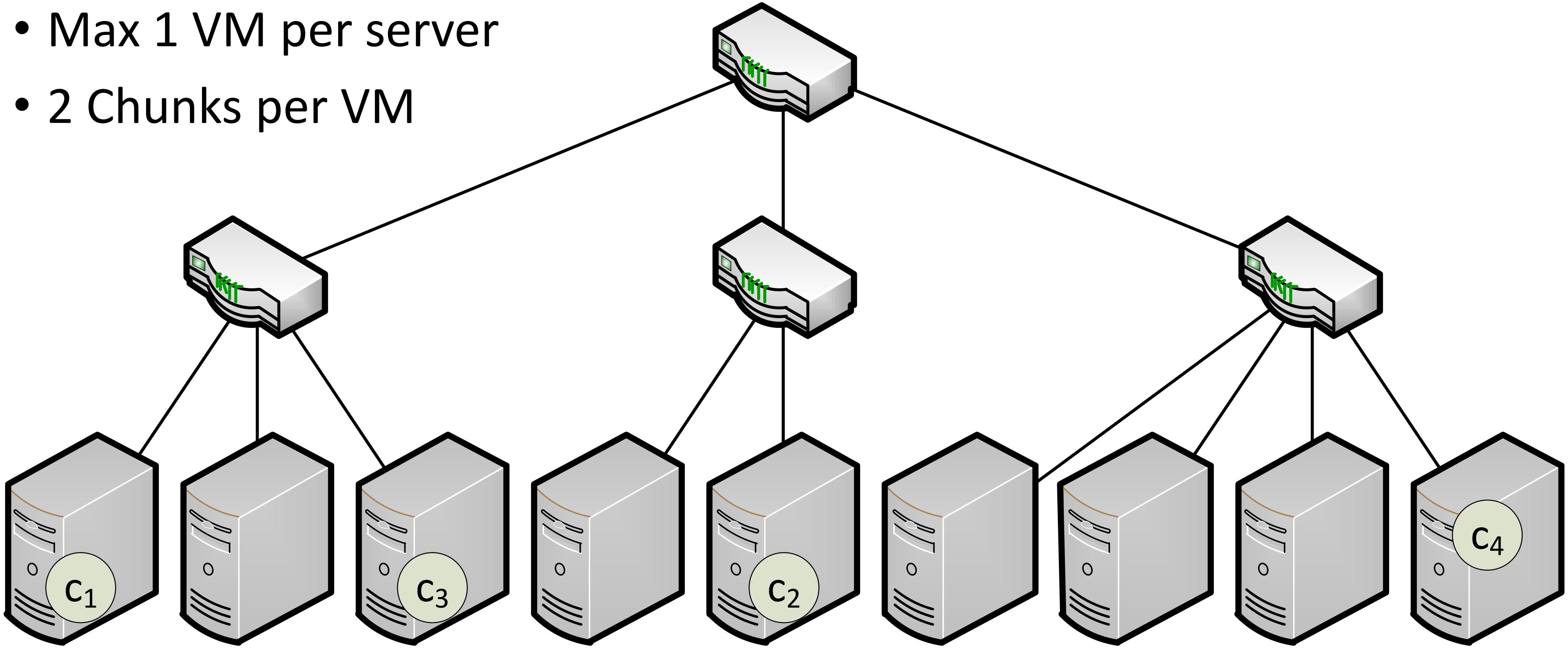


Dynamic Programming

- Create physical topology annotations in a bottom-up manner
- Start at the servers
- For each amount n of VMs in {0,...,N}
  - Set cost[n] to ∞ if n exceeds the servers capacity
  - Set cost[n] to the bandwidth costs of placing n VMs at the server

Dynamic Programming

- Max 1 VM per server
- 2 Chunks per VM



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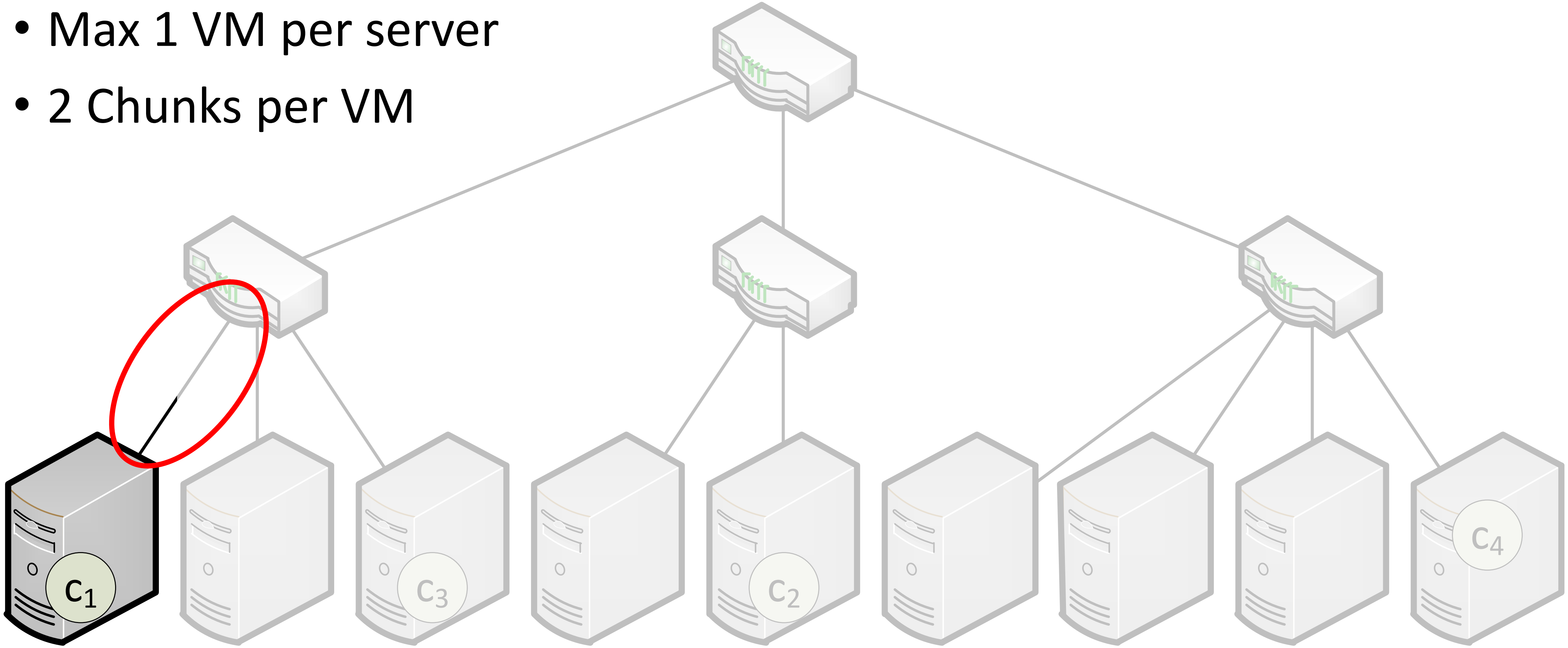

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- For each switch and each amount of VMs in {0,…,N}
    - Set cost[n] to the sum of the cheapest combination of the children and add the costs for the bandwdith on the uplink

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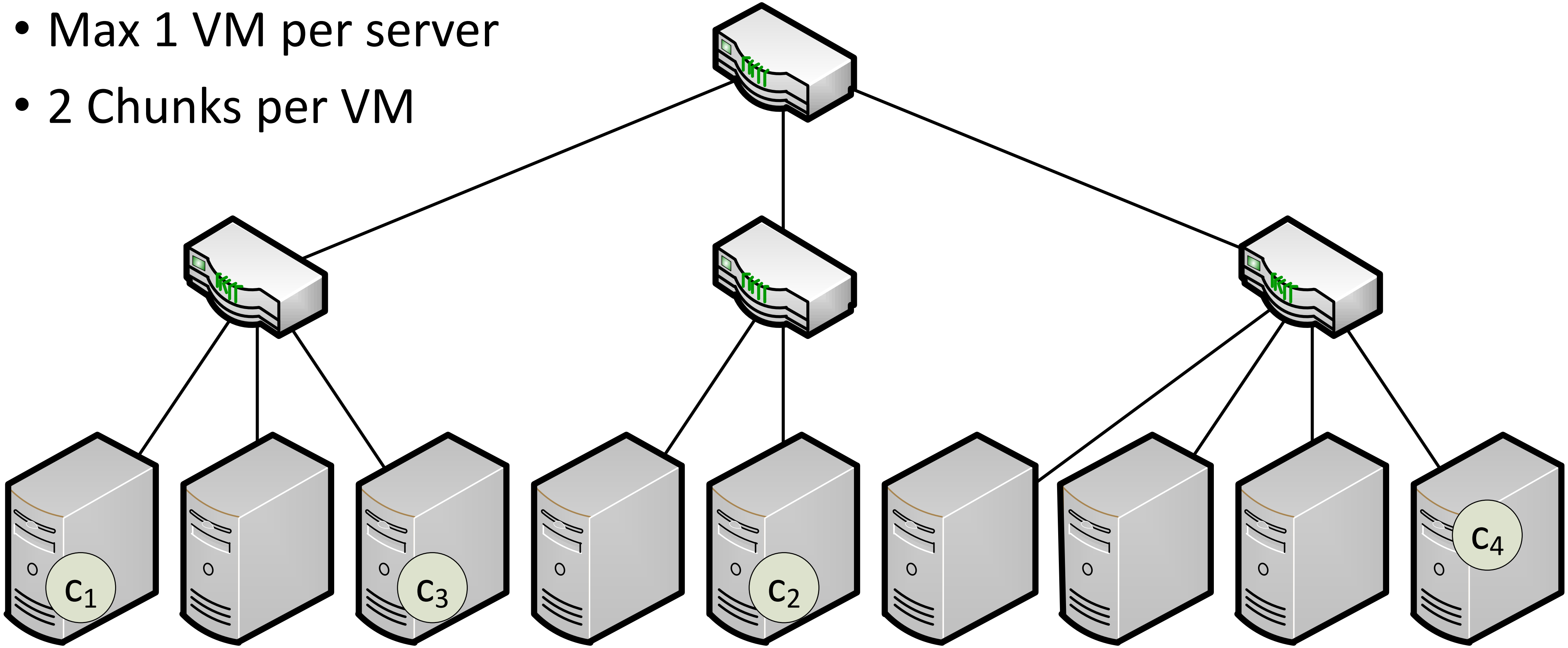

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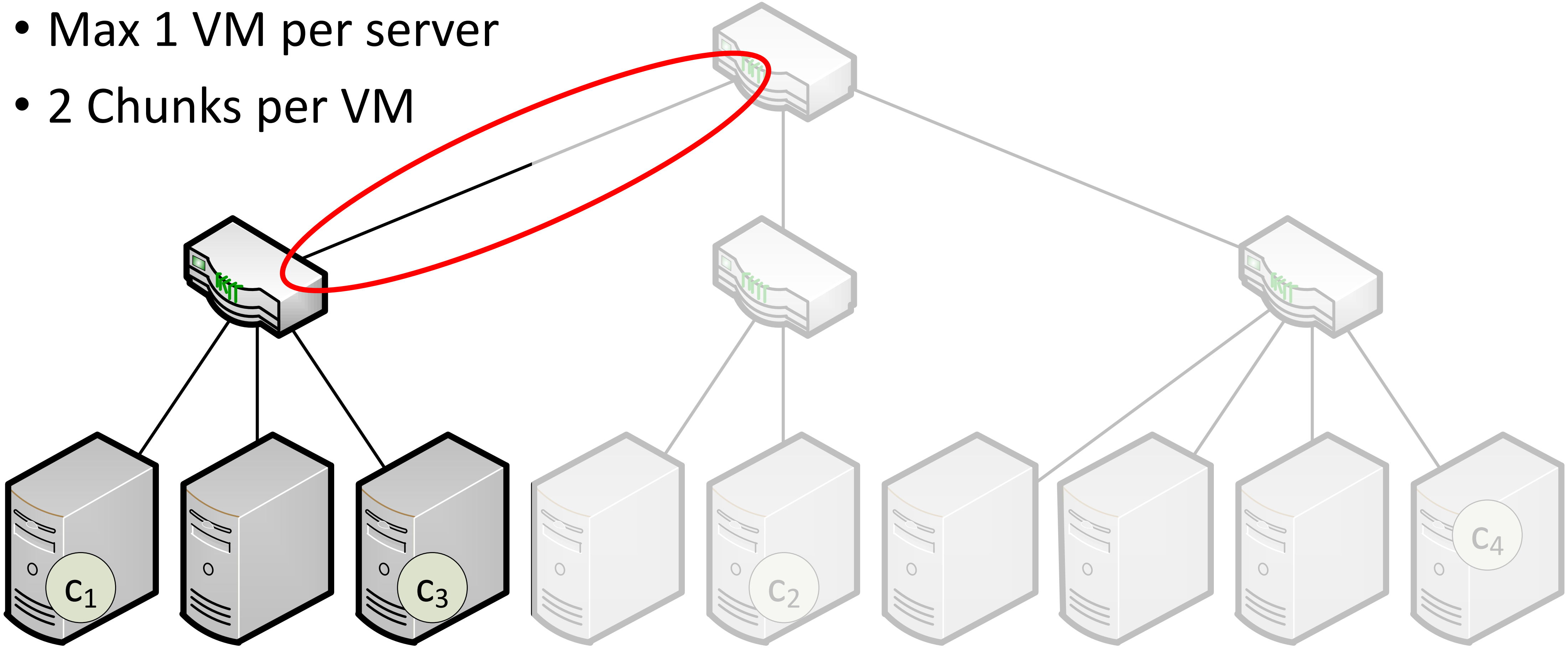
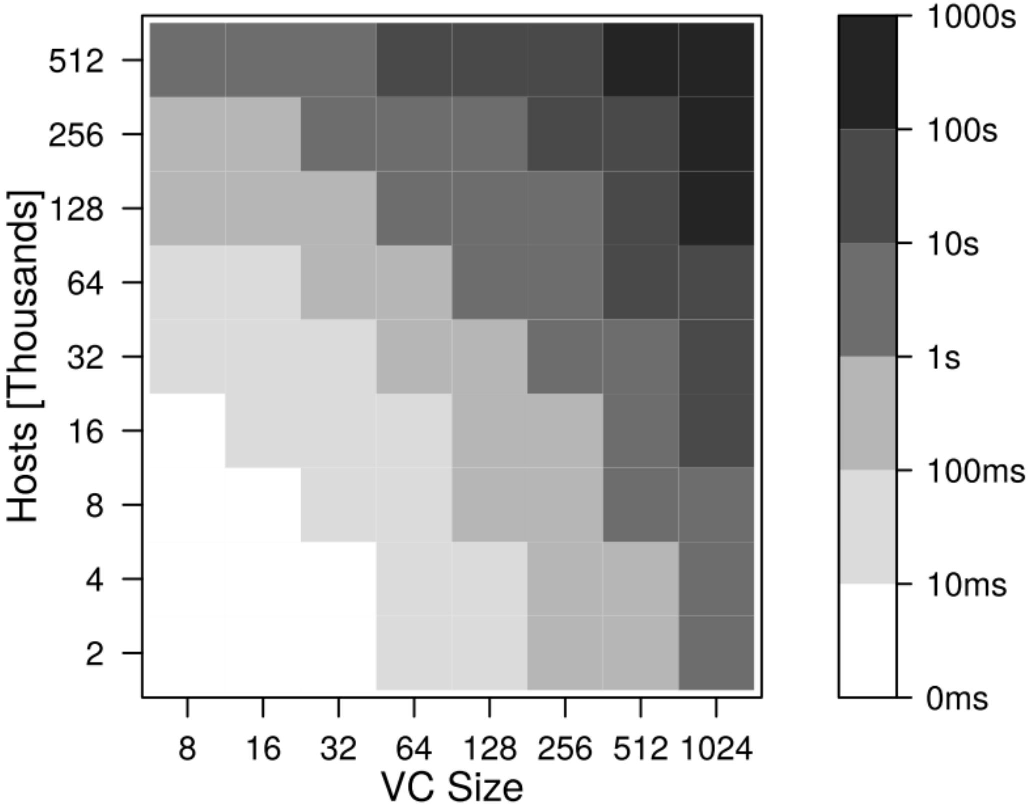


Runtimes

- Intel(R) Xeon(R) CPU L5420 @ 2.50GHzwith (single threaded)
- 512 MB
- openjdk-7
- Max 4 VMs per Server
- 3 Chunks per VM



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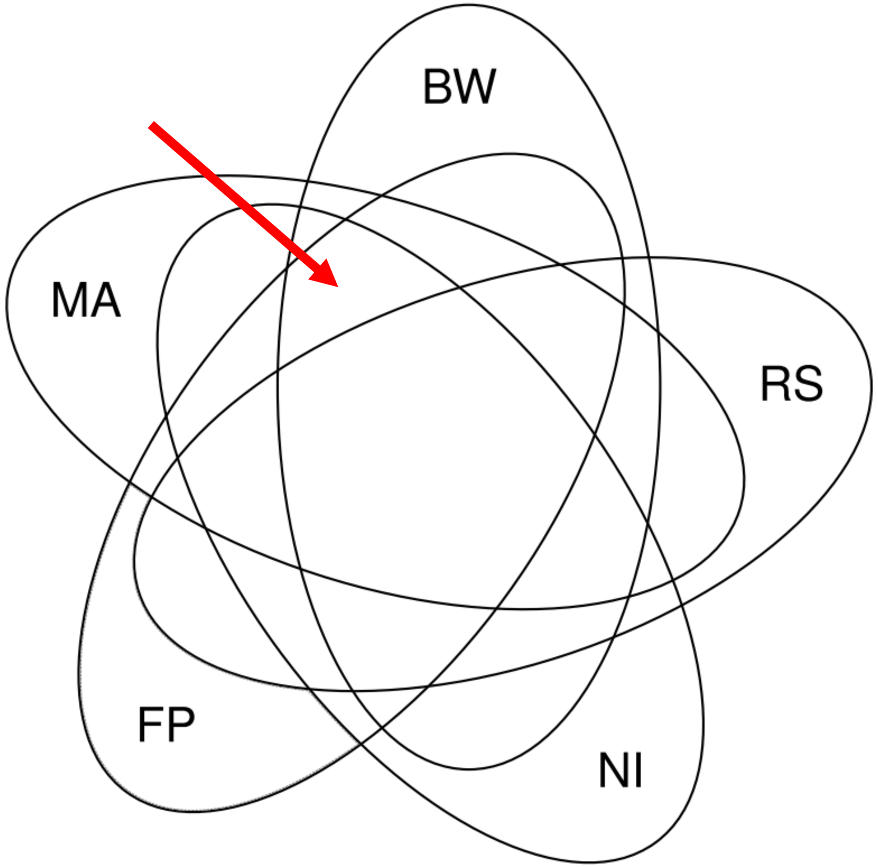

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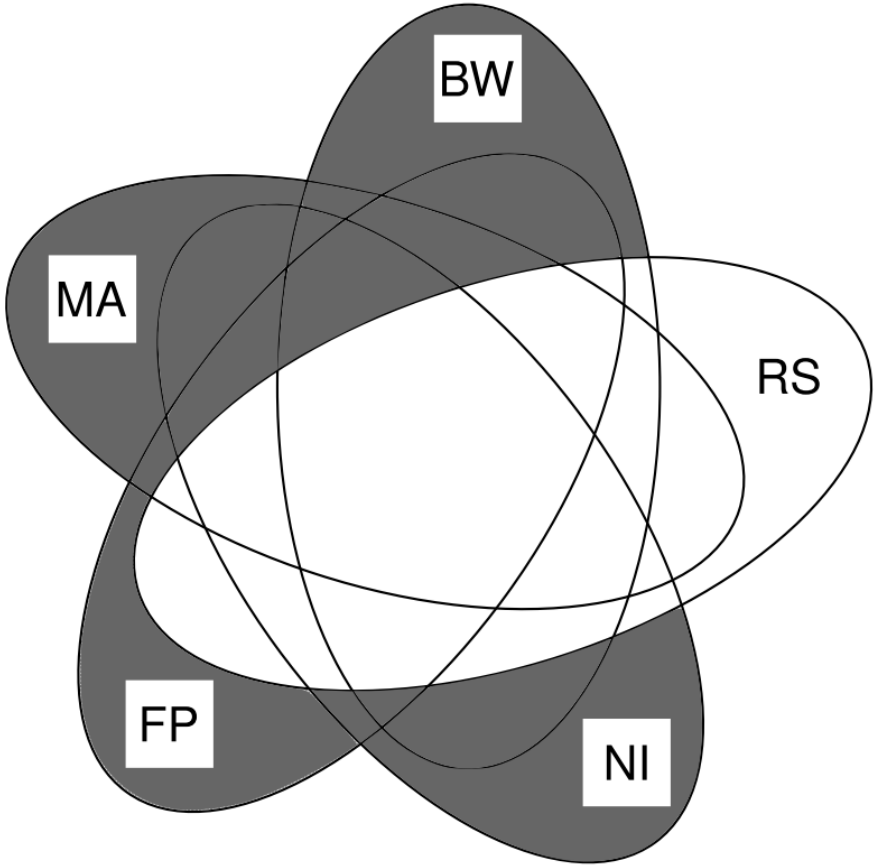

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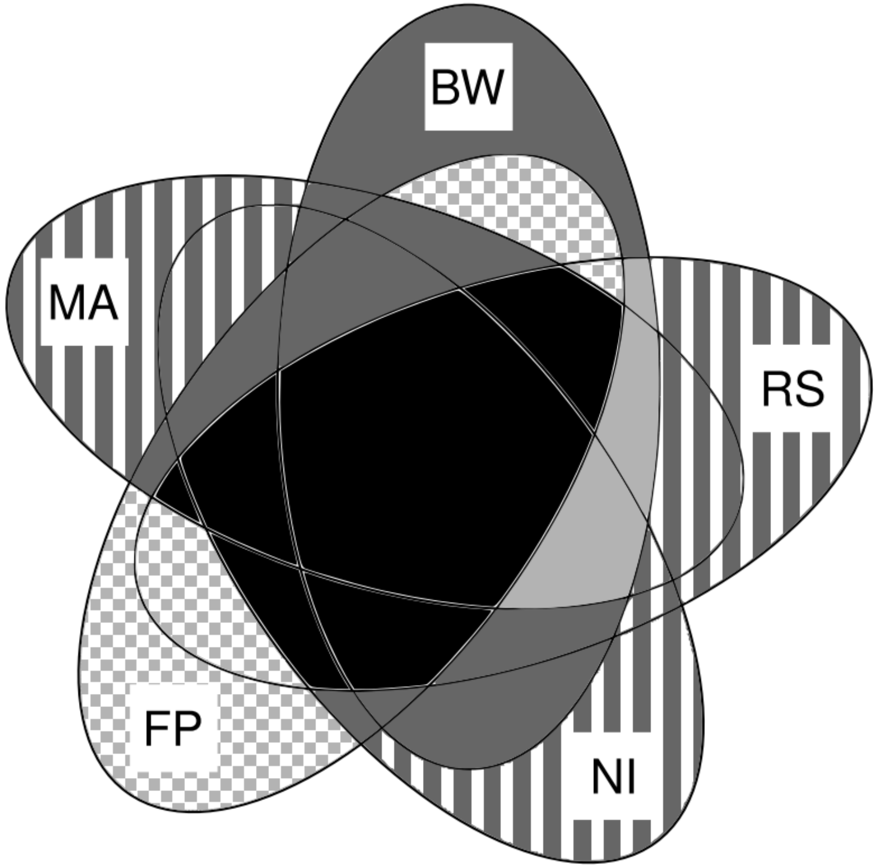

Summary

- Virtual clusters provide dedicated resource guarantees
- Datalocality can be incorporated into the virtual cluster abstraction
- Problem decomposition into five properties
  - NP-hardness proofs for some property combinations
  - Algorithms for all other property combinations

References

[1] Ballani et al. „**Towards Predictable Datacenter Networks“** The ACM SIGCOMM Conference on Data Communication (SIGCOMM'11), Toronto,Canada, August 2011

[2] Chowdhury et al. „**Managing Data Transfers in Computer Clusters with Orchestra**.“ The ACM SIGCOMMConference on Data Communication (SIGCOMM'11)

[3] D. Xie, et al. "**The only constant is change: incorporating time-varying network reservations in data centers.**" The ACM SIGCOMMConference on Data Communication (SIGCOMM'12)

[4] M. Rost, et al. "**Beyond the stars: Revisiting virtual cluster embeddings**." ACM SIGCOMM Computer Communication Review 45.3(2015)