

Data center resource management for in-network processing

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Outline

1. Introduction

2. Analysis

3. Design

4. Evaluation

5. Conclusions

Introduction

Introduction

- (NetCache introduction: "modern Internet services, such as search, social networking and e-commerce, critically depend on high-performance key-value stores. Rendering even a single web page often requires hundreds or even thousands of storage accesses." [6])
- need to scale up (SHArP introduction, *justifying INP*: "As the number of compute elements grows, and the need to expose and utilize higher levels of parallelism grows, it is essential to reconsider system architectures, and focus on developing architectures that lend themselves better to providing extreme-scale simulation capabilities.") [3])
- However, modern-day data centers only exploit servers to perform computation

In-Network Processing (INP)

- Offloading computation to network devices (e.g., programmable switches, network accelerators, middleboxes, etc.), hence reducing load on servers
- (Daiet introduction: "The functionality of networks can now be enriched without hardware changes while retaining the capability of processing packets at very high rates, even above Terabits per second") [10]
- Few solutions out there already: Daiet [10], SHArP [3], NetChain [6], IncBricks [8]

Problem statement

- TODO mention network-aware RMs
- there is no Resource Manager (RM) that considering server and switch resources **conjunctly**...

Goals

(abstract)

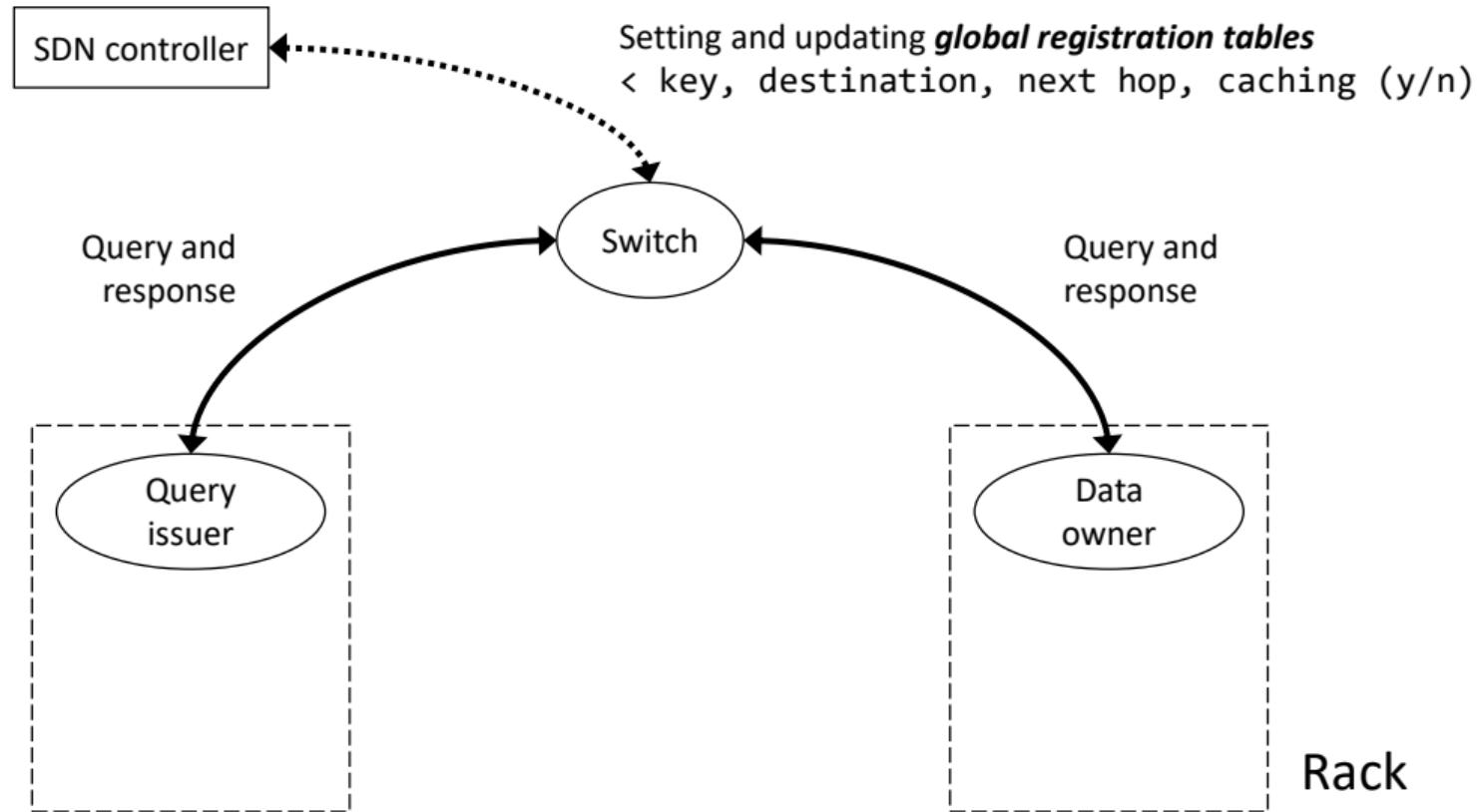
1. Model and evaluate an API through which applications can ask for INP resources
2. Discuss the importance of a scheduler which can reject INP requests and propose their server-only equivalent when needed (e.g., high switch utilization)

Analysis

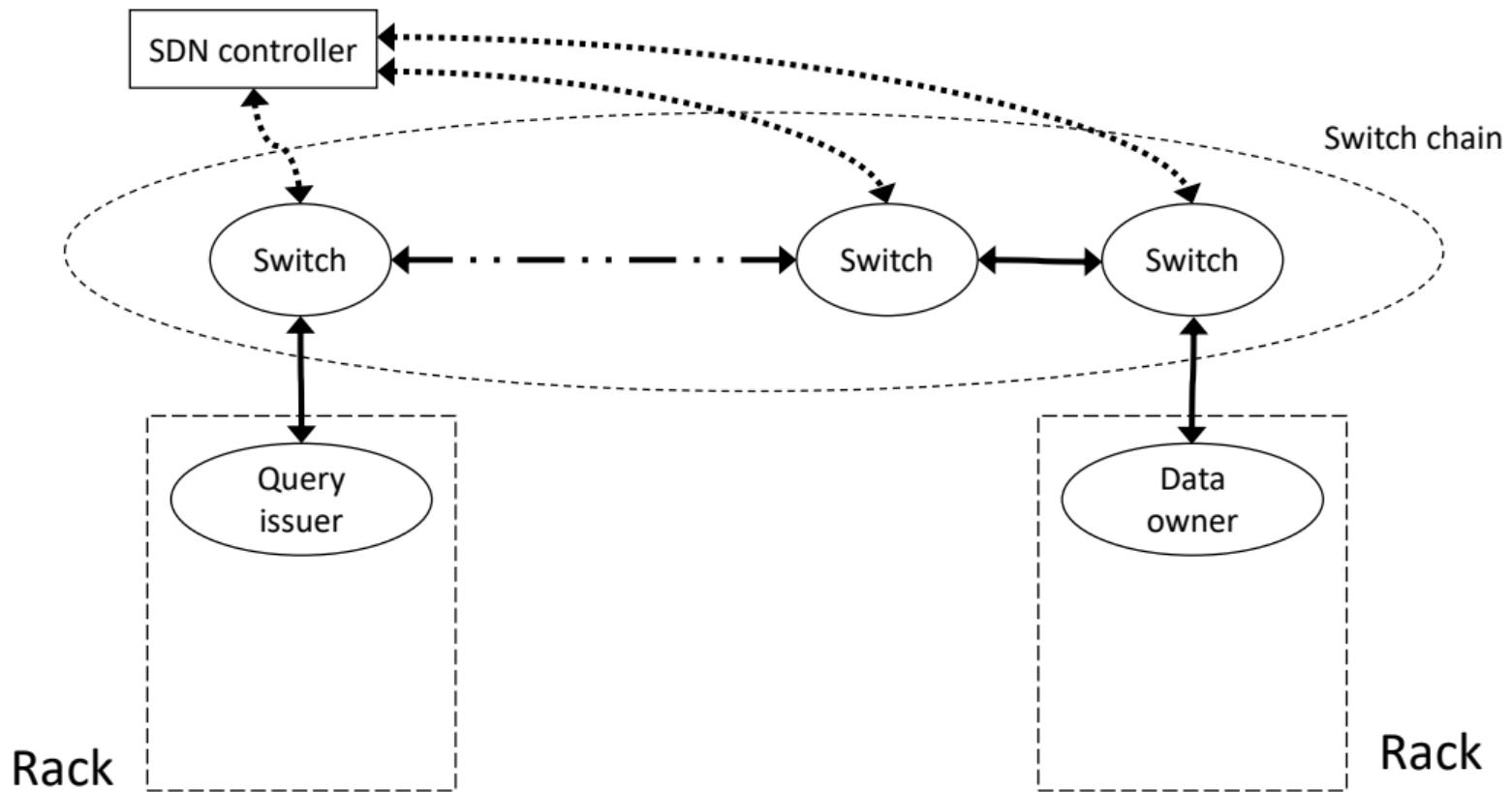
Currently existing In-Network Processing (INP) solutions

1. IncBricks (In-network caching system)
2. NetChain (Coordination services)
3. Daiet (In-network aggregation)
4. SHArP (Aggregation protocol)

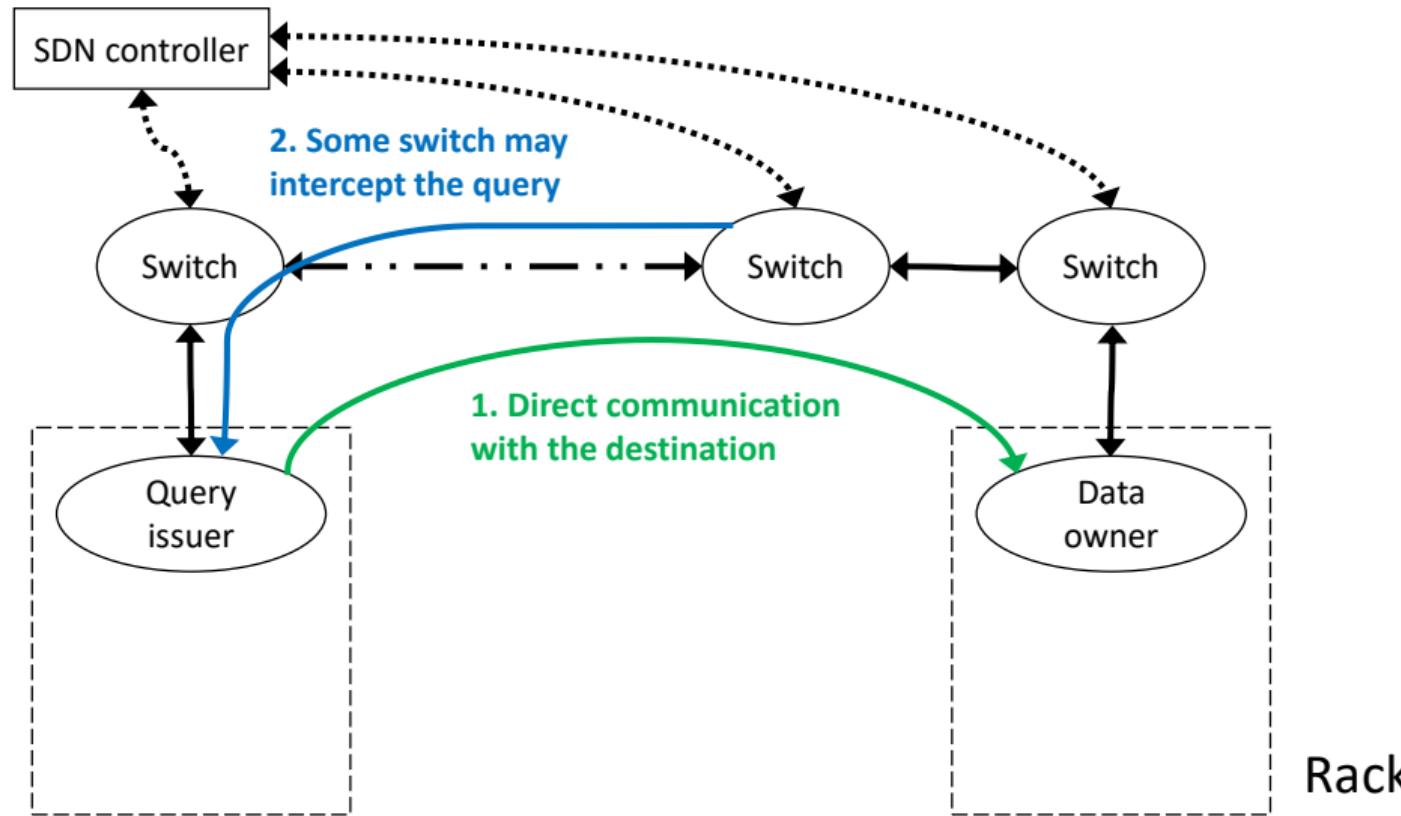
In-network caching system: IncBricks



In-network caching system: IncBricks



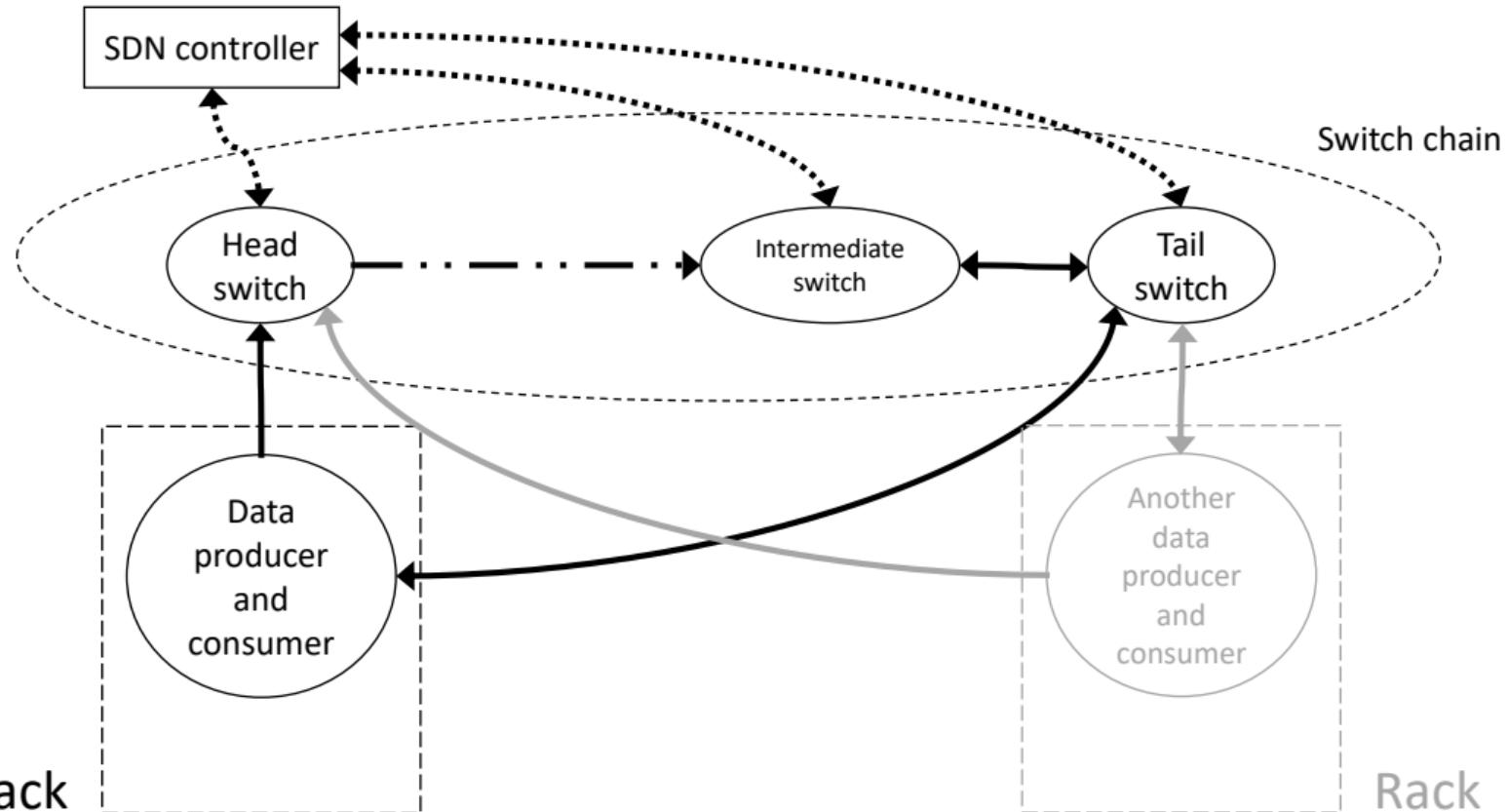
In-network caching system: IncBricks



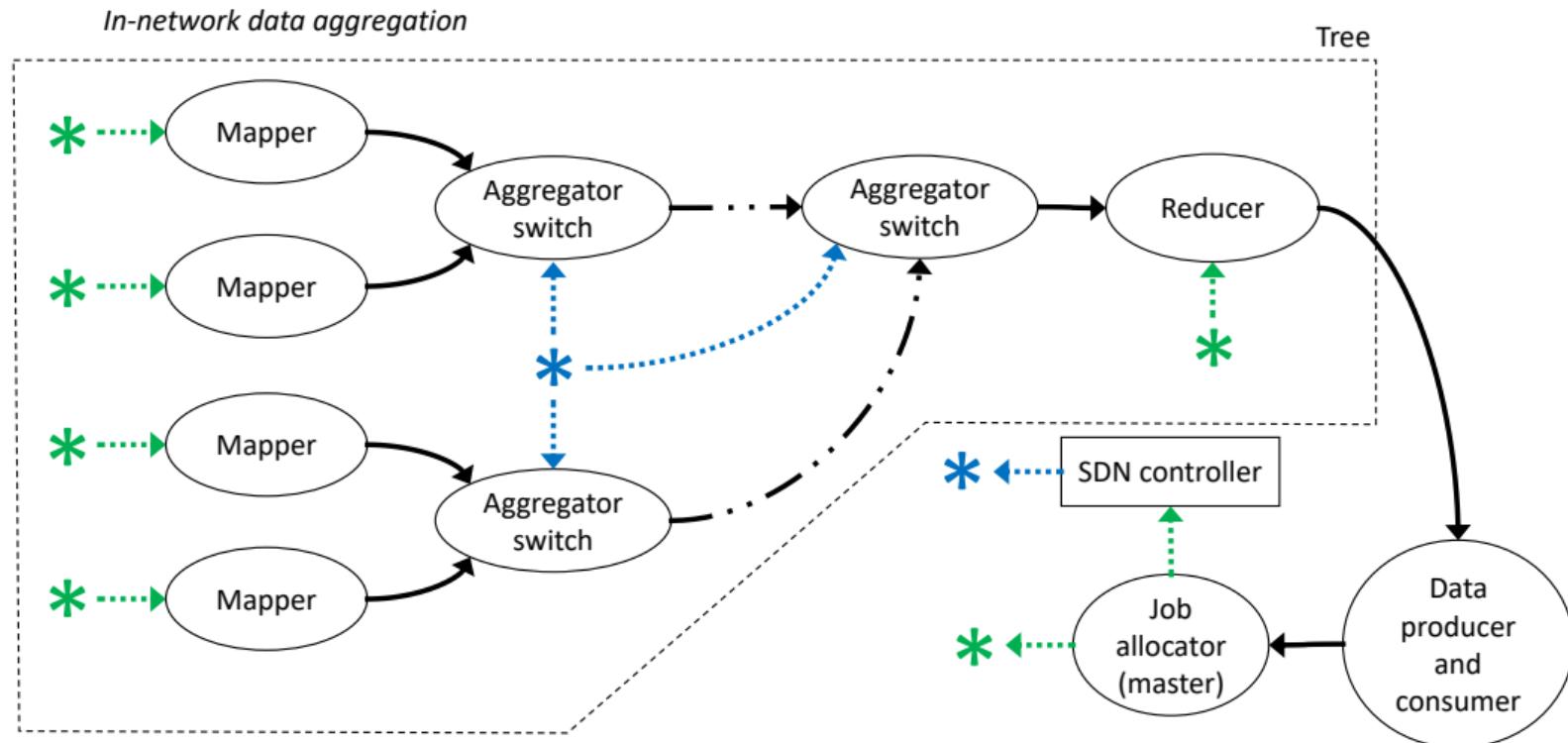
Rack

Rack

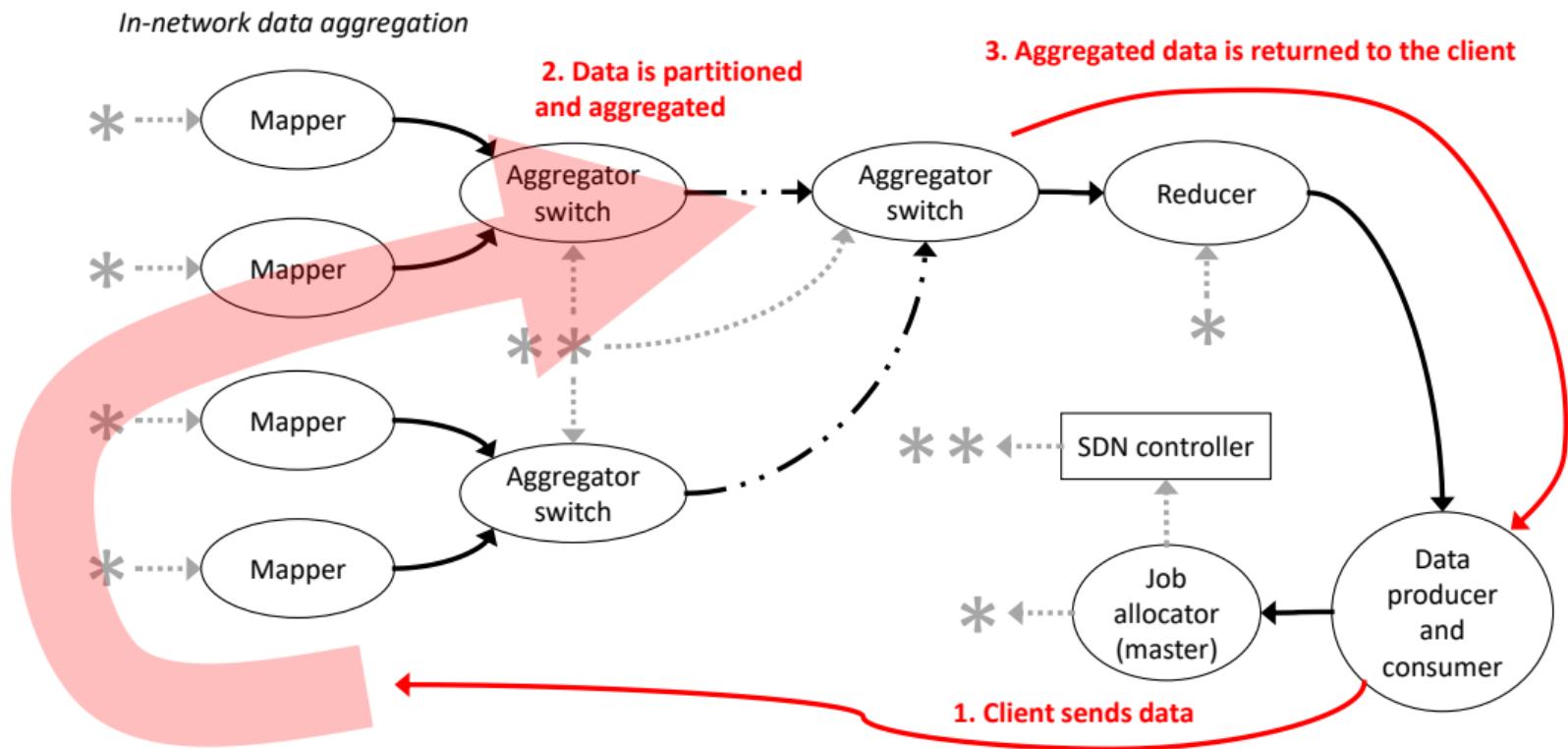
Coordination services: NetChain



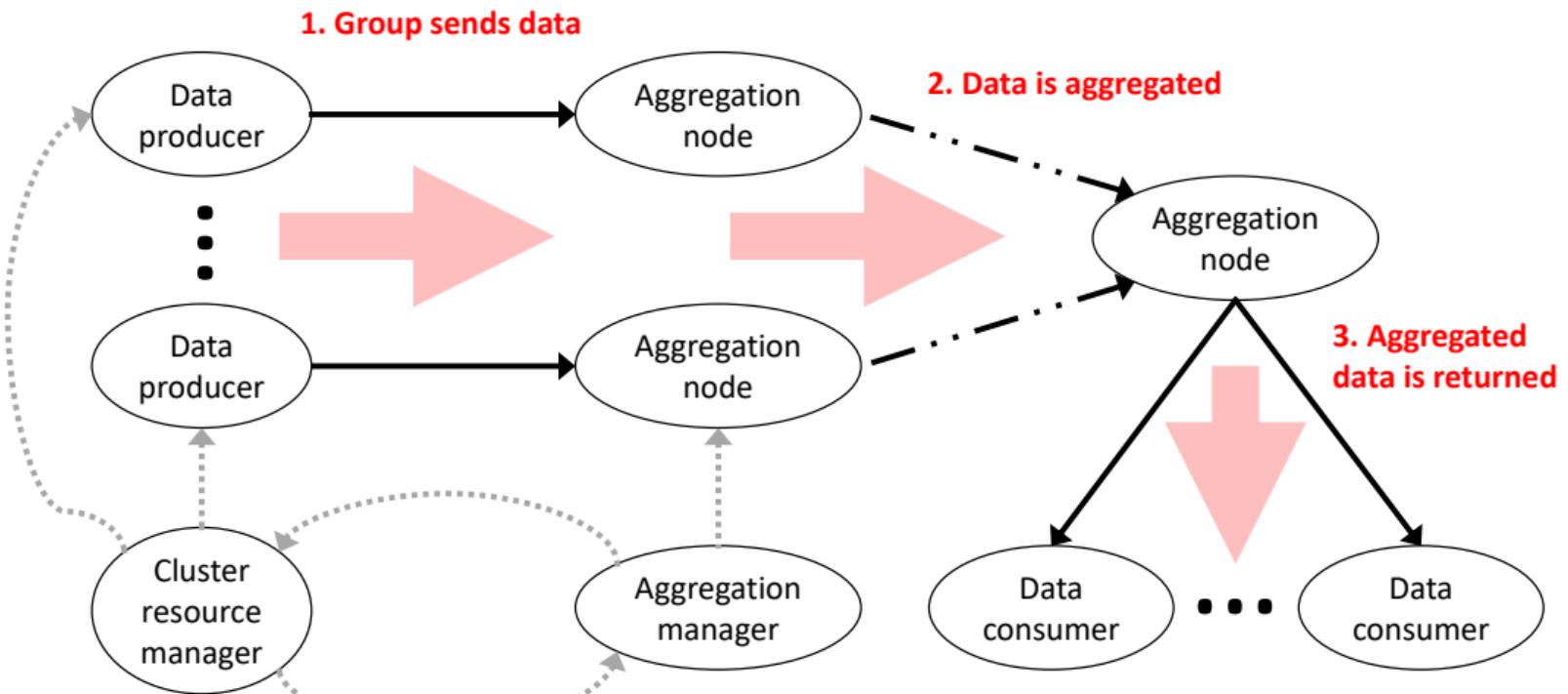
In-network aggregation: Daiet



In-network aggregation: Daiet

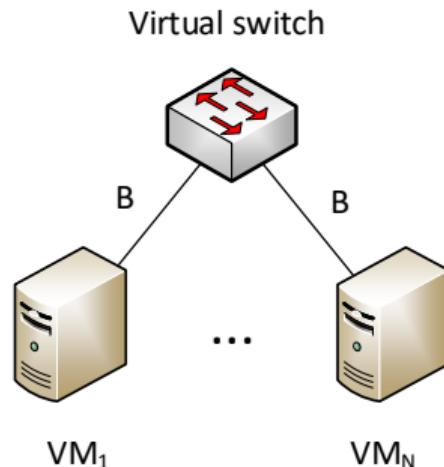


Aggregation protocol: SHArP



Resource models (3.4)

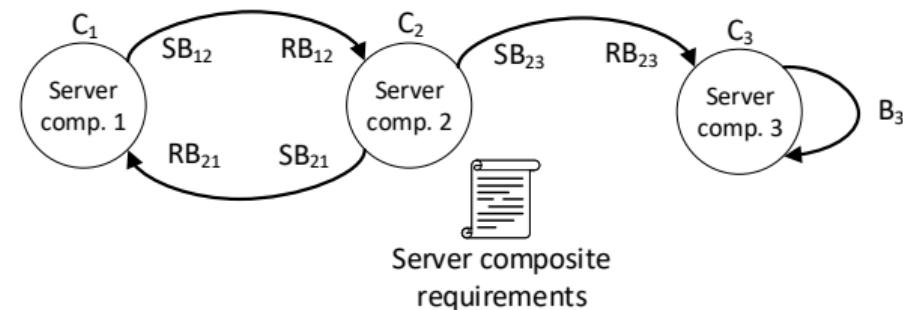
1. Virtual Cluster (VC)



2. Virtual Oversubscribed Cluster (VOC)

- N VCs connected to a single root virtual switch

3. Tenant Application Graph (TAG)



4. Fine-grained resource requests

- List of server-only resource demands

5. High-level goals

- E.g., job completion time (Bazaar [5])

Level of network awareness in RMs

- VMs proximity-aware
 - Spreading VMs across different failure domains (e.g., racks, power domains, etc.)
 - Omega [11], Apache™ YARN [12], Mesos [4], etc.
- Bandwidth-aware
 - Allowing tenants to specify bandwidth demands
 - "Virtual network" models (i.e., VCs, VOCs and TAGs)
 - CloudMirror [7], Oktopus [1], Kraken [2], Proteus [13], etc.
- Network resources-aware
 - At the time of writing, there seemed to be only one embedding solution¹ considering switch resources
 - The scheduler places server and switch resources in separate rounds

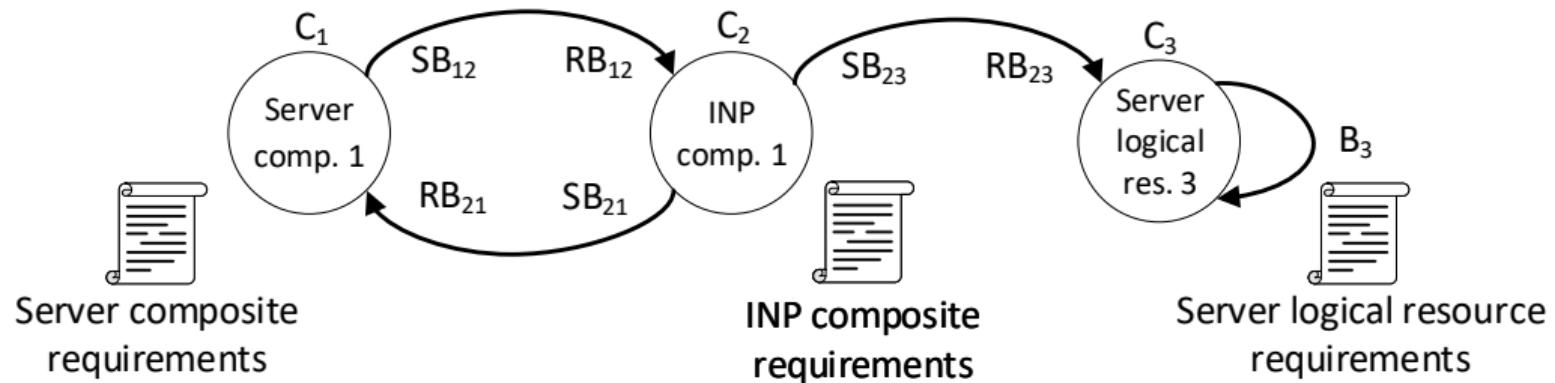
¹ Rabbani, Md Golam, et al. "On tackling virtual data center embedding problem." *2013 IFIP/IEEE International Symposium on Integrated Network Management (IM 2013)*. IEEE, 2013. [9]

Design

Composites

- A composite is a template that describes high-level logical components
 - It can be of two types:
 - Server (e.g., “web server”, “database”, ...)
 - INP (e.g., “IncBricks caching system”, “NetChain locking system”, ...)
 - It can be made out of
 - Other Composites
 - A composite loop must not be valid, since it would be impossible to place
 - Logical resources

The extended-Tenant Application Graph (eTag)

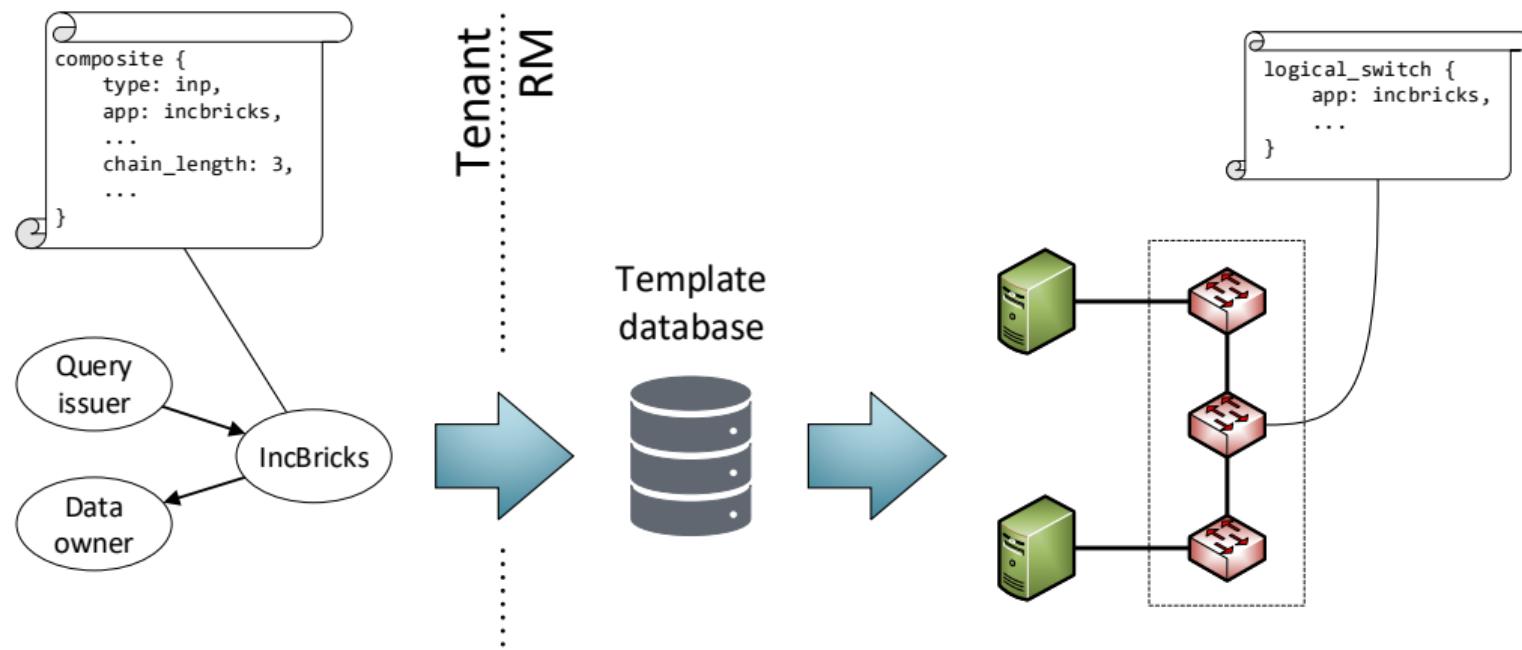


Generic groups

- In-network **storage**
 - Switches must
 - dedicate part of their local memory to store a distributed map
 - form a chain
 - IncBricks [8], NetChain [6]
- In-network **data aggregation**
 - Switches must
 - form a tree whose root is connected to data consumers and whose leaves are connected to data producers
 - dedicate part of their local memory to store a key-value map
 - be able to perform basic operations on data, such as writing and hashing
 - wait for all its children to send aggregated data
 - Daiet [10], SHArP [3]

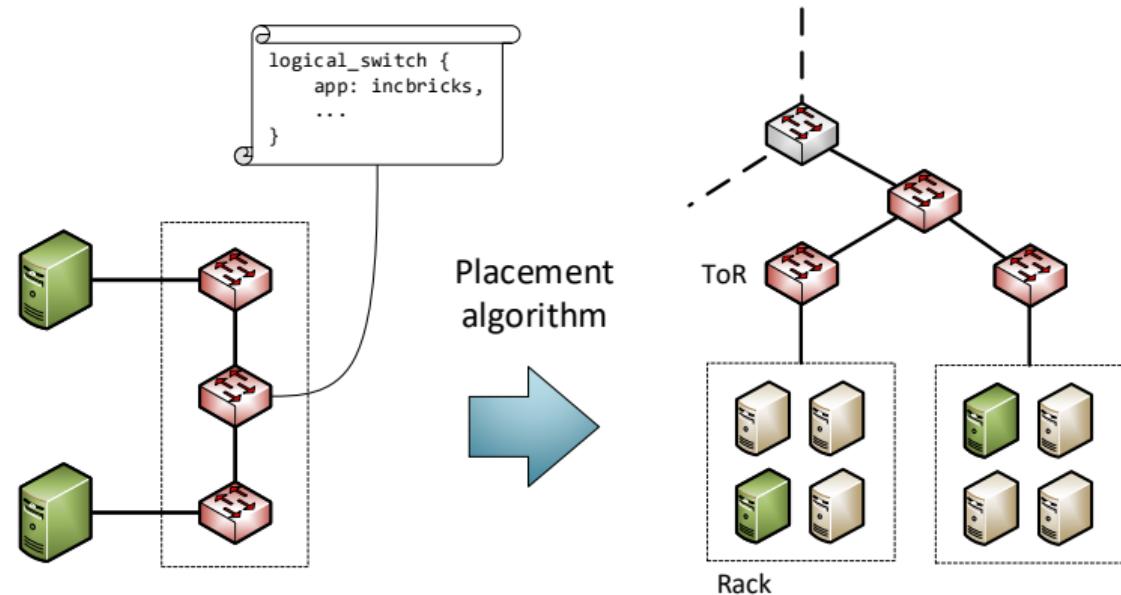
Mapping composites to logical resources

- The *template database* maps composites (or generic groups) to their equivalent made out of just logical resources

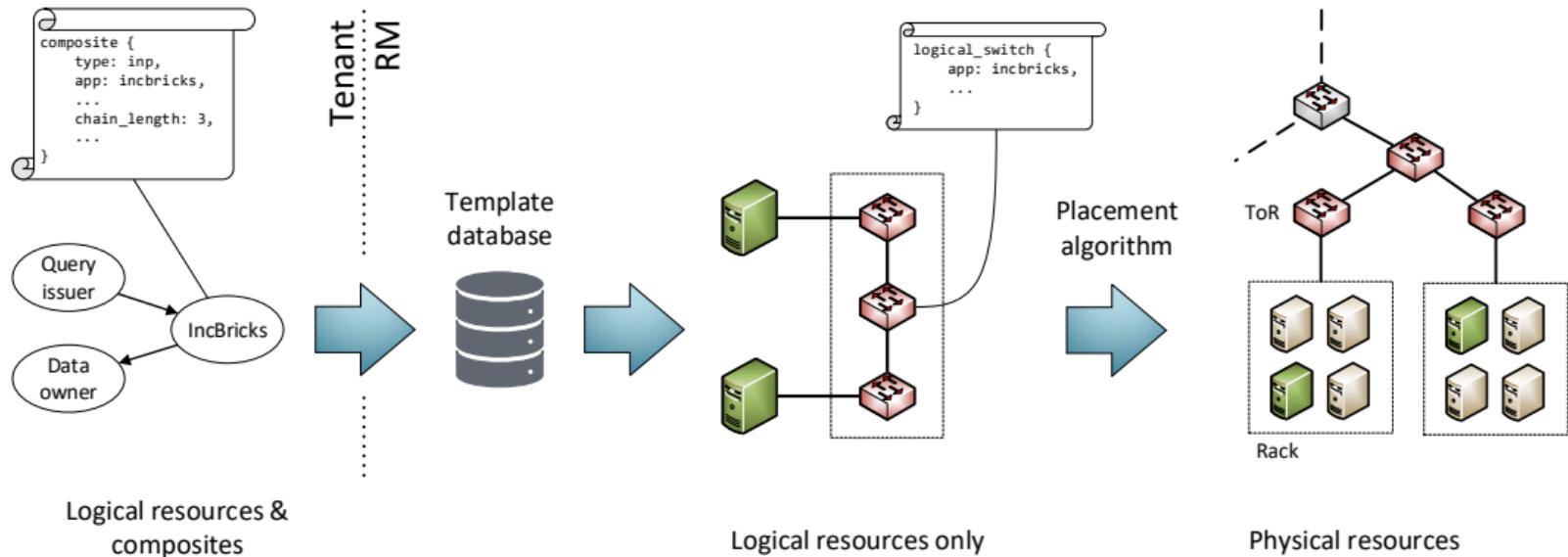


Placing logical resources

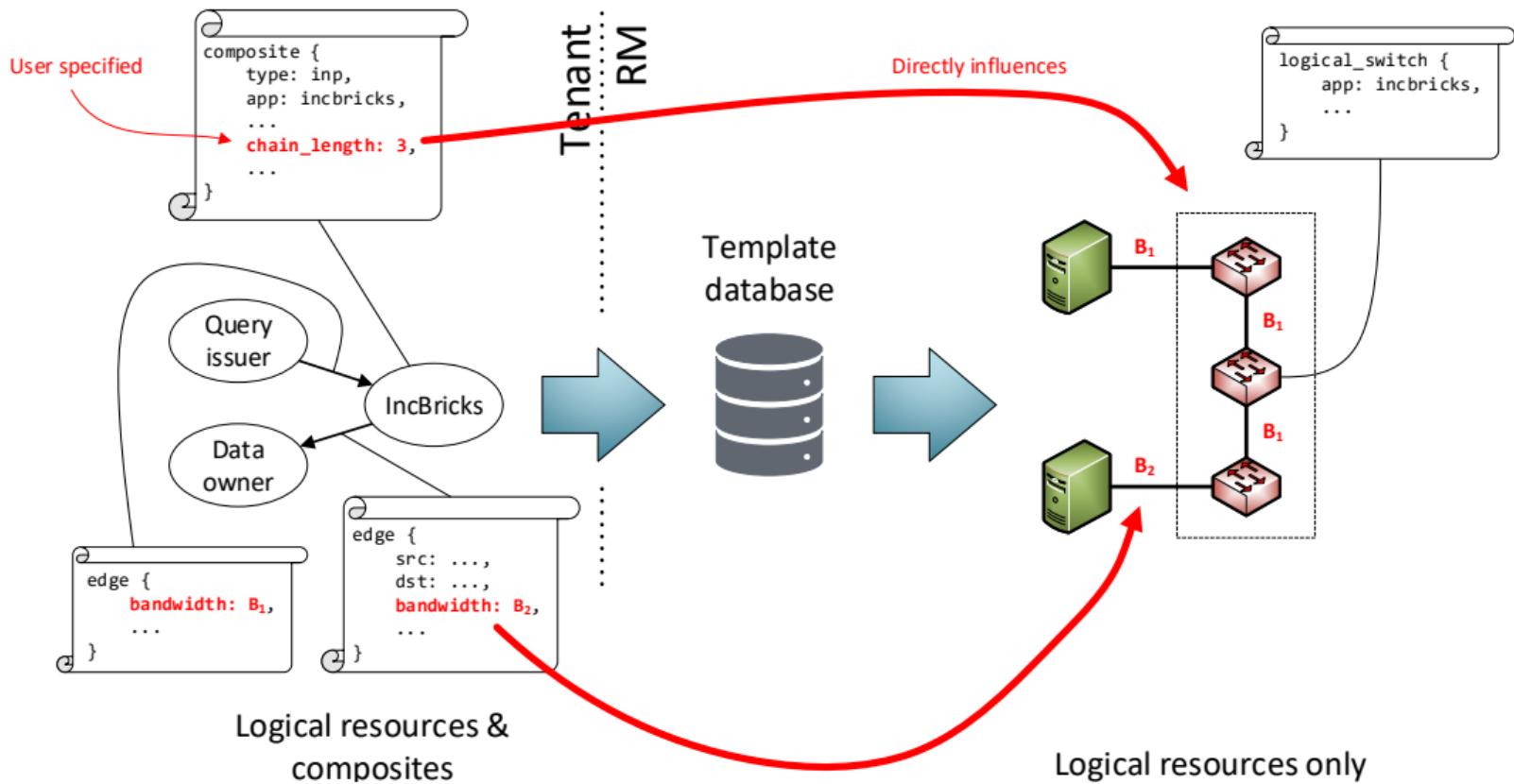
- The placement algorithm places logical resource onto physical ones
- Three types of physical resources:
 - Server
 - Switch
 - Link



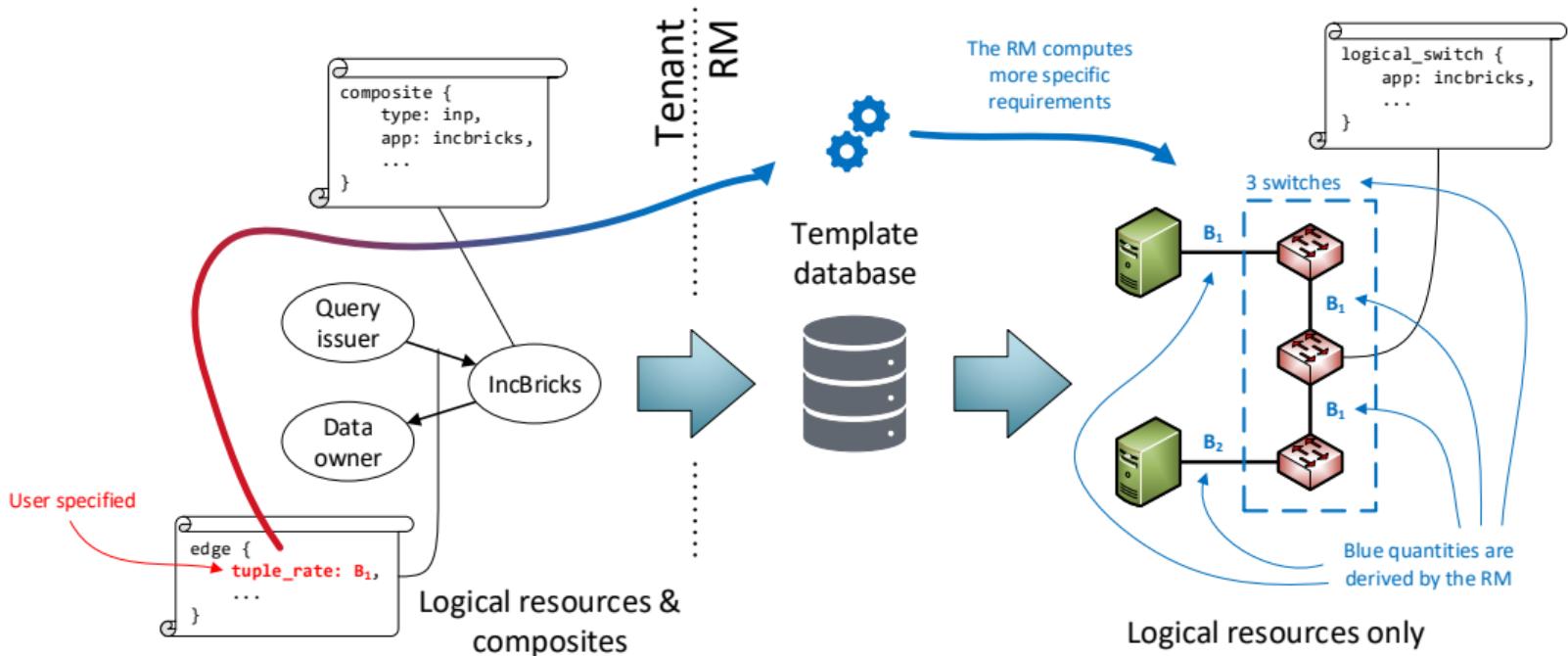
The whole picture



1st approach: passive template mapping



2nd approach: active template mapping



Evaluation

Simulation 1/2

- Simulator built from the ground up
 - Inspired by Omega's [11] *lightweight simulator*²
 - Supports multiple resource dimensions, switch resources, and composites
 - Switches have *properties* (e.g., supported INP solutions)
- Simulated data center physical architecture: fat-tree with 4 pods
- 3 days-long randomly-generated workload
 - Job properties (e.g., requirements, requests' interarrival time, etc.) are sampled from exponential distributions
- Simple greedy scheduler

²Available at github.com/google/cluster-scheduler-simulator

Simulation 2/2

- The template database contains two entries for the previously-mentioned generic groups
 - In-network storage (switch chain)
 - In-network data aggregation (switch tree)
- Server Tasks Cutback (STC): the reduction of server tasks once an INP solution is introduced

$$STC = \frac{\# \text{server tasks without INP}}{\# \text{server tasks with INP}} \quad (1)$$

- Sweep: percentage of requests including INP composites

Results 1/3

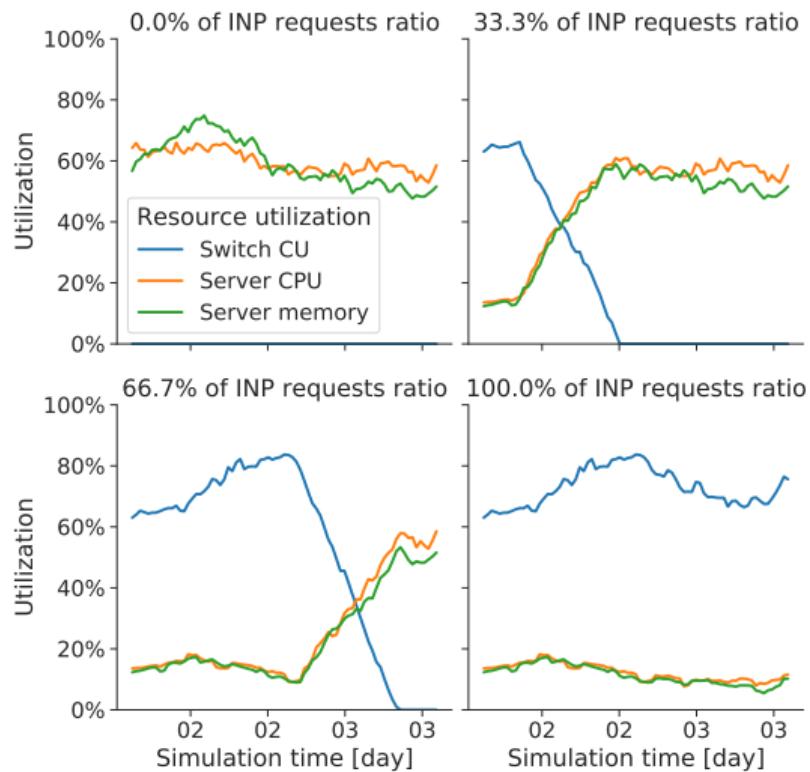


Figure 1: Physical resource utilization for different amounts of INP requests

Results 2/3

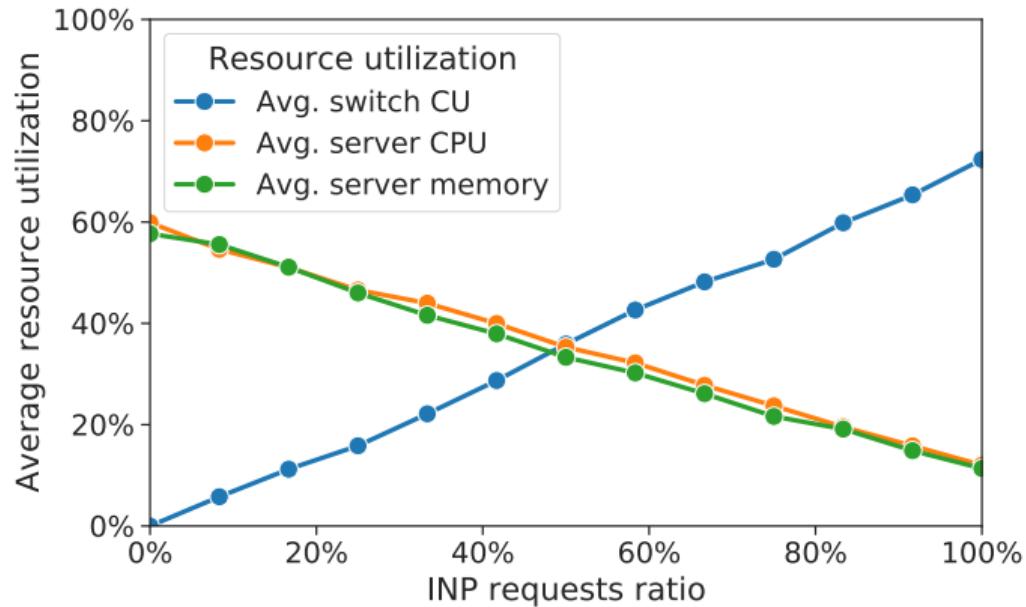


Figure 2: Average resource utilization as a function of the INP requests ratio

Results 3/3

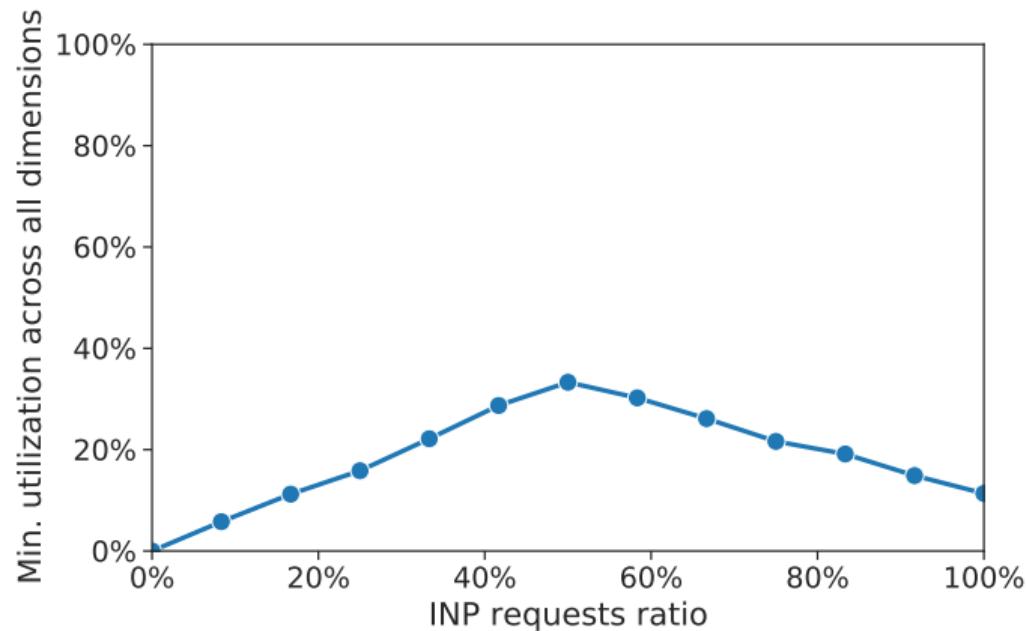


Figure 3: Minimum resource utilization across all dimensions

Conclusions

Questions?

Thank you

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