Crystal: Software-Defined Storage for Multi-tenant Object Stores

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A LESSON FROM A PALM TREE

A lesson from a palm tree

- When the **weather is good**, all the trees enjoy ☺

A lesson from a palm tree

- But weather conditions may change dramatically… And, when the **storm comes**…

A lesson from a palm tree

- Some trees get through a storm better than others.


- One of the key properties for a tree to survive a storm is being **flexible**.

A lesson from a palm tree

- This work aims to make **object stores flexible** for adapting the system to **changing requirements**.

Flexibility

- Programmability
- Extensibility
- Automation
- Control

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CONTEXT: SOFTWARE DEFINED OBJECT STORAGE

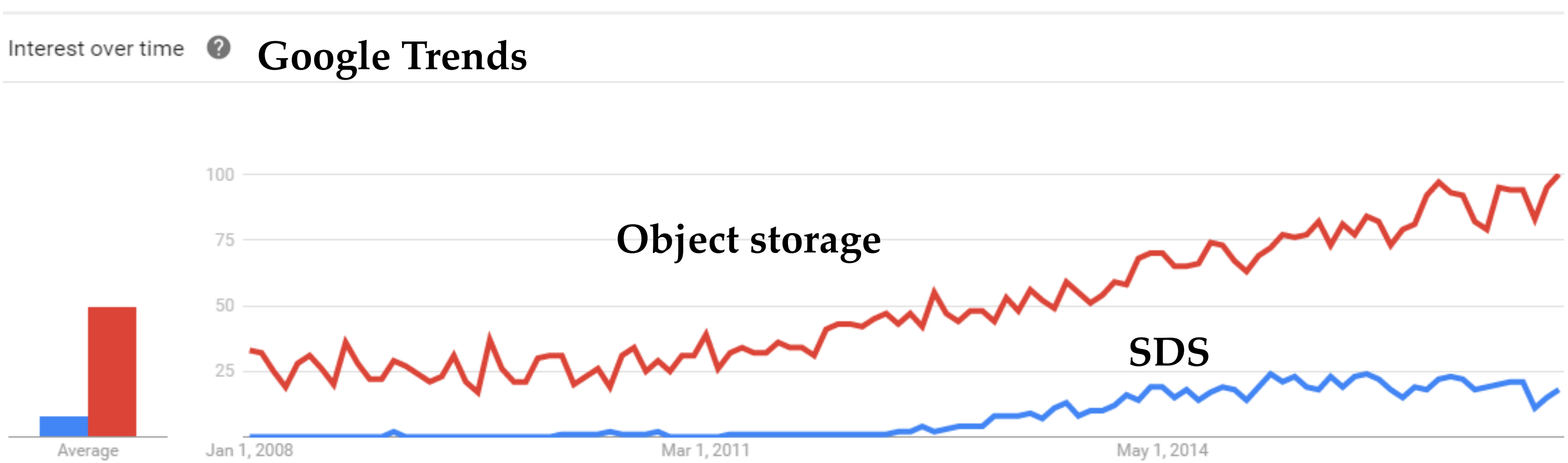
What is Software-Defined Storage?

- Hey! What does Software-Defined Storage **mean**?

*“**Software-defined storage** (SDS) is a new term for data **storage software** that provides **policy-based provisioning and management** of data storage **independent** of the underlying hardware.”*

(Wikipedia)

- *SDS*: Automation, management, optimize workloads,…



SDS Concepts & Works

- SDS systems **decouple control/data planes**:
  - *Control plane*: Definition of policies, intelligence
  - *Data plane*: Enforcement of policies, manage data flows

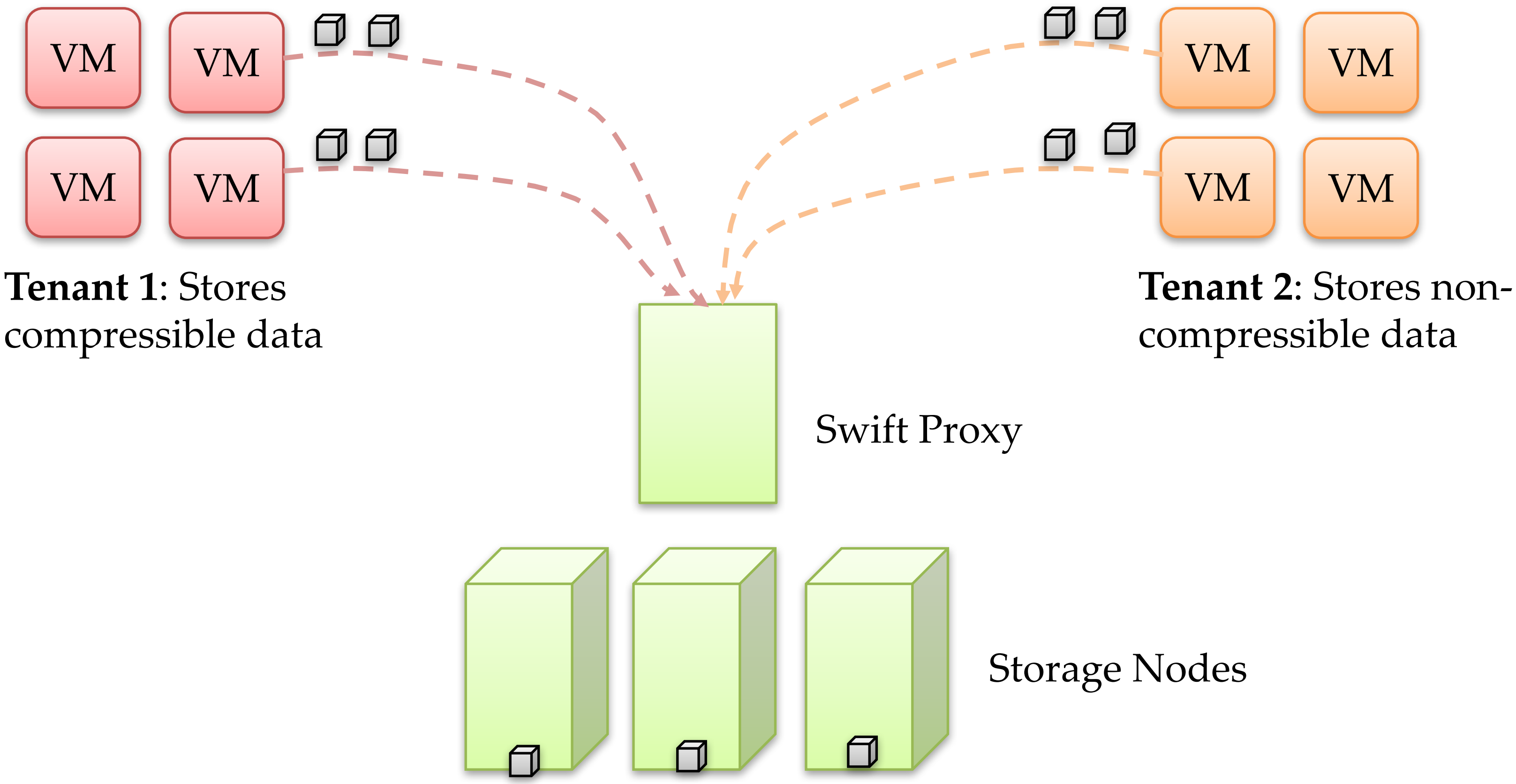
- SDS systems in the literature:
  - *IOFlow (SOSP'13):* BW control/middleboxes, targets **file-system**
  - *Retro (NSDI'15)*: **Resource management**, guarantee SLOs
  - *sRoute (FAST'16)*: **Network-like model** to treat flows (sSwitches)

- We focus on **object storage** (OpenStack Swift):
  - **Policy-based redundancy** models in Swift (from Kilo version)
  - Companies like **SwiftStack** sell automation, provisioning, and metering services.

- *But, can we go a step further? And, why?*

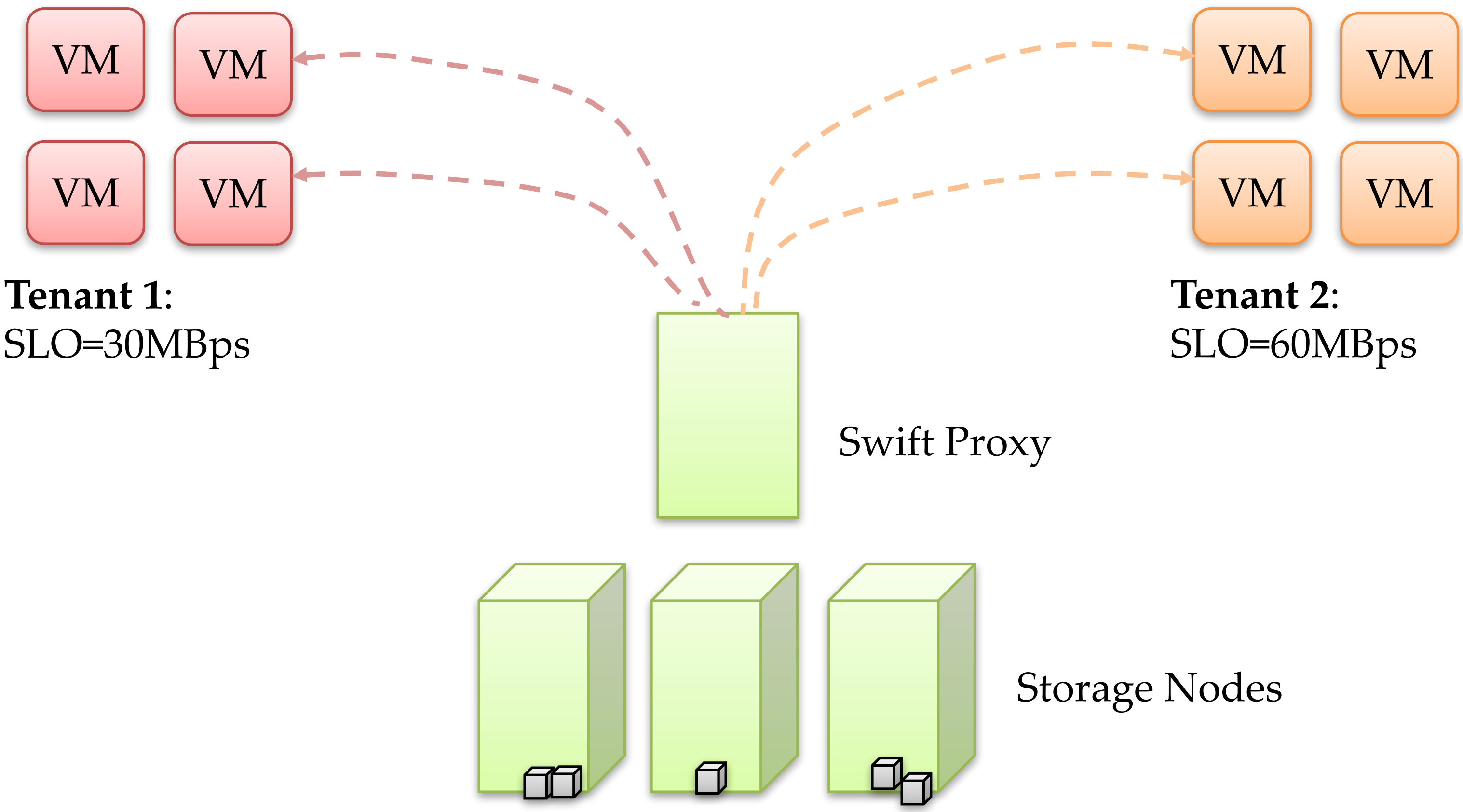
PROBLEM: ADVANCED STORAGE MANAGEMENT

What if…



Can we compress only T1's data to save storage space?

Or, what happens if…



Can we enforce service-level objectives on tenants?

Sadly, Swift lacks from flexibility…

CRYSTAL

Design Principles of Crystal

- Crystal is a **SDS framework to solve storage management problems** in object stores (OpenStack Swift):
  - It is **not** an ad-hoc solution to a particular problem!

- Crystal decouples **control/data planes**:

Control Plane

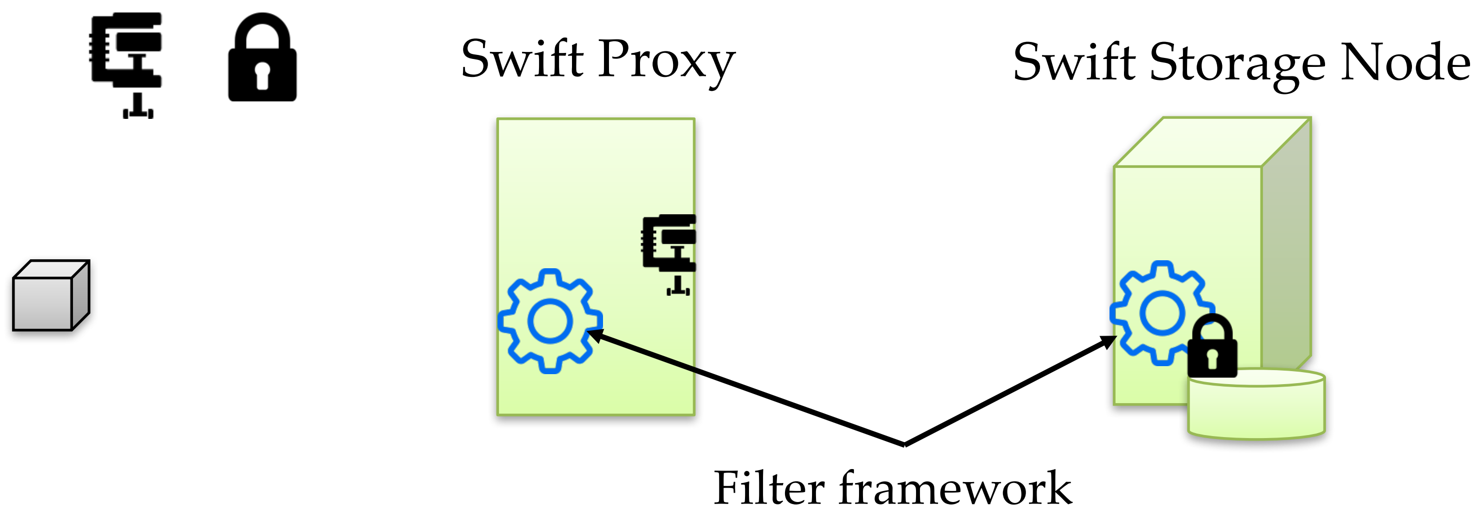
Policies, Controllers

Data Plane

Filters, Triggers

Crystal Design (Data Plane)

- **Filter**: Data transformation executed on object requests.
  E.g., compression, caching, encryption, bandwidth allocation…

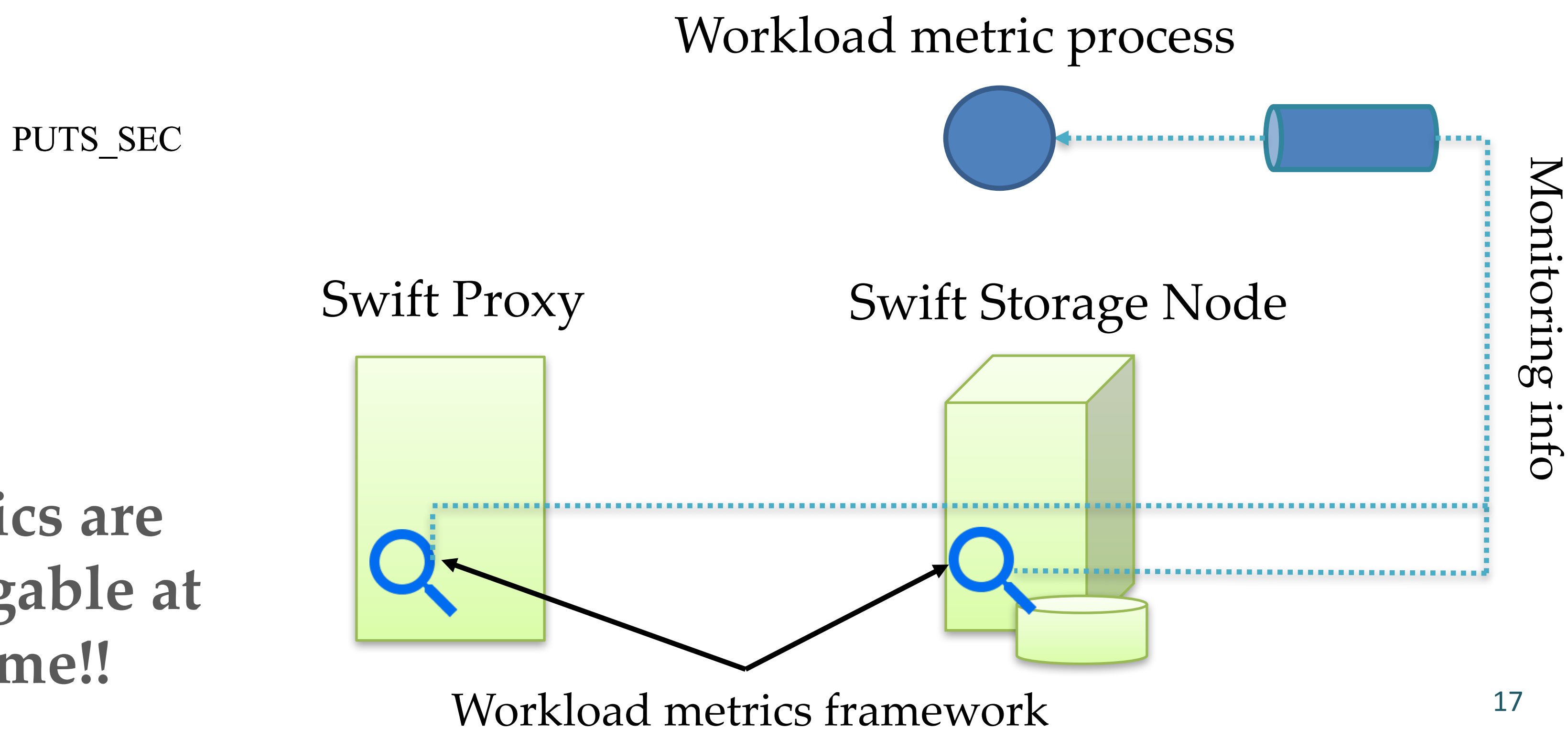


- Two types of filters:
  - **OpenStack Storlets** (isolated execution)
  - **Native filters** (non-isolated execution)

Filters are pluggable at runtime!!

Crystal Design (Data Plane)

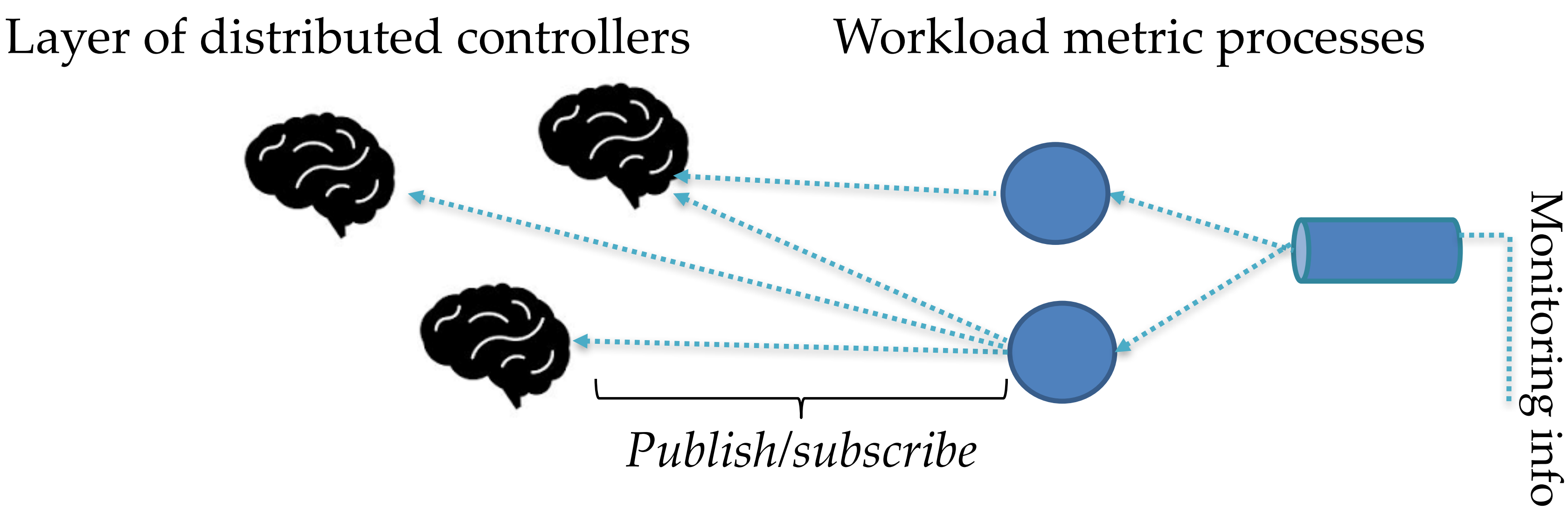
- **Inspection triggers**: Information of a particular aspect of the system operation to trigger the execution of filters.
  - **Object metadata**: object size, type,…
  - **Workload metrics**: E.g., requests/sec, CPU load, object contents,…



Metrics are pluggable at runtime!!

Crystal Design (Control Plane)

- **Controller**: Algorithm that receives as input workload metrics to manage the execution of filters.



- We provide two types of controllers:
  - **Automation controllers**: Simple activation rules (*self-generated*).
  - **Global controllers**: Global visibility and coordination of a filter at the data plane (*user-defined*).

Crystal Design (Control Plane)

- **IFTTT-like policies**: Crystal provides administrators with a simple "If-This-Then-That"-like DSL

	FOR	*[TARGET]*	WHEN	*[TRIGGER CLAUSE]*	DO	*[ACTION CLAUSE]*
P1		**TENANT** T1		OBJECT_TYPE=DOCS		**SET** COMPRESSION **WITH** TYPE=LZ4, **SET** ENCRYPTION
P2		**CONTAINER** C1		GETS_SEC > 5 **AND** OBJECT_SIZE<10M		**SET** CACHING **ON PROXY TRANSIENT**
P3		**TENANT** T2				**SET** BANDWIDTH **WITH** GET_BW=30MBps

Content management policy   Data management policy   Resource management policy

Storage automation policy   Globally coordinated policy

- The vocabulary of the DSL **can be expanded at runtime:**
  - By adding new **filters**
  - By adding new **workload metrics and triggers**

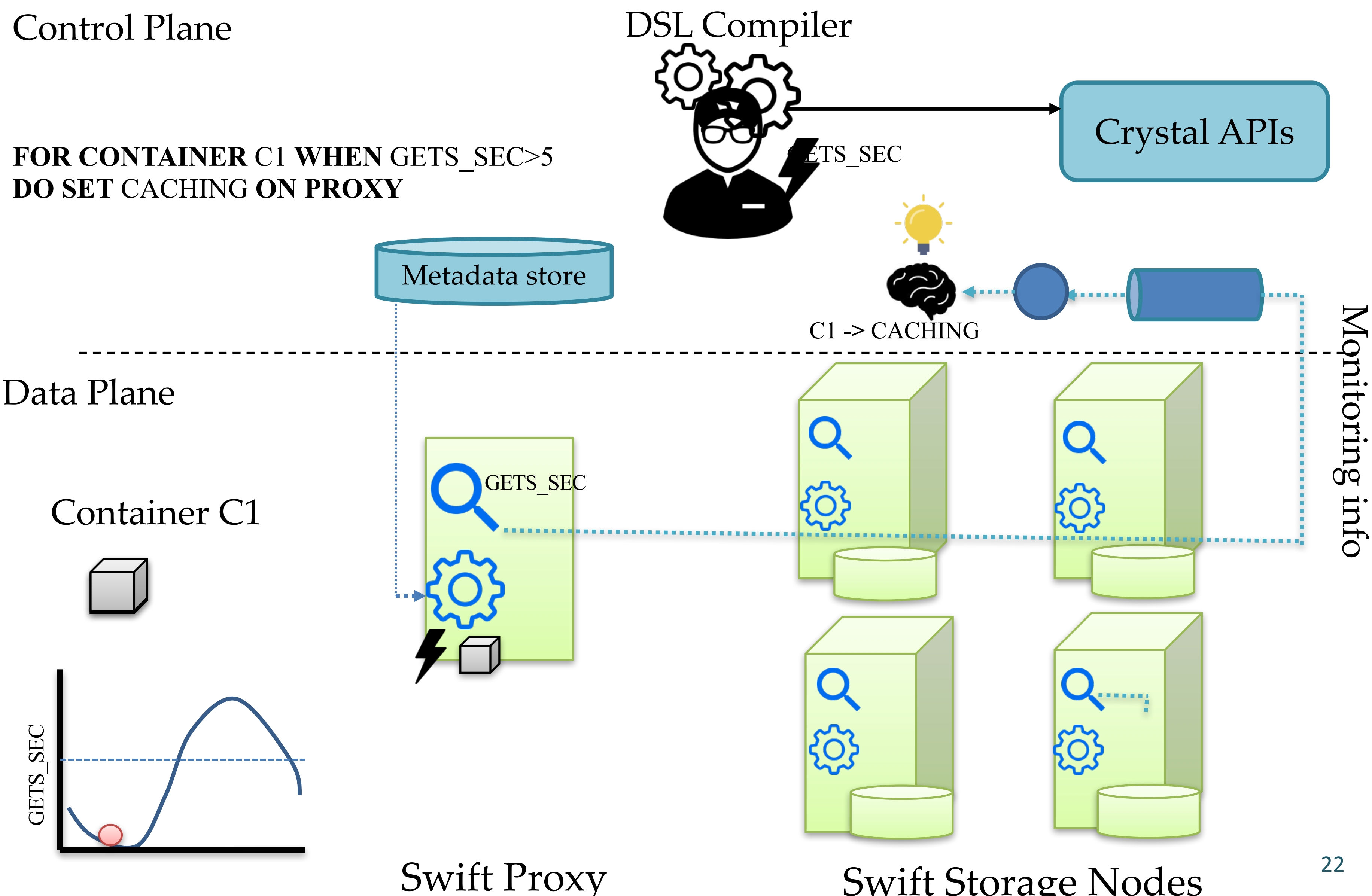
EXPERIMENTAL RESULTS

Setup

- 13 nodes cluster:
  - 1 Controller: controllers, metadata, messaging, authentication, Swift proxy (*Dell PowerEdge 420, 32GB RAM, 1TB HDD*)
  - 3 nodes to execute workloads (*Dell PowerEdge 420, 32GB RAM, 1TB HDD)*
  - 2 Swift Proxies (*Dell PowerEdge 320 , 28GB RAM, 1TB HDD, 500GB SSD)*
  - 7 Storage nodes (*Dell PowerEdge 320, 16GB RAM, 2x1TB HDD*)

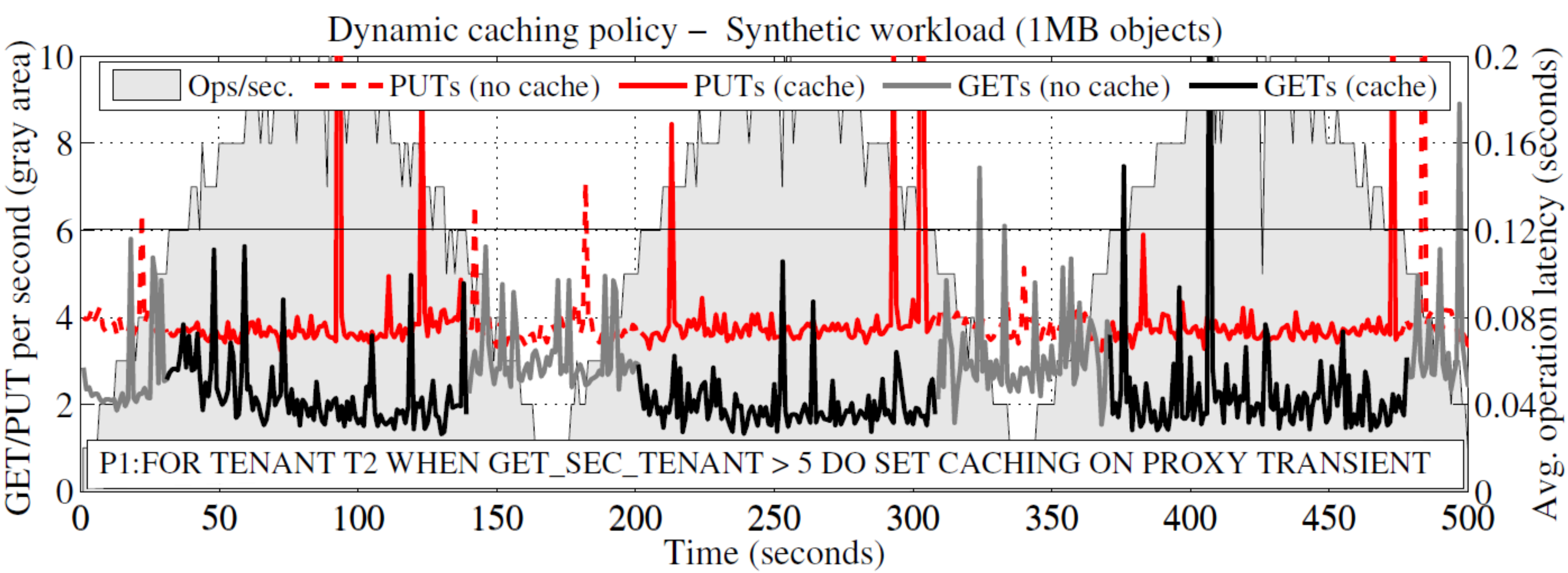
- Switched 1GBit Ethernet
- OpenStack Swift Kilo version

Storage Automation



Storage Automation

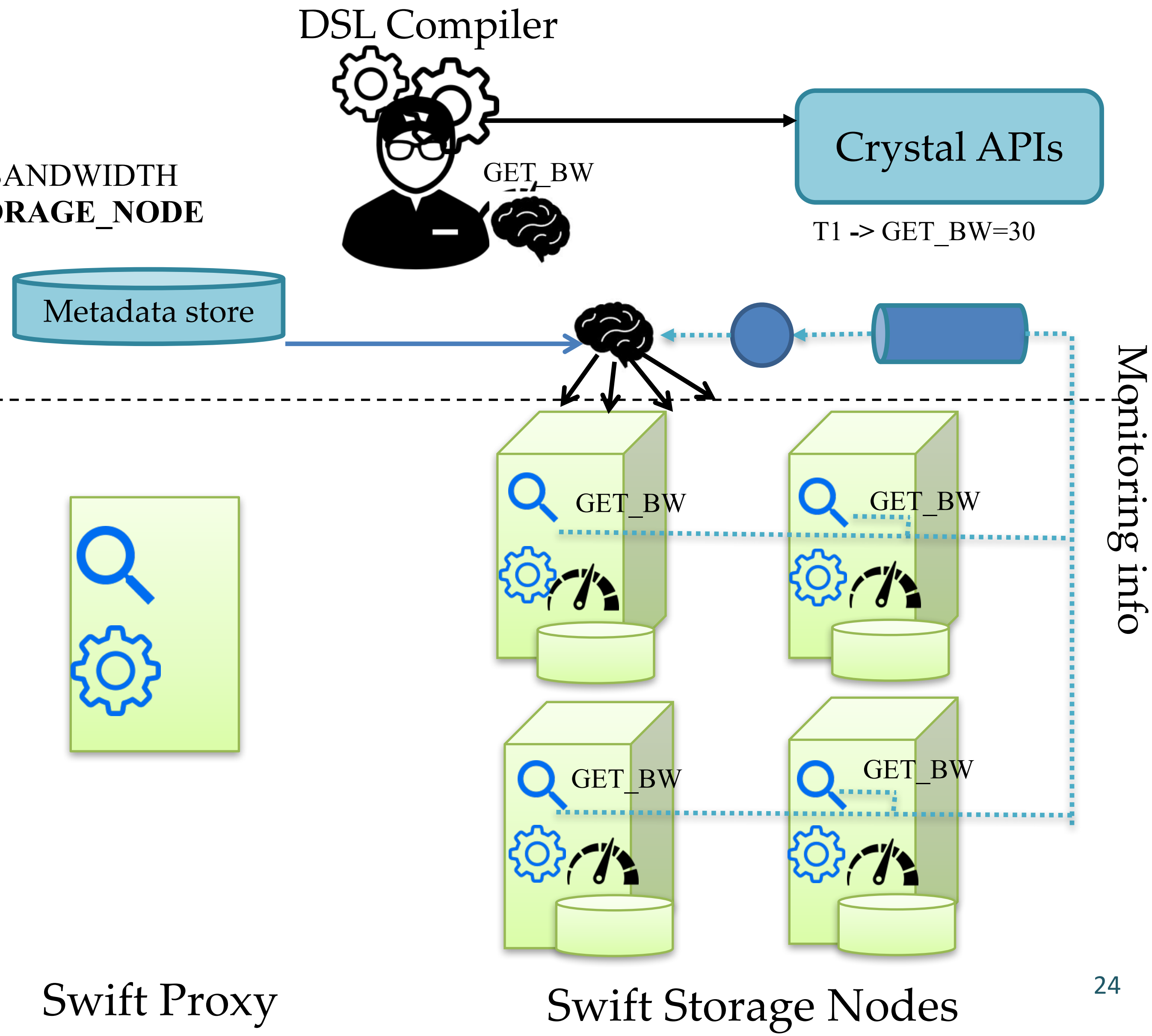
- **Oscillatory workload with high locality** (0 to 10 PUT/GET per sec.).
- Simple LRU **caching filter** exploiting **proxy SSDs**.
- Enforce caching **under higher loads** (GET_SEC>5)
  - **Reads are 30% faster** (in median) when caching is activated.
  - Writes are almost **not affected**.



Bandwidth Differentiation

Control Plane

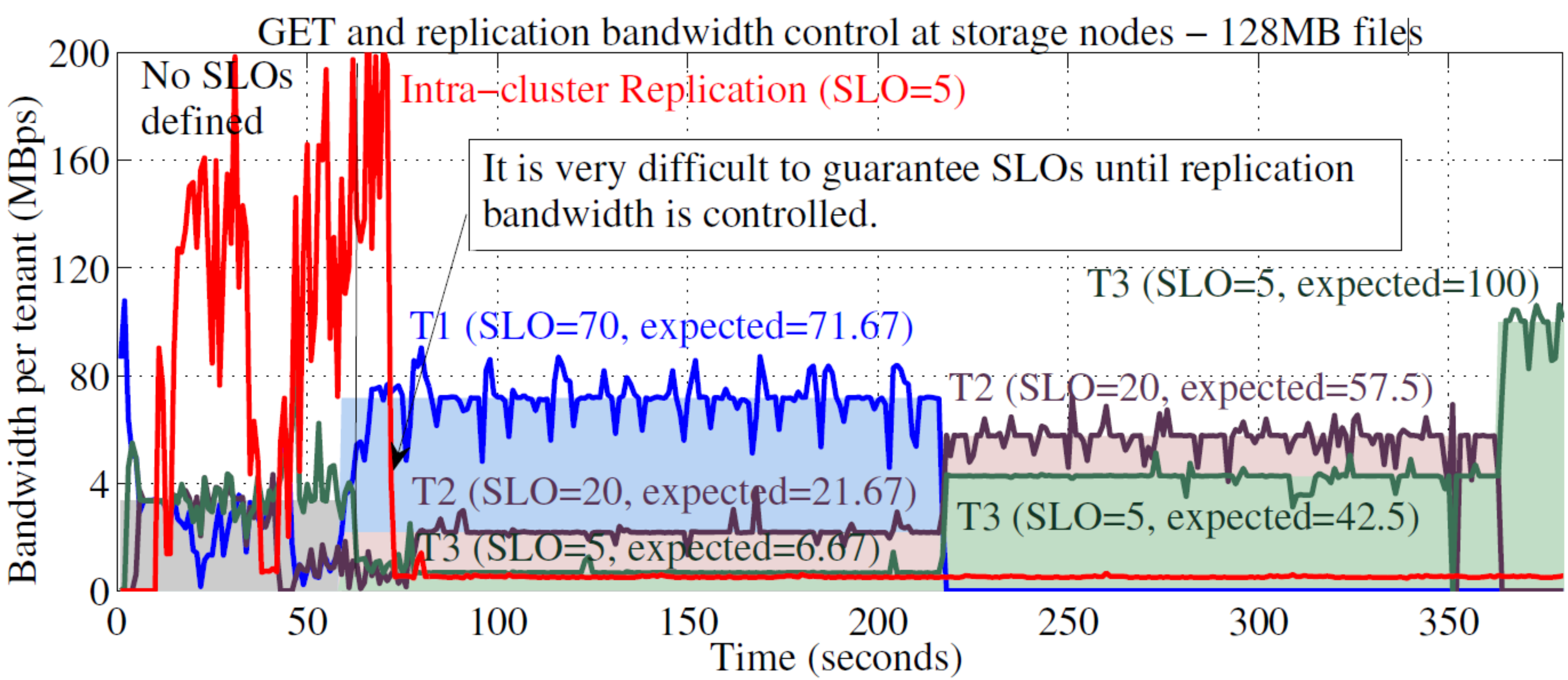
FOR TENANT T1 **DO SET** BANDWIDTH
WITH GET_BW=30 **ON STORAGE_NODE**



Data Plane

Bandwidth Differentiation

- **3 ssbench tenants** executing 128MB GETs against the cluster.
- **Bandwidth throttling filter** (deployed at storage nodes).
- **2 global controllers** (GET BW, Replication BW)
- Until **replication traffic is controlled**, SLOs are not achieved.



CONCLUSIONS

Conclusions

- Many object stores are **hard to adapt to new requirements**.
- We presented Crystal, the first **SDS architecture for object stores**:
  - *Control plane*: **Policies** (IFTTT-like), **Controllers** (distributed algorithms)
  - *Data plane*: **Filters** (compute on objects), **Triggers** (metrics, metadata)
- We demonstrated the **extensible design of Crystal**:
  - **New storage automation policies** (compression, caching,…).
  - **A global bandwidth control filter**.
- The framework opens the door to **investigate new storage filters and control algorithms**.

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IOSTACK

SOFTWARE-DEFINED STORAGE FOR BIG DATA

-Crystal-

SDS for OpenStack Swift

http://crystal-sds.org

https://github.com/Crystal-SDS

QUESTIONS?
THANK YOU!

Overheads

- **Metadata access overhead**:
  - 3.9% 1MB
- **Isolated flow interception**:
  - 15.7% 1MB
  - 5.7% 10MB
- Performance may also depend on **data content** & **access patterns**.