Comet: An Active Distributed Key-Value Store

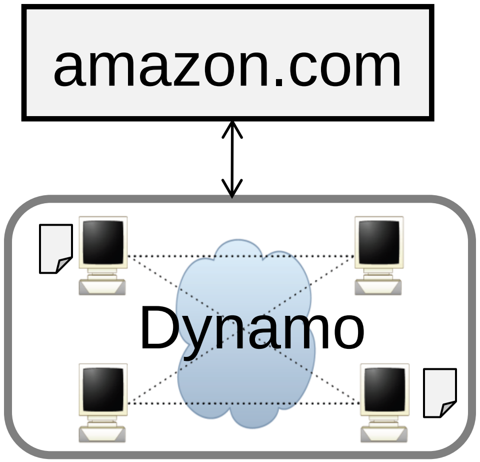
Roxana Geambasu
Amit Levy
Yoshi Kohno
Arvind Krishnamurthy
Hank Levy

University of Washington

Distributed Key/Value Stores

- A simple **`put/get`** interface
- Great properties: scalability, availability, reliability
- Increasingly popular both within data centers and in P2P

Data center



P2P

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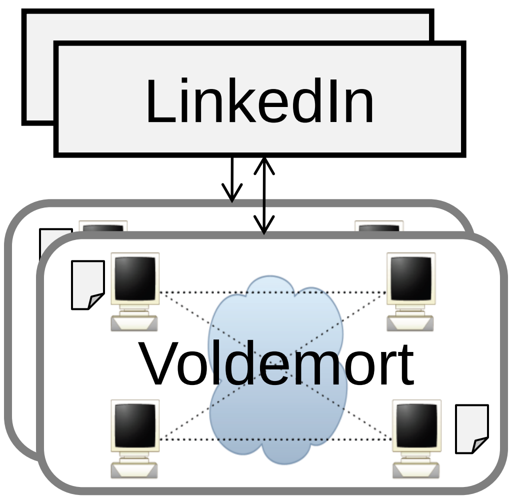

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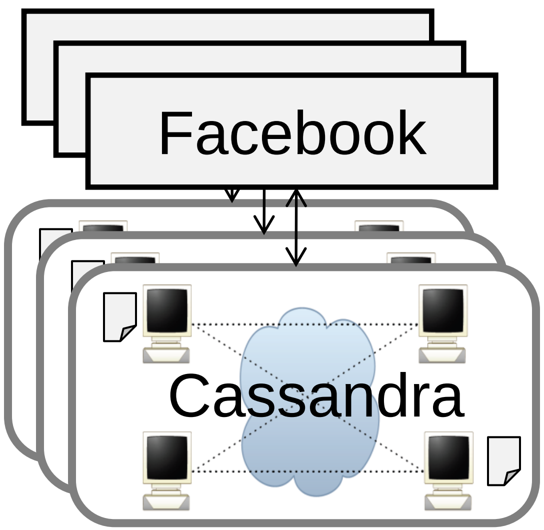

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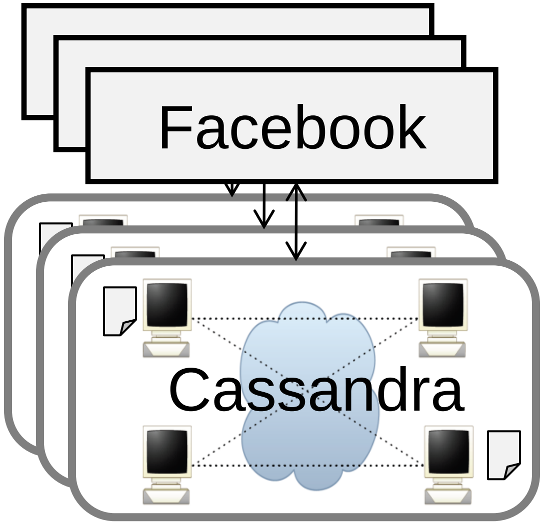

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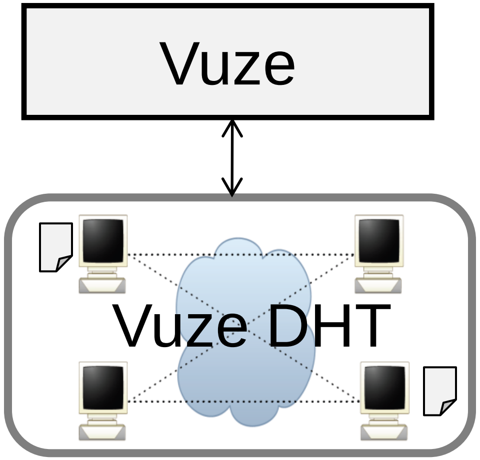

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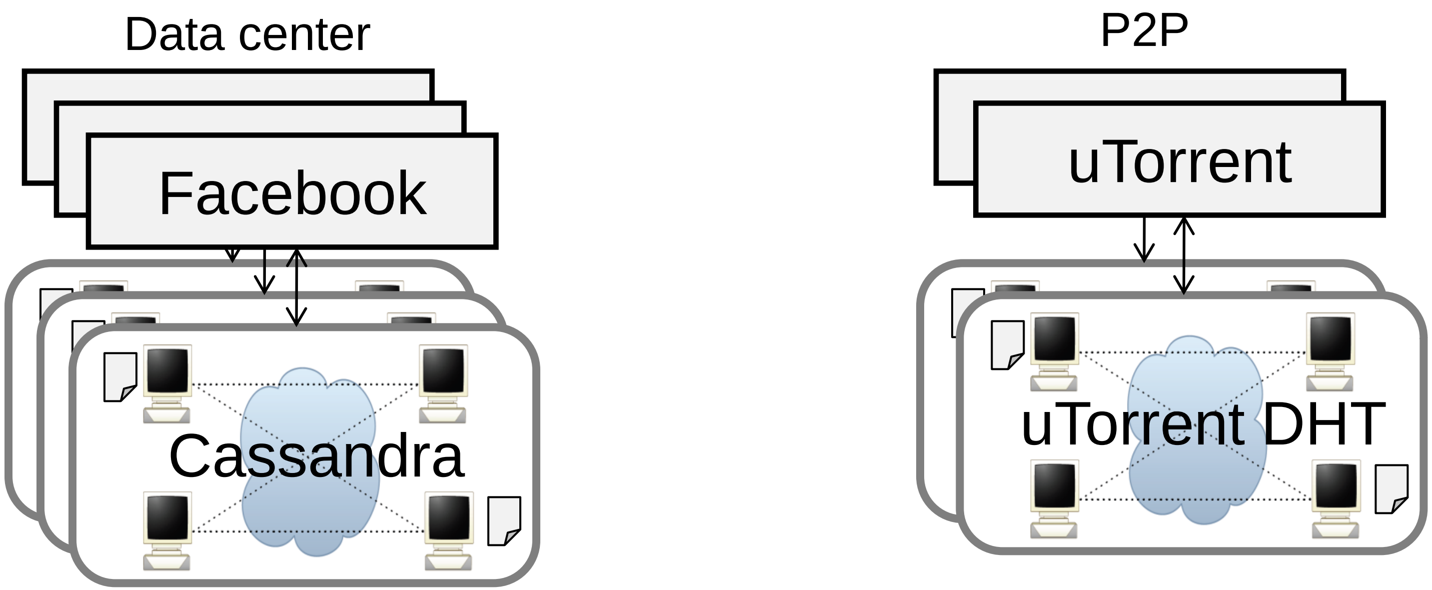
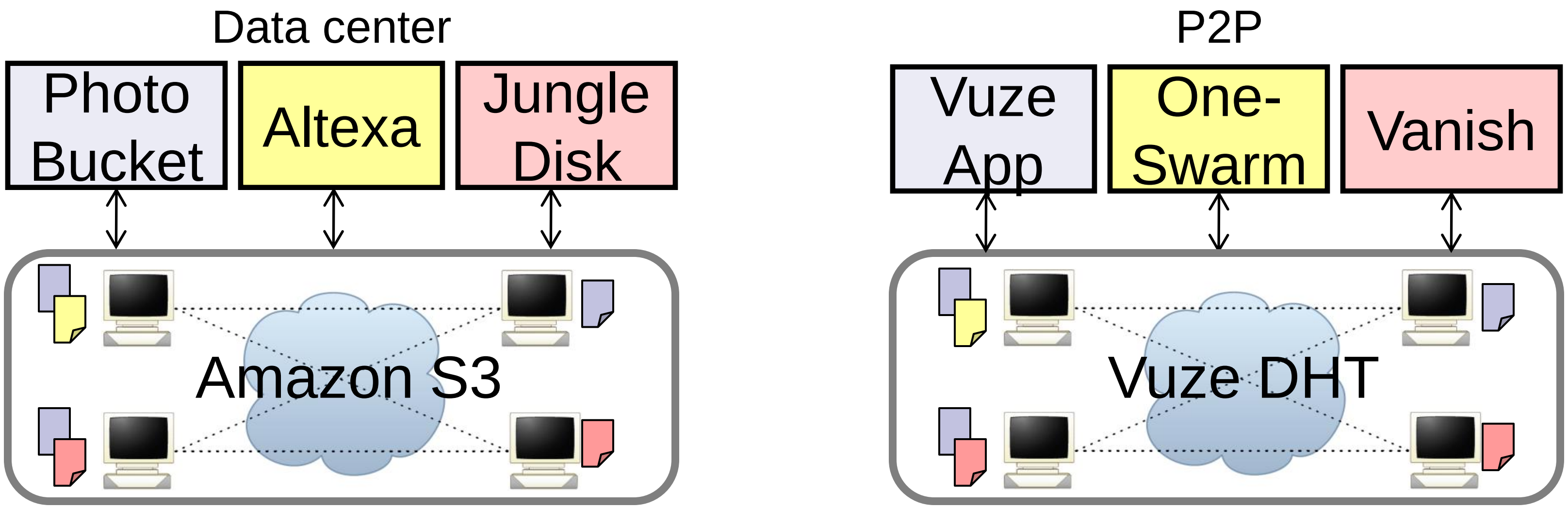


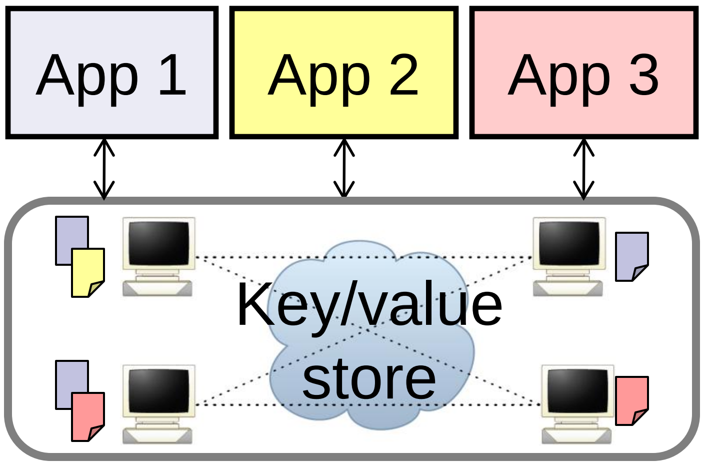
Distributed Key/Value Storage Services

- Increasingly, key/value stores are shared by many apps
  - Avoids per-app storage system deployment
- However, building apps atop today's stores is challenging



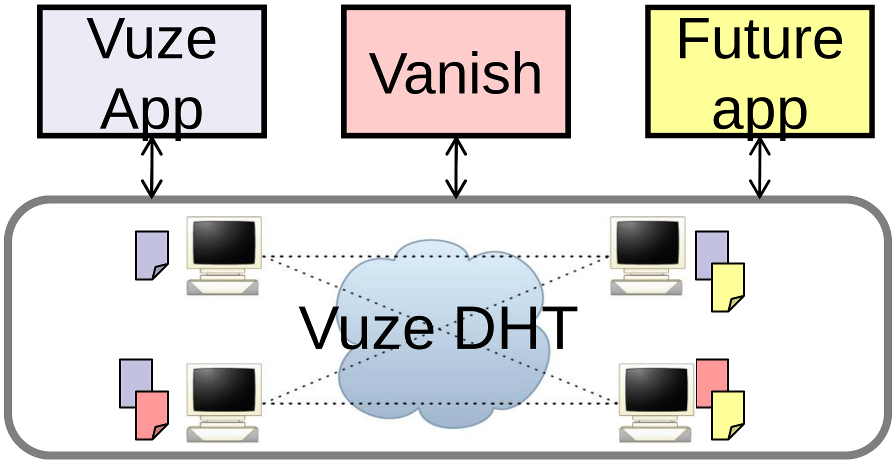
Challenge: Inflexible Key/Value Stores

- Applications have different (even conflicting) needs:
  - Availability, security, performance, functionality
- But today's key/value stores are one-size-fits-all
- Motivating example: our Vanish experience



Motivating Example: Vanish [USENIX Security ‘09]

- Vanish is a self-destructing data system built on Vuze
- Vuze problems for Vanish:
  - Fixed 8-hour data timeout
  - Overly aggressive replication, which hurts security
- Changes were simple, but deploying them was difficult:
  - Need Vuze engineer
  - Long deployment cycle
  - Hard to evaluate before deployment



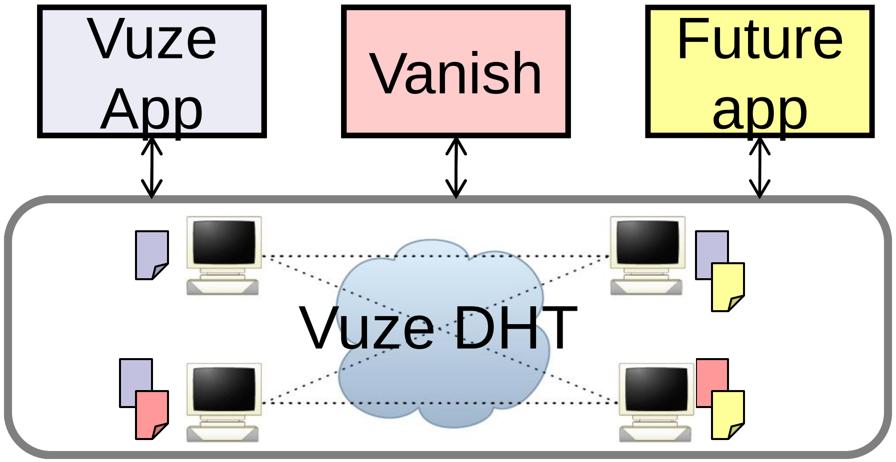
Motivating Example: Vanish [USENIX Security '09]

- Vanish is a self-destructing data system built on Vuze
- Vuze p
  - Fixe
  - Ove

Question:

How can a key/value store support many applications with different needs?

- Changes were simple, but deploying them was difficult:
  - Need Vuze engineer
  - Long deployment cycle
  - Hard to evaluate before deployment



Extensible Key/Value Stores

- Allow apps to customize store's functions
  - Different data lifetimes
  - Different numbers of replicas
  - Different replication intervals
- Allow apps to define new functions
  - Tracking popularity: data item counts the number of reads
  - Access logging: data item logs readers' IPs
  - Adapting to context: data item returns different values to different requestors

Design Philosophy

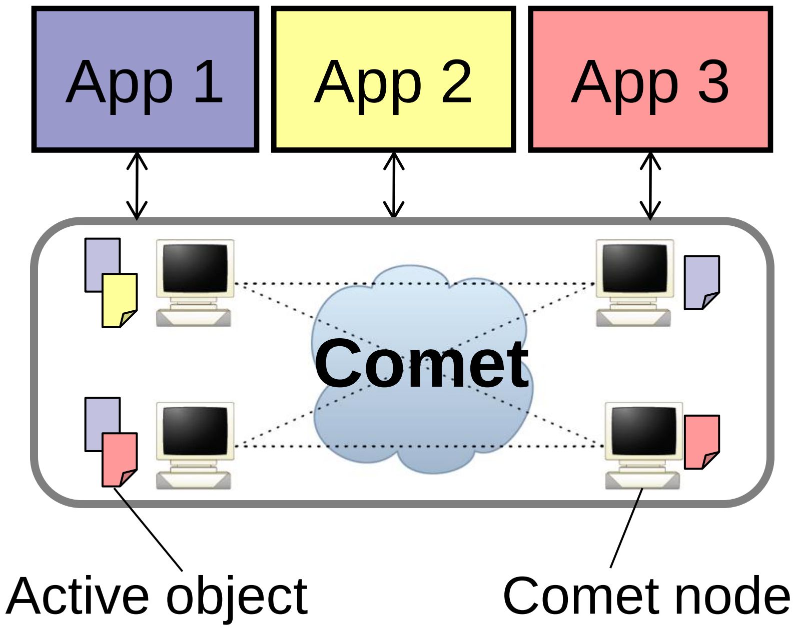
- We want an extensible key/value store
- But we want to keep it simple!
  - Allow apps to inject tiny code fragments (10s of lines of code)
  - Adding even a tiny amount of programmability into key/value stores can be extremely powerful
- This paper shows how to build extensible P2P DHTs
  - We leverage our DHT experience to drive our design

Outline

- Motivation
- Architecture
- Applications
- Conclusions

Comet

- DHT that supports application-specific customizations
- Applications store active objects instead of passive values
  - Active objects contain small code snippets that control their behavior in the DHT

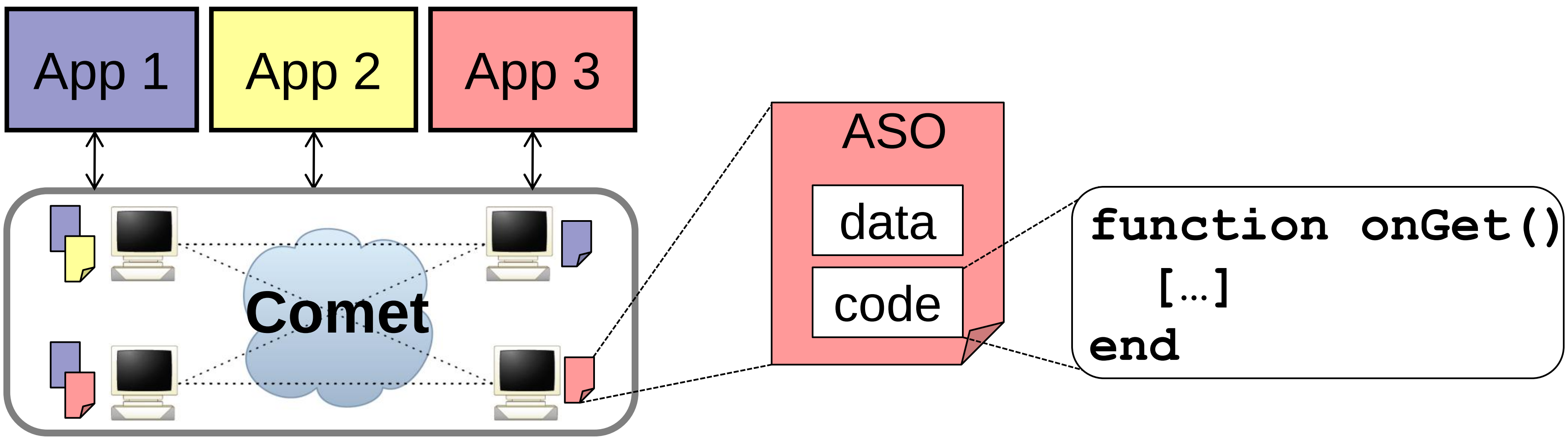


Comet's Goals

- Flexibility
  - Support a wide variety of small, lightweight customizations
- Isolation and safety
  - Limited knowledge, resource consumption, communication
- Lightweight
  - Low overhead for hosting nodes

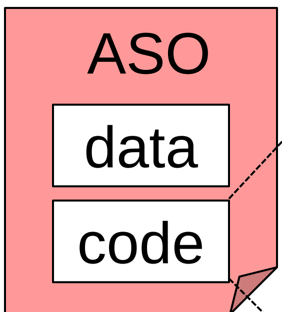
Active Storage Objects (ASOs)

- The ASO consists of data and code
  - The data is the value
  - The code is a set of handlers that are called on **put/get**



Simple ASO Example

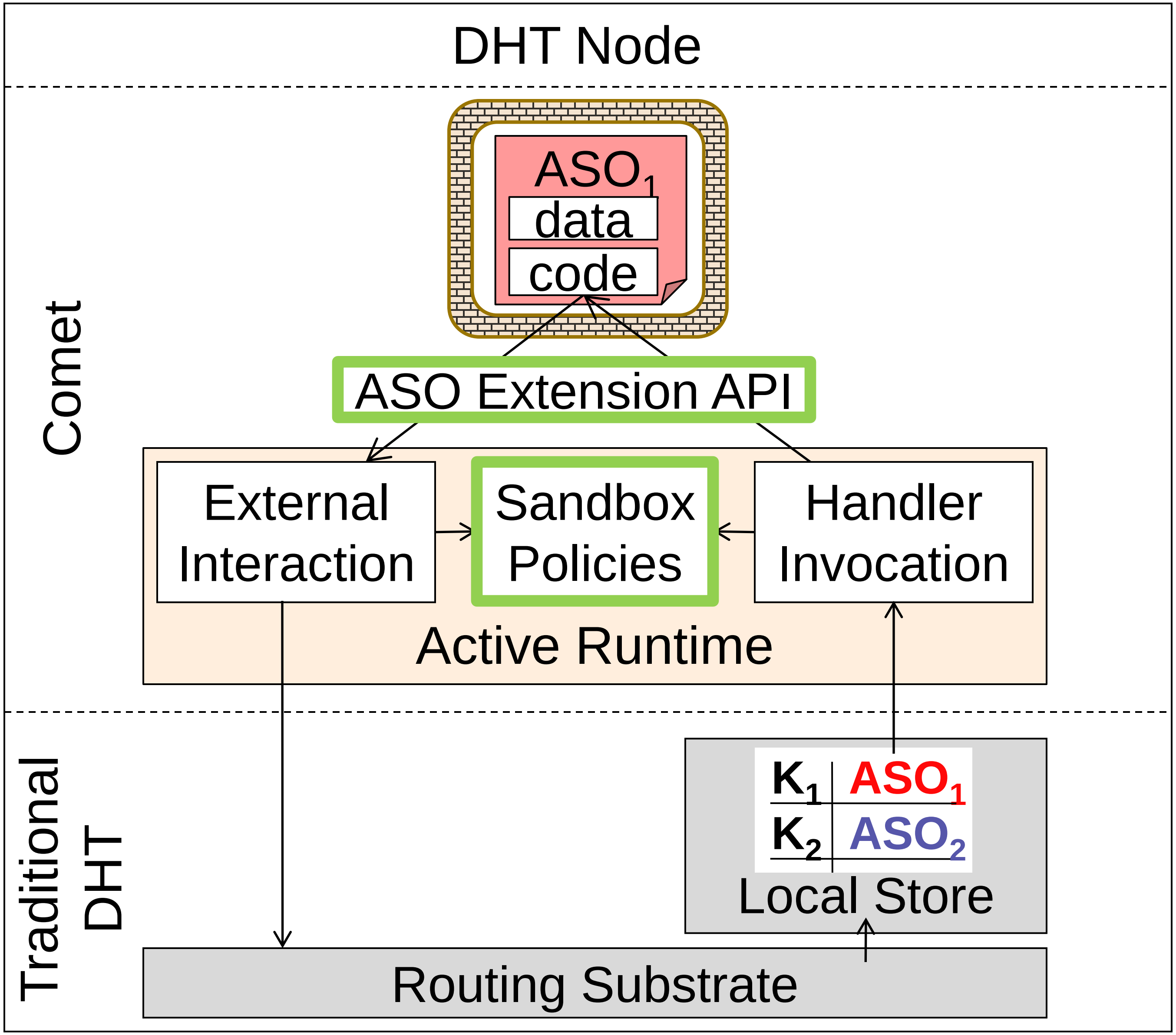
- Each replica keeps track of number of **`gets`** on an object




```
aso.value = "Hello world!"
aso.getCount = 0
function onGet()
   self.getCount = self.getCount + 1
   return {self.value, self.getCount}
end
```

- The effect is powerful:
  - Difficult to track object popularity in today's DHTs
  - Trivial to do so in Comet without DHT modifications

Comet Architecture



The ASO Extension API

Applications	Customizations
Vanish	Replication
	Timeout
	One-time values
Adeona	Password access
	Access logging
P2P File Sharing	Smart tracker
	Recursive gets
P2P Twitter	Publish / subscribe
	Hierarchical pub/sub
Measurement	Node lifetimes
	Replica monitoring

The ASO Extension API

Intercept accesses	Periodic Tasks	Host Interaction	DHT Interaction
`onPut`(*caller*)	**`onTimer`**()	**`getSystemTime`**()	**`get`**(*key, nodes*)
`onGet`(*caller*)		**`getNodeIP`**()	**`put`**(*key*, *data*, *nodes*)
`onUpdate`(*caller*)		**`getNodeID`**()	**`lookup`**(*key*)
		`getASOKey`()	
		`deleteSelf`()	

- Small yet powerful API for a wide variety of applications
  - We built over a dozen application customizations
- We have explicitly chosen not to support:
  - Sending arbitrary messages on the Internet
  - Doing I/O operations
  - Customizing routing …

The ASO Sandbox

1. Limit ASO’s knowledge and access
   - Use a standard language-based sandbox
   - Make the sandbox as small as possible (<5,000 LOC)
     - Start with tiny Lua language and remove unneeded functions
2. Limit ASO’s resource consumption
   - Limit per-handler bytecode instructions and memory
   - Rate-limit incoming and outgoing ASO requests
3. Restrict ASO’s DHT interaction
   - Prevent traffic amplification and DDoS attacks
   - ASOs can talk only to their neighbors, no recursive requests

Comet Prototype

- We built Comet on top of Vuze and Lua
  - We deployed experimental nodes on PlanetLab
- In the future, we hope to deploy at a large scale
  - Vuze engineer is particularly interested in Comet for debugging and experimentation purposes

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Comet Applications

Applications	Customization	Lines of Code
Vanish	Security-enhanced replication	41
	Flexible timeout	15
	One-time values	15
Adeona	Password-based access	11
	Access logging	22
P2P File Sharing	Smart Bittorrent tracker	43
	Recursive gets*	9
P2P Twitter	Publish/subscribe	14
	Hierarchical pub/sub*	20
Measurement	DHT-internal node lifetimes	41
	Replica monitoring	21

* Require signed ASOs (see paper)

Three Examples

1. Application-specific DHT customization
2. Context-aware storage object
3. Self-monitoring DHT

1. Application-Specific DHT Customization

- Example: customize the replication scheme

```
function aso:selectReplicas(neighbors)
  [...]
end
function aso:onTimer()
  neighbors = comet.lookup()
  replicas = self.selectReplicas(neighbors)
  comet.put(self, replicas)
end
```

- We have implemented the Vanish-specific replication
  - Code is 41 lines in Lua

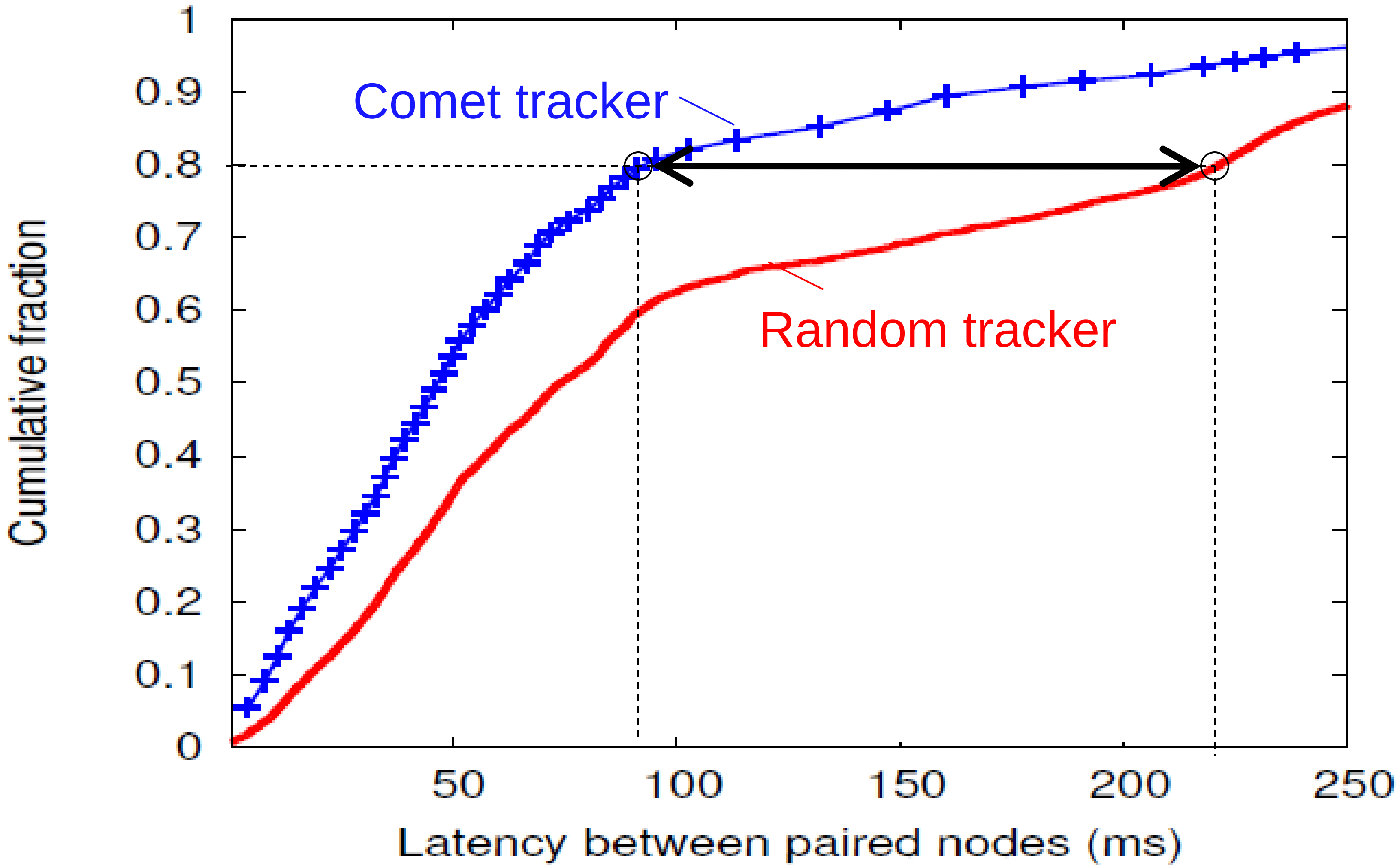
2. Context-Aware Storage Object

- Traditional distributed trackers return a randomized subset of the nodes

- Comet: a proximity-based distributed tracker
  - Peers **`put`** their IPs and Vivaldi coordinates at **`torrentID`**
  - On **`get`**, the ASO computes and returns the set of closest peers to the requestor

- ASO has 37 lines of Lua code

Proximity-Based Distributed Tracker



3. Self-Monitoring DHT

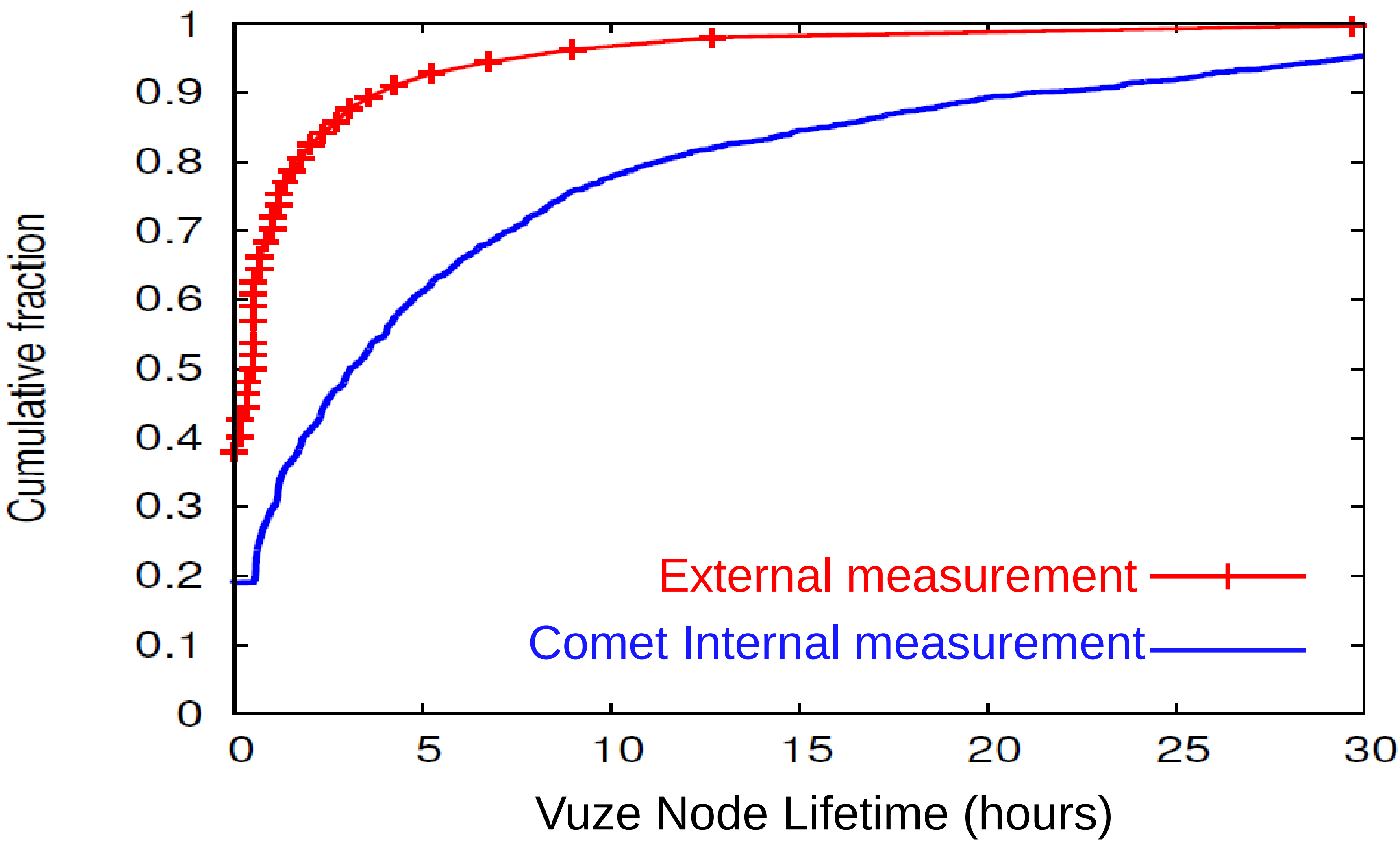
- Example: monitor a remote node's neighbors
  - **`Put`** a monitoring ASO that "pings" its neighbors periodically

```
aso.neighbors = {}

function aso:onTimer()
  neighbors = comet.lookup()
  self.neighbors[comet.systemTime()] = neighbors
end
```

- Useful for internal measurements of DHTs
  - Provides additional visibility over external measurement (e.g., NAT/firewall traversal)

Example Measurement: Vuze Node Lifetimes



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Conclusions

- Extensibility allows a shared storage system to support applications with different needs
- Comet is an extensible DHT that allows per-application customizations
  - Limited interfaces, language sandboxing, and resource and communication limits
  - Opens DHTs to a new set of stronger applications
- Extensibility is likely useful in data centers (e.g., S3):
  - Assured delete
  - Logging and forensics
  - Storage location awareness
  - Popularity