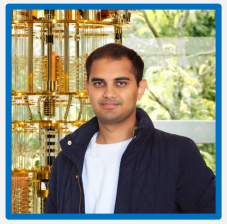
Self-service Data Protection for Stateful Containers



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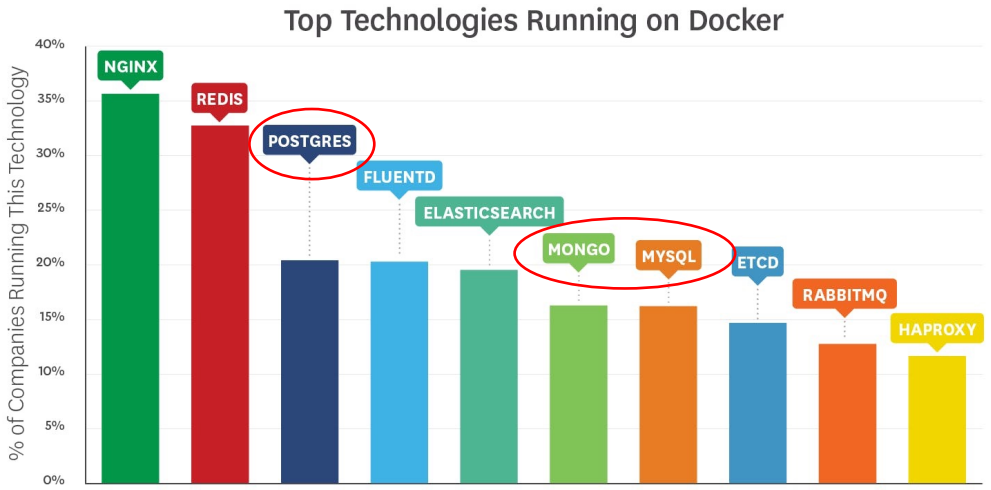
Data Protection in Containerized Environment

- **Rapid adoption of container native storage**: According to IDC, 90% of applications on cloud platforms and over 95% of new microservices are being deployed in containers.
- Users of containerized environment expect self-service model for data protection, like other services, e.g., fault tolerance, load balancing.

```yaml
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: web
spec:
  selector:
    matchLabels:
      app: nginx # has to match .spec.
  serviceName: "nginx"
  replicas: 3 # by default is 1
  template:
    metadata:
      labels:
        app: nginx # has to match .spe
```



Source: Datadog

Challenges in Providing Data Protection Guarantee

Recovery Point Objective (RPO): The RPO is said to be T hours if the application can lose no more data than the changes made in the last T hours.

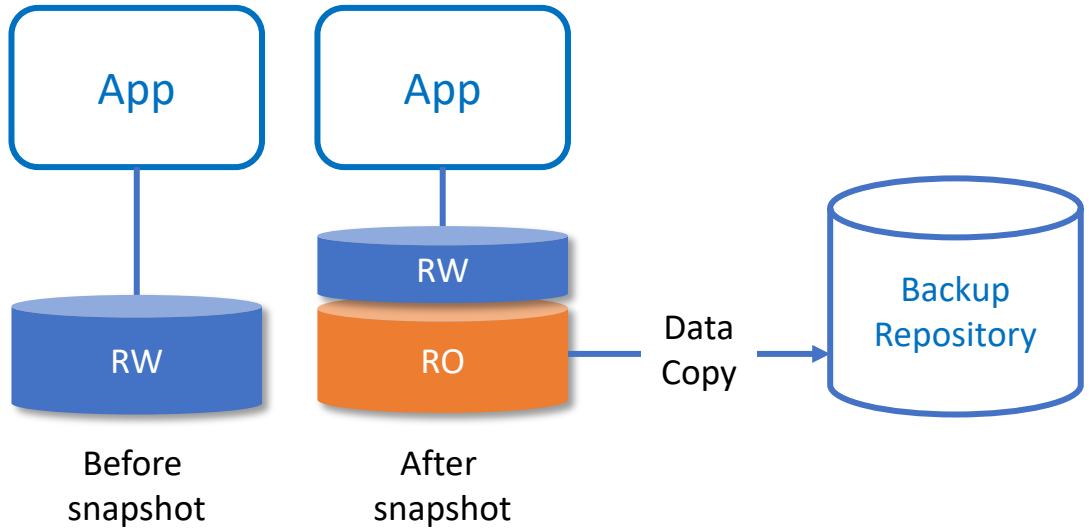
Challenges

- User may not know if the infrastructure can guarantee the specified RPO
- Applications and backups competing for resources

Goal: Self-service data protection to a large number of volumes with varying RPOs in face of resource outages and fluctuations

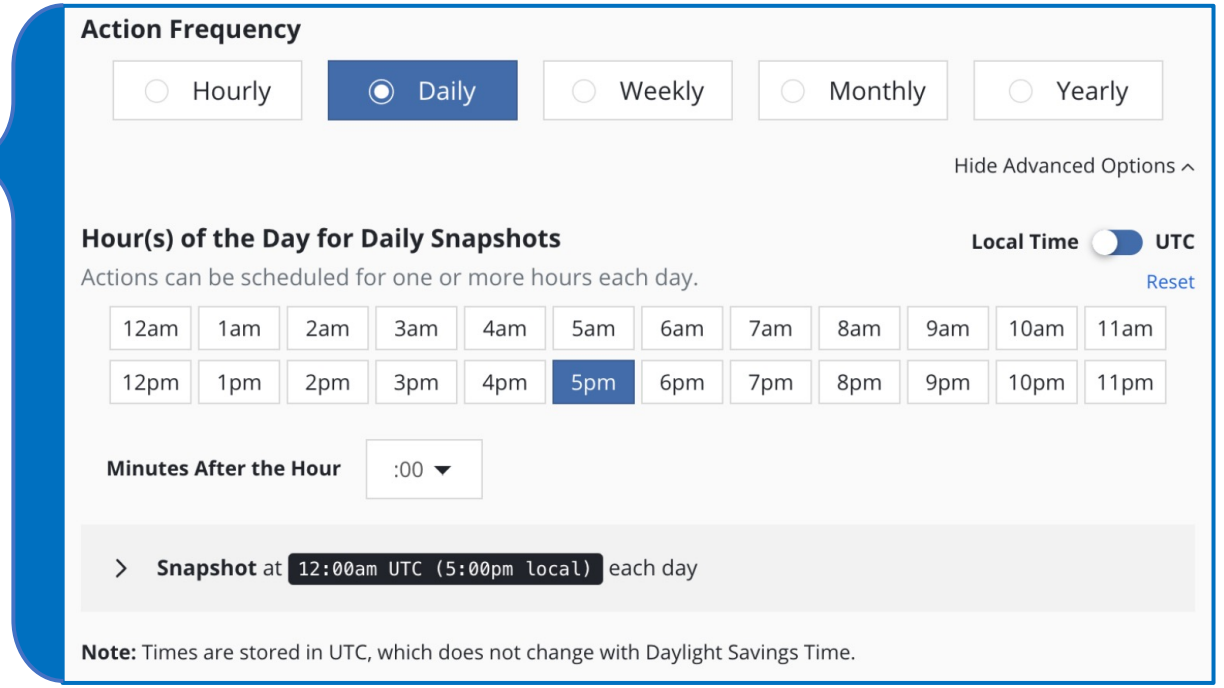
Data Protection with Volume-level Snapshotting

- Snapshot is a point-in-time representation of a volume
- **Incremental**: Only capture the changes since the previous snapshot
- **Quick**: Crash-consistent snapshots do not require state synchronization



Existing Work

- Periodic Backups for Containers
  - Velero, KastenIO, IBM Spectrum Protect Plus
- Backup Optimization
  - Reduce overhead
    [Natanzon et.al., NAS'16]
    [Cherkasova, et.al., MASCOT'09]
  - Selectively backup applications
    [Kettimuthu et.al., SC'15]
- **Quickly react to the failures or resource fluctuations for RPO compliance**



Self-service Data Protection

- User need not dictate when or how often the volumes are snapshotted or backed up
- Resiliency against resource, component and backup job failures by treating each operation (request creation, snapshot, data copy) as a transaction
- **Adaptive scheduling** of backups to provide data protection for volumes with a wide range of RPOs

```
apiVersion: "backup.io/v1"
kind: BackupReq
metadata:
  name: <request_name>
  namespace: <namespace_name>
spec:
  requesttype: Backup
  rpo: <time in minutes>
  retention: <time in minutes>
```

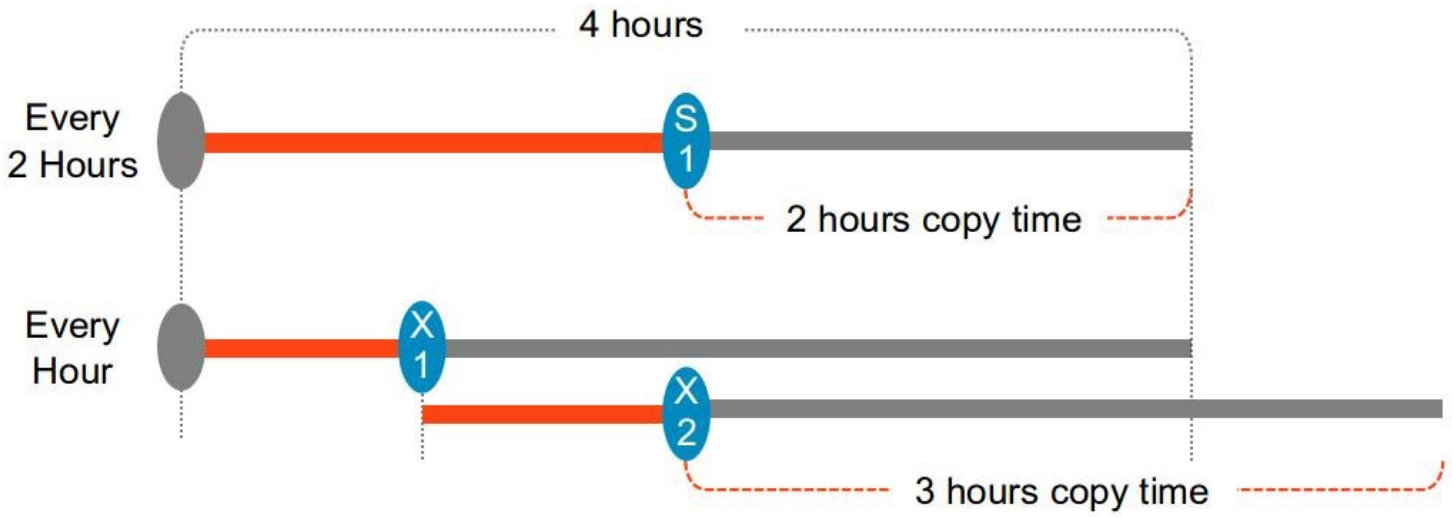
Backup Request using a Yaml configuration file.

User can observe status of the request with..

```
kubectl get backupreq <request_name>
```

Insight Behind Snapshot Scheduling

- **Insight**: Reducing the interval between snapshots can allow more time for data copying without RPO violation.
- Scheduler increases the snapshot frequency if the backups are falling behind, e.g., due to resource contention or outages.
- **Assumption**: X1 + X2 < 2 * S1



RPO = 4 hours. Frequent snapshots capture smaller change and allow more time for copying out the data without RPO violation.

Adaptive Scheduling for Backups

Phase 1: Snapshot Scheduling

- **Snapshot Now? = F_n(Per-volume slack, Cluster slack)**
- **Per-volumes slack**: Indicator of flexibility w.r.t. the amount of data, RPO and predicted bandwidth.
- **Cluster slack**: Indicator of how well the backups across the cluster are meeting their deadlines.

Phase 2: Data Copy Scheduling

- Snapshots with lower slacks are copied first

Evaluation and Test Setup

Simulate 2500 volumes with varying RPOs over 10 day period

- **Rate of Change Models**
  - Uniform
  - Bursty
  - Variable
- **Bandwidth Models**
  - Outage
  - Spikes
  - Periodicity

Comparison of Scheduling Strategies

- 2 variations of fixed scheduling with different aggressiveness
- 2 variation of adaptive scheduling with different aggressiveness (with volume-level information)
- Cluster-aware Adaptive Scheduling

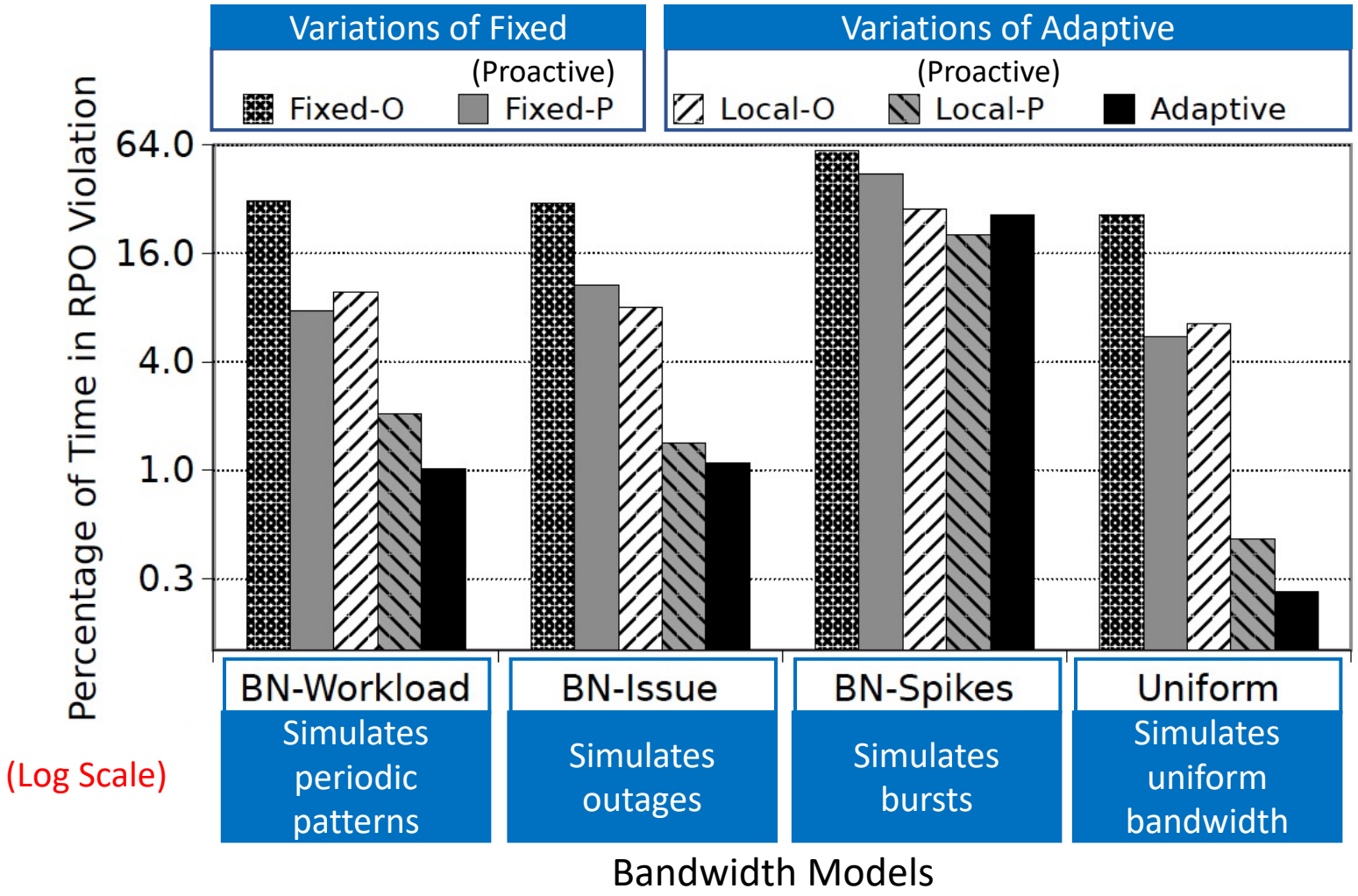
Metrics

- Percentage of time spent in RPO violation
- Number of snapshots

Percentage of Time in RPO Violation

Observations:

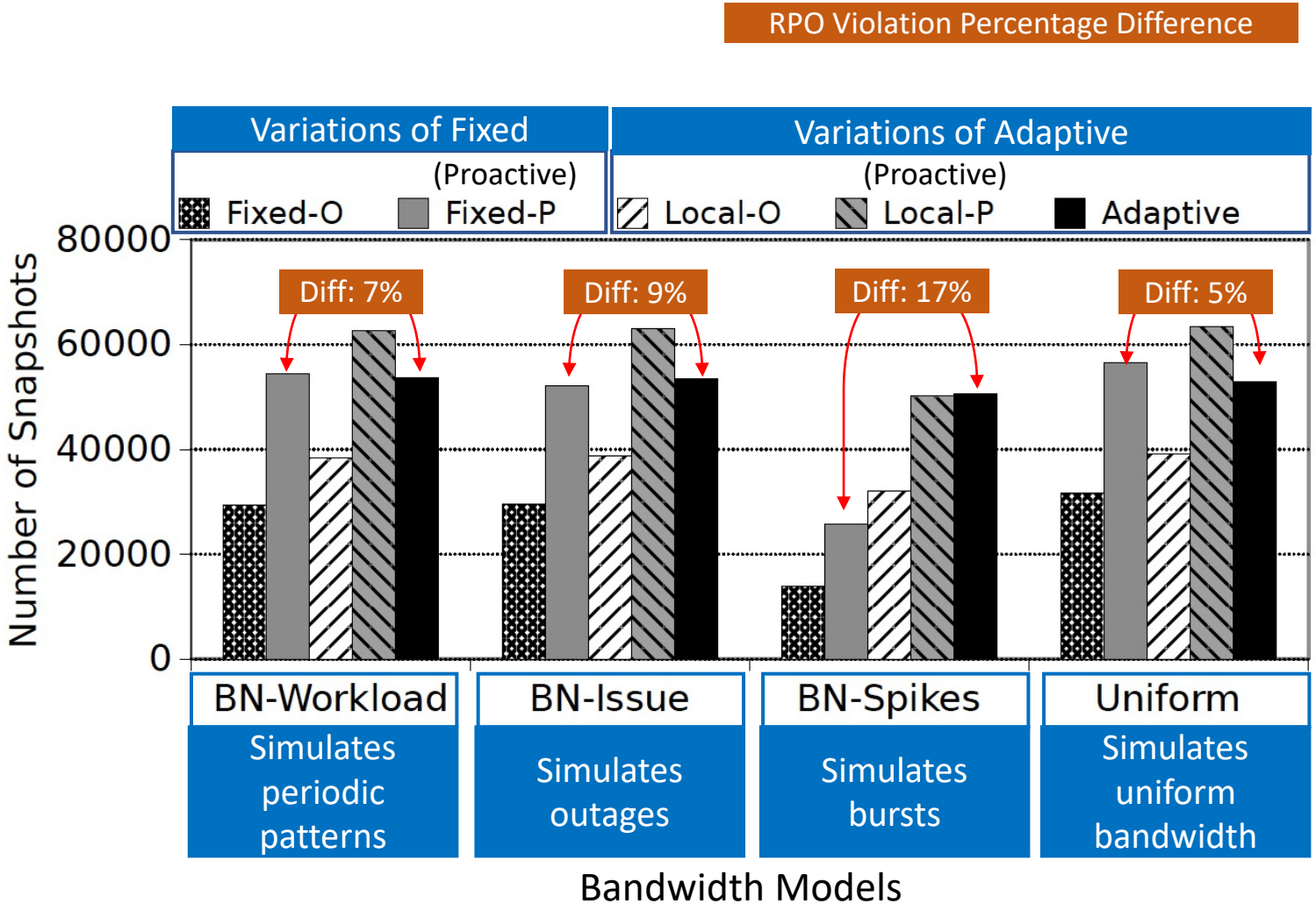
- Frequent snapshots are helpful in reducing RPO violations
- **Timeliness**: Important to perform snapshots when necessary



Number of Snapshots

Observations:

- Adaptive approach reduces RPO violation with similar number of snapshots as the fixed-proactive approach.

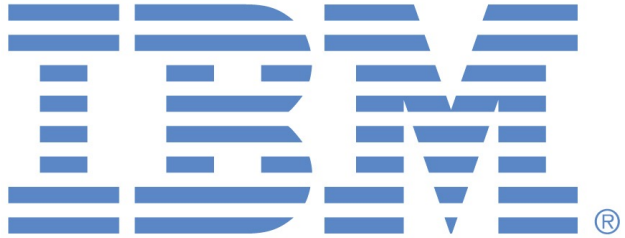


Conclusions and Future Work

- To summarize,
  - **Self-service**: User need not dictate how often or when snapshots are performed
  - **Transactional semantics:** Ensures continuity of jobs through various failures
  - **Scheduling Strategy**: Adapts snapshot frequency to reduce RPO violation

- Future Work
  - Application-consistent snapshots
  - Application consisting of multiple volumes

Thank You!



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