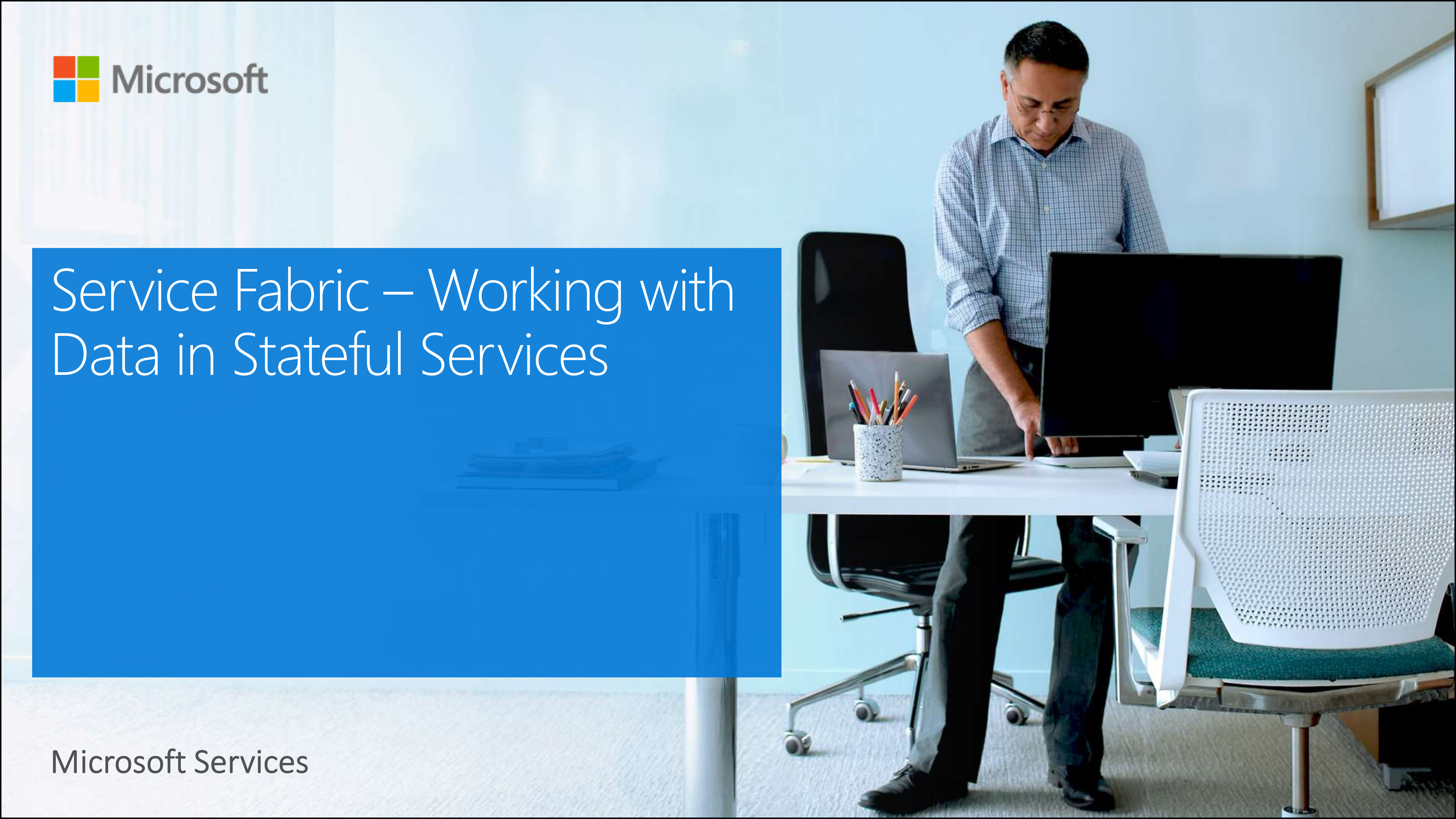

Service Fabric – Working with Data in Stateful Services

Microsoft Services

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Agenda

- Stateful Services details
- Partitioning and Scale
- Data and State
- Backup Reliable Services and Reliable Actors

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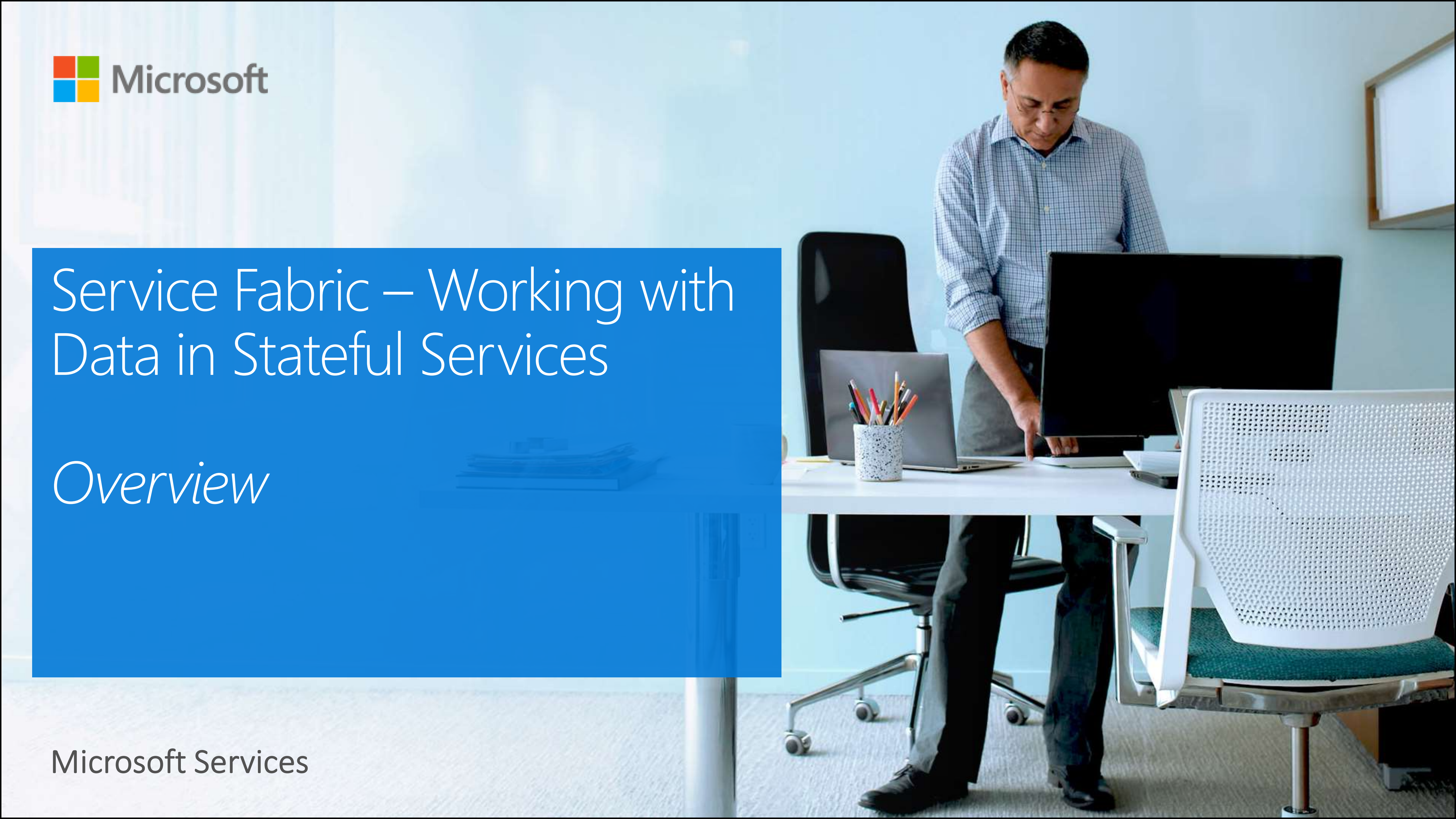

Service Fabric – Working with Data in Stateful Services

Overview

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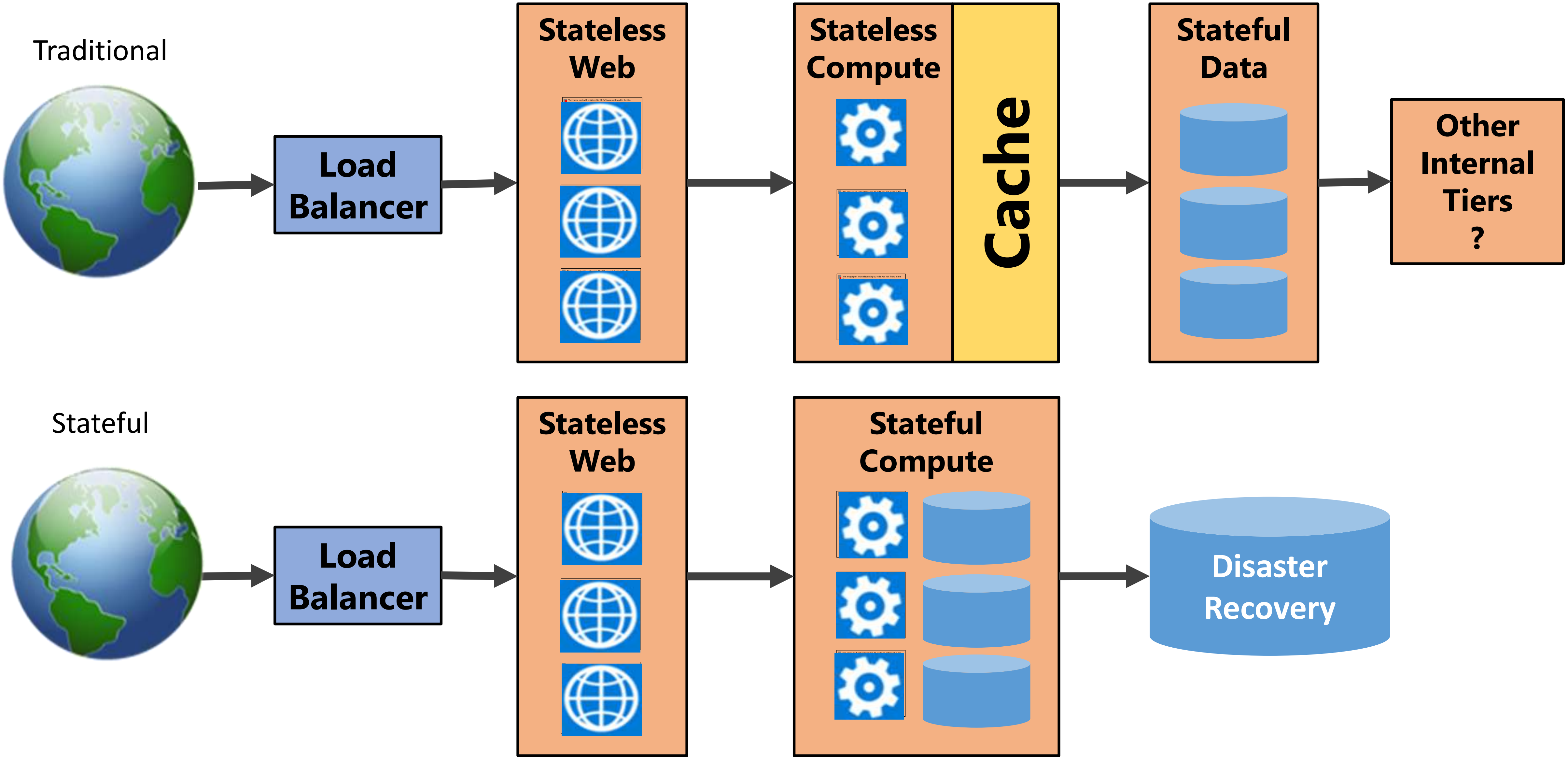
State Architectures: Traditional vs Service Fabric



Traditional

Load Balancer

Stateless Web

Stateless Compute

Cache

Stateful Data

Other Internal Tiers ?

Stateful

Load Balancer

Stateless Web

Stateful Compute

Disaster Recovery

Stateful Reliable Services Review

- Pros
  - Compute code has low-latency, strongly-consistent read access to hot data
  - Reduces dependency on external storage services
- Cons
  - Keeping (replicated) data on compute nodes can be costly
- Named services’ Reliable Dictionary/Queue collections
  - Partitioned for data scalability
  - Replicated for availability
  - Transacted (within a partition) for ACID semantics
  - Asynchronous for efficiency
  - Persisted for quick node failure recovery
  - Provides automatic locking for multi-threaded access

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Service Fabric – Working with Data in Stateful Services

Partitioning and Scale

Microsoft Services

A Named Service's Partitions

- You can scale a named services data by splitting it across partitions
  - Allows data/computation to be spread across nodes for appropriate storage/speed
  - A partition must fit in 1 node; but, 1 node can hold multiple partitions
- Each partition has 0+ Reliable Collection objects.
- Architecting a service's partitions is often very hard
  - Cross-partition operations require network hops and different transactions
  - How many partitions depends on how much data you'll have ***in the future***
  - By default, Service Fabric balances partitions across nodes so try to keep the partitions data size as even as possible
    - Report capacity load metrics to better control balancing
- Service Fabric identifies each partition with a static globally unique identifier (GUID)

Service Fabric Offers 3 Partition Schemes

- Uniform Int64 Range (key range and ***n*** partitions) ~ Ranged partitioning

Distribution:
Data → Algorithm → Int64 key → Partition #

Key range=0-99; Partitions=5				
0-19	20-39	40-59	60-79	80-99
0	1	2	3	4

- Singleton partitioning (1 partition)

Distribution:
Data → Algorithm → Partition #

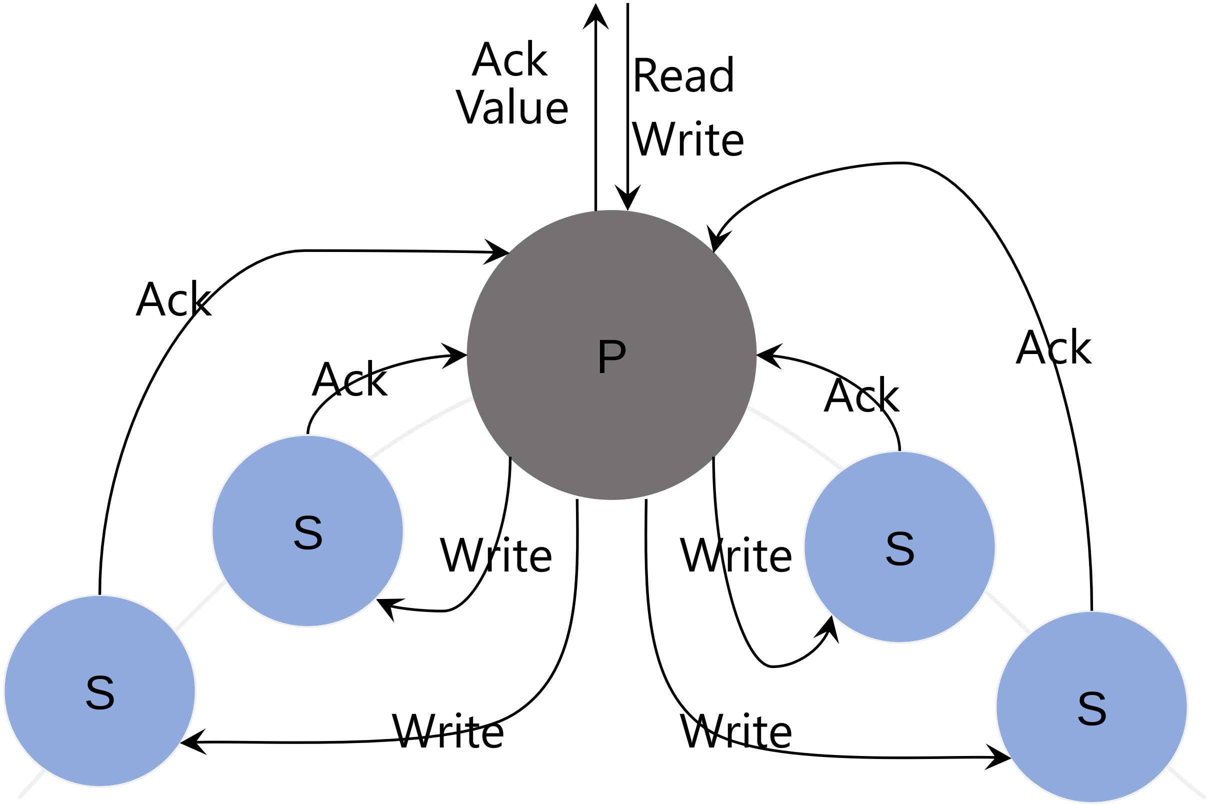
- String (1 string per partition) ~ Named partitioning

Distribution:
Data → Algorithm → String-key → Partition
#

Strings=5; Partitions=5				
Arctic	Atlantic	Indian	Pacific	Southern
0	1	2	3	4

Replication – Stateful Services

- Reads are completed at the primary
- Writes are replicated to the write quorum of secondary's



A Service's Replicas

- Replicating state increases chance of data surviving 1+ ***simultaneous*** node failures
  - But, more replicas increase cost & network latency to sync replicas
  - The less replicas that exist, the more risk for data loss
  - Consider writing to external state (reducing replica costs & failure recovery) and reading from a replica (for speed)
- Replicas go across FDs/UDs; avoids single point of failure
- Service Fabric identifies each replica with a dynamic 64-bit integer (changes on create/move)

Configuring Partitions & Replicas

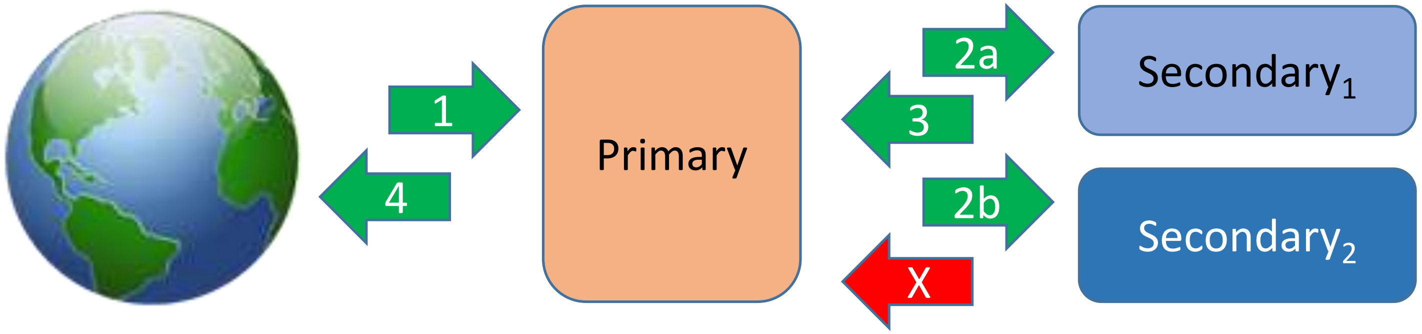
- New-ServiceFabricService cmdlet requires
  - Partition scheme (low key, high key, & partition count)
  - Replica counts (minimum & target)
- Update-ServiceFabricService cmdlet lets you change
  - Replica counts (minimum & target)
- Partition settings are in the ApplicationManifest.xml

NOTE: You can’t update/change partition scheme

- It’s OK to have many partitions since smaller partitions are fairly cheap
  - But, if a node fails, even empty partitions have to be re-built (some performance hit)

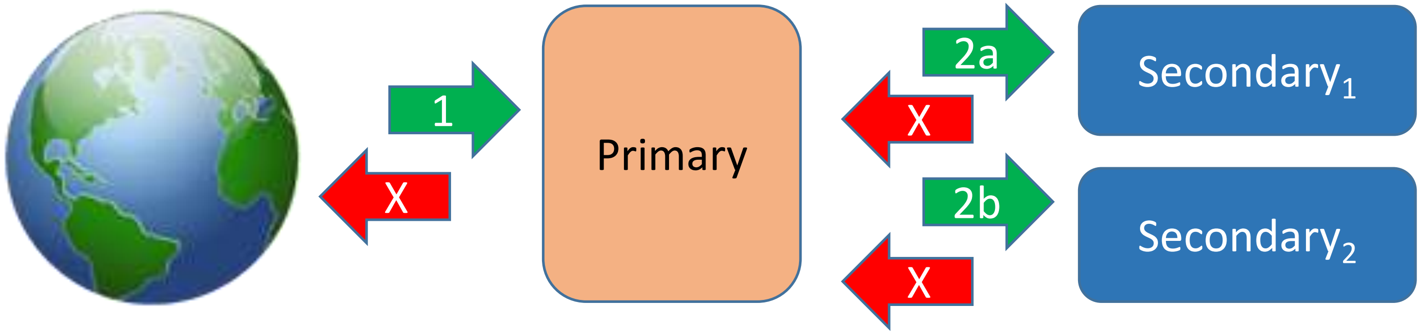
Partition Write Scenarios (Replicas=3, Quorum=2)

Write with P and S_1 up, S_2 is down



Either S_2 comes back up or Service Fabric will create another Secondary

Write with P up, S_1 and S_2 down (quorum loss)



Client won't get a response if Service Fabric can't create new Secondary. NOTE: Clients can still read from Primary.

Calculating Partitions / Capacity Planning

- Partitioning your service does NOT scale out the service itself
- Each partition must fit within a single VM, but multiple (small) partitions can be placed on a single VM
- Having a larger number of small partitions gives you greater flexibility than having a small number of larger partitions.
- Trade-offs
  - Increases Service Fabric overhead
  - You cannot perform transacted operations across partitions.
  - More potential network traffic if your service code frequently needs to access pieces of data that is located in different partitions

Scaling at the service name level

- Another option for scaling
- Data partitions must be decided at build time, but more service instances can be added dynamically
- Services can be added via PowerShell or by API
- Example – embed dates in service name
  - Customers who joined in Year 2015 get Service1, customers who joined in 2016 get Service2
  - Both have underlying partition schemes but partition size may be different

Demonstration

Partitioning

Service Fabric – Working with Data in Stateful Services

Data and State

Microsoft Services

Types of Data

Data usage categories

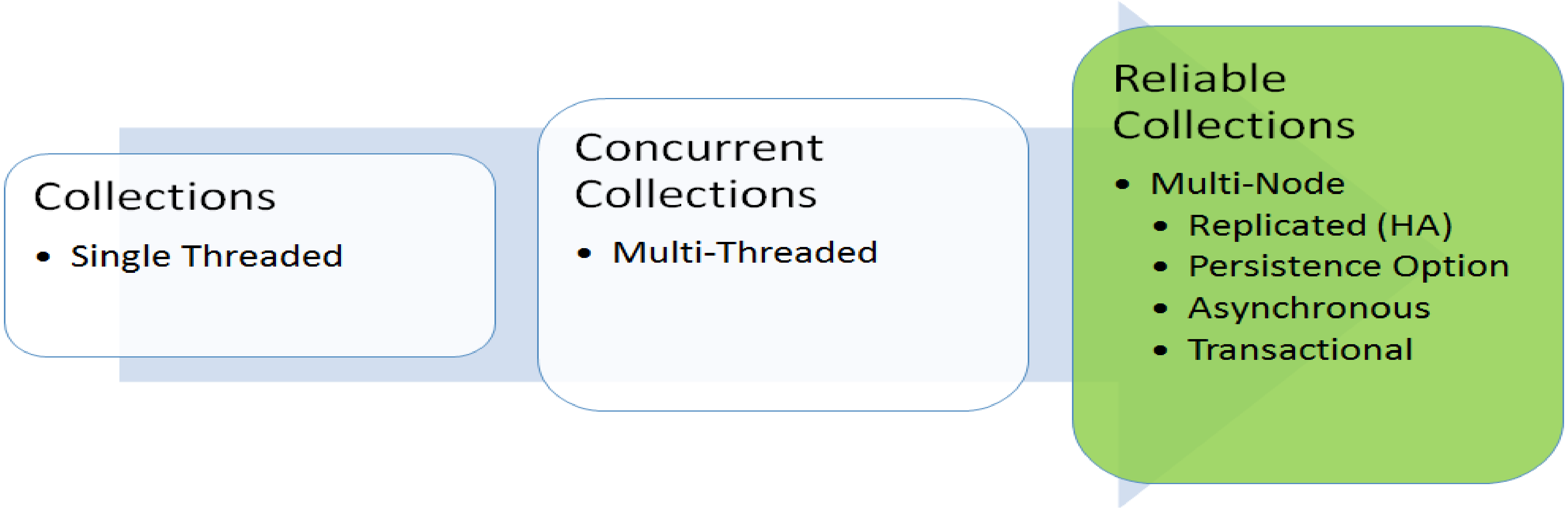
- Hot path data
- Warm path data
- Cold path data

Data stores

- Reliable Collections – Service State
- Traditional Stores
- Static Data – Configuration and Settings

Reliable Collections

Enables you to write highly available, scalable, and low-latency cloud applications as though you were writing single computer applications



Collections

- Single Threaded

Concurrent Collections

- Multi-Threaded

Reliable Collections

- Multi-Node
  - Replicated (HA)
  - Persistence Option
  - Asynchronous
  - Transactional

Reliable Collections

- Strong consistency is achieved by ensuring transaction commits finish only after the entire transaction has been applied on a quorum of replicas, including the Primary
    - To achieve weaker consistency, applications can acknowledge back to the client/requester before the asynchronous commit returns
- Two supported isolation levels
    - Repeatable read:
        - Outside transaction cannot read anything modified and not yet committed by transaction
        - No other transaction can modify anything until read by current transaction is finished
    - Snapshot
        - Data transaction sees will be the data that existed at transaction start (like it gets a snapshot)

Isolation Levels

- Repeatable Read – can’t read from incomplete transaction
- Snapshot – data at the beginning of the transaction is the same as at the end

Reliable Dictionary

Operation/Role	Primary	Secondary
Single Entity Read	Repeatable Read	Snapshot
Enumeration	Snapshot	Snapshot

Reliable Queue

Operation/Role	Primary	Secondary
Single Entity Read	Snapshot	Snapshot
Enumeration	Snapshot	Snapshot

NOT Your Typical .NET Collections

- .NET collections hold **references**
- Reliable Collections hold **objects** (think database hand-offs)
    - Misusing a reliable collection **will corrupt your data!**

```
using (ITransaction tx = StateManager.CreateTransaction()) {
   await m_dic.AddAsync(tx, name, user1);
   user1.LastLogin = DateTime.UtcNow;  // Corruption!

   ConditionalResult<User> user2 = await m_dic.TryGetValueAsync(tx, name);
   if (user2.HasValue) user2.Value.LastLogin = DateTime.UtcNow; // Corruption!

   await tx.CommitAsync();
   // Of course, if you modify an object after CommitAsync, corruption!
}
```

- Correct: Get reference, copy/change object, write new object

Adding a Key/Value to a Dictionary

```
retry:
try {
   // Create a new Transaction object for this partition
   using (ITransaction tx = StateManager.CreateTransaction()) {
      // AddAsync takes key's write lock; if >4 secs, TimeoutException
      // key & value put in temp dictionary (read your own writes),
      // serialized, redo/undo record is logged & sent to secondary replicas
      await m_dic.AddAsync(tx, key, value);

      // CommitAsync sends Commit record to log & secondary replicas
      // After quorum responds, all locks released
      await tx.CommitAsync();
   }
   // If CommitAsync not called, Dispose sends Abort record
   // to log & secondary replicas, all locks released
}
catch (TimeoutException) { await Task.Delay(ms, cancellationToken); goto retry; }
```

Define Immutable Types to Force Correct Behavior

```
// If you don’t seal, derived classes must also be immutable
[DataContract] public sealed class UserInfo
 {

   public UserInfo(Email email, IEnumerable<ItemId> itemsBidding = null)
   {
      // We can assign to the read-only properties only in the ctor
      Email = email;
      ItemsBidding = itemsBidding ?? new ItemId[0];
   }

   // Read-only properties (you can set default values):
   [DataMember] public readonly Email Email; // Value type
   [DataMember] public readonly IEnumerable<ItemId> ItemsBidding = null;

   // "Modify" the object by creating a new one with the desired new state
   public UserInfo AddItemBidding(ItemId itemId) =>
      new UserInfo(Email, ItemsBidding.Concat(new[] { itemId }));
}
```

Querying Reliable Collections

- Both IReliableDictionary and IReliableQueue implement IAsyncEnumerable
- Microsoft is working on setting up async LINQ, in the meantime there are workarounds
  - Wrap the async calls with synchronous methods
  - Use library on GitHub Gist which supports Select, SelectMany, and Where
- ReliableDictionary supports enumeration through CreateEnumerableAsync
- Note that IEnumerables returned by CreateEnumerableAsync can only be enumerated within a transaction scope, so if you intend to use them elsewhere, you will need move the results into a temporary collection, such as a List.
- Snapshot isolation – lock free
  - Structure does not reflect changes that happen after the start of enumeration

Persistence Model Details

- State Provider stores data in the service
- Can be in-memory only or in-memory + local disk
- Default Actor state provider = in-memory + local disk but keeps hot data in memory so your storage requirements are not memory bound.
- Reliable Collections state provider stores all data both in-memory and on local disk
    - May be configurable in future release

Serialization

- Objects are serialized for persistence and wire transfer
- Persistent serializers must maintain infinite backward compatibility and +1 forward compatibility
    - Because data gets stored at lots of places (log, checkpoints, backups, etc.) and is retained for a very long time
- Wire transfer serializers must maintain +1/-1 compatibility
    - Because upgrading clusters have old and new code running simultaneously

Reliable Collections

- Recommendations
  - Do not modify an object of a custom type returned by read operations (e.g., TryPeekAsync or TryGetAsync)
  - Do a deep copy of the returned object of a custom type before modifying it. Since structs and built-in types are pass-by-value, you do not need to do a deep copy on them
  - Do not use TimeSpan.MaxValue for time-outs. Time-outs should be used to detect deadlocks
  - Do not create a transaction within another transaction’s using statement because it can cause deadlocks

Reliable Collections

- Considerations
    - The default time-out is 4 seconds for all the Reliable Collection API operations. Most users should not override this
    - The default cancellation token is CancellationToken.None in all Reliable Collections APIs
    - Enumerations are snapshot consistent within a collection. However, enumerations of multiple collections are not consistent across collections
    - To achieve high availability for the Reliable Collections, each service should have at least a target and minimum replica set size of 3

Configuration and static data

- Service Fabric xcopys all data in the package directory including the config, code, and data directories
- Any static data placed here will be available to all instances of the service
- Settings files and dependencies use this mechanism

Demonstration

Query Reliable Collections

Microsoft

Service Fabric – Working with Data in Stateful Services

Backup And Restore Reliable Services and Actors

Microsoft Services

Why backup reliable service or reliable actor data?

- In the event of the permanent loss of an entire Service Fabric cluster or nodes in a given partition
- Administrative errors whereby the state accidentally gets delete or corrupted
- Bugs in the service that causes data corruption
- Offline data processing, ie, for nightly batch runs or BI
- When moving to a new cluster environment

Backup Types

- Full – contains all data required to restore the state of the replica
  - Challenge – If the checkpoint for the data is large, a short Recovery Point Objective can cause excessive data collection
- Incremental – Only the log records since the last backup are backed up
  - Can not be restored on its own, ie, the entire backup chain is required

How does Backup and Restore work?

- Currently, you can only perform backup and restores by using API calls, no ARM templates or PowerShell
- Backup
  - To start a backup, the service needs to invoke the inherited member function BackupAsync
  - When BackupAsync is called, the Reliable State Manager instructs all Reliable objects to copy their latest checkpoint files to a local backup folder. The reliable services knows what is in the reliable objects already
  - The Reliable State Manager copies all log records, starting from the "start pointer" to the latest log record into the backup folder
- Restore
  - The service author needs to override the base class method OnDataLossAsync
  - A RestoreContext is provided by the OnDataLossAsync method
  - Call the RestoreAsync API on the RestoreContext to restore data

Demonstration

Backup and Restore Reliable Service Data

Recovery scenarios

- Partial data loss in Reliable Services
  - Service Fabric runtime automatically detects the data loss and calls OnDataLossAsync that the service author has provided
- Deleted or lost service
  - This typically happens when a service is removed
  - Recreate the service first then invoke OnDataLossAsync on each partition
- Replication of corrupt application data
  - Could be caused by a bug in an updated service
  - You need to first freeze the service at the application level
  - Per partition, start restoring the most recent data down to the least
  - Find the most recent backup that does not have corruption

Testing Backup and Restore

- Data loss in a particular partition can be invoked by calling the Invoke-ServiceFabricPartitionDataLoss cmdlet in PowerShell
- Programmatic API access can also be used to invoke data loss

```
$s = "fabric:/WebReferenceApplication/InventoryService"

$p = Get-ServiceFabricApplication | Get-ServiceFabricService -ServiceName $s | Get-ServiceFabricPartition | Select -First 1

$p | Invoke-ServiceFabricPartitionDataLoss -DataLossMode FullDataLoss -ServiceName $s
```

How often should I do a backup?

- Determining a backup frequency is very workload specific and therefore is hard to determine
- Generally, the frequency of your backups (whether full or incremental) depends on your Recovery Point Objective (RPO)
- Also how many incremental backups to take before a full backup depends on the following factors:
  - Your Recovery Time objective (RTO) – It takes more time to recover using incremental backups
  - The storage requirement – Full backups require more storage than incremental ones
  - Configured value for **MaxAccumulatedBackupLogSizeInMB**. If this setting is exceeded by the incremental backup(s) a full backup must be taken. This setting can be configured.

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