Indexing in Distributed Actor Systems

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Stateful Object-Oriented Applications

- Today's interactive apps are built around a stateful, object-oriented middle tier
  - Multi-player games, IoT, social networking, mobile, telemetry
  - They comprise a large fraction of new app development
  - Naturally object-oriented, modeling real-world objects

- Examples of objects
  - Gaming: players, games, grid positions, lobbies, player profiles, leaderboards, in-game money, and weapon caches
  - Social: chat rooms, messages, photos, and news items
  - IoT: sensors, virtual sensors (flood, break-in), buildings, vehicles, locations

Application Properties

- Properties of these apps
  - Objects are active for minutes to days, sometimes forever
  - App manages a lot of state: millions of objects, knowledge graphs, images, videos
  - App does heavy computation: complex actions, render images, compute over graphs, …
- Properties of the system
  - Scale out to large number of servers
  - Compute servers must scale out independently of storage servers
  - Geo-distributed for worldwide low-latency access

Middle-tier Objects Comprise a Distributed DB

- Many objects outlive the processes that created them
- Many (but not all) objects are persistent
- Latest state is in main memory. Storage might be stale
- Active objects are in-memory for fast response

Actor Systems

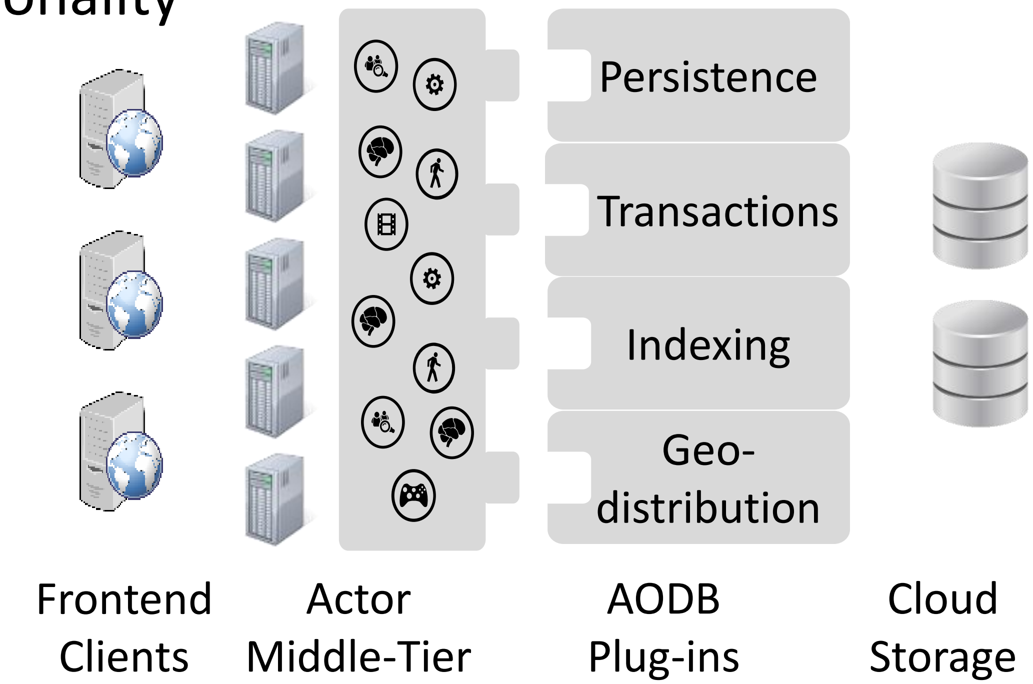
- Many of these apps are implemented using **actor systems**
  - Simplifies distributed programming
- Actors are objects that …
- Communicate only via asynchronous message-passing
  - Messages are queued in the recipient's mailbox
  - No shared-memory state between actors
- Process one message at a time
  - No multi-threaded execution inside an actor

Orleans Actor Programming Framework

- Orleans is an open-source actor framework built on C#
  - Ensures apps are fault tolerant and scalable
  - https://dotnet.github.io/orleans/
- Virtual actor model
  - Each actor has a unique location-independent ID, always valid
  - Actors are transparently activated on invocation
  - On activation, actor invokes its constructor to initialize its state (e.g., read from storage)
  - Actor can save state at any time (e.g., to storage)
  - Runtime automates fault-tolerance, load balancing, actor lifecycle, …

Actor-Oriented Database System (AODB)

- Current distributed actor systems lack DB functionality
  - But users frequently ask for it (and hack it)
- Vision: Actor-Oriented DB System
  - Indexes, queries, streams, transactions, replication, geo-distribution, views, triggers
- AODB's main distinguishing features
  - Compatible with actor framework's programming model (developer friendly)
  - In-memory and elastically scales out to hundreds of servers
  - Agnostic to the storage system, e.g., cloud storage services



Scalable and Storage-Agnostic

- Elastic scalability implies
  - Limited ability to co-locate functionality
  - Functionality must be parallelizable
  - Scale-out is more important than a fast path
- Storage agnostic implies each DB feature
  - Must work for persisted and non-persisted objects
  - Must not require the storage system to support it
  - Should benefit from a storage system that does support it
  - Must cope with storage latency of cloud storage

Requirements for AODB Indexes

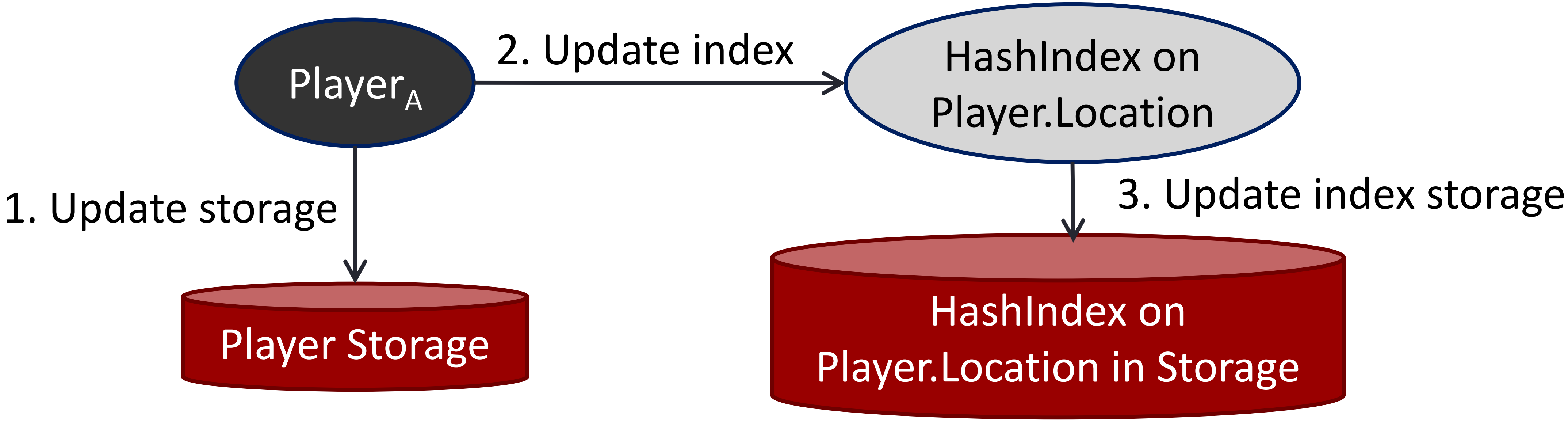
- Statically choose indexed fields
- Optional uniqueness constraints (e.g., ensure Player.Email is unique)
- Index is eventually-consistent with actor and fault tolerant
- Can index active actors only (e.g., offer a tournament to certain on-line players)
- Can index persistent and non-persistent actors
- Leverage actor storage that supports indexing
- Support actor storage that does not support indexing

Challenges

- Lookup should avoid activating actors
- No type extents
- No multi-actor transactions

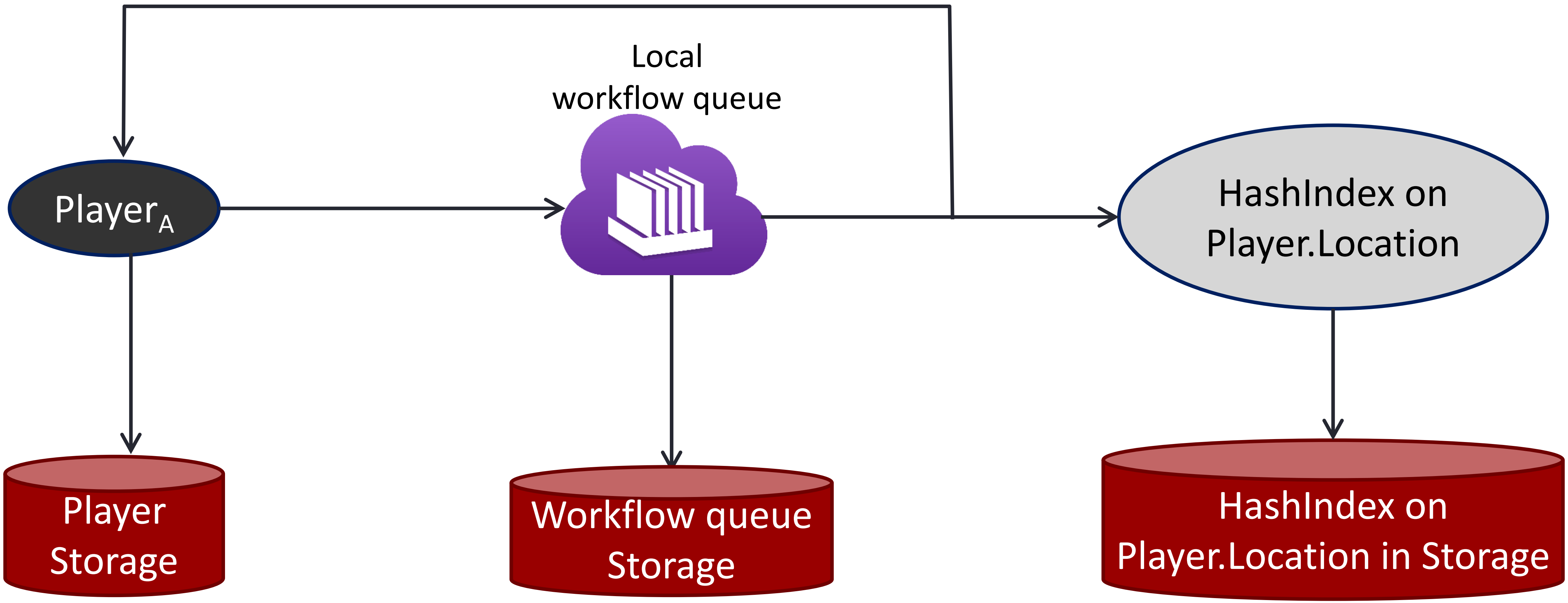
Fault Tolerance

- Index is comprised of actors, to gain benefits of Orleans
- Suppose we have an index on Player.Location

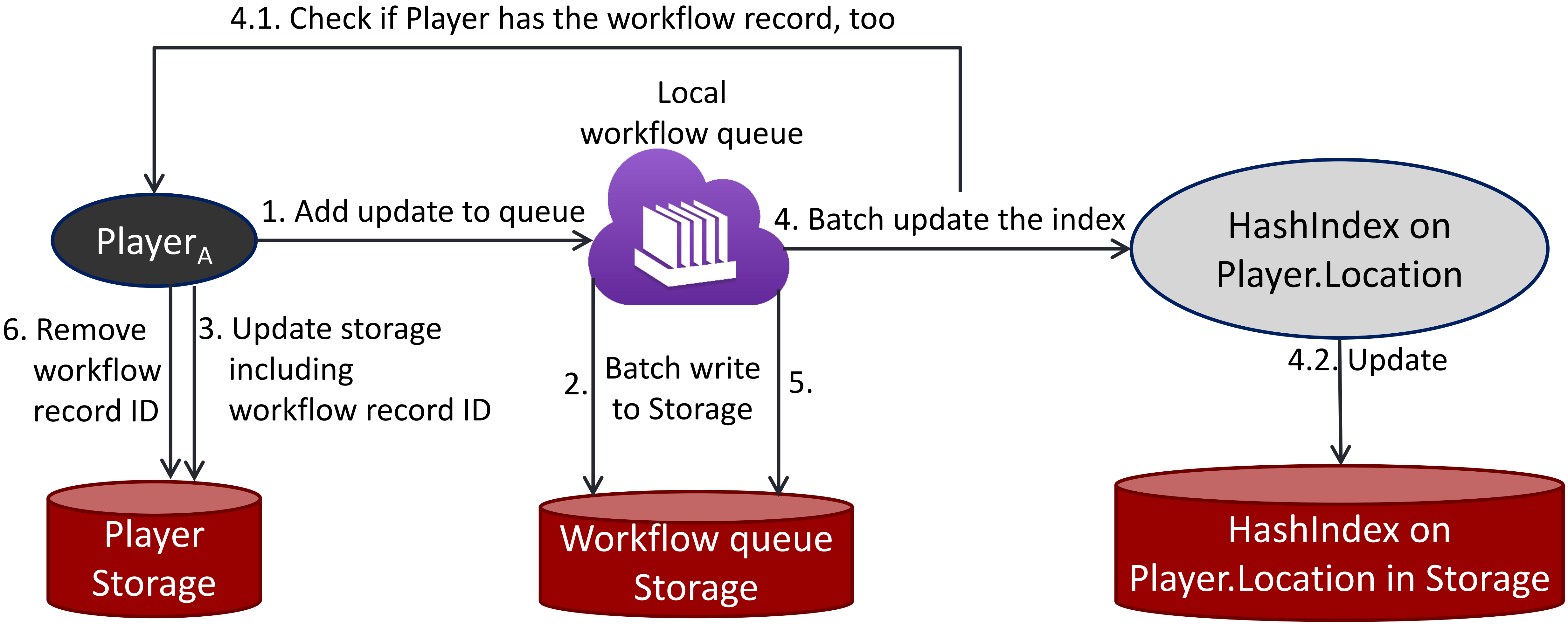


- Ensure recoverability after each write to storage

Our solution: Multi-step Fault-tolerant Workflow

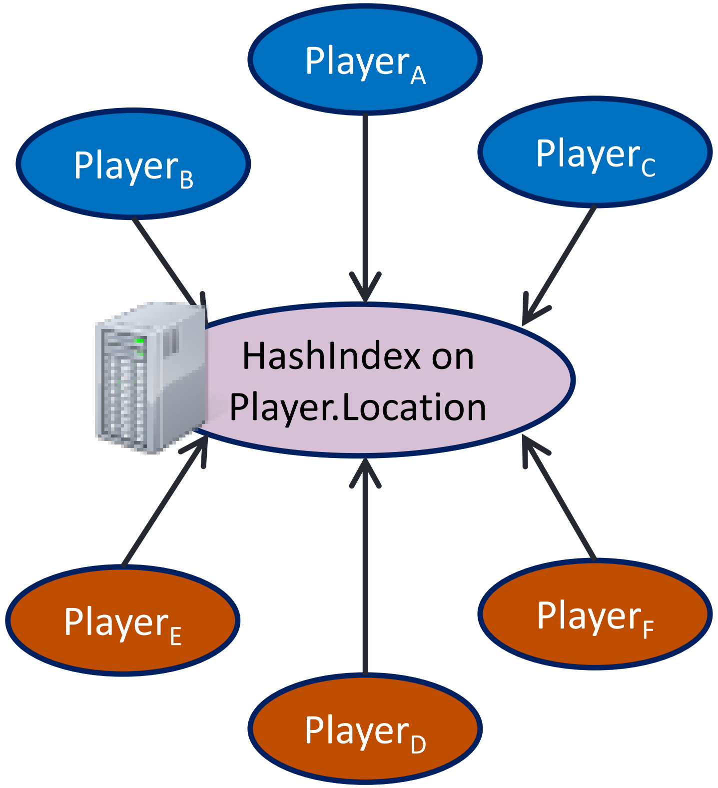


Our solution: Multi-step Fault-tolerant Workflow Cont.

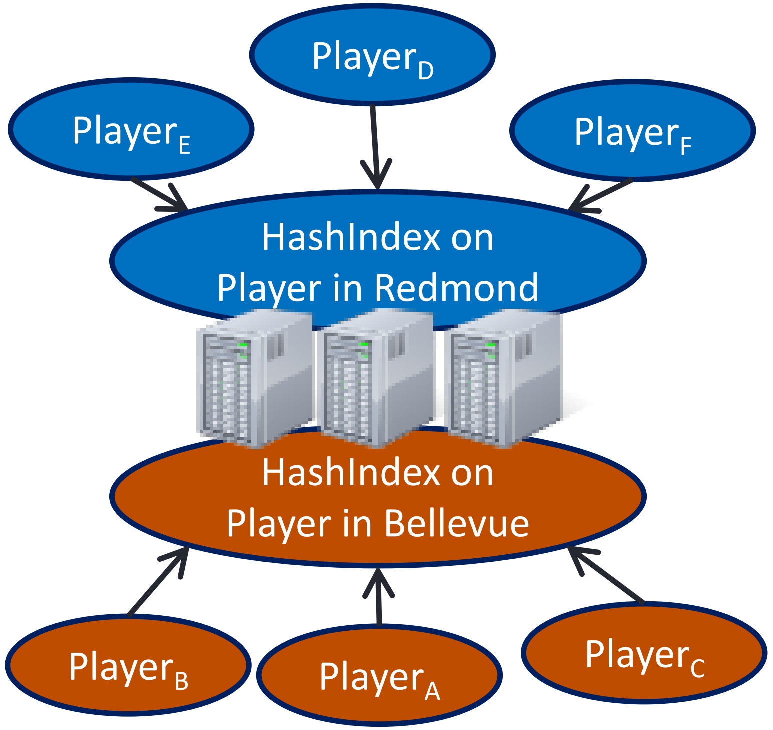


Index Physical Representation

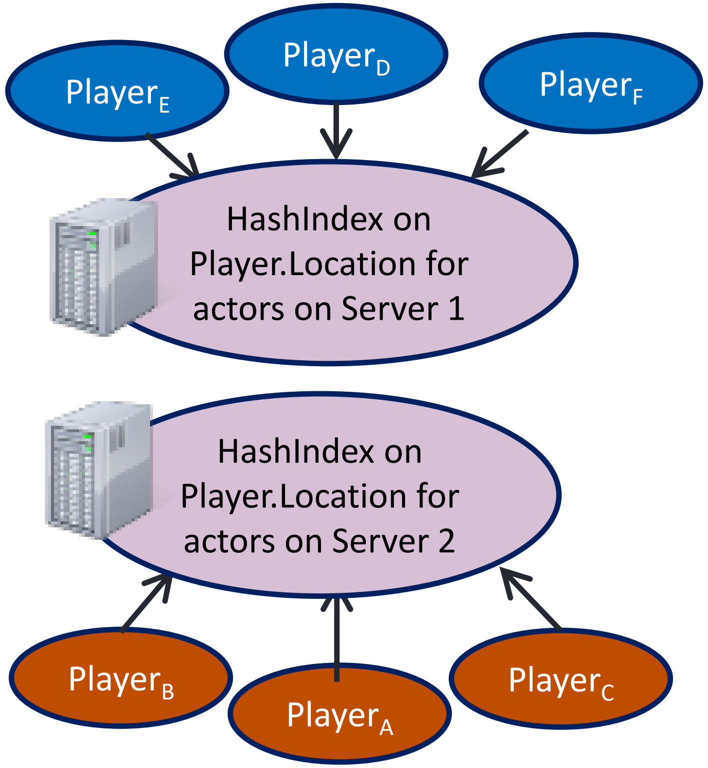
Entire index in one actor



One index-actor per index bucket



One index-actor per server



Programming Interface: Index Definition

```
public interface IPlayer : IIndexableGrain<PlayerProperties>
{
    Task Move(Direction d);

    Task<string> GetLocation();
}
```

```
public class Player :
             IndexableGrain<PlayerState, PlayerProperties>, IPlayer
{
    public Task Move(Direction d)
    {
        State.Location =
            d.GetDestination(State.Location);
        return WriteStateAsync();
    }

    public Task<string> GetLocation()
    {
        return Task.FromResult(State.Location);
    }
}
```

```
public class PlayerProperties
{
   public int Rank { get; set; }

   [Index]
   public string Location { get; set; }
}
```

```
public class PlayerState
{
   public string Name { get; set; }
   public int Rank { get; set; }
   public string Location { get; set; }
}
```

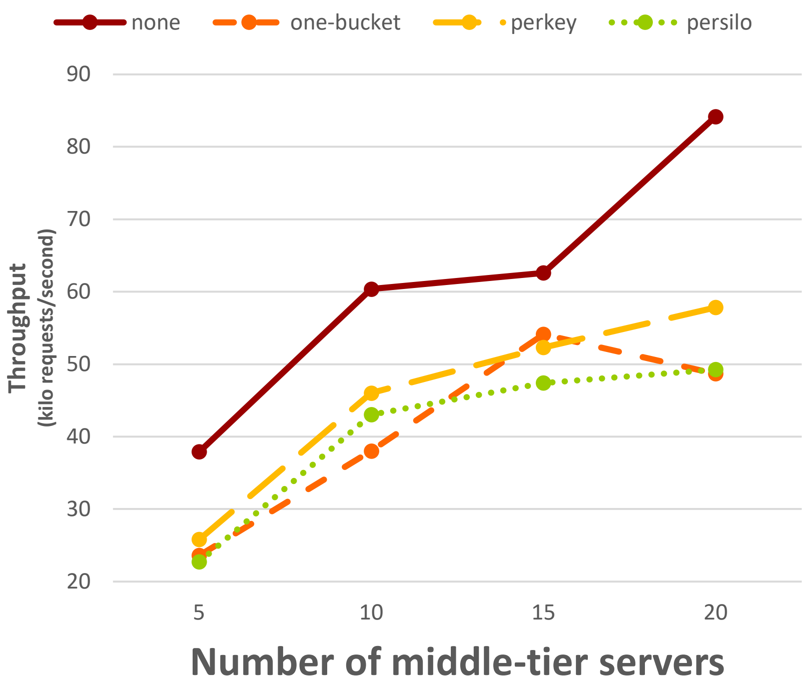
Programming Interface: Index Lookup

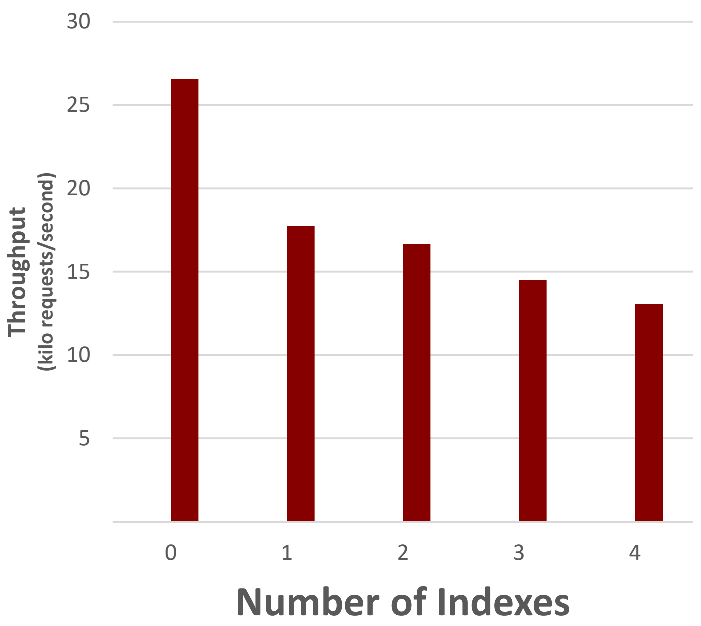
- Use LINQ to access the index

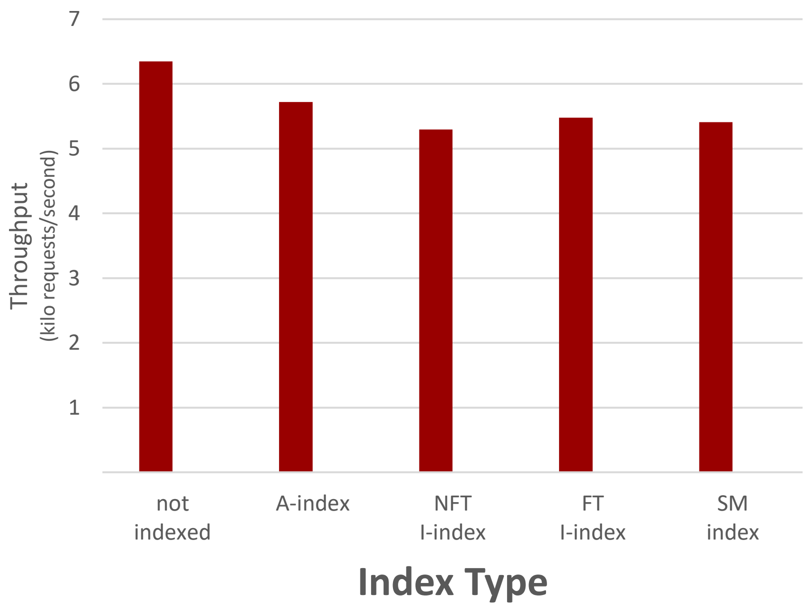
```
IOrleansQueryable<IPlayer> activePlayersInRedmond =
                                   from player in GrainFactory.GetActiveGrains<IPlayer, PlayerProperties>()
                                   where player.Location == "Redmond"
                                   select player;


//IOrleansQueryable extends IQueryable interface
foreach(IPlayer player in activePlayersInRedmond)
{
    Console.WriteLine(player.GetPrimaryKeyLong());
}
```

Performance







Future Work on Indexing

- Transactionally update actor and index
- Range indexes
- Richer materialized views
- Offer indexing with other AODB features, e.g., transactions, queries, geo-dist’n

Status of Orleans' AODB Features

- Stream processing (January 2015)
- Geo-distribution and multi-master replication (January 2016)
- Distributed transactions (preview, this month) [MSR Technical Report]
- Indexing (prototype, August 2016)

Acknowledgments

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- More at https://dotnet.github.io/orleans/

Thank you!