Microsoft

# Project Orleans
# Distributed Virtual Actors for Programmability and Scalability

Philip A. Bernstein
Microsoft Research
Joint work with Sergey Bykov, Alan Geller, Gabriel Kliot, Michael Roberts, Jorgen Thelin

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Project “Orleans” is a programming model and runtime for building *cloud native* services

It’s available as open source on github

# What is Project “Orleans”?

- Distributed C#
- You define .NET interfaces and classes, as if they run in a single process.
- Orleans runs your app on a cluster of servers
- Orleans ensures your app is scalable, reliable, and elastic
- Performance is near-real-time (milliseconds)
- 3-5x less code to write than on a bare virtual machine

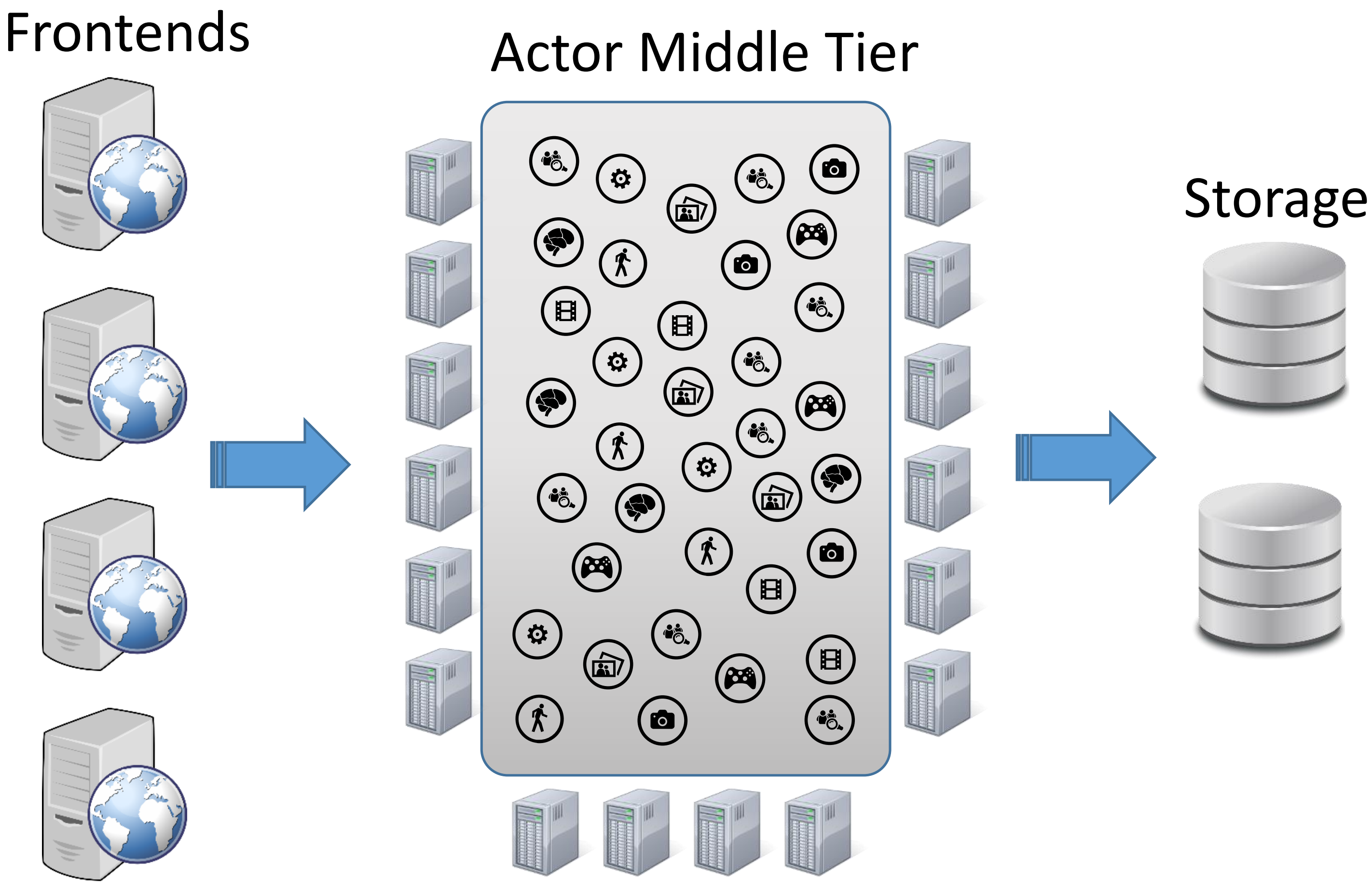
# Motivation

- Developer Productivity
  - Challenges: concurrency, distribution, fault tolerance, resource management…
  - Domain of distributed systems experts
  - Orleans helps desktop developers [and experts] succeed
  - You write much less code.
- Scalability by default
  - Designs and architectures break at scale
  - Failure to scale may be fatal for business
  - Code must be scale-proof – must scale out without rewriting

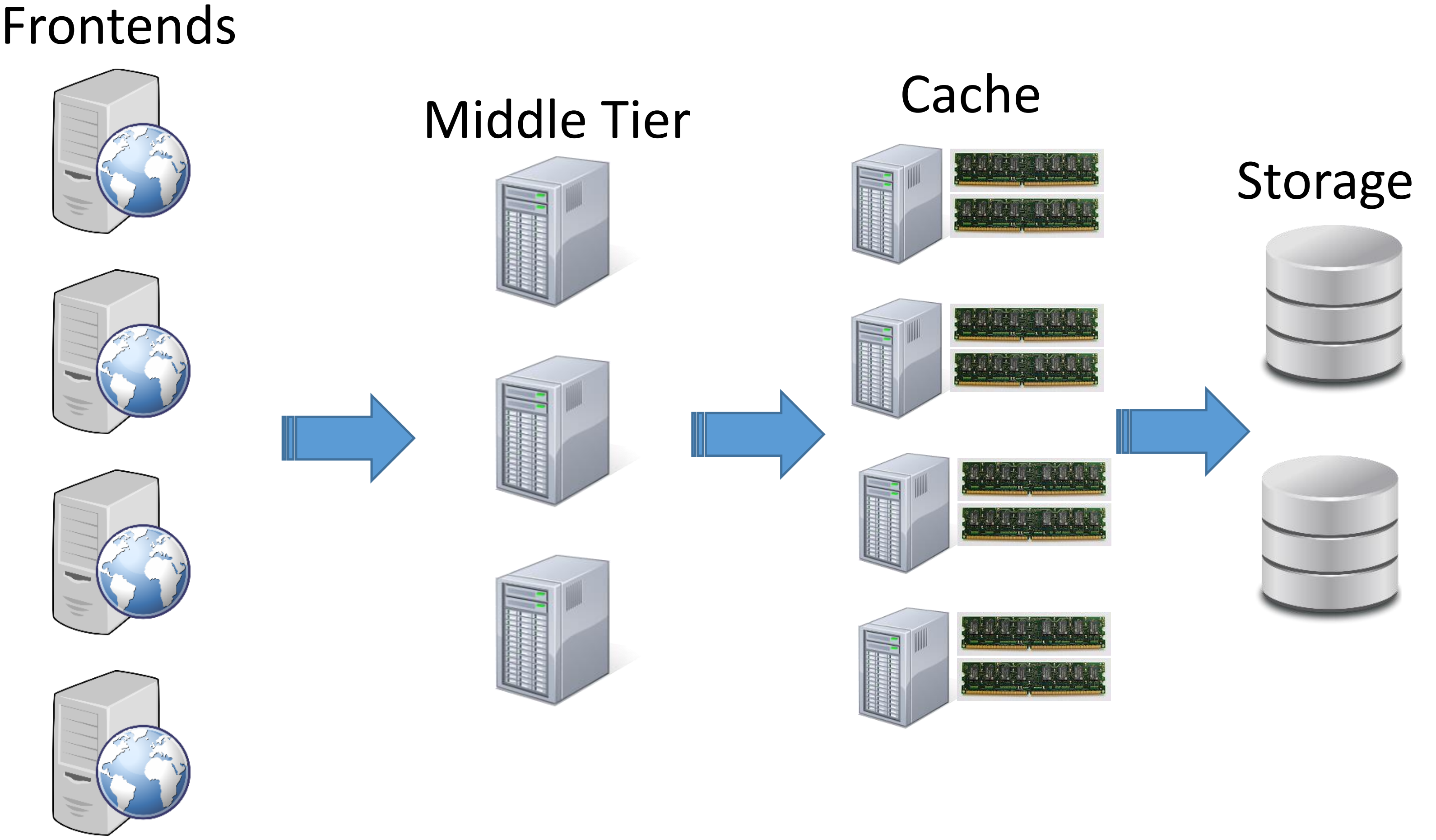
# Actor Model

- Orleans programs use the actor model
- Actors are objects that don’t share variables
- Orleans adapts the actor model for challenges of cloud computing

# Actor Model as Stateful Middle Tier



# What's the Alternative?
# A Cache Tier




- **Lost semantics of storage**
- **Lost concurrency control**
- **Data shipping**
- **Actor model can solve all of these problems**

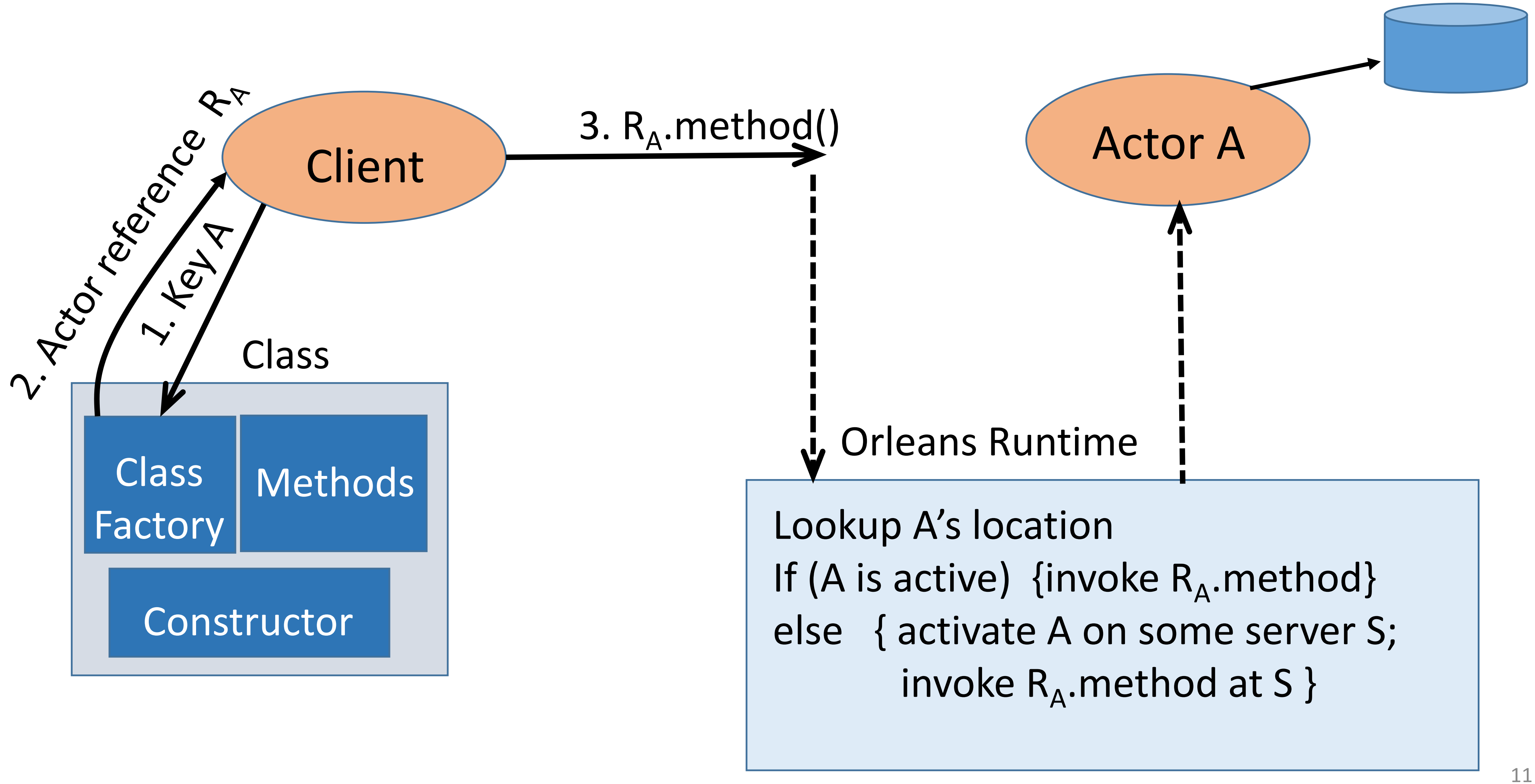
# Problems with Actor Model Frameworks

- Too low level
  - App manages lifecycle of actors, exposed to distributed races
  - App has to deal with actor failures, supervision trees
  - App manages placement of actors – resource management
- *Developer has to be a distributed systems expert*
- Orleans avoids these problems with a higher level actor model

# Orleans Programming Model

- Each class has a key, whose values uniquely identify actors (i.e. instances)
  - Game, player, phone, device, scoreboard, location, etc.
- To invoke a method M on an actor A of class C:
  - Call C's local class factory with A's key as parameter
  - Class factory returns an actor reference $R_A$
  - The caller invokes M on $R_A$
- The Orleans runtime manages activations of actors

# Invoking a method on actor A



# Key Innovation: *Virtual* actors

1. Actor instances always exist, virtually
    - Application neither creates nor deletes them. They never fail.
    - Code can always call methods on an actor

2. Activations of actors are created on-demand
    - If there is no existing activation, a message sent to it triggers instantiation
    - Transparent recovery from server failures
    - If an actor isn’t used for a while, it is deactivated
    - The Orleans runtime manages the actor’s lifecycle

3. Location transparency
    - Actors can pass actor references as parameters to a method and can persist them
    - These are logical (virtual) references, always valid, not tied to a specific activation

# Asynchronous RPC

- Method invocations are asynchronous
- Method returns a “task” (i.e., a promise), and caller continues executing
- When caller references a task’s result, it blocks until the task completes
- .NET has language support for this (Async/Await)

```
async Task<int> MyMethodAsync() { ... };
. . .
Task<int> myTask = MyMethodAsync();
// Other work
int x = await myTask; //blocks until MyMethod returns
```

# Single Threading

- Orleans runtime schedules invocations of actor methods on hardware threads
- Activations are single-threaded
  - Since actors don't share state, there's no need for locks
  - Optionally re-entrant
  - Multiplexed across hardware threads
- Cooperative multitasking
  - Since multithreading is at the user level, all I/O and method calls must be asynchronous
  - Synchronous call would block the hardware thread

# Actor State Management

- The runtime instantiates an actor by invoking the actor's constructor
  - The constructor typically reads the actor's state based on its key
  - Usually from storage, but possibly from a device (e.g. phone, game console, sensor)
- The actor saves its state to storage whenever it wants
  - Typically before returning from a method call that mutates its state
  - Or could be after *n* seconds, or after *n* calls, etc.
- Declarative persistence
  - Attach all state variables to an interface that inherits from IState
  - Declare a persistence provider for the class (Azure Table, Azure SQL DB, Redis…)
  - Invoke "WriteStateAsync" to save the state to the persistent store

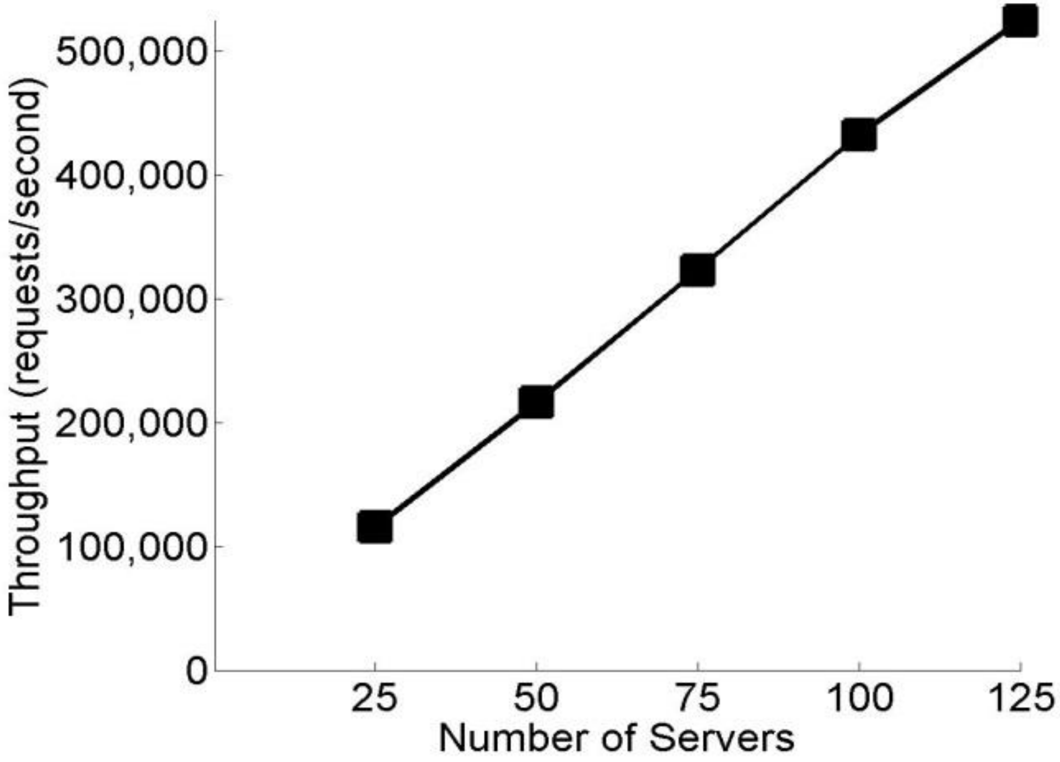
# Stateless Actors

- By default, there’s at most one activation of an actor
- But if an actor is declared to be stateless, then the runtime creates an activation local to the caller
- So there will be multiple activations of the actor
- Enables high throughput on actors with immutable state (e.g., a cache)

# Scalability

- Near linear scaling to hundreds of thousands of requests per second
- Scalable in number of actors
- Multiplexes resources for efficiency
- Location transparency simplifies scaling up or down
- Elastic – transparently adjusts to adding or removing servers

Test Lab Numbers




Request: Client → Actor 1 → Actor 2

# Orleans was built for…

## Scenarios

- Social graphs
- Mobile backend
- Internet of things
- Real-time analytics
- 'Intelligent' cache
- Interactive entertainment

## Common characteristics

- Large numbers of independent actors
- Free-form relations between actors
- High throughput/low latency
- Fine-grained partitioning is natural
- Cloud-based scale-out & elasticity
- Broad range of developer experience

- Not good for a service where different requests span different combinations of records over a large database

# Production usage

- First production deployment in 2011
- Halo 4 (December 2012) - all back end services
  - Players, games, statistics, regions, scoreboards, ….
  - Dozens of services, 10s to 100s of machines each
  - 100Ks of requests per second
  - Bursty load (evenings, weekends) and peak load at product launch
- Public preview since April 2014. Open source since January 2015.
- Back end services of many other Microsoft game studios
- About ten other Microsoft services run on Orleans
  - Examples: intelligent cache, telemetry.

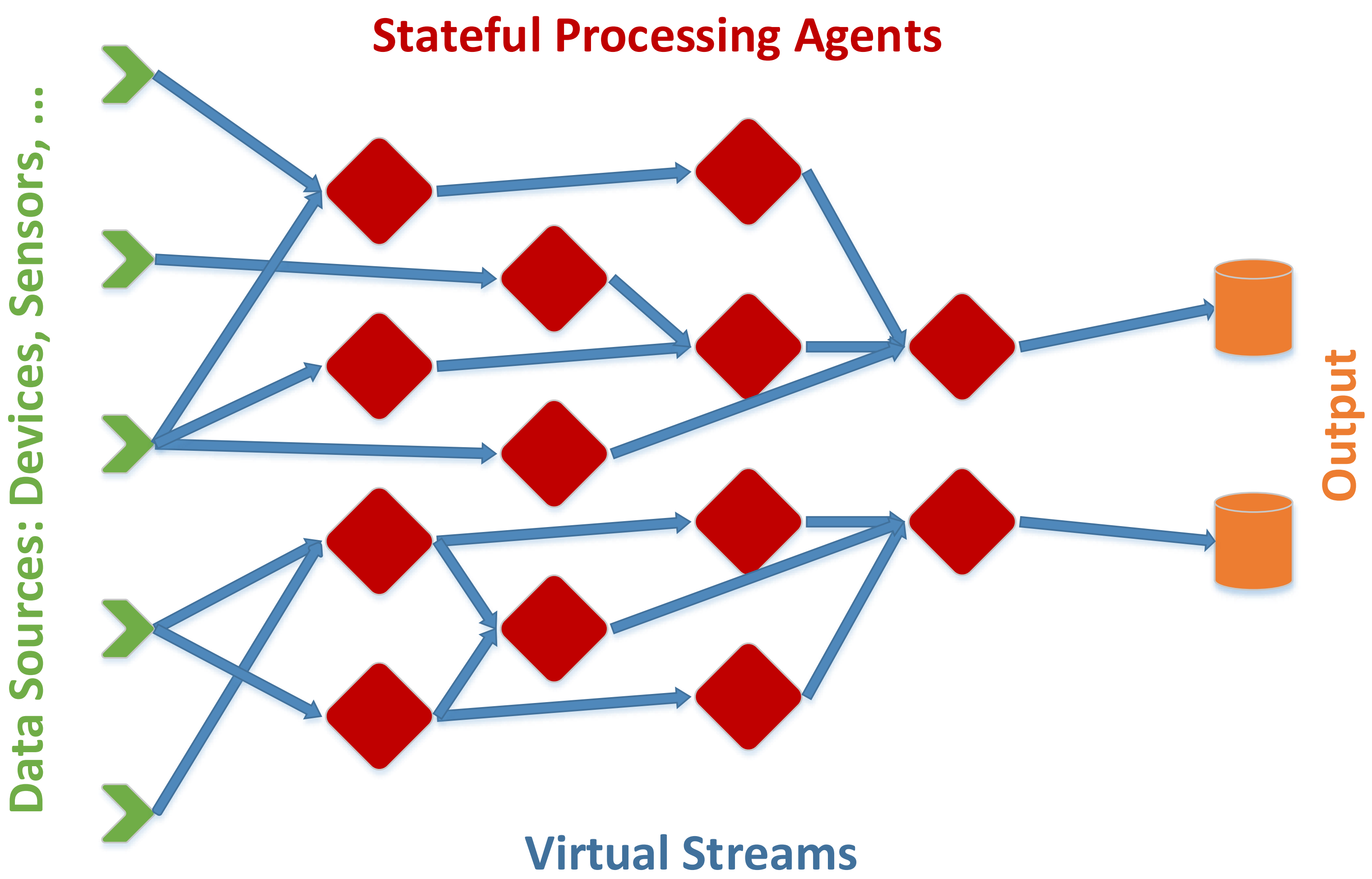
# Conclusion

- Orleans Benefits
  - Significantly improved developer productivity
  - Makes cloud-scale programming attainable to desktop developers
  - Scalability by default. Excellent performance
  - Proven in multiple production services
- A main innovation: Virtual actor programming model
- What I skipped: Virtual streams, timers, reminders, exceptions
- Future work: transactions, dynamic optimization, geo-distribution

Open Source Release: https://github.com/dotnet/orleans

# Backup slides

# Orleans Streams
## Combines dataflow & imperative styles

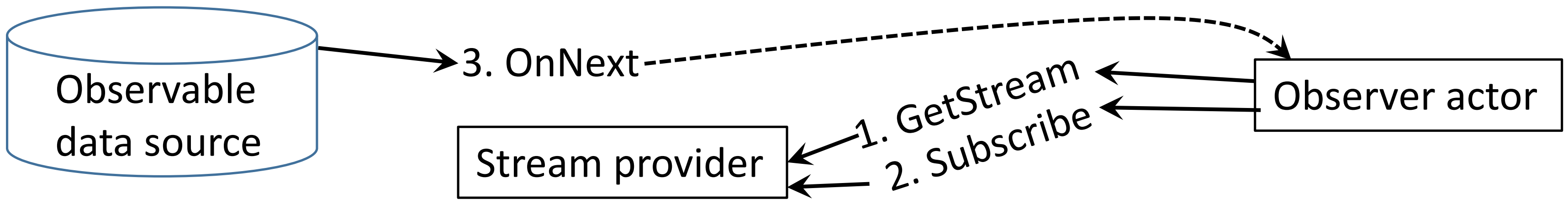



- Event source
- Processing agent (actor)
  - Imperative code
  - LINQ query
  - Stream processing engine
- Output
- Virtual stream
  - 'Stream provider' plug-in maps physical stream to virtual stream

# Orleans Streams – Programming model

- Programming model innovation – Virtual Streams
  - Stream is always available (i.e. fault tolerant).
  - No need to explicitly create or delete it.

- API –a session from observable data source to observer actor
  - Observer calls a *stream provider* with a stream identity and callback method
  - Stream provider registers the observer for the observable stream
  - For each of its events, the observable stream calls the observer's callback method
  - Similar to .NET's Rx interface, extended for remote, asynchronous access




- In production with a major internal customer