Project Orleans
Distributed Virtual Actors for Programmability and Scalability

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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

Frontends → Actor Middle Tier → Storage
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

1. Key A
2. Actor reference $R_A$
3. $R_A$.method()

Client

Actor A

Orleans Runtime

Lookup A’s location
If (A is active)  \{invoke $R_A$.method\}
else  \{ activate A on some server S; invoke $R_A$.method at S \}
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)

```csharp
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

Graph: Throughput (requests/second) vs. Number of Servers

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

Data Sources: Devices, Sensors, ...
Stateful Processing Agents
Output
Virtual Streams

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