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Distributed Streams

The Stream API on Steroids

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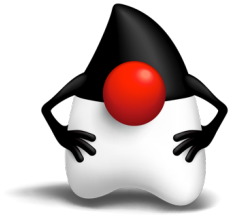
Program Agenda

1. Streams
2. Distributed Streams
3. Demonstrations
4. Optimizations
5. Summary

Streams

Streams

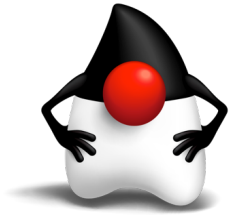


A defining new feature of the Java 8 Platform

- Provide Functional Programming constructs for processing information
  - Typically requires heavy use of lambdas
- Both a query and aggregation API for various ‘stream sources’
  - Collections, files, sockets…
- Define a pipeline of zero or more intermediate operations and a single terminal operation
- Replaces external with internal iteration
- Enables execution parallelization without code changes

Streams

Query Example

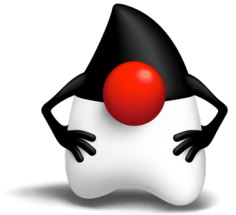


```
Map<Long, Order> orders = new HashMap<>();

Set<Long> customersForProduct = orders.values().stream()
    .flatMap(order -> order.getItems().stream())
    .filter(orderItem -> orderItem.getProductId() == productId)
    .map(OrderItem::getOrder)
    .map(Order::getCustomerId)
    .collect(toSet());
```

Streams

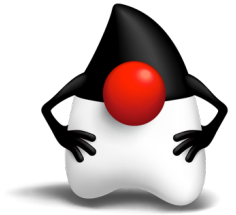
Aggregation Example



```
Map<Long, Double> salesByProduct = orders.values().stream()
    .flatMap(order -> order.getItems().stream())
    .collect(groupingBy(OrderItem::getProductId,
                        summingDouble(OrderItem::getTotal)));
```

Streams

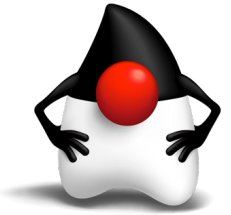
Intermediate Operations



- *Stateless* intermediate operations are:
  - `filter(Predicate<? super T> predicate)`
  - `map(Function<? super T,? extends R> mapper)`
  - `flatMap(Function<? super T,? extends Stream<? extends R>> mapper)`
  - `peek(Consumer<? super T> action)`
- *Stateful* intermediate operations are:
  - `distinct()`
  - `limit(long maxSize)`
  - `skip(long n)`
  - `sorted([Comparator<? super T> comparator])`

Streams

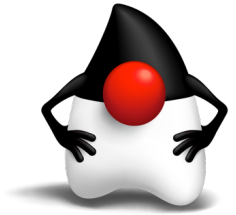
Terminal Operations



- `forEach(Consumer<? super T> action)`
- `reduce(BinaryOperator<T> accumulator)`
- `toArray(IntFunction<A[]> generator)`
- `min(Comparator<? super T> comparator)`
- `max(Comparator<? super T> comparator)`
- `count()`
- `anyMatch(Predicate<? super T> predicate)`
- `allMatch(Predicate<? super T> predicate)`
- `noneMatch(Predicate<? super T> predicate)`
- `findFirst()`
- `findAny()`
- `collect(Collector<? super T,A,R> collector)`

Streams

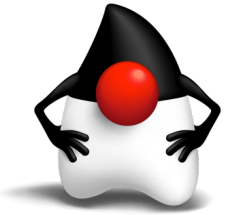
Collectors



- Some of the most powerful use cases require *Collectors*
- Allow custom “collection” of results in pipeline
- A *Collector* has four components:
  - **Supplier**: creates a new result container
  - **Accumulator**: incorporates single data element into a result container
  - **Combiner**: merges two result containers into one
  - **Finisher**: performs final transformation of a result container

Streams

Collectors



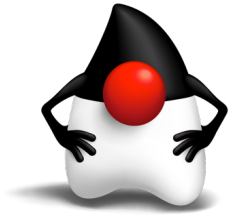
- Some Collectors, such as *groupingBy*, can have nested Collectors:

```
Map<Long, Map<String, Double>> salesByCustomerByProduct =
    orders.values().stream()
        .flatMap(order -> order.getItems().stream())
        .collect(groupingBy(
                    item -> item.getOrder().getCustomerId(),
                    groupingBy(OrderItem::getName,
                               summingDouble(OrderItem::getTotal))));
```

- Powerful and flexible
  - No need for custom code
- Much better than a bunch of nested loops?

Streams

Collectors



- averagingInt/Long/Double
- summingInt/Long/Double
- summarizingInt/Long/Double
- groupingBy
- partitioningBy
- joining
- mapping
- minBy, maxBy
- counting
- reducing
- toCollection/Set/List/Map

What is Oracle Coherence?

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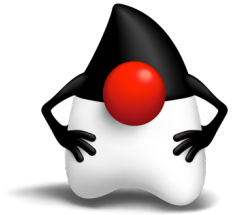
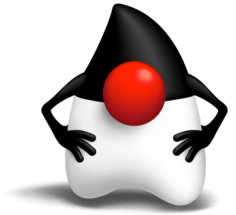


- In-Memory-Data-Grid
  - Clustered, Shared, Data-Structures, RAID-like availability, Dynamic-Live-Scale-Out
  - Pure Java
  - Typically used for Distributed Caching
  - Fully parallel query / aggregation / in-place processing
  - Cluster-wide concurrently control
- Implements Standard Java Platform Data-Structures
  - Eg: NamedCache == java.util.Map (on steroids)

Distributed Streams

Distributed Streams

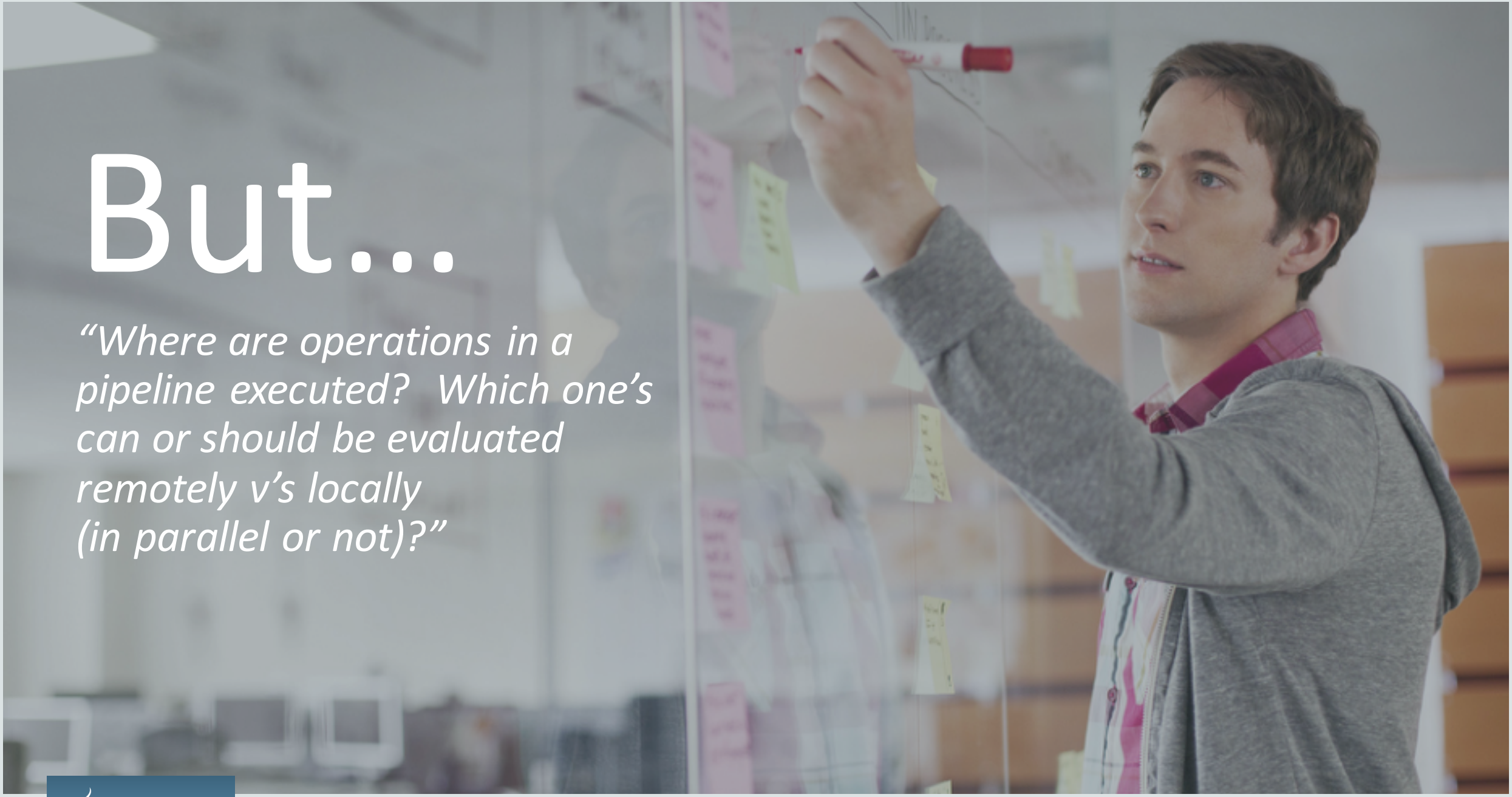


Limitations of the current Java Platform

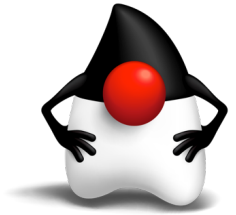
- Query & Aggregation concepts already exist in Coherence…
- Standard Java Design and Implementation is limiting
- Parallel execution only within a single process
  - We want to parallelize it across many processes on many machines
- Design assumes data locality
  - Non-serializable Lambdas used as arguments
  - Built-in Collectors and some of the return types are not serializable
- But… it's an awesome model for distributed computing!
  - Could we make them work in a distributed manner?

But…

"Where are operations in a pipeline executed? Which one's can or should be evaluated remotely v's locally (in parallel or not)?"



Distributed Streams

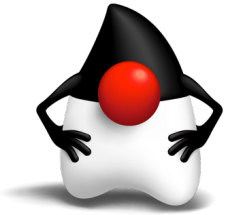


Where can and should operations be executed? What about collectors?

```
Map<Long, Order> orders = new HashMap<>();

Set<Long> customersForProduct = orders.values().stream()
    .flatMap(order -> order.getItems().stream())
    .filter(orderItem -> orderItem.getProductId() == productId)
    .map(OrderItem::getOrder)
    .map(Order::getCustomerId)
    .collect(toSet());
```

Distributed Streams



Terminal Operations: Evaluate Locally or Remotely (or both?)

- `forEach(Consumer<? super T> action)`
- `reduce(BinaryOperator<T> accumulator)`
- `toArray(IntFunction<A[]> generator)`
- `min(Comparator<? super T> comparator)`
- `max(Comparator<? super T> comparator)`
- `count()`
- `anyMatch(Predicate<? super T> predicate)`
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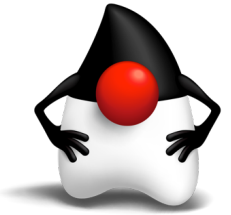


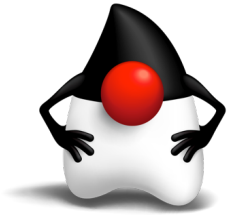
On Coherence

- Re-implemented Stream API
  - Support for serialization of pipeline operations, including partial and final results
  - Evaluate pipeline operations in a distributed manner, in parallel
- Implemented serializable versions of the standard JDK Collectors

```
long customerId = ...;

List<Order> custOrders = orders.stream()
        .map(Map.Entry::getValue)
        .filter(order -> order.getCustomerId() == customerId)
        .collect(RemoteCollectors.toList());
```

Distributed Streams



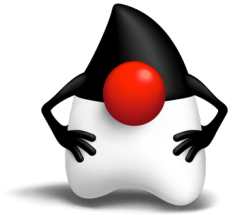
Query Example

- What should we process? Keys? Values? Entries?
  - Eg: Don't Call "stream" on result of values(), entrySet(), keySet()

```
NamedCache<Long, Order> orders = ...;

Set<Long> customersForProduct = orders.stream()
        .map(Map.Entry::getValue)
        .flatMap(order -> order.getItems().stream())
        .filter(orderItem -> orderItem.getProductId() == productId)
        .map(OrderItem::getOrder)
        .map(Order::getCustomerId)
        .collect(RemoteCollectors.toSet());
```

Distributed Streams



Aggregation Example

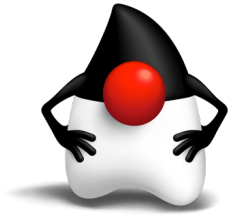
```
import static com.tangosol.util.stream.RemoteCollectors.*;

NamedCache<Long, Order> orders = ...;

Map<Long, Map<String, Double>> salesByCustomerByProduct =
    orders.stream()
        .map(Map.Entry::getValue)
        .flatMap(order -> order.getItems().stream())
        .collect(groupingBy(
                    (item) -> item.getOrder().getCustomerId(),
                    groupingBy(OrderItem::getName,
                                summingDouble(OrderItem::getTotal))));
```

Optimizations

Optimizations



Pre-filter to avoid placing entries in the pipeline (and creating garbage)

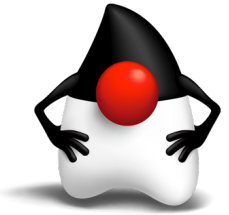
- Don’t do this:

```
orders.stream()
    .map(Map.Entry::getValue)
    .filter(order -> order.getCustomerId() == customerId)
    ...
```

- Do this instead:

```
orders.stream(equal(Order::getCustomerId, customerId))
    .map(Map.Entry::getValue)
    .filter(order -> order.getCustomerId() == customerId)
    ...
```

Optimizations



Pre-map to allow using forward indexes (and avoid deserialization)

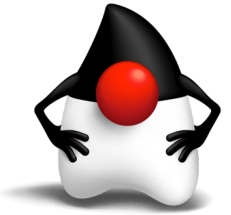
- Don’t do this:

```
orders.stream()
    .map(Map.Entry::getValue)
    .mapToDouble(Order::getTotal)
    .sum();
```

- Do this instead:

```
orders.stream(Order::getTotal)
    .map(Map.Entry::getValue)
    .mapToDouble(Order::getTotalNumber::doubleValue)
    .sum();
```

Optimizations



Combine them (use indexes for getCustomer and getTotal)

- So the following:

```
double total =
    orders.stream()
        .map(Map.Entry::getValue)
        .filter(order -> order.getCustomerId() == customerId)
        .mapToDouble(Order::getTotal)
        .sum();
```

- Becomes:

```
double total =
    orders.stream(equal(Order::getCustomerId, customerId),
                  Order::getTotal)
        .mapToDouble(Number::doubleValue)
        .sum();
```

Summary

Summary

CREATE THE FUTURE

Distributed Streaming Rocks!

- Stream API provides functional API for query and aggregation
- Collectors eliminate the need for custom code
- Coherence provides Distributed Stream API
  - Allows parallel processing of data streams across a cluster “in-place”
  - Scales multiple threads in a single process to multiple threads in multiple processes across machines across the Coherence cluster (with high-availablity)
  - Provides optimizations to avoid deserialization & use indexes
  - Stable results even during cluster failure / recovery
- Next generation? Real-time continuous stream processing

Next Steps

Start Playing!

Coherence for Developers!

CREATE THE FUTURE

- https://www.oracle.com/goto/coherence
- https://coherence.java.net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