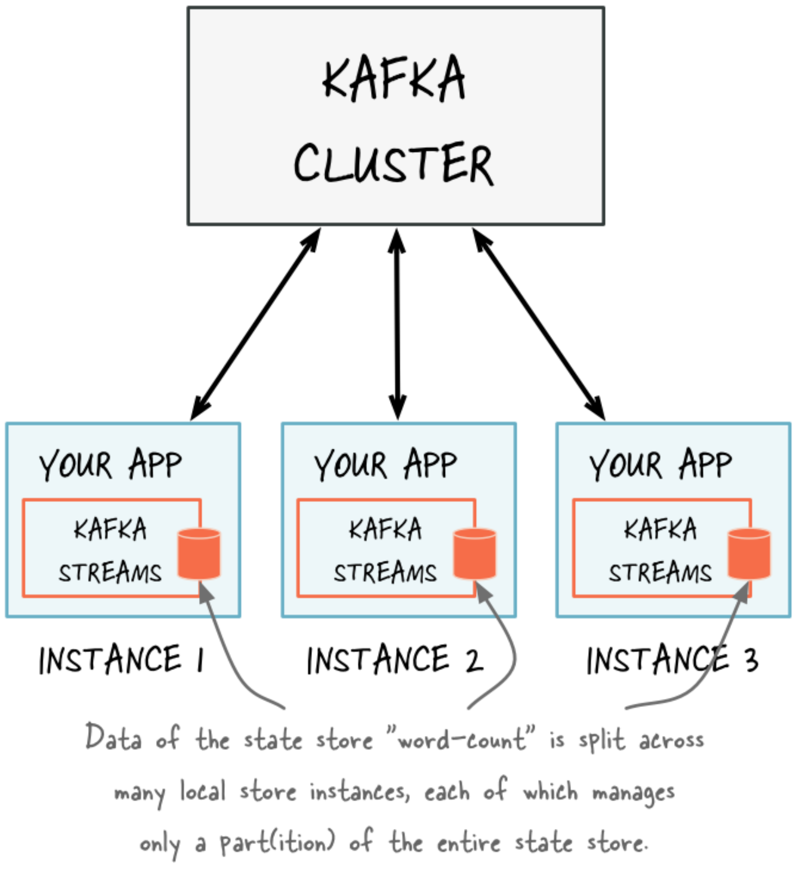
Interactive Queries

Interactive Queries allow you to leverage the state of your application from outside your application. The Kafka Streams API enables your applications to be queryable.

The full state of your application is typicallysplit across many distributed instances of your application, and across many state stores that are managed locally by these application instances.


KAFKA
CLUSTER
YOUR APP
KAFKA
STREAMS
INSTANCE 1
YOUR APP
KAFKA
STREAMS
INSTANCE 2
YOUR APP
KAFKA
STREAMS
INSTANCE 3
Data of the state store "word-count" is split across
many local store instances, each of which manages
only a part(ition) of the entire state store.

There are local and remote components to interactively querying the state of your application.

Local state

An application instance can query the locally managed portion of the state and directly query its own local state stores. You can use the corresponding local data in other parts of your application code, as long as it doesn't required calling the Kafka Streams API. Querying state stores is always read-only to guarantee that the underlying state stores will never be mutated out-of-band (e.g., you cannot add new entries). State stores should only be mutated by the corresponding processor topology and the input data it operates on. For more information, see Querying local state stores for an app instance

Remote state

To query the full state of your application, you must connect the various fragments of the state, including:

- query local state stores
- discover all running instances of your application in the network and their state stores
- communicate with these instances over the network (e.g., an RPC layer)

Connecting these fragments enables communication between instances of the same app and communication from other applications for Interactive Queries. For more information, see Querying remote state stores for the entire app

Kafka Streams natively provides all of the required functionality for interactively querying the state of your application, except if you w expose the full state of your application via Interactive Queries. To allow application instances to communicate over the network, you Remote Procedure Call (RPC) layer to your application (e.g., REST API).

Expand
Content

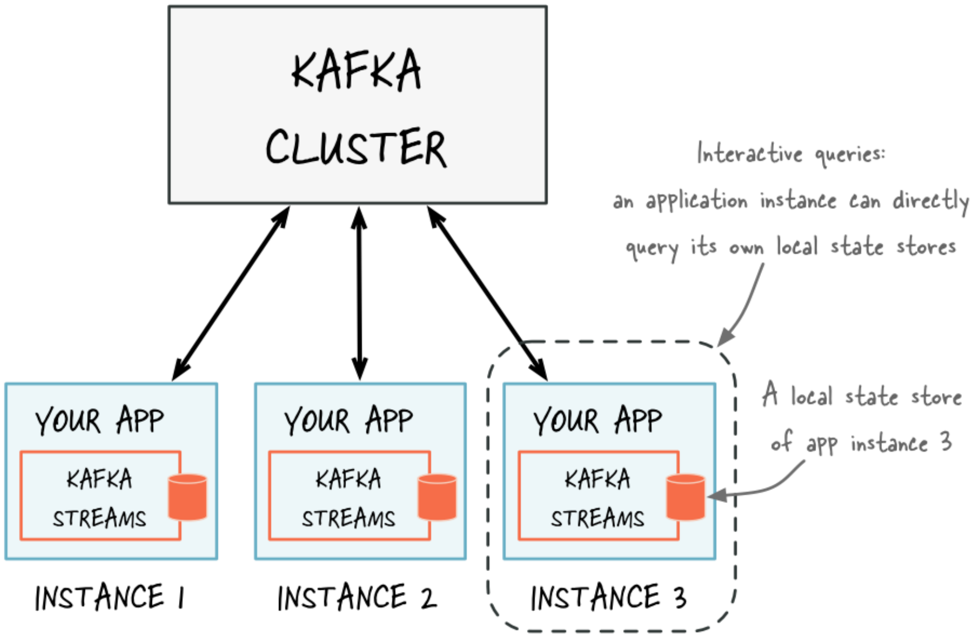
This table shows the Kafka Streams native communication support for various procedures.

Procedure	Application instance	Entire application
Query local state stores of an app instance	Supported	Supported
Make an app instance discoverable to others	Supported	Supported
Discover all running app instances and their state stores	Supported	Supported
Communicate with app instances over the network (RPC)	Supported	Not supported (you must configure)

Querying local state stores for an app instance

A Kafka Streams application typically runs on multiple instances. The state that is locally available on any given instance is only a subset of the application's entire state. Querying the local stores on an instance will only return data locally available on that particular instance.

The method `KafkaStreams#store(...)` finds an application instance's local state stores by name and type.



Every application instance can directly query any of its local state stores.

The *name* of a state store is defined when you create the store. You can create the store explicitly by using the Processor API or implicitly by using stateful operations in the DSL.

The *type* of a state store is defined by `QueryableStoreType`. You can access the built-in types via the class `QueryableStoreTypes`. Kafka Streams currently has two built-in types:

- A key-value store `QueryableStoreTypes#keyValueStore()`, see Querying local key-value stores.
- A window store `QueryableStoreTypes#windowStore()`, see Querying local window stores.

You can also implement your own QueryableStoreType as described in section Querying local custom state stores.

Note

Kafka Streams materializes one state store per stream partition. This means your application will potentially manage many underlying state stores. The API enables you to query all of the underlying stores without having to know which partition the data is in.

Querying local key-value stores

To query a local key-value store, you must first create a topology with a key-value store. This example creates a key-value store named "CountsKeyValueStore". This store will hold the latest count for any word that is found on the topic "word-count-input".

```
Properties props = ...;
StreamsBuilder builder = ...;
KStream<String, String> textLines = ...;

// Define the processing topology (here: WordCount)
KGroupedStream<String, String> groupedByWord = textLines
  .flatMapValues(value -> Arrays.asList(value.toLowerCase().split("\\W+")))
  .groupBy((key, word) -> word, Grouped.with(stringSerde, stringSerde));

// Create a key-value store named "CountsKeyValueStore" for the all-time word counts
groupedByWord.count(Materialized.<String, String, KeyValueStore<Bytes, byte[]>as("CountsKeyValueStore"));

// Start an instance of the topology
KafkaStreams streams = new KafkaStreams(builder.build(), props);
streams.start();
```

After the application has started, you can get access to "CountsKeyValueStore" and then query it via the ReadOnlyKeyValueStore API:

```
// Get the key-value store CountsKeyValueStore
ReadOnlyKeyValueStore<String, Long> keyValueStore =
    streams.store("CountsKeyValueStore", QueryableStoreTypes.keyValueStore());

// Get value by key
System.out.println("count for hello:" + keyValueStore.get("hello"));

// Get the values for a range of keys available in this application instance
KeyValueIterator<String, Long> range = keyValueStore.range("all", "streams");
while (range.hasNext()) {
  KeyValue<String, Long> next = range.next();
  System.out.println("count for " + next.key + ": " + value);
}
// close the iterator to release resources
range.close()

// Get the values for all of the keys available in this application instance
KeyValueIterator<String, Long> range = keyValueStore.all();
while (range.hasNext()) {
  KeyValue<String, Long> next = range.next();
  System.out.println("count for " + next.key + ": " + value);
}
// close the iterator to release resources
range.close()
```

You can also materialize the results of stateless operators by using the overloaded methods that take `queryableStoreName` as shown in the example below:

```
StreamsBuilder builder = ...;
KTable<String, Integer> regionCounts = ...;

// materialize the result of filtering corresponding to odd numbers
// the "queryableStoreName" can be subsequently queried.
KTable<String, Integer> oddCounts = numberLines.filter((region, count) -> (count % 2 != 0),
  Materialized.<String, Integer, KeyValueStore<Bytes, byte[]>as("queryableStoreName"));

// do not materialize the result of filtering corresponding to even numbers
// this means that these results will not be materialized and cannot be queried.
KTable<String, Integer> oddCounts = numberLines.filter((region, count) -> (count % 2 == 0));
```

Querying local window stores

A window store will potentially have many results for any given key because the key can be present in multiple windows. However, there is only one result per window for a given key.

To query a local window store, you must first create a topology with a window store. This example creates a window store named "CountsWindowStore" that contains the counts for words in 1-minute windows.

```
StreamsBuilder builder = ...;
KStream<String, String> textLines = ...;

// Define the processing topology (here: WordCount)
KGroupedStream<String, String> groupedByWord = textLines
  .flatMapValues(value -> Arrays.asList(value.toLowerCase().split("\\W+")))
  .groupBy((key, word) -> word, Grouped.with(stringSerde, stringSerde));

// Create a window state store named "CountsWindowStore" that contains the word counts for every minute
groupedByWord.windowedBy(TimeWindows.of(Duration.ofMinutes(1)))
  .count(Materialized.<String, Long, WindowStore<Bytes, byte[]>as("CountsWindowStore"));
```

After the application has started, you can get access to "CountsWindowStore" and then query it via theReadOnlyWindowStore API:

```
// Get the window store named "CountsWindowStore"
ReadOnlyWindowStore<String, Long> windowStore =
    streams.store("CountsWindowStore", QueryableStoreTypes.windowStore());

// Fetch values for the key "world" for all of the windows available in this application instance.
// To get *all* available windows we fetch windows from the beginning of time until now.
Instant timeFrom = Instant.ofEpochMilli(0); // beginning of time = oldest available
Instant timeTo = Instant.now(); // now (in processing-time)
WindowStoreIterator<Long> iterator = windowStore.fetch("world", timeFrom, timeTo);
while (iterator.hasNext()) {
  KeyValue<Long, Long> next = iterator.next();
  long windowTimestamp = next.key;
  System.out.println("Count of 'world' @ time " + windowTimestamp + " is " + next.value);
}
// close the iterator to release resources
iterator.close()
```

Querying local custom state stores

Note

Only the Processor API supports custom state stores.

Before querying the custom state stores you must implement these interfaces:

- Your custom state store must implement `StateStore`.
- You must have an interface to represent the operations available on the store.
- You must provide an implementation of `StoreBuilder` for creating instances of your store.
- It is recommended that you provide an interface that restricts access to read-only operations. This prevents users of this API from mutating the state of your running Kafka Streams application out-of-band.

The class/interface hierarchy for your custom store might look something like:

```
public class MyCustomStore<K,V> implements StateStore, MyWriteableCustomStore<K,V> {
  // implementation of the actual store
}

// Read-write interface for MyCustomStore
public interface MyWriteableCustomStore<K,V> extends MyReadableCustomStore<K,V> {
  void write(K Key, V value);
}

// Read-only interface for MyCustomStore
public interface MyReadableCustomStore<K,V> {
  V read(K key);
}

public class MyCustomStoreBuilder implements StoreBuilder<MyCustomStore<K,V>> {
  // implementation of the supplier for MyCustomStore
}
```

To make this store queryable you must:

- Provide an implementation ofQueryableStoreType.
- Provide a wrapper class that has access to all of the underlying instances of the store and is used for querying.

Here is how to implement `QueryableStoreType`:

```
public class MyCustomStoreType<K,V> implements QueryableStoreType<MyReadableCustomStore<K,V>> {

  // Only accept StateStores that are of type MyCustomStore
  public boolean accepts(final StateStore stateStore) {
    return stateStore instanceOf MyCustomStore;
  }

  public MyReadableCustomStore<K,V> create(final StateStoreProvider storeProvider, final String storeName) {
      return new MyCustomStoreTypeWrapper(storeProvider, storeName, this);
  }

}
```

A wrapper class is required because each instance of a Kafka Streams application may run multiple stream tasks and manage multiple local instances of a particular state store. The wrapper class hides this complexity and lets you query a "logical" state store by name without having to know about all of the underlying local instances of that state store.

When implementing your wrapper class you must use theStateStoreProvider interface to get access to the underlying instances of your store. `StateStoreProvider#stores(String storeName, QueryableStoreType<T> queryableStoreType)` returns a `List` of state stores with the given storeName and of the type as defined by `queryableStoreType`.

Here is an example implementation of the wrapper follows (Java 8+):

```
// We strongly recommended implementing a read-only interface
// to restrict usage of the store to safe read operations!
public class MyCustomStoreTypeWrapper<K,V> implements MyReadableCustomStore<K,V> {

  private final QueryableStoreType<MyReadableCustomStore<K, V>> customStoreType;
  private final String storeName;
  private final StateStoreProvider provider;

  public CustomStoreTypeWrapper(final StateStoreProvider provider,
                                final String storeName,
                                final QueryableStoreType<MyReadableCustomStore<K, V>> customStoreType) {

    // ... assign fields ...
  }

  // Implement a safe read method
  @Override
  public V read(final K key) {
    // Get all the stores with storeName and of customStoreType
    final List<MyReadableCustomStore<K, V>> stores = provider.getStores(storeName, customStoreType);
    // Try and find the value for the given key
    final Optional<V> value = stores.stream().filter(store -> store.read(key) != null).findFirst();
    // Return the value if it exists
    return value.orElse(null);
  }

}
```

You can now find and query your custom store:

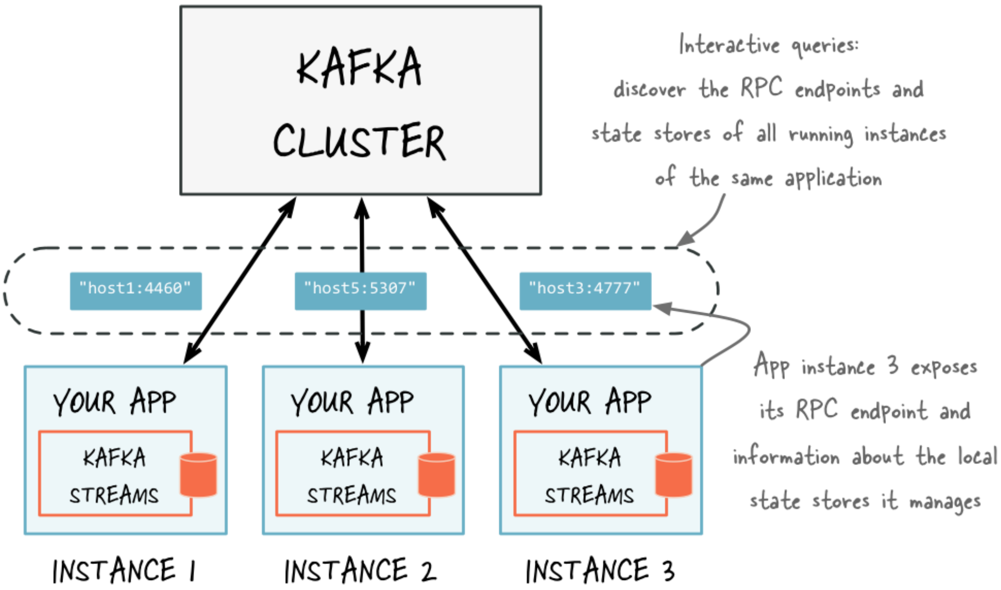
```
Topology topology = ...;
ProcessorSupplier processorSuppler = ...;

// Create CustomStoreSupplier for store name the-custom-store
MyCustomStoreBuilder customStoreBuilder = new MyCustomStoreBuilder("the-custom-store") //...;
// Add the source topic
topology.addSource("input", "inputTopic");
// Add a custom processor that reads from the source topic
topology.addProcessor("the-processor", processorSupplier, "input");
// Connect your custom state store to the custom processor above
topology.addStateStore(customStoreBuilder, "the-processor");

KafkaStreams streams = new KafkaStreams(topology, props);
streams.start();

// Get access to the custom store
MyReadableCustomStore<String,String> store = streams.store("the-custom-store", new MyCustomStoreType<String,String>());

// Query the store
String value = store.read("key");
```

Querying remote state stores for the entire app

To query remote states for the entire app, you must expose the application's full state to other applications, including applications that are running on different machines.

For example, you have a Kafka Streams application that processes user events in a multi-player video game, and you want to retrieve the latest status of each user directly and display it in a mobile app. Here are the required steps to make the full state of your application queryable:

1. Add an RPC layer to your applicationso that the instances of your application can be interacted with via the network (e.g., a REST API, Thrift, a custom protocol, and so on). The instances must respond to Interactive Queries. You can follow the reference examples provided to get started.
2. Expose the RPC endpoints of your application's instances via the `application.server` configuration setting of Kafka Streams. Because RPC endpoints must be unique within a network, each instance has its own value for this configuration setting. This makes an application instance discoverable by other instances.
3. In the RPC layer, discover remote application instances and their state stores andquery locally available state stores to make the full state of your application queryable. The remote application instances can forward queries to other app instances if a particular instance lacks the local data to respond to a query. The locally available state stores can directly respond to queries.


KAFKA CLUSTER
Interactive queries: discover the RPC endpoints and state stores of all running instances of the same application
"host1:4460"
"host5:5307"
"host3:4777"
YOUR APP
KAFKA STREAMS
YOUR APP
KAFKA STREAMS
YOUR APP
KAFKA STREAMS
App instance 3 exposes its RPC endpoint and information about the local state stores it manages
INSTANCE 1
INSTANCE 2
INSTANCE 3

Discover any running instances of the same application as well as the respective RPC endpoints they expose for Interactive Queries

Adding an RPC layer to your application

There are many ways to add an RPC layer. The only requirements are that the RPC layer is embedded within the Kafka Streams application and that it exposes an endpoint that other application instances and applications can connect to.

The KafkaMusicExample and WordCountInteractiveQueriesExample are end-to-end demo applications for Interactive Queries that showcase the implementation of an RPC layer through a REST API.

Exposing the RPC endpoints of your application

To enable remote state store discovery in a distributed Kafka Streams application, you must set theconfiguration property in the config properties instance. The `application.server` property defines a unique `host:port` pair that points to the RPC endpoint of the respective instance of a Kafka Streams application. The value of this configuration property will vary across the instances of your application. When this property is set, Kafka Streams will keep track of the RPC endpoint information for every instance of an application, its state stores, and assigned stream partitions through instances of StreamsMetadata.

Tip

Consider leveraging the exposed RPC endpoints of your application for further functionality, such as piggybacking additional inter-application communication that goes beyond Interactive Queries.

This example shows how to configure and run a Kafka Streams application that supports the discovery of its state stores.

```
Properties props = new Properties();
// Set the unique RPC endpoint of this application instance through which it
// can be interactively queried.  In a real application, the value would most
// probably not be hardcoded but derived dynamically.
String rpcEndpoint = "host1:4460";
props.put(StreamsConfig.APPLICATION_SERVER_CONFIG, rpcEndpoint);
// ... further settings may follow here ...

StreamsBuilder builder = new StreamsBuilder();

KStream<String, String> textLines = builder.stream(stringSerde, stringSerde, "word-count-input");

final KGroupedStream<String, String> groupedByWord = textLines
    .flatMapValues(value -> Arrays.asList(value.toLowerCase().split("\\W+")))
    .groupBy((key, word) -> word, Grouped.with(stringSerde, stringSerde));

// This call to `count()` creates a state store named "word-count".
// The state store is discoverable and can be queried interactively.
groupedByWord.count(Materialized.<String, Long, KeyValueStore<Bytes, byte[]>as("word-count"));

// Start an instance of the topology
KafkaStreams streams = new KafkaStreams(builder.build(), props);
streams.start();

// Then, create and start the actual RPC service for remote access to this
// application instance's local state stores.
//
// This service should be started on the same host and port as defined above by
// the property `StreamsConfig.APPLICATION_SERVER_CONFIG`.  The example below is
// fictitious, but we provide end-to-end demo applications (such as KafkaMusicExample)
// that showcase how to implement such a service to get you started.
MyRPCService rpcService = ...;
rpcService.listenAt(rpcEndpoint);
```

Discovering and accessing application instances and their local state stores

The following methods return StreamsMetadata objects, which provide meta-information about application instances such as their RPC endpoint and locally available state stores.

- `KafkaStreams#allMetadata()`: find all instances of this application
- `KafkaStreams#allMetadataForStore(String storeName)`: find those applications instances that manage local instances of the state store "storeName"
- `KafkaStreams#metadataForKey(String storeName, K key, Serializer<K> keySerializer)`: using the default stream partitioning strategy, find the one application instance that holds the data for the given key in the given state store
- `KafkaStreams#metadataForKey(String storeName, K key, StreamPartitioner<K, ?> partitioner)`: using `partitioner`, find the one application instance that holds the data for the given key in the given state store

Attention

If `application.server` is not configured for an application instance, then the above methods will not find any StreamsMetadata for it.

For example, we can now find the `StreamsMetadata` for the state store named "word-count" that we defined in the code example shown in the previous section:

```
KafkaStreams streams = ...;
// Find all the locations of local instances of the state store named "word-count"
Collection<StreamsMetadata> wordCountHosts = streams.allMetadataForStore("word-count");

// For illustrative purposes, we assume using an HTTP client to talk to remote app instances.
HttpClient http = ...;

// Get the word count for word (aka key) 'alice': Approach 1
//
// We first find the one app instance that manages the count for 'alice' in its local state stores.
StreamsMetadata metadata = streams.metadataForKey("word-count", "alice", Serdes.String().serializer());
// Then, we query only that single app instance for the latest count of 'alice'.
// Note: The RPC URL shown below is fictitious and only serves to illustrate the idea.  Ultimately,
// the URL (or, in general, the method of communication) will depend on the RPC layer you opted to
// implement.  Again, we provide end-to-end demo applications (such as KafkaMusicExample) that showcase
// how to implement such an RPC layer.
Long result = http.getLong("http://" + metadata.host() + ":" + metadata.port() + "/word-count/alice");

// Get the word count for word (aka key) 'alice': Approach 2
//
// Alternatively, we could also choose (say) a brute-force approach where we query every app instance
// until we find the one that happens to know about 'alice'.
Optional<Long> result = streams.allMetadataForStore("word-count")
    .stream()
    .map(streamsMetadata -> {
        // Construct the (fictituous) full endpoint URL to query the current remote application instance
        String url = "http://" + streamsMetadata.host() + ":" + streamsMetadata.port() + "/word-count/alice";
        // Read and return the count for 'alice', if any.
        return http.getLong(url);
    })
    .filter(s -> s != null)
    .findFirst();
```

At this point the full state of the application is interactively queryable:

- You can discover the running instances of the application and the state stores they manage locally.
- Through the RPC layer that was added to the application, you can communicate with these application instances over the network and query them for locally available state.
- The application instances are able to serve such queries because they can directly query their own local state stores and respond via the RPC layer.
- Collectively, this allows us to query the full state of the entire application.

To see an end-to-end application with Interactive Queries, review thedemo applications.

Demo applications

Here are a couple of end-to-end demo applications to get you started:

- KafkaMusicExample: This application continuously computes the latest Top 5 music charts based on song play events collected in real-time in a Apache Kafka® topic. This charts data is maintained in a continuously updated state store that can be queried interactively via a REST API.
- WordCountInteractiveQueriesExample: This application continuously counts the occurrences of words based on text data that is consumed in real-time from a Kafka topic. The word counts are maintained in a continuously updated state store that can be queried interactively via a REST API.

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