Testing Coroutines

Unit testing a Coroutine

Kotlin coroutines provide an elegant way to write asynchronous code, but sometimes coroutines make it difficult to write unit tests.

The unit tests must be *efficient* and *stable*.

- *How to build a coroutine* from the unit tests
- How to *make unit tests wait until all the jobs* in the coroutine have *finished*.
- How to make unit test run *as fast as possible*, and not sit around waiting for a coroutine delay to finish.

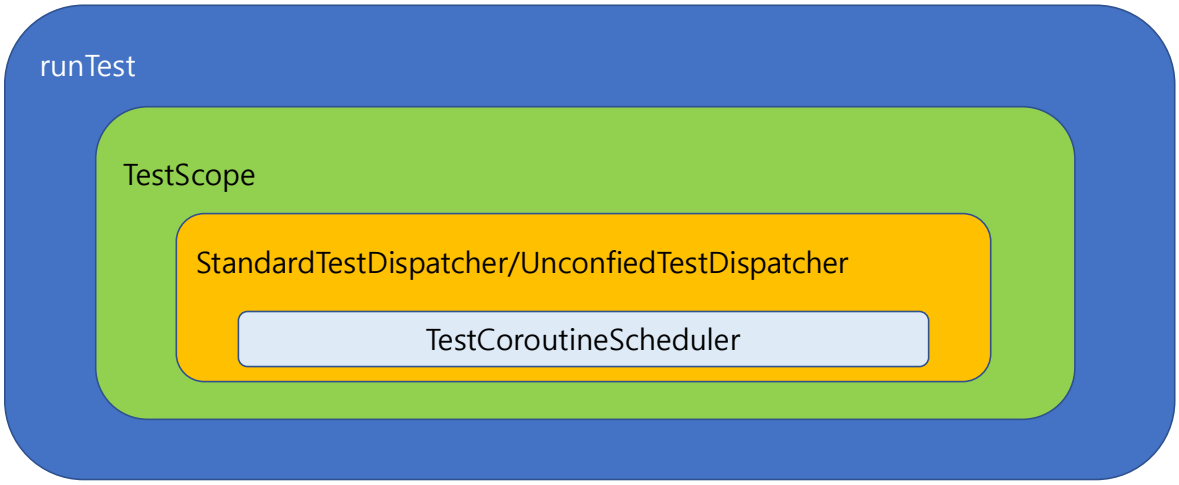
Module `kotlinx-coroutines-test`

- Test utilities for `kotlinx.coroutines`.
- This package provides testing utilities for effectively testing coroutines.

```
Dependencies {
  testImplementation        "org.jetbrains.kotlinx:kotlinx-coroutines-test:$version"
  androidTestImplementation "org.jetbrains.kotlinx:kotlinx-coroutines-test:$version"
}
```

As of version 1.6.0, the API of the test module changed significantly

`kotlinx-coroutines-test` consists of four ingredients



`kotlinx-coroutines-test` consists of four ingredients

- **runTest()** (was `runBlockingTest()`)
  - Similar to `runBlocking()`, but automatically skips delays and handles uncaught exceptions
- **TestScope**
  - A `CoroutineScope` that integrates with `runTest`, providing access to `TestCoroutineScheduler`
- **TestCoroutineScheduler**
  - The source of virtual time, used for controlling execution order and skipping delays
- **TestDispatcher**
  - Gives you fine grained control on the virtual time using `TestCoroutineScheduler`
  - `StandardTestDispatcher`: simple dispatcher with no special behavior
  - `UnconfinedTestDispatcher`: Enters top-level `launch` or `async` eagerly

How to build a coroutine from the unit tests

Which options?

To call a suspend function, we need to use a coroutine builder. There's a few to choose from:

- kotlinx.coroutines.**runBlocking**
- kotlinx.coroutines.test.**runTest**
- kotlinx.coroutines.test.~~**runBlockingTest**~~ (*deprecated*)

runBlocking

- Runs a new coroutine and *blocks the current thread* until its completion.
  - Bridge regular blocking code to libraries written in suspending style
  - To be used in main functions and in tests,
- The default `CoroutineDispatcher` is an internal implementation of event loop that processes continuations in this blocked thread.

Use Case 1: The test doesn't trigger new coroutines and we don't care about delays

```
suspend fun loadData() {
  val articles = networkRequest()
  show(articles)
}

suspend fun networkRequest(): List<Article> {
  return apiService.getArticles()
}

private fun show(
  articles: List<Article>
) {
  _articles.value = articles
}
```

```
@Test fun `test loadData`() = runBlocking {
  coEvery {
     apiService.getArticles()
  } returns testArticles

  viewModel.loadData()

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

Use Case 2: The test triggers new coroutines and/or we care about delays

```
class MyViewModel(val apiService:ApiService) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())
  fun onButtonClicked() {
     scope.launch {
       loadData()
     }
  }
```

Dispatchers.Default

```
@Test fun `test onButtonClicked`() = runBlocking {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3_000)
    testArticles
  }

  viewModel.onButtonClicked()

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

expected: [Article(id=T001, ...
but was : null

Use Case 2: The test triggers new coroutines and/or we care about delays

```
class MyViewModel(val apiService:ApiService) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())
  fun onButtonClicked() {
     scope.launch {
       loadData()
     }
  }
```

```
@Test fun `test onButtonClicked`() = runBlocking {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000)
    testArticles
  }

  viewModel.onButtonClicked()

  delay(3000)

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

takes time; unreliable

passes

`runBlockingTest` to the rescue?

To test suspend functions or coroutines started with `launch` or `async` use the `runBlockingTest` that provides extra test control to coroutines.

- *Eager execution* of `launch` or `async` code blocks
- *Explicit time control* for testing multiple coroutines
- *Auto-advancing* of time for suspend functions
- *Pause*, manually *advance*, and *resume* the execution of coroutines in a test
- *Report uncaught exceptions* as test failures

Caution!

- `runBlockingTest` is experimental, and currently has *a bug that makes it fail the test if a coroutine switches to a dispatcher that executes a coroutine on another thread*.
- As of `kotlinx.coroutines.test` 1.6.0, it is *deprecated*.

`runTest` to the rescue?

To test suspend functions or coroutines started with `launch` or `async` use the `runTest` that provides extra test control to coroutines.

- *Eager execution* of *top-level* `launch` or `async` code blocks if used with `UnconfinedTestDispatcher`
  - But, default is `StandardTestDispatcher`
- *Explicit time control* for testing multiple coroutines
- *Auto-advancing* of time for suspend functions
- ~~*Pause*~~, manually *advance*, ~~and *resume*~~ the execution of coroutines in a test
- ~~*Report uncaught exceptions* as test failures~~
  - **Rethrows the first uncaught exception** as test failures <= same as `runBlocking`
  - Manal capture is possible if needed

Auto-advance time

```
coEvery { apiService.getArticles() } coAnswers {
    delay(3000)
  testArticles
}
```

```
@Test
fun `test loadData`() = runBlocking {
  val duration = measureTimeMillis {
    viewModel.loadData()
    viewModel.articles.getValueForTest()
  }
  println("time elapsed = $duration")
}
```

```
@Test
fun `test loadData`() = runTest {
  val duration = measureTimeMillis {
    viewModel.loadData()
    viewModel.articles.getValueForTest()
  }
  println("time elapsed = $duration")
}
```

time elapsed = 3044

time elapsed = 69

Use Case 2: The test triggers new coroutines and/or we care about delays

```
class MyViewModel(val apiService:ApiService) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())
  fun onButtonClicked() {
     scope.launch {
       loadData()
     }
  }
```

Dispatchers.Default

```
@Test fun `test onButtonClicked`() = runTest {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000)
    testArticles
  }

  viewModel.onButtonClicked()

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

expected: [Article(id=T001, ...
but was : null

Use Case 2: The test triggers new coroutines and/or we care about delays

```
class MyViewModel(val apiService:ApiService) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())
  fun onButtonClicked() {
     scope.launch {
       loadData()
     }
  }
```

Dispatchers.Default

```
@Test fun `test onButtonClicked`() = runTest {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000)
    testArticles
  }

  viewModel.onButtonClicked()

  delay(3000)  // will this help?

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

expected: [Article(id=T001, ...
but was : null

Inject CoroutineDispatcher for Testing

```
class ArticleViewModel(
    val apiService: ApiService
) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())

  fun onButtonClicked() {
    scope.launch {
      loadData()
    }
  }
```

```
class ArticleViewModel(
    val apiService: ApiService,
    val dispatcher: CoroutineDispatcher
) : ViewModel() {
  val scope = CoroutineScope(SupervisorJob())

  fun onButtonClicked() {
    scope.launch(dispatcher) {
      loadData()
    }
  }
```


Solution (runTest)

```
@Test fun `test onButtonClicked`() = runTest {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000); testArticles
  }
  val testDispatcher =
      coroutineContext[ContinuationInterceptor] as TestDispatcher
  viewModel = ArticleViewModel(apiService, testDispatcher)

  viewModel.onButtonClicked()
  advanceTimeBy(3000); runCurrent()

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

```
fun onButtonClicked() {
    scope.launch(dispatcher) {
      loadData()
    }
  }
```

passes

Solution (runTest)

```
@Test fun `test onButtonClicked`() = runTest {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000); testArticles
  }
  val testDispatcher =
      coroutineContext[ContinuationInterceptor] as TestDispatcher
  viewModel = ArticleViewModel(apiService, testDispatcher)

  viewModel.onButtonClicked()
  advanceUntilIdle() // this is also OK

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

```
fun onButtonClicked() {
    scope.launch(dispatcher) {
      loadData()
    }
  }
```

passes

More Realistic Demo for Timing Control

```
class ArticleViewModel(apiService…, dispatcher…): ViewModel() {
  fun onButtonClicked() {
      _articles.value = Resource.Loading
      scope.launch(dispatcher) {
         loadData() // Let's inline this method call for illustration purpose
      }
  }
  suspend fun loadData() {
      _articles.value = networkRequest()
  }
  suspend fun networkRequest(): Resource<List<Article>> {
      return apiService.getArticles()
  }
}
```

```
sealed class Resource<out R> {
    data class Success<out T>(val data: T?): Resource<T>()
    data class Error(val message: String?): Resource<Nothing>()
    object Loading : Resource<Nothing>() }
```

More Realistic Demo for Timing Control

```
class ArticleViewModel(apiService…, dispatcher…): ViewModel() {
  fun onButtonClicked() {
    _articles.value = Resource.Loading
    scope.launch(dispatcher) {
        _articles.value = apiService.getArticles()
    }
  }
}
```

How to test the value of the livedata _*articles*
when `onButtonClicked()` is called?


```
fun onButtonClicked() {
  _articles.value = Resource.Loading
  scope.launch(dispatcher) {
    _articles.value = apiService.getArticles()
  }
}
```

```
@Test
fun `realistic test example`() = runTest {
    // Given
    coEvery { apiService.getArticles() } coAnswers {
        delay(3000)
        Resource.Success(testArticles)
    }

    val testDispatcher =
    coroutineContext[ContinuationInterceptor] as TestDispatcher

    viewModel = ArticleViewModel(apiService, testDispatcher)

    // When
    viewModel.onButtonClicked()

    var articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Loading)

    advanceTimeBy(3000); runCurrent()

    // Then
    articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Success(testArticles))
}
```

```
fun onButtonClicked() {
  _articles.value = Resource.Loading
  scope.launch(dispatcher) {
    _articles.value = apiService.getArticles()
  }
}
```

```
@Test
fun `realistic test example`() = runTest {
    // Given
    coEvery { apiService.getArticles() } coAnswers {
        delay(3000)
        Resource.Success(testArticles)
    }

    val testDispatcher =
    coroutineContext[ContinuationInterceptor] as TestDispatcher

    viewModel = ArticleViewModel(apiService, testDispatcher)

    // When
    viewModel.onButtonClicked()

    var articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Loading)

    advanceTimeBy(3000); runCurrent()

    // Then
    articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Success(testArticles))
}
```



```
fun onButtonClicked() {
  _articles.value = Resource.Loading
  scope.launch(dispatcher) {
    _articles.value = apiService.getArticles()
  }
}
```

```
@Test
fun `realistic test example`() = runTest {
    // Given
    coEvery { apiService.getArticles() } coAnswers {
        delay(3000)
        Resource.Success(testArticles)
    }

    val testDispatcher =
    coroutineContext[ContinuationInterceptor] as? TestDispatcher

    viewModel = ArticleViewModel(apiService, testDispatcher)

    // When
    viewModel.onButtonClicked()

    var articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Loading)

    advanceTimeBy(3000); runCurrent()

    // Then
    articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Success(testArticles))
}
```

```
fun onButtonClicked() {
  _articles.value = Resource.Loading
  scope.launch(dispatcher) {
    _articles.value = apiService.getArticles()
  }
}
```

```
@Test
fun `realistic test example`() = runTest {
    // Given
    coEvery { apiService.getArticles() } coAnswers {
        delay(3000)
        Resource.Success(testArticles)
    }

    val testDispatcher =
    coroutineContext[ContinuationInterceptor] as TestDispatcher

    viewModel = ArticleViewModel(apiService, testDispatcher)

    // When
    viewModel.onButtonClicked()

    var articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Loading)

    advanceTimeBy(3000); runCurrent()

    // Then
    articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Success(testArticles))
}
```



```
fun onButtonClicked() {
  _articles.value = Resource.Loading
  scope.launch(dispatcher) {
    _articles.value = apiService.getArticles()
  }
}
```

```
@Test
fun `realistic test example`() = runTest {
    // Given
    coEvery { apiService.getArticles() } coAnswers {
        delay(3000)
        Resource.Success(testArticles)
    }

    val testDispatcher =
    coroutineContext[ContinuationInterceptor] as TestDispatcher

    viewModel = ArticleViewModel(apiService, testDispatcher)

    // When
    viewModel.onButtonClicked()

    var articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Loading)

    advanceTimeBy(3000); runCurrent()

    // Then
    articles = viewModel.articles.getValueForTest()
    assertThat(articles).isEqualTo(Resource.Success(testArticles))
}
```

Review on `runTest`

- `runTest` relies on `TestDispatcher` and `TestScope`.
- When `runTest` calls a suspend function or launches a new coroutine, it *executes it immediately* if `UnconfinedTestDispatcher` is used.
  - This has the effect of making the coroutines single threaded and offers the ability to explicitly control all coroutines in tests.
- `TestDispatcher` implements a virtual time and gives you fine grained control on it.
  - control its virtual clock.

Important!!

- The function `runTest` will always block the caller, just like a regular function call. The coroutine will *run synchronously on the same thread*.
- You should avoid `runBlocking` and `runTest` in your application code and prefer `launch` which returns immediately.
- `runTest` should only be used from tests as it executes coroutines in a test-controlled manner.
- `runBlocking` can be used to provide blocking interfaces to coroutines.

Scopes in ViewModels

- A CoroutineScope keeps track of all coroutines it creates.
- Cancelling a scope cancels all coroutines it created
  - ***structured concurrency***
- If your ViewModel is getting destroyed, all the asynchronous work that it might be doing must be stopped. Otherwise, you'll waste resources and potentially leaking memory.
- **If you consider that certain asynchronous work should persist after ViewModel destruction, it is because it should be done in a lower layer of your app's architecture.**

viewModelScope

- `viewModelScope` is provided as an *extension property* of the `ViewModel` class.
- This scope is bound to `Dispatchers.Main` and will automatically be cancelled when the `ViewModel` is cleared.

```
val ViewModel.viewModelScope: CoroutineScope
  get() {
    …
    CloseableCoroutineScope(SupervisorJob() + Dispatchers.Main.immediate)
    …
  }
```

```
dependencies {
  implementation "androidx.lifecycle:lifecycle-viewmodel-ktx:$version"
}
```

Using viewModelScope

```
class ArticleViewModel(
    val apiService: ApiService
) : ViewModel() {
  val scope =
    CoroutineScope(SupervisorJob())

  fun onButtonClicked() {
    scope.launch {
      loadData()
    }
  }

  override fun onCleared() {
    super.onCleared()
    scope.cancel()
  }
```

Dispatchers.Default

```
class ArticleViewModel(
    val apiService: ApiService
) : ViewModel() {

  fun onButtonClicked() {
    viewModelScope.launch {
      loadData()
    }
  }
```

Dispatchers.Main

Will this work?

```
class ArticleViewModel(
    val apiService: ApiService
) : ViewModel() {

  fun onButtonClicked() {
    viewModelScope.launch {
      loadData()
    }
  }
```

Dispatchers.Main

java.lang.IllegalStateException:
Module with the Main dispatcher had failed to initialize.

```
@Test fun `test onButtonClicked`() = runTest {
  coEvery { apiService.getArticles() } coAnswers {
    delay(3000)
    testArticles
  }

  viewModel.onButtonClicked()
  advanceUntilIdle()

  val articles = viewModel.articles.getValueForTest()
  assertThat(articles).isEqualTo(testArticles)
}
```

`Dispatchers.Main` uses `Looper.getMainLooper()` to run code in the UI thread, which is available in Instrumented tests but **not** in Unit tests.

Dispatchers.Main Delegation

- `Dispatchers.setMain` will override the `Main` dispatcher in test situations:
  - To execute a test in situations where the platform `Main` dispatcher is not available, or
  - To replace `Dispatchers.Main` with a testing dispatcher.
- Once you have this dependency in the runtime, `ServiceLoader` mechanism will overwrite `Dispatchers.Main` with a testable implementation.

Unit Testing viewModelScope

- `viewModelScope` uses the `Dispathers.Main`.
- *Replace the main dispatcher* by calling `Dispatchers.setMain(dispatcher: CoroutineDispatcher)` with a `TestDispatcher`.*
- *Should call* `Dispatchers.resetMain()` when the test finishes running, to ensure that a unit test run in isolation and without any side effects.

**Note that `Dispatchers.setMain` is only needed if you use `viewModelScope` or you hardcode `Dispatchers.Main` in your codebase.*

Replace Dispatchers.Main with TestDispatcher

```
val testDispatcher = StandardTestDispatcher()

@Before
fun init() {
    Dispatchers.setMain(testDispatcher)
    viewModel = ArticleViewModel(apiService)
}

@After
fun teardown() {
    Dispatchers.resetMain()
}

@Test
fun `test`() = runTest {
    ...
}
```


Dispatchers should be injected into your ViewModels so you can properly test. Passing the Dispatcher via the constructor would make sure that your test and production code use the same dispatcher.

Custom JUnit4 Rule for runTest

```
class CoroutineRule(
    val testDispatcher: TestDispatcher = StandardTestDispatcher()
) : TestWatcher() {

    override fun starting(description: Description?) {
        super.starting(description)

        Dispatchers.setMain(testDispatcher)
    }

    override fun finished(description: Description?) {
        super.finished(description)

        Dispatchers.resetMain()
    }
}
```


Recommended Way to Use Coroutines in Android

- On Android, you can use a scope to cancel all running coroutines when, for example, the user navigates away from an **Activity** or **Fragment**.
- For coroutines started by the UI, it is typically correct to start them on `Dispatchers.Main` (main thread on Android).
- A coroutine started on `Dispatchers.Main` shouldn't block the main thread while suspended.
- Since a `ViewModel` coroutine almost always updates the UI on the main thread, starting coroutines on the main thread saves you extra thread switches.
- A coroutine started on the `Main` thread can switch dispatchers any time after it's started.
  - Ex) it can use another dispatcher to parse a large JSON result off the main thread.

Calling heavy-lifting suspend function from coroutines

```
suspend fun <T> withContext(
    context: CoroutineContext,
    block: suspend CoroutineScope.() -> T
): T
```

- To switch between any dispatcher, use `withContext`.
  - Calling `withContext` switches to the other dispatcher just for the lambda then comes back to the dispatcher that called it with the result of that lambda.
- By default, Kotlin coroutines provides three Dispatchers: `Main`, `IO`, and `Default`.
  - The IO dispatcher is optimized for IO work like reading from the network or disk, while the Default dispatcher is optimized for CPU intensive tasks.

Calling heavy-lifting suspend function from coroutines

```
class ArticleViewModel(
    val apiService: ApiService,
    val dispatchers: DispatcherProvider = DefaultDispatcherProvider()
) : ViewModel() {
    fun onButtonClicked() {
        viewModelScope.launch {
            loadData()
        }
    }
    suspend fun loadData() {
        val articles = networkRequest()
        show(articles)
    }
    suspend fun networkRequest(): List<Article> {
        return withContext(dispatchers.io) {
            apiService.getArticles()
        }
    }
    private fun show(articles: List<Article>) { … }
}
```

Main-safety

```
interface DispatcherProvider {
    val main: CoroutineDispatcher
    val mainImmediate: CoroutineDispatcher
    val default: CoroutineDispatcher
    val io: CoroutineDispatcher
}
```

```
class DefaultDispatcherProvider(
  override val main: CoroutineDispatcher = Dispatchers.Main,
  override val mainImmediate: CoroutineDispatcher = Dispatchers.Main.immediate,
  override val default: CoroutineDispatcher = Dispatchers.Default,
  override val io: CoroutineDispatcher = Dispatchers.IO,
) : DispatcherProvider
```


Suspend functions should guarantee **main-safety**

- It's a good idea to start UI-related coroutines on the Main thread.
- By convention, you should ***ensure that suspend functions are main-safe***.
- Then it is safe to call them from any dispatcher, even Dispatchers.Main.

```
suspend fun networkRequest(): List<Article> {
  return withContext(dispatchers.io) {
    apiService.getArticles()
  }
}
```

- You do not need to use withContext to call main-safe suspending functions.

*Libraries like **Room** and **Retrofit** offer **main-safety** out of the box.*

Write a timeout test

```
interface Api {
    suspend fun fetch(): String
}

class SuspendingFakeApi : Api {
    val deferred = CompletableDeferred<String>()

    override suspend fun fetch(): String {
        return deferred.await() // wait forever ...
    }
}

suspend fun loadData(api: Api): String {
    return withTimeout(5_000) {
        api.fetch()
    }
}
```


Write a timeout test (Cont'd)

```
@Test(expected = TimeoutCancellationException::class)
fun `bad test`() = runTest {
    val api = SuspendingFakeApi()

    println("result = ${loadData(api)}") // always timeout ...
}
```

```
@Test fun `test timeout expired`() = runTest {
    val api = SuspendingFakeApi()

    launch {
        loadData(api)
    }

    advanceTimeBy(5_000); runCurrent()

    api.deferred.complete("Hello")
}
```

Test launches a separate coroutine to call loadData. **This is a key part of testing timeouts**, the timeout should happen in a different coroutine than the one runTest creates. By doing so, we can call the next line, advanceTimeBy(5_000) which will advance time by 5 seconds and cause the other coroutine to timeout.