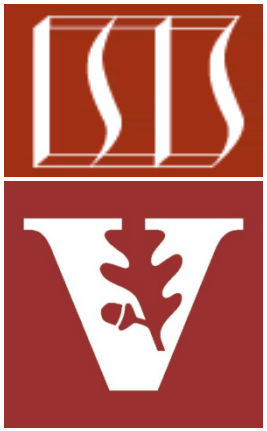
Android Concurrency:
The Half-Sync/Half-Async Pattern (Part 1)



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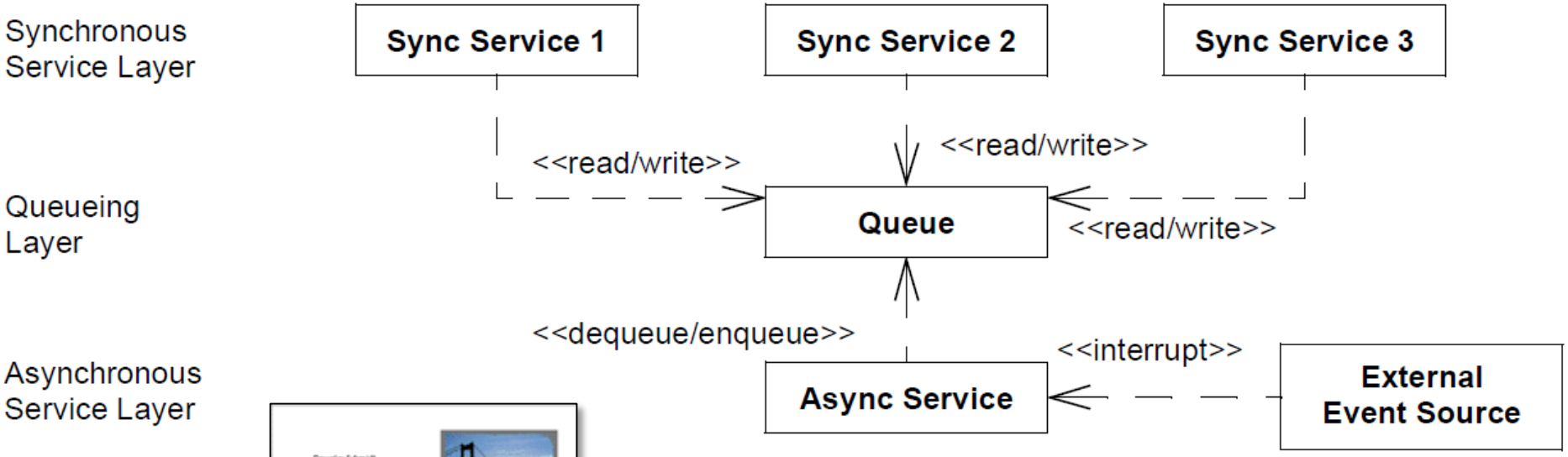
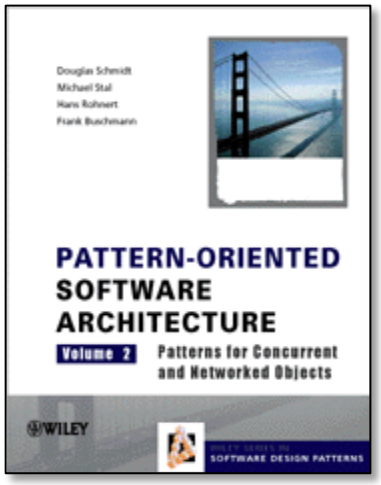
CS 282 Principles of Operating Systems II

Systems Programming for Android

Learning Objectives in this Part of the Module

- Understand the *Half-Sync/Half-Async* pattern

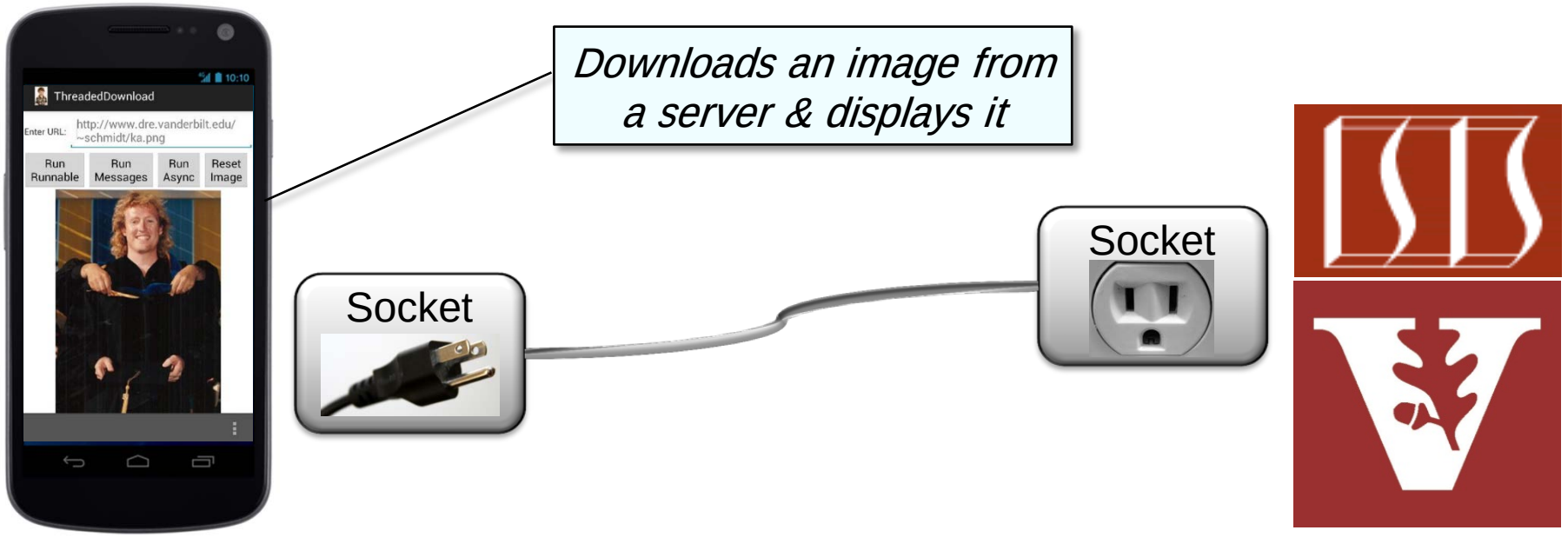




Challenge: Combining Sync & Async Processing

Context

- A concurrent system that performs both asynchronous & synchronous processing services that must communicate
  - The ThreadedDownload app a good example of this context

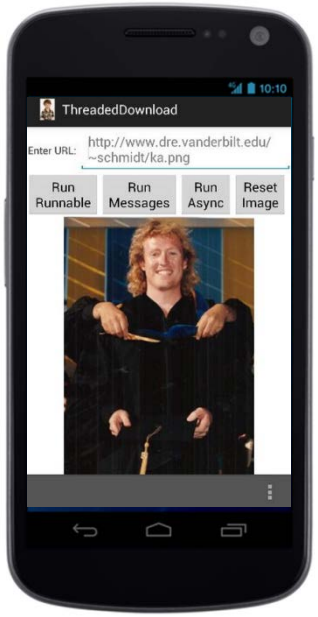


Challenge: Combining Sync & Async Processing

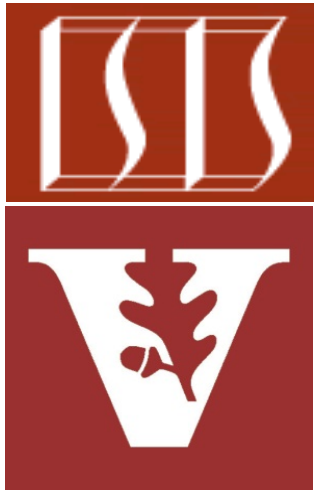
Problems

- Services that want the simplicity of synchronous processing shouldn't need to address the complexities of asynchrony

```
Bitmap downloadBitmap(String url) {
  InputStream is = (InputStream) new URL(url).getContent();
  return BitmapFactory.decodeStream(is);
}
```



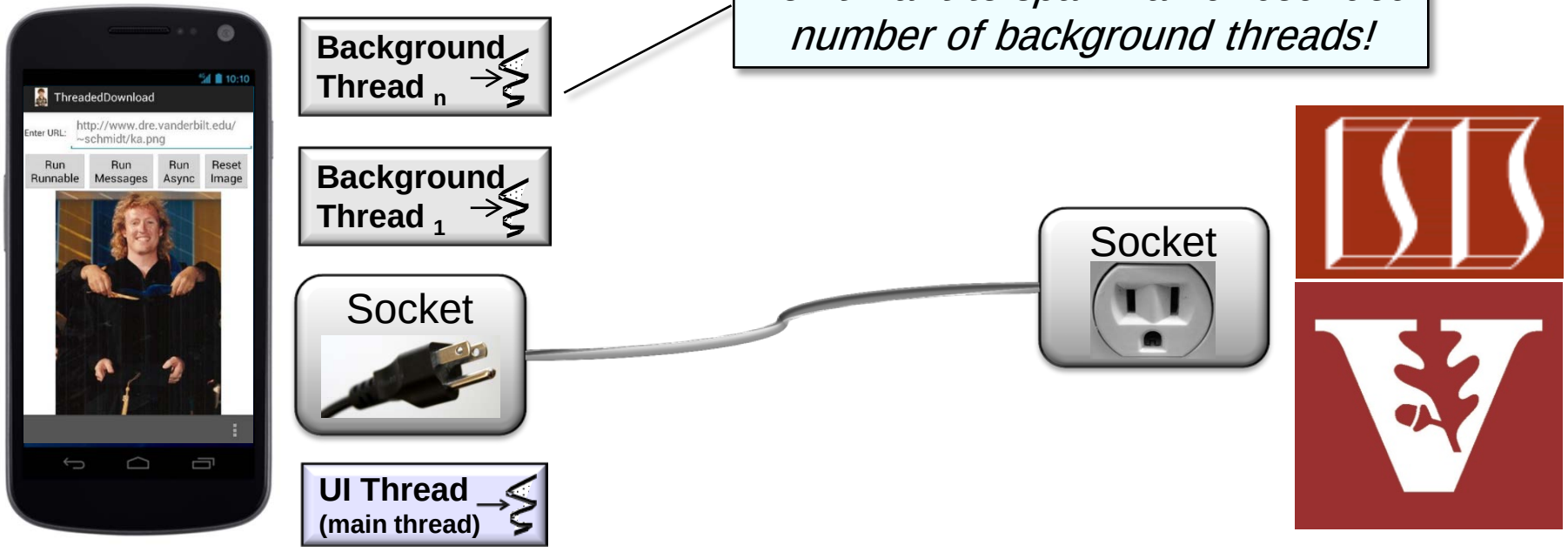
Each thread needs to block independently to prevent a flow-controlled connection from degrading the QoS that other clients receive



Challenge: Combining Sync & Async Processing

Problems

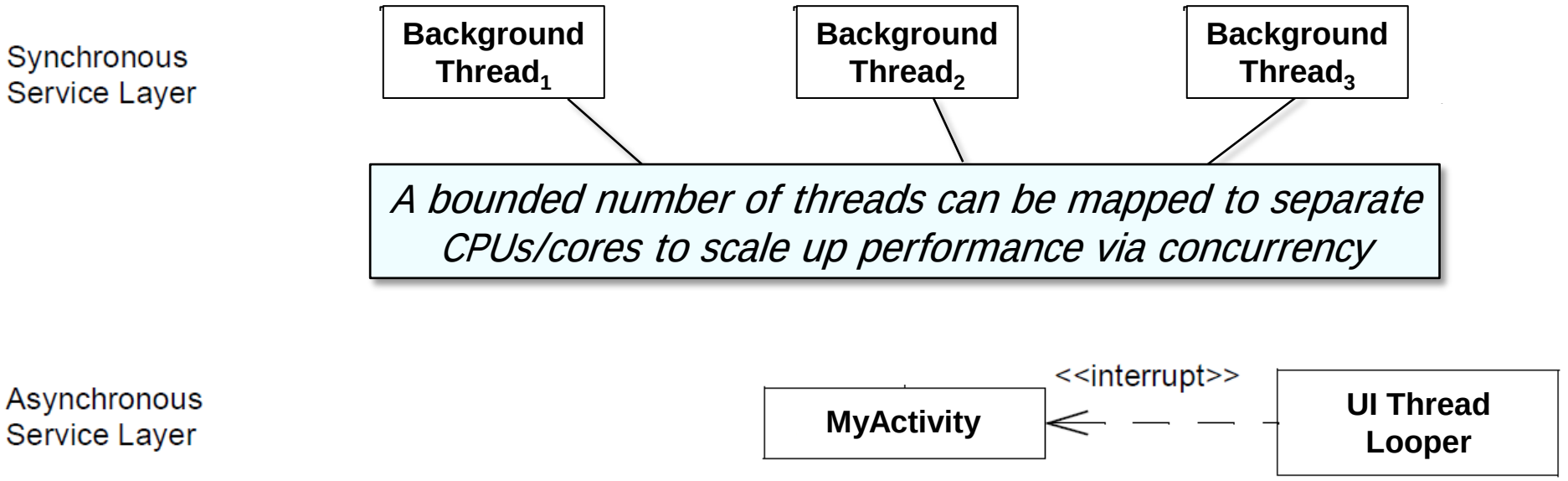
- Services that want the simplicity of synchronous processing shouldn't need to address the complexities of asynchrony
- Synchronous & asynchronous processing services should be able to communicate without complicating their programming model or unduly degrading their performance



Challenge: Combining Sync & Async Processing

Solution

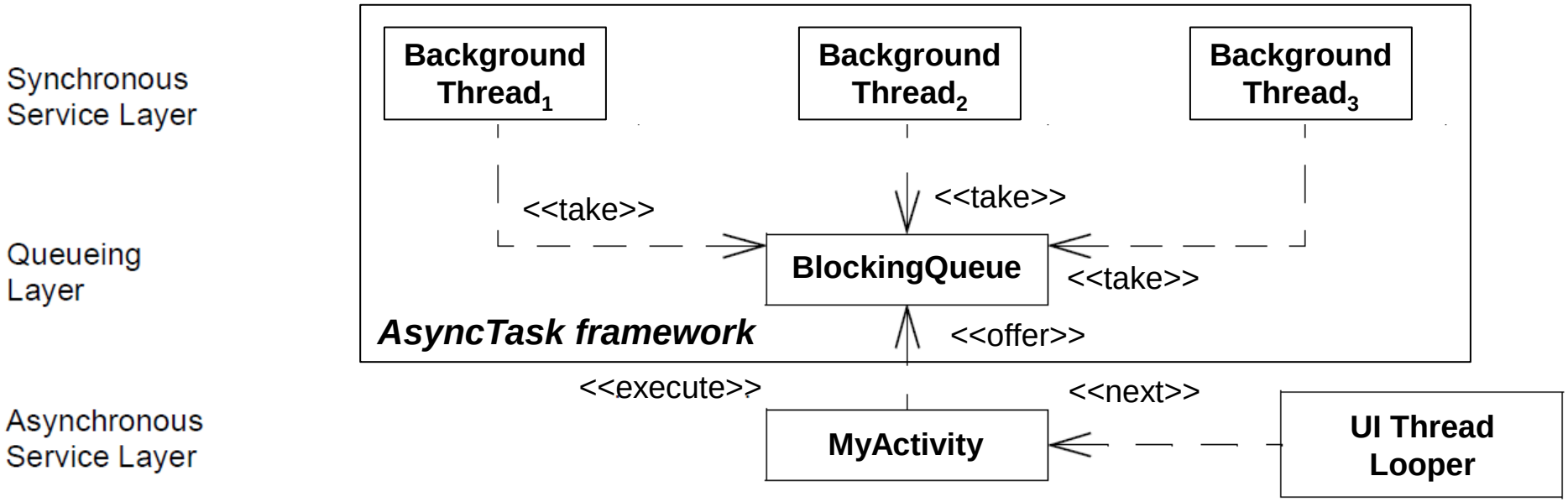
- Decompose the services in the system into two layers: *synchronous* & *asynchronous*



Challenge: Combining Sync & Async Processing

Solution

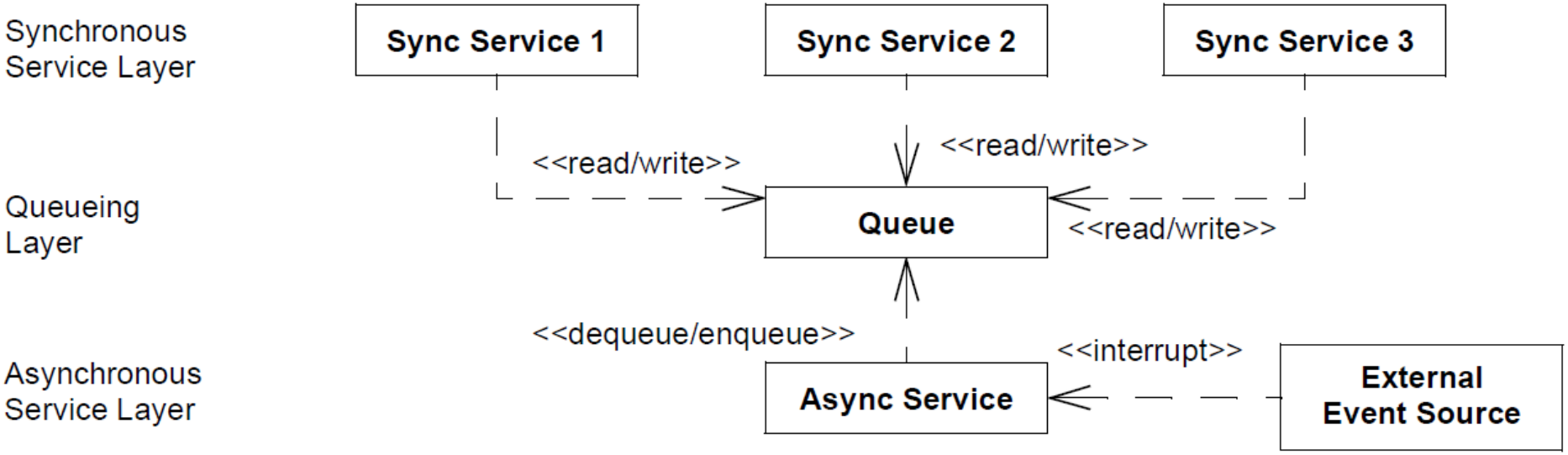
- Decompose the services in the system into two layers: *synchronous* & *asynchronous*
- Add a queueing layer between them to mediate the communication between services in the asynchronous & synchronous layers



Half-Sync/Half-Async POSA2 Concurrency

Intent

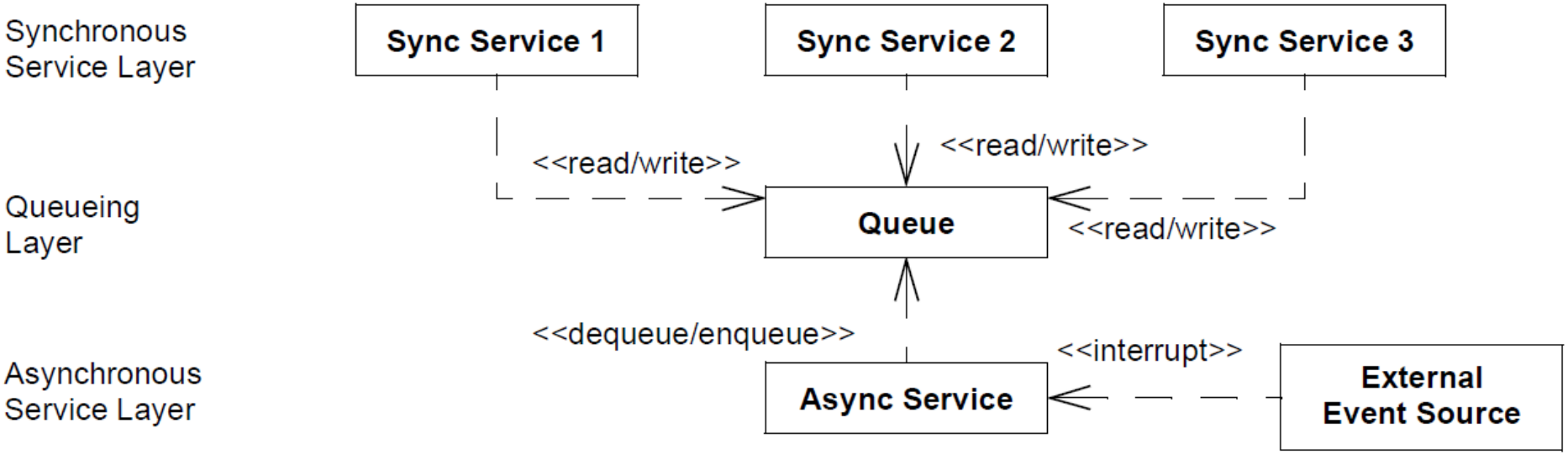
- Decouple asynchronous (async) & synchronous (sync) service processing in concurrent systems by introducing two intercommunicating layers—one for async & one for sync service processing—to simplify programming without unduly reducing performance



Half-Sync/Half-Async POSA2 Concurrency

Applicability

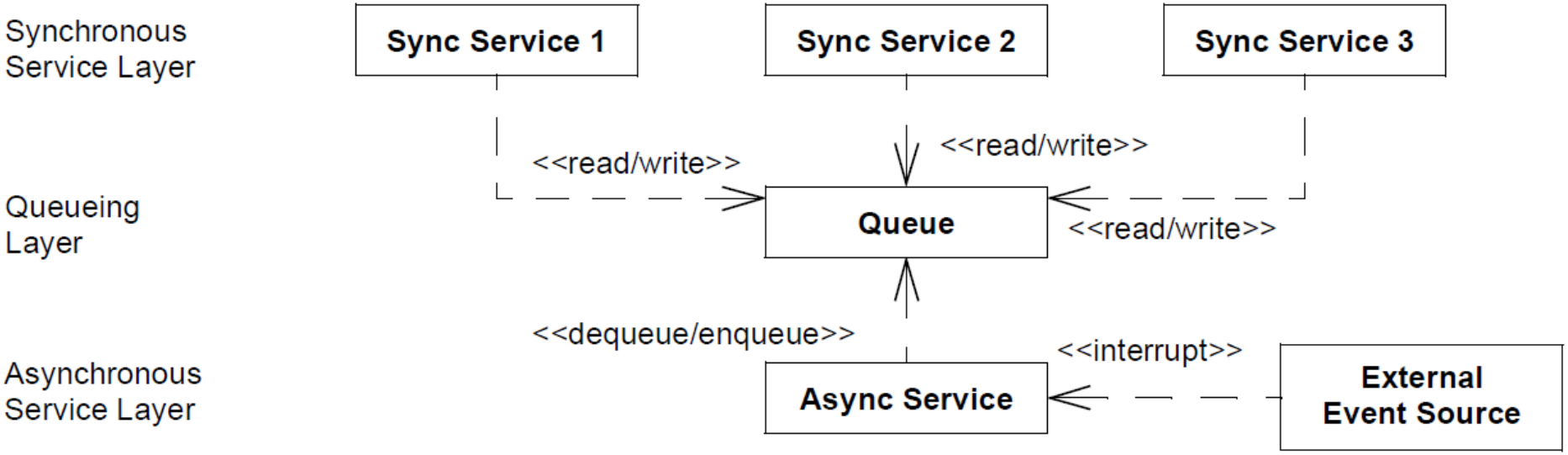
- When it's necessary to make performance efficient & scalable, while also ensuring that the use of concurrency simplifies—rather than complicates—programming



Half-Sync/Half-Async POSA2 Concurrency

Applicability

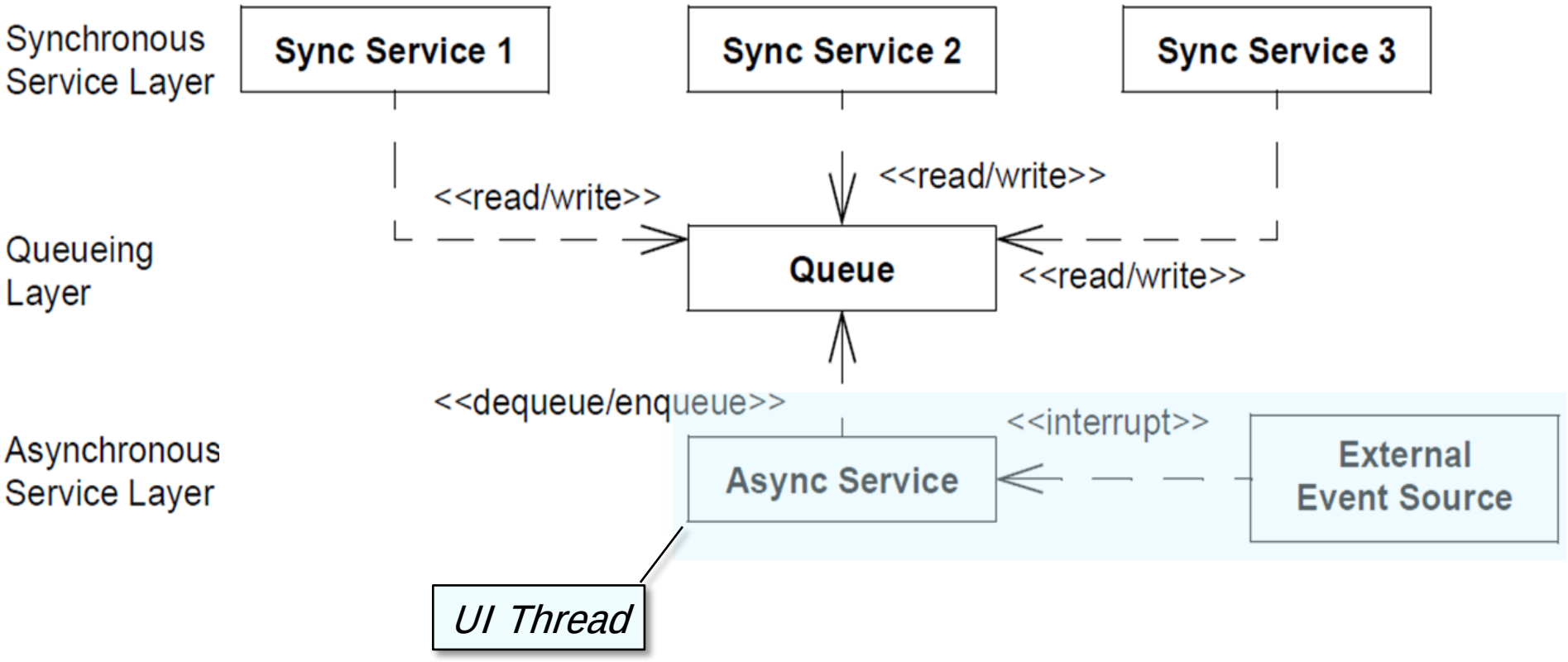
- When it's necessary to make performance efficient & scalable, while also ensuring that the use of concurrency simplifies—rather than complicates—programming
- When there are constraints on certain types of operations in certain contexts
  - e.g., short-duration vs. long-duration, blocking vs. non-blocking, etc.



This pattern is widely applied in operating systems & modern GUI frameworks

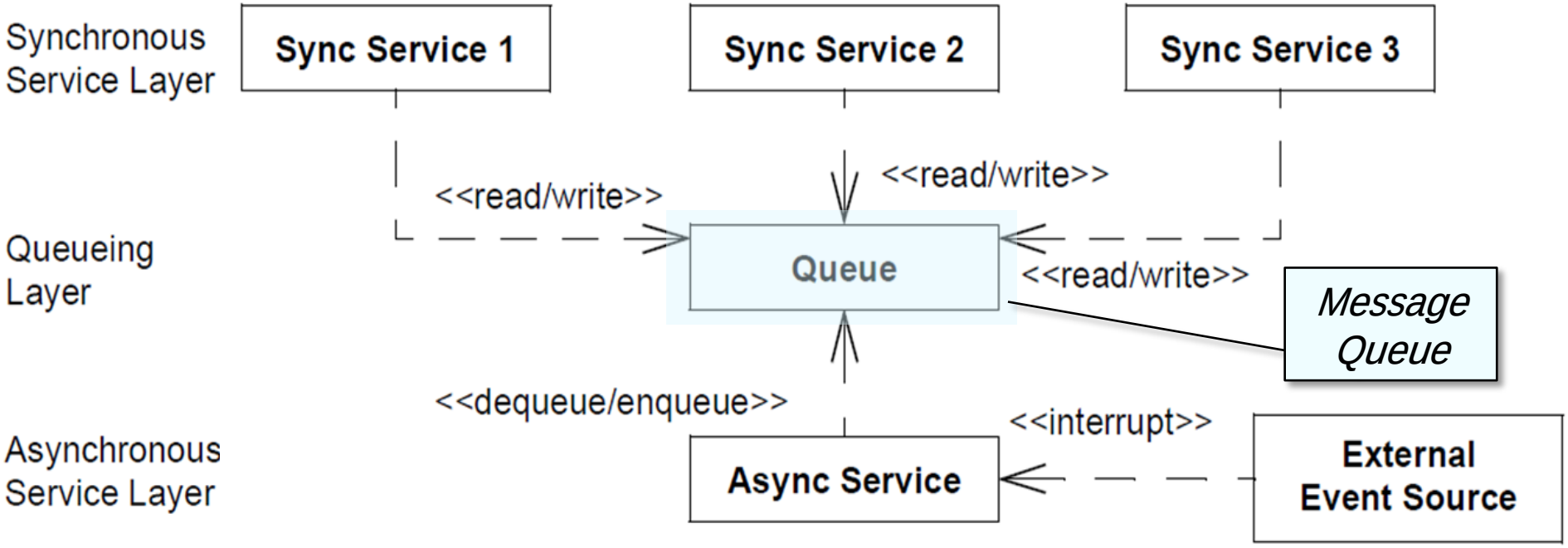
Half-Sync/Half-Async POSA2 Concurrency

Structure & Participants



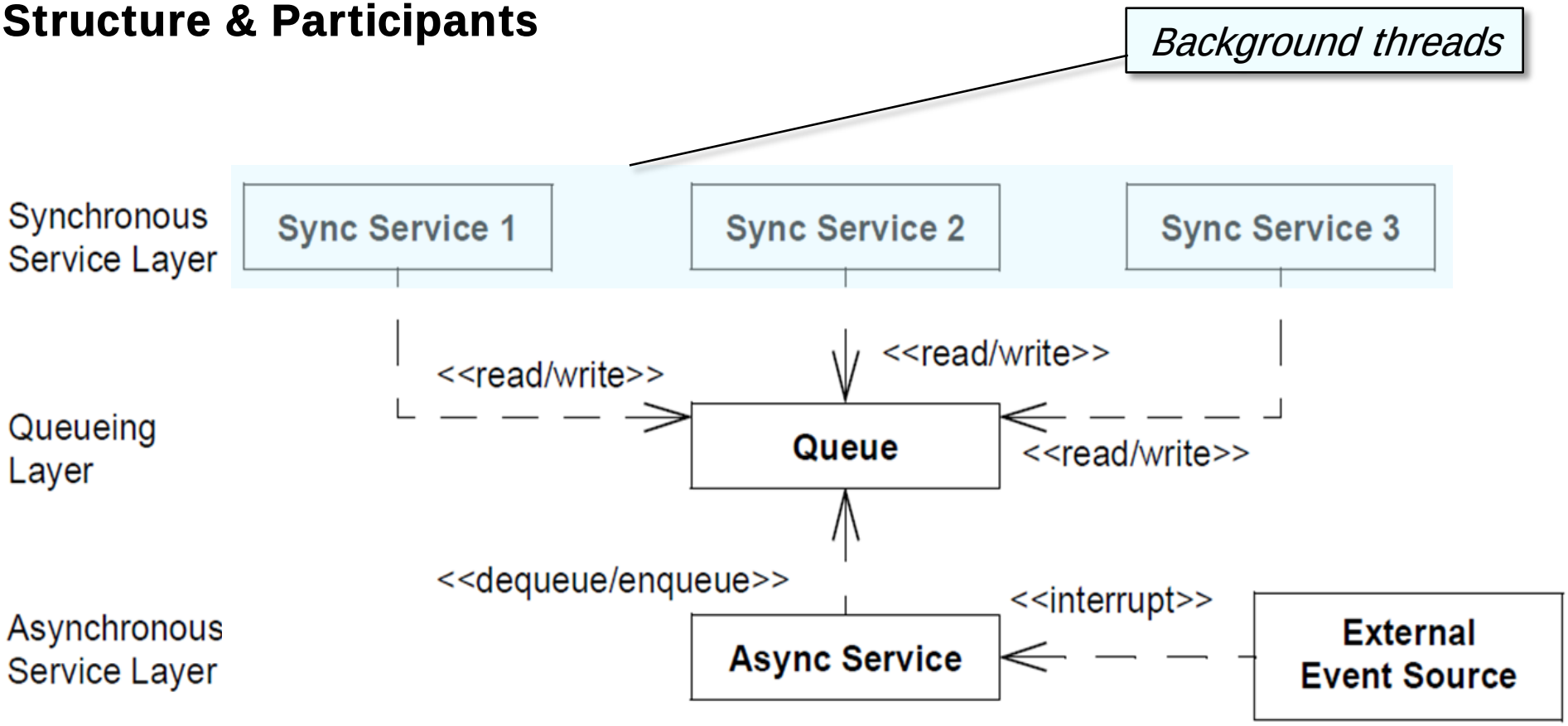
Half-Sync/Half-Async POSA2 Concurrency

Structure & Participants



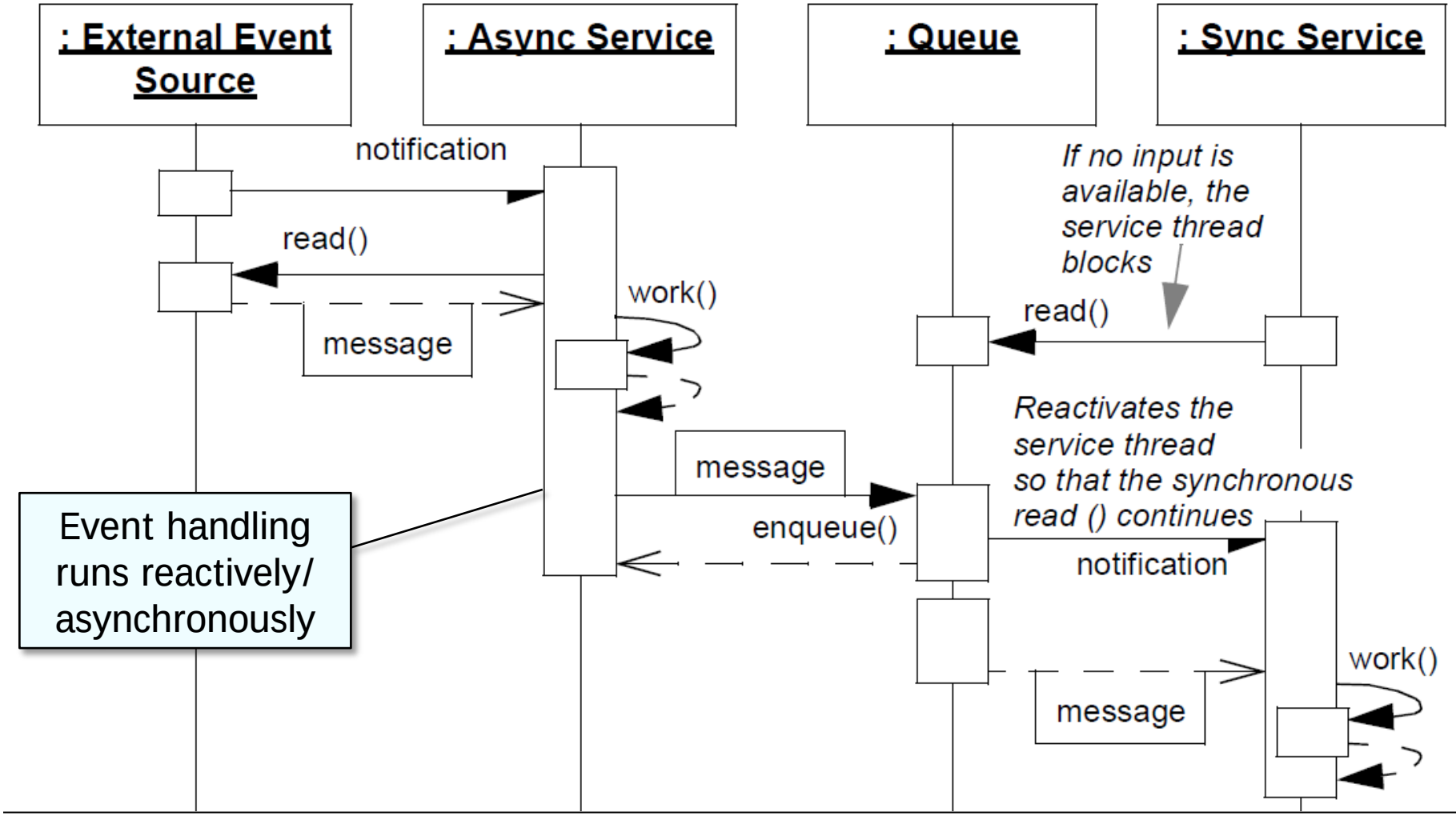
Half-Sync/Half-Async POSA2 Concurrency

Structure & Participants



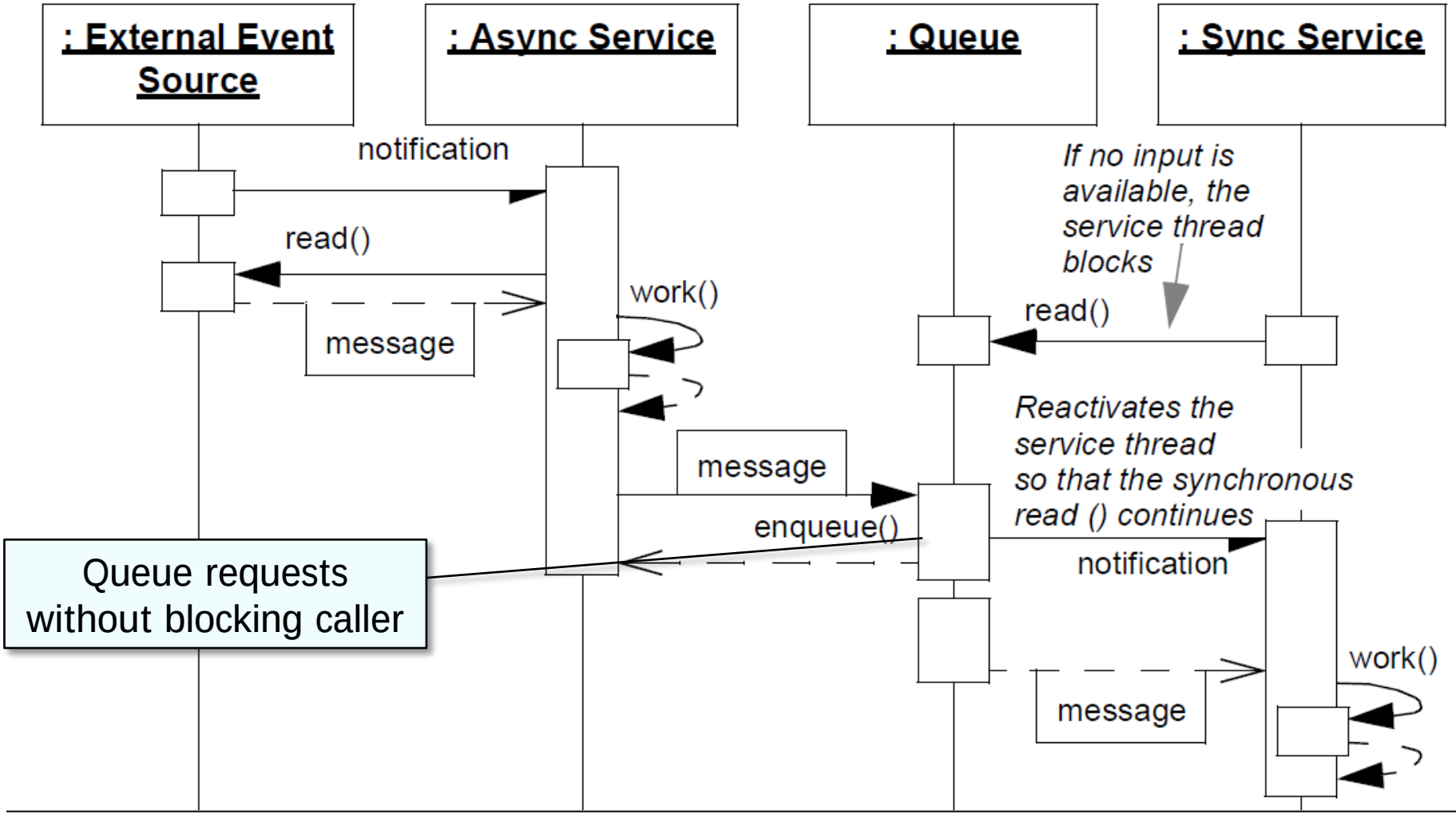
Half-Sync/Half-Async POSA2 Concurrency

Dynamics



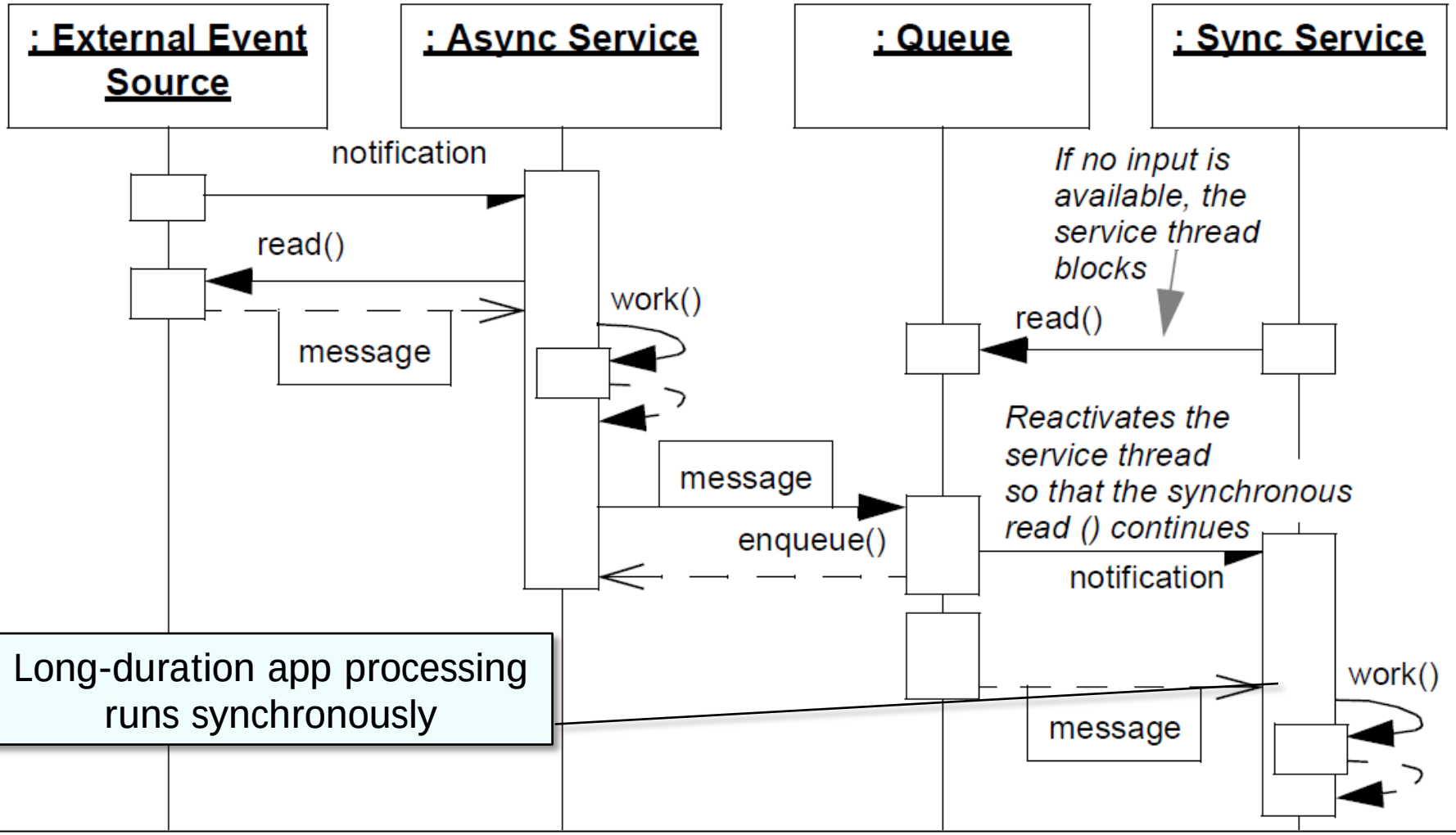
Half-Sync/Half-Async POSA2 Concurrency

Dynamics



Half-Sync/Half-Async POSA2 Concurrency

Dynamics

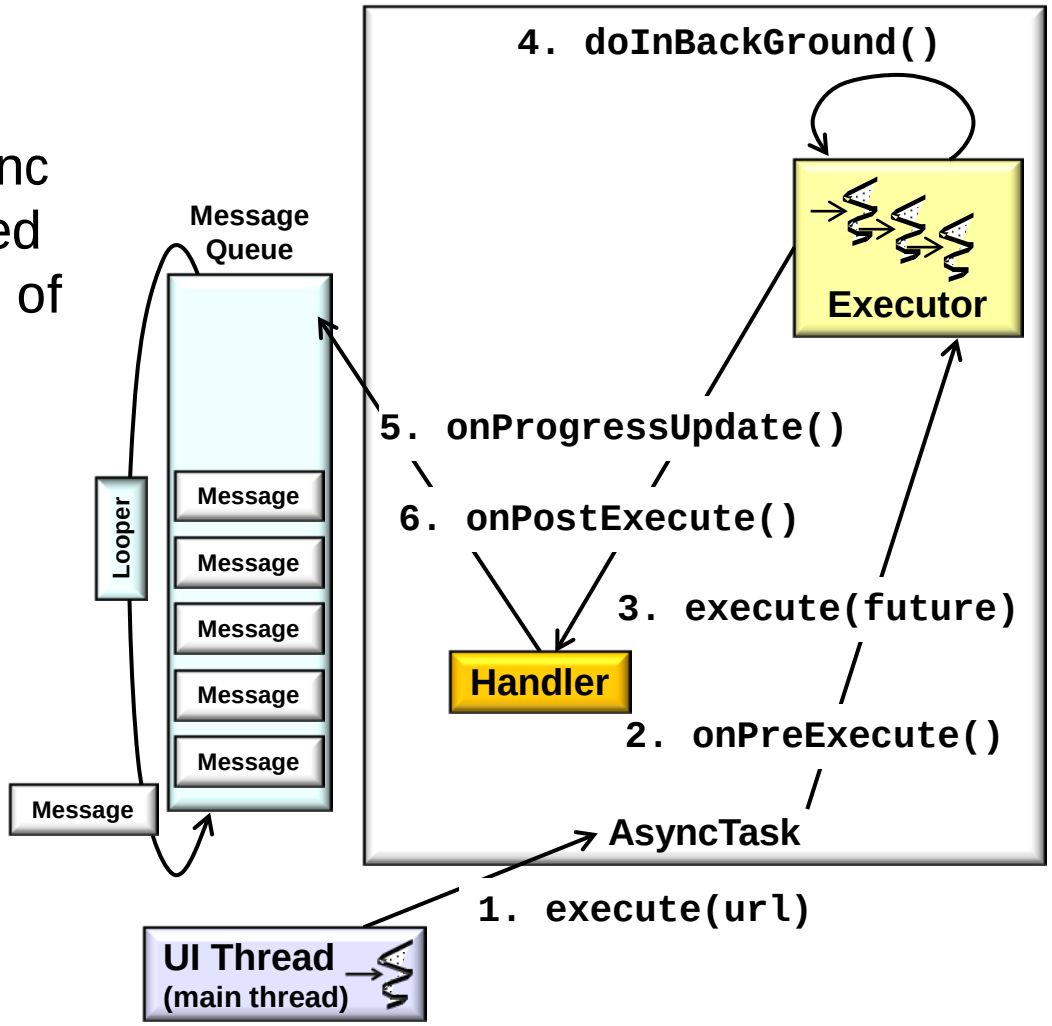


Sync services run concurrently, relative both to each other & to async services

Half-Sync/Half-Async POSA2 Concurrency

Consequences

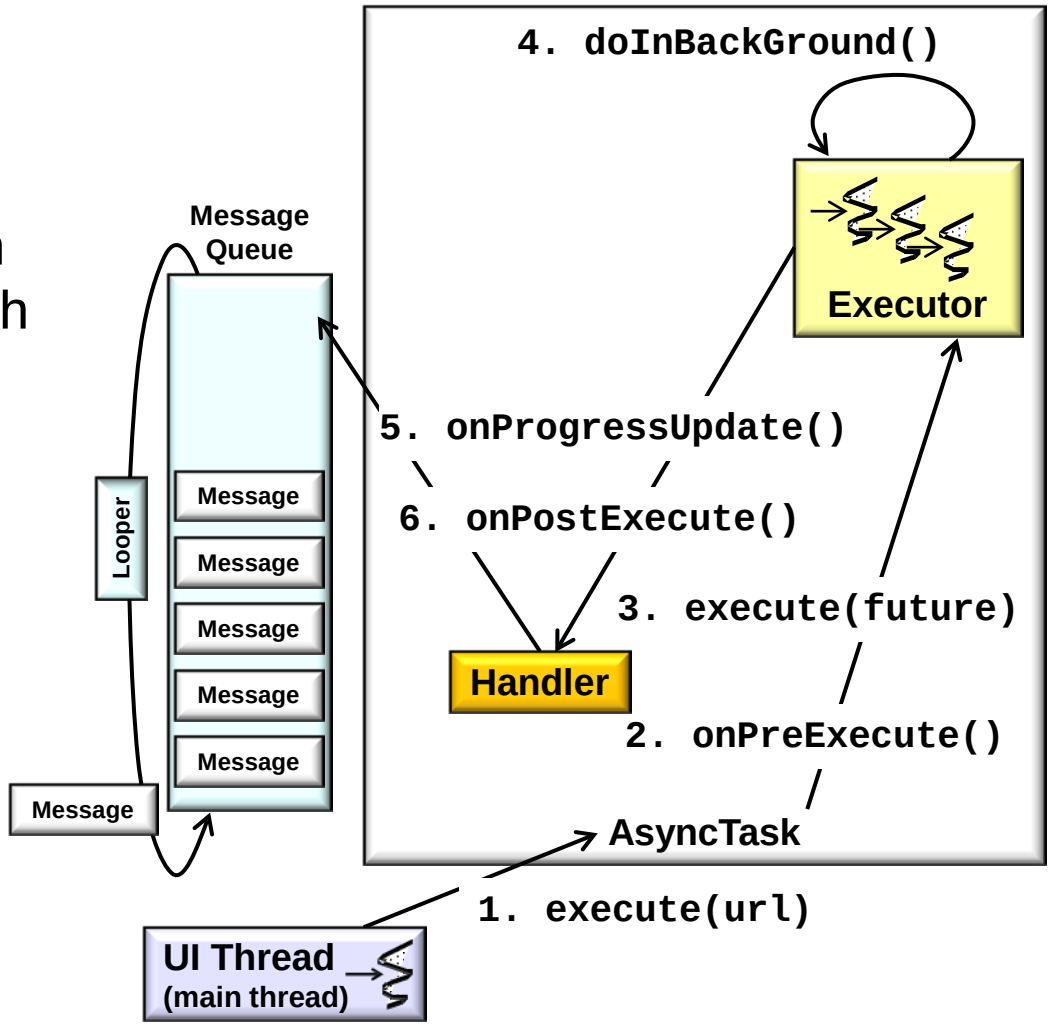
+ Simplification & performance
  - Programming of higher-level sync processing services are simplified without degrading performance of lower-level system services



Half-Sync/Half-Async POSA2 Concurrency

Consequences

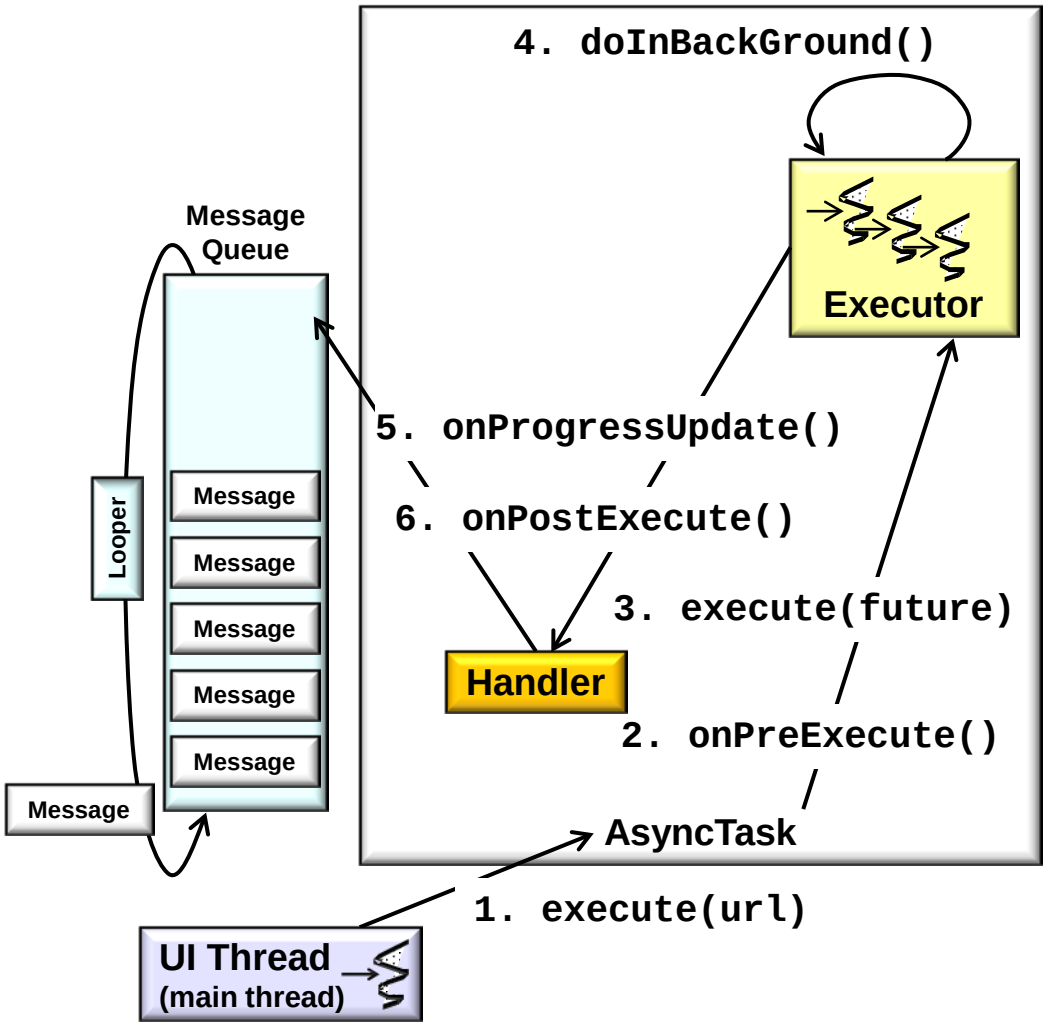
+ Simplification & performance
+ Separation of concerns
  - Synchronization policies in each layer are decoupled so that each layer need not use the same concurrency strategies



Half-Sync/Half-Async POSA2 Concurrency

Consequences

+ Simplification & performance
+ Separation of concerns
+ Centralization of inter-layer communication
  - Inter-layer communication is centralized because all interaction is mediated by the queueing layer

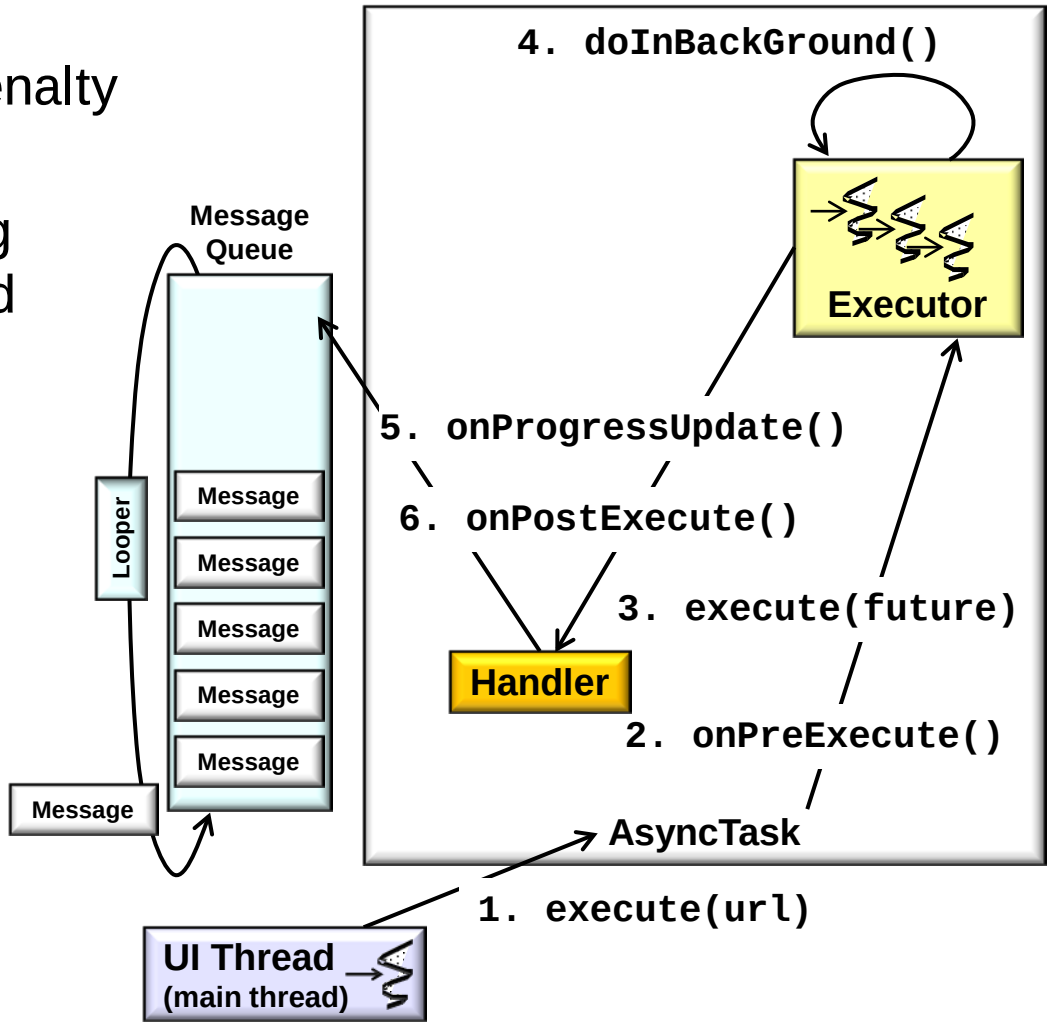


Half-Sync/Half-Async POSA2 Concurrency

Consequences

– May incur a boundary-crossing penalty

- Arising from context switching, synchronization, & data copying overhead when data transferred between sync & async service layers via queueing layer



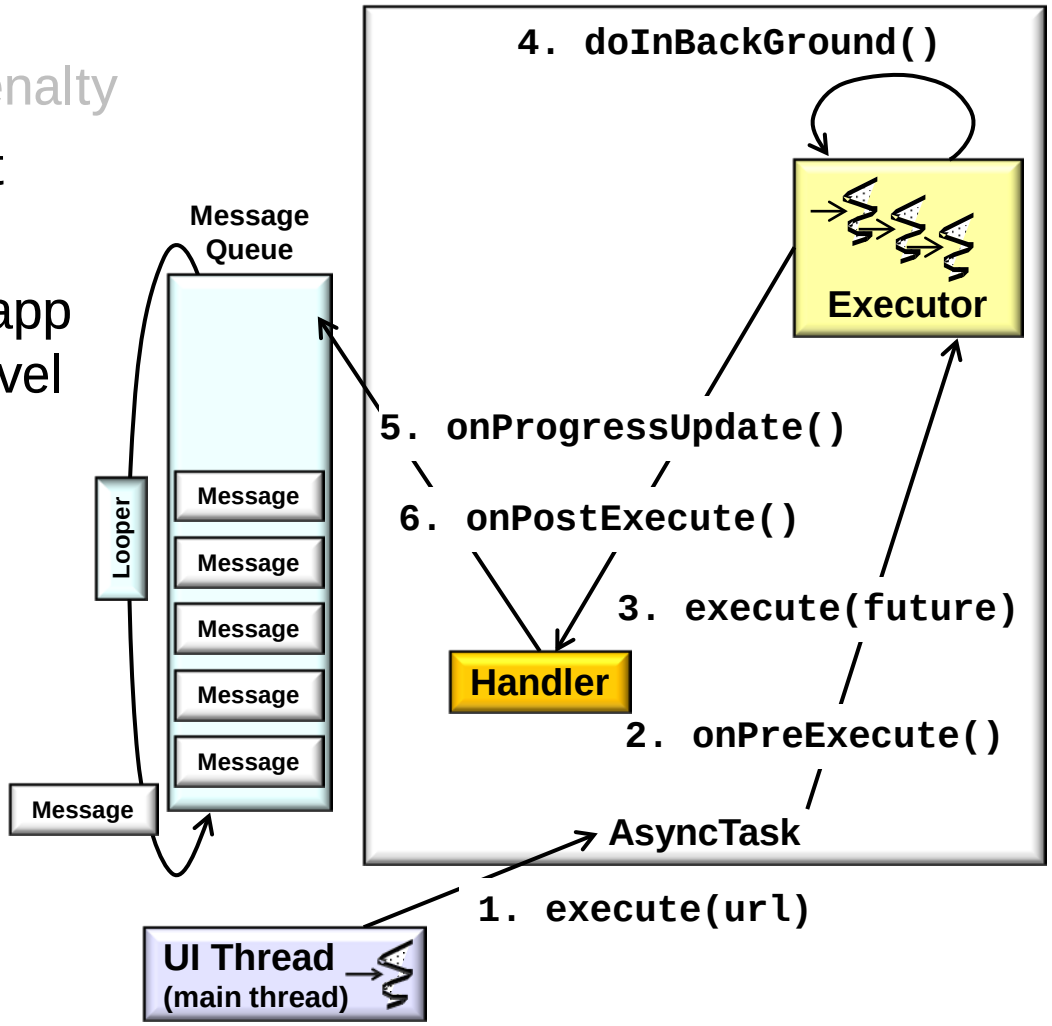
Half-Sync/Half-Async POSA2 Concurrency

Consequences

– May incur a boundary-crossing penalty

– Higher-level app services may not benefit from async I/O

- Depending on design of OS or app framework interfaces, higher-level services may not use low-level async I/O devices effectively



Half-Sync/Half-Async POSA2 Concurrency

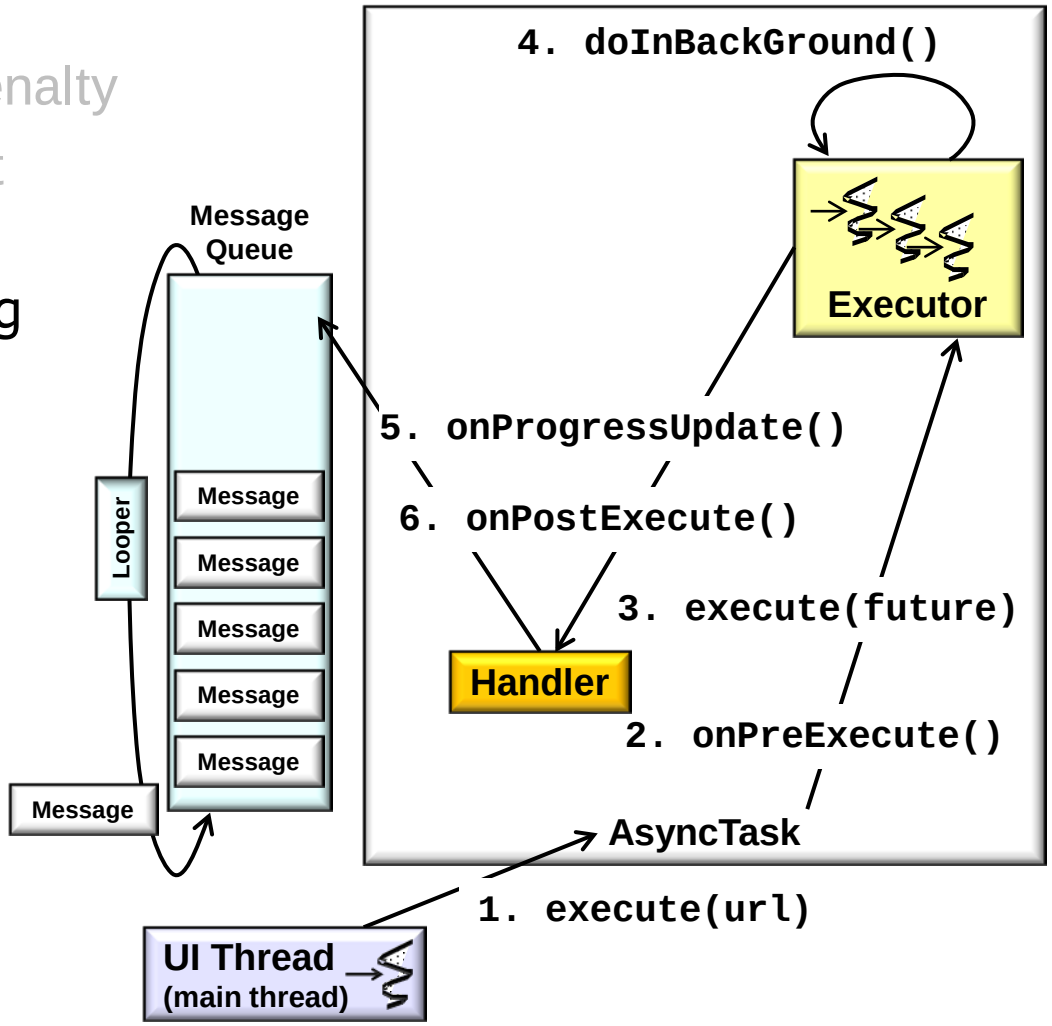
Consequences

– May incur a boundary-crossing penalty

– Higher-level app services may not benefit from async I/O

– Complexity of debugging & testing

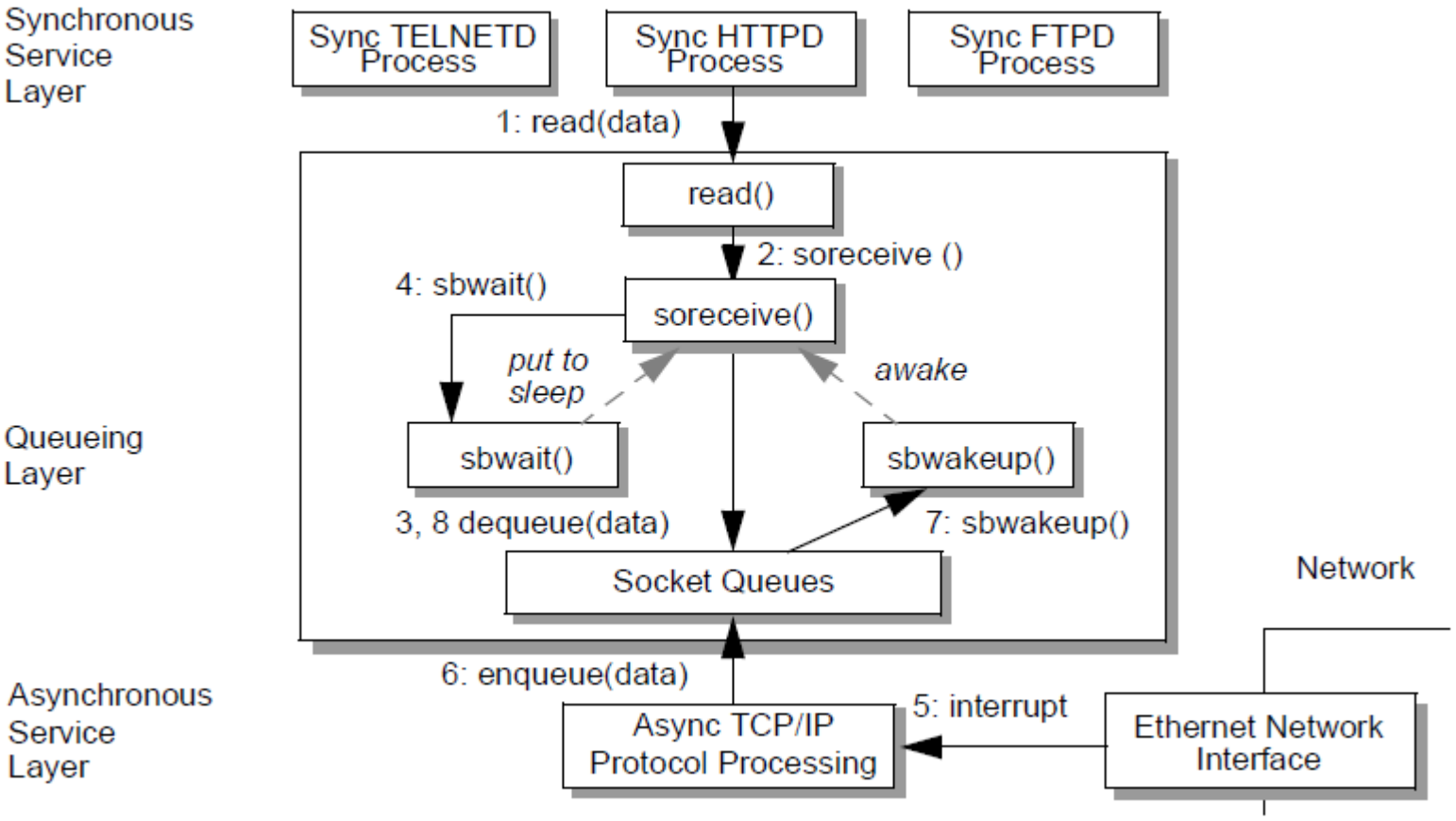
- Apps can be hard to debug due to concurrent execution



Half-Sync/Half-Async POSA2 Concurrency

Known Uses

- UNIX Networking Subsystems

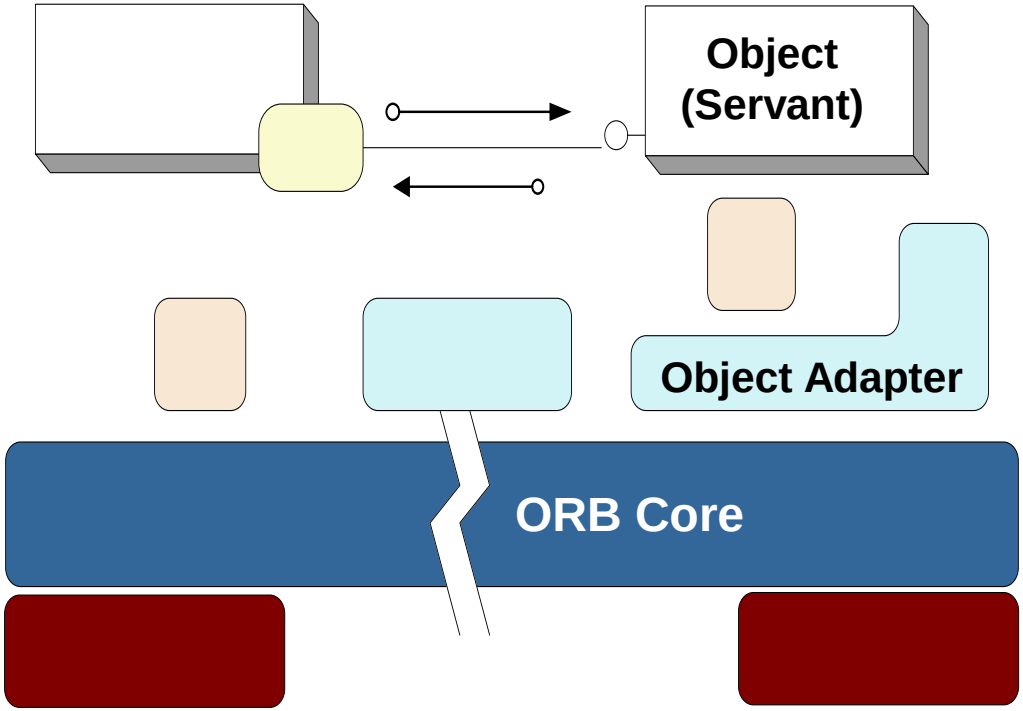


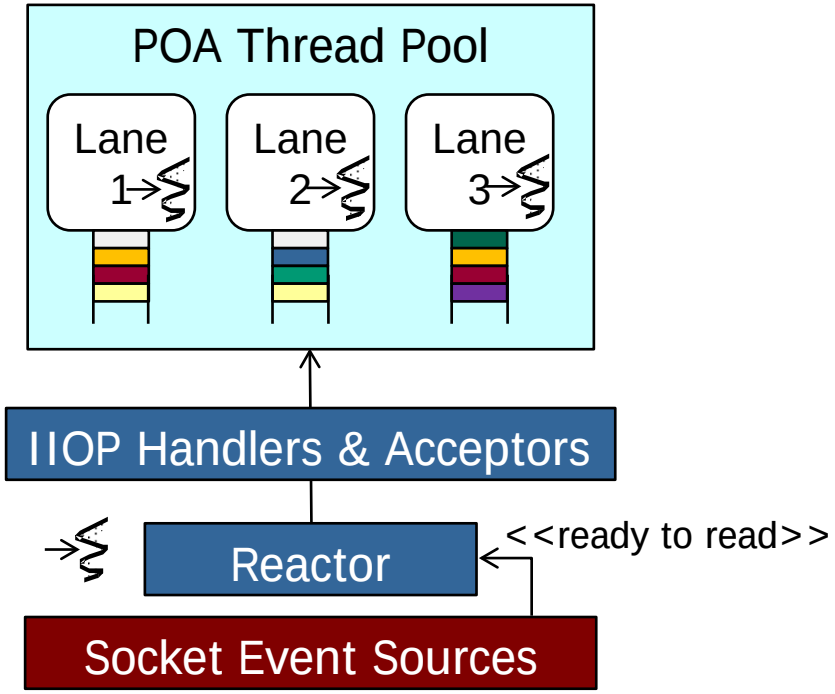
www.dre.vanderbilt.edu/~schmidt/PDF/HS-HA.pdf has more info

Half-Sync/Half-Async POSA2 Concurrency

Known Uses

- UNIX Networking Subsystems
- Object Request Brokers (ORBs)

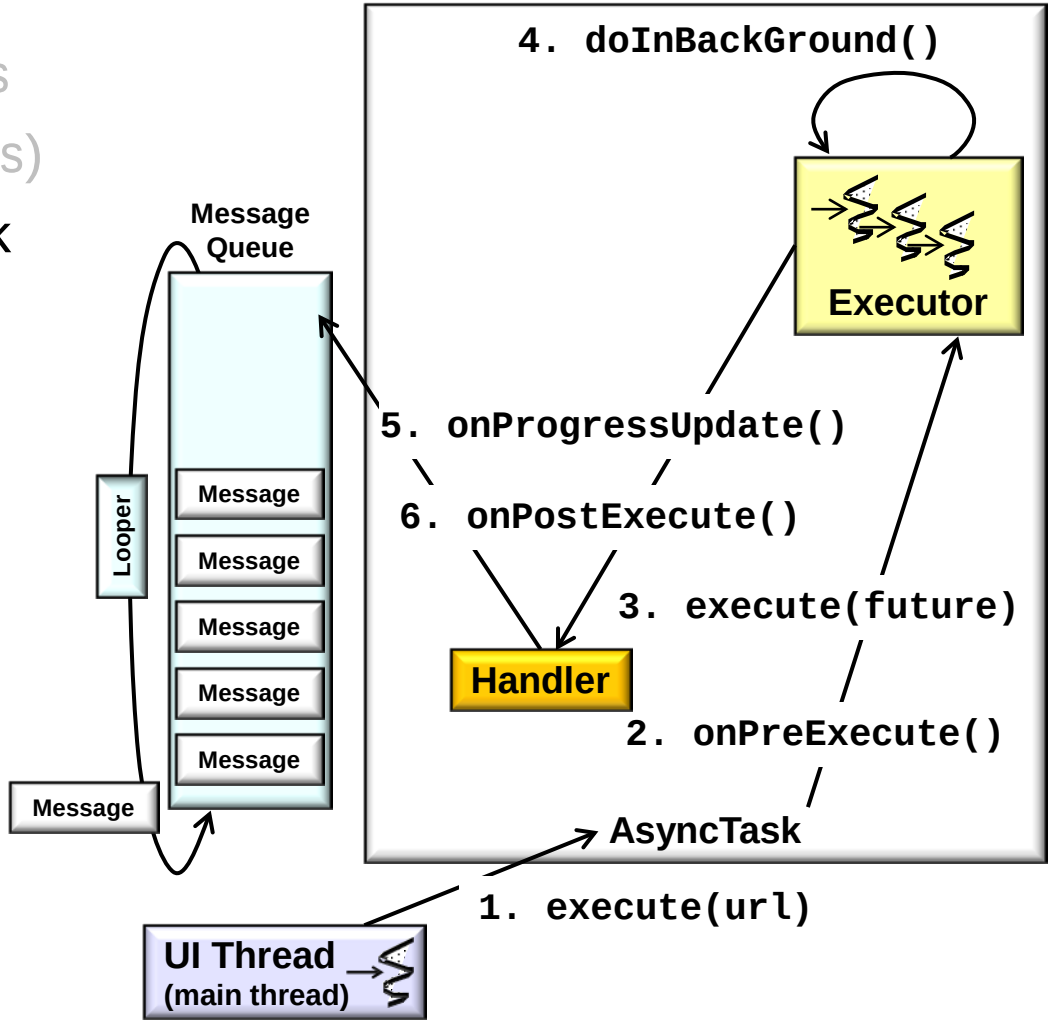




Half-Sync/Half-Async POSA2 Concurrency

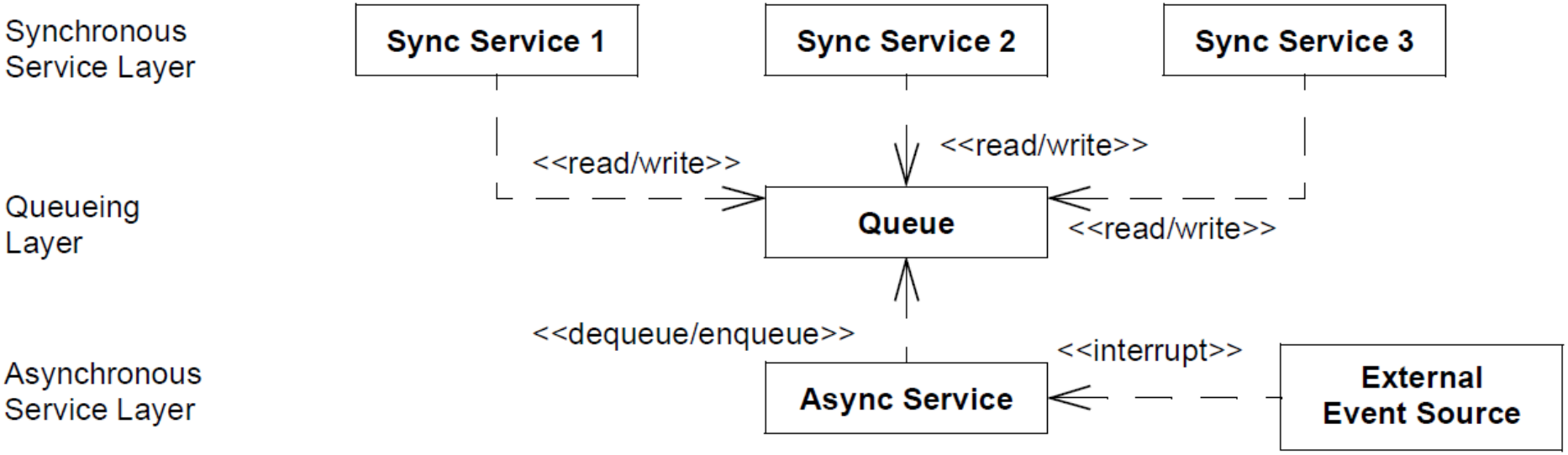
Known Uses

- UNIX Networking Subsystems
- Object Request Brokers (ORBs)
- Android AsyncTask framework



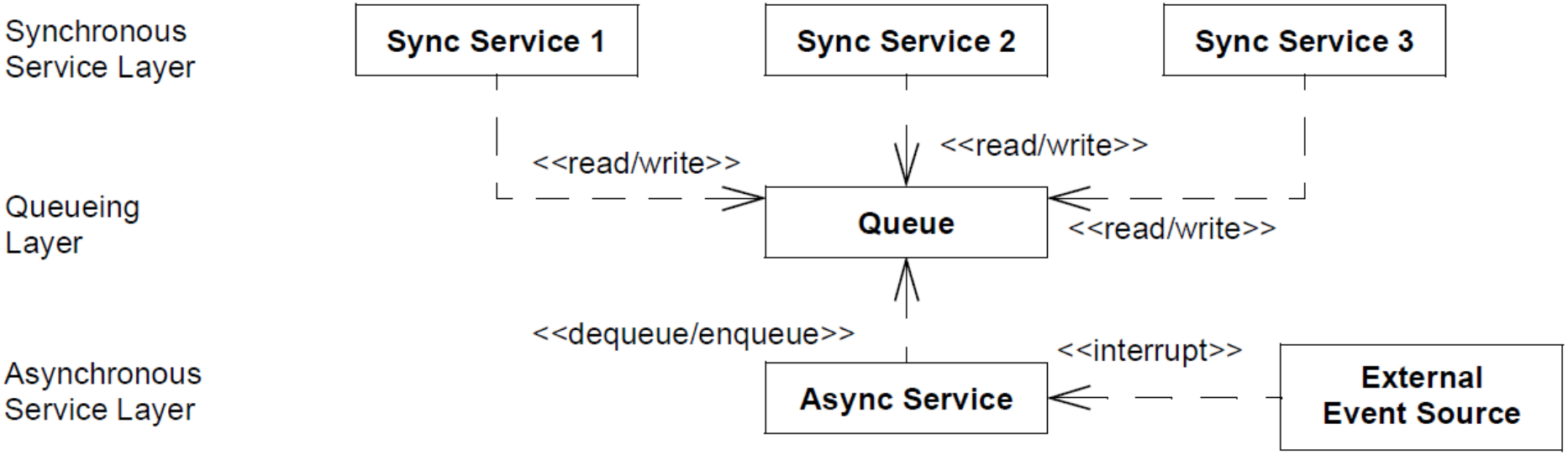
developer.android.com/training/multiple-threads/communicate-ui.html

Summary



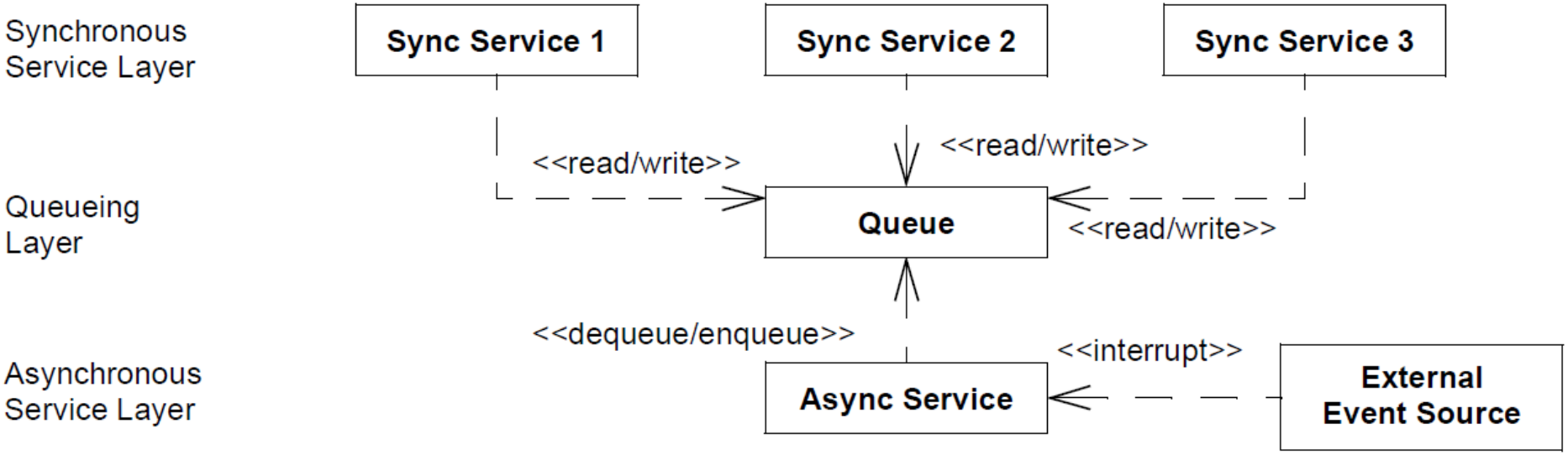
- This pattern separates concerns between the three layers, which makes concurrent software easier to understand, debug, & evolve

Summary



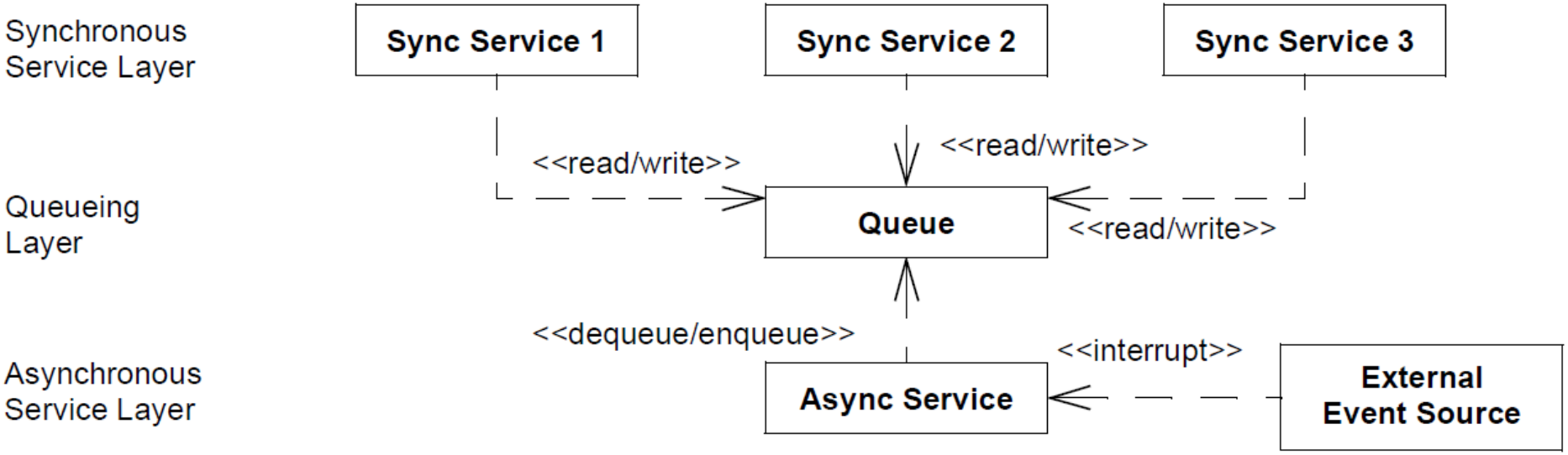
- This pattern separates concerns between the three layers, which makes concurrent software easier to understand, debug, & evolve
- In addition, async & sync services do not suffer from each other's liabilities
  - Async service performance does not degrade due to blocking sync services

Summary



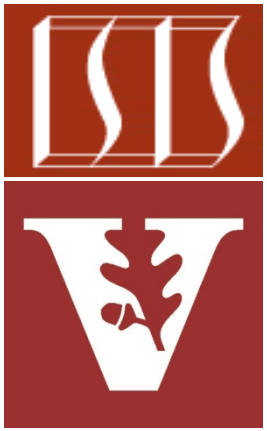
- This pattern separates concerns between the three layers, which makes concurrent software easier to understand, debug, & evolve
- In addition, async & sync services do not suffer from each other's liabilities
  - Async service performance does not degrade due to blocking sync services
  - The simplicity of programming sync services is unaffected by async complexities, such as explicit state management

Summary



- This pattern separates concerns between the three layers, which makes concurrent software easier to understand, debug, & evolve
- In addition, async & sync services do not suffer from each other's liabilities
- The queueing layer avoids hard-coded dependencies between the async & sync service layers
  - It's also easy to reprioritize the order in which messages are processed

Android Concurrency: The Half-Sync/Half-Async Pattern (Part 2)



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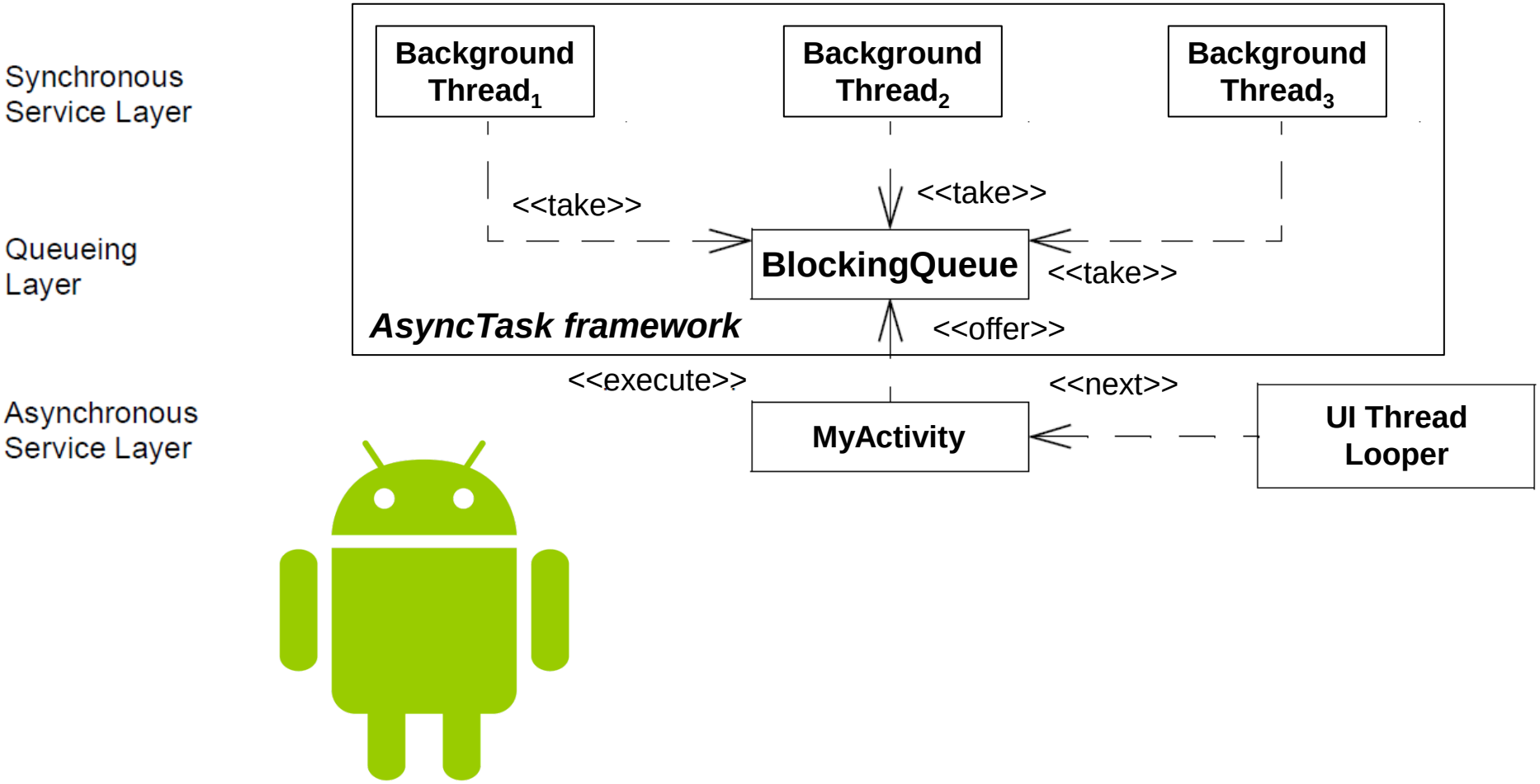
CS 282 Principles of Operating Systems II

Systems Programming for Android

Learning Objectives in this Part of the Module

- Understand how *Half-Sync/Half-Async* is implemented & applied in Android



Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing

```
public abstract class AsyncTask<Params, Progress, Result> {
  public final AsyncTask<Params, Progress, Result>
    execute(Params... params) {
    return executeOnExecutor(sDefaultExecutor, params);
  }

  public final AsyncTask<Params, Progress, Result>
    executeOnExecutor(Executor exec, Params... params) {
    onPreExecute();
    mWorker.mParams = params;
    exec.execute(mFuture);
    return this;
  }
  ...
```

Identify short-duration services & implement them in the async layer

frameworks/base/core/java/android/os/AsyncTask.java has the source code

Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing

```
public abstract class AsyncTask<Params, Progress, Result> {
  public AsyncTask() {
    mWorker = new WorkerRunnable<Params, Result>() {
      public Result call() throws Exception {
        ...
        return postResult(doInBackground(mParams));
      }
    };
    ...
```

Identify long-duration services & implement them in the sync layer

frameworks/base/core/java/android/os/AsyncTask.java has the source code

Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing

```
public class ThreadPoolExecutor
       extends AbstractExecutorService {
  /**
   * The queue used for holding tasks and handing off to worker
   * threads. */
  private final BlockingQueue<Runnable> workQueue;
```

Identify inter-layer communication strategies & implement them in the queueing layer

frameworks/base/core/java/android/os/AsyncTask.java has the source code

Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing
- Implement the services in the synchronous layer

```
class DownloadAsyncTask extends
      AsyncTask<String, Integer, Bitmap> {
  ...
  protected Bitmap
  doInBackground(String... url) {
    return downloadImage(url[0]);
  }
```

Download in background thread

Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing
- Implement the services in the synchronous layer
- Implement the services in the asynchronous layer

```
class DownloadAsyncTask extends
      AsyncTask<String, Integer, Bitmap> {

  protected void onPreExecute() {
    dialog.display();
  }

  protected void onPostExecute
                        (Bitmap bitmap) {
    performPostDownloadOperations(bitmap);
    dialog.dismiss();
  }
}
```

Perform on UI thread

Perform on UI thread

Half-Sync/Half-Async POSA2 Concurrency

Implementation

- Decompose overall system into three layers: synchronous, asynchronous, & queueing
- Implement the services in the synchronous layer
- Implement the services in the asynchronous layer
- Implement (or reuse) the queueing layer

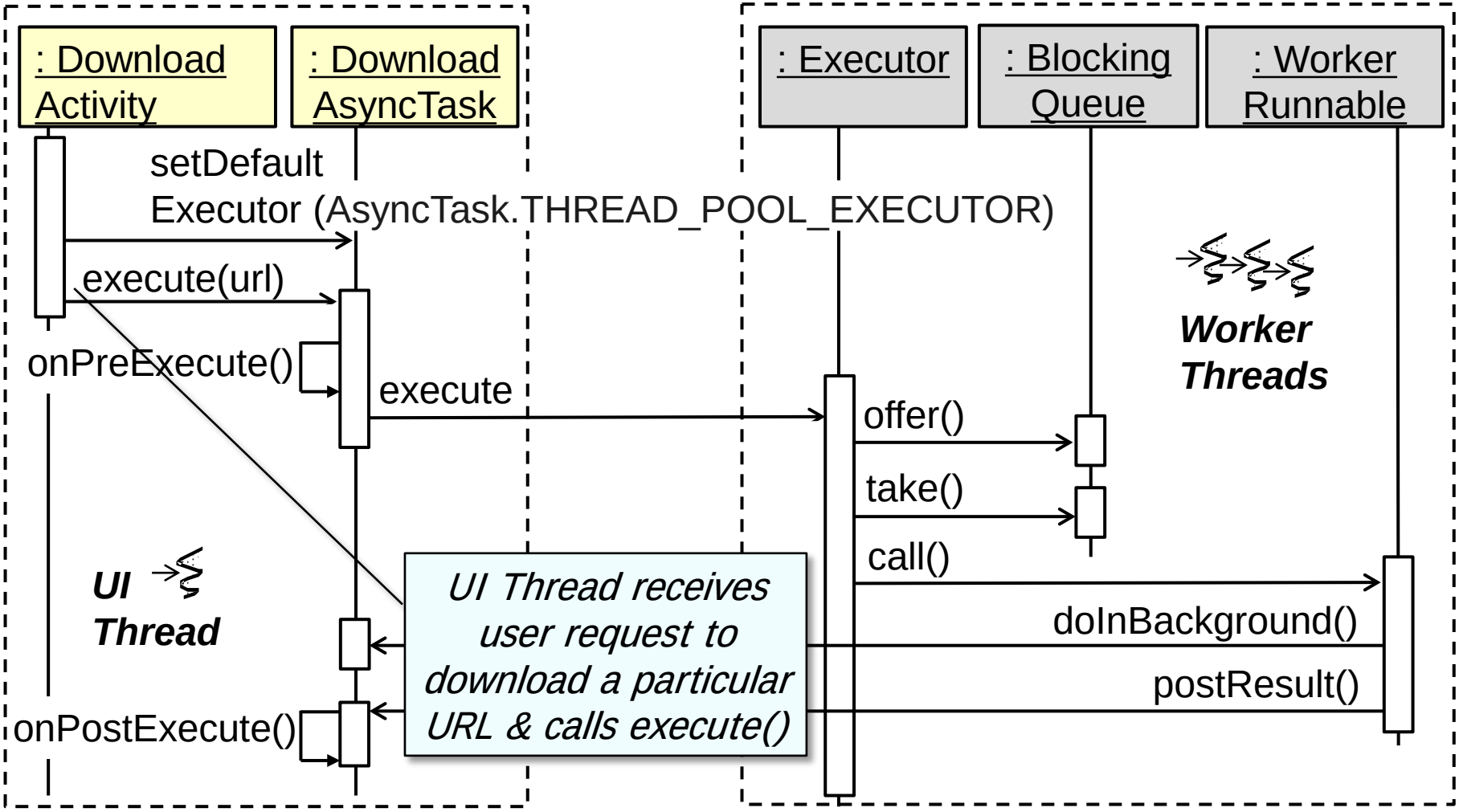
```
public class ThreadPoolExecutor
      extends AbstractExecutorService {
  ...
  private Runnable getTask() {
    ...
    Runnable r = workQueue.take();
    ...
    return r;
    ...

  public void execute(Runnable command) {
    ...
    workQueue.offer(command);
    ...
```

frameworks/base/core/java/android/os/AsyncTask.java has the source code

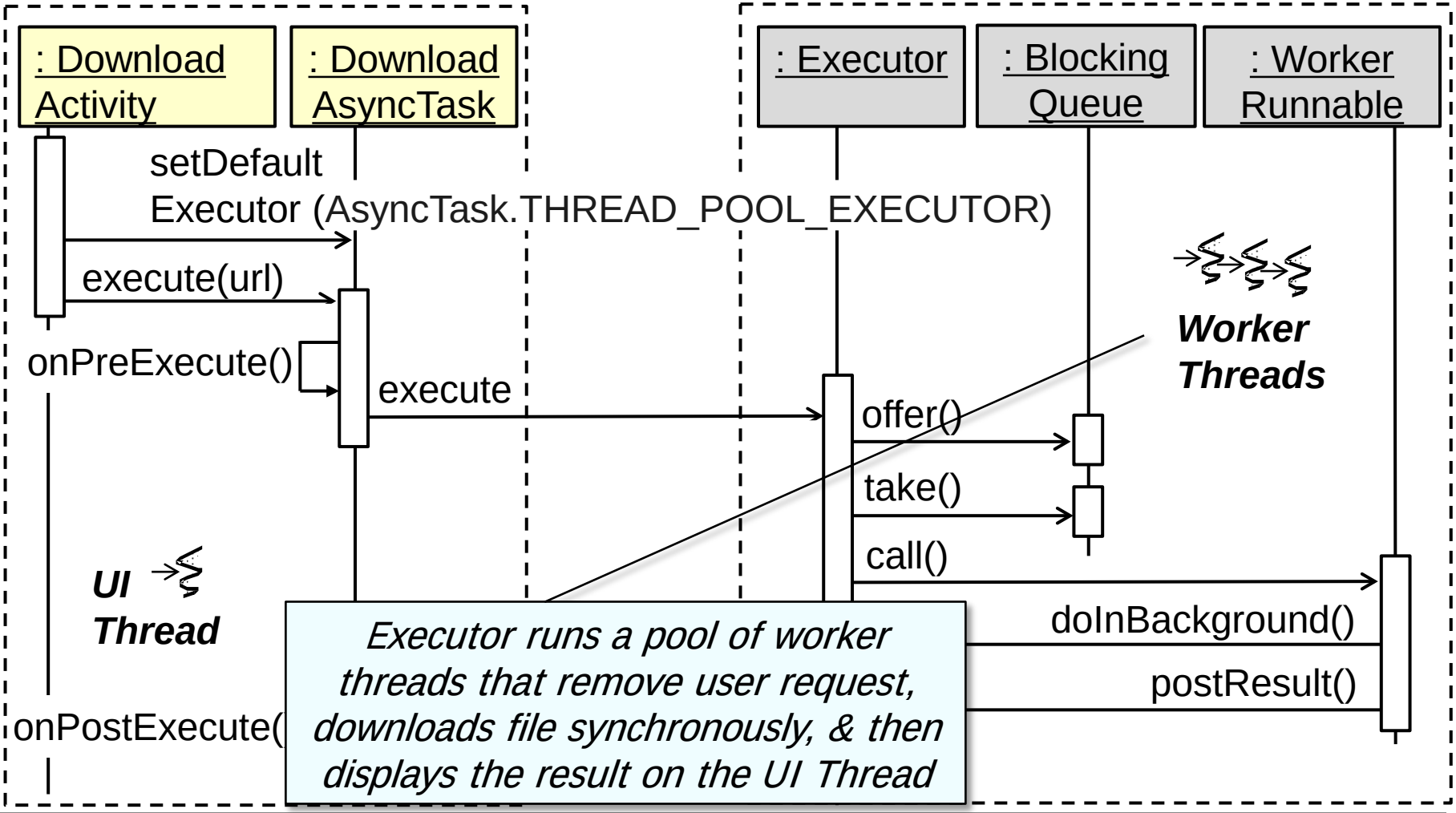
Half-Sync/Half-Async POSA2 Concurrency

Applying Half-Sync/Half-Async in Android



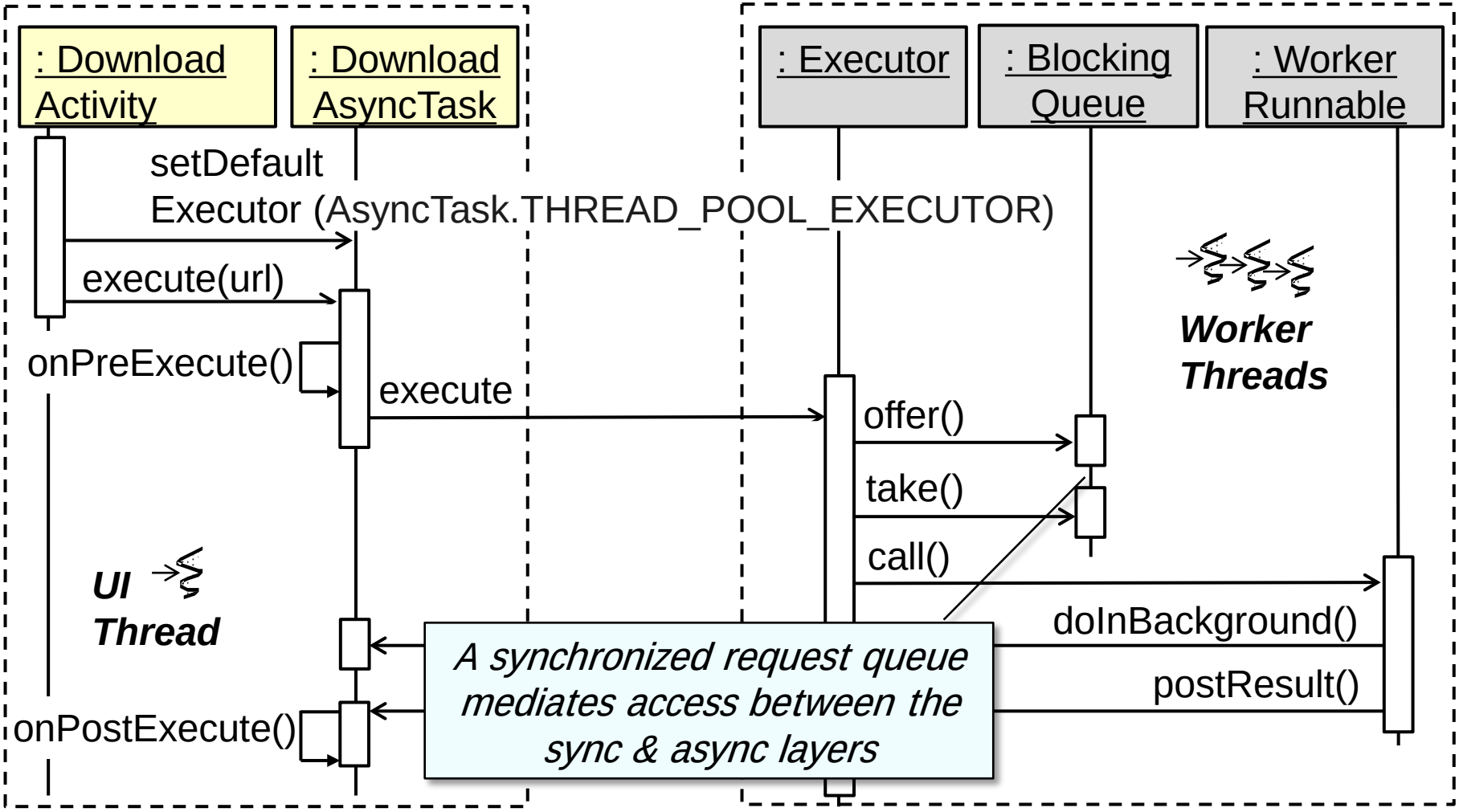
Half-Sync/Half-Async POSA2 Concurrency

Applying Half-Sync/Half-Async in Android



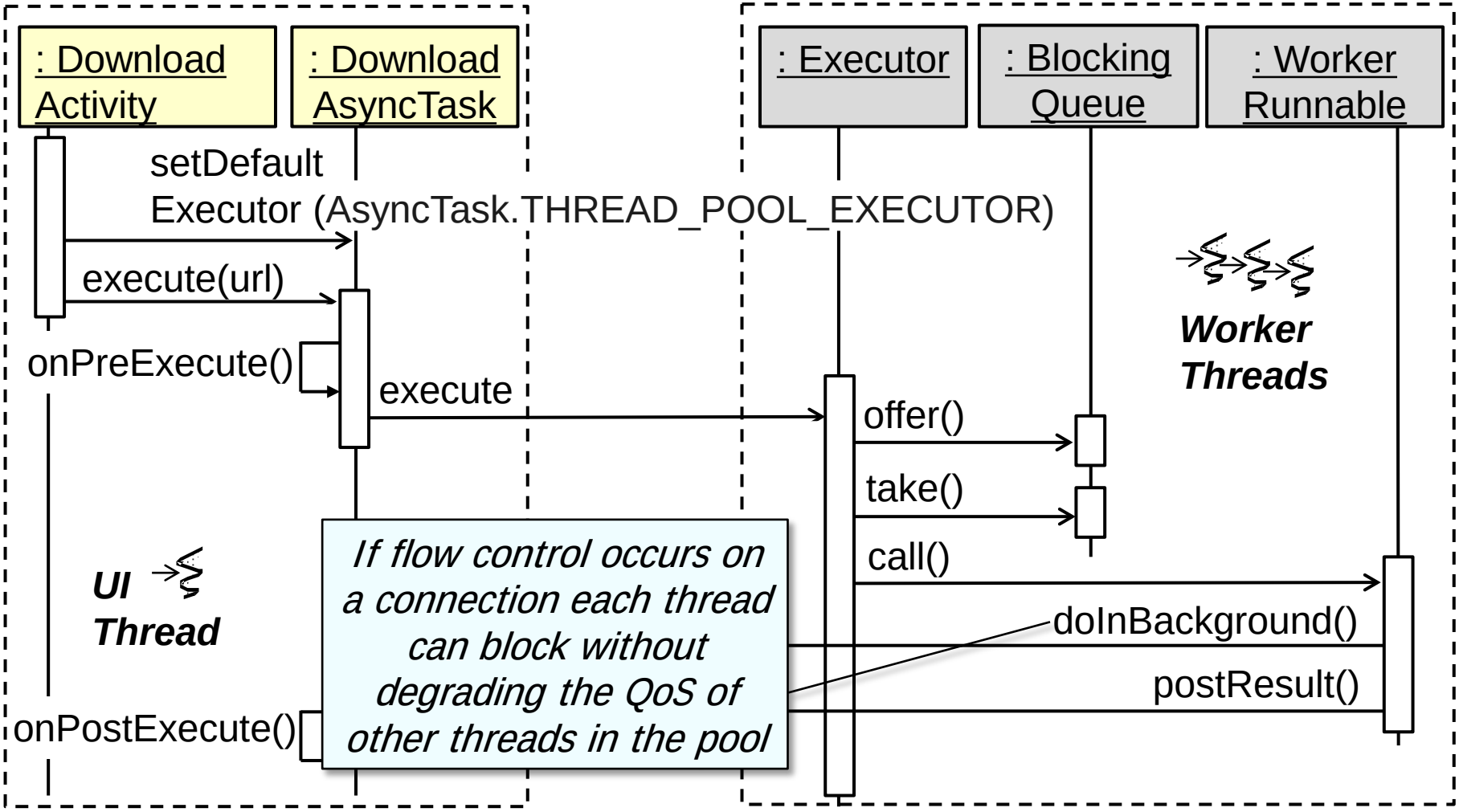
Half-Sync/Half-Async POSA2 Concurrency

Applying Half-Sync/Half-Async in Android

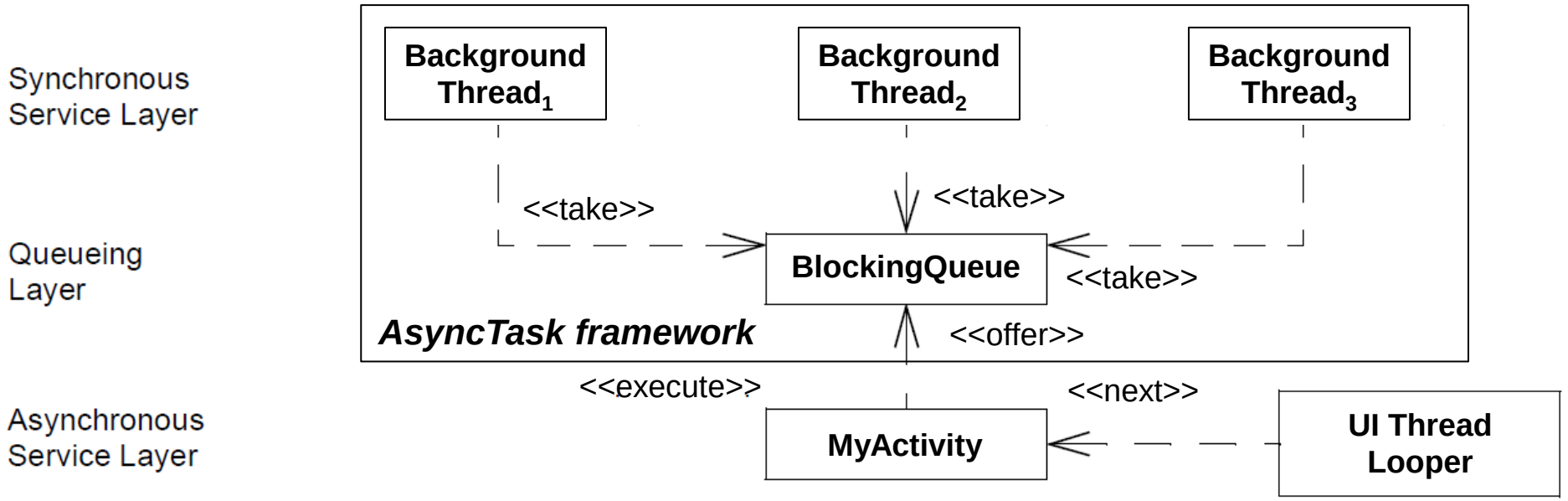


Half-Sync/Half-Async POSA2 Concurrency

Applying Half-Sync/Half-Async in Android

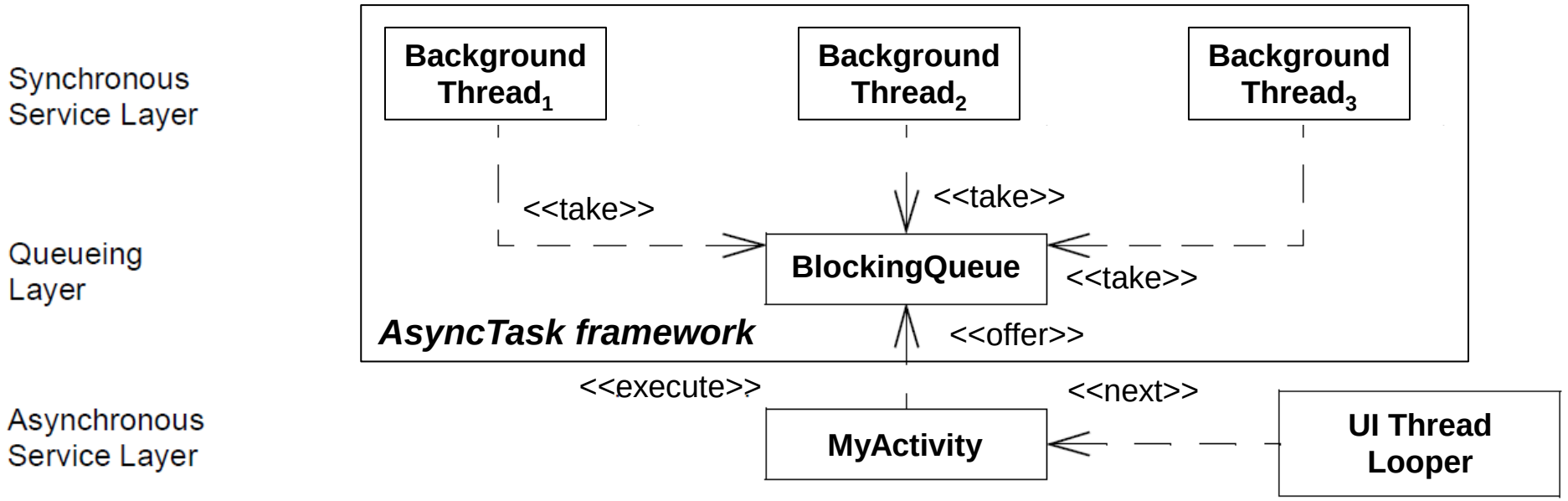


Summary



- The Android AsyncTask framework implements *Half-Sync/Half-Async* pattern to encapsulate the creation of background thread processing & synchronization with the UI Thread
  - It also supports reporting progress of the running tasks

Summary



- The Android AsyncTask framework implements *Half-Sync/Half-Async* pattern to encapsulate the creation of background thread processing & synchronization with the UI Thread
- The AsyncTask framework is a sophisticated implementation of Half-Sync/Half-Async
  - e.g., there are multiple interactions between the sync & async portions via various queues