CSE 486/586: Distributed Systems

Android Architecture and Development (Part 1)

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Moments Ago…

The end-to-end principle is powerful.

The transport layer provides additional functionality:

- TCP: App. differentiation, flow control, reliability
- UDP: Application differentiation

TCP guarantees are end-to-end at the host level.

Introduction

Today we will discuss:

- The architecture of an Android app
- Concurrency and races
- Event-driven techniques
- The handout code for Project 1

…or however much of that we accomplish!

Android Architecture

An Android application is an event-driven, loosely-coupled system of inter-operating components.

It's almost a distributed system all by itself!

Each application provides a set of:

- Activities
- Services
- BroadcastReceivers
- ContentProviders

It may also have other components.

Callbacks

Each of those major Android components consists of a set of callbacks that determine its behavior.

There is no `main()`-style function or method![1]

A designated Activity provides the application entry point.

Each callback must return quickly to avoid hanging the application!

This has implications on design.

[1] Sort of...

Callbacks Example

```
public class Activity extends ApplicationContext
    {
     protected void onCreate(Bundle
         savedInstanceState);
     protected void onStart();
     protected void onRestart();
     protected void onResume();
     protected void onPause();
     protected void onStop();
     protected void onDestroy();
}
```

Metadata

The file `AndroidManifest.xml` describes:

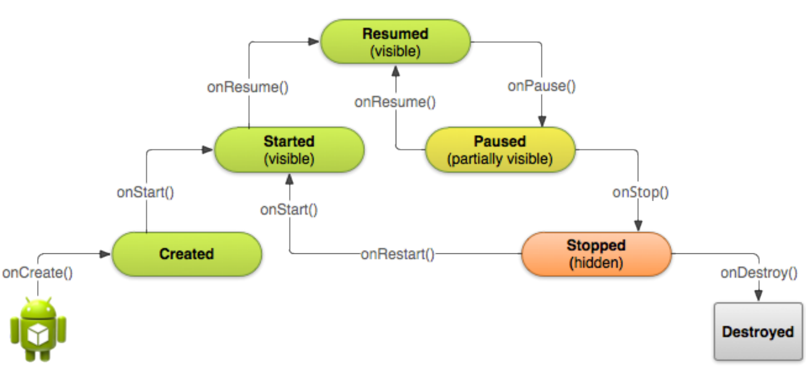
- The main Activity
- Special permissions required
- Services provided

This is a declarative description of the application.

Manifest Example (abbreviated)

```
<manifest xmlns:android="http://..."
    package="edu.buffalo.cse.cse486586.simplemessenger
    <uses-permission
        android:name="android.permission.INTERNET"/>
    <application>
        <activity
            android:name=".SimpleMessengerActivity">
            <intent-filter>
                <action android:name="..." />
                <category android:name="..." />
            </intent-filter>
        </activity>
    </application>
</manifest>
```

Activity Lifecycle



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Event-Driven Execution

Many Android components, and in particular all UI Activities, are event-driven.

This means that:

- There is only one thread of execution
- The Activity responds serially to events
- Event durations must be finite

Each event is handled by a callback.

There is no `main()` because it's an event loop!

Event Loops

The main event loop proceeds as follows:

1. Block waiting for an event to occur
2. Identify the event, find a callback to handle it
3. Invoke the callback
4. Go to 1

Messages

Many Android events are messages called Intents.

Remember this?

> *We define a distributed system as one in which hardware or software components located at networked computers communicate and coordinate their actions only by passing messages. [1]*

Intents can:

- Notify any interested parties of a condition/action
- Request a specific action from another Activity/Service

Blocking

Facts:

1. Events cannot block indefinitely
2. Java I/O is blocking[2]

So …how do we do I/O? (*E.g.*, `Socket.accept()`!)

Android also has AsyncTasks, which are threads.

- Create an AsyncTask
- Block in it
- Notify the event loop via a message (*e.g.*, `publishProgress()`)

[2] Channels provide a non-blocking API, but the program must still block for the next Channel activity.

The `AsyncTask` Interface

AsyncTask provides:

- A wrapper for Java thread
- A way to communicate with the UI thread
- Some state transition callbacks

In particular, calling `publishProgress()` causes:

- A `Progress` message to be sent to the UI thread
- The UI thread to invoke `onProgressUpdate(Progress...)`

… While `doInBackground(Params...)` is invoked on the thread.

Flavors of `AsyncTask`

Instances of `AsyncTask` can be run:

- Serially on a shared thread, with `SERIAL_EXECUTOR`
- On a dedicated thread, with `THREAD_POOL_EXECUTOR`

Tasks that are expected to block should use a dedicated thread!

There are *about* 5 dedicated threads available per App [3].

Concurrency

There are two major types of concurrency in an Android application.

- Interleaved events
- `AsyncTasks`

Events on a single thread are mutually exclusive.
E.g., *all UI thread events.*

Data Races

```
1  int x, y;
2
3  void addx() {
4      x += 2;
5  }
```

```
6  void swapXY() {
7      int tmp = x;
8      x = y;
9      y = tmp;
10 }
```

What happens if `addx()` is called during execution

- Before line 7
- Between lines 7 and 8?
- Between lines 8 and 9?

Protecting from races

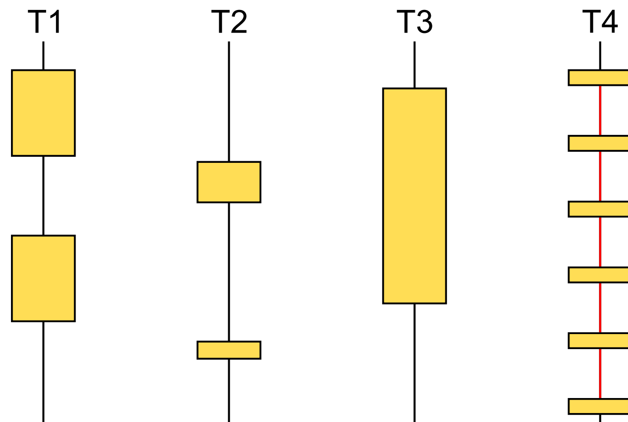
```
11 int x, y;
12
13 synchronized void
       addx() {
14     x += 2;
15 }
```

```
16 synchronized void
       swapXY() {
17     int tmp = x;
18     x = y;
19     y = tmp;
20 }
```

What happens if `addx()` and `swapxy()` are `synchronized`?

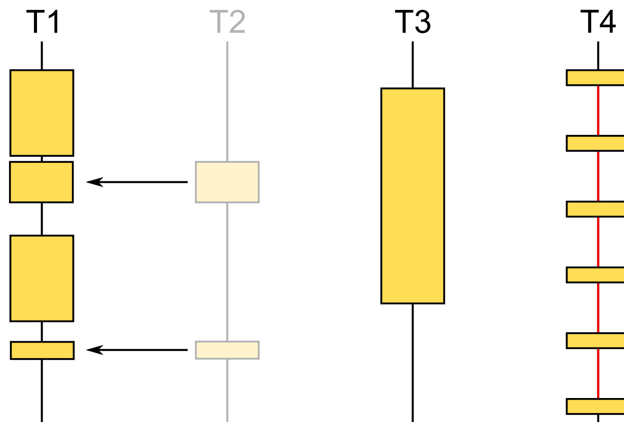
What happens if they're unsynchronized event callbacks?

Example Application



Executing
Blocking

Example Application — Event Loop



Executing
Blocking

Mutual Exclusion

Mutual exclusion is a property of code regions.[3]

Two regions are mutually exclusive if they cannot run simultaneously.

This property is pairwise between regions.

Actions are atomic if they appear to be mutually exclusive with all other regions.

[3] It's more complicated than that, but for now.

Defending Against Races

Mutual exclusion can be used to prevent data races.
Recall `swapxy()` *and* `addx()`.

Regions of code that:

- mutate shared state, or
- rely on stability of shared state

should be mutually exclusive.

Event Loops and Concurrency

We said that events are mutually exclusive.
What does that mean?

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[4] On the same event loop, that is!

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What does that mean?

Each event starts and runs to completion alone.

Therefore, no synchronization is required between events.[4]

Note: You can't even add `synchronized` to a callback!

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Each event starts and runs to completion alone.

Therefore, no synchronization is required between events.[4]

Note: You can't even add `synchronized` to a callback!

Question: What about synchronizing between events and `AsyncTasks`?

[4] On the same event loop, that is!

Java Memory Model

The Java Memory Model [2] defines atomicity and mutual exclusion for Java.

Doug Lea has some good explanations of the JMM.

Explicit mutual exclusion is provided by Java monitors.

Monitors are entered via the `synchronized` keyword.

Development Guidelines

- Learn the APIs: read the API documentation!
- Learn the tools
  - `adb`, `emulator`
  - The Android Studio debugger
- Become familiar with the environment
  - Environment variables
  - The shell
- Use good practices
  - Write clean, documented code
  - Maintain loop invariants
  - Iteratively refine your application

Summary

Android Architecture:

- Android is event-driven.
- The manifest describes the application.
- Threads are provided by `AsyncTask`.

Concurrency:

- The JMM defines Java monitors.
- Events on an event loop are mutually exclusive.
- Shared state must be protected.

References I

Optional Readings

[1] George Coulouris et al. *Distributed Systems. Concepts and Design*. Fifth Edition. Addison-Wesley, 2012. ISBN: 978-0-13-214301-1.

[2] James Gosling, Bill Joy, and Guy Steele. *The Java Language Specification*. Third Edition. Sun Microsystems, Inc., 1996. Chap. 17.4 Memory Model.

[3] *Thread Pool Executor*. URL: `https://developer.android.com/reference/java/util/concurrent/ThreadPoolExecutor.html` (visited on 02/04/2017).