Android Services & Security: Activity & Service Communication

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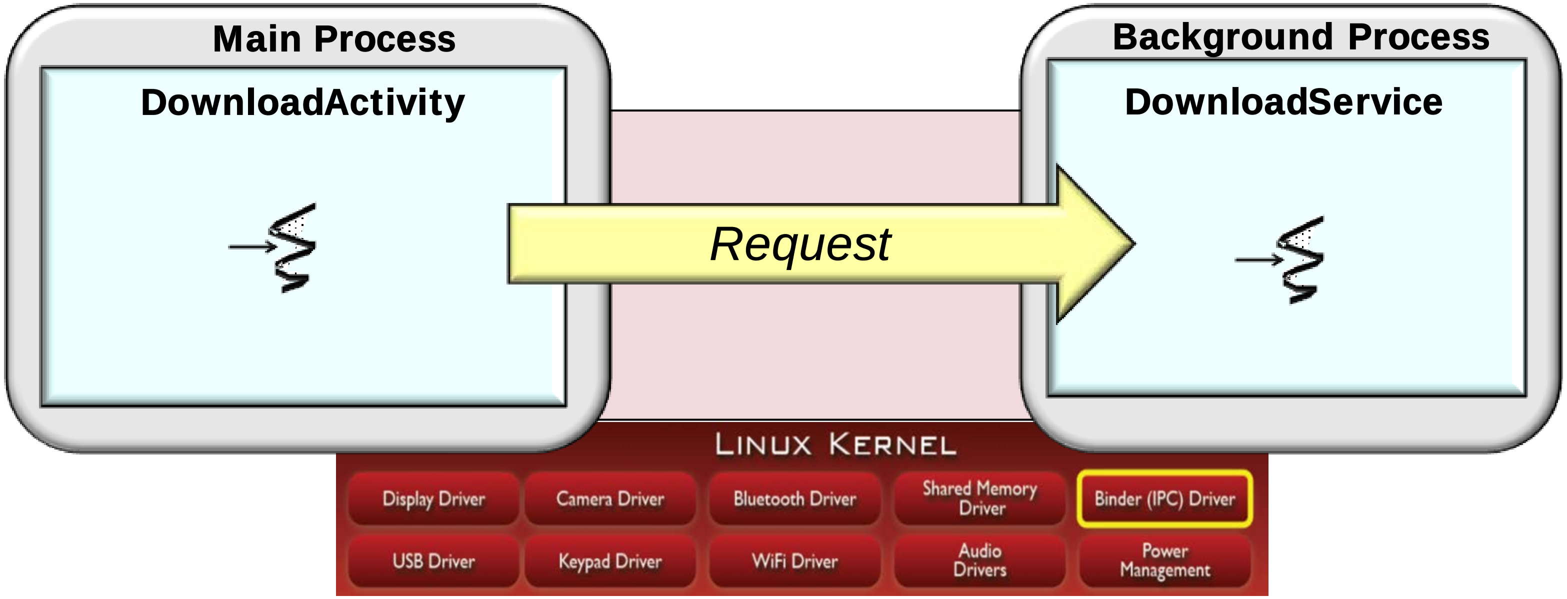
Learning Objectives in this Part of the Module

- Understand various mechanisms that Activities & Services use to communicate



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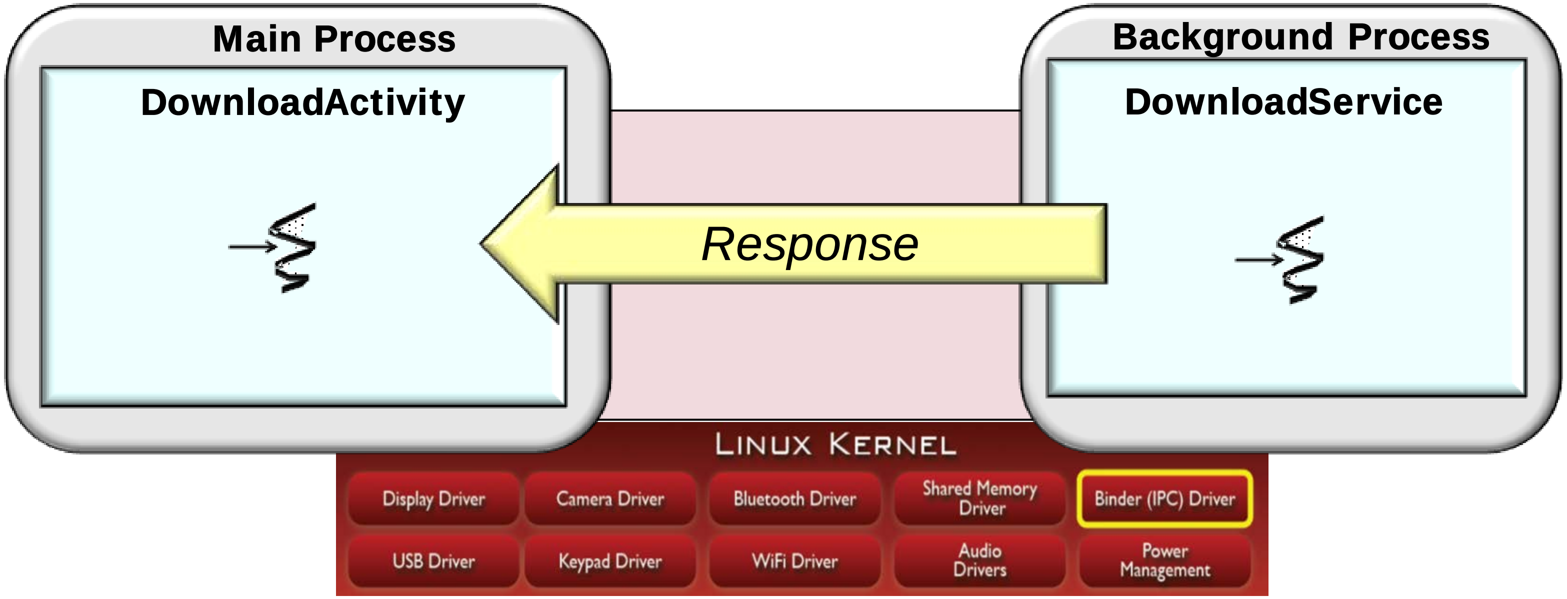
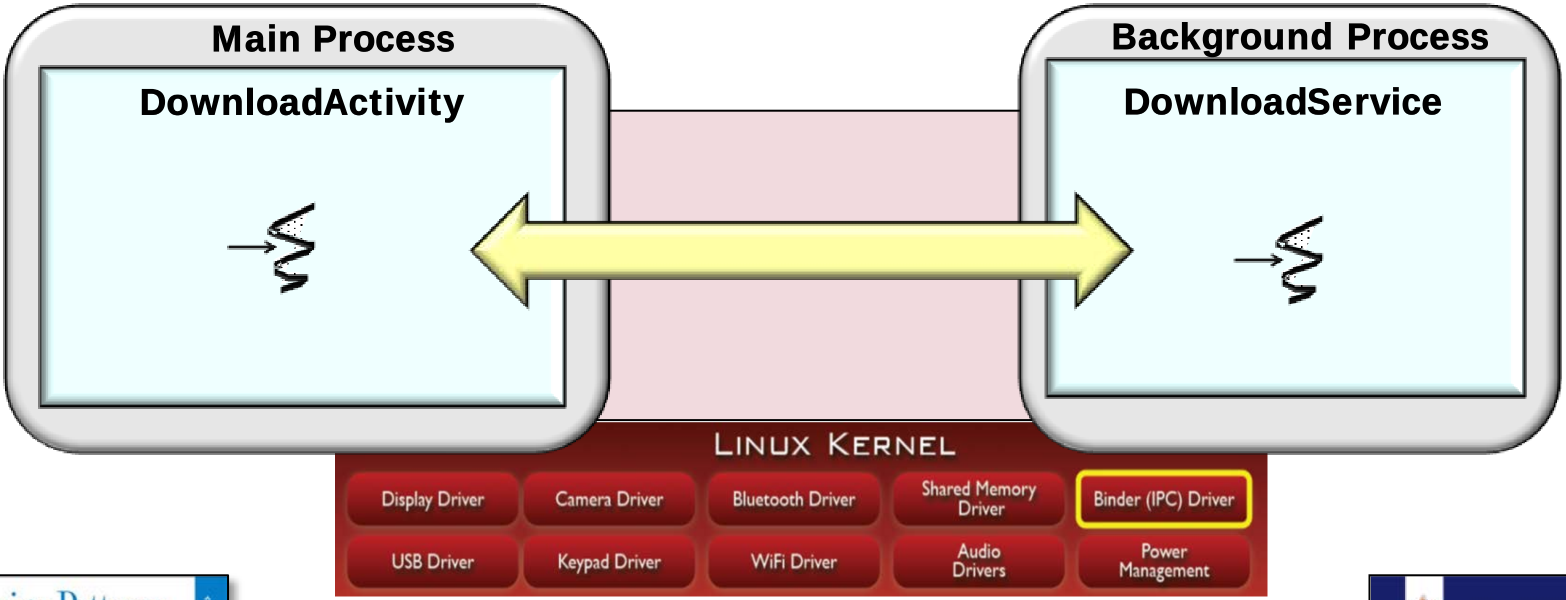
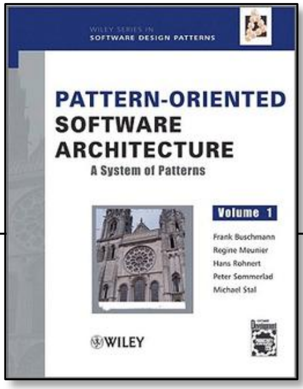
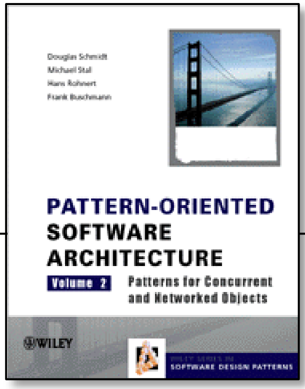


Learning Objectives in this Part of the Module

- Understand various mechanisms that Activities & Services use to communicate
- Recognize the common patterns used to implement communication with Services



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Volume 2
Patterns for Concurrent and Networked Objects
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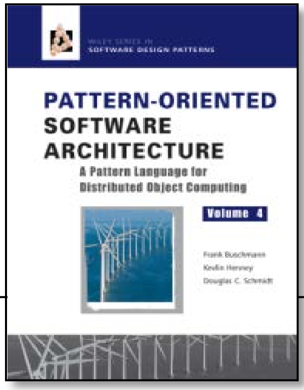
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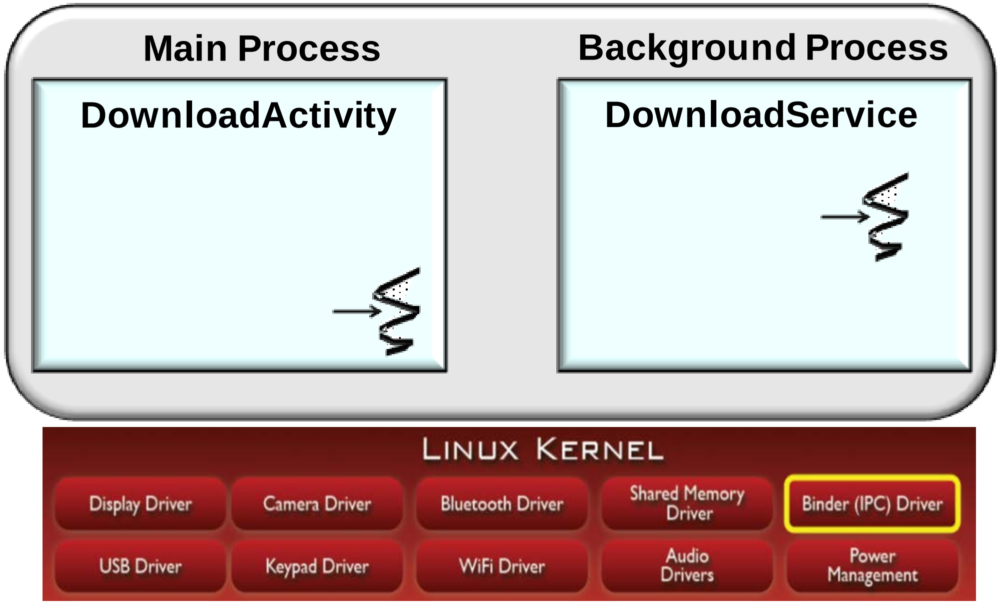
Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients



Main Process

DownloadActivity

Background Process

DownloadService

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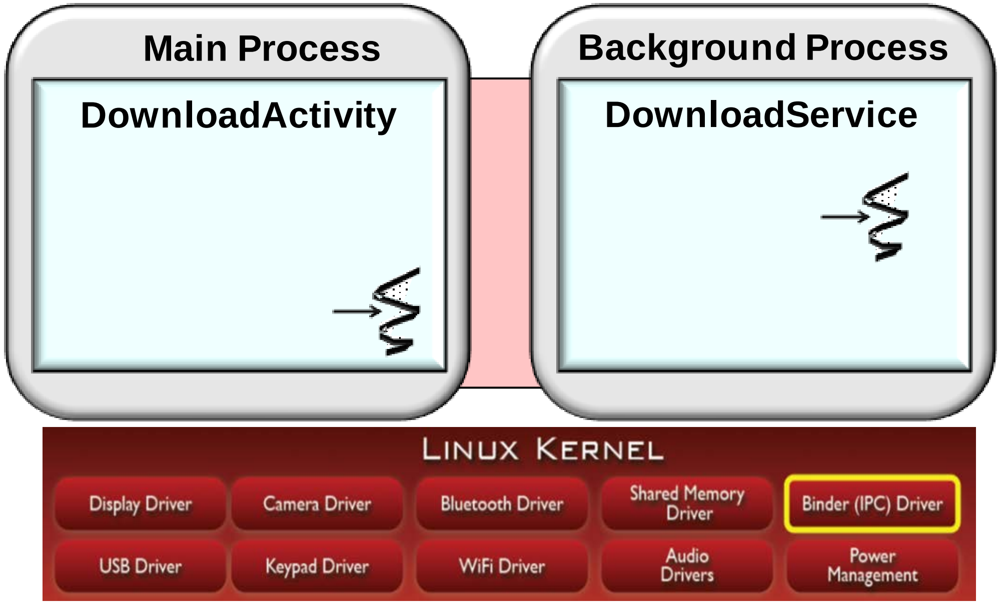
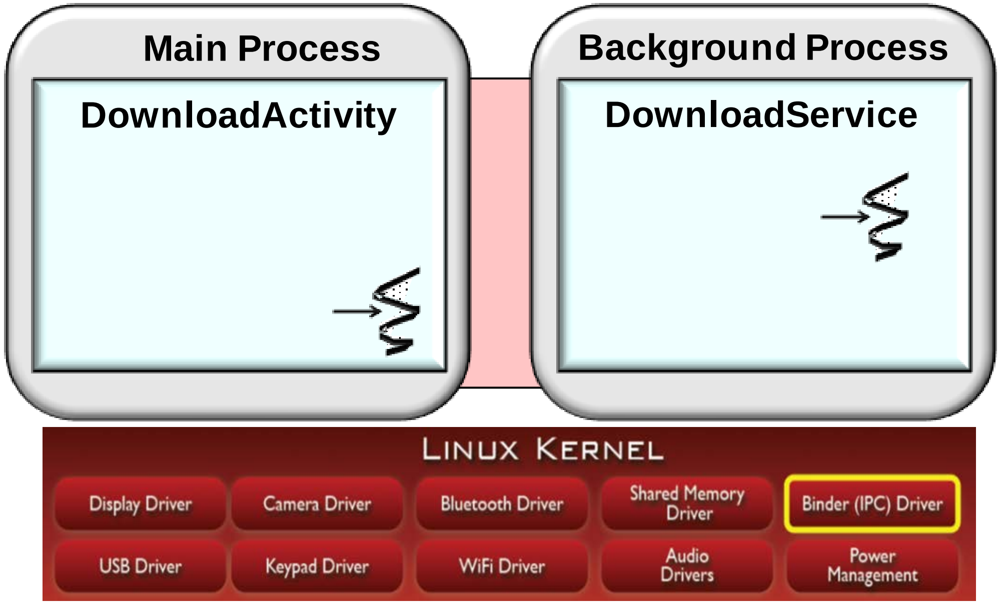


Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients
  - This choice is determined via a configuration setting in AndroidManifest.xml



```
<service
    android:enabled
      =["true" | "false"]
    android:exported
      =["true" | "false"]
    android:icon="drawable resource"
    android:isolatedProcess=["true" | "false"]
    android:label="string resource"
    android:name="string"
    android:permission="string"
    android:process="string" >
    ...
</service>
```

developer.android.com/guide/topics/manifest/service-element.html has more

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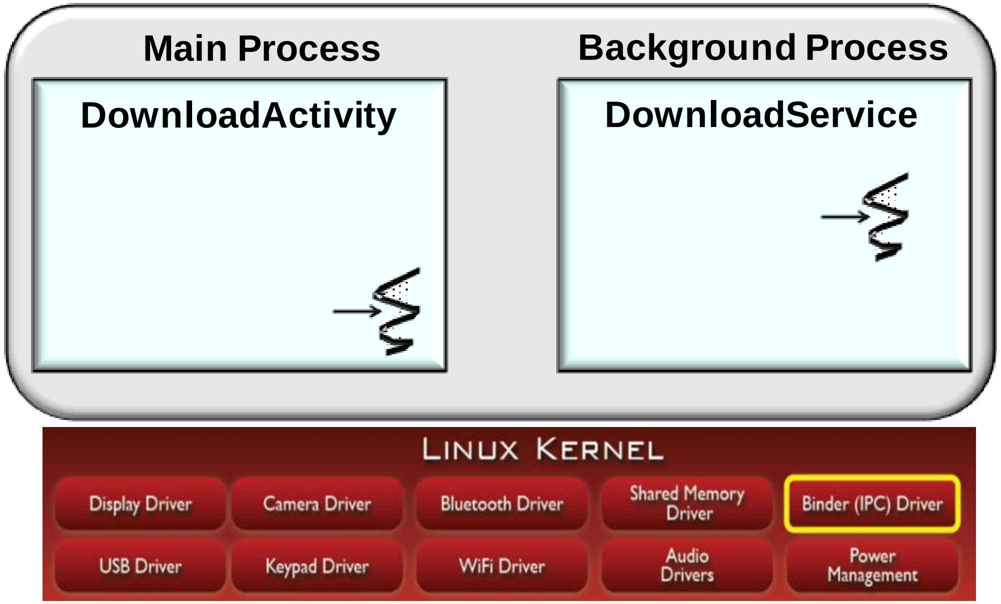

AndroidManifest.xml

```
...
<service android:name=
         "DownloadService"
         android:exported=
         "false"

                      />
...
```

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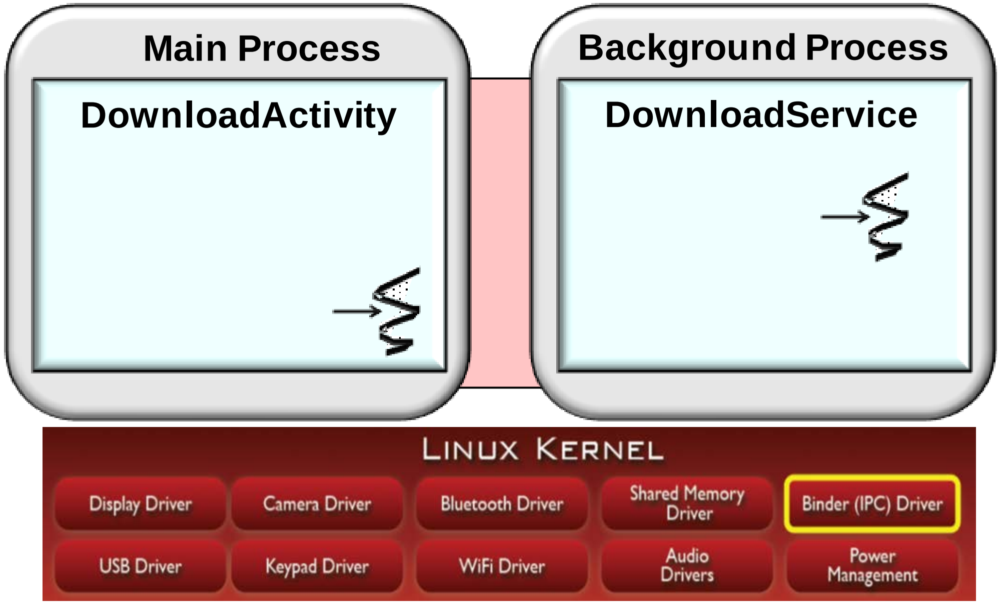

AndroidManifest.xml

```
...
<service android:name=
         "DownloadService"
         android:exported=
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         android:process=
         ":myProcess"/>
...
```
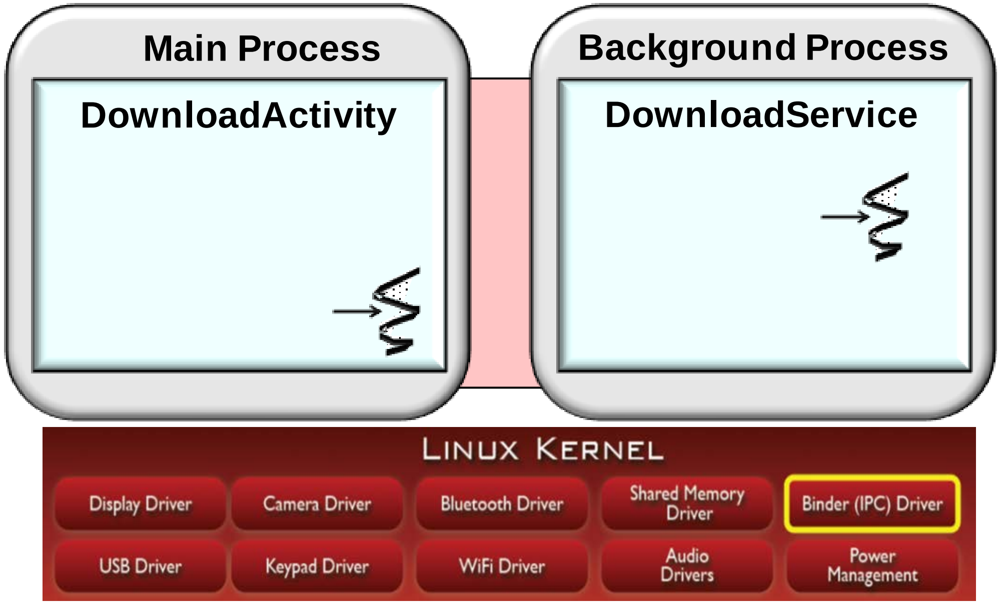

Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients
- There are several reasons for running a Service in its own process



See www.vogella.com/tutorials/AndroidServices/article.html#service_advice

Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients
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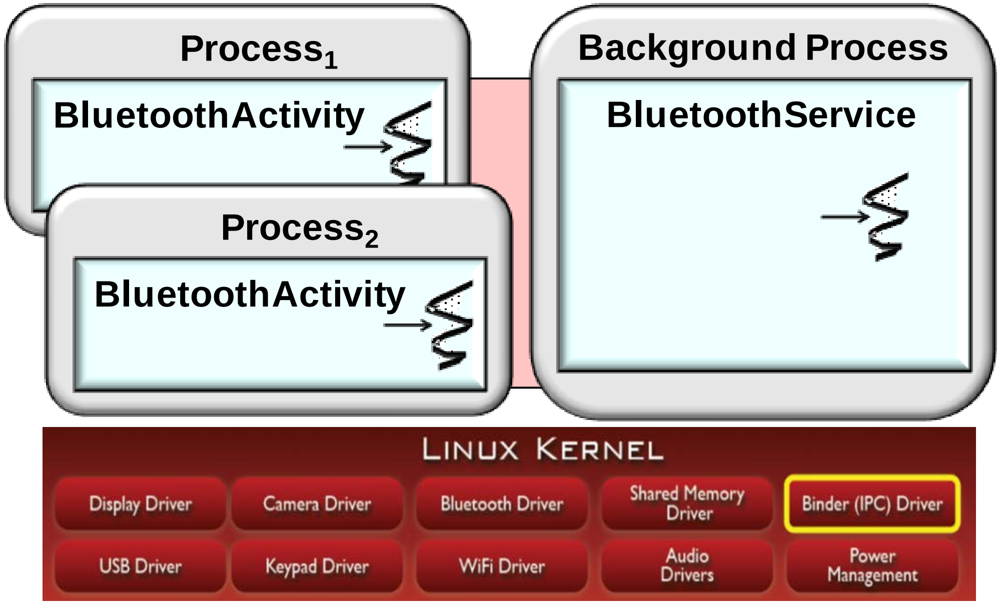
  - Services shared by multiple applications need to run in separate processes

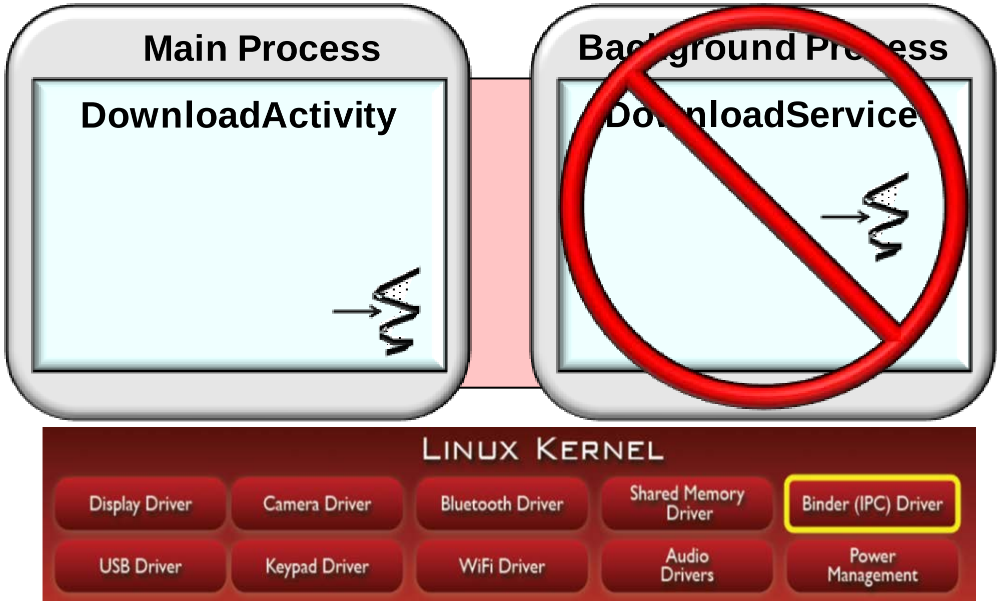


```
<service android:process="@string/process"
         android:name=".opp.BluetoothOppService"
         android:permission=
            "android.permission.ACCESS_BLUETOOTH_SHARE" />
```

See packages/apps/Bluetooth/AndroidManifest.xml

Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients
- There are several reasons for running a Service in its own process
  - Services shared by multiple applications need to run in separate processes
  - Giving a Service its own address space can make applications more robust if failures or hangs occur



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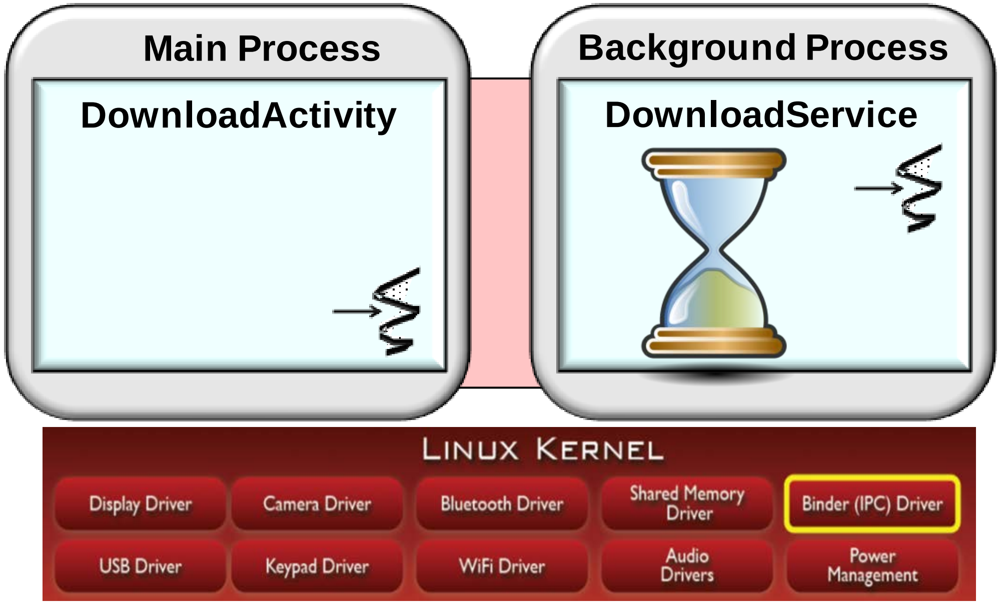
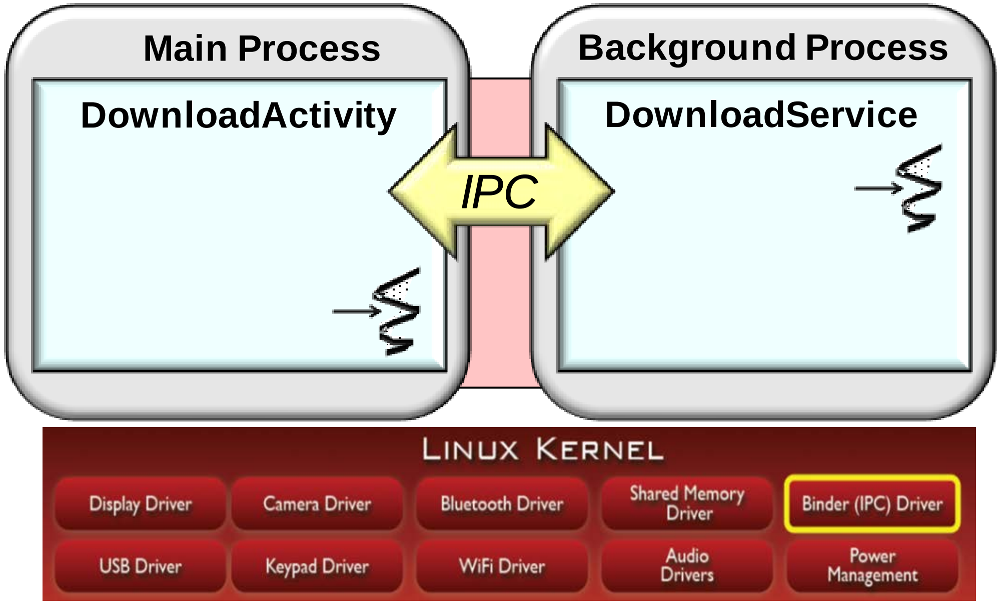
- There are several reasons for running a Service in its own process
  - Services shared by multiple applications need to run in separate processes
  - Giving a Service its own address space can make applications more robust if failures or hangs occur
  - Garbage collection of the virtual machine in a separate Service process doesn't affect the Application process



Overview of Service Deployment Models

- Started & Bound Services can run in the same or different processes as their clients
- There are several reasons for running a Service in its own process
- IPC mechanisms are needed to communicate with Services running in different processes



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- Started & Bound Services can run in the same or different processes as their clients
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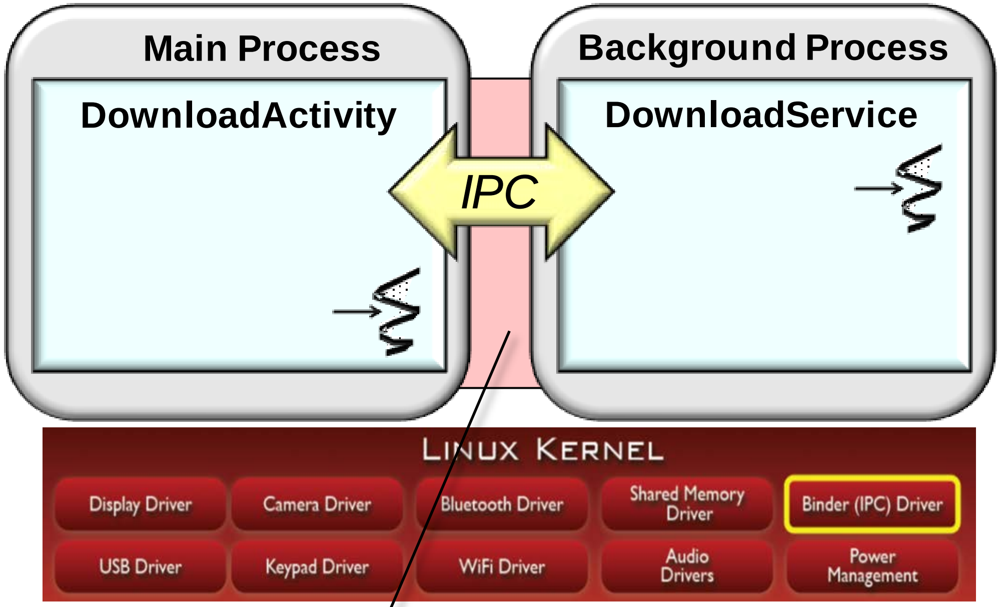
- IPC mechanisms are needed to communicate with Services running in different processes
  - The Android Binder RPC framework underlies the various IPC mechanisms



The Binder supports two-way or one-way client-service communication models

See elinux.org/Android_Binder for more on Binder

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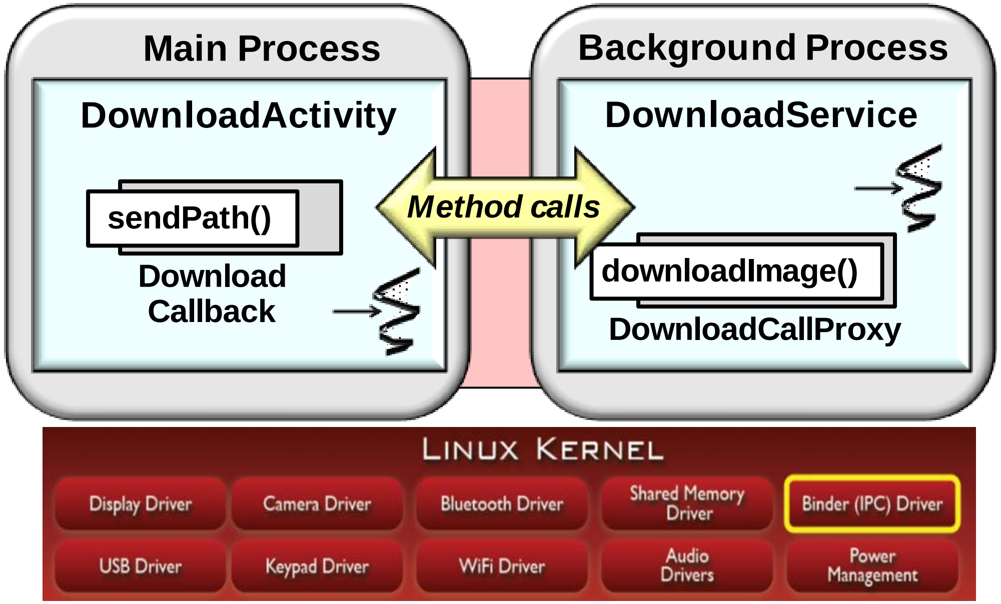

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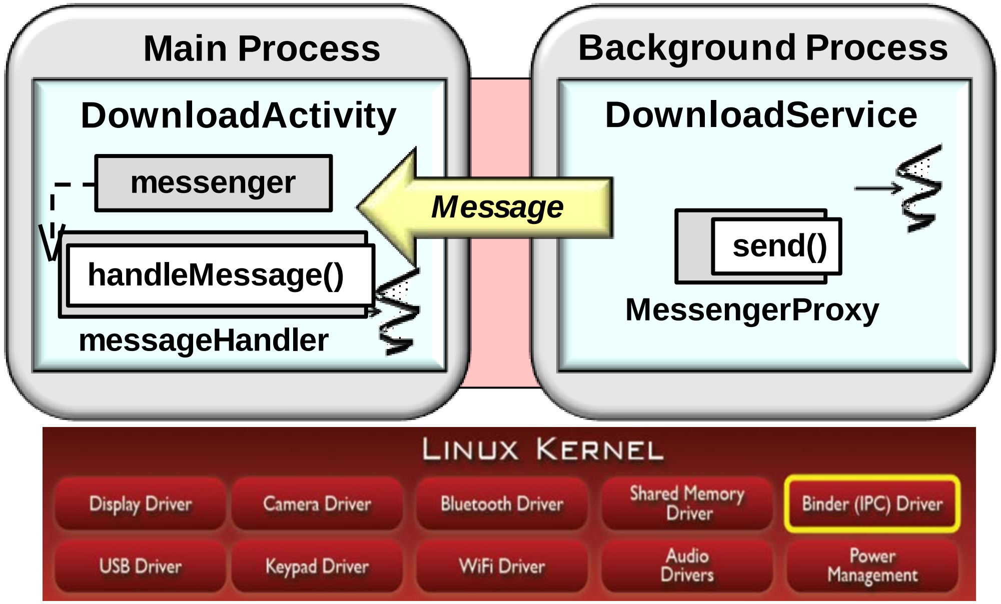

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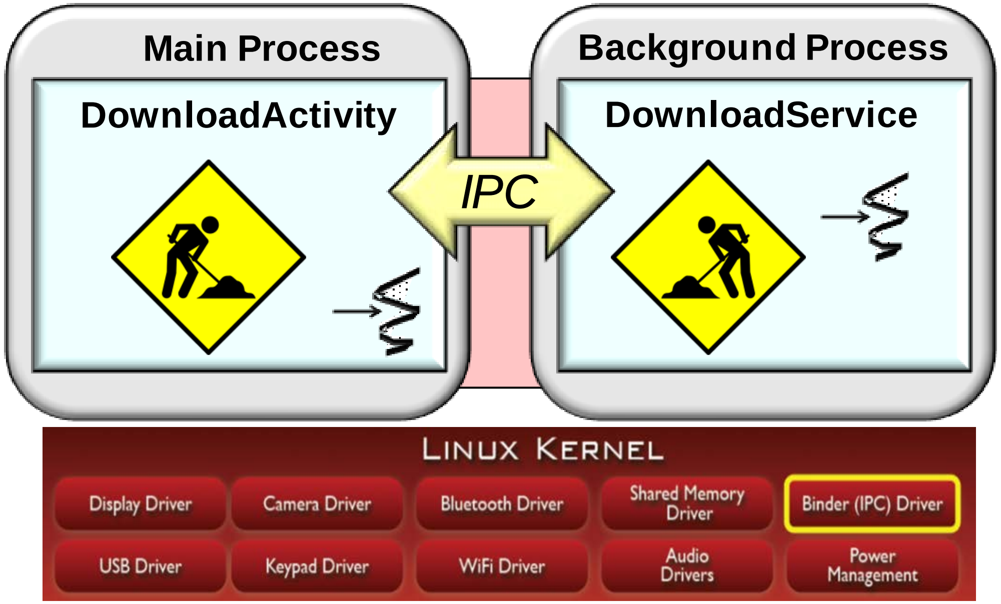
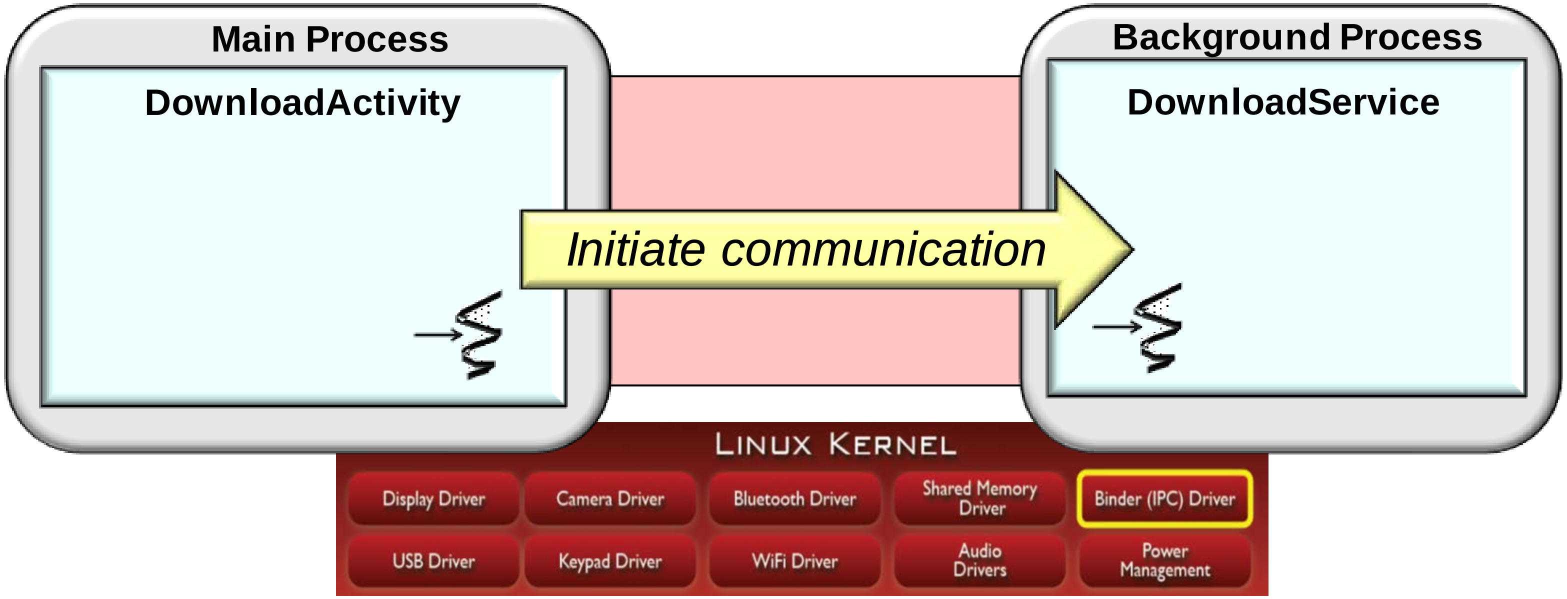


Running a Service in its own process may also require modifications to how data is exchanged

Communicating from Activities to Services

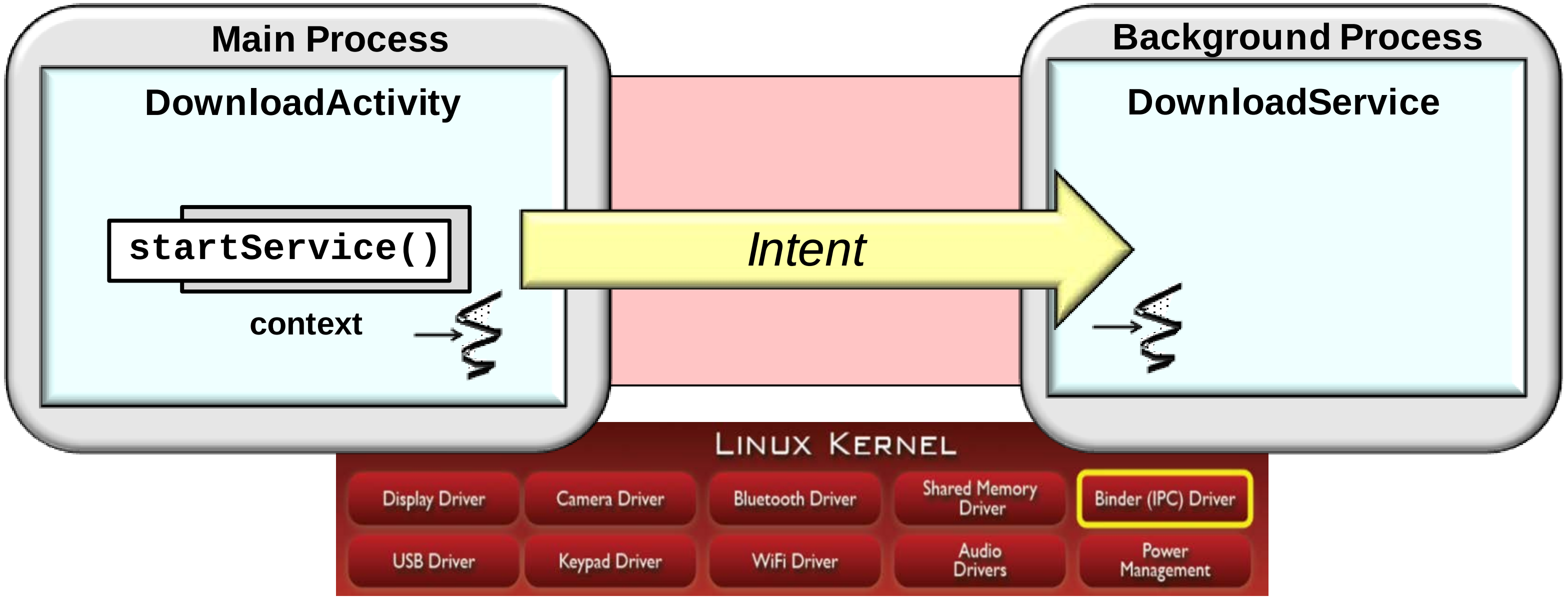
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service

Mechanism selection depends on factors like Started vs. Bound Services or message- vs. method-oriented

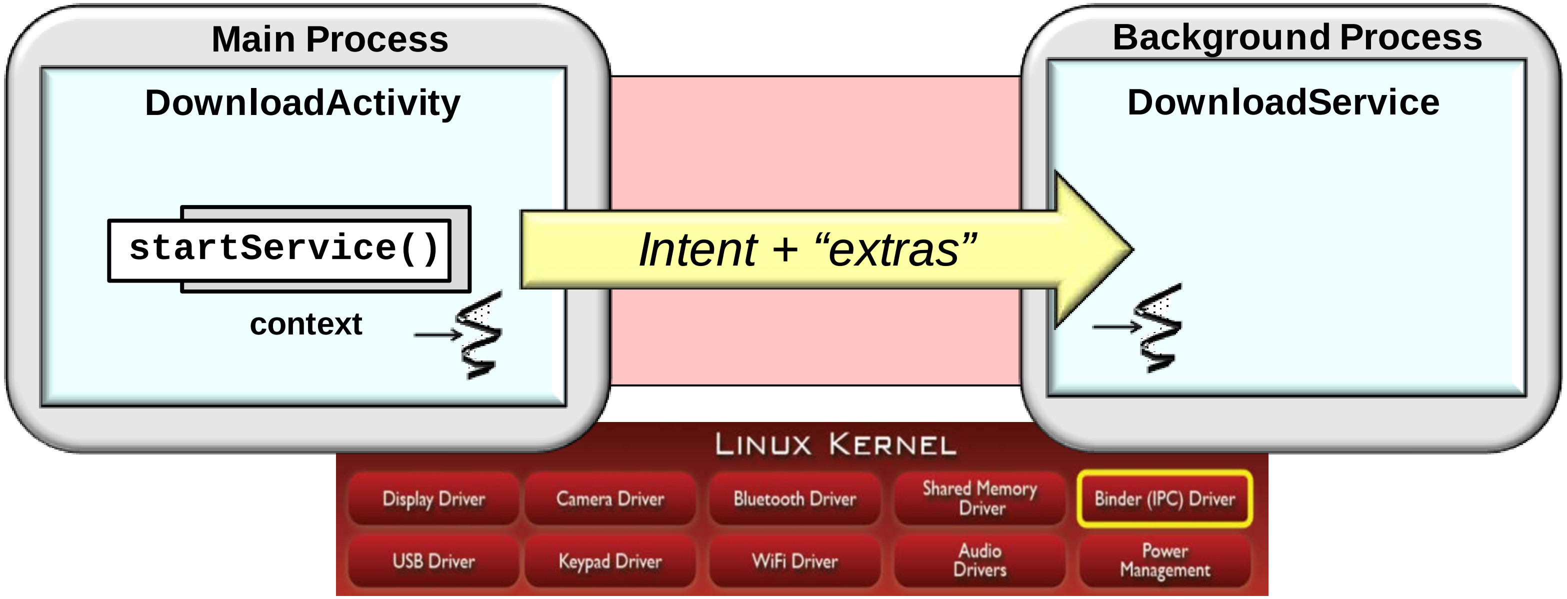
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()

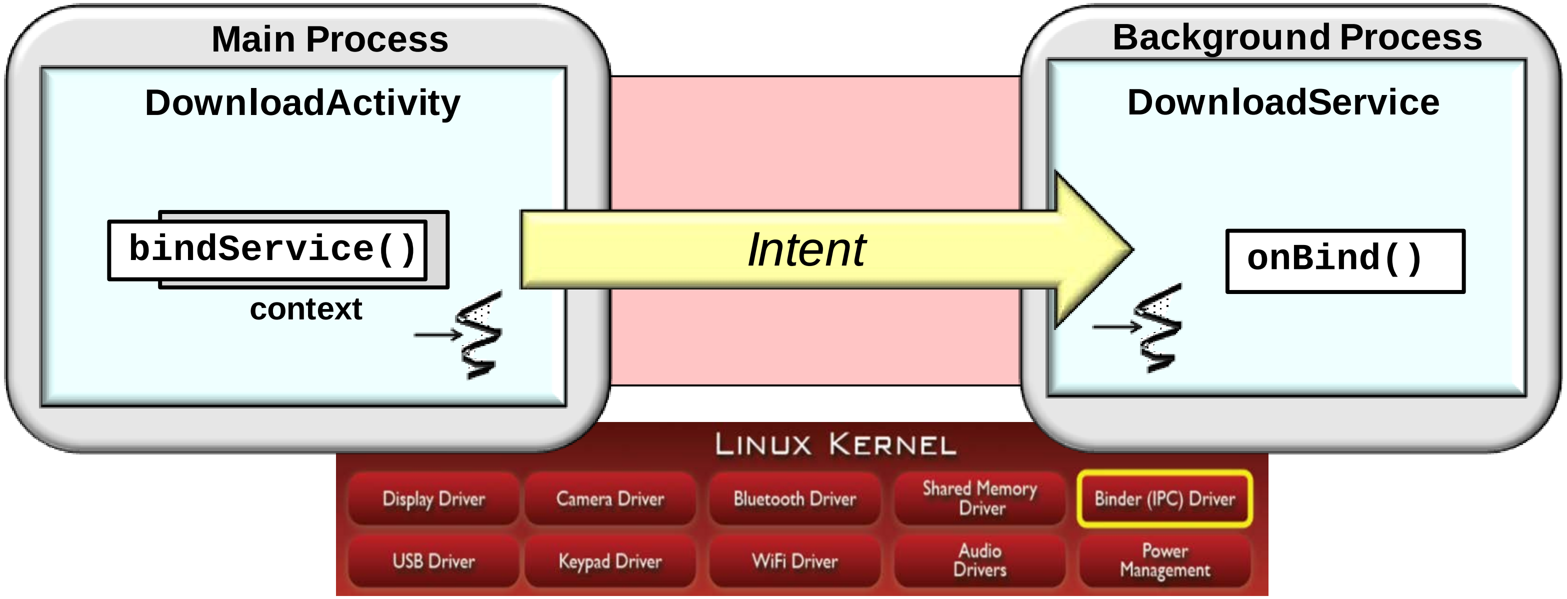
See earlier parts on “Programming Started Services” & “Android Intent Service”

Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
    - Parameters can be added as "extras" to the Intent used to start a Service

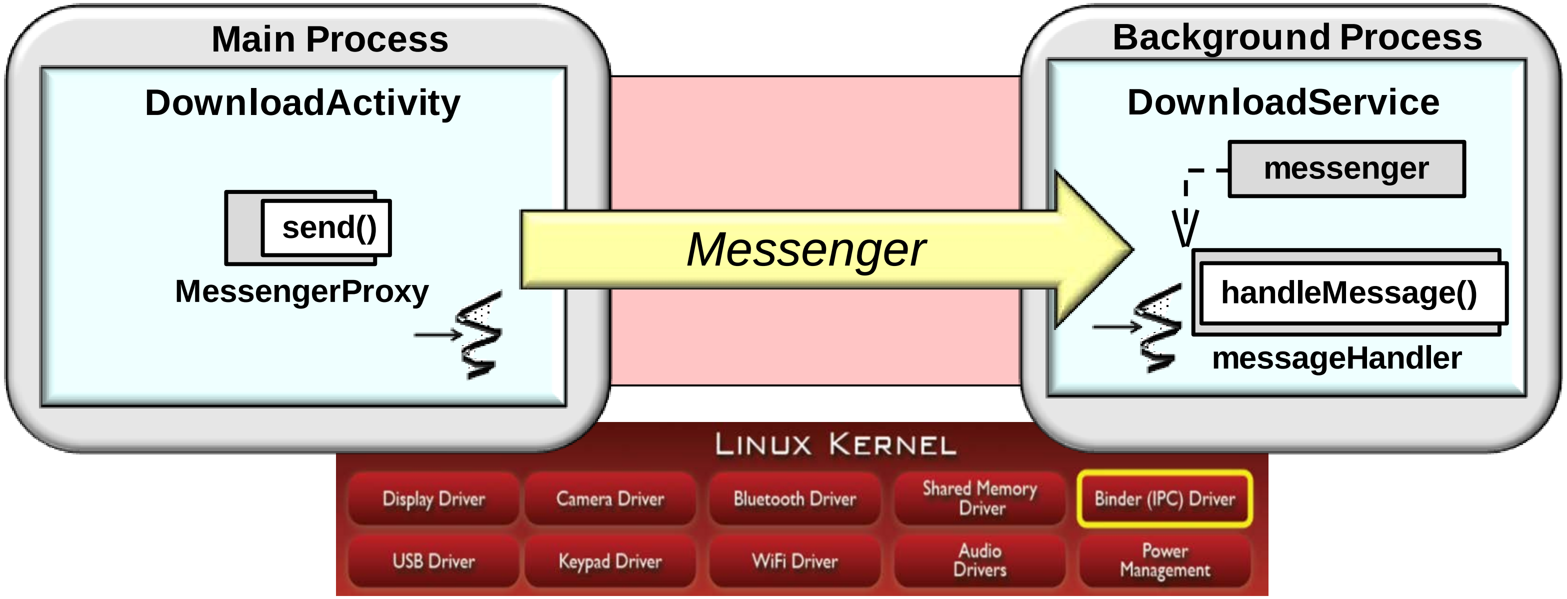
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
  - Bind to a Bound Service via BindService()

See earlier part on “Overview of Android Services”

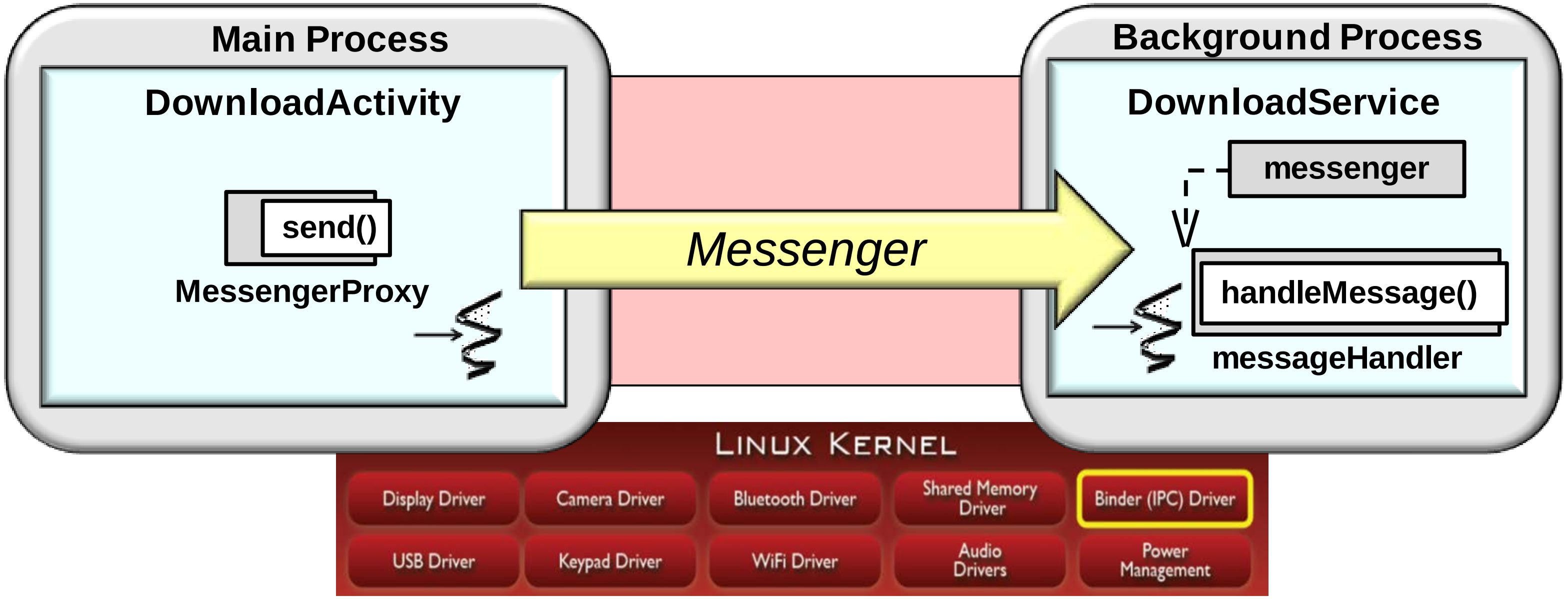
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
  - Bind to a Bound Service via BindService()
    - Call send() on a reference to a Messenger

See developer.android.com/reference/android/os/Messenger.html

Communicating from Activities to Services



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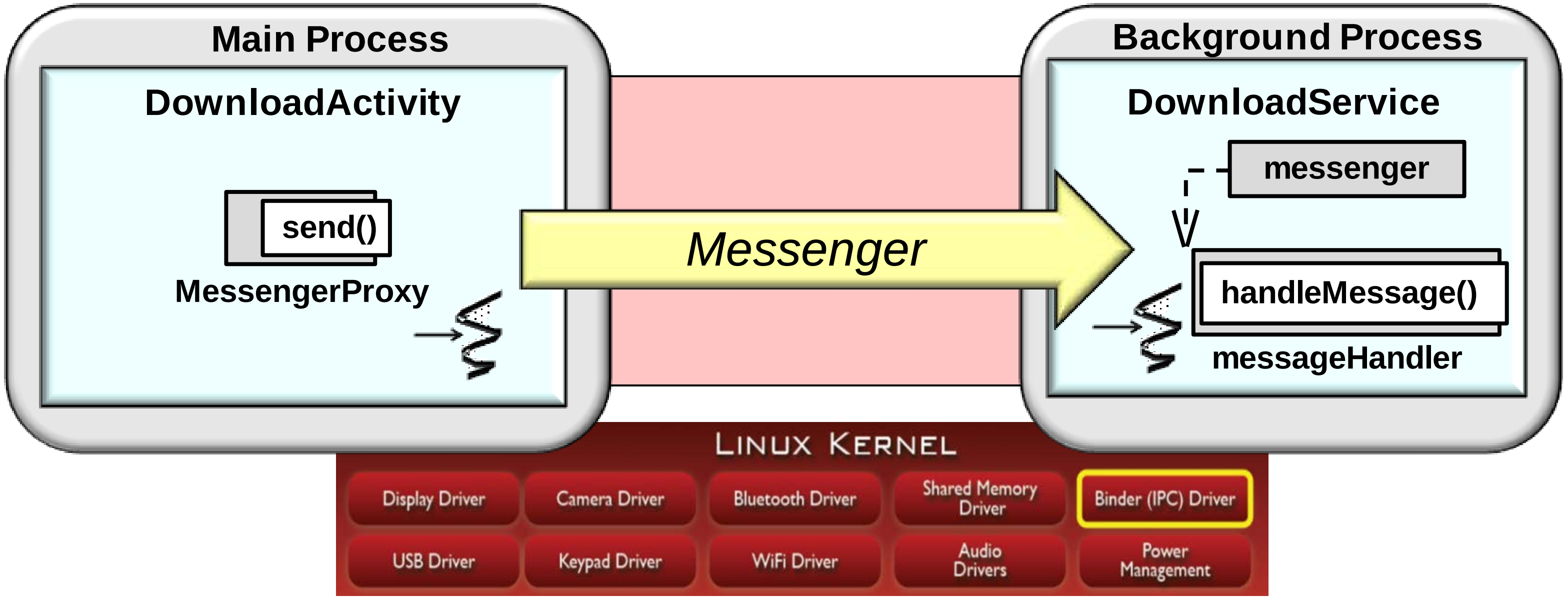
See earlier part on “Sending & Handling Messages with Android Handler”

Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
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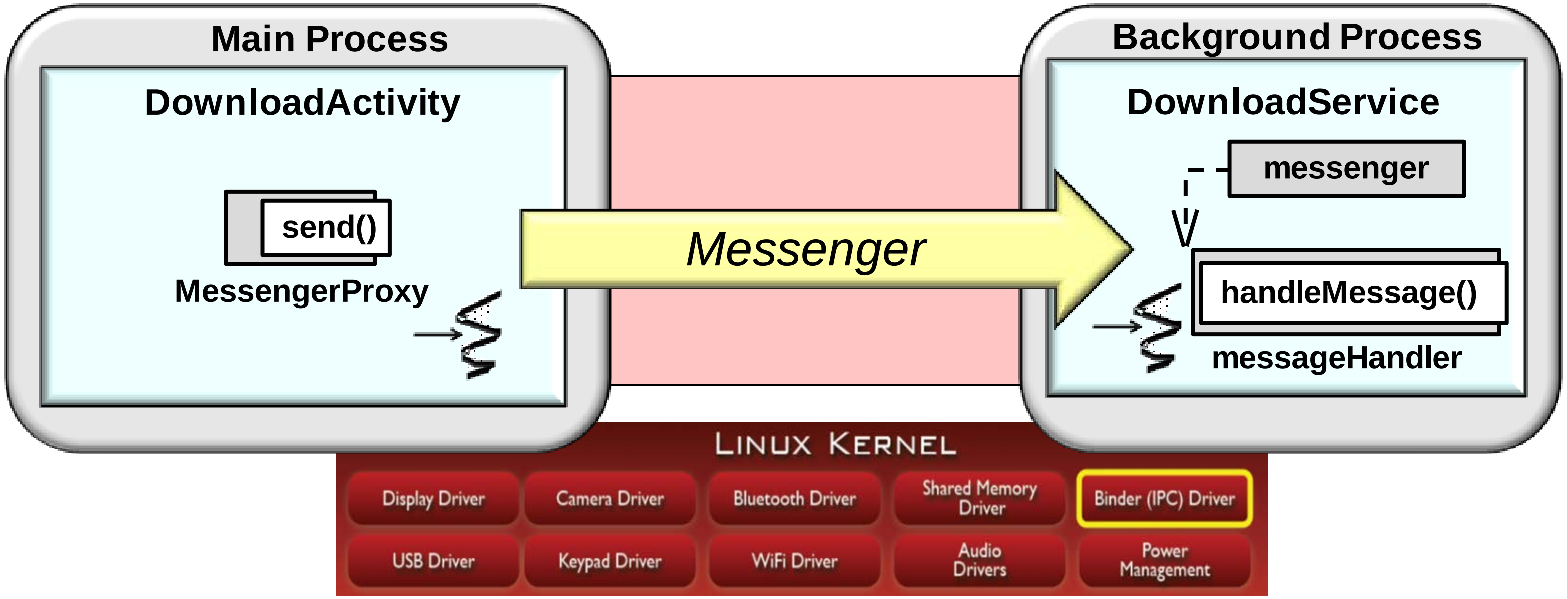
      - A Messenger encapsulates a Handler implemented within a Service

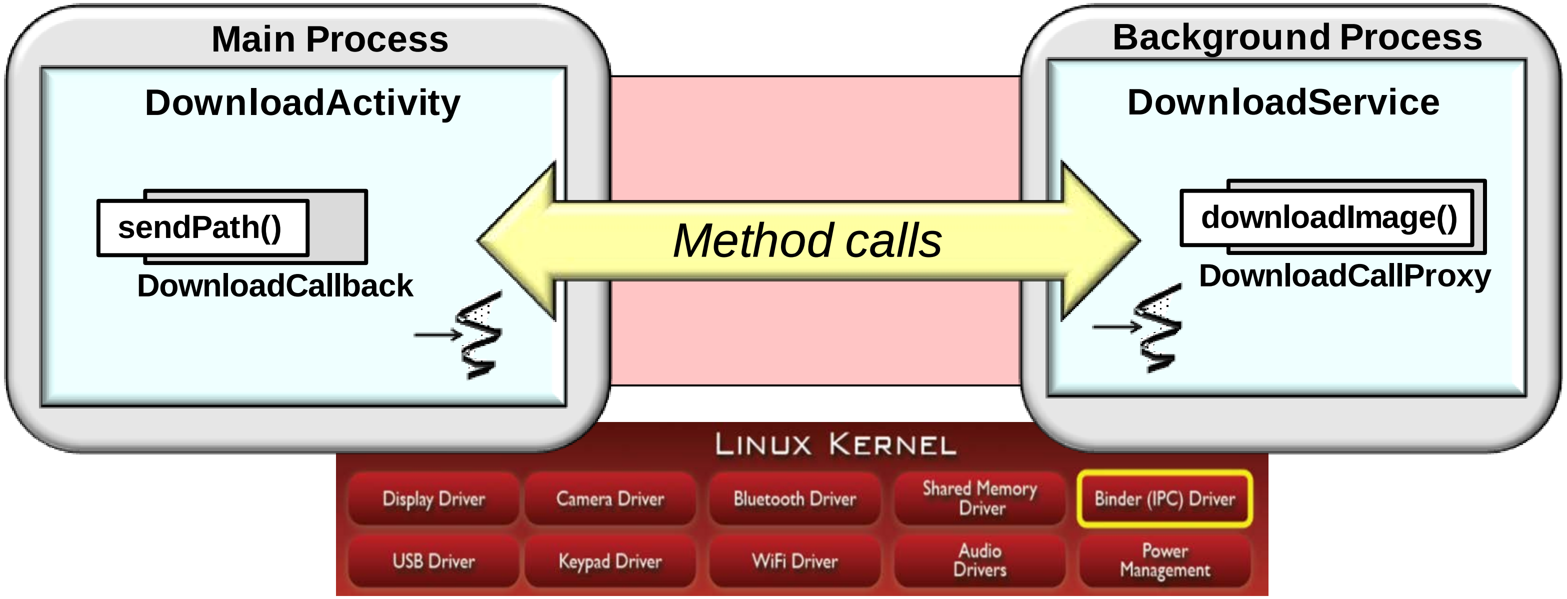
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
  - Bind to a Bound Service via BindService()
    - Call send() on a reference to a Messenger
      - A Messenger encapsulates a Handler implemented within a Service
      - Enables passing Messages to a Handler across process boundaries

See upcoming part on "Service to Activity Communication via Android Messenger"

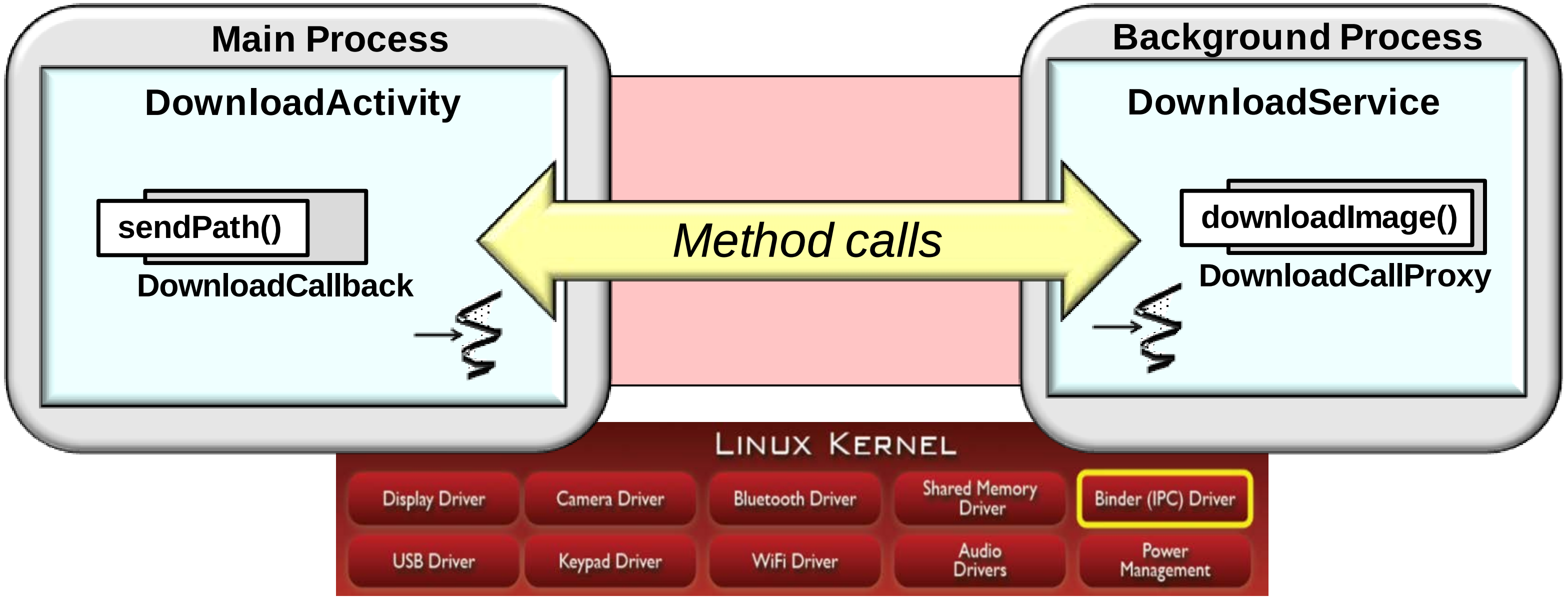
Communicating from Activities to Services



- Activities can use several mechanisms to communicate to a Service
  - Send an Intent command to Started Service via startService()
  - Bind to a Bound Service via BindService()
    - Call send() on a reference to a Messenger
    - Invoke method calls
      - Use stubs generated by the AIDL compiler

See developer.android.com/guide/components/aidl.html

Communicating from Activities to Services



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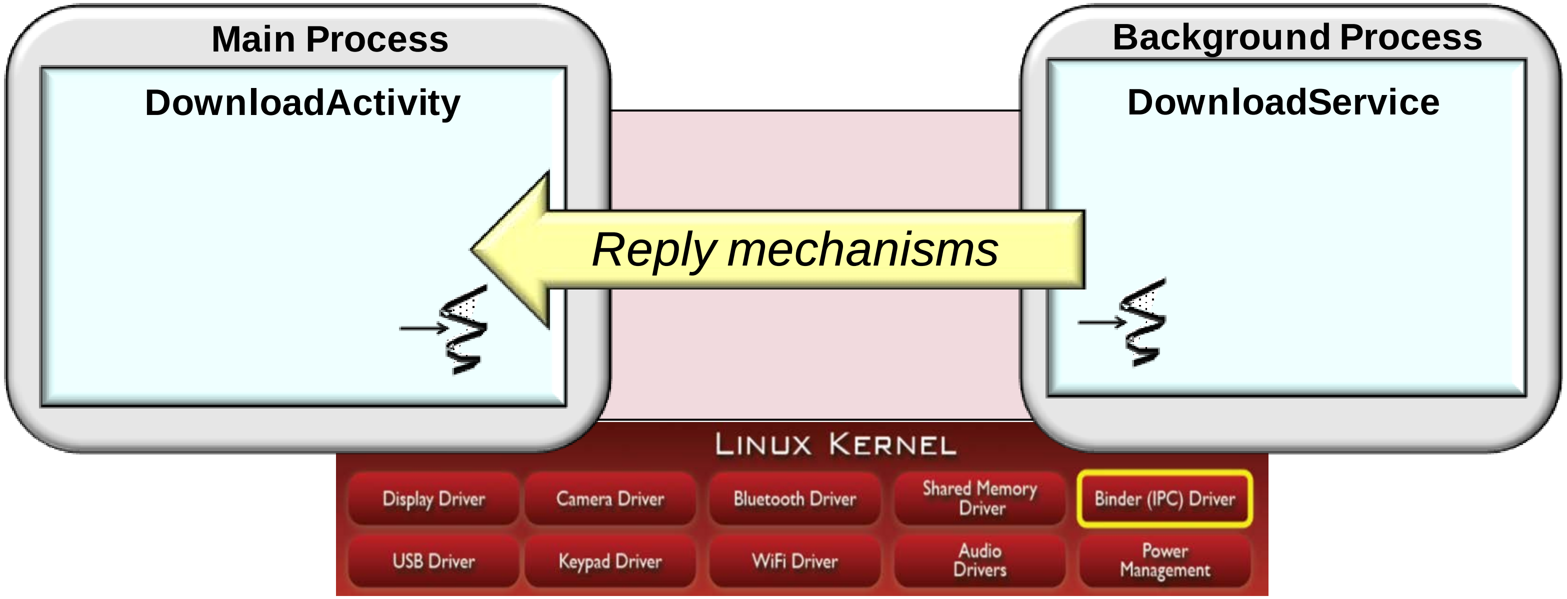
  - Send an Intent command to Started Service via startService()
  - Bind to a Bound Service via BindService()
    - Call send() on a reference to a Messenger
    - Invoke method calls
      - Use stubs generated by the AIDL compiler
      - These methods can be programmed to implement various behaviors

See upcoming part on "Programming Bound Services"

Communicating from Services to Activities

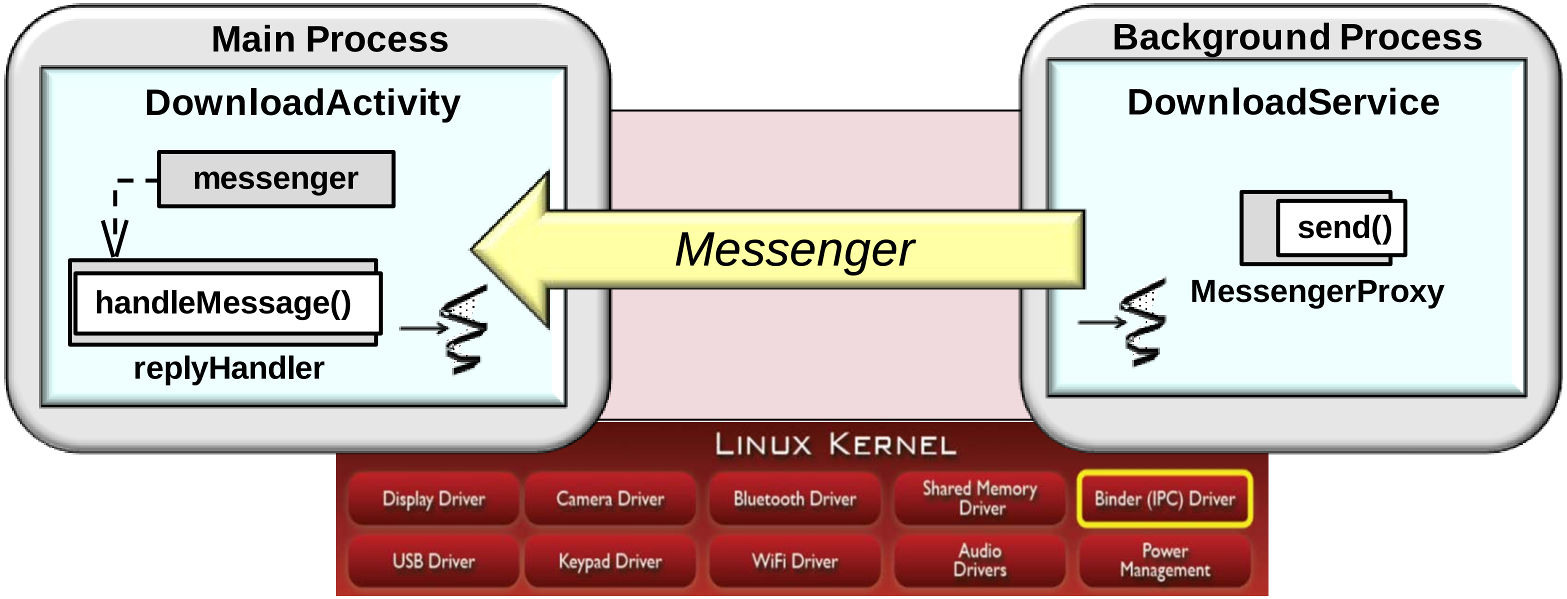
Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them

The Activity initiating the communication typically dictates the reply mechanism

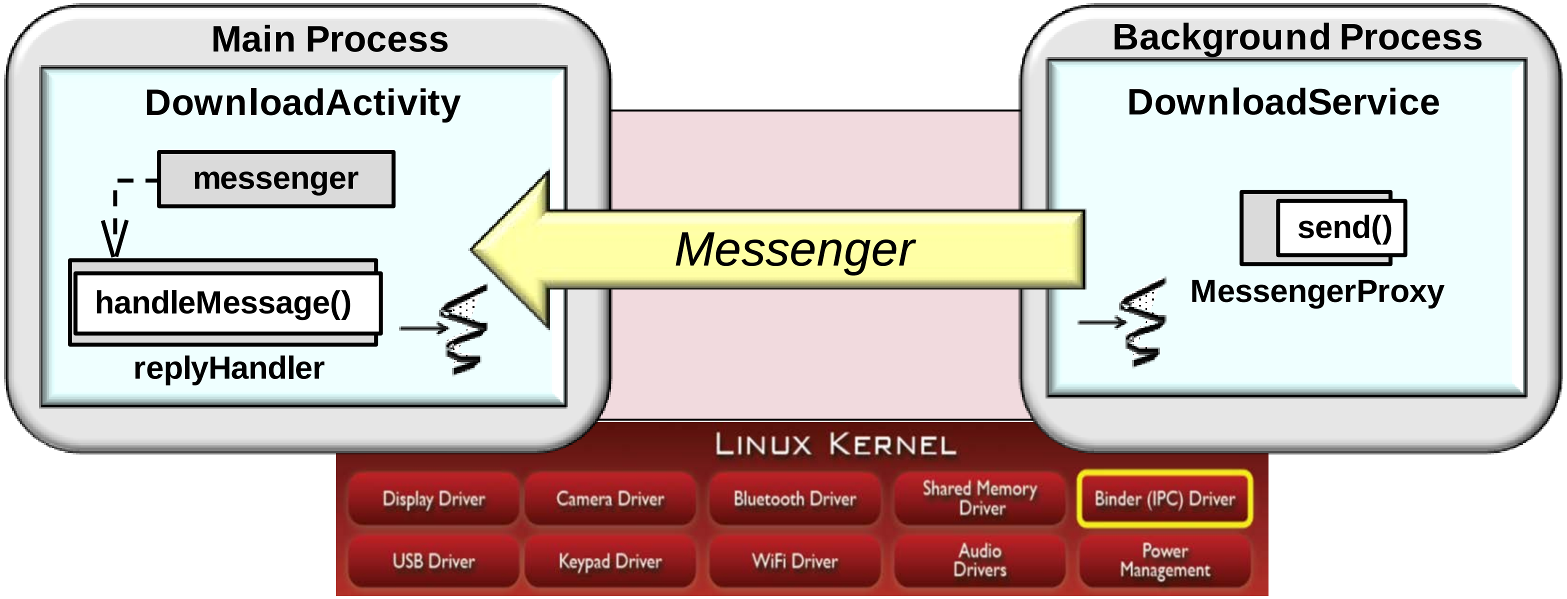
Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service

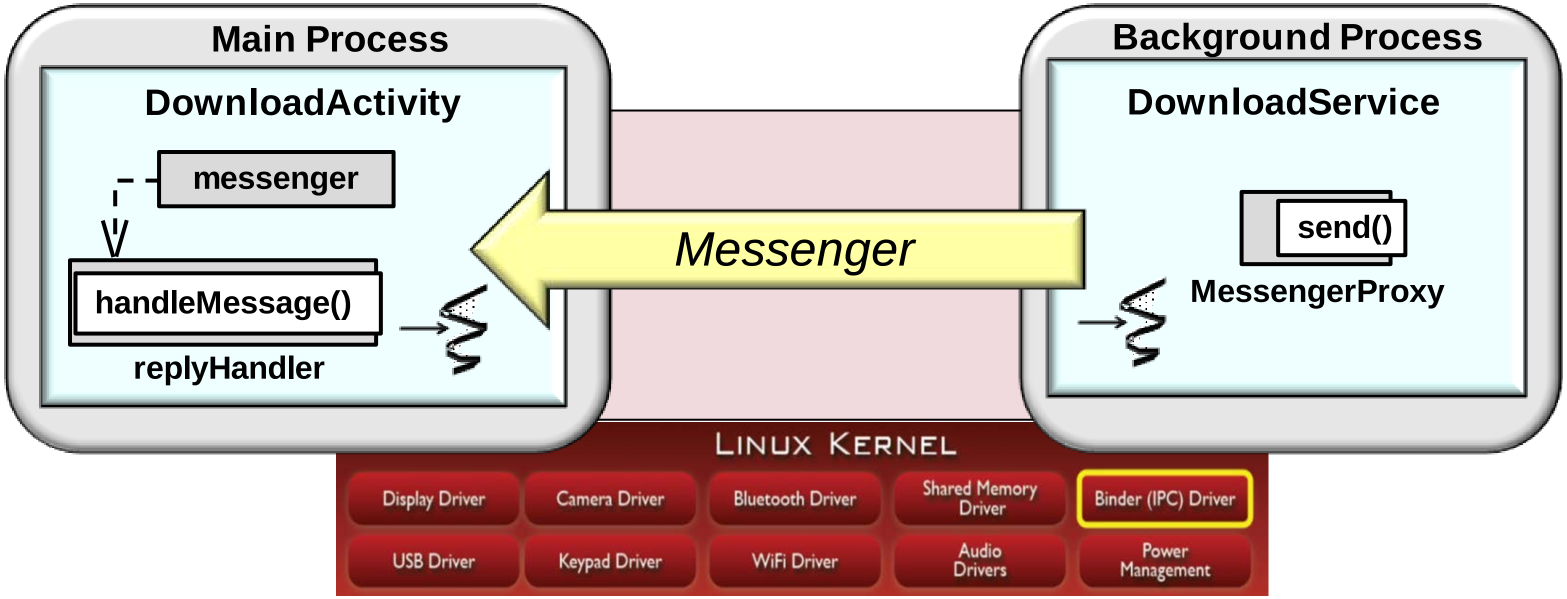
See developer.android.com/reference/android/os/Messenger.html

Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service
    - The Activity creates a Messenger Service & gives a reference to it to the Service

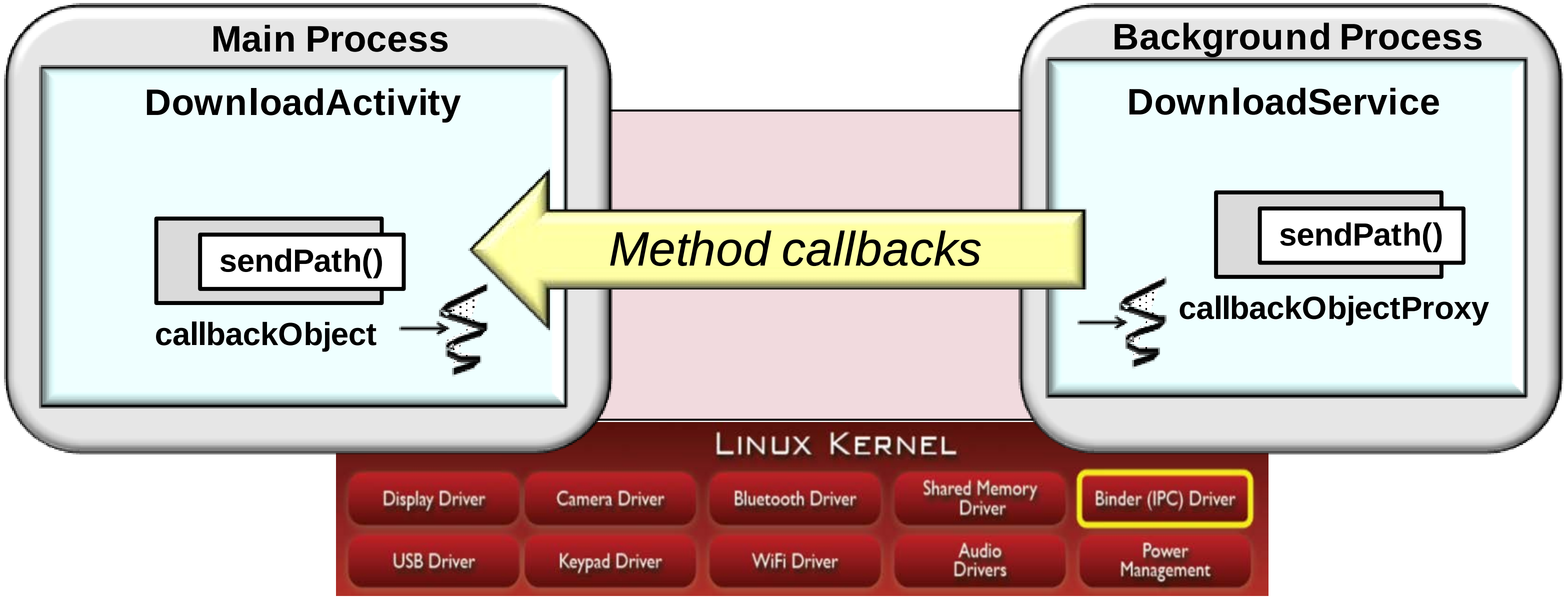
Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service
    - The Activity creates a Messenger Service & gives a reference to it to the Service
    - The Service then uses this Messenger to send reply Messages back to the Activity’s Handler

See upcoming part on “Service to Activity Communication via Android Messenger”

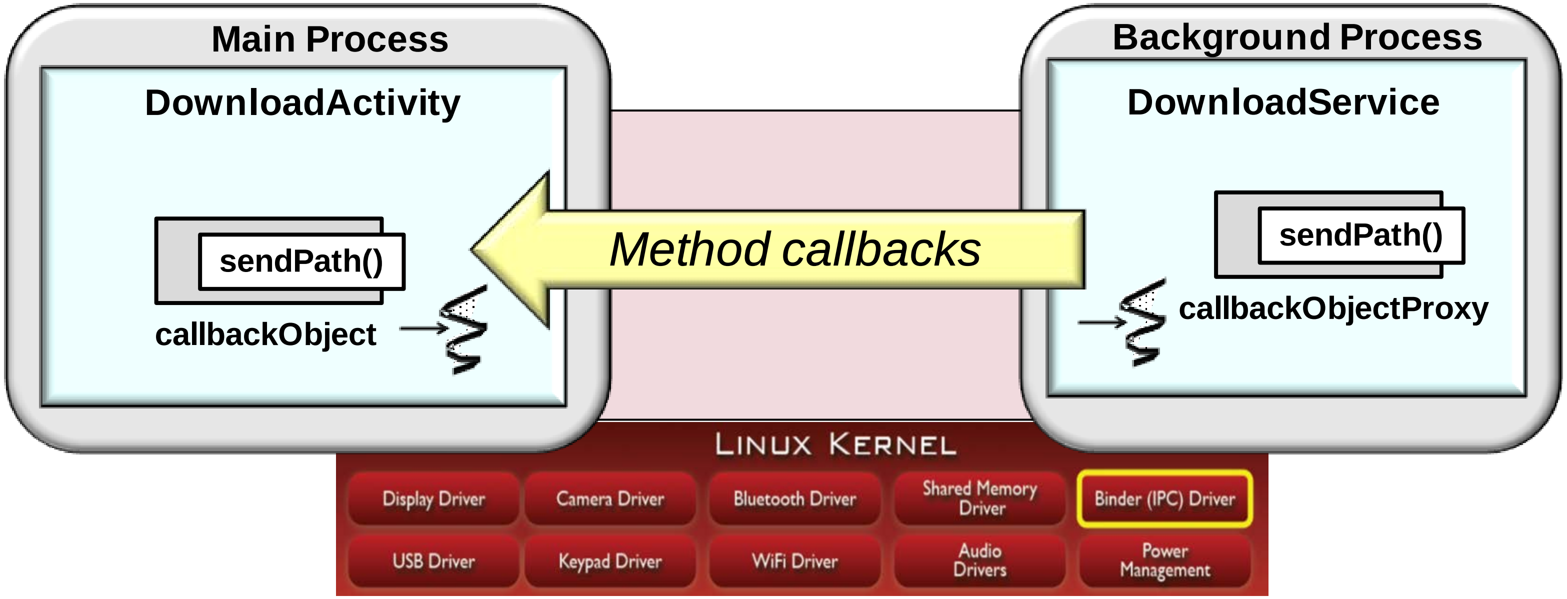
Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service
  - Use an AIDL-based callback object passed from the Activity to the Service

See developer.android.com/guide/components/aidl.html

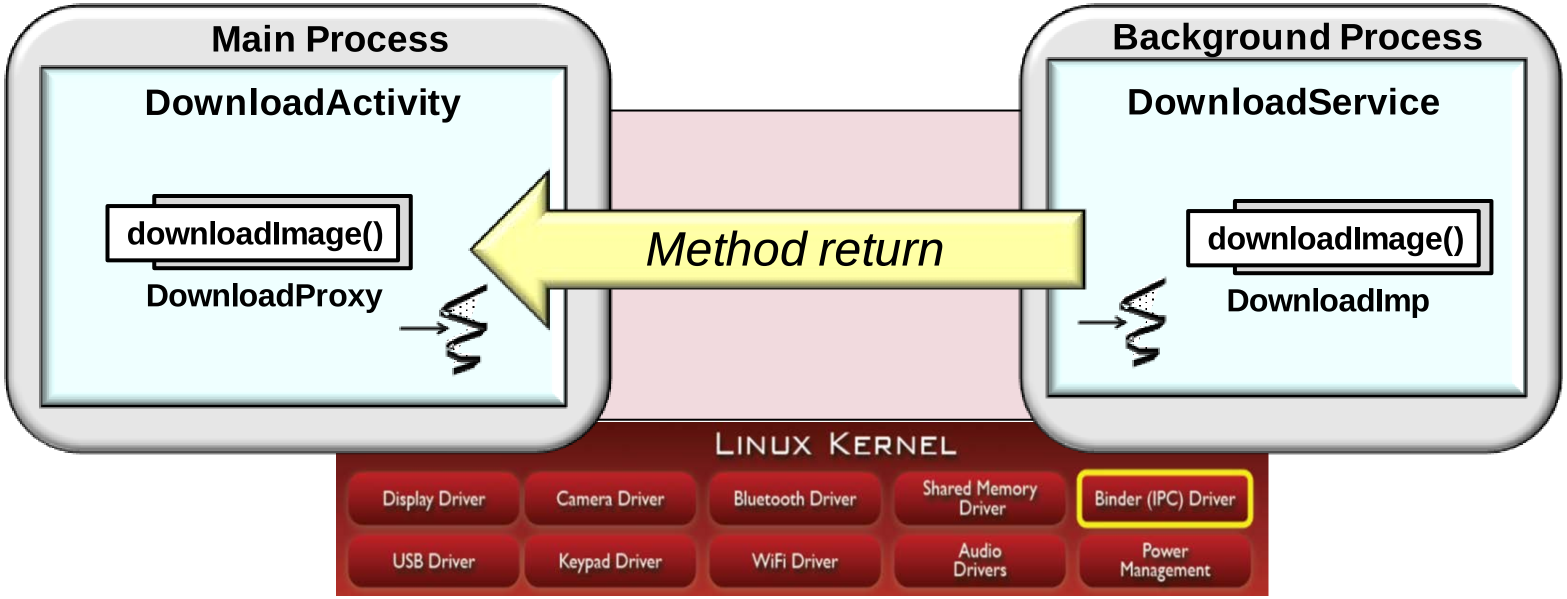
Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
    - Use a Messenger passed from the Activity to the Service
    - Use an AIDL-based callback object passed from the Activity to the Service
        - Invoke oneway method to return the reply to the Activity

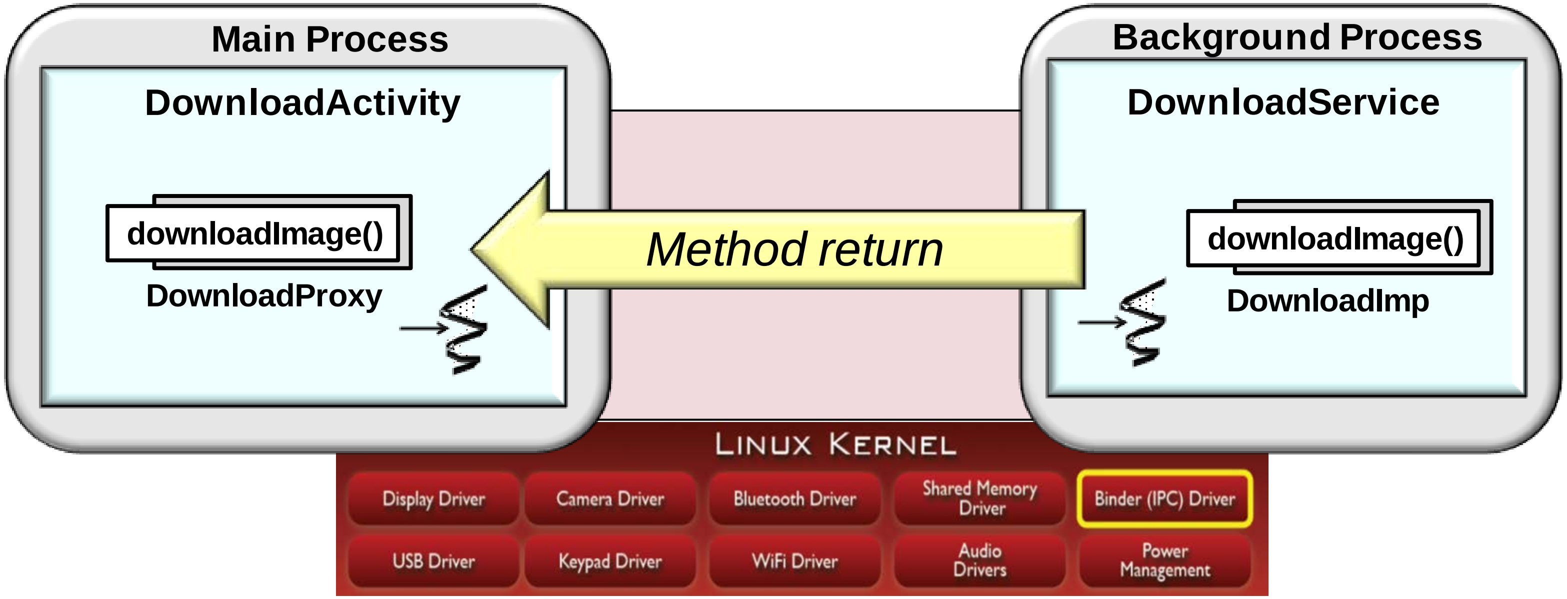
See upcoming part on
"Programming Bound Services"

Communicating from Services to Activities



- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service
  - Use an AIDL-based callback object passed from the Activity to the Service
  - Use an AIDL-based twoway method called from the Activity on the Service

Communicating from Services to Activities



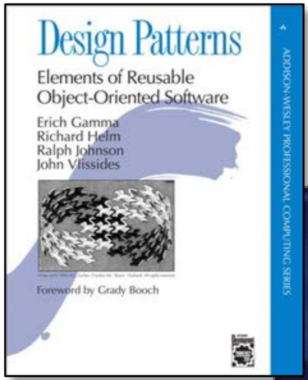
- Services can reply to Activities that initiated communication with them
  - Use a Messenger passed from the Activity to the Service
  - Use an AIDL-based callback object passed from the Activity to the Service
  - Use an AIDL-based twoway method called from the Activity on the Service
    - The return value and/or out parameters of the twoway method implementation implicitly sends a reply from the Service back to the Activity

Although twoway method calls seem convenient, they are problematic..

Patterns Used by Communication & Service Frameworks (Part 1)

Patterns in Android's Frameworks

- Android's frameworks & applications of these frameworks are designed, implemented, & integrated in accordance with many POSA & GoF patterns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Elements of Reusable Object-Oriented Software
Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides
Foreword by Grady Booch
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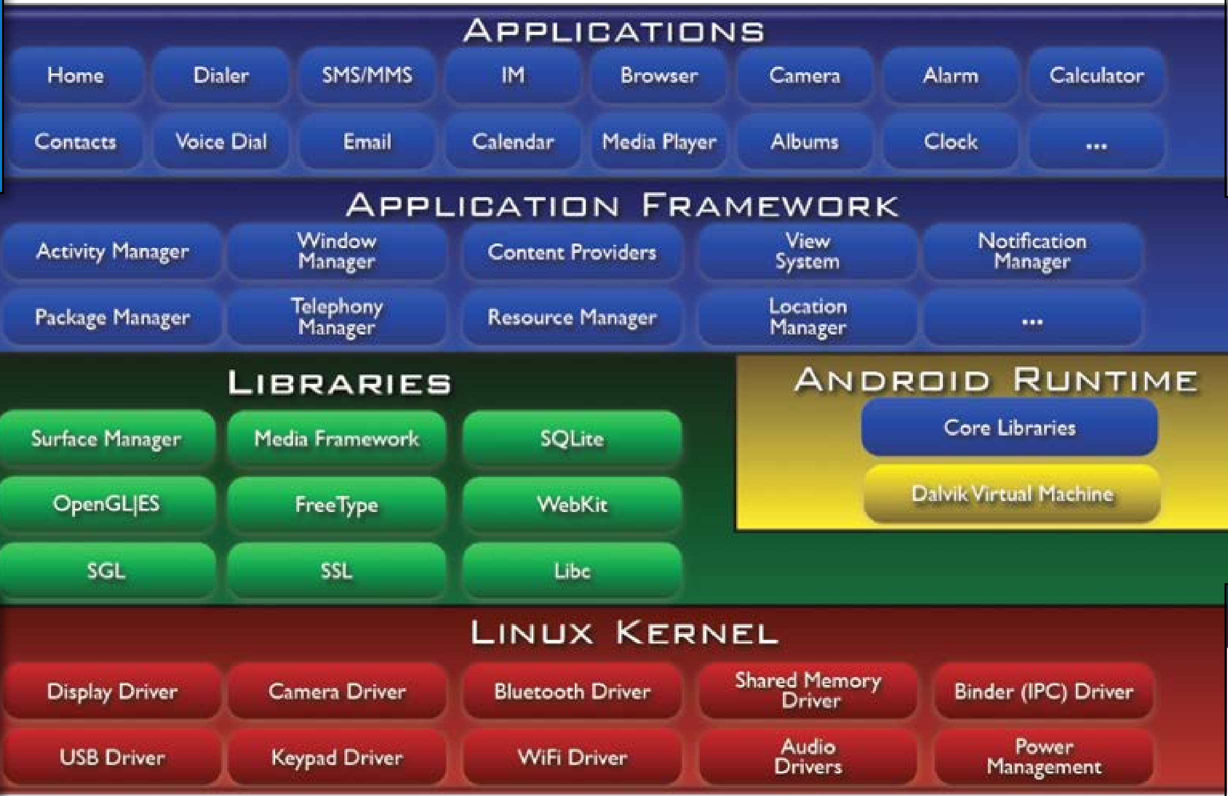


APPLICATIONS

Home | Dialer | SMS/MMS | IM | Browser | Camera | Alarm | Calculator

Contacts | Voice Dial | Email | Calendar | Media Player | Albums | Clock | ...

APPLICATION FRAMEWORK

Activity Manager | Window Manager | Content Providers | View System | Notification Manager

Package Manager | Telephony Manager | Resource Manager | Location Manager | ...

LIBRARIES

Surface Manager | Media Framework | SQLite

OpenGL|ES | FreeType | WebKit

SGL | SSL | Libc

ANDROID RUNTIME

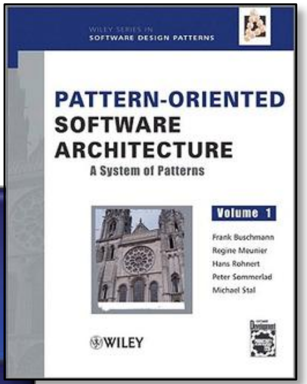
Core Libraries

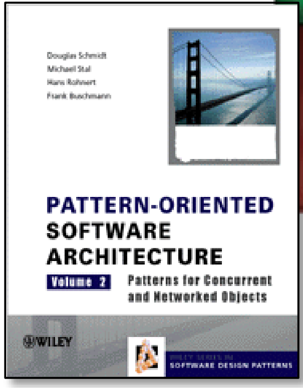
Dalvik Virtual Machine

LINUX KERNEL

Display Driver | Camera Driver | Bluetooth Driver | Shared Memory Driver | Binder (IPC) Driver

USB Driver | Keypad Driver | WiFi Driver | Audio Drivers | Power Management

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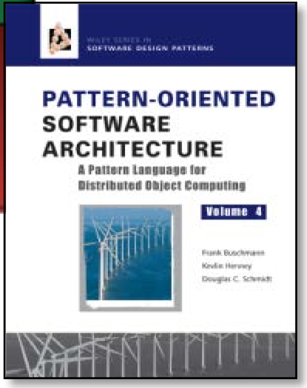
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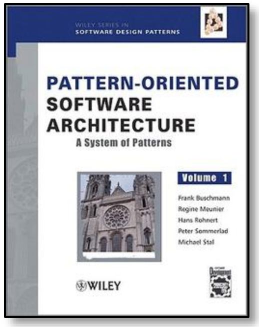
Kevlin Henney
Douglas C. Schmidt

Patterns in Android's Frameworks

- Android's frameworks & applications of these frameworks are designed, implemented, & integrated in accordance with many POSA & GoF patterns
  - We've summarized key patterns used in Android's concurrency frameworks



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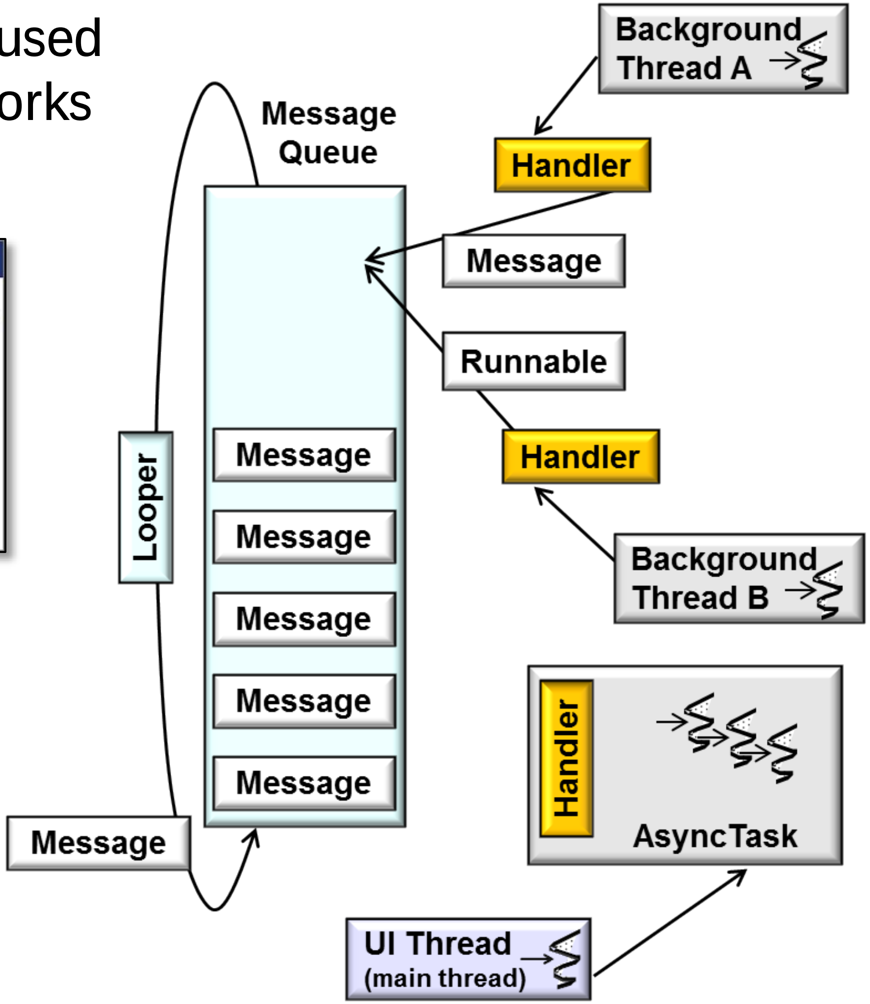
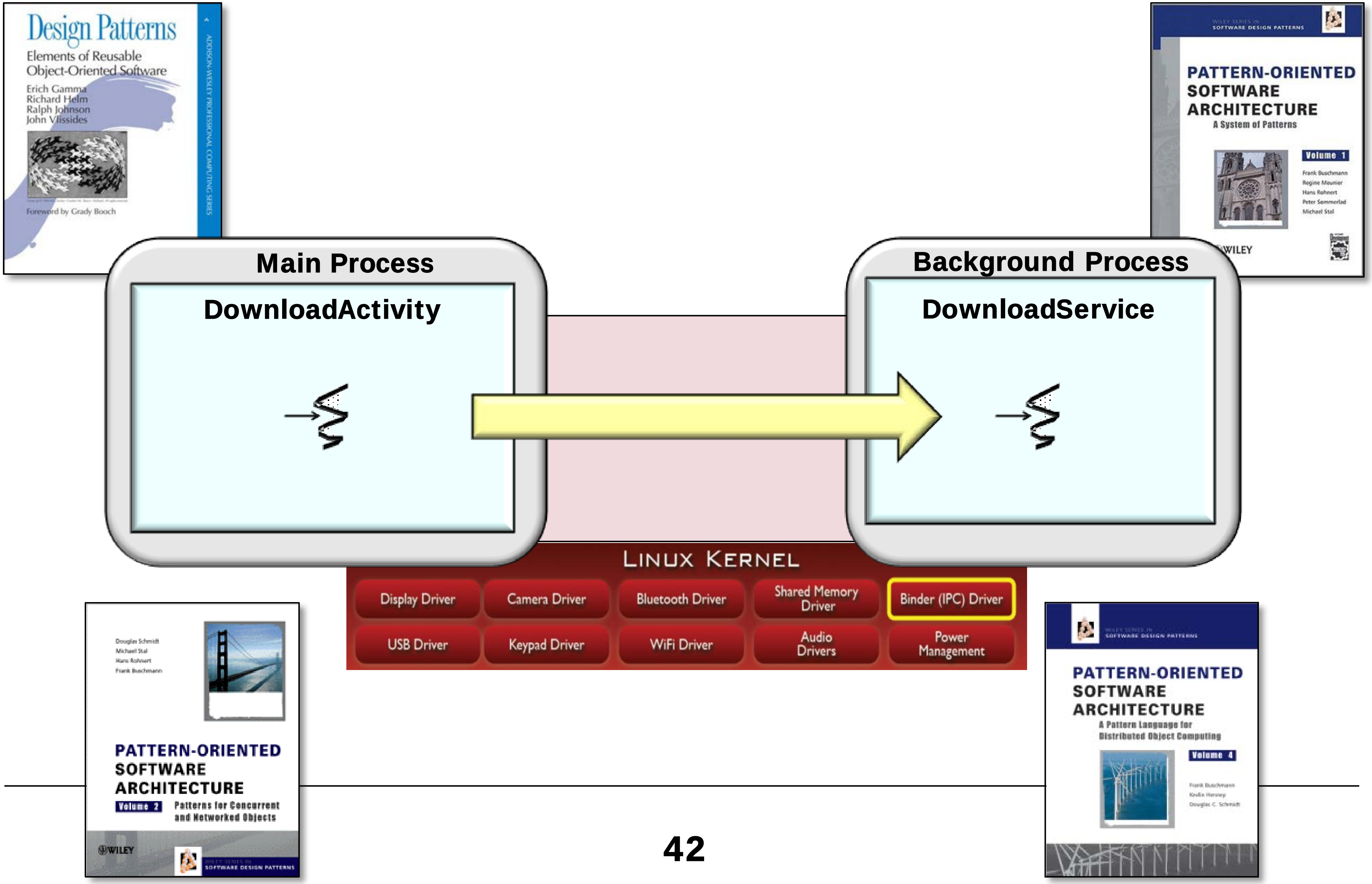


See earlier part on "Overview of Patterns & Frameworks (Part 2)"

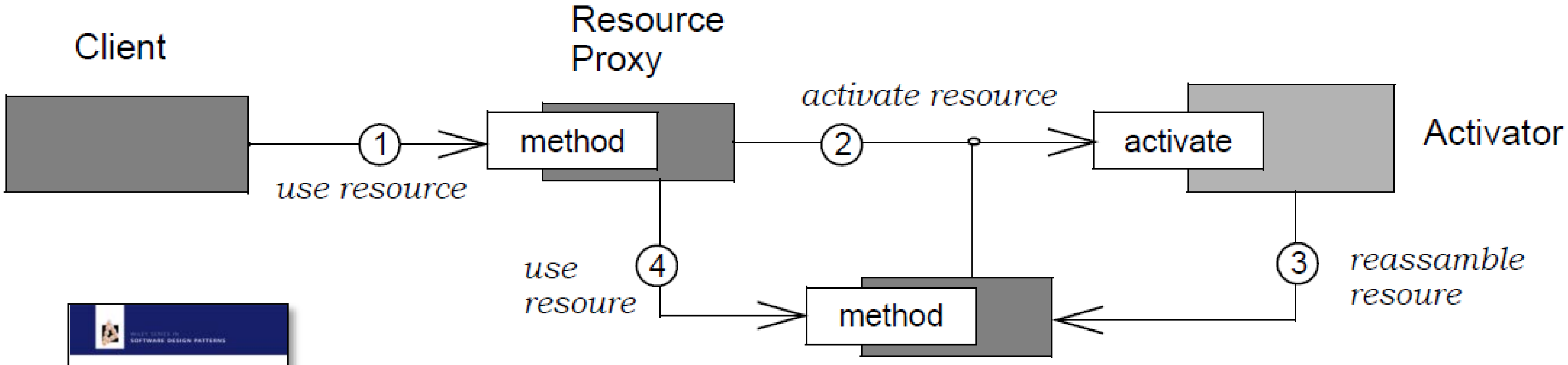
Patterns in Communication & Service Frameworks

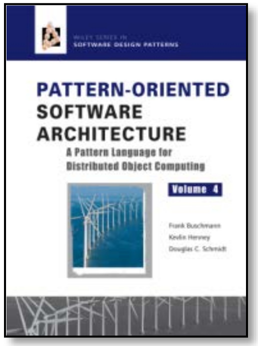
- Android's communication & service frameworks apply POSA & GoF patterns



Patterns in Communication & Service Frameworks

- Android's communication & service frameworks apply POSA & GoF patterns
  - *Activator* – Automate scalable on-demand activation & deactivation of service execution contexts to run services accessed by multiple clients without consuming resources unnecessarily





www.dre.vanderbilt.edu/~schmidt/PDF/Activator.pdf has more info

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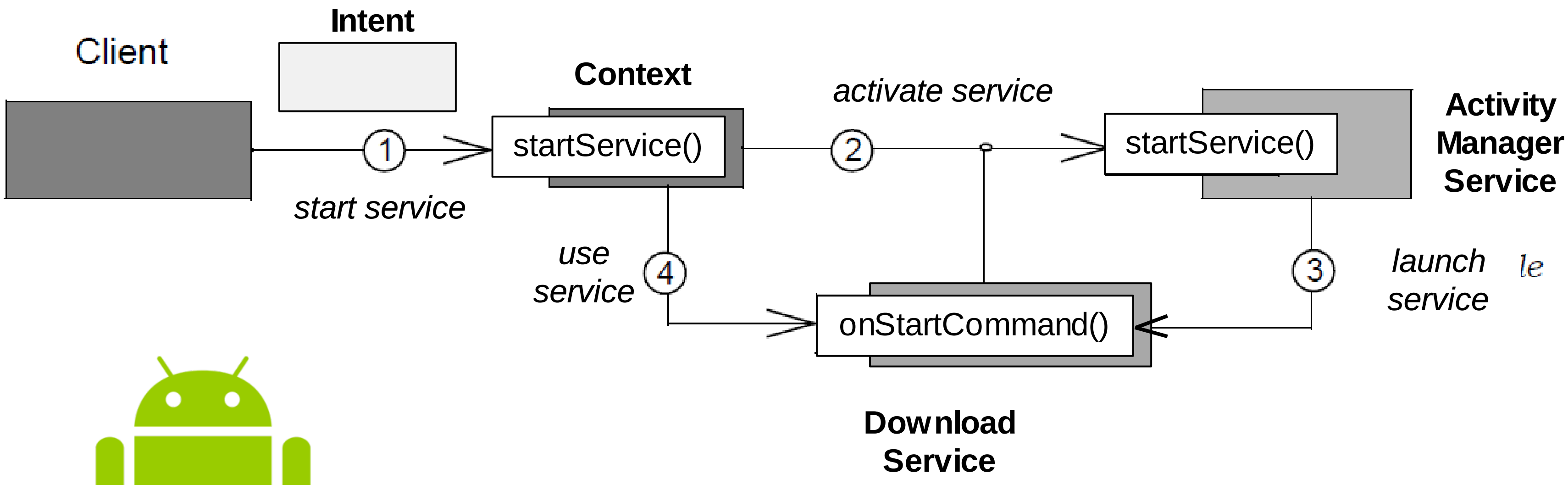

See upcoming part on "The Activator Pattern"

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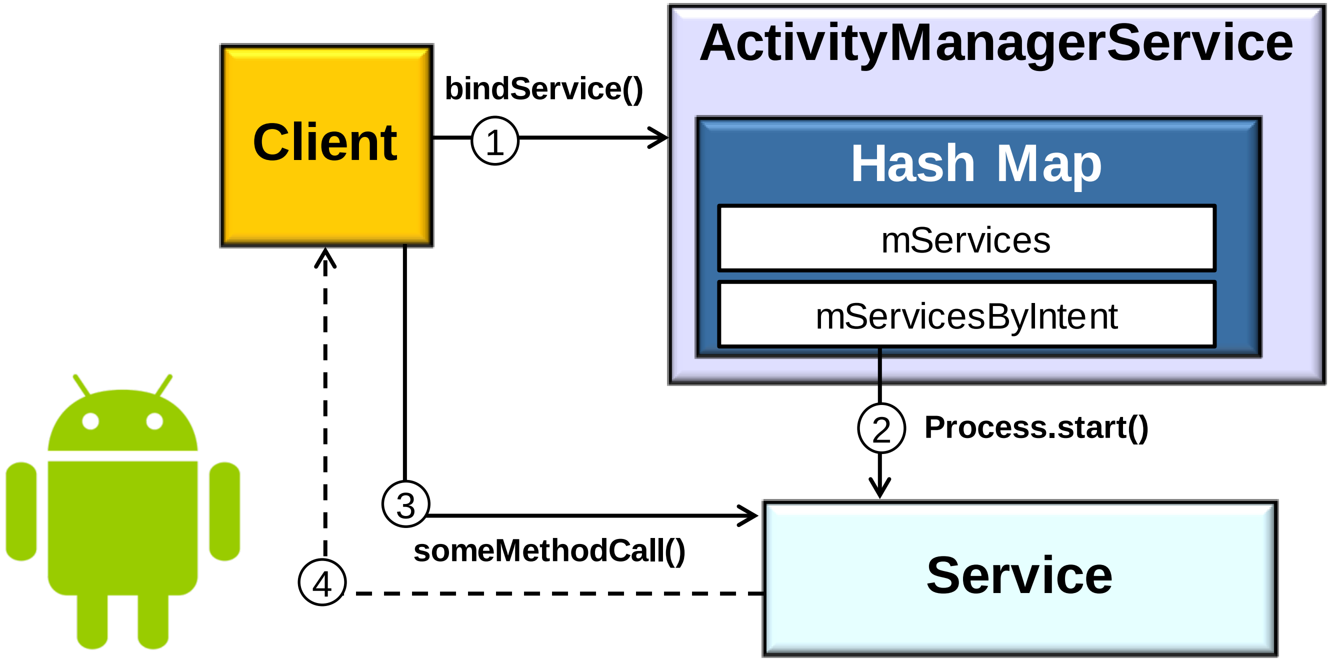

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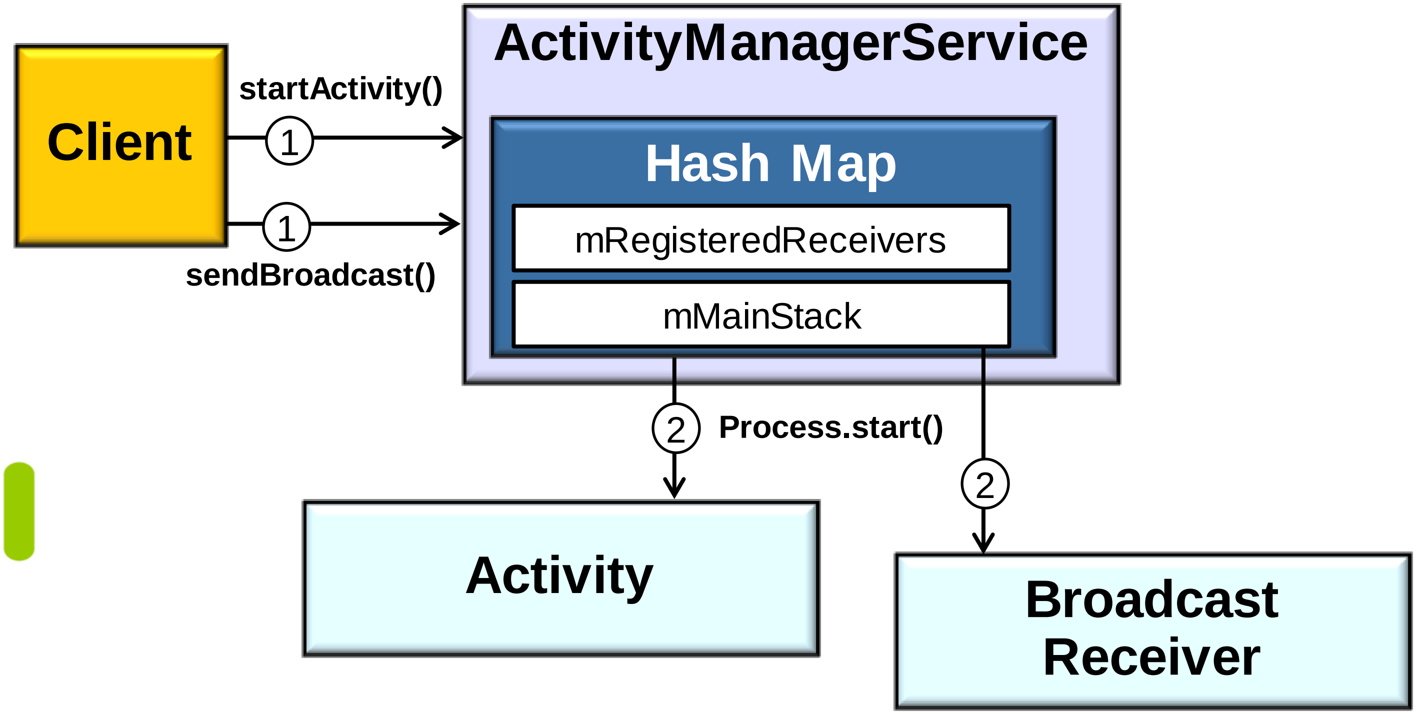
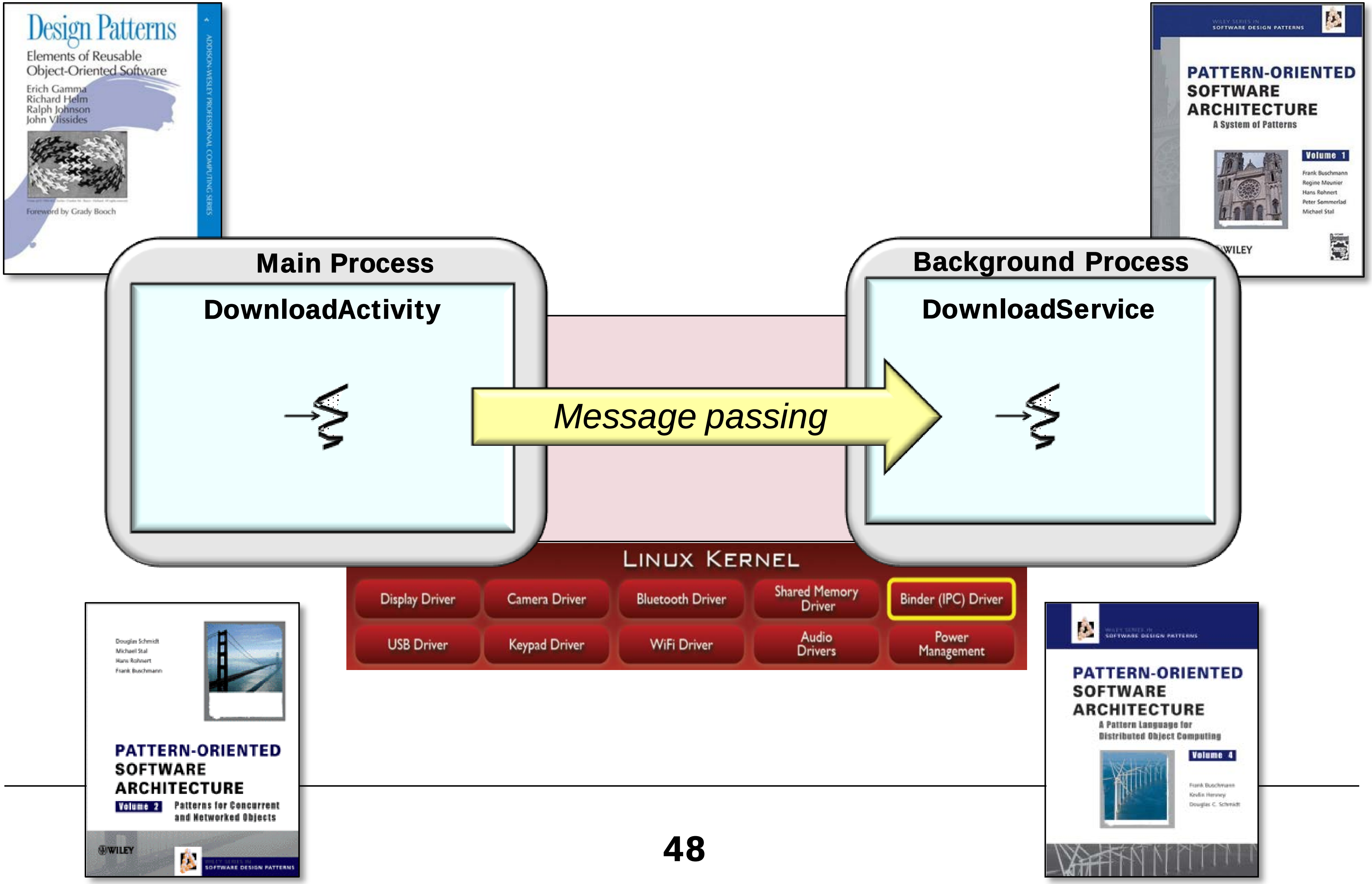


See frameworks/base/services/java/com/android/server/am for source code

Patterns Used by Communication & Service Frameworks (Part 2)

Patterns in Communication & Service Frameworks

- Android's communication & service frameworks apply POSA & GoF patterns



Main Process

DownloadActivity

Message passing

Background Process

DownloadService

LINUX KERNEL

Display Driver

Camera Driver

Bluetooth Driver

Shared Memory Driver

Binder (IPC) Driver

USB Driver

Keypad Driver

WiFi Driver

Audio Drivers

Power Management

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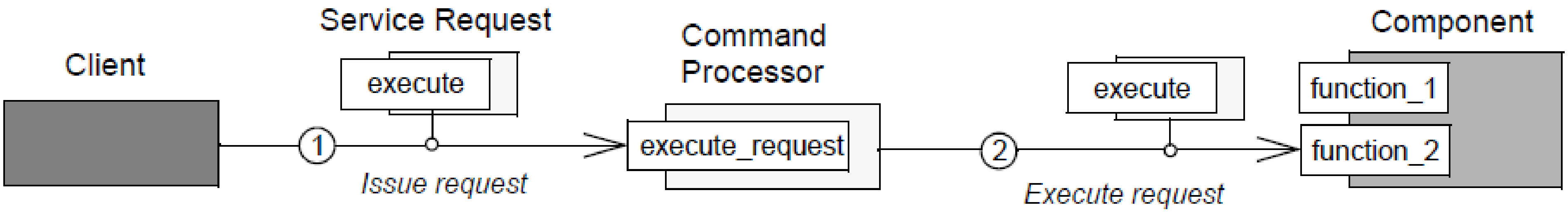
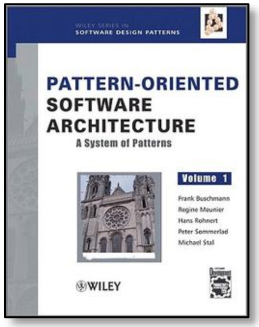
Patterns in Communication & Service Frameworks

- Android's communication & service frameworks apply POSA & GoF patterns
  - *Command Processor* – package a piece of application functionality—as well as its parameterization in an object—to execute it in another context
    - e.g., at a later point in time, in a different process or thread, etc.





www.dre.vanderbilt.edu/~schmidt/PDF/CommandRevisited.pdf has more info

Patterns in Communication & Service Frameworks

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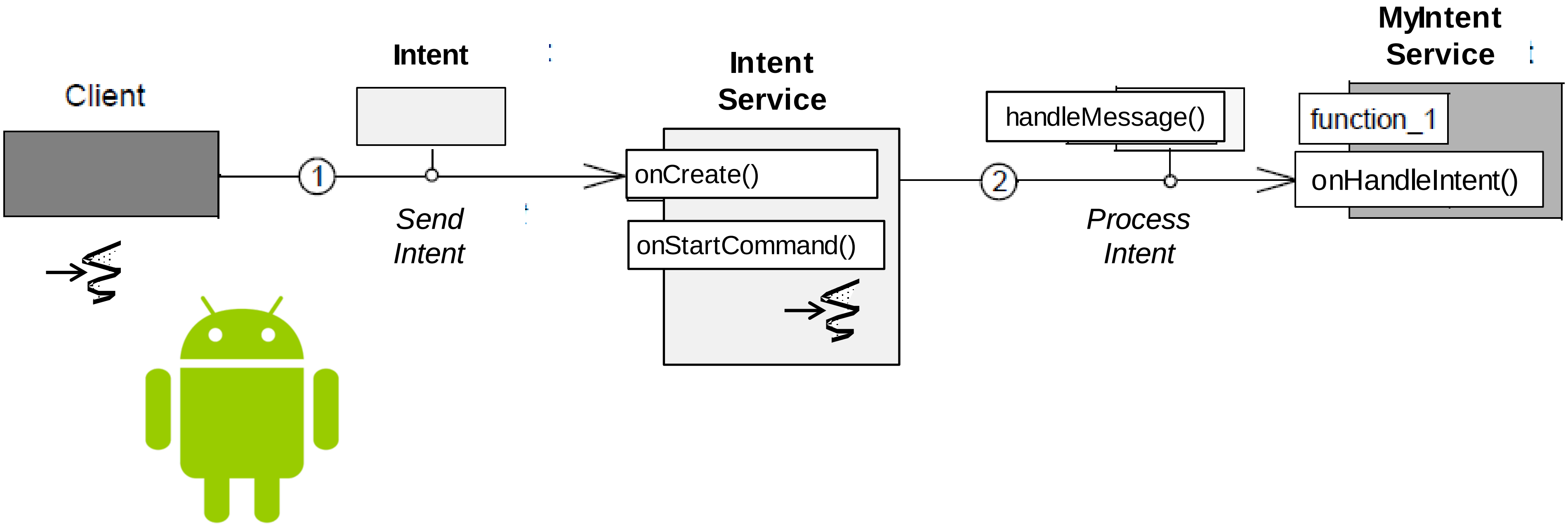

See earlier part on the "Android IntentService"

Patterns in Communication & Service Frameworks

- Android's communication & service frameworks apply POSA & GoF patterns
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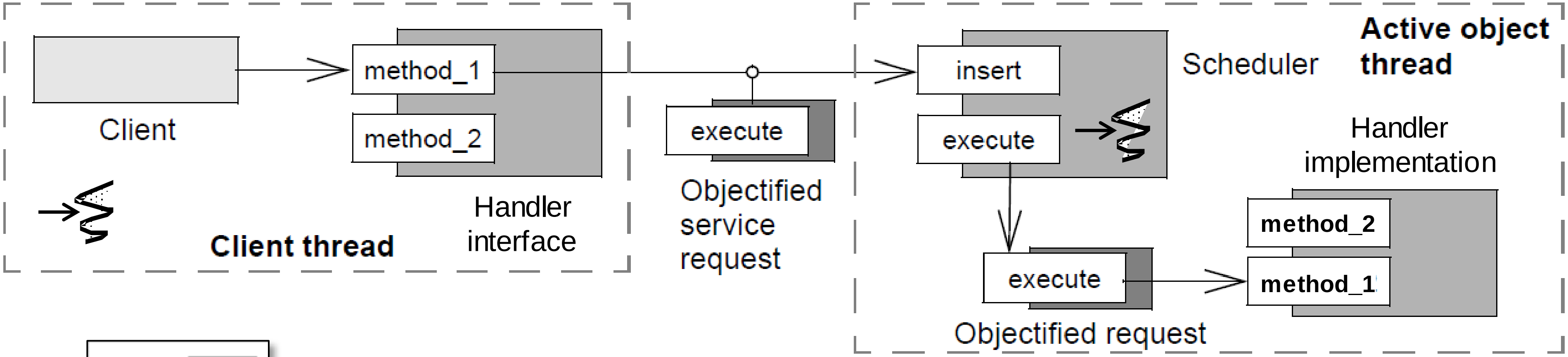

www.dre.vanderbilt.edu/~schmidt/PDF/Act-Obj.pdf has more info

Patterns in Communication & Service Frameworks

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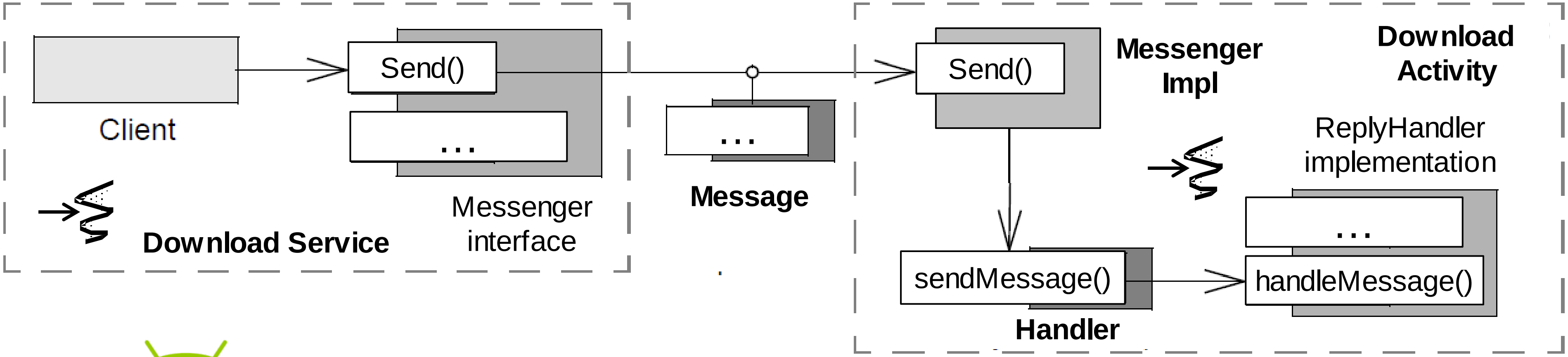
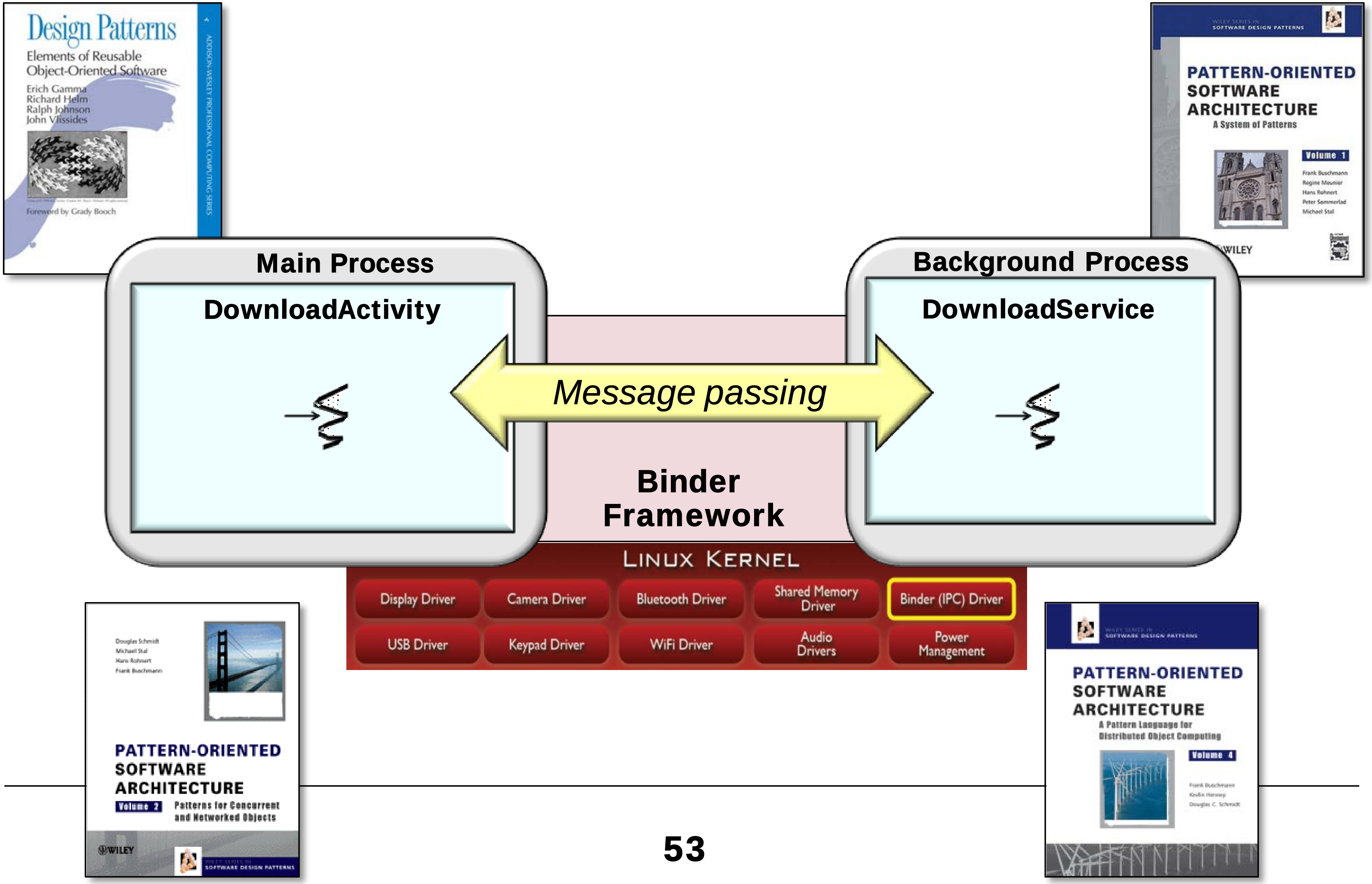


See upcoming part on "Service to Activity Communication via Android Messenger"

Patterns in Communication & Service Frameworks

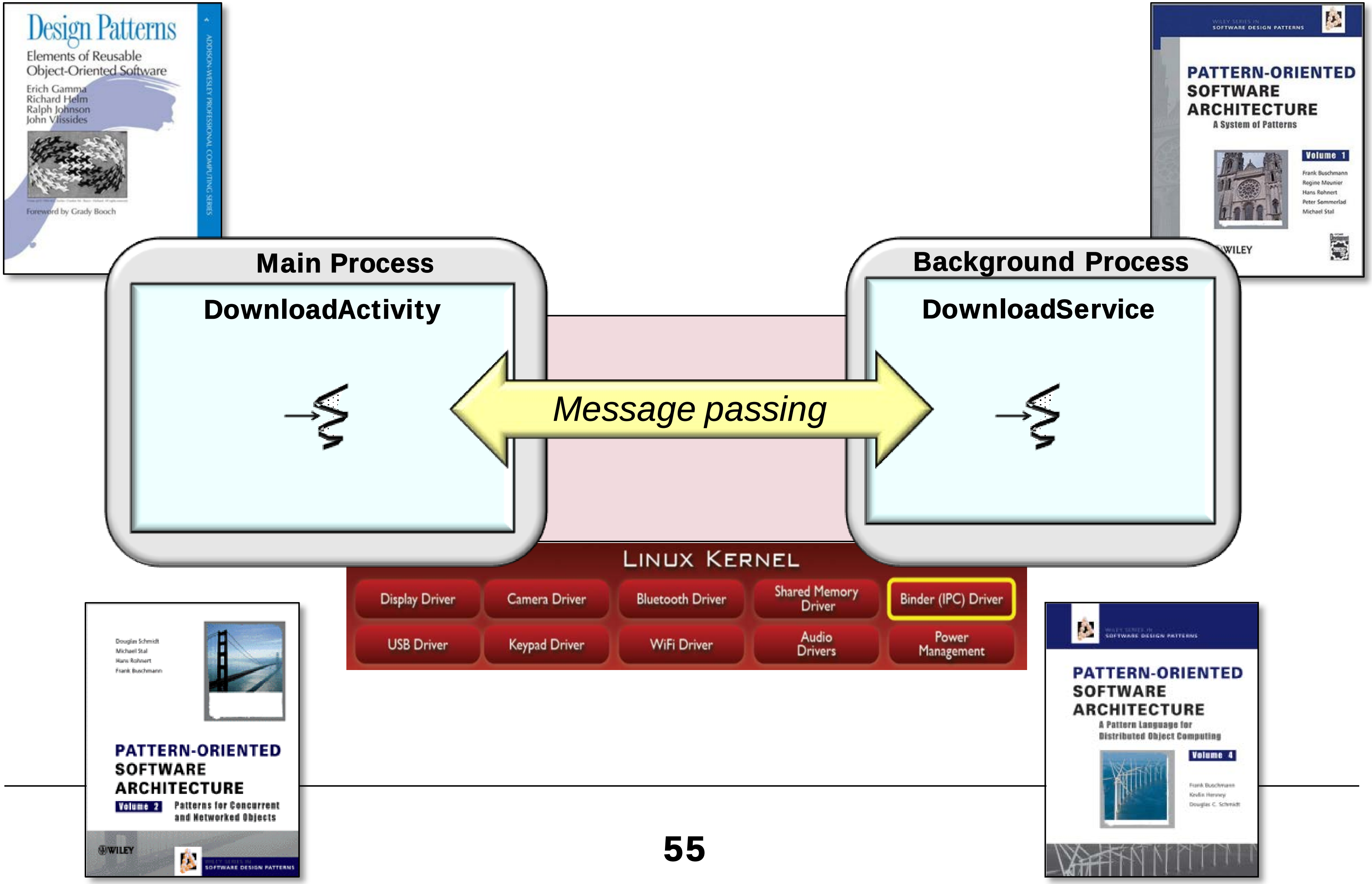
- Android's communication & service frameworks apply POSA & GoF patterns



Patterns Used by Communication & Service Frameworks (Part 3)

Patterns in Communication & Service Frameworks

- Android’s communication & service frameworks apply POSA & GoF patterns



Patterns in Communication & Service Frameworks

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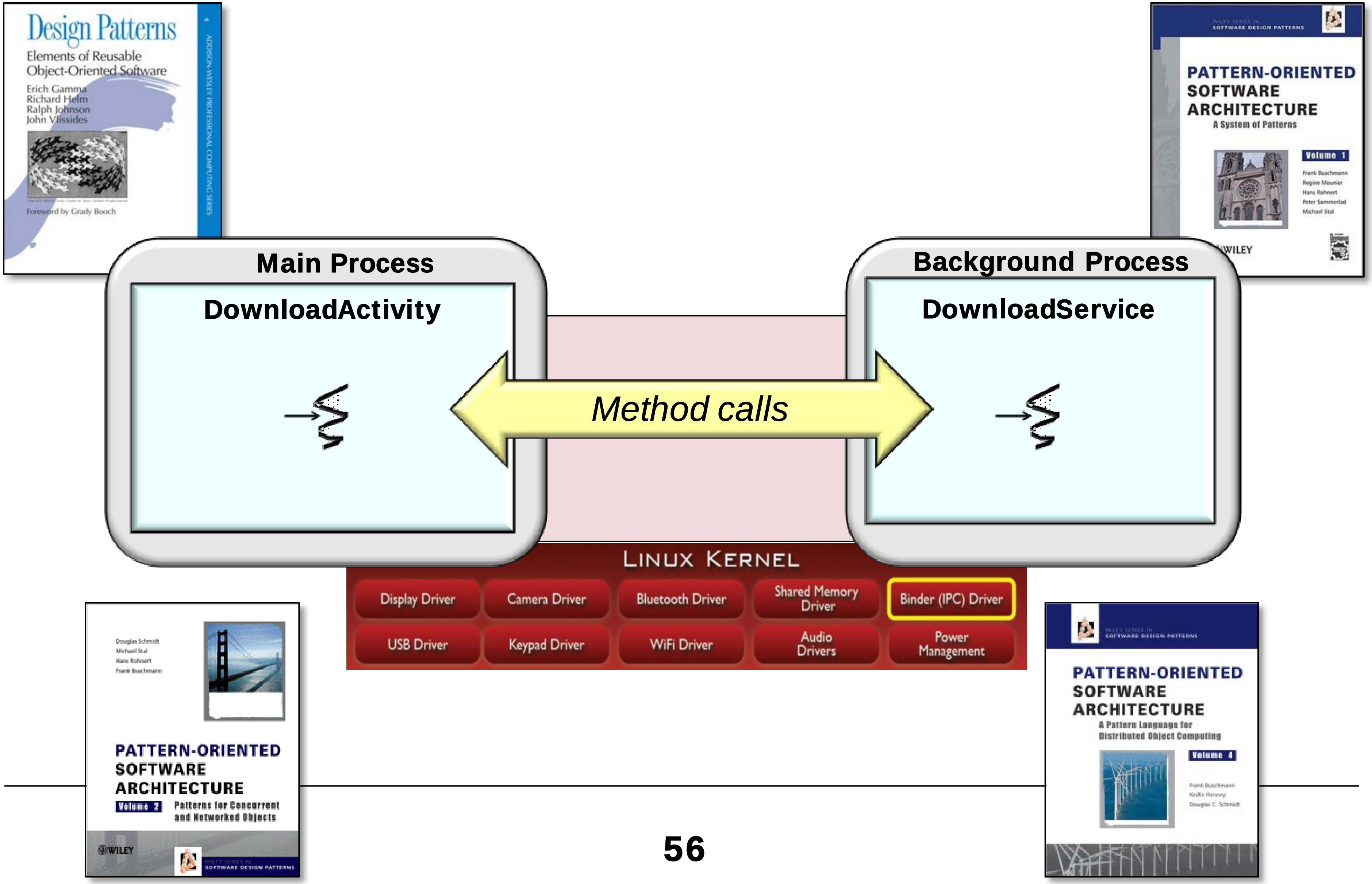
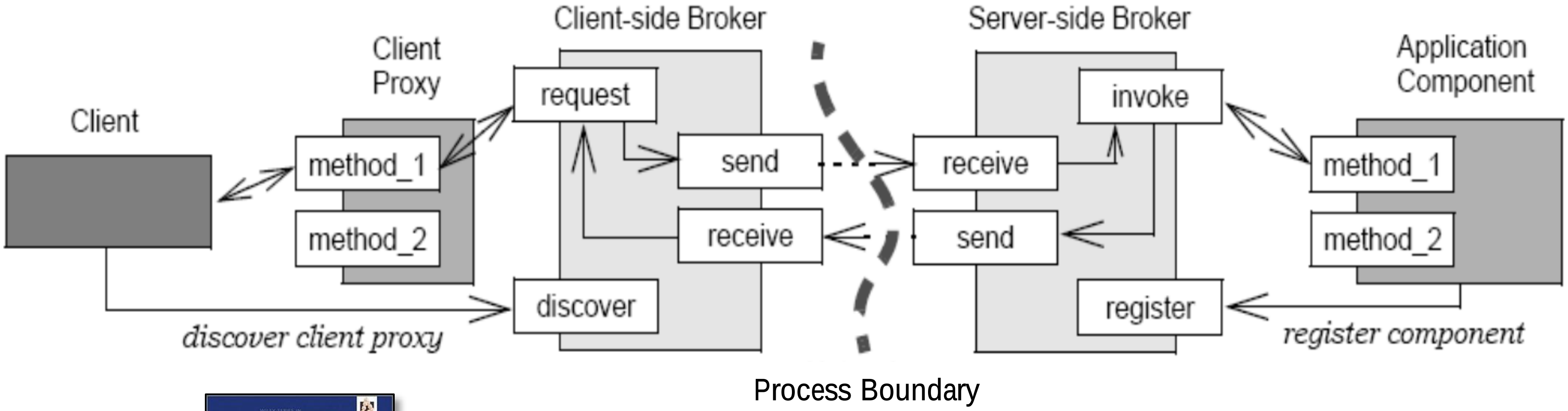
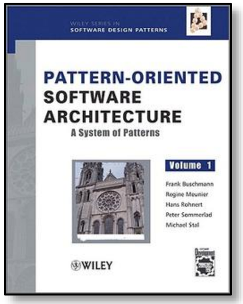


Patterns in Communication & Service Frameworks

- Android’s communication & service frameworks apply POSA & GoF patterns
  - *Broker* – Connect clients with remote objects by mediating invocations from clients to remote objects, while encapsulating the details of local and/or remote inter-process communication (IPC)

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See www.kircher-schwanninger.de/michael/publications/BrokerRevisited.pdf

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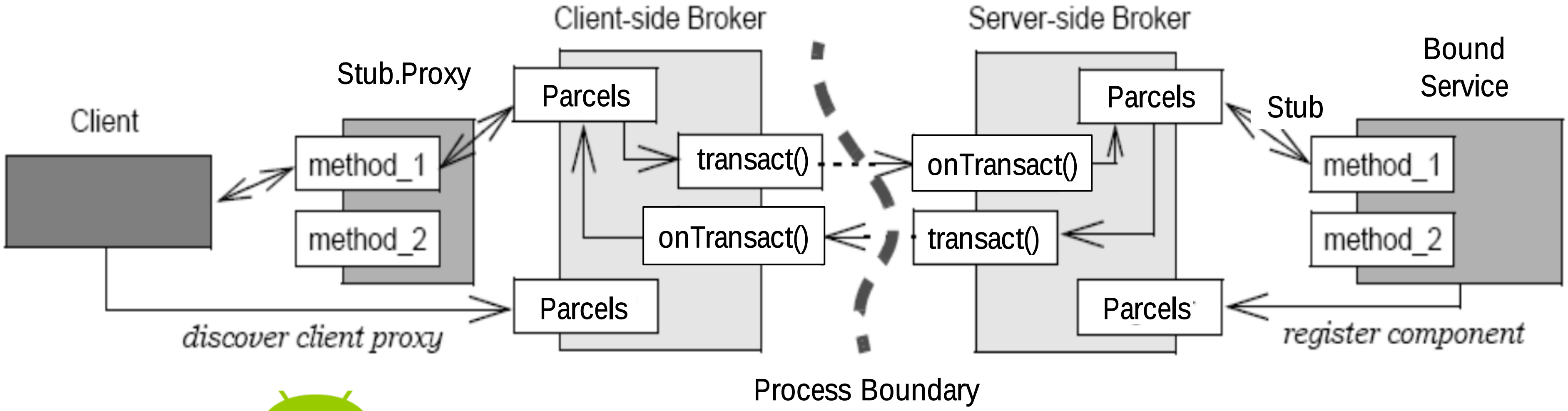

See upcoming parts on "Programming Bound Services"

Patterns in Communication & Service Frameworks

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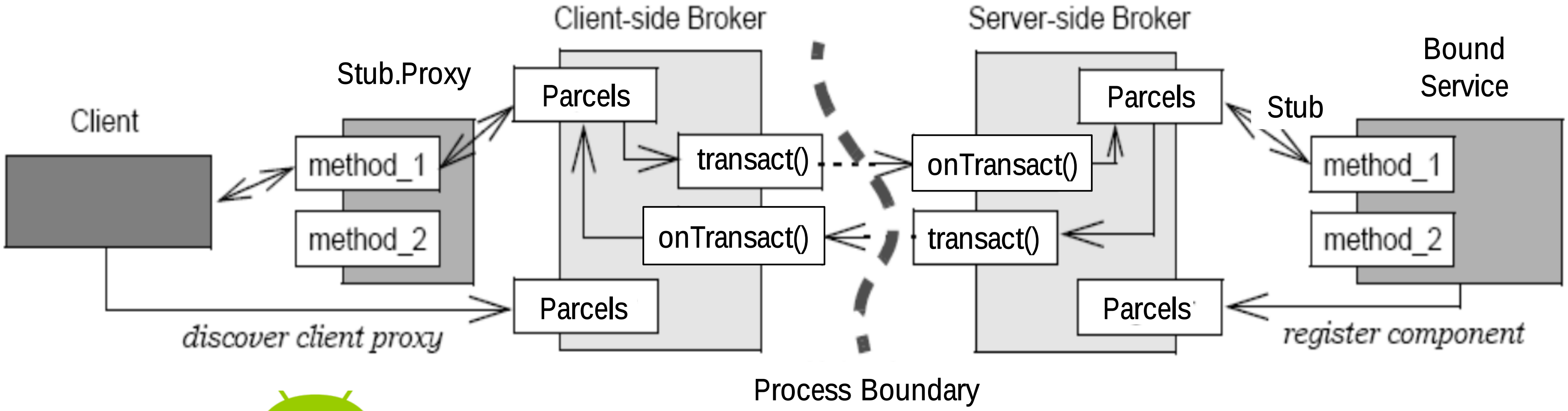
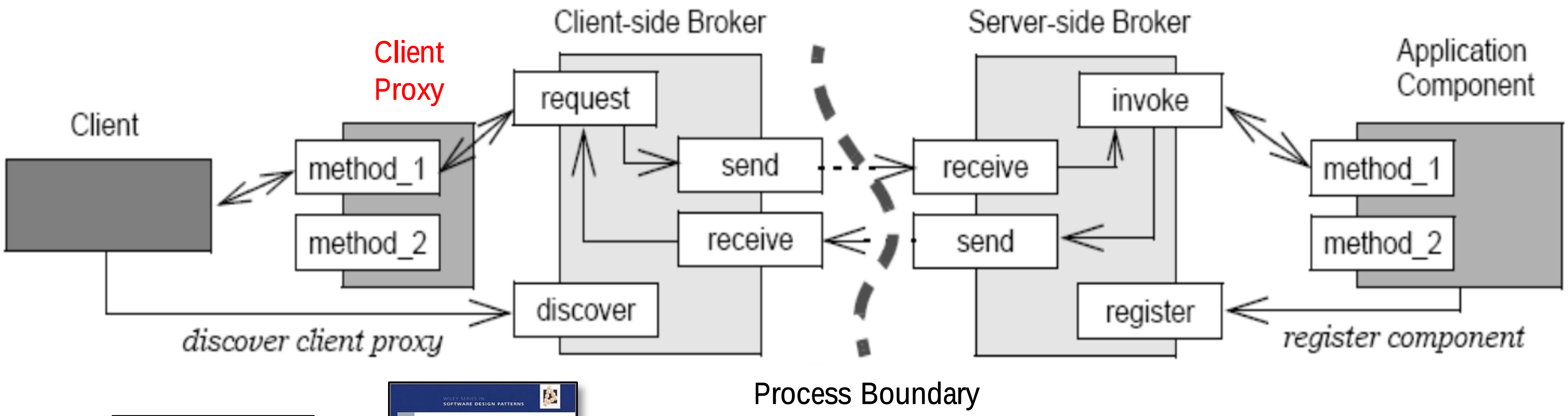


See www.dre.vanderbilt.edu/~schmidt/PDF/remoting-patterns.pdf

Patterns in Communication & Service Frameworks

- Android's communication & service frameworks apply POSA & GoF patterns
  - *Proxy* – Provide a surrogate or placeholder for another object to control access to it



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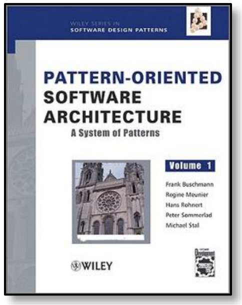

en.wikipedia.org/wiki/Proxy_pattern has more info

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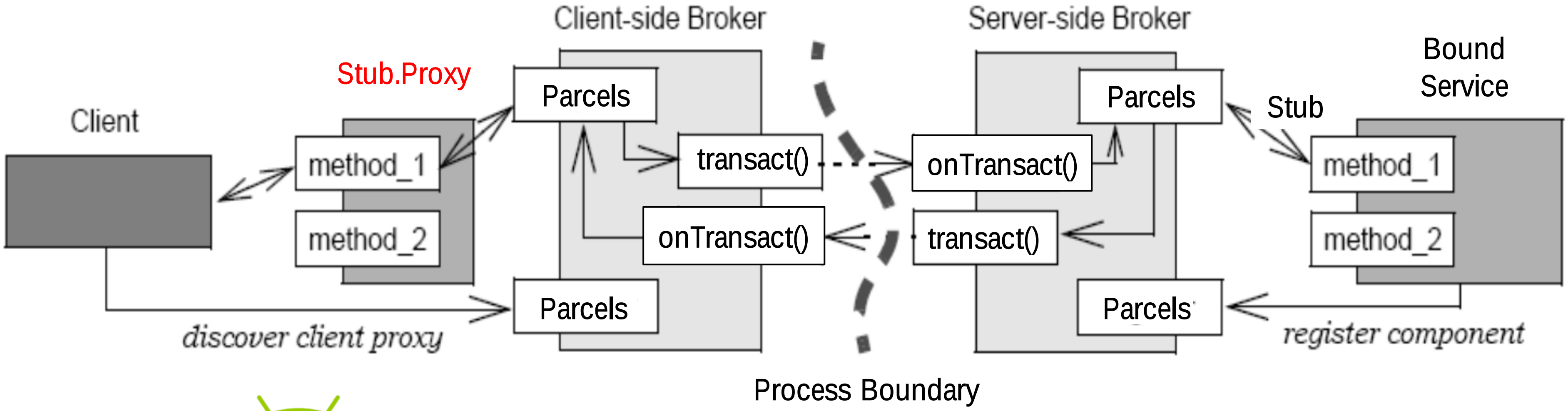

developer.android.com/guide/components/aidl.html explains (un)marshaling

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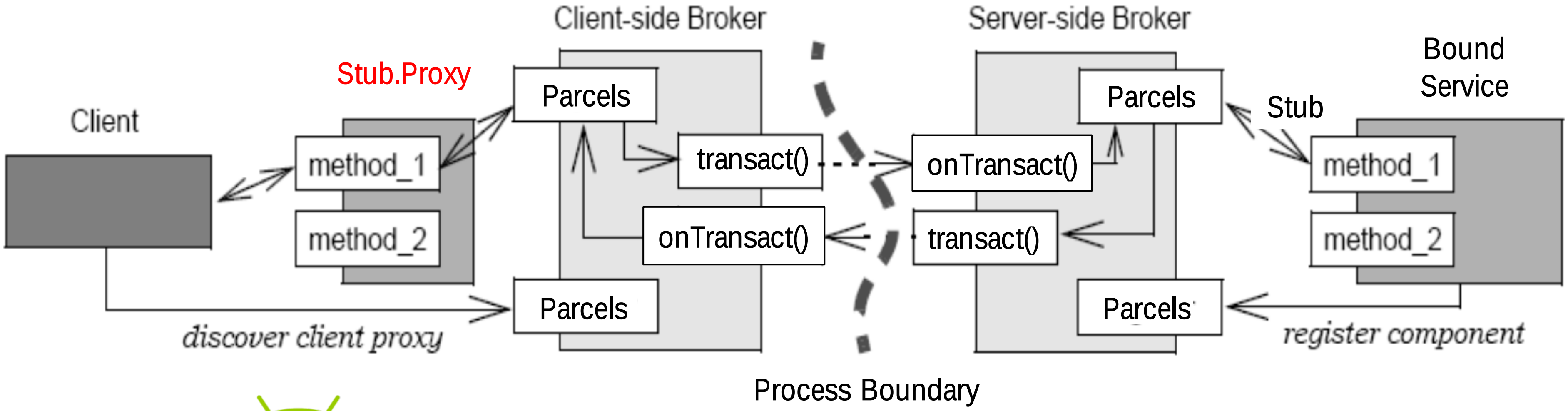

See upcoming part on "The Proxy Pattern"

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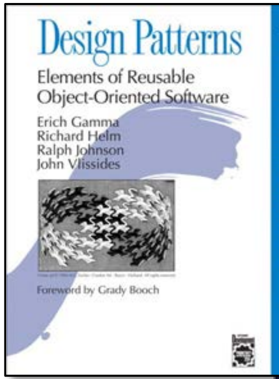
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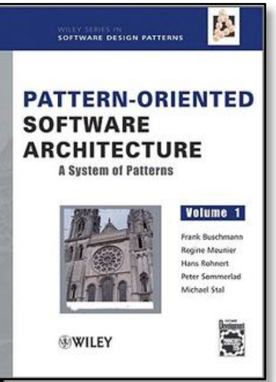

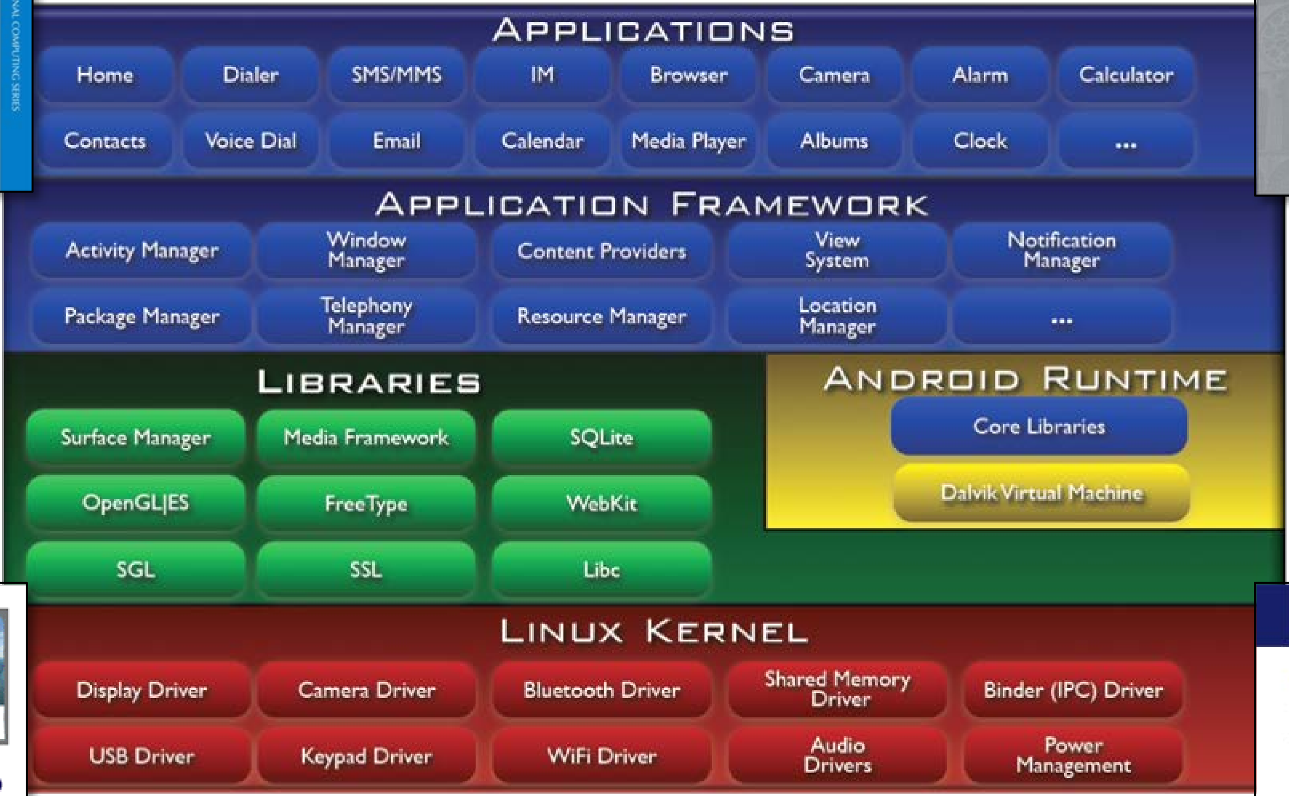

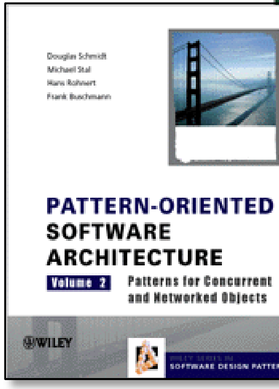
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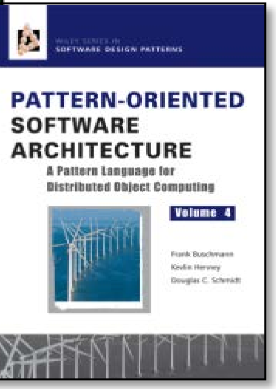
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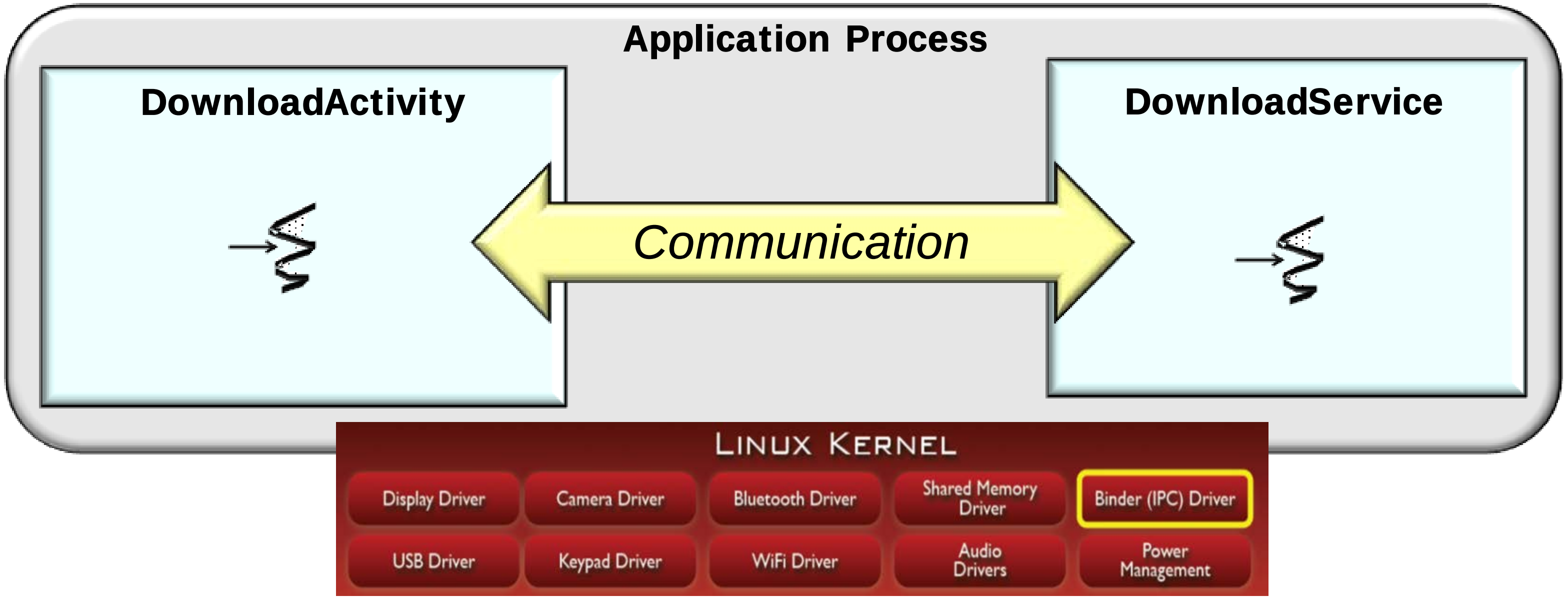
See upcoming section on “Concurrency & Communication Patterns”

Summary

Summary

- Android provides mechanisms that enable Activity & Service communication



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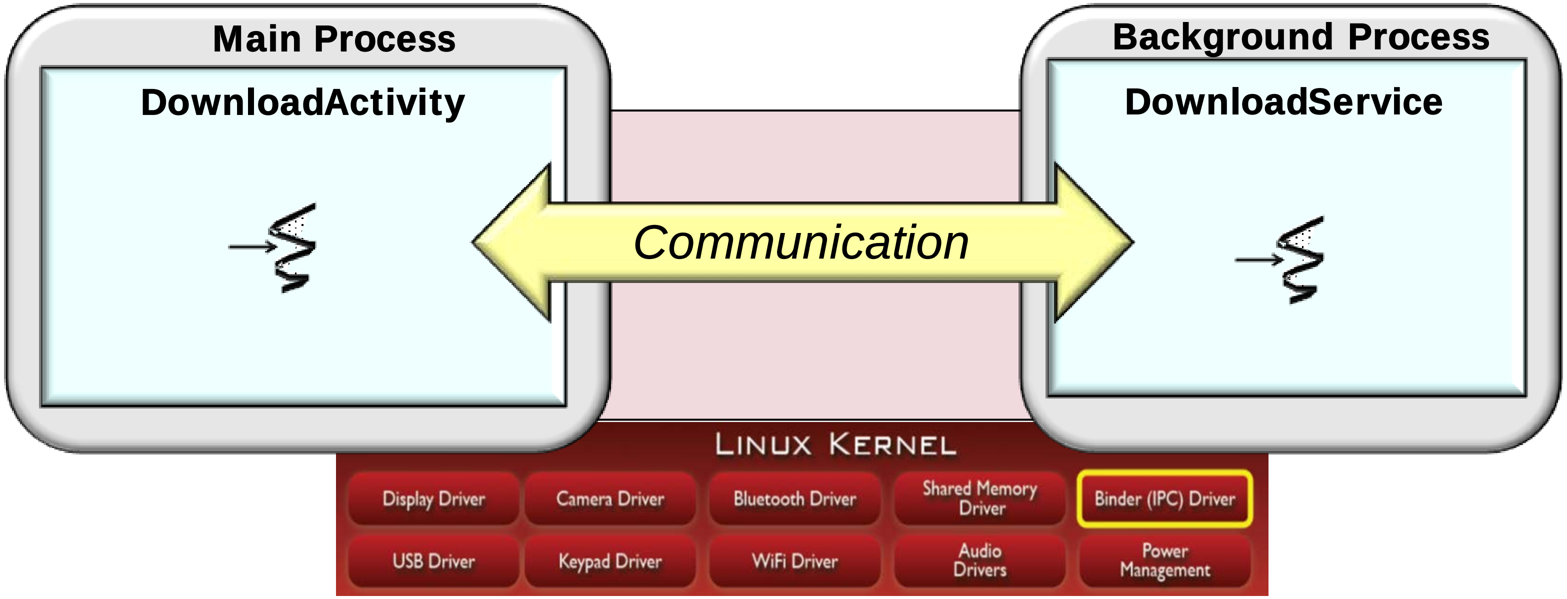

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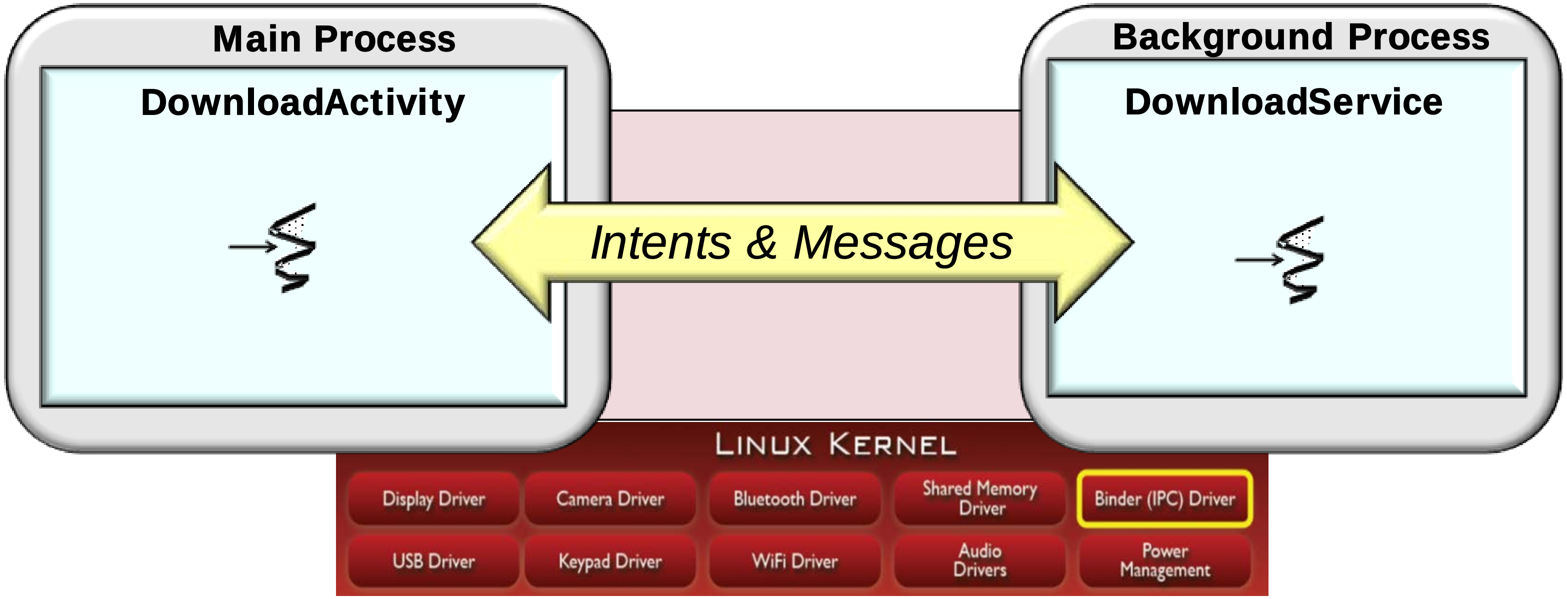

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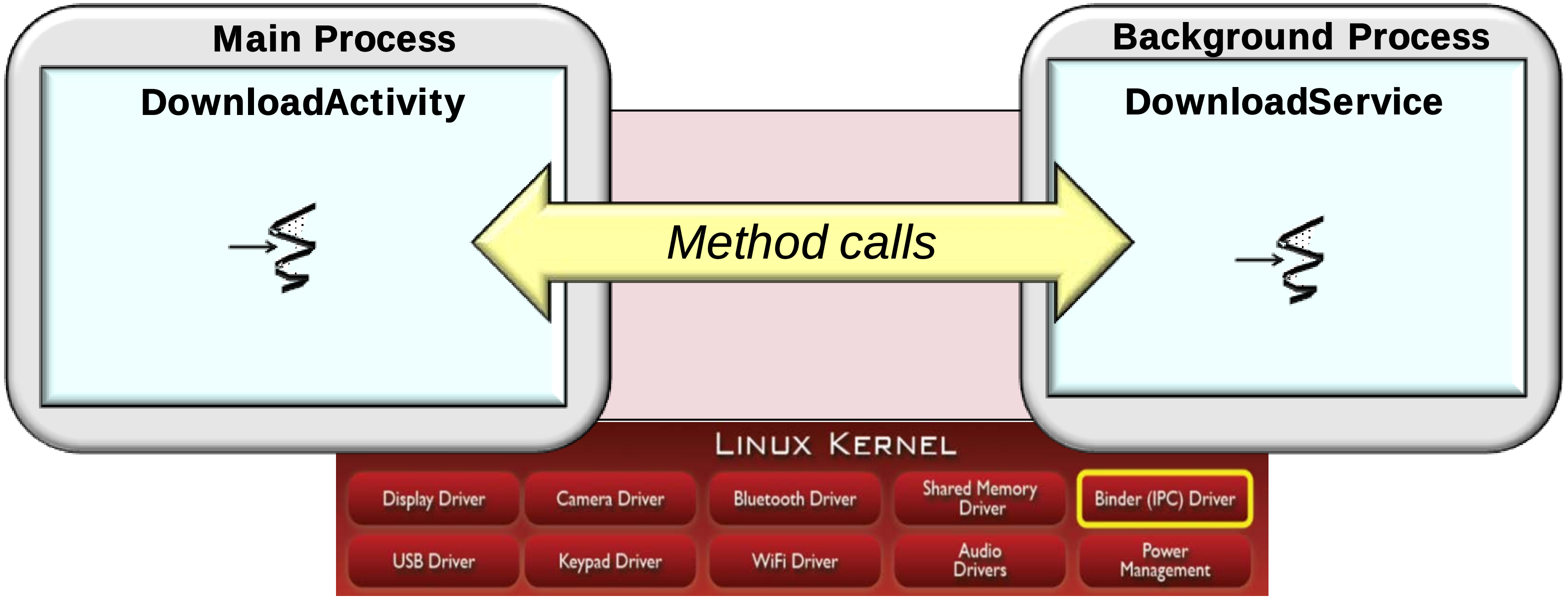

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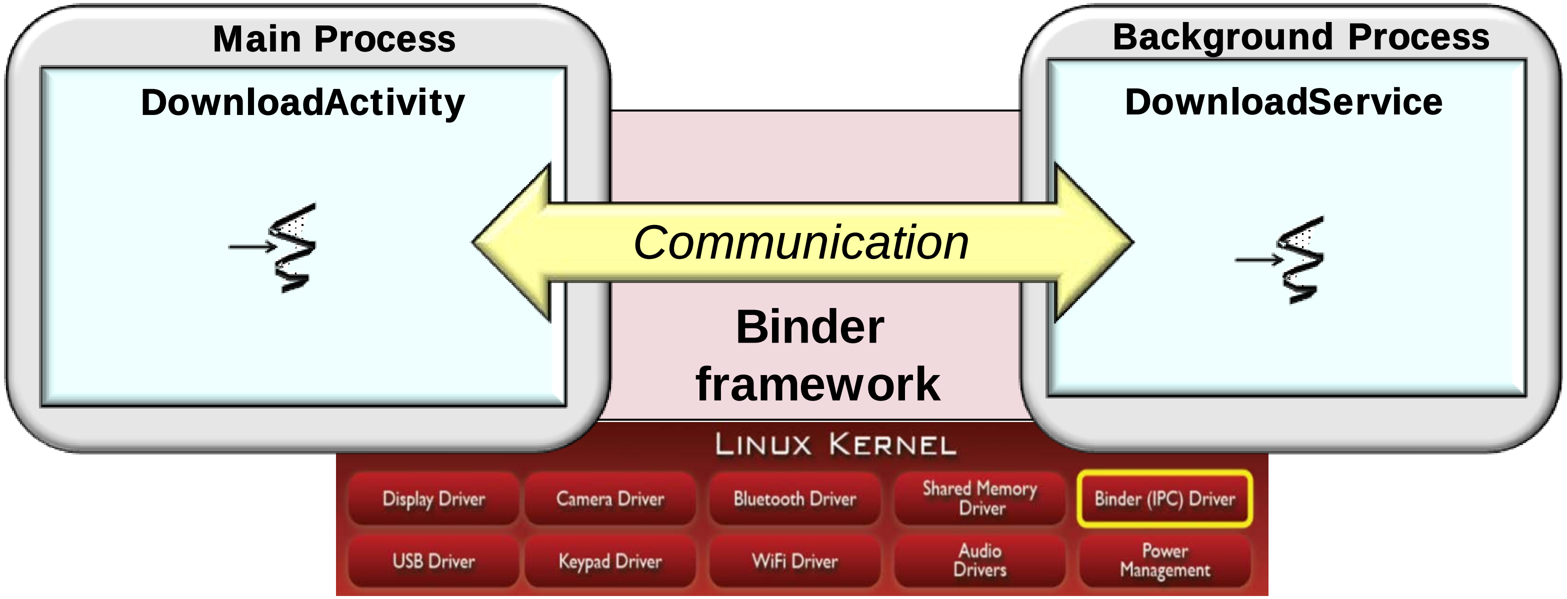

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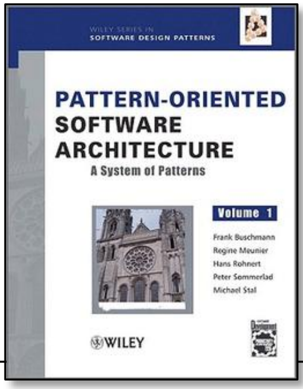
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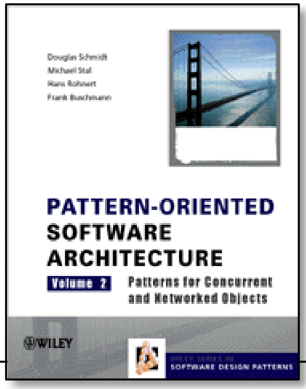
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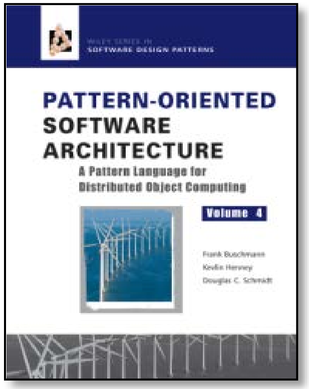
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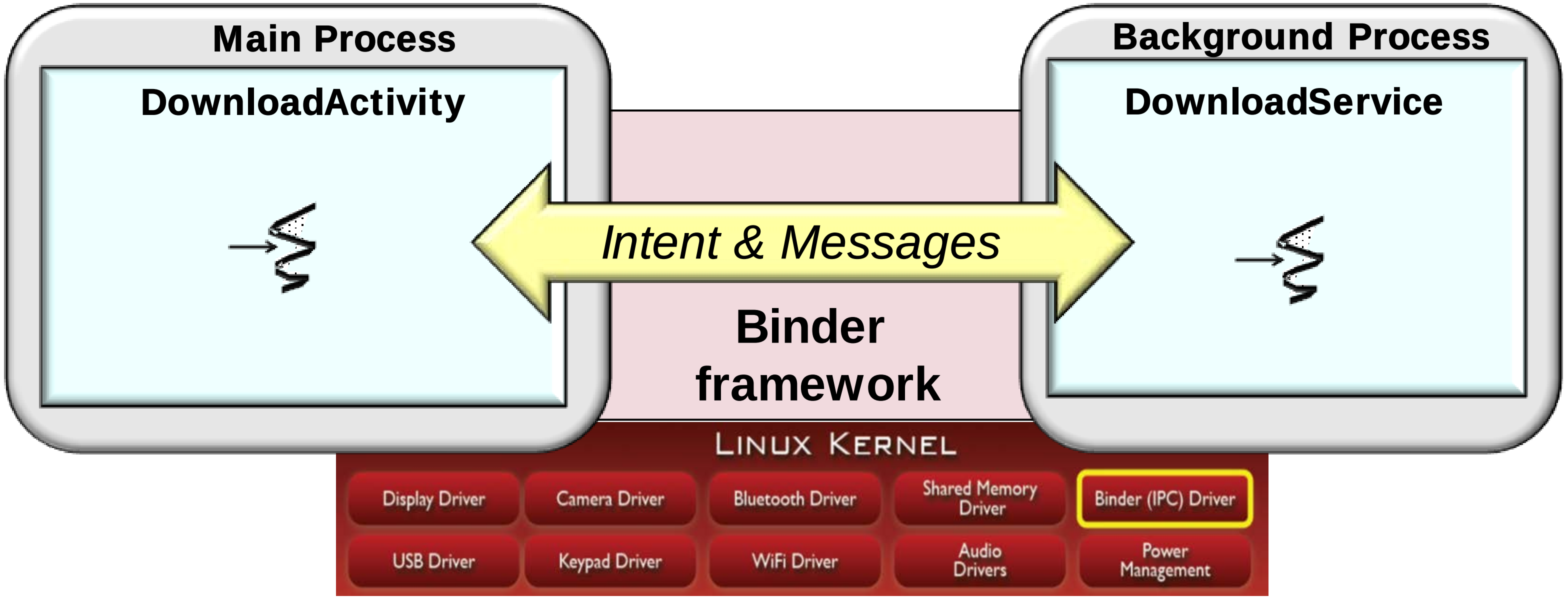

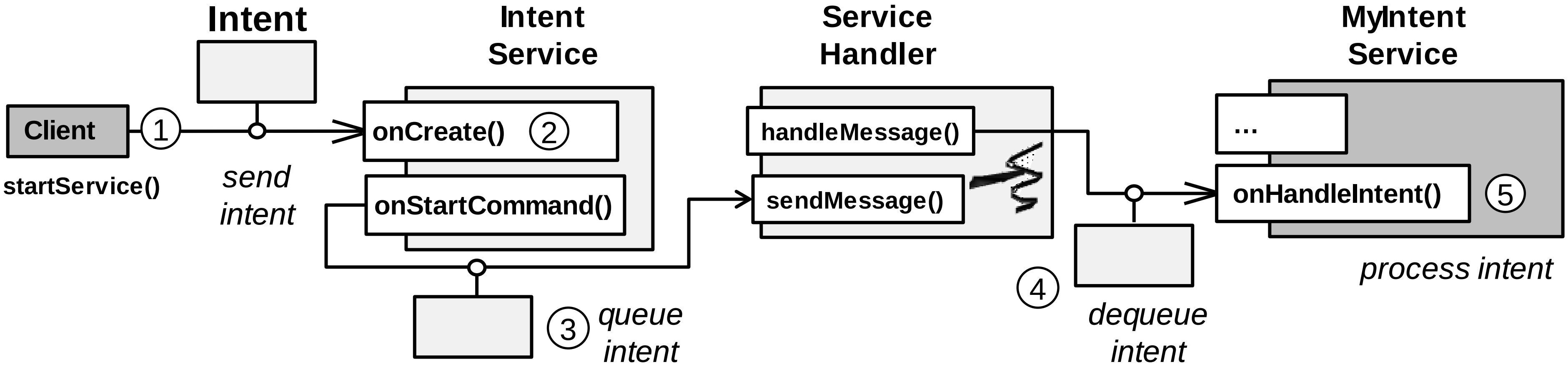

IntentService-based programs apply the *Command Processor* pattern

Summary

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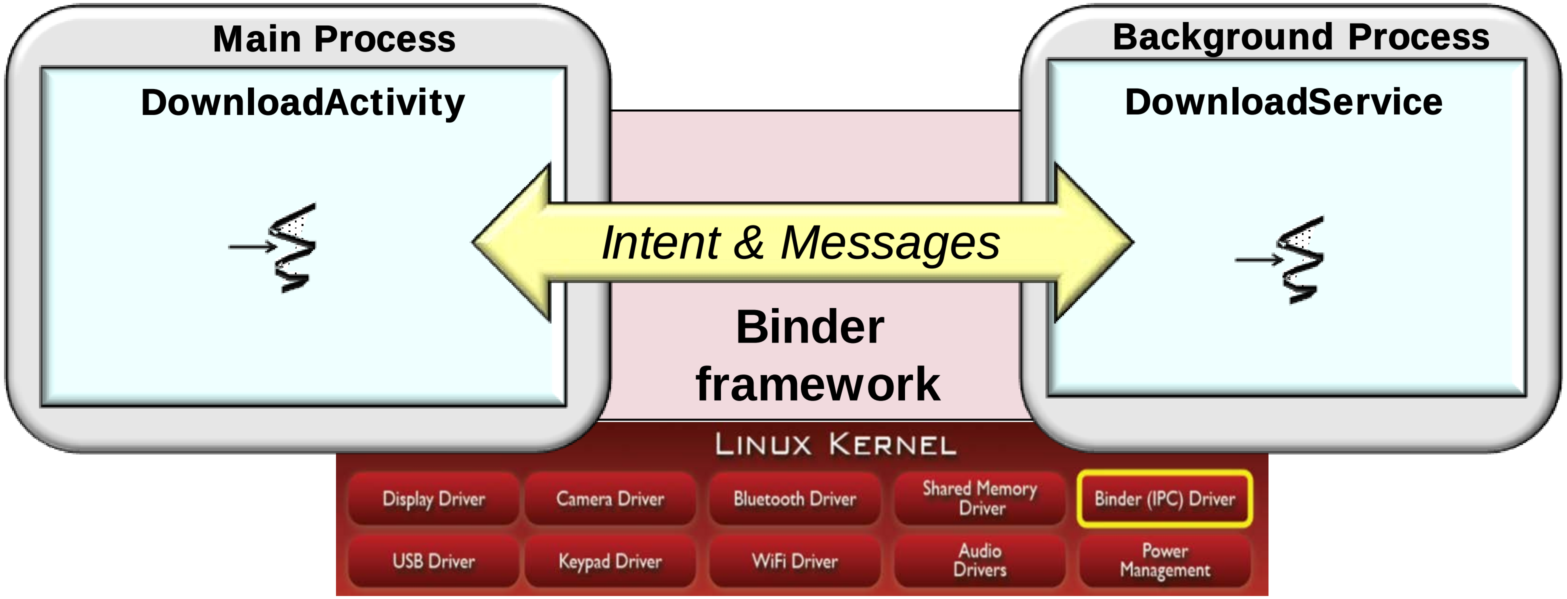

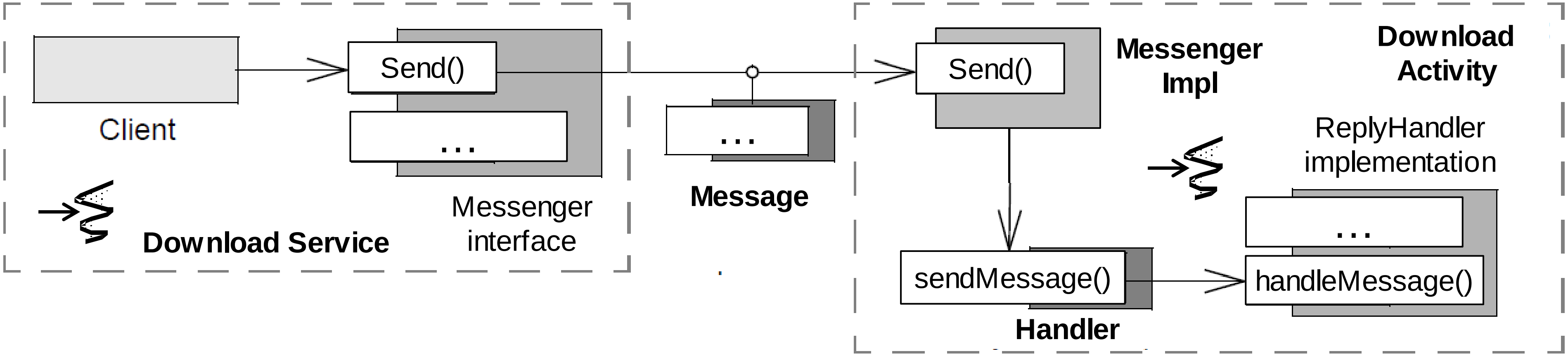

Messenger-based programs apply the *Active Object* pattern

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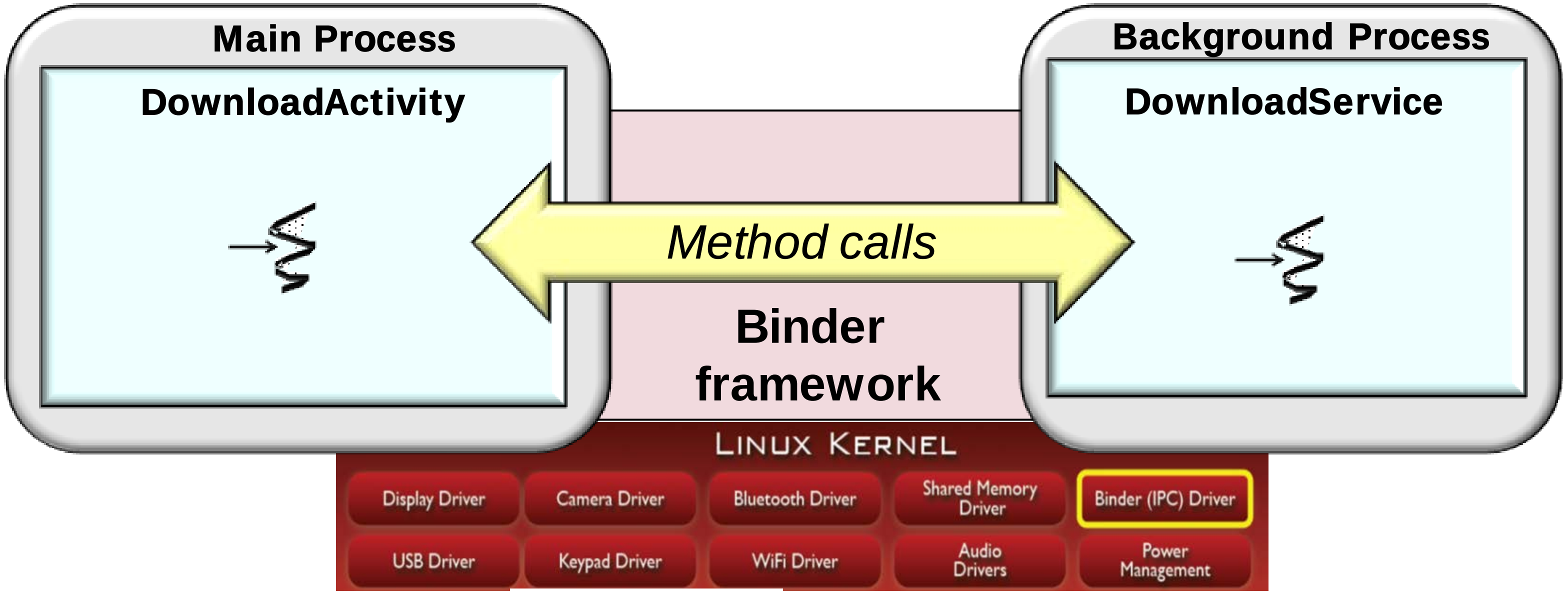
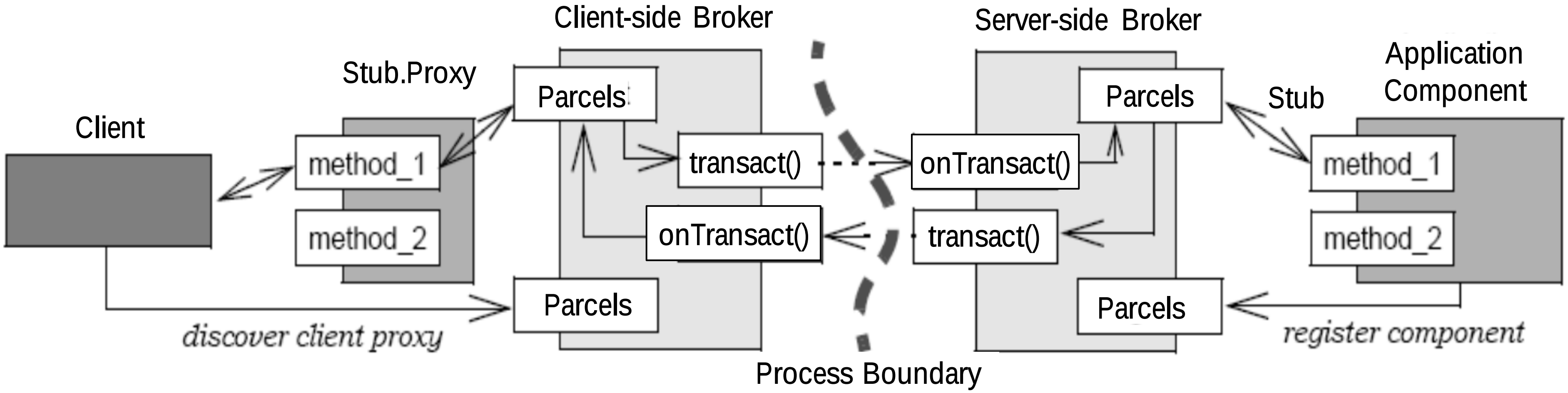
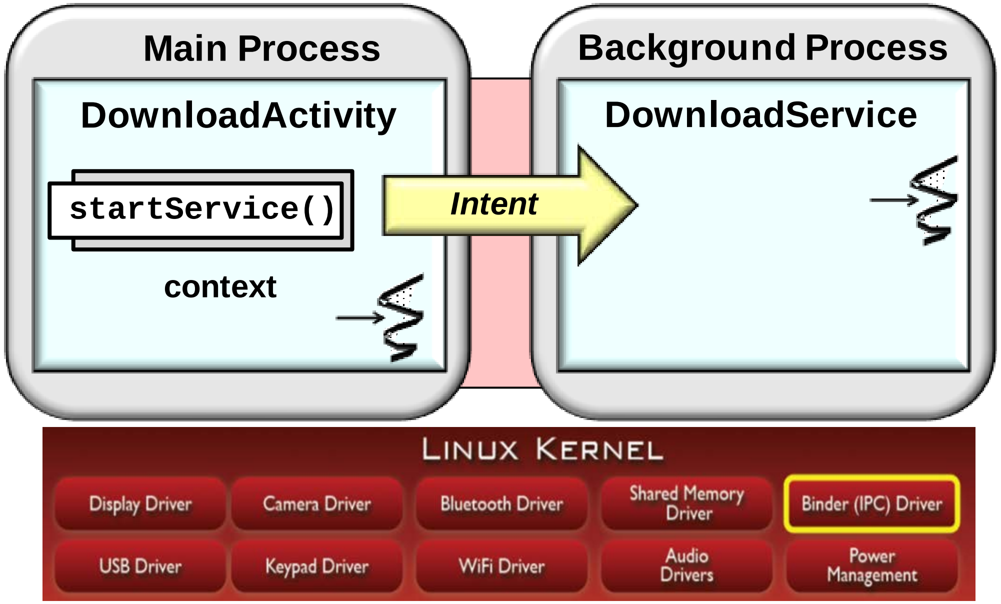




AIDL-based solutions apply the Broker pattern

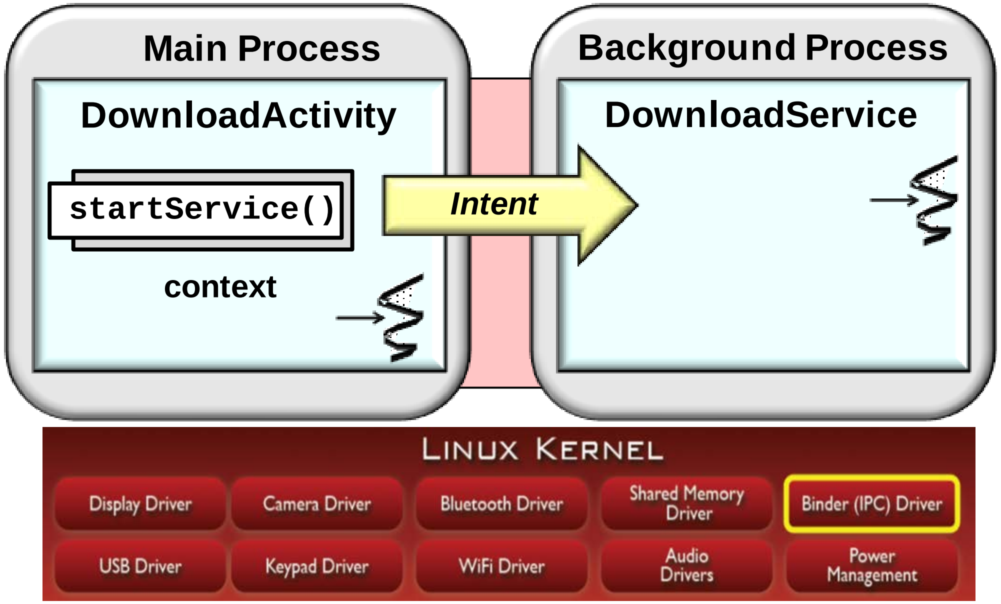
Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services



Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
  - However, it's also limited since there's no equivalent interface for the Service to pass an Intent reply back to the Activity



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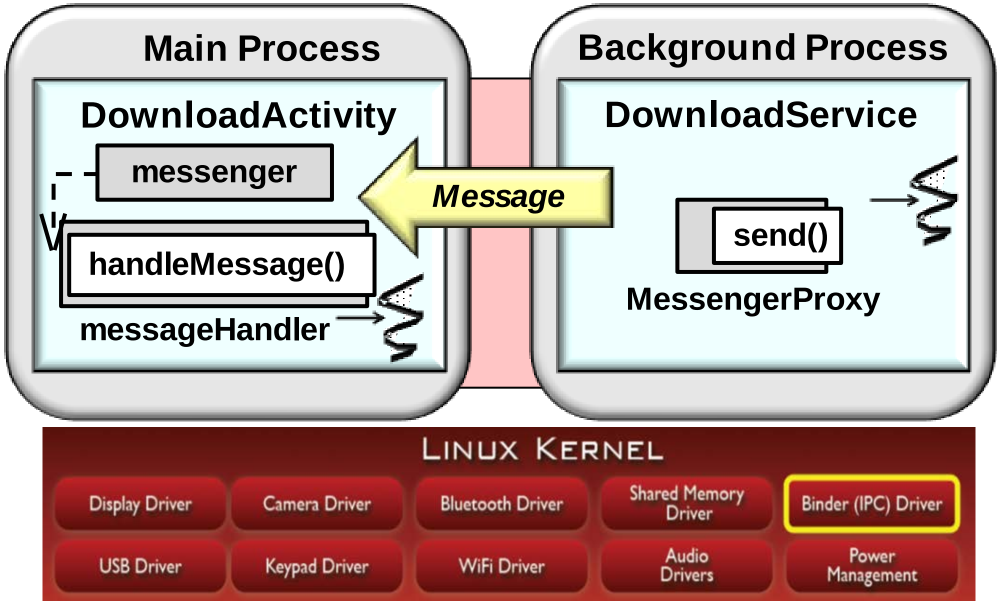
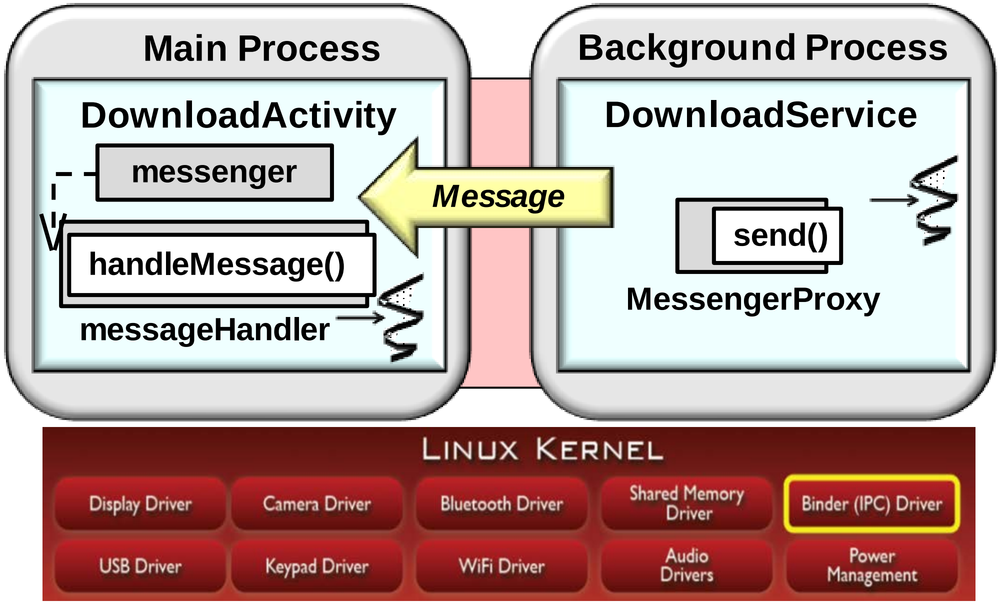


- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services

Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services
  - Often used to send replies from a Started Service back to the Activity that initiated it



Summary

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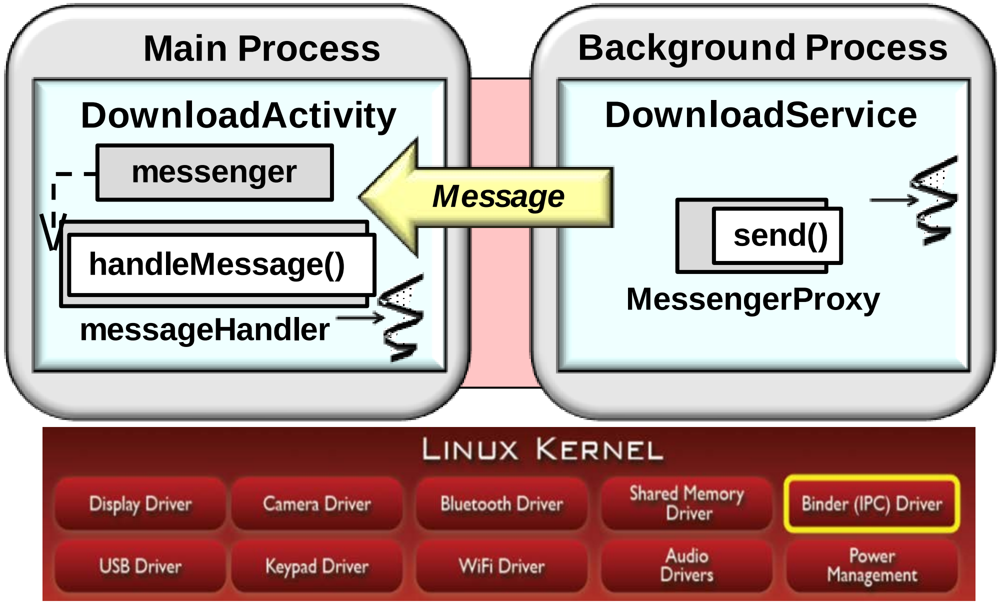
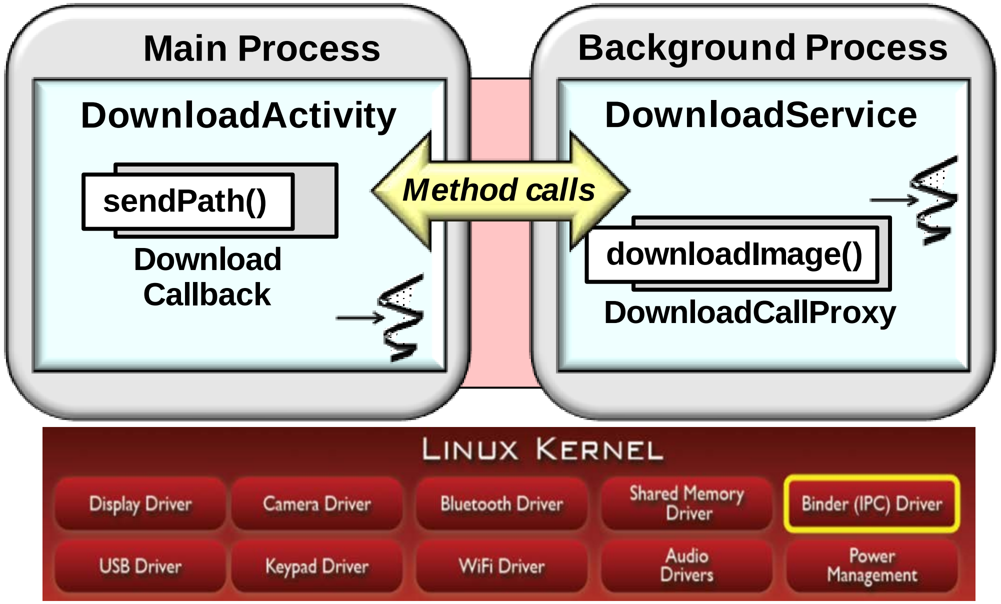
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services
    - Often used to send replies from a Started Service back to the Activity that initiated it
    - Harder to use for more complex interactions involving complex data types



Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services
- Invoking methods via AIDL Stubs is often more effective & efficient for complex interactions



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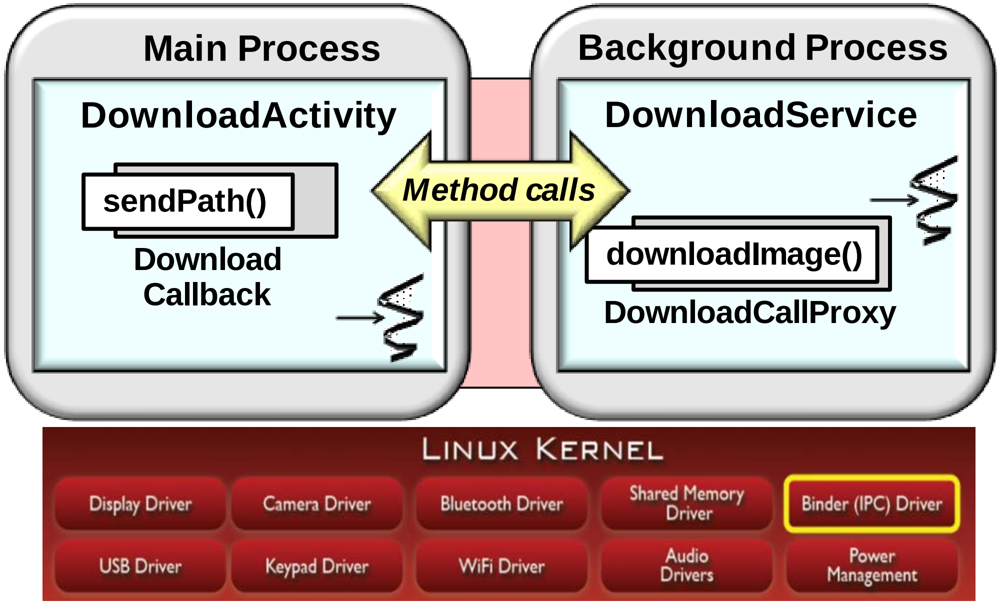
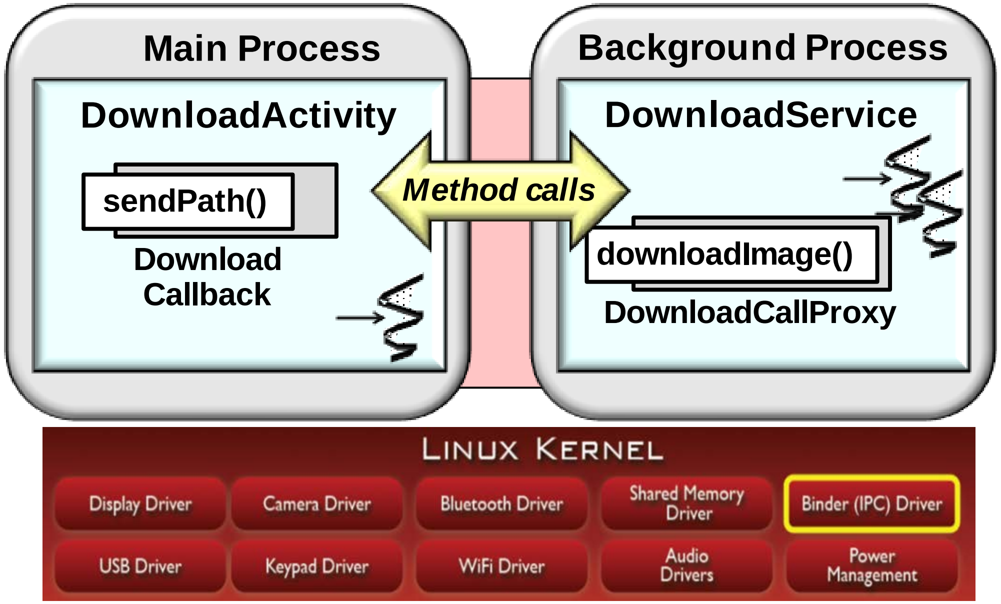


- Invoking methods via AIDL Stubs is often more effective & efficient for complex interactions
  - AIDL compiler generates Stubs that perform (de)marshaling

See en.wikipedia.org/wiki/Marshalling_(computer_science)

Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services
- Invoking methods via AIDL Stubs is often more effective & efficient for complex interactions
  - AIDL compiler generates Stubs that perform (de)marshaling
  - AIDL-based method calls run concurrently in a pool of Threads



developer.android.com/guide/components/aidl.html has info on AIDL thread pools

Summary

- Android provides mechanisms that enable Activity & Service communication
- Passing Intents via startService() or bindService() is straightforward for oneway communication from Activities to Services
- Sending Messages via Messengers is also straightforward for simple interactions between Activities & Services
- Invoking methods via AIDL Stubs is often more effective & efficient for complex interactions
  - AIDL compiler generates Stubs that perform (de)marshaling
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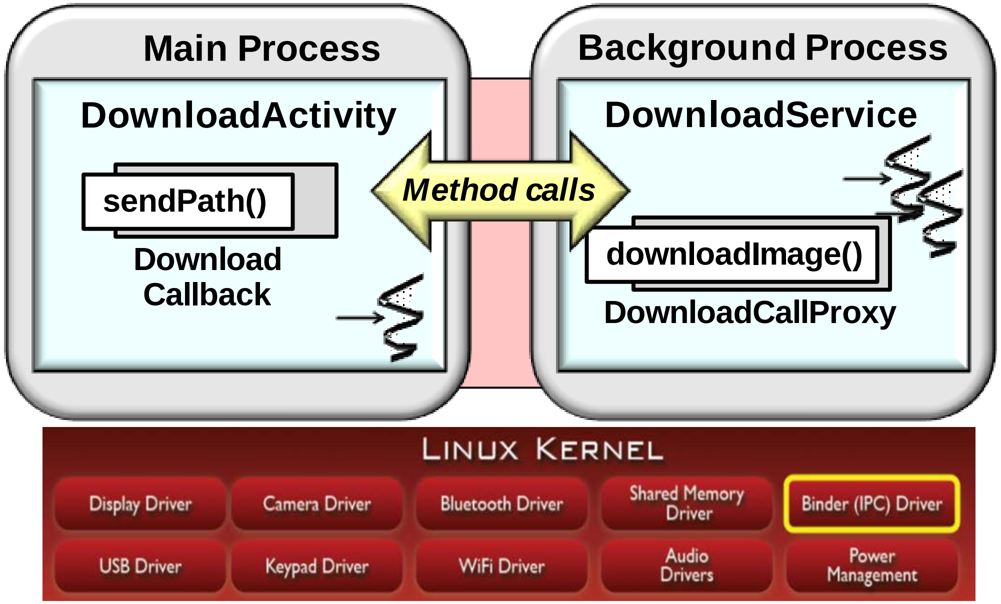

- In contrast, Messengers don't require any particular concurrency model