

Overview of Layered Architectures

Douglas C. Schmidt

d.schmidt@vanderbilt.edu

www.dre.vanderbilt.edu/~schmidt



Professor of Computer Science

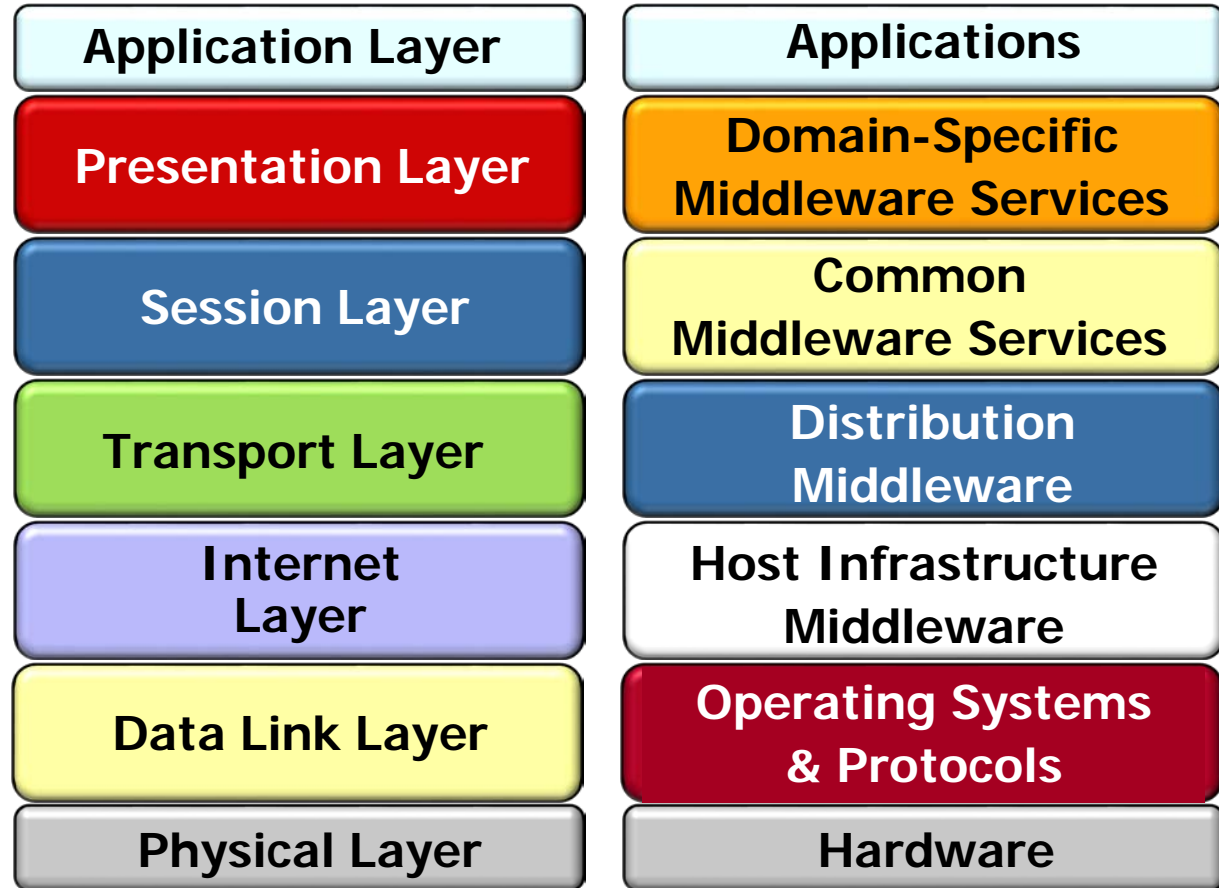
Institute for Software
Integrated Systems

Vanderbilt University
Nashville, Tennessee, USA



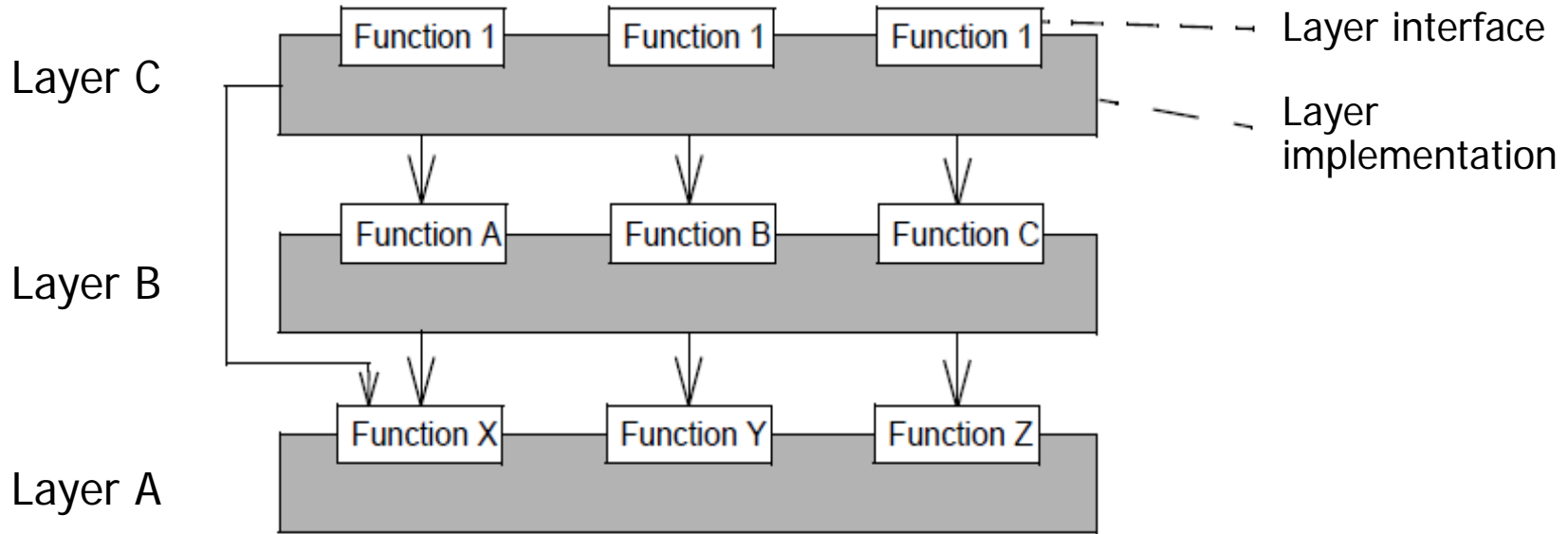
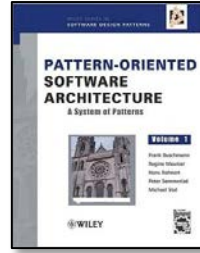
Learning Objectives in this Lesson

1. Know what layered architectures are



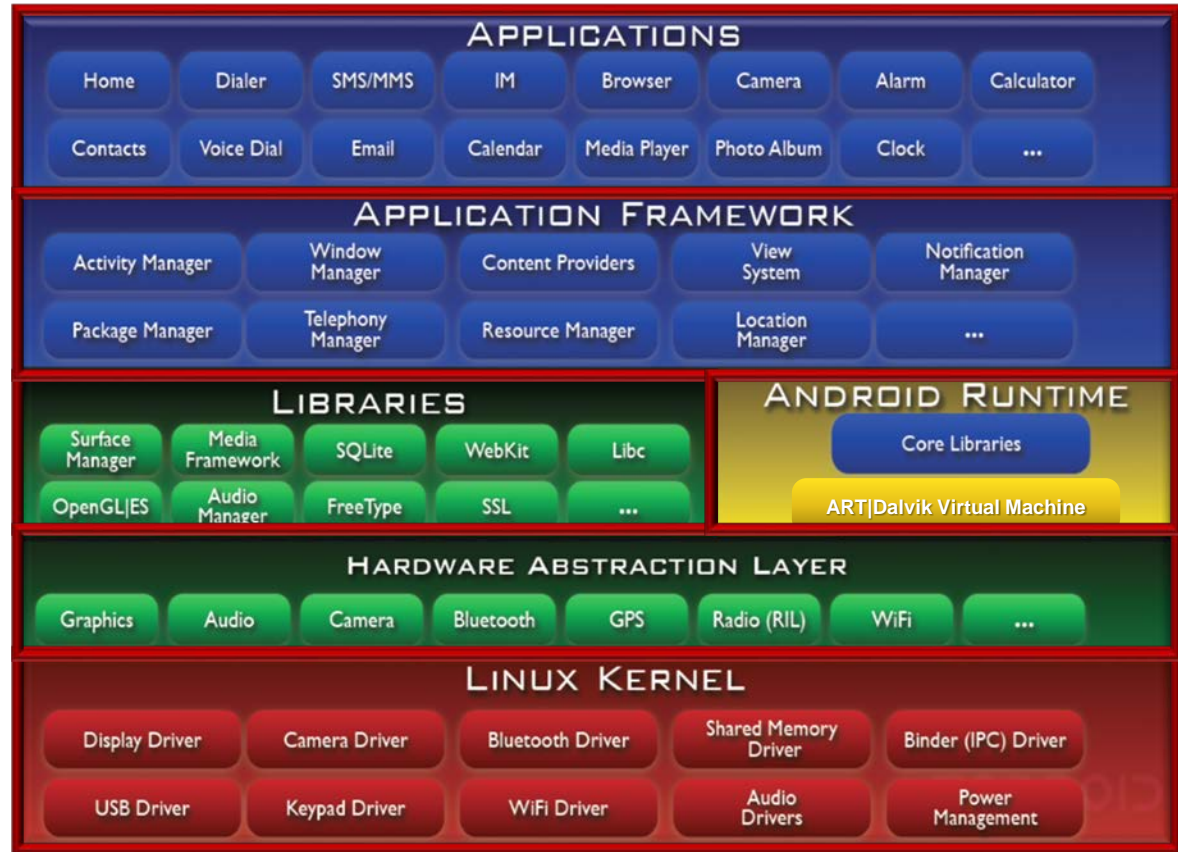
Learning Objectives in this Lesson

1. Know what layered architectures are
2. Understand the *Layers* architectural pattern



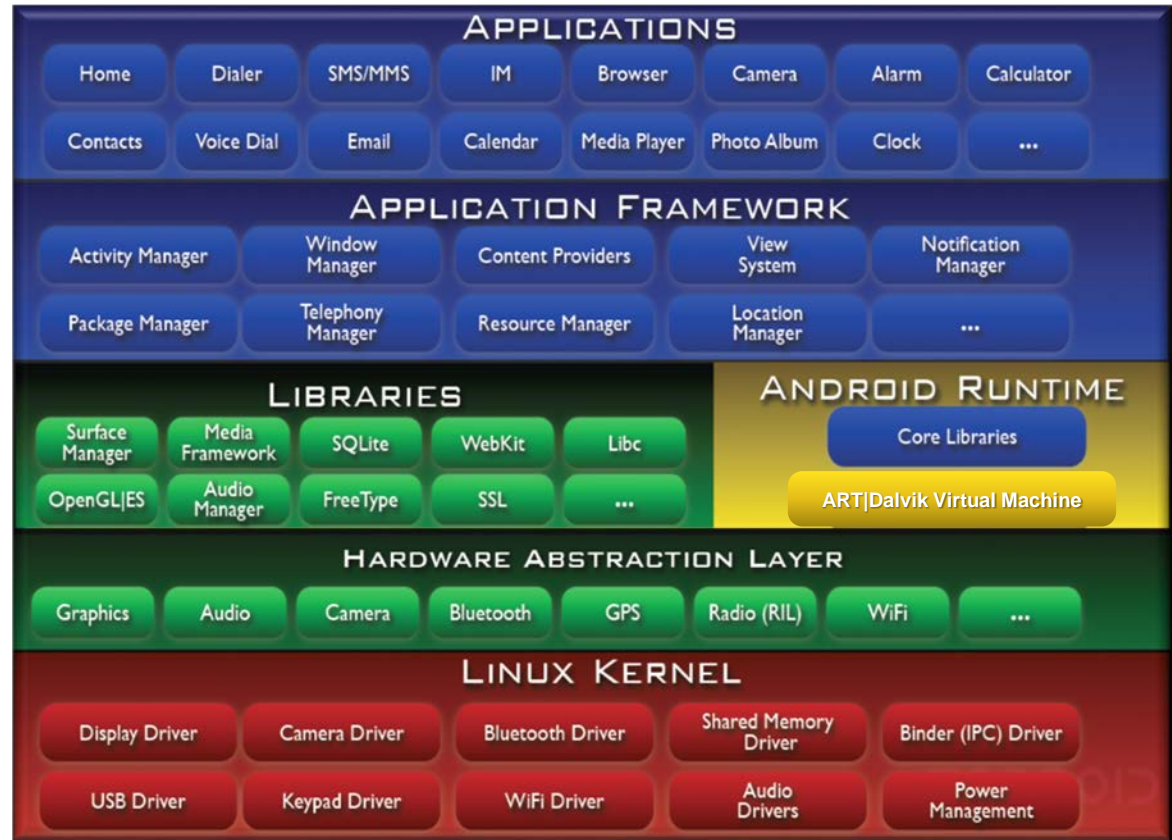
Learning Objectives in this Lesson

1. Know what layered architectures are
2. Understand the *Layers* architectural pattern
3. Recognize the layers in Android's software stack



Learning Objectives in this Lesson

1. Know what layered architectures are
2. Understand the *Layers* architectural pattern
3. Recognize the layers in Android's software stack
4. Realize *why* layering is used in Android



Overview of Layered Architectures

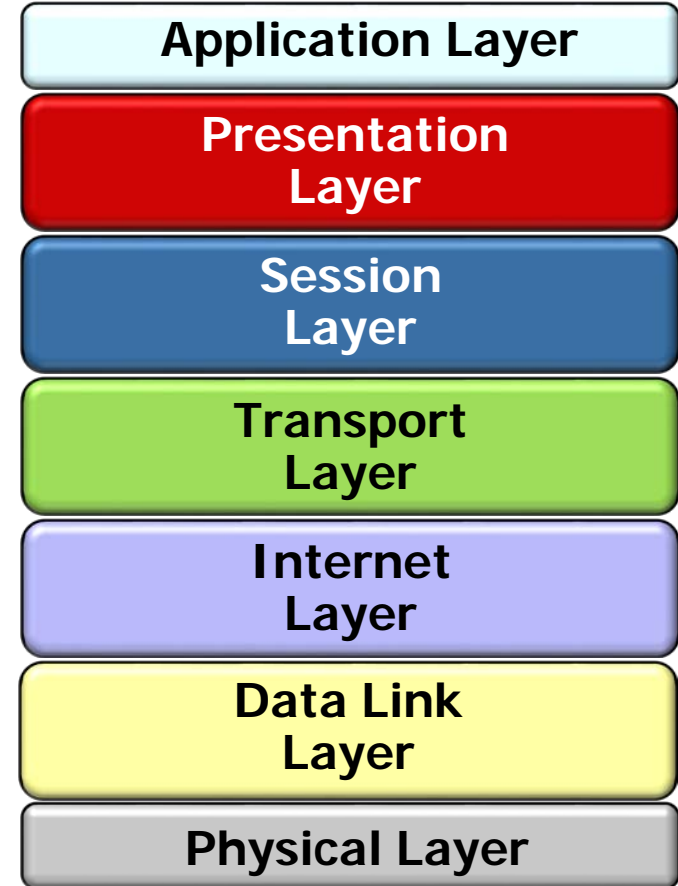
An Overview of Layered Architectures

- Layering is applied in many domains



An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks

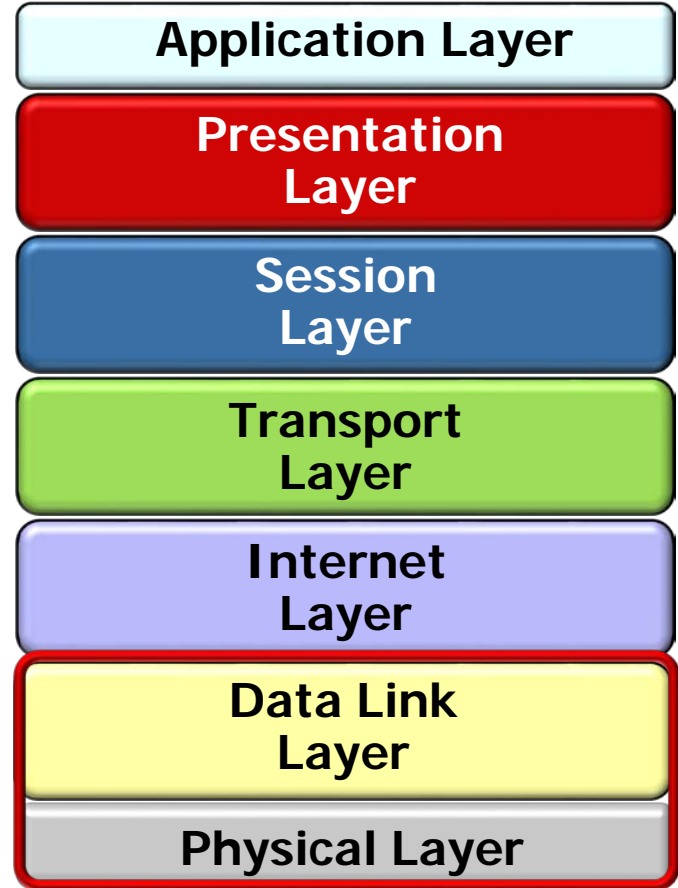


Enables end-to-end communication by specifying how data should be (un)packetized, addressed, transmitted, routed, & received

See en.wikipedia.org/wiki/Protocol_stack

An Overview of Layered Architectures

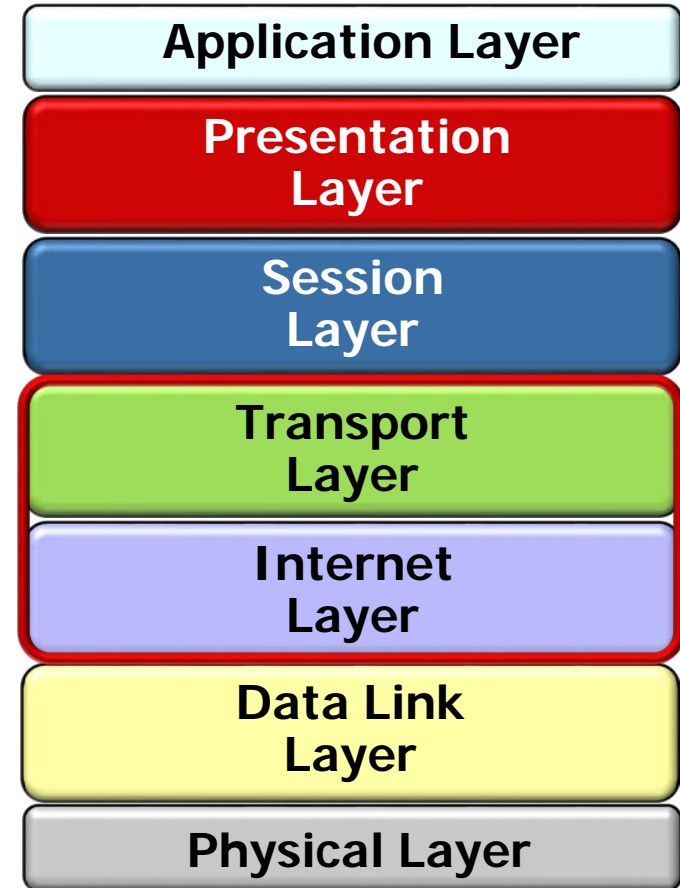
- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
 - Lower layers handle interactions with the hardware
 - e.g., GSM, DSL, & Ethernet



See en.wikipedia.org/wiki/Link_layer & en.wikipedia.org/wiki/Physical_layer

An Overview of Layered Architectures

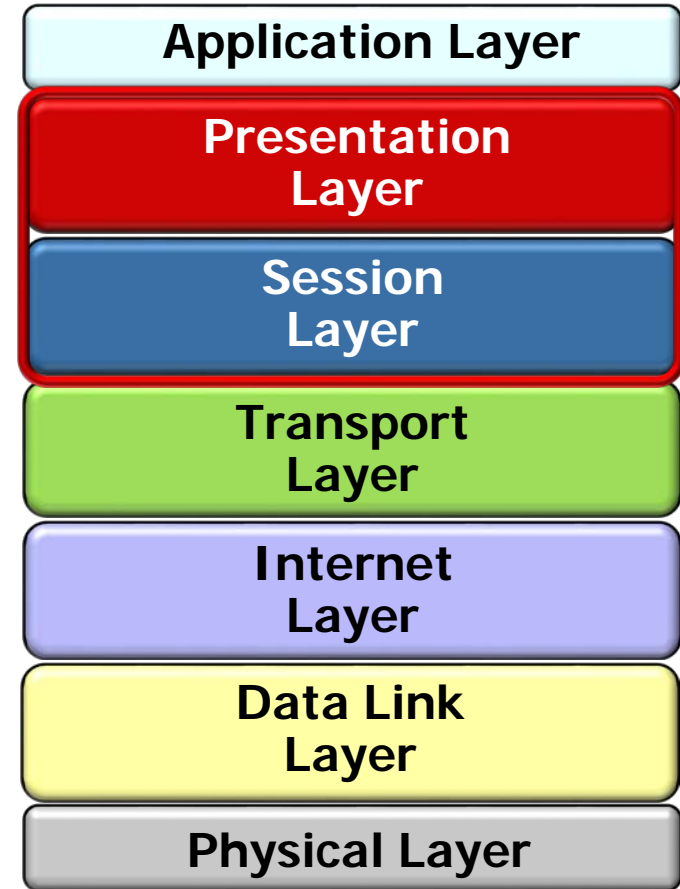
- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
 - Lower layers handle interactions with the hardware
 - Middle layers exchange packets across hosts & routers
 - e.g., IP, TCP, & UDP



See en.wikipedia.org/wiki/Internet_layer & en.wikipedia.org/wiki/Transport_layer

An Overview of Layered Architectures

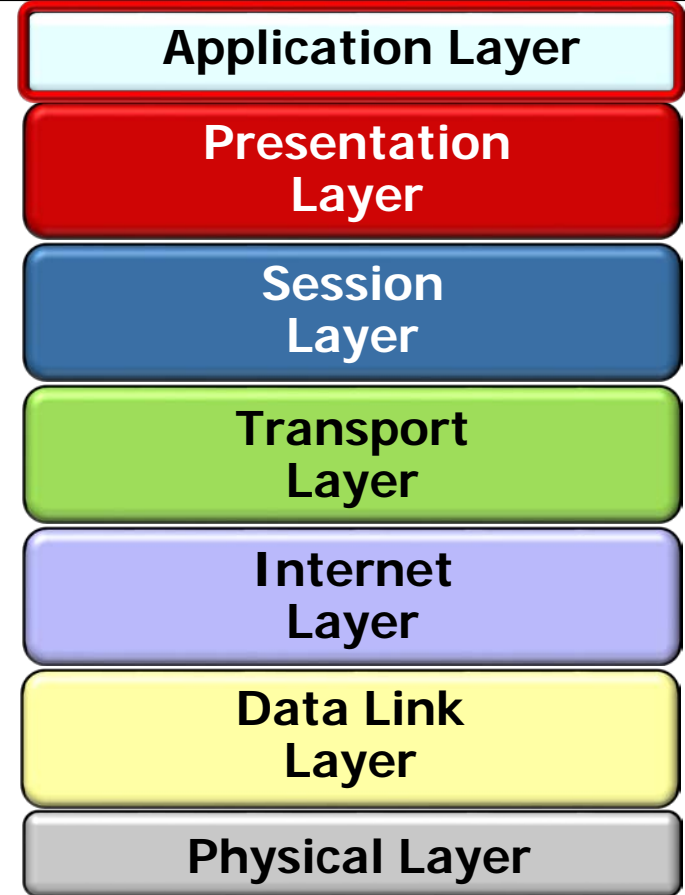
- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
 - Lower layers handle interactions with the hardware
 - Middle layers exchange packets across hosts & routers
 - Upper layers implement & interact with applications
 - e.g., PPTP, XDR, CDR, JSON



See en.wikipedia.org/wiki/Session_layer & en.wikipedia.org/wiki/Presentation_layer

An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
 - Lower layers handle interactions with the hardware
 - Middle layers exchange packets across hosts & routers
 - Upper layers implement & interact with applications
 - Applications (& middleware) mostly just deal with the upper layer(s)
 - e.g., FTP, TELNET, SMTP, & SNMP

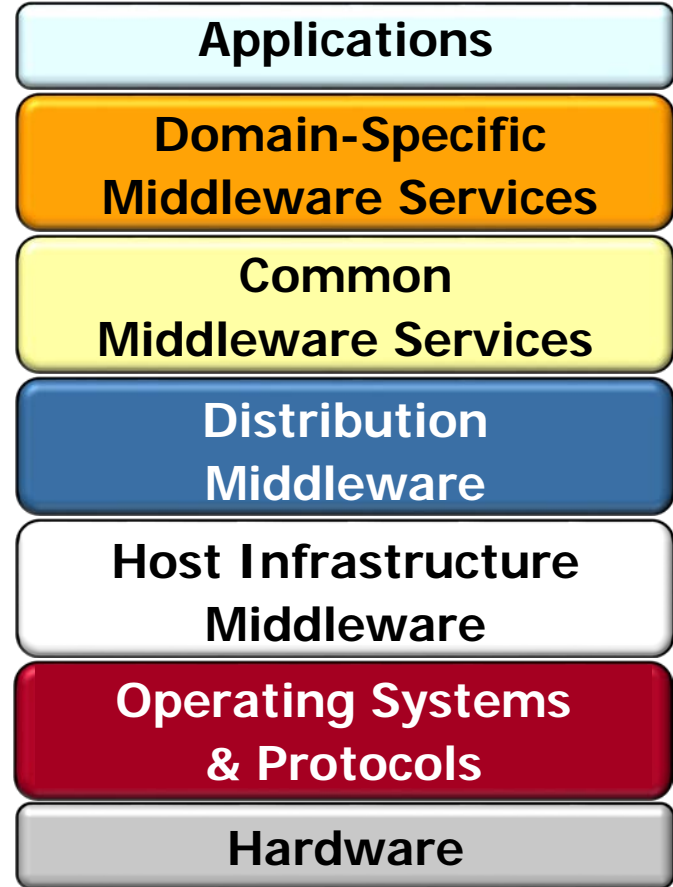


See en.wikipedia.org/wiki/Application_layer

An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
 - Communication middleware in multi-tier enterprise IT systems

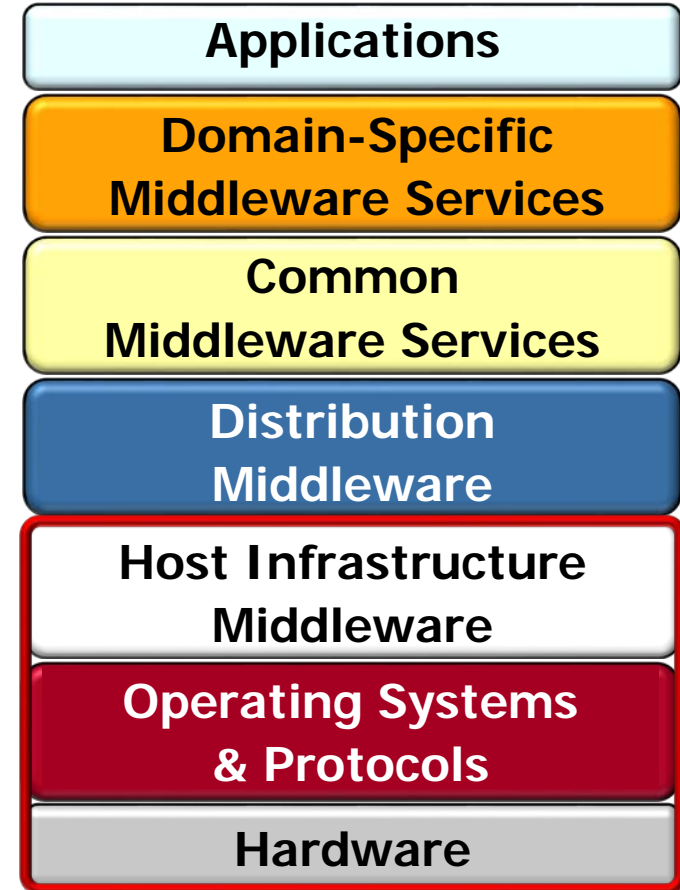
Provides services beyond the operating system & protocol stacks to enable components in a distributed system to communicate & manage data



See [en.wikipedia.org/wiki/Middleware_\(distributed_applications\)](https://en.wikipedia.org/wiki/Middleware_(distributed_applications))

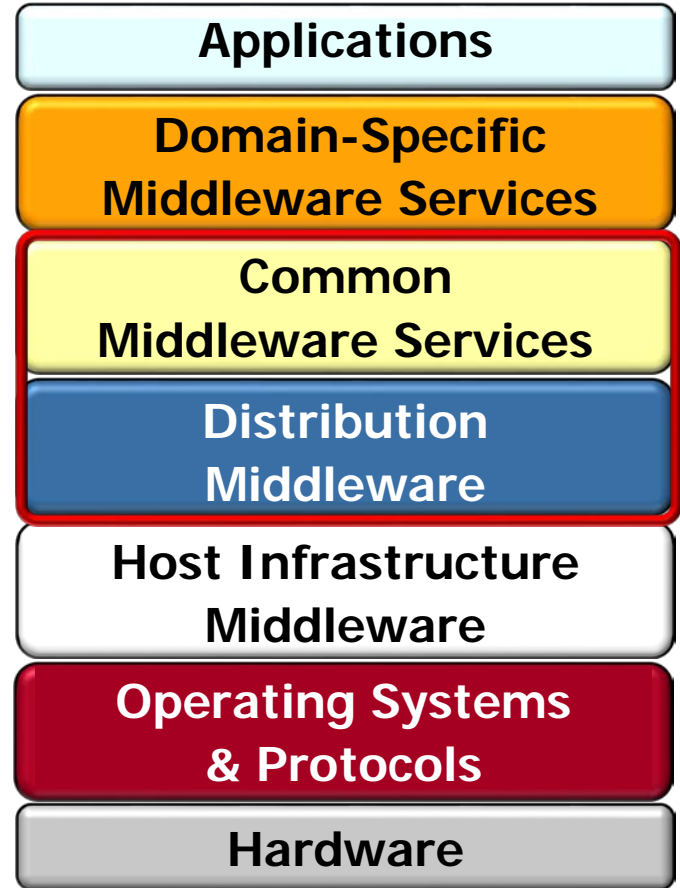
An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
- Communication middleware in multi-tier enterprise IT systems
 - Lower layers provide portable APIs for accessing hardware & system resources
 - e.g., Linux, Windows, JVM, & ACE



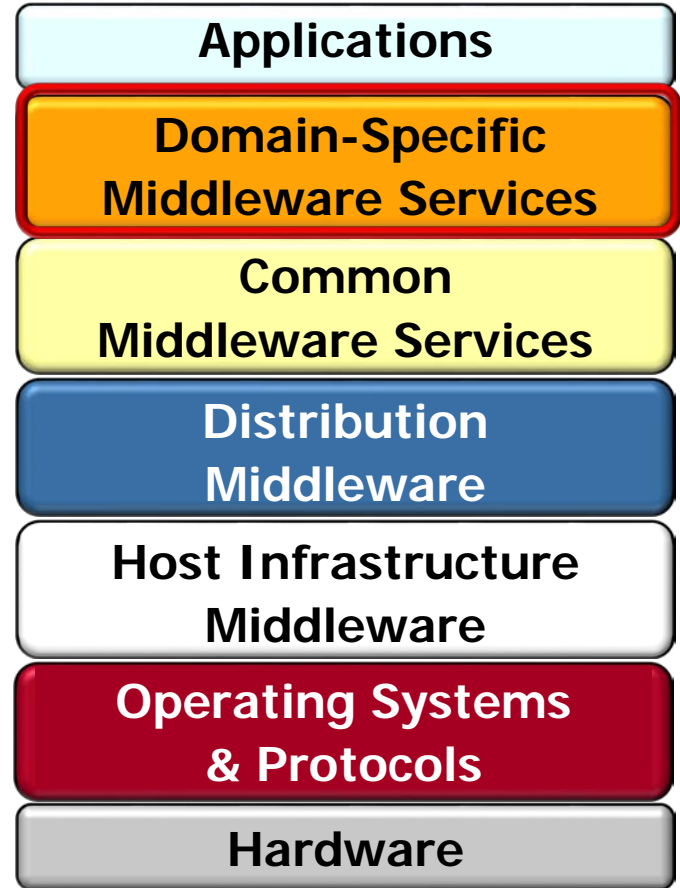
An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
- Communication middleware in multi-tier enterprise IT systems
 - Lower layers provide portable APIs for accessing hardware & system resources
- Middle layers shield applications from network programming details
 - e.g., DDS, Web Services, MQTT, Spring, CORBA, etc.



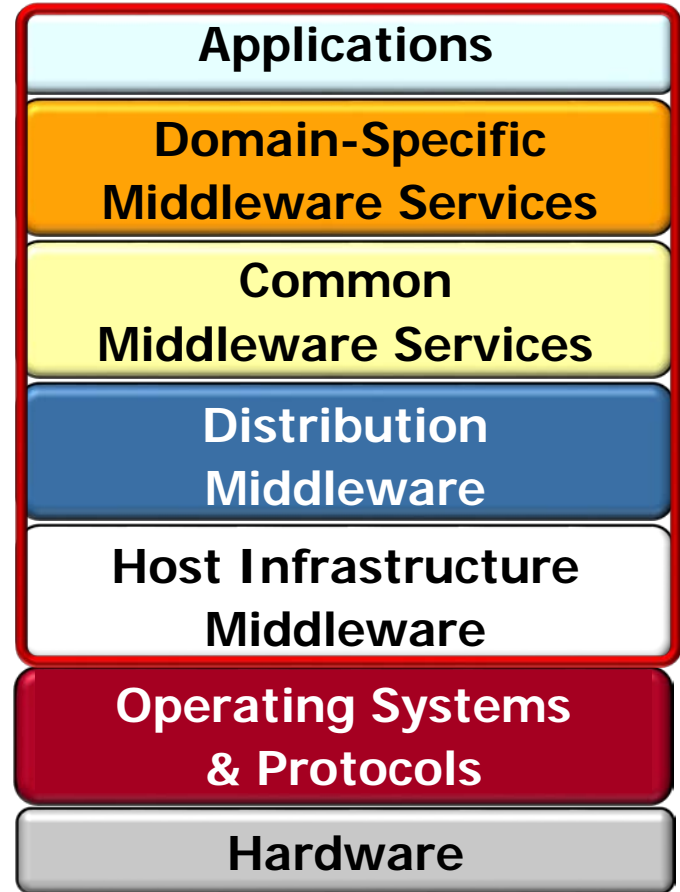
An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
- Communication middleware in multi-tier enterprise IT systems
 - Lower layers provide portable APIs for accessing hardware & system resources
 - Middle layers shield applications from network programming details
 - Upper layers enable domain-specific reuse of capabilities
 - e.g., MD-PnP, IIC, & FACE



An Overview of Layered Architectures

- Layering is applied in many domains, e.g.
 - Computer networking protocol stacks
- Communication middleware in multi-tier enterprise IT systems
 - Lower layers provide portable APIs for accessing hardware & system resources
 - Middle layers shield applications from network programming details
 - Upper layers enable domain-specific reuse of capabilities
- Applications may deal w/multiple layers

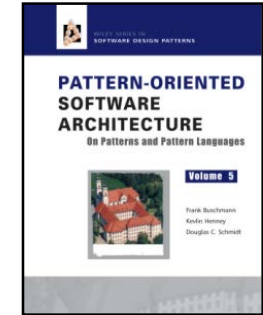
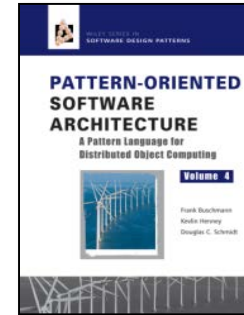
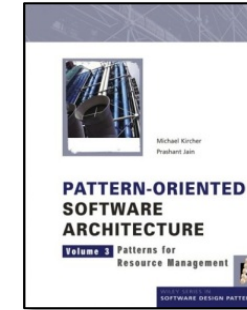
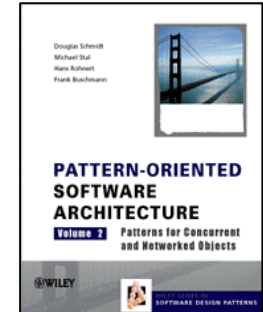


See www.dre.vanderbilt.edu/~schmidt/PDF/middleware-encyclopedia.pdf

Overview of the Layers Architectural Pattern

An Overview of the Layers Architectural Pattern

- The concept of layering has been expressed as an *architectural pattern*



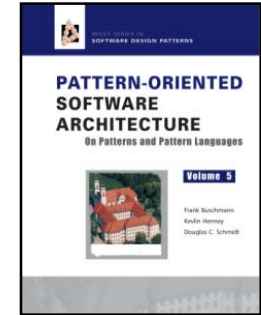
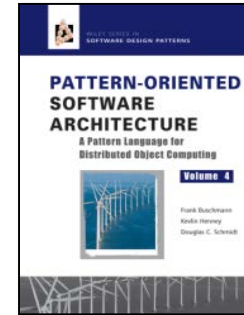
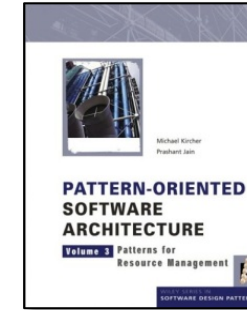
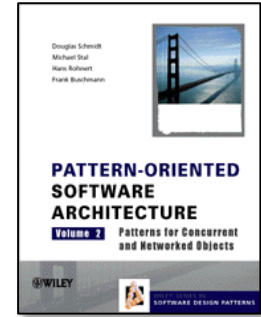
See www.dre.vanderbilt.edu/~schmidt/POSA

An Overview of the Layers Architectural Pattern

- The concept of layering has been expressed as an *architectural pattern*

"a structural organization schema for software *systems* that

- provides a set of predefined *subsystems*
- specifies their responsibilities &
- includes rules & guidelines for organizing the *relationships* between these roles"



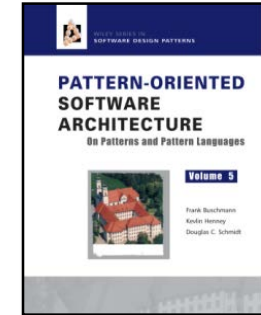
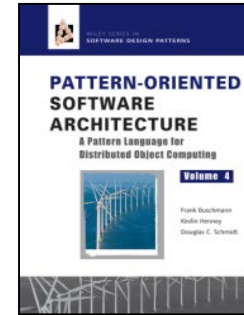
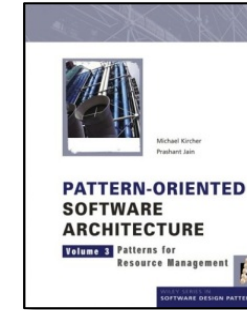
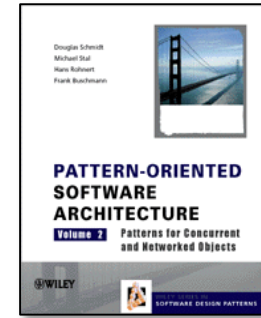
See en.wikipedia.org/wiki/Architectural_pattern

An Overview of the Layers Architectural Pattern

- The concept of layering has been expressed as an *architectural pattern*

"a structural organization schema for software *systems* that

- provides a set of predefined *subsystems*
- specifies their responsibilities &
- includes rules & guidelines for organizing the *relationships* between these roles"



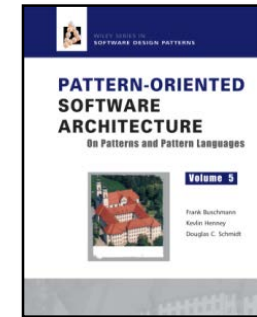
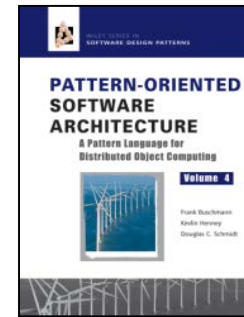
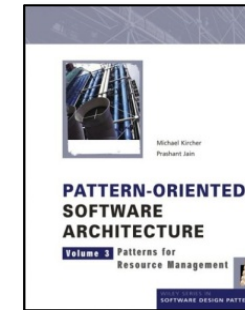
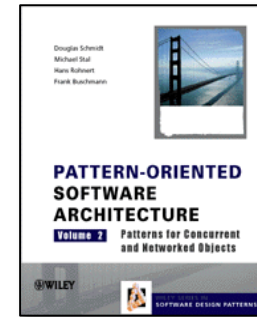
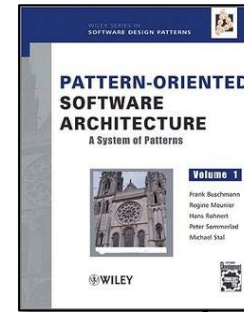
See en.wikipedia.org/wiki/Architectural_pattern

An Overview of the Layers Architectural Pattern

- The concept of layering has been expressed as an *architectural pattern*

"a structural organization schema for software *systems* that

- provides a set of predefined *subsystems*
- specifies their responsibilities &**
- includes rules & guidelines for organizing the *relationships* between these roles"



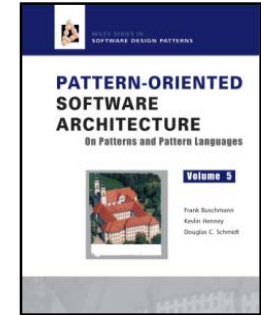
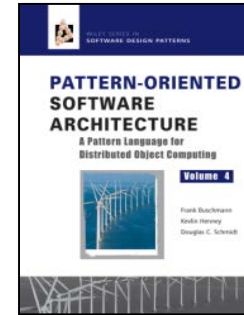
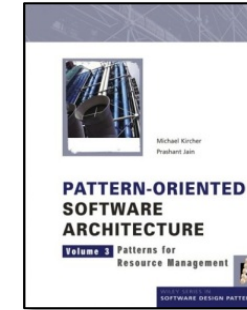
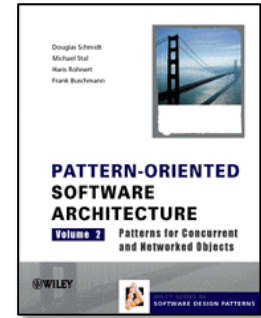
See en.wikipedia.org/wiki/Architectural_pattern

An Overview of the Layers Architectural Pattern

- The concept of layering has been expressed as an *architectural pattern*

"a structural organization schema for software *systems* that

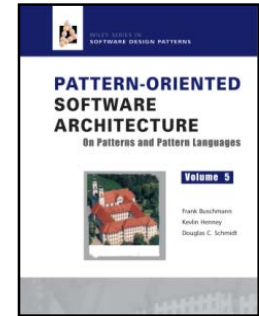
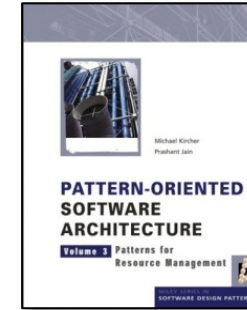
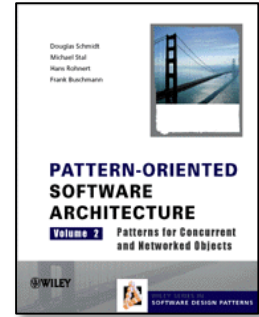
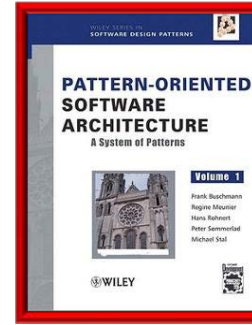
- provides a set of predefined *subsystems*
- specifies their responsibilities &
- includes rules & guidelines for organizing the *relationships* between these roles"



See en.wikipedia.org/wiki/Architectural_pattern

An Overview of the Layers Architectural Pattern

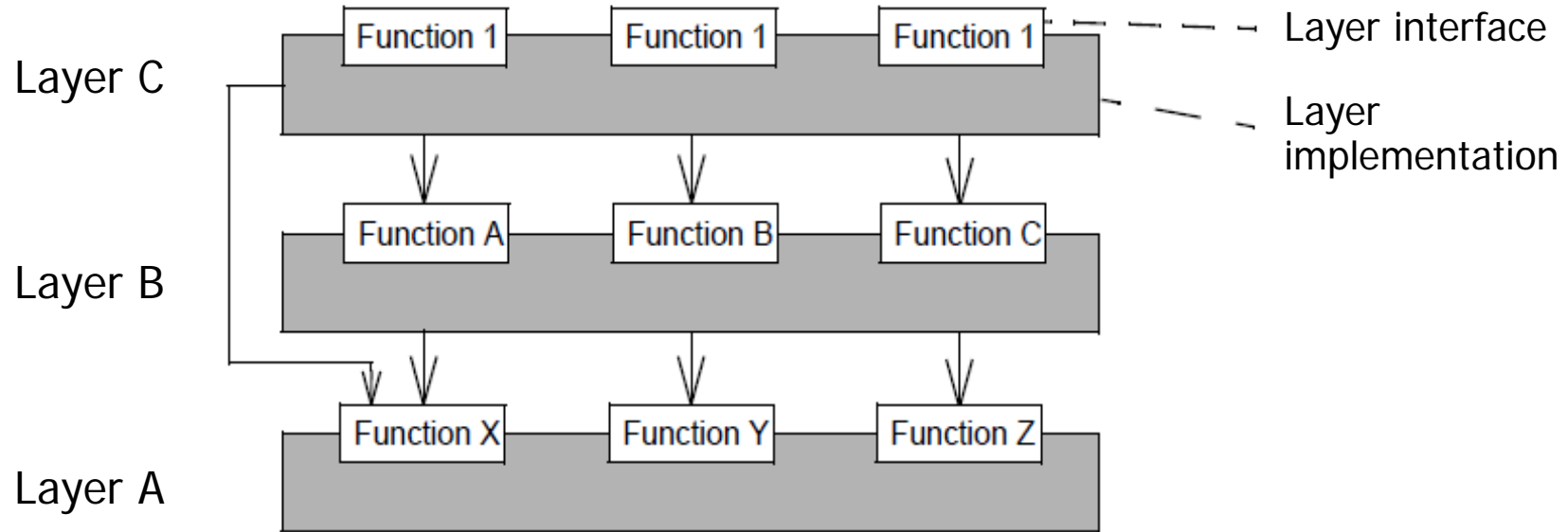
- The *Layers* architectural pattern has been described in various publications



See en.wikipedia.org/wiki/Multilayered_architecture

An Overview of the Layers Architectural Pattern

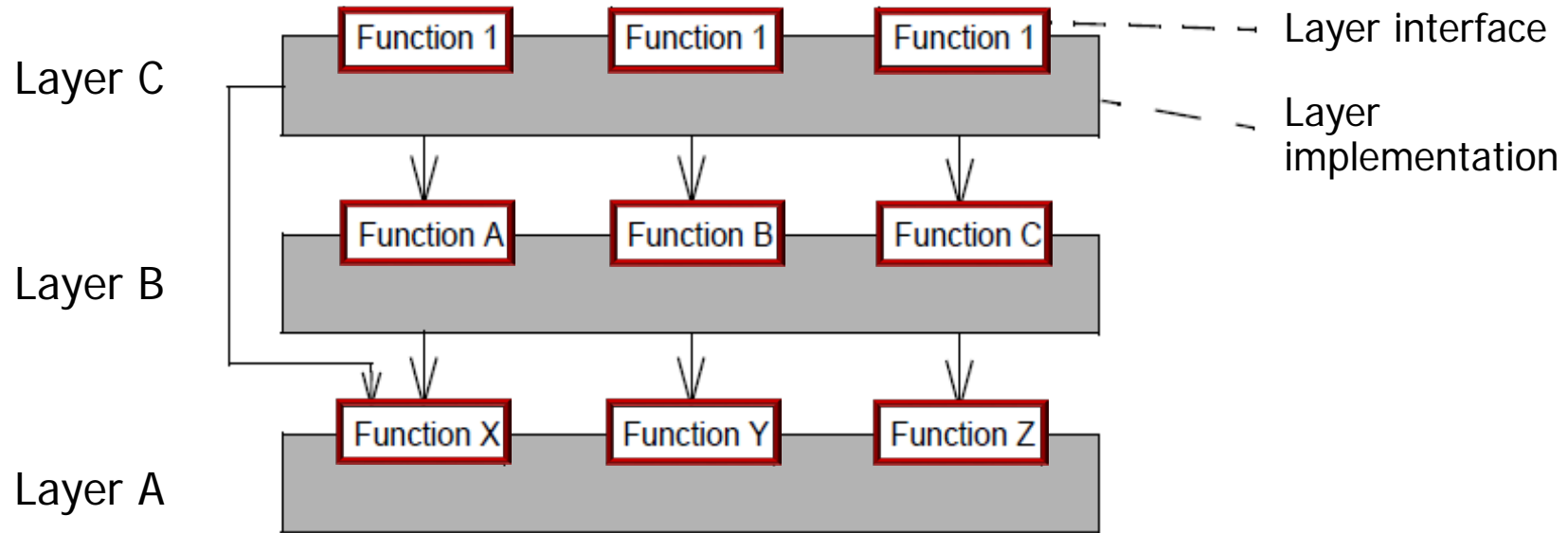
- The *Layers* pattern structures software apps & infrastructure in several ways



See posa1.blogspot.com/2008/05/layered-architecture-pattern.html

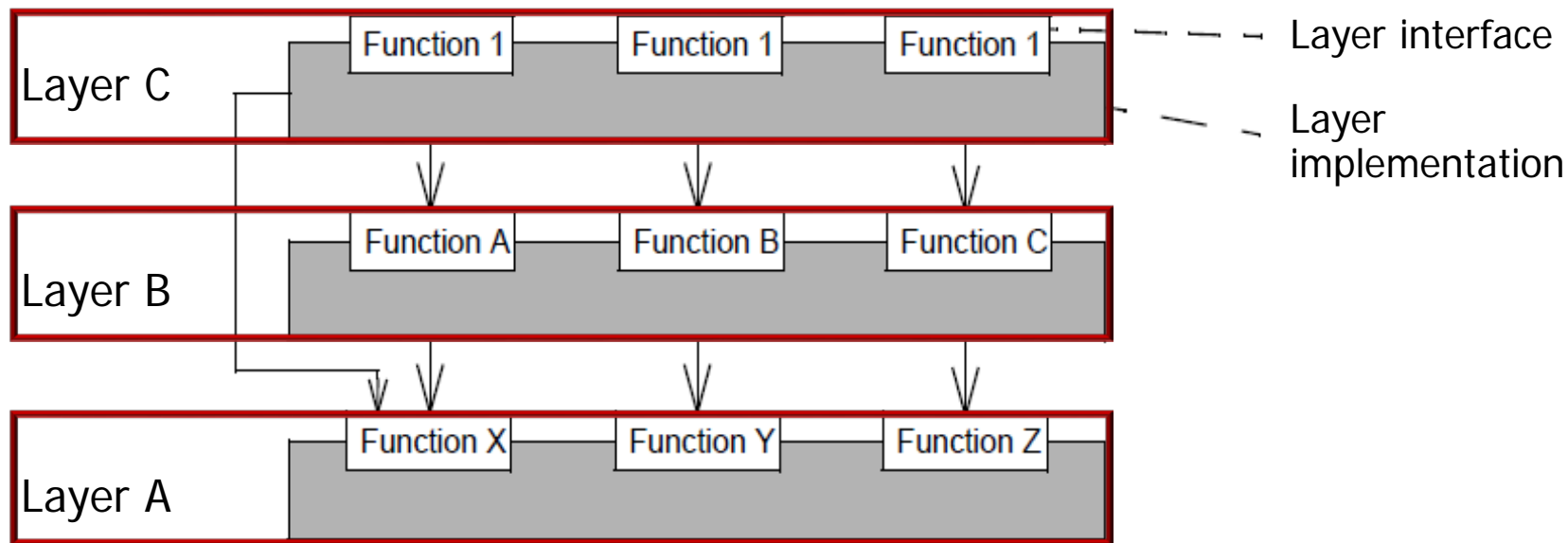
An Overview of the Layers Architectural Pattern

- The *Layers* pattern structures software apps & infrastructure in several ways
 - a. Partitions an overall system architecture into groups of subtasks



An Overview of the Layers Architectural Pattern

- The *Layers* pattern structures software apps & infrastructure in several ways
 - a. Partitions an overall system architecture into groups of subtasks
 - b. Decomposes groups of subtasks into levels of abstraction



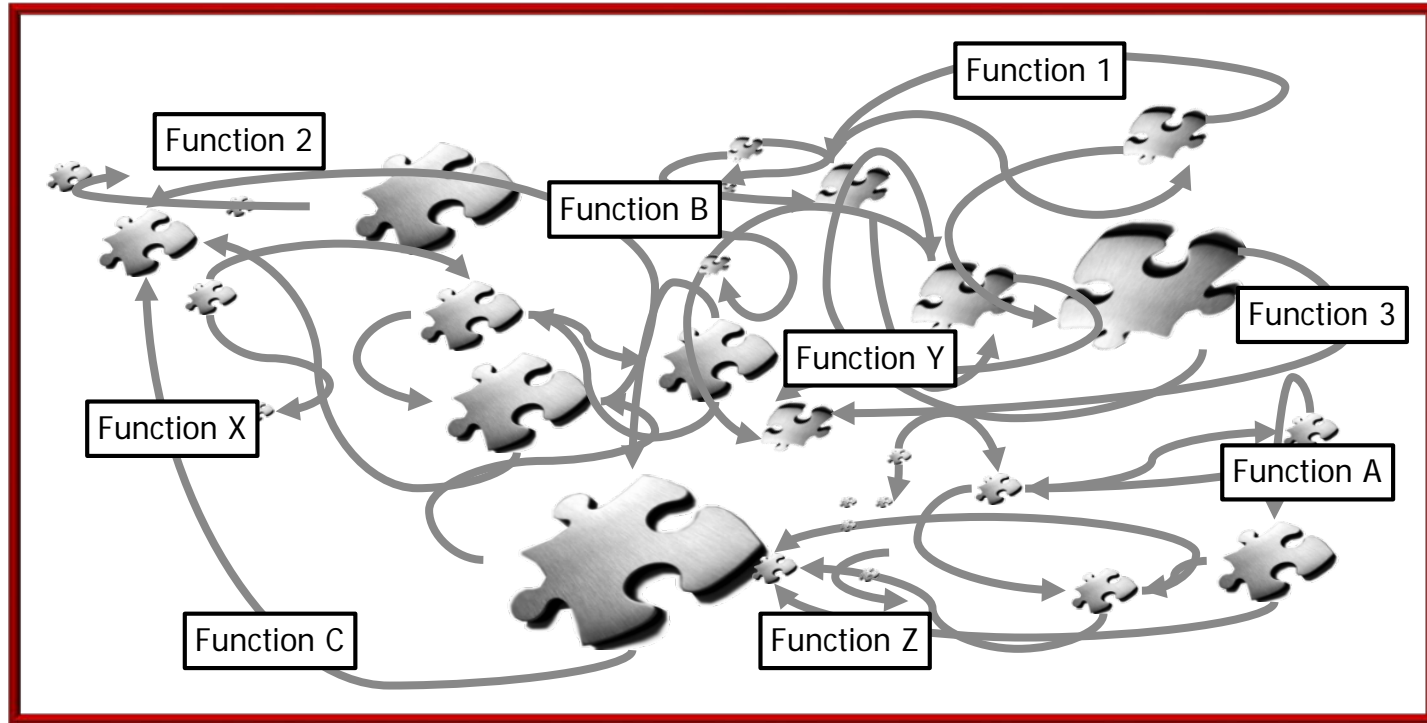
An Overview of the Layers Architectural Pattern

- The *Layers* pattern helps to simplify software development & evolution



An Overview of the Layers Architectural Pattern

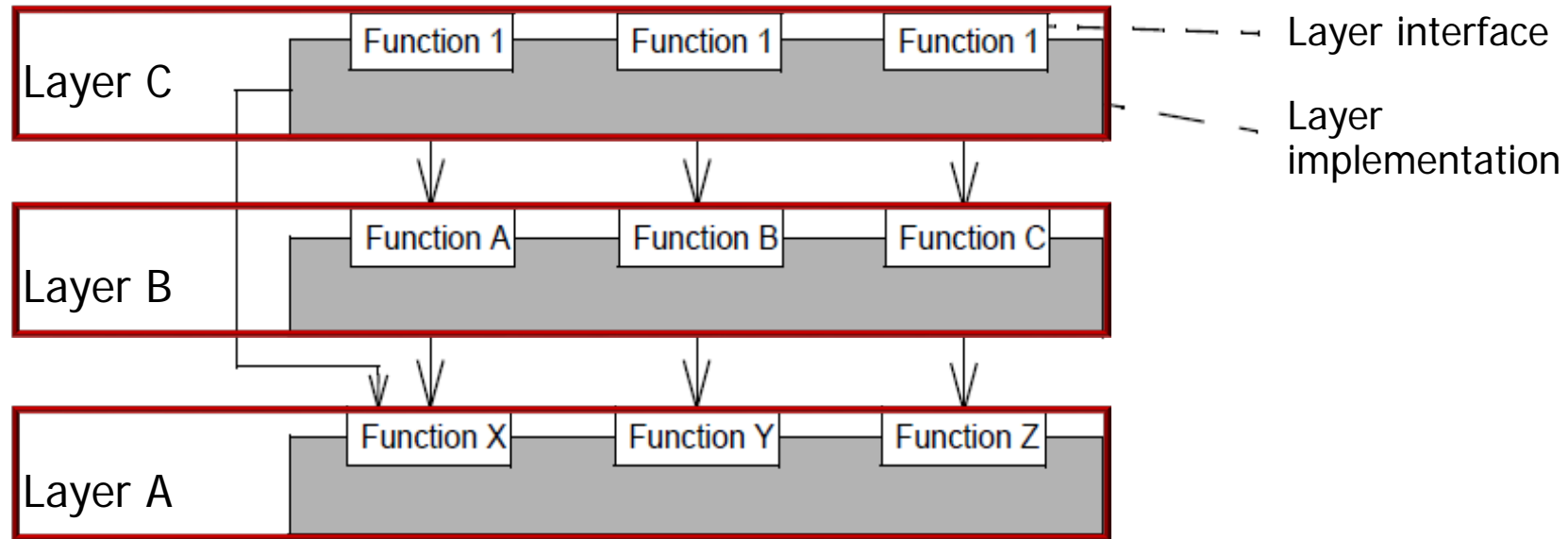
- The *Layers* pattern helps to simplify software development & evolution
 - e.g., it replaces tightly coupled “big balls of mud”...



See en.wikipedia.org/wiki/Big_ball_of_mud

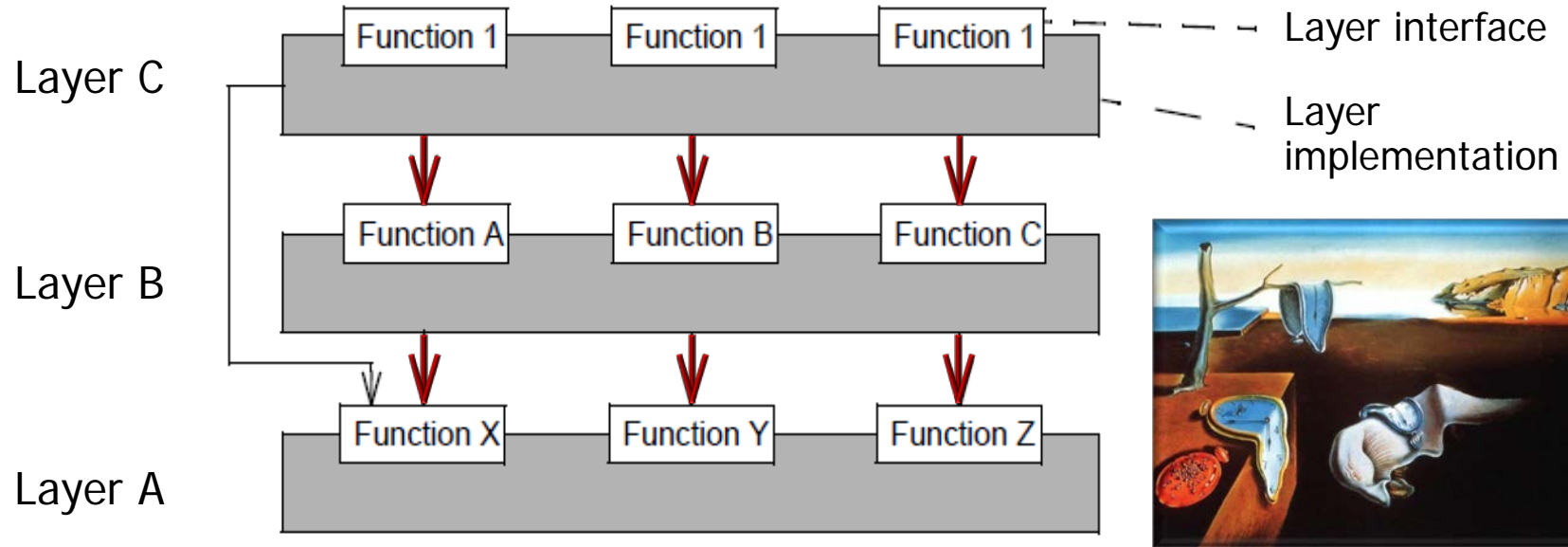
An Overview of the Layers Architectural Pattern

- The *Layers* pattern helps to simplify software development & evolution
 - e.g., it replaces tightly coupled “big balls of mud”... with modular solutions that can be extended & contracted more easily



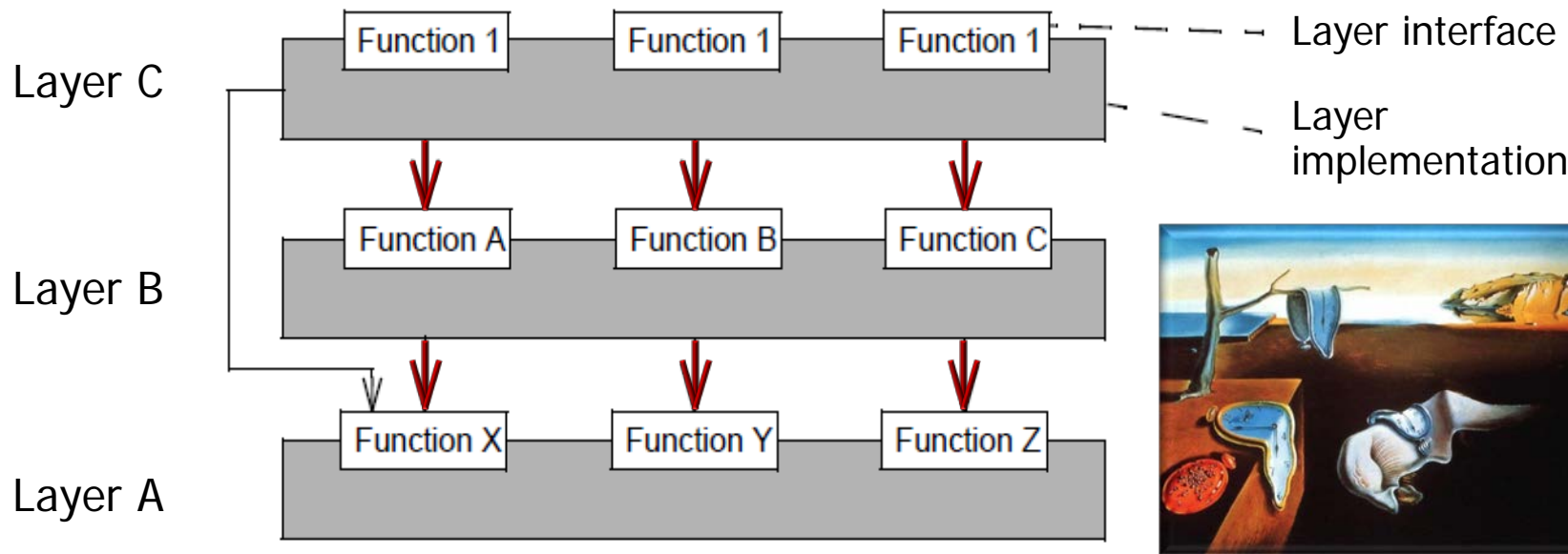
An Overview of the Layers Architectural Pattern

- Be careful when implementing a layered architecture to avoid unnecessary overhead when exchanging data between the layers



An Overview of the Layers Architectural Pattern

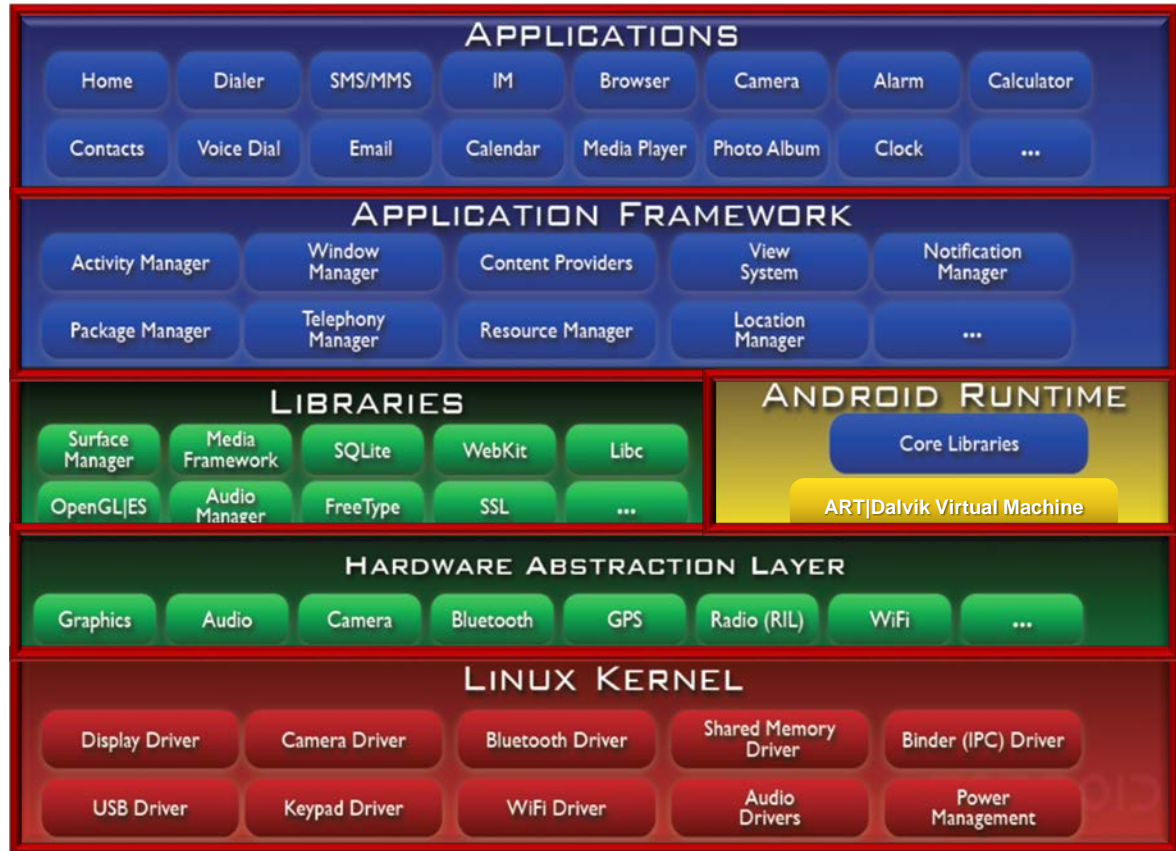
- Be careful when implementing a layered architecture to avoid unnecessary overhead when exchanging data between the layers
 - e.g., minimize context switching, synchronization, & data copying overhead



An Overview of Android's Layered Architecture

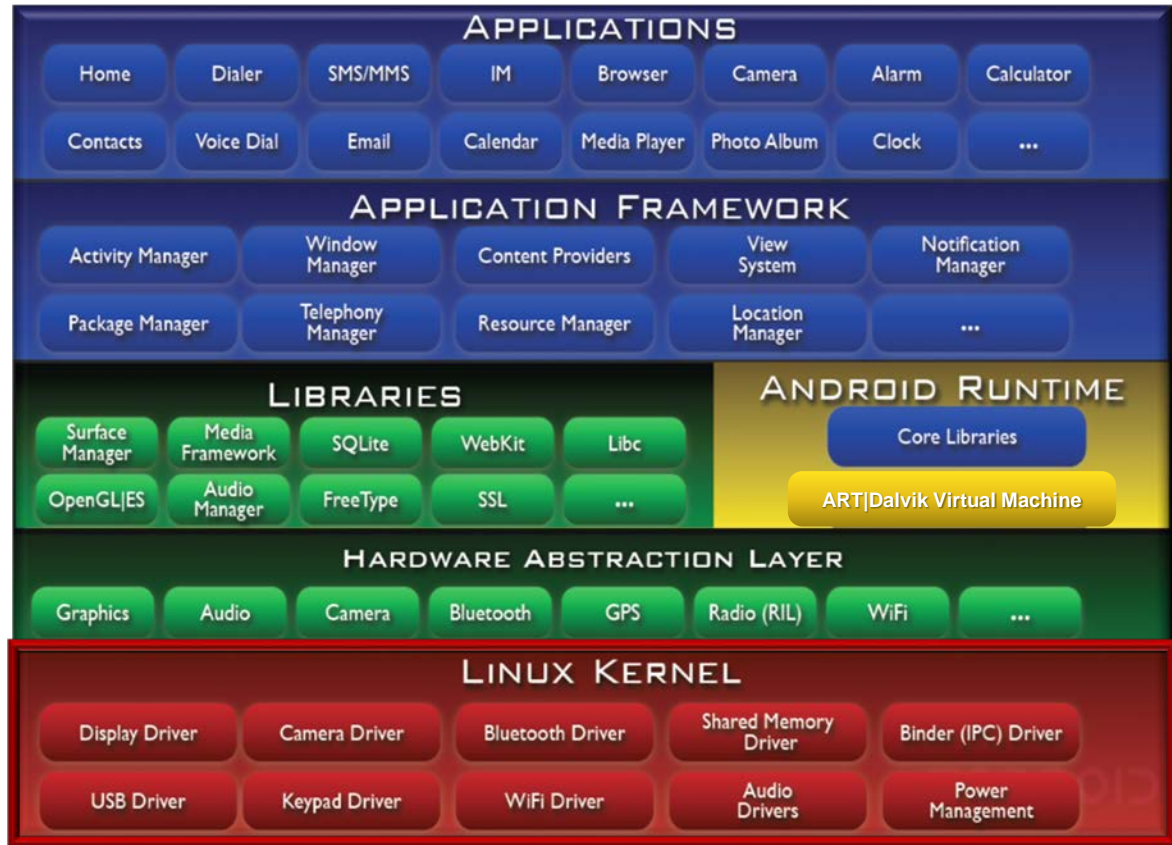
An Overview of Android's Layered Architecture

- Android's architecture is structured in accordance to multiple layers



An Overview of Android's Layered Architecture

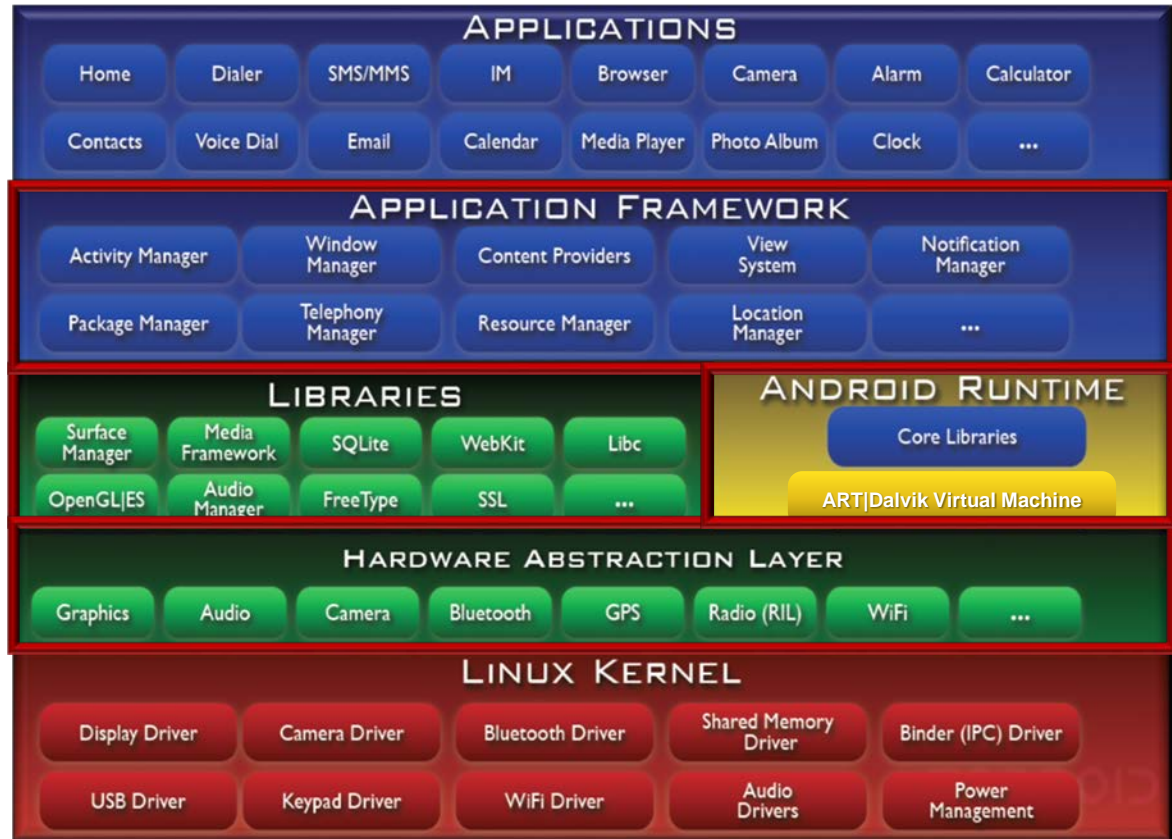
- Android's architecture is structured in accordance to multiple layers



The Android Linux kernel controls hardware & manages system resources

An Overview of Android's Layered Architecture

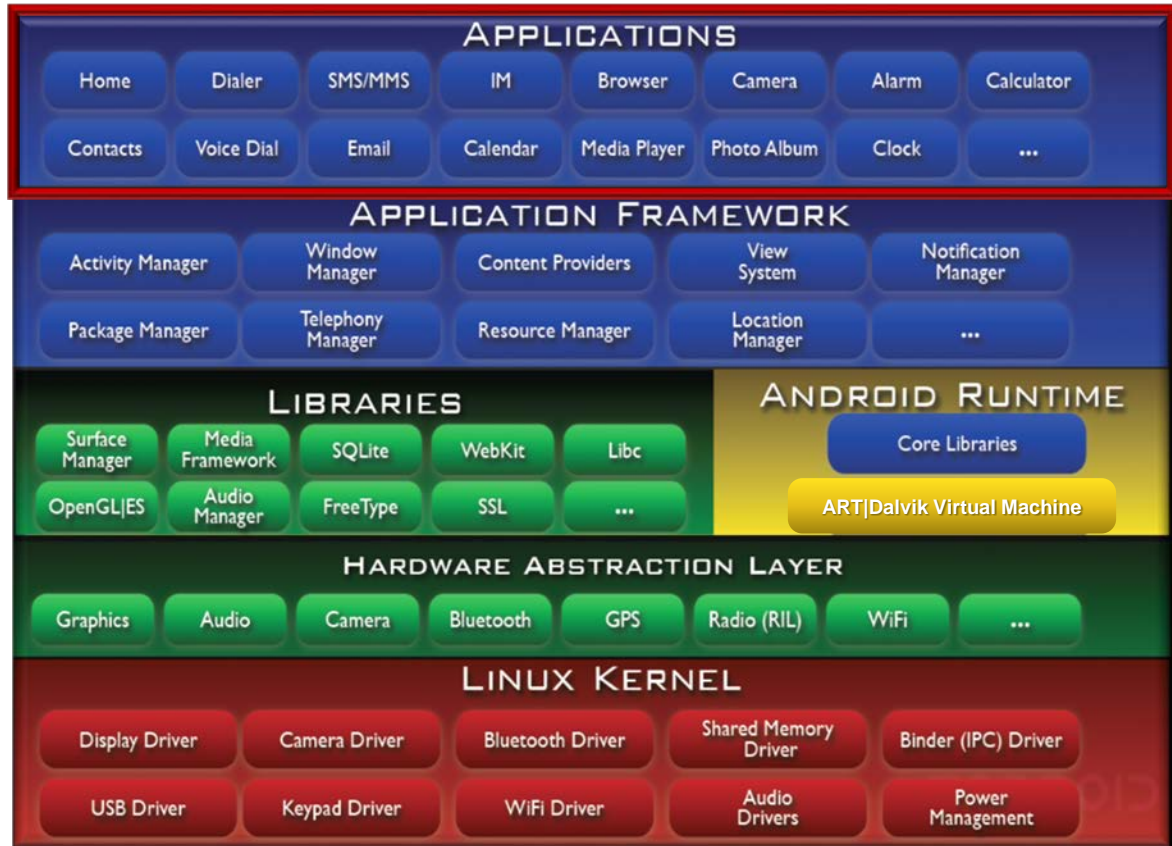
- Android's architecture is structured in accordance to multiple layers



Several layers of middleware provide higher-level reusable services to apps

An Overview of Android's Layered Architecture

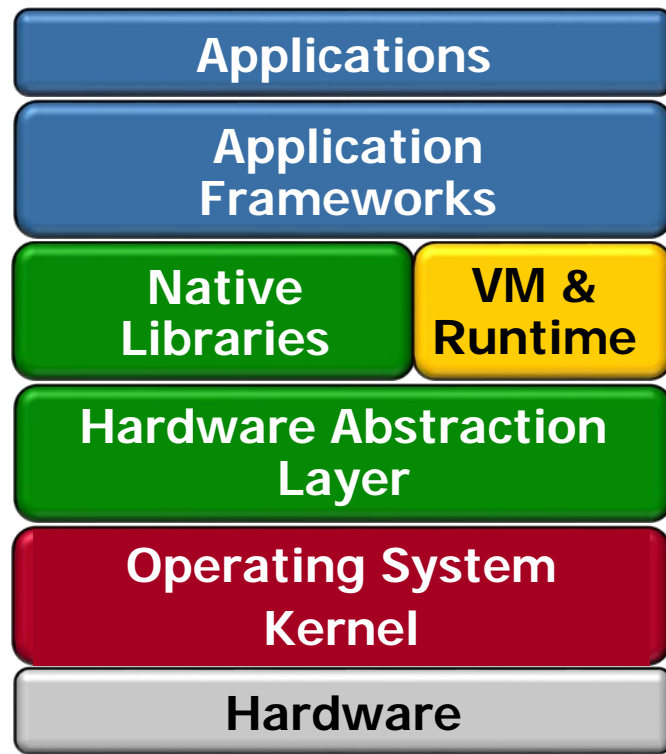
- Android's architecture is structured in accordance to multiple layers



The application layer provides packaged functionality to end-users

An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons

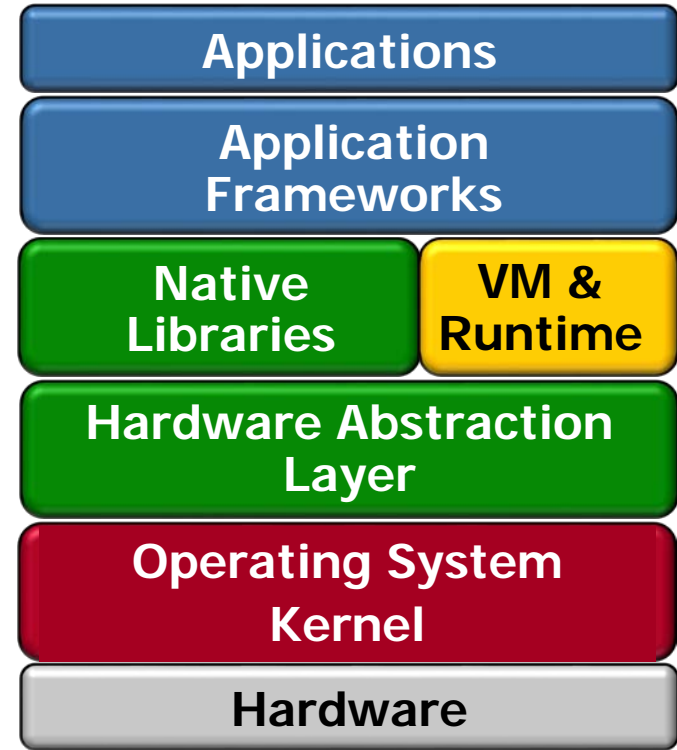


An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse



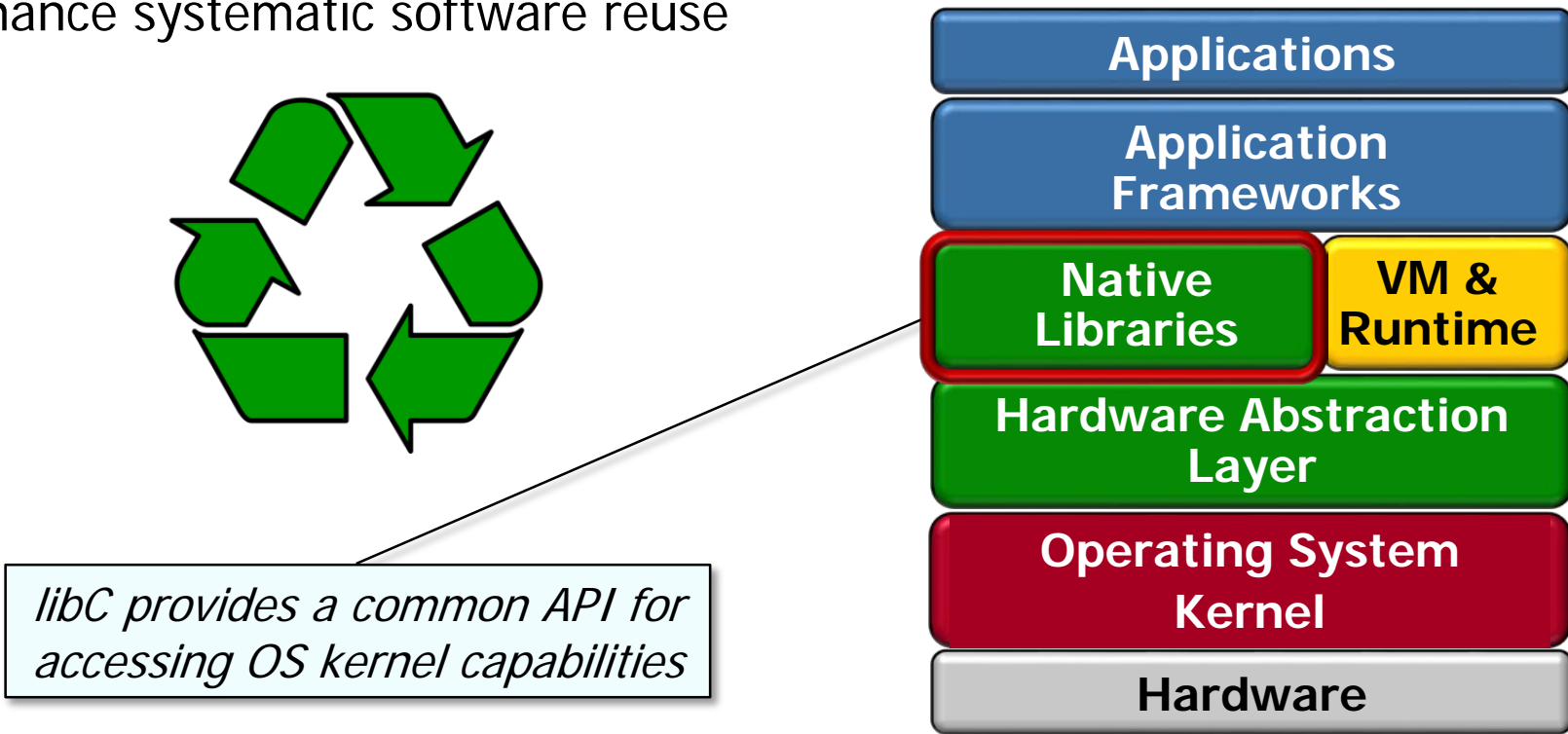
An intentional strategy for increasing productivity & improving software quality



See en.wikipedia.org/wiki/Code_reuse#Systematic_software_reuse

An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse

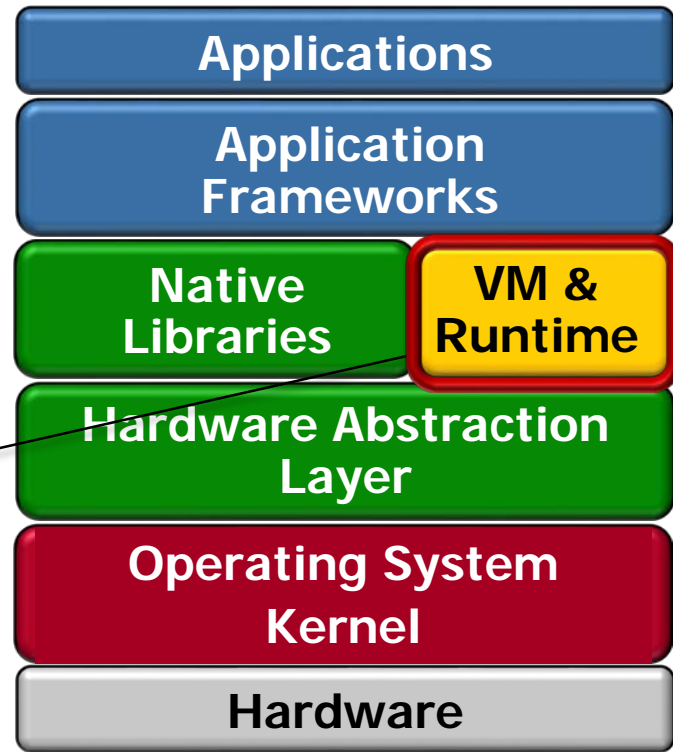


An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse

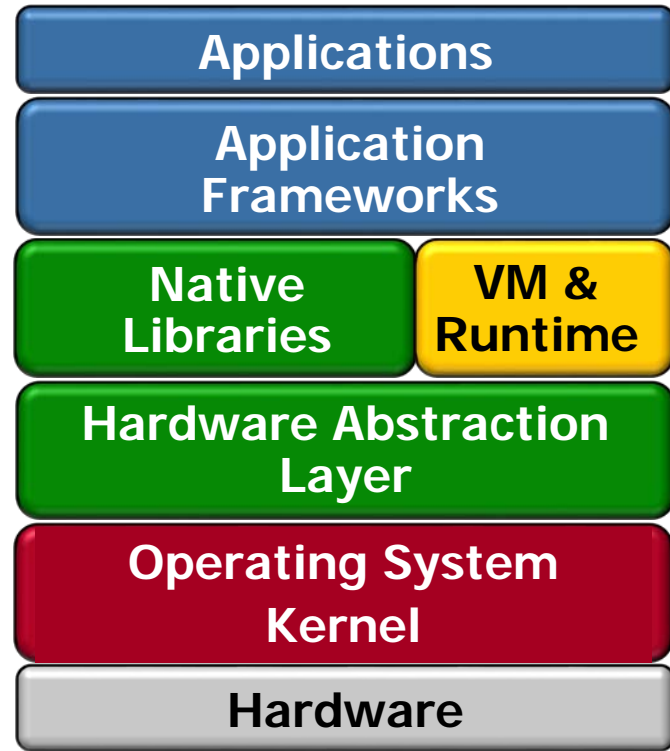


Enable apps to run concurrently over various types of multi-core hardware



An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations

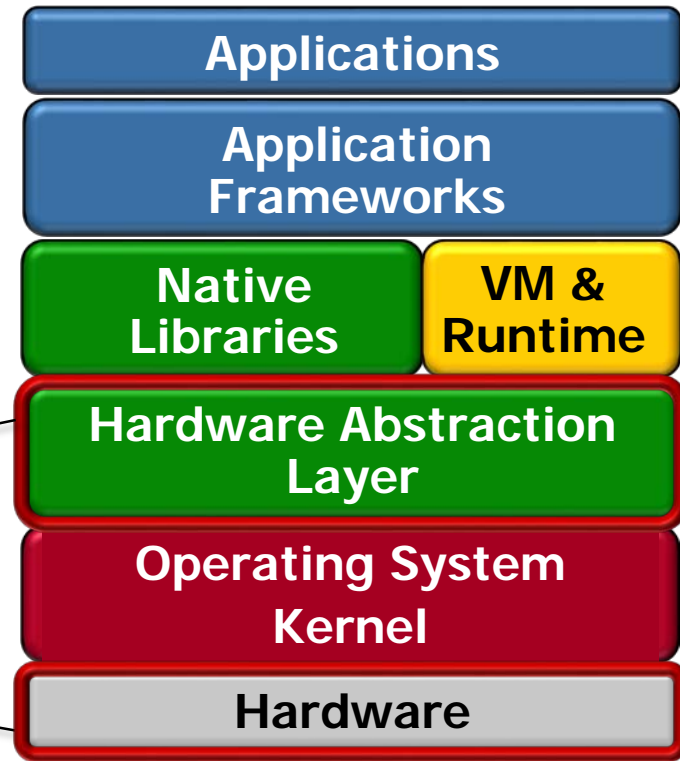


An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations

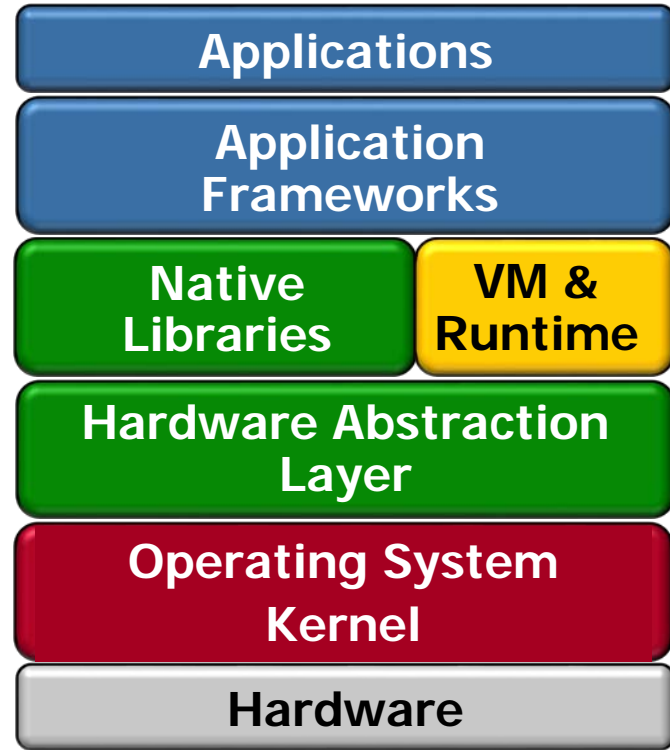


*Shield apps from
inconsistent
hardware APIs*



An Overview of Android's Layered Architecture

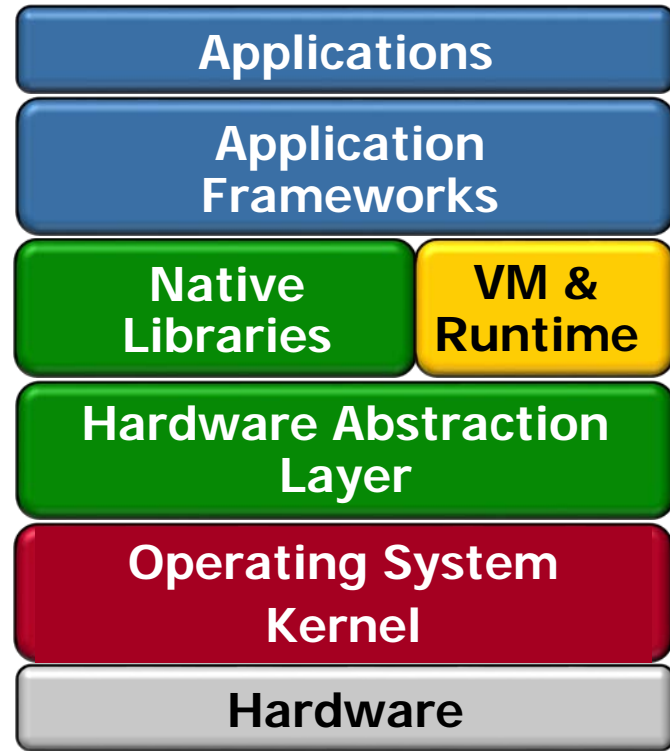
- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations



Effects of updates can be confined to the layer whose implementation changes

An Overview of Android's Layered Architecture

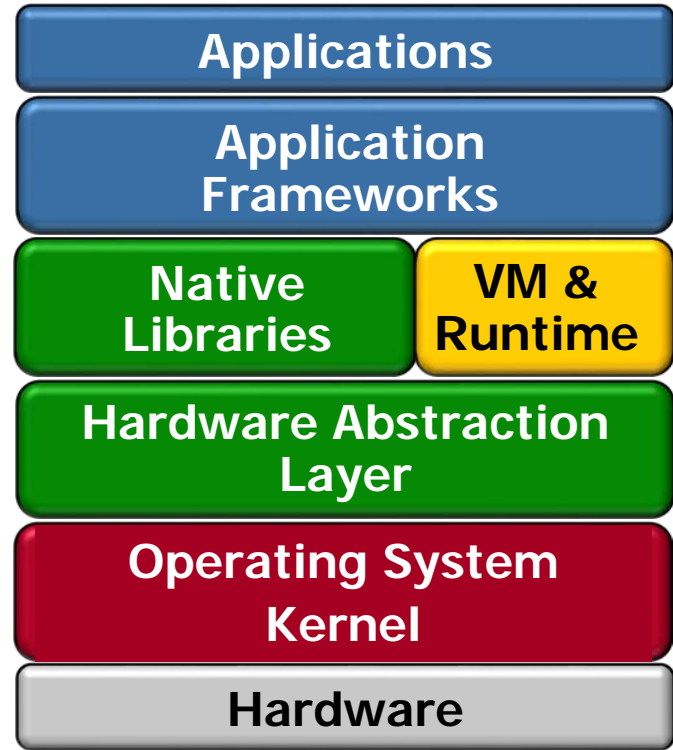
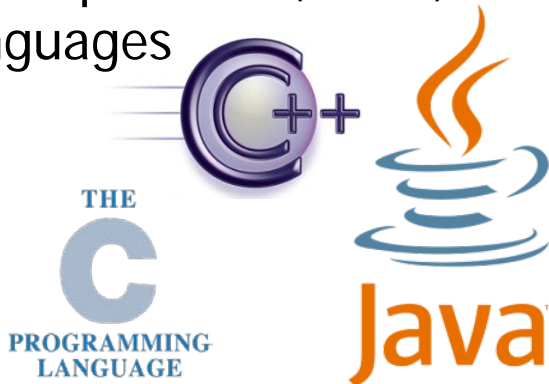
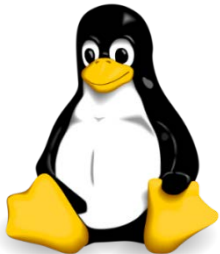
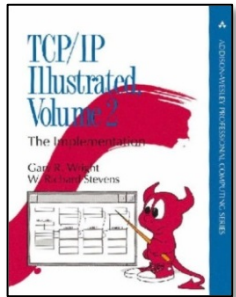
- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations
 - Reduce the complexity of APIs that app developers must understand



See en.wikipedia.org/wiki/Facade_pattern

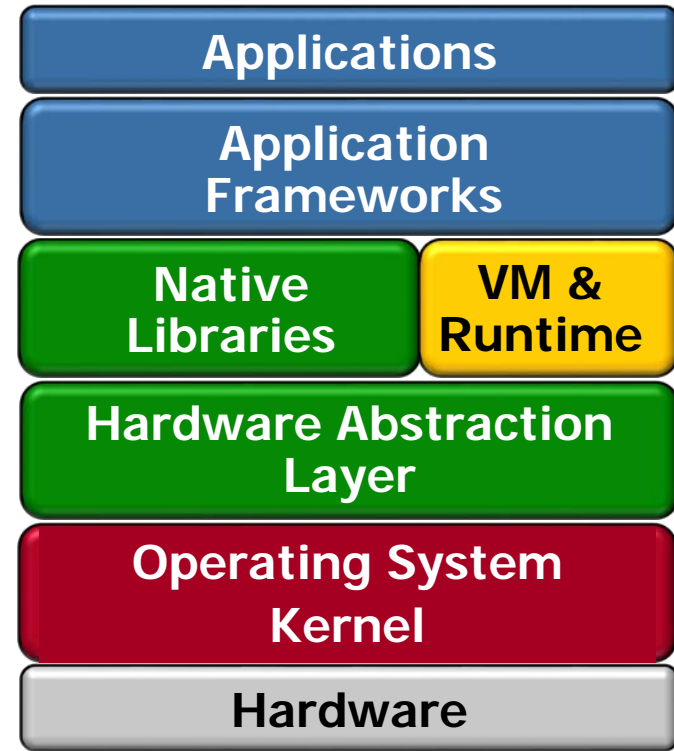
An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations
 - Reduce the complexity of APIs that app developers must understand
 - Enable use of popular protocols, APIs, & programming languages



An Overview of Android's Layered Architecture

- Layering is applied in complex systems like Android for several reasons, e.g.
 - Enhance systematic software reuse
 - Enable “plug & play” replacement of certain layer implementations
 - Reduce the complexity of APIs that app developers must understand
- Enable use of popular protocols, APIs, & programming languages
 - These popular protocols & APIs are available in open-source form



See source.android.com & source.android.com/source/building-kernels.html

End of Overview of Layered Architectures