Principles and Architecture

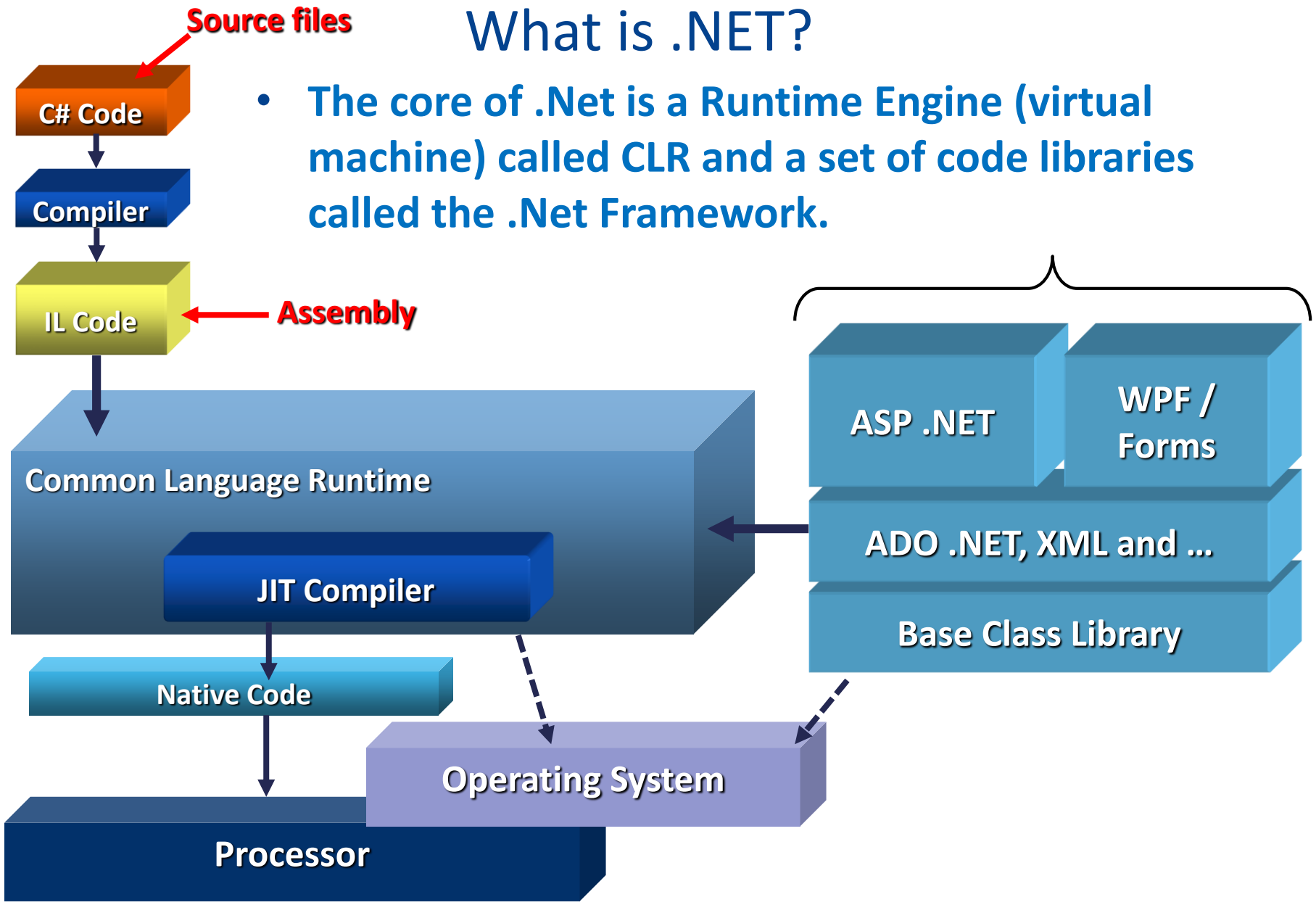
Agenda

- What is .Net?
- Architecture
- Assemblies
- Garbage Collection

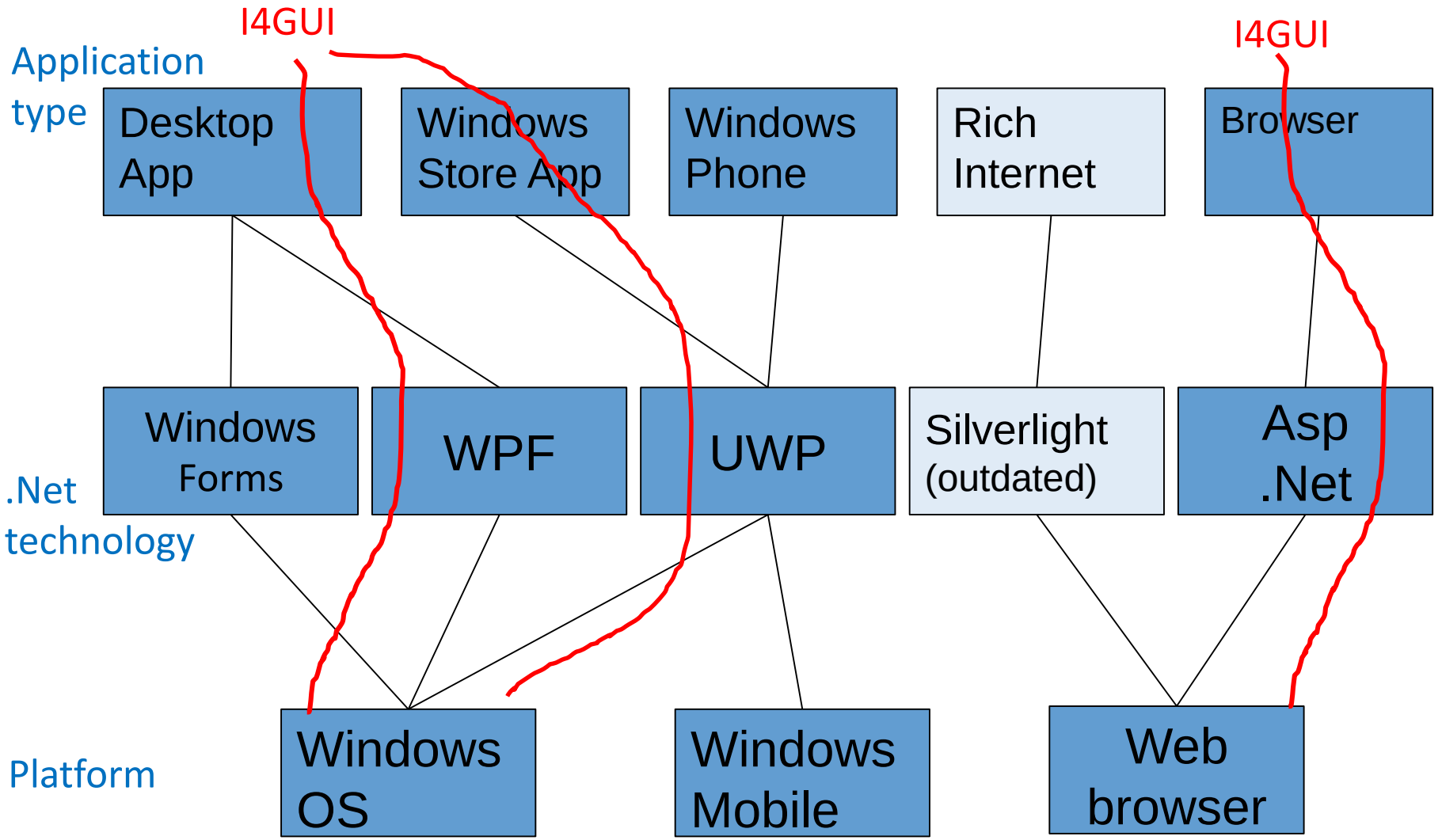
Læringsmål:
Redegøre for principperne i .Net frameworket og dets overordnede arkitektur.

What is .NET?

- The core of .Net is a Runtime Engine (virtual machine) called CLR and a set of code libraries called the .Net Framework.

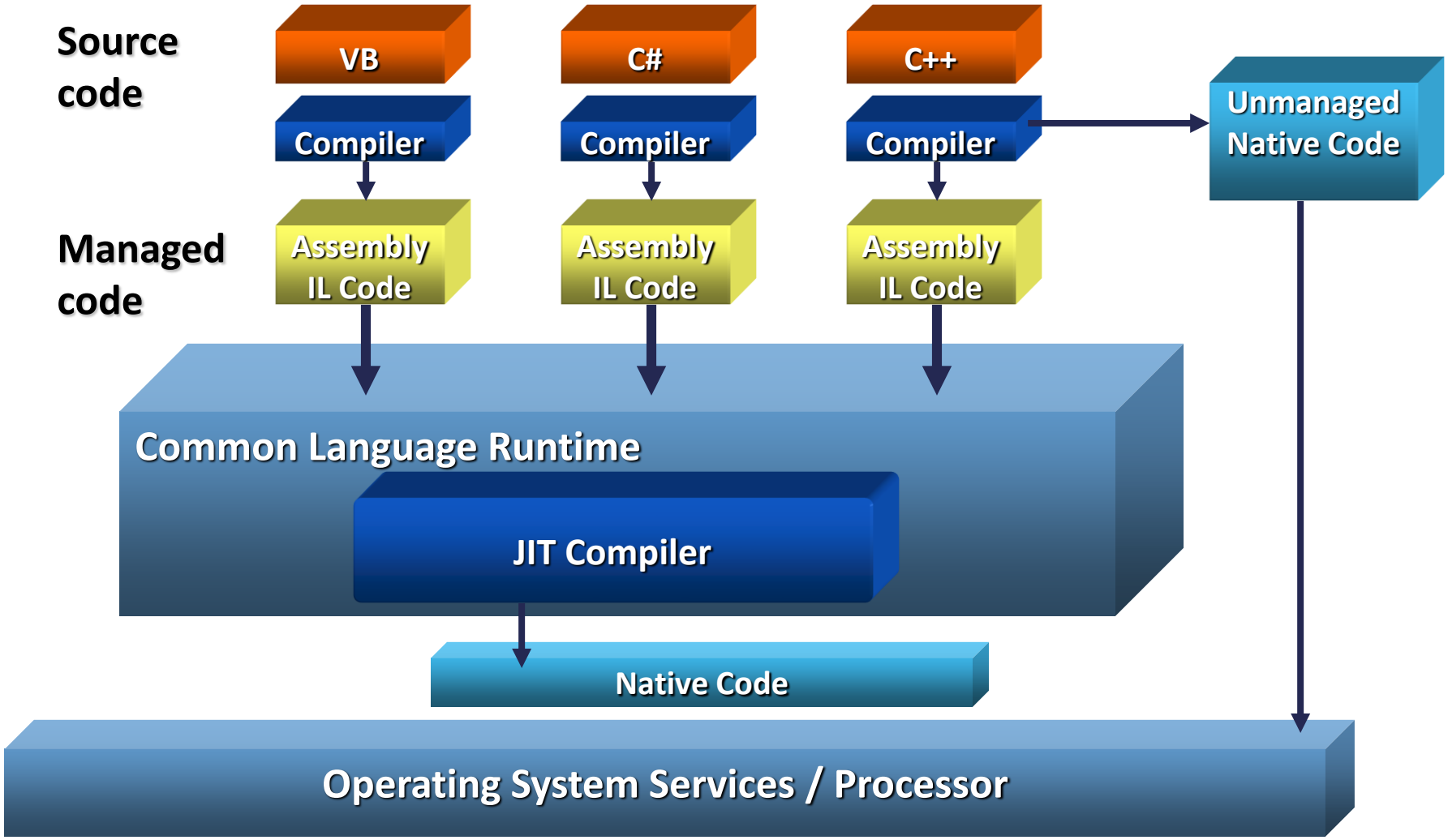


WPF, Windows Phone and Silverlight
Unified programming model

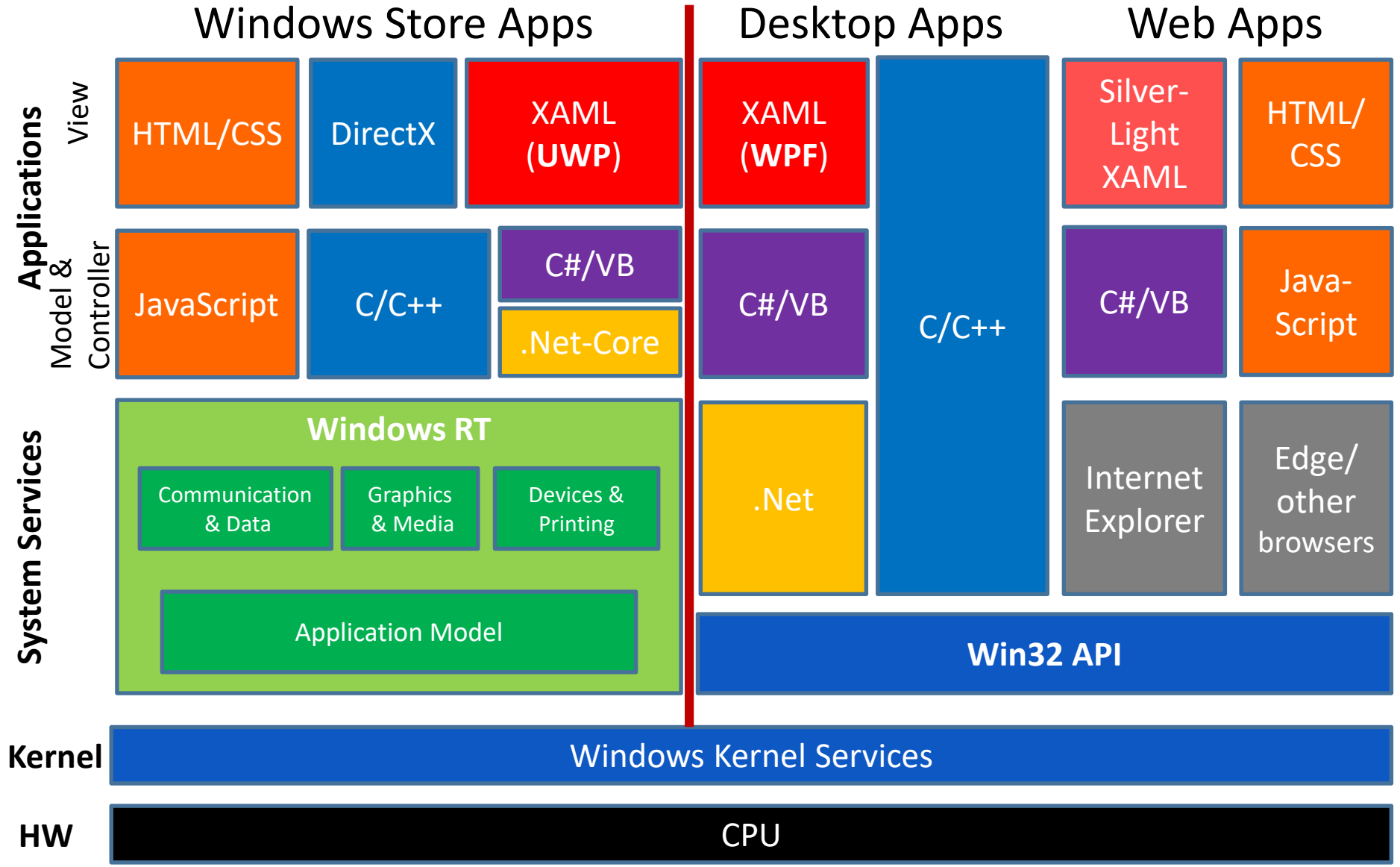


Architectural Overview of the .NET Framework

.Net Framework
Execution Model



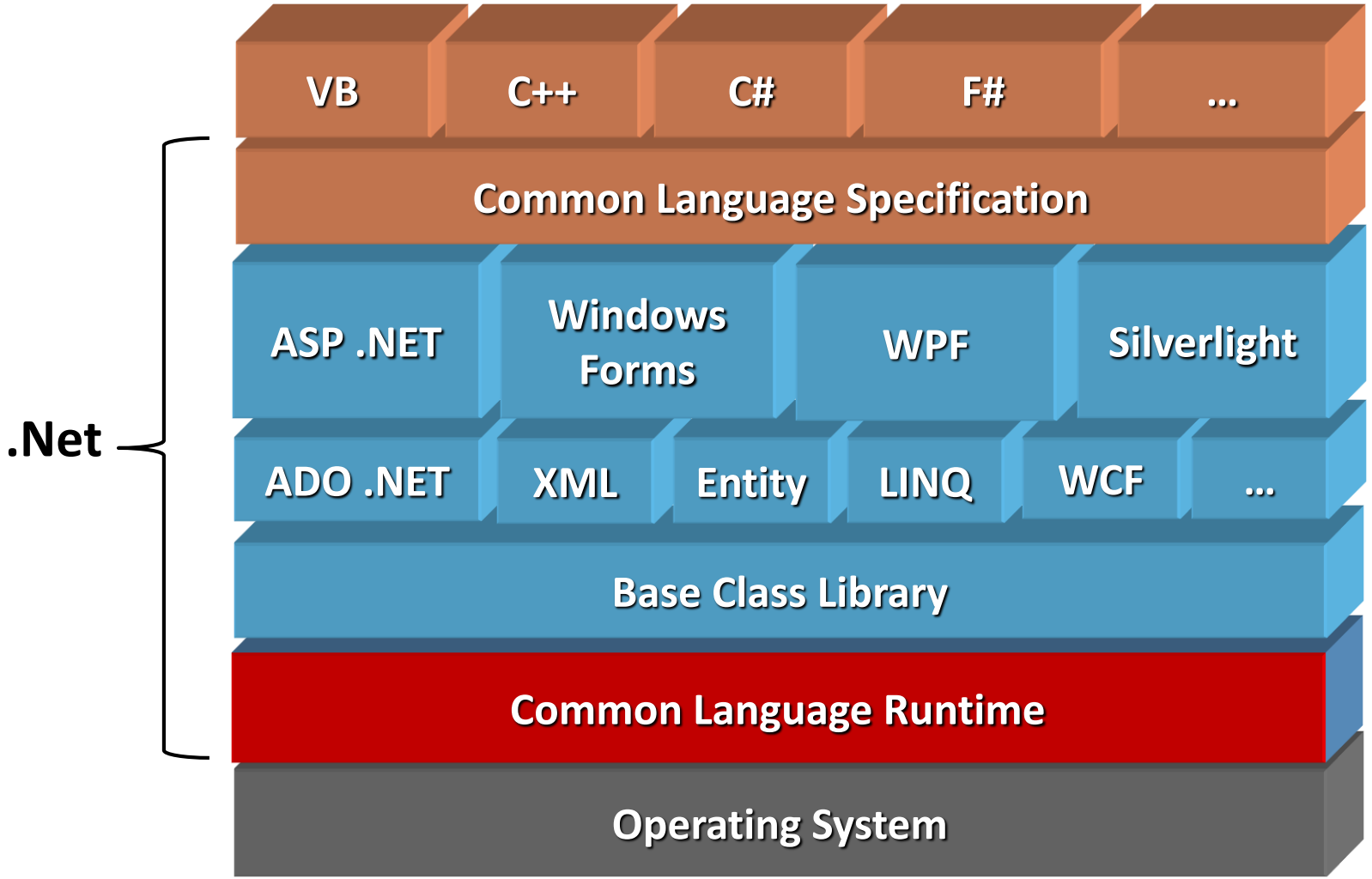
Windows 10 Application Types



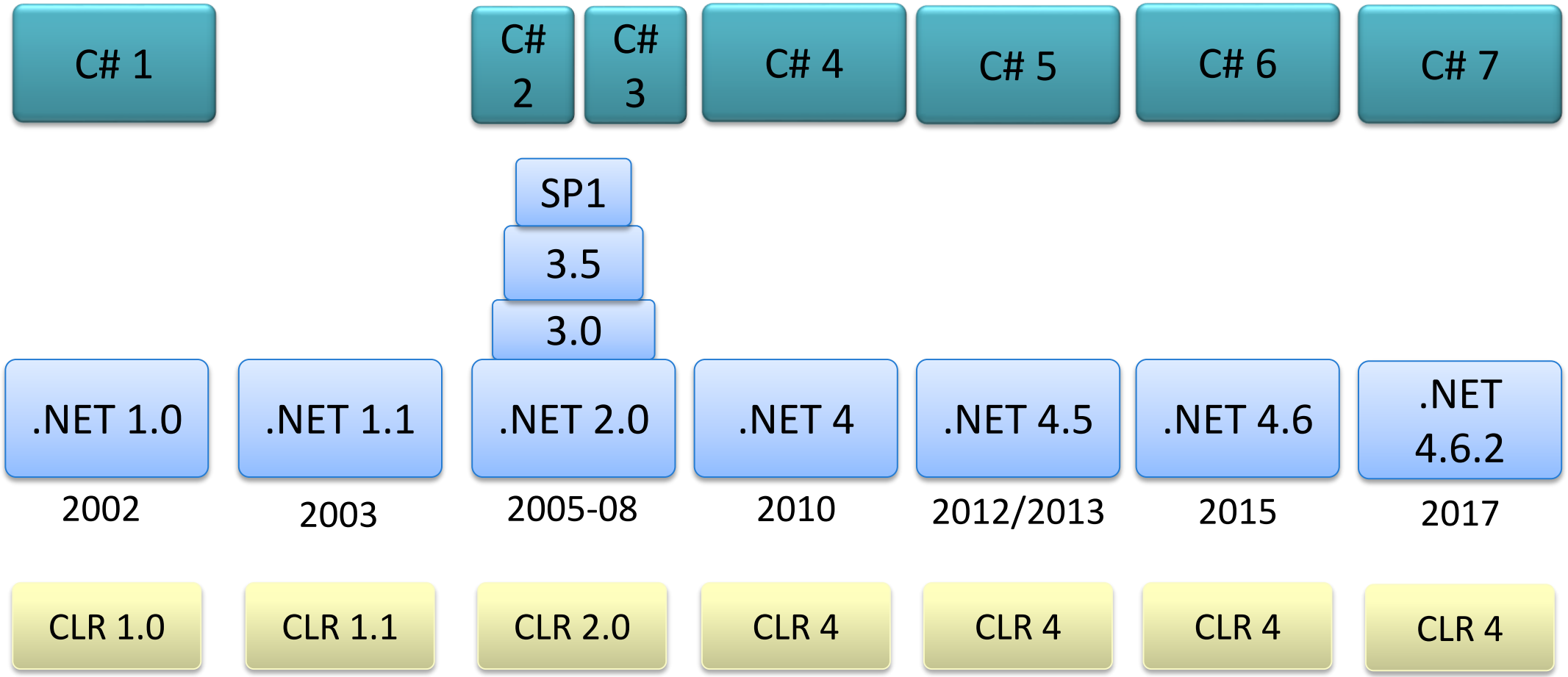
.NET Native

- Typically, apps that target the .NET Framework are compiled to intermediate language (IL)
  - At run time, the just-in-time (JIT) compiler translates the IL to native code
- .NET Native compiles Windows Store apps directly to native code
- .NET Native offers these advantages:
  - Consistently speedy startup times
  - Fast execution times

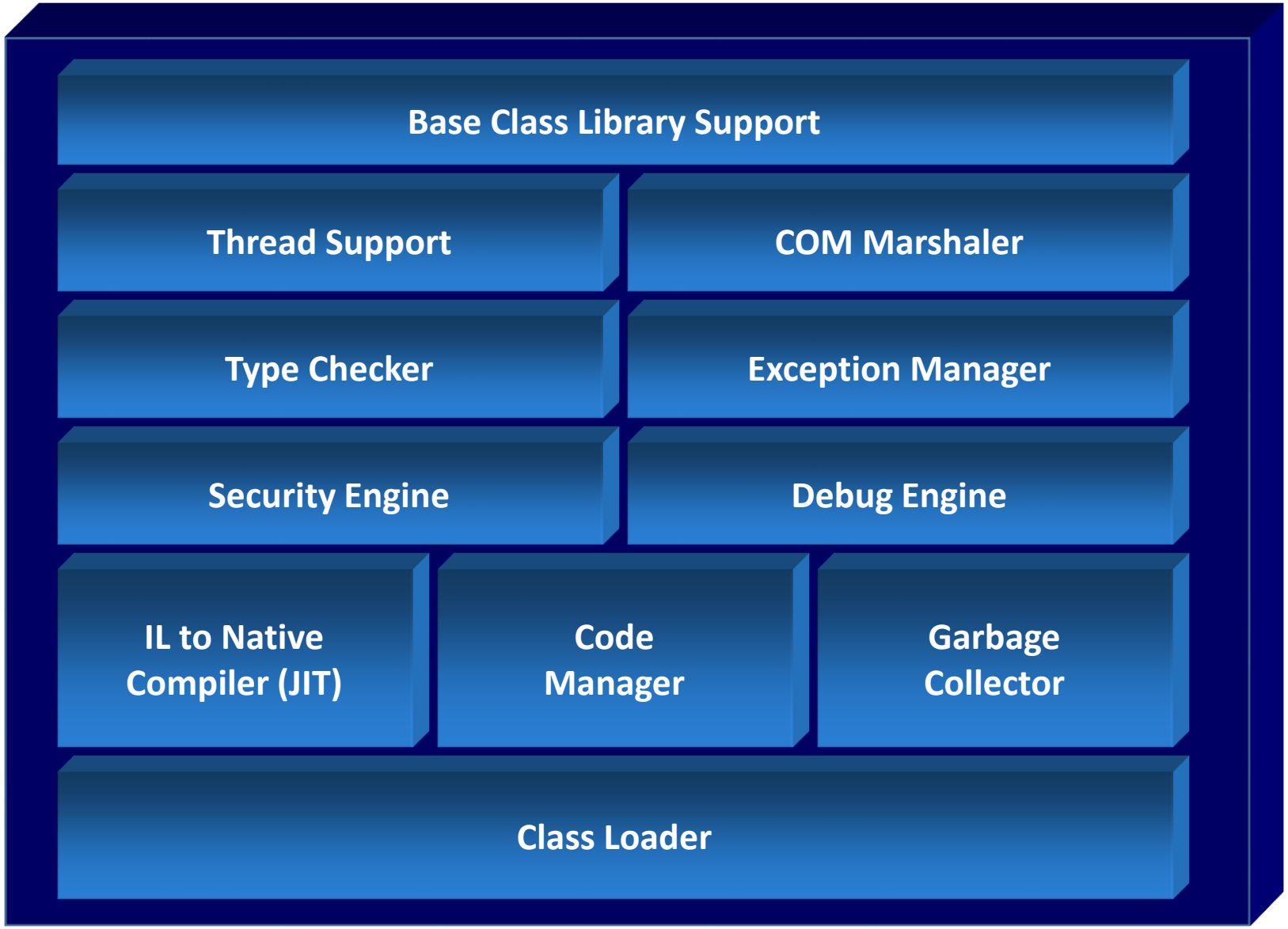
.NET Framework Architecture



A Look Back…


C# 1
C# 2
C# 3
C# 4
C# 5
C# 6
C# 7
SP1
3.5
3.0
.NET 1.0
.NET 1.1
.NET 2.0
.NET 4
.NET 4.5
.NET 4.6
.NET 4.6.2
2002
2003
2005-08
2010
2012/2013
2015
2017
CLR 1.0
CLR 1.1
CLR 2.0
CLR 4
CLR 4
CLR 4
CLR 4

Common Language Runtime



.NET Aim: Robust and Secure

- Automatic lifetime management
  - All .NET objects are garbage collected
    - No stray pointers, no problem with circular references
  - **Multi-generational mark-and-compact GC**
  - Concurrent, self configuring, dynamically tuned
- Exception handling
  - Error handling is a 1st class concept
  - No error return codes – only exceptions
  - Pass exceptions across components & languages
- **Code correctness and type-safety**
  - IL can be verified to guarantee type-safety
  - No unsafe casts
  - no uninitialized variables
  - no out-of-bounds array indexing

.NET Aim: Robust and Secure

- **Intermediate Language code**
  - IL (Intermediate Language) ~ CIL (C for Common) ~ MSIL (MS for Microsoft)
  - No interpreter
  - Install-time (Ngen) or **run-time IL to native compilation (JIT)**

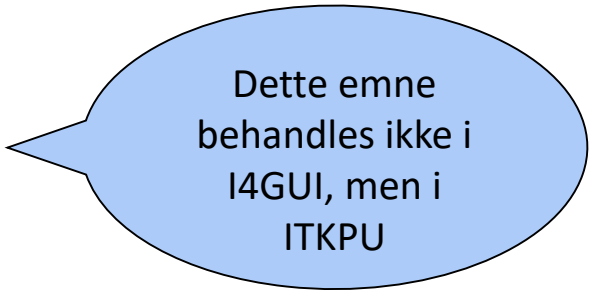
- **Native code (UWP apps)**
  - Fast execution times
  - Consistently speedy startup times
  - Low deployment and update costs
  - Optimized app memory usage

.NET Aim: Simplify Deployment

- Assemblies
  - The unit of deployment, versioning, and security
  - Self-describing through manifest
- Zero-impact install
  - Applications and components can be shared or private
- Side-by-side execution
  - Multiple versions of the same component can co-exist, even in the same process

.NET Aim: Seamless Integration

- Interoperability in .Net
  - .NET classes can be used as a COM class
  - COM classes can be imported as .NET classes
- PInvoke
  - Can call DLL entry points (exported functions) in unmanaged DLL's
- C++ managed extensions



.NET Aim: Make It Simple To Use

- Organization
  - Code organized in hierarchical namespaces and classes
- Unified type system
  - Eg: one string type!
  - Everything is an object
    - Reference Types or Value Types (primitive types)
- Component Oriented
  - Properties, methods, events, and attributes are first class constructs
  - Design-time functionality

.NET Aim: Factored And Extensible

- The Framework is not a “black box”
- Many .NET class are available for you to extend through inheritance
- Cross-language inheritance!

.NET Aim: Multi-language Platform

- The freedom to choose language
  - All features of .NET platform available to any .NET programming language
  - Application components can be written in multiple languages
- Highly leveraged tools
  - Debuggers, profilers, code coverage analyzers, etc. Work for all languages

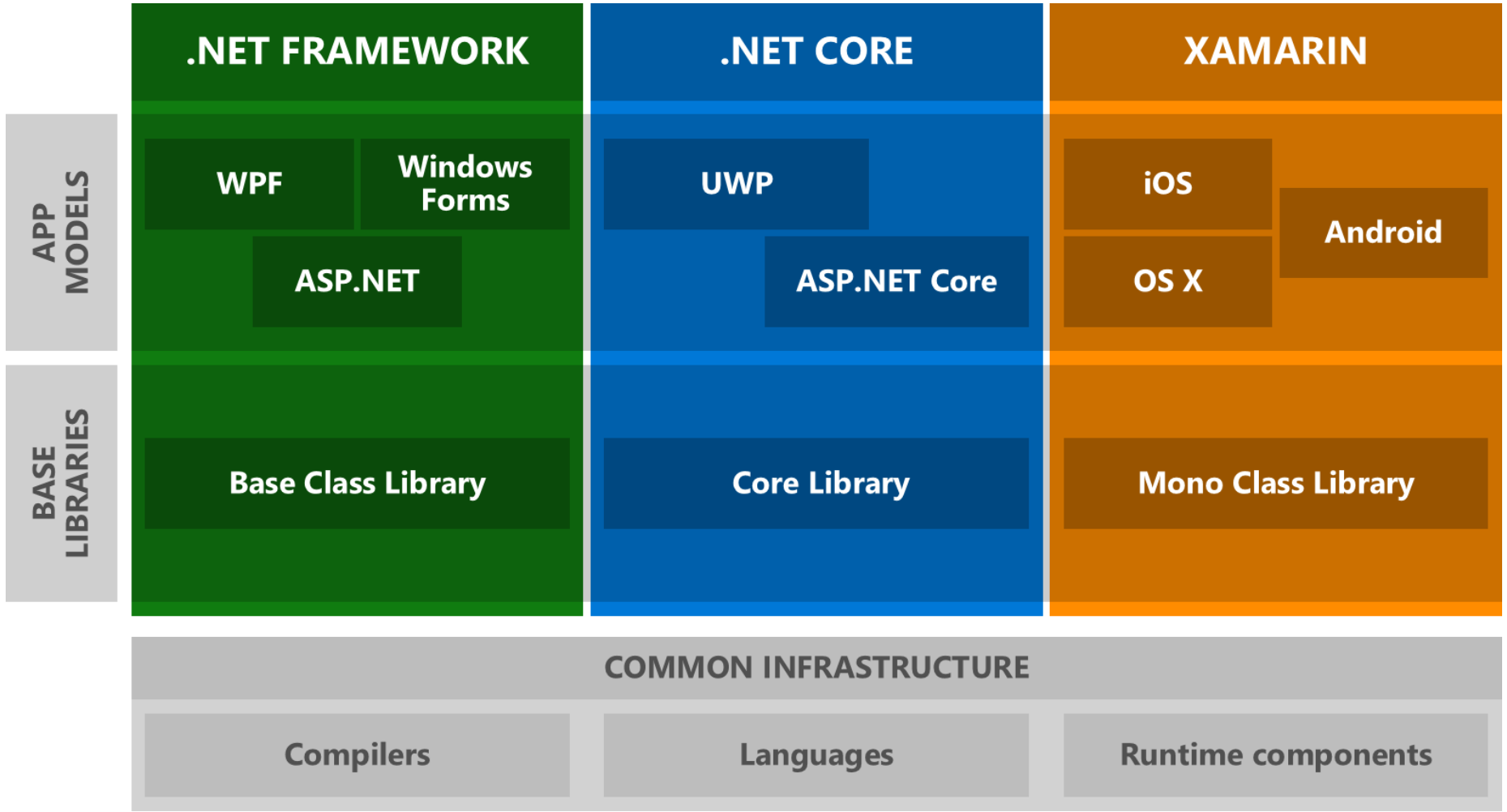
Languages

- The .NET Platform is Language Neutral
  - All .NET languages are first class players
- Common Language Specification
  - Consumer Languages (Script languages): Can use the .NET Framework
  - Extender Languages: Can extend the .NET Framework
- Microsoft are providing
  - VB, C++, C#, F# (+ Iron Python, + …)
- Third-parties offers
  - APL, COBOL, Pascal, Eiffel, Haskell, Perl, Python, Scheme, Smalltalk + ?

Multiple .NET platforms

- On windows PC:
  - The full .NET Framework
  - .NET Core https://dotnet.github.io/
  - Mono http://www.mono-project.com/
- On phones:
  - .Net Core (on Windows Phone 10)
  - Windows Phone 8.1 platform
  - The Xamarin platforms for iOS and Android (based on Mono)
- The list goes on:
  - Mono on Linux and OS X
  - Silverlight
  - .NET CF
  - .NET Micro

The main .NET platforms

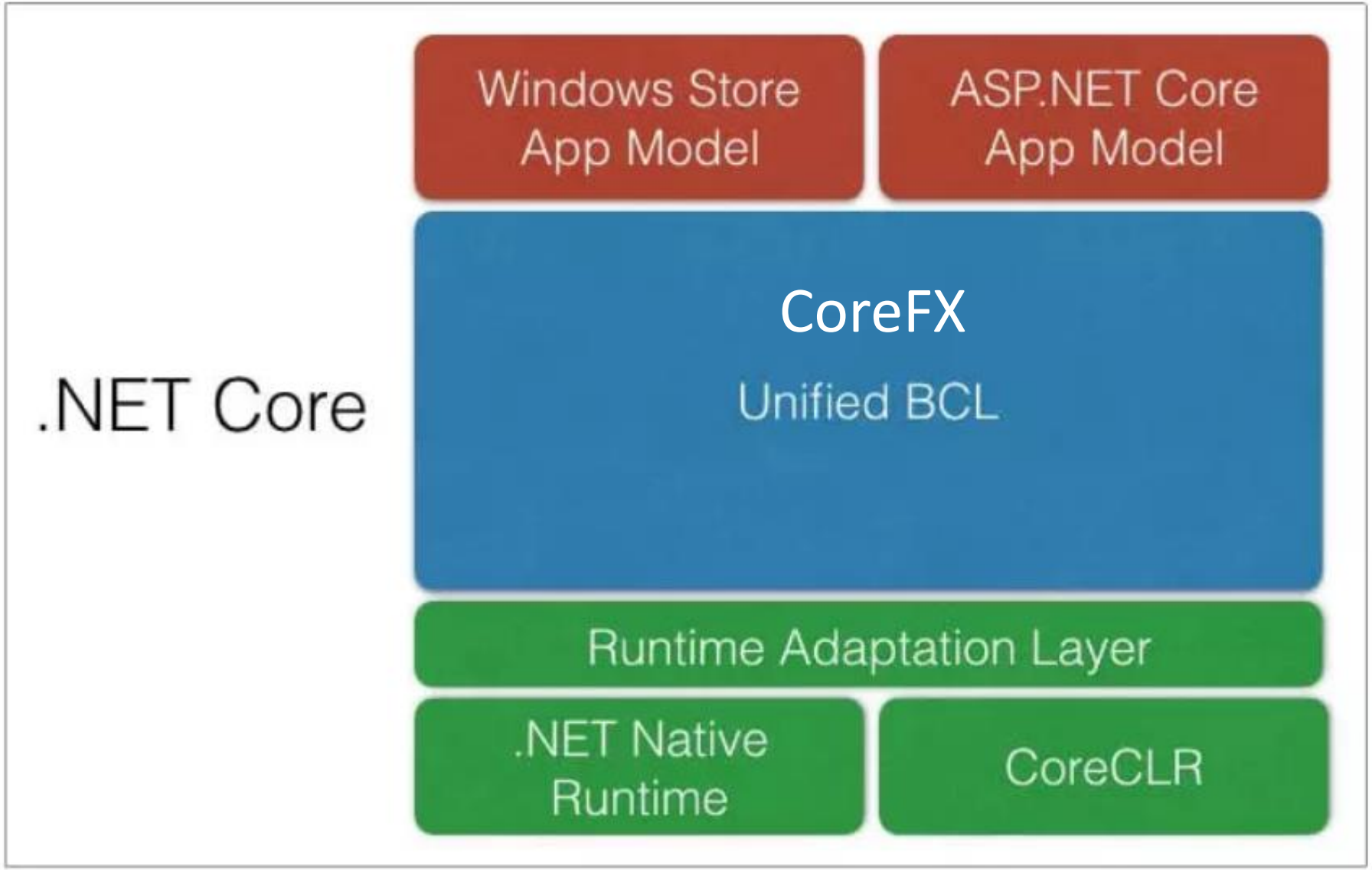


.NET Core

- Is a modular version of the .NET Framework designed to be portable across platforms
- Is a subset of the full .NET framework but it provides key functionality to implement the app features you need
- Is released through NuGet in smaller assembly packages
  - Rather than one large assembly that contains most of the core functionality, .NET Core is made available as smaller feature-centric packages
- Is open-source and accept contributions

Main use:
- To build a ASP.Net Web server that also runs on Mac OS, Linux and Docker
- To build cross platform mobil apps that runs on ios, Android and Windows Phone (requires use of Xamarin too)

.NET Core Architecture



.Net Standard

- .NET Standard is Microsoft's solution to provide .NET compatibility across multiple platforms, including .NET Framework, .NET Core, and Xamarin. In the near future, Unity will support .NET Standard
- Microsoft has announced the final version of .NET Standard 2.0 which includes over 32k APIs, a 400% increase over .NET Standard 1.0.
- Versions that supports .NET Standard 2.0
  - .NET Framework ver. 4.6.1
  - .NET Core 2
  - Mono 5.4
  - Xamarin.iOS 10.14
  - Xamarin.Mac 3.8
  - Xamarin.Android 7.5
  - UWP will add support ultimo 2017
  - Unity (3D game engine) will add support

ASSEMBLIES

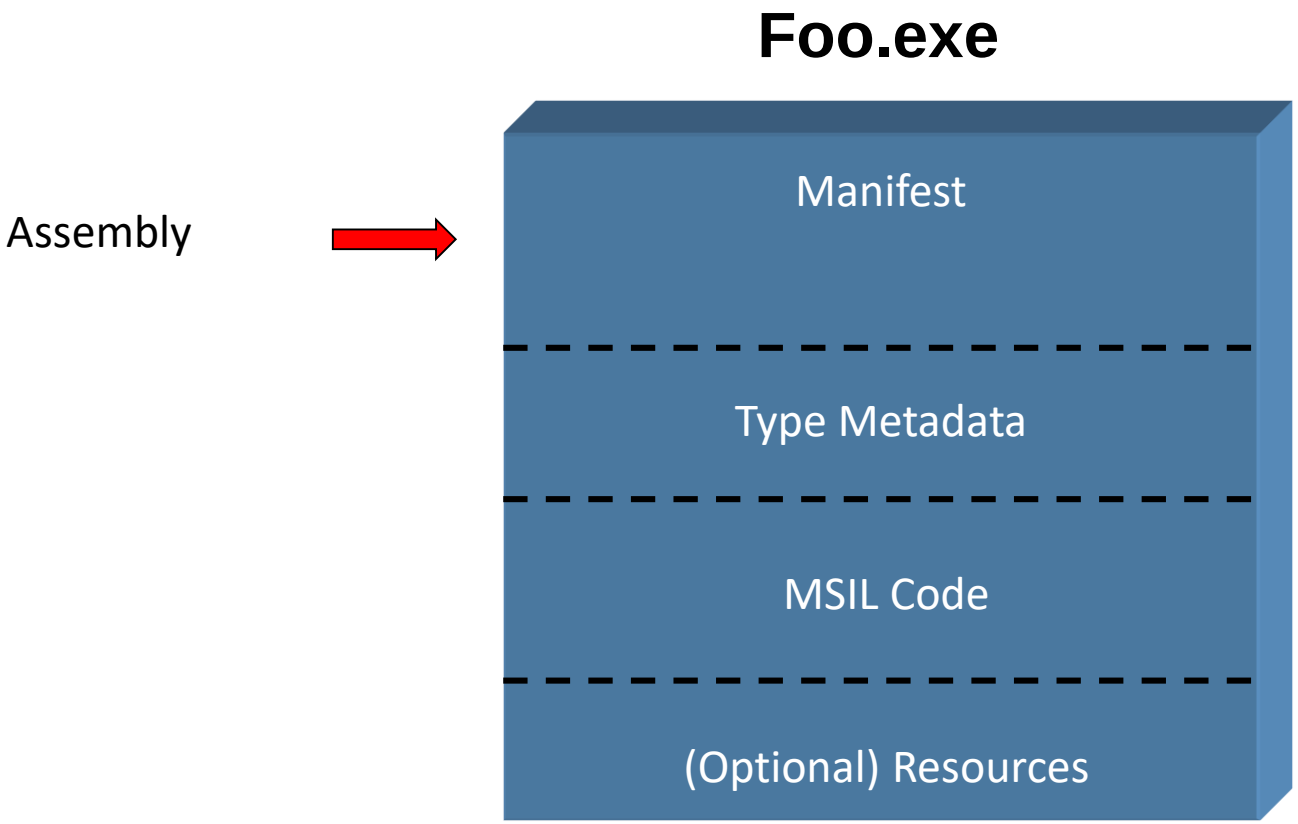
Assemblies

- Unit of deployment
  - One or more files, independent of packaging
  - Self-describing via metadata and manifest
- Versioning
  - Captured by compiler
- Security boundary
  - Assemblies are granted permissions
- Mediate type import and export
  - Types named are relative to assembly

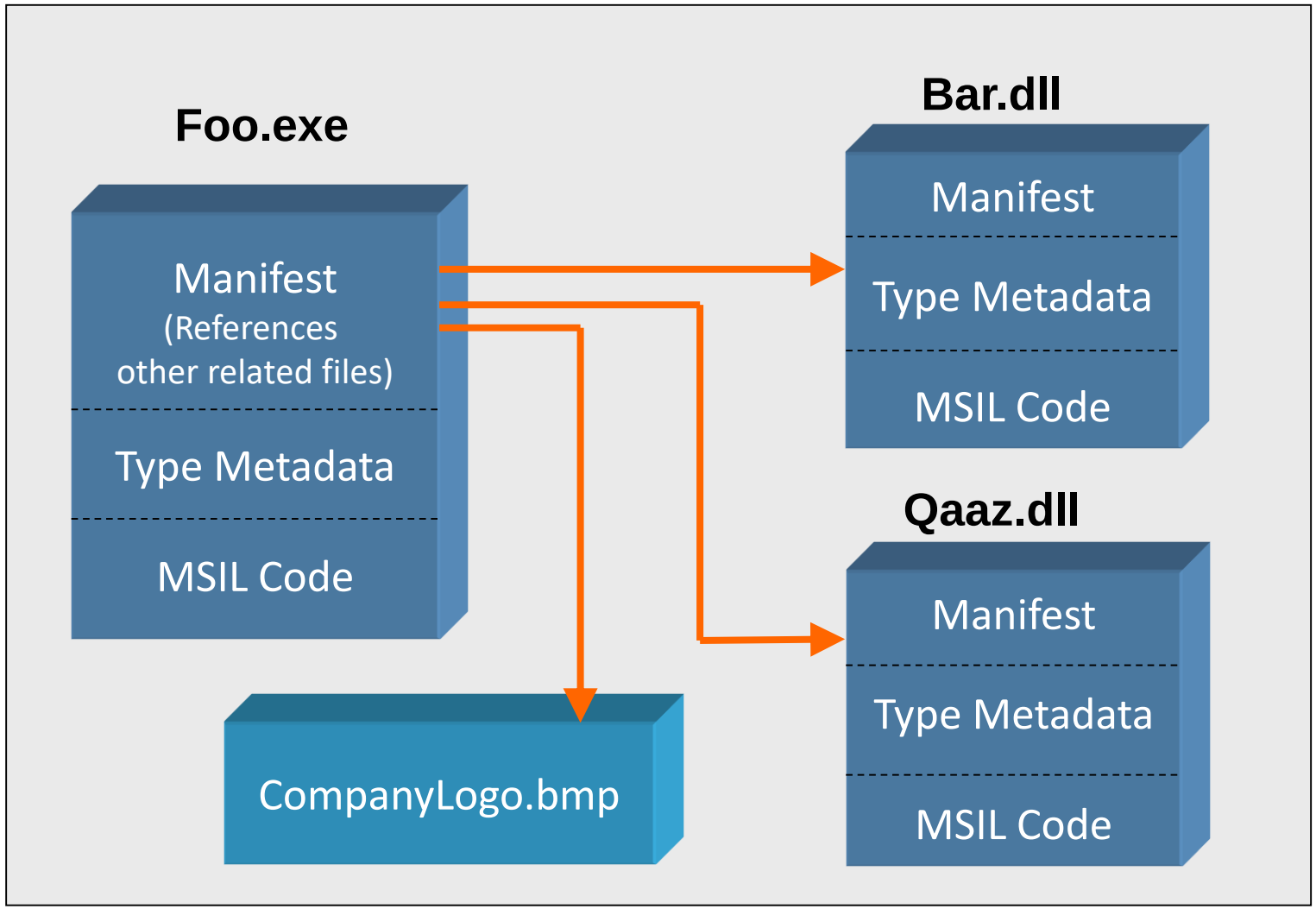
Applications

- Applications are configurable units
  - Consists of one or more assemblies
  - Application-specific files or data
- Assemblies are located based on…
  - Their logical name and
  - The application that loads them
- Applications can have private versions of assemblies
  - Private version preferred over shared
- Shared assemblies must be installed in Global Assembly Cache (a subfolder named assembly in the Windows folder)

A Single File Application

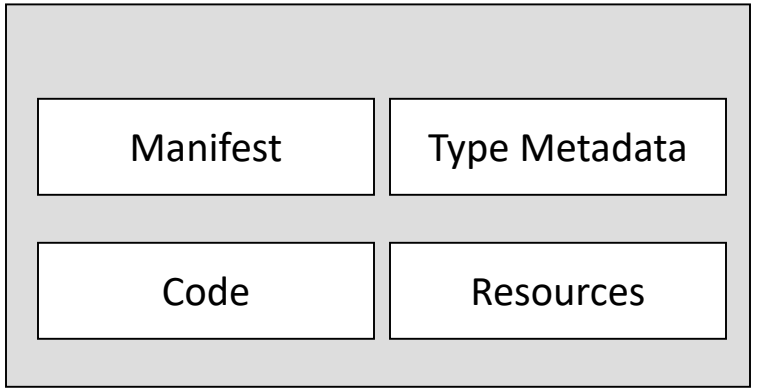


A Multi File Application

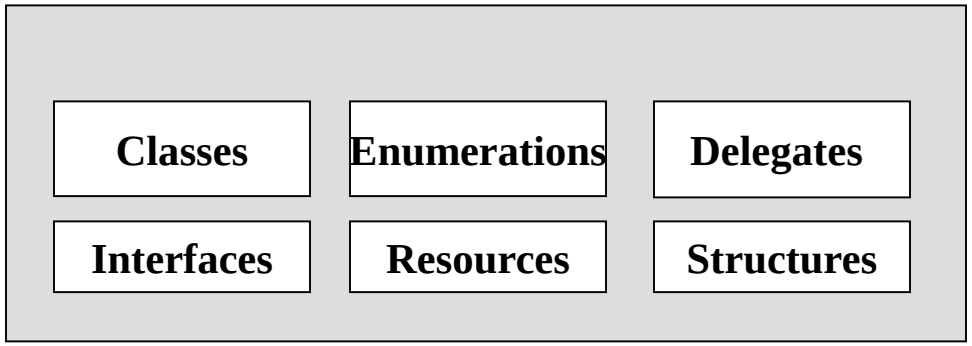


Two conceptual ‘views’

Physical view of an Assembly



Logical view of an Assembly



Garbage Collection

AKA

Managed Heap

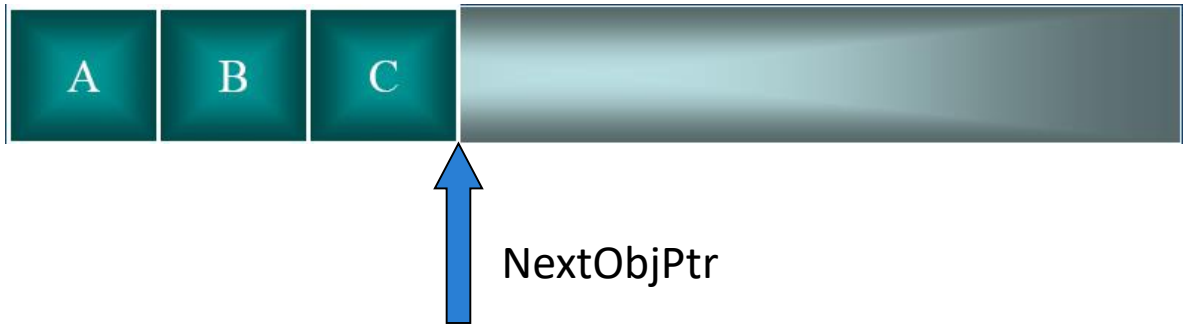
http://channel9.msdn.com/posts/Maoni-Stephens-CLR-45-Server-Background-GC

Memory Overview

- Every program uses memory
  - Files, memory buffers, screen space, network connections, database resources, and so on.
- A class identifies some type of resource
- Usual programming paradigm
  1. Allocate memory for resource (new operator)
  2. Initialize memory to make resource usable (constructor)
  3. Use the resource (access members) – repeat as necessary
  4. Tear-down the resource (destructor)
  5. Free the memory
- Common problems
  - Forgetting to free memory → **memory leak**
  - Using memory after freeing it → **memory corruption**
- These bugs are worse than most other bugs
  - Consequence and timing is unpredictable

Solution

- **G**arbage **C**ollection (GC) makes these bugs a thing of the past.
- All reference types are allocated on the managed heap
  - Your code never frees an object.
  - The GC frees objects when they are no longer reachable.
- Each process gets its own managed heap
  - Virtual address space region.
- The new operator always allocates objects at the end.
- If heap is full, a GC occurs
  - Reality: GC occurs when generation 0 is full – Or when the processor has idle time (background GC)



The GC Algorithm Overview

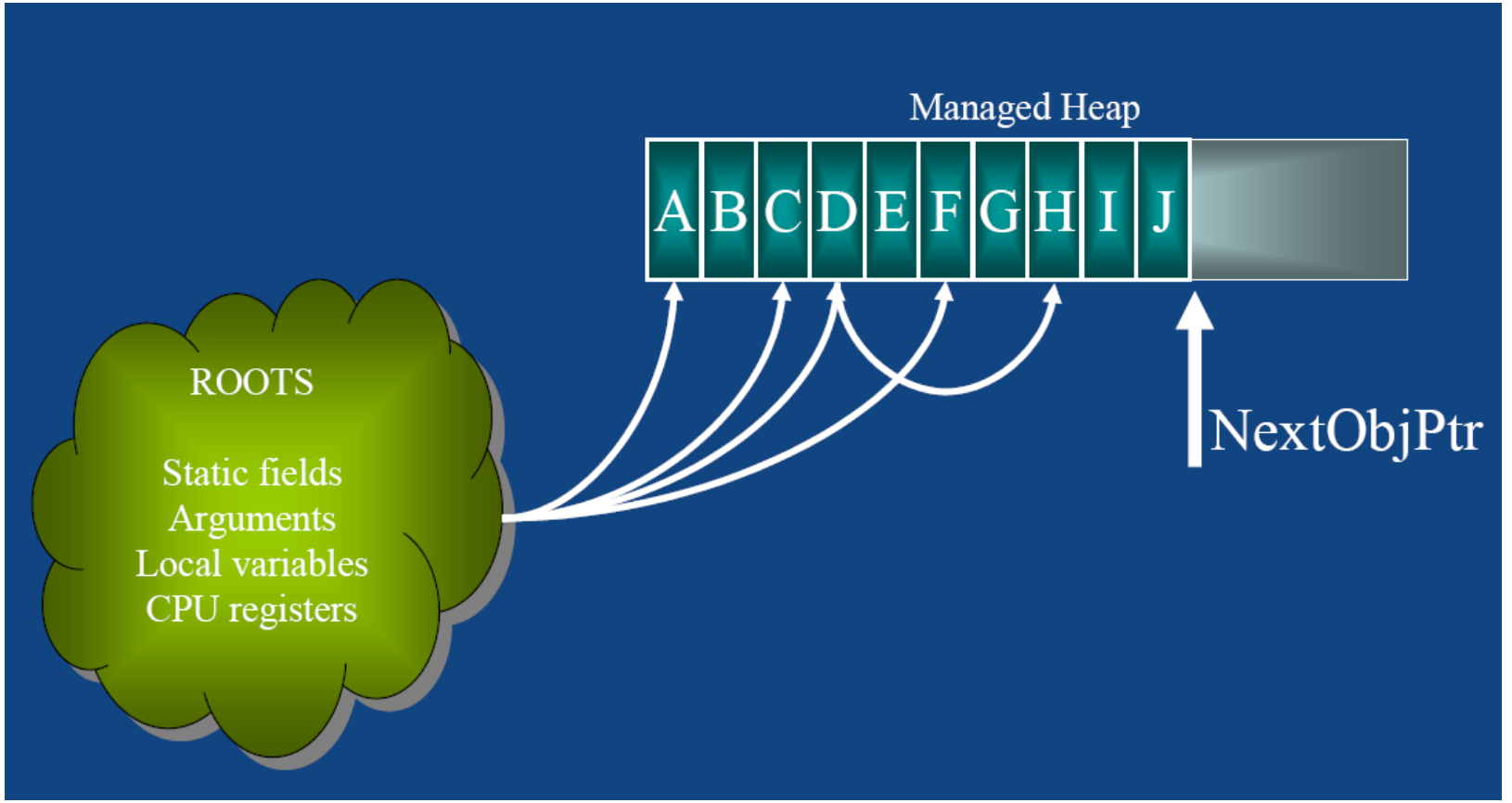
- Allocating objects:
  - new operator always allocates objects at the end
  - Almost as fast as a stack allocation
  - Much faster than unmanaged new/malloc/HeapAlloc
  - Large objects are allocated from a special heap
    - Large objects aren't moved in memory (can be if…)
    - Large objects are >= 85,000 bytes (*may change*)
- Garbage Collection:
  - Marking:
    - Objects referred to by app's variables (the Roots) are marked.
  - Compacting:
    - Marked objects are moved down over unmarked objects
  - If all objects are marked, no compacting occurs
    - new throws OutOfMemoryException

This algorithm is called: "***Mark and Compact***"

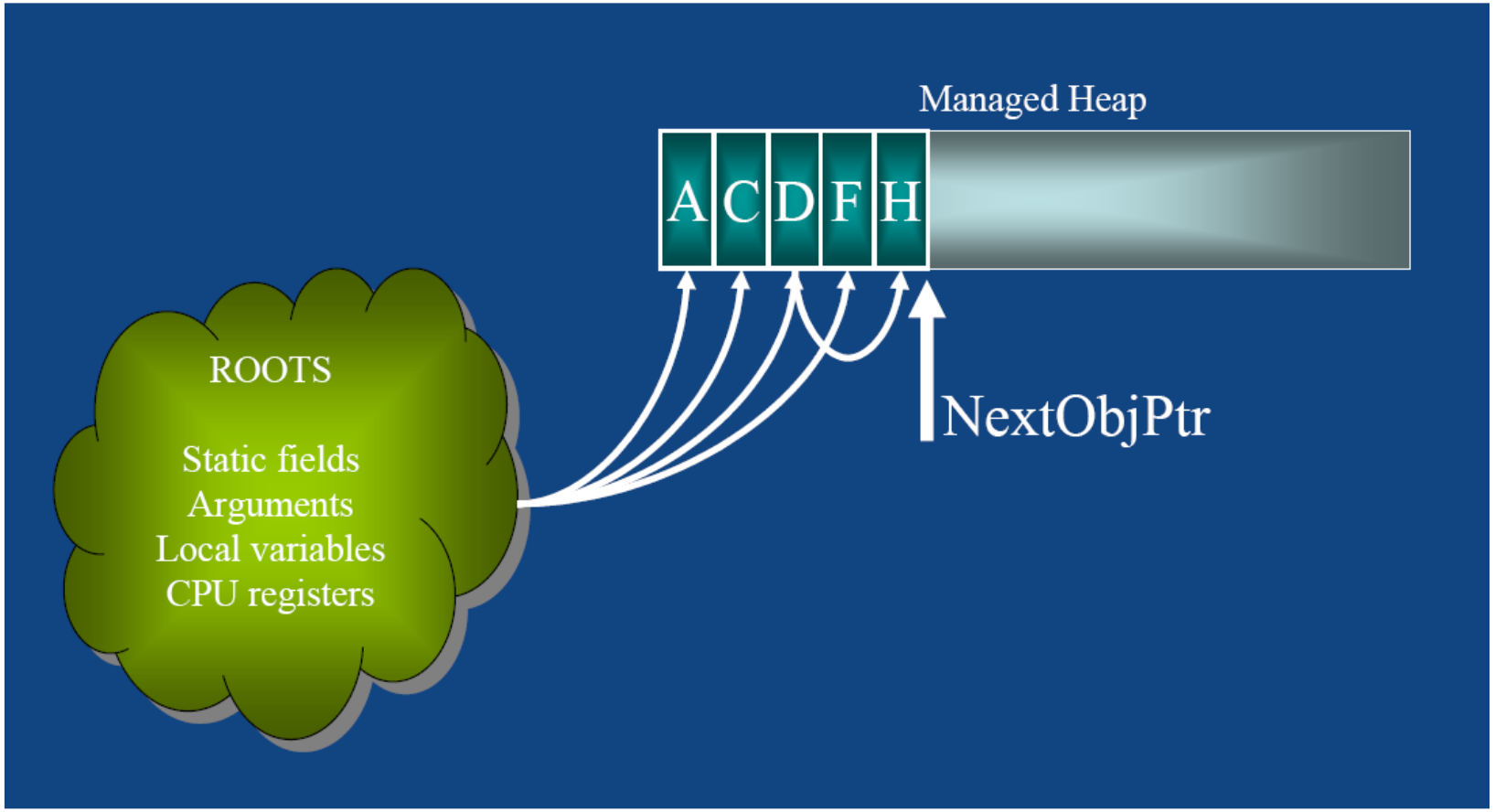
Using Roots to Mark Objects

- When a garbage collection starts all objects in heap are considered garbage
- Marking Phase:
  1. Marks objects reachable from Roots
     - A Root is a memory location that can refer to an object (or be null)
       - Static fields defined within a type
       - Arguments passed to a method
       - Local variables declared within a method
       - CPU registers (enregistered fields, arguments, or variables)
     - Roots are always reference types (never value types)
     - Each method has a root table (produced by JIT compiler)
  2. Each marked object has its fields checked; these objects are marked too (recursively)
  3. GC walks up the thread's call stack determining roots for the calling methods by accessing each method's root table
     - Already marked objects are skipped
       - Improves performance
       - Prevents infinite loops due to circular references
       - Static fields are checked; these objects are marked too

Before a Collection



After a Collection



Compacting Objects in the Heap

- **Compacting Phase**: Compacts marked objects
  - Marked objects are shifted down (simple memory copy)
- No address space fragmentation unlike the unmanaged heap!
  - Each root is updated to point to object's new memory address
- After compacting the heap...
  - The NextObjPtr pointer is positioned after last surviving object

Generations

- Makes assumptions about your code
  - The newer an object is, the shorter its lifetime will be
  - The older an object is, the longer its lifetime will be
  - New objects have a strong relationship are accessed together
- Studies show that assumptions are valid for many apps
- Generational GC improves perf by collecting new objects only
  - Old objects are not marked and walked recursively
  - Only new surviving objects are compacted
  - Only new objects' roots need updating

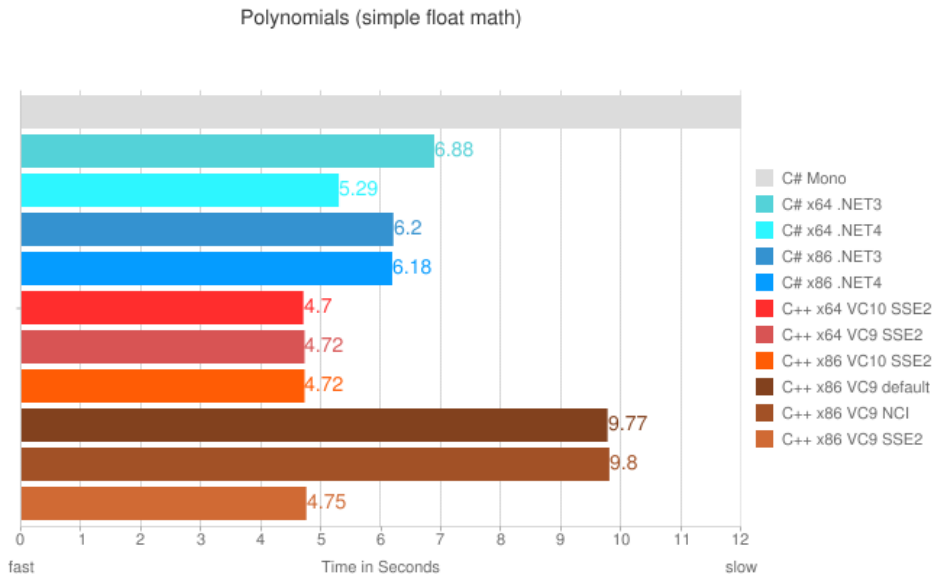
Improves Performance!

Tools for Monitoring the GC

- PerfMon
  - Graphs many .NET-related objects/counters
  - Comes with Windows
- CLR Profiler
  - Shows objects by: most-allocated, size
  - Show function call graphs, loaded types, etc.
  - Search for:
    "Writing High-Performance Managed Applications :
    A Primer" by Gregor Noriskin
- Plus several commercial products like Red Gates Ants Profiler: http://www.red-gate.com/ or
  dotMemory fra JetBrains: https://www.jetbrains.com/dotmemory/

IS C# Slow?

- It depends heavily on the algorithm
- In general you can expect C# programs to run approximately 10 % slower than C++ programs, due to Garbage Collections and range checks on arrays etc
- But Head-to-head benchmark: C++ vs. .NET shows that C# sometimes perform better, and sometimes are 2 – 3 times slower than C++



Ref.: http://www.codeproject.com/KB/cross-platform/BenchmarkCppVsDotNet.aspx

References

- Automatic Memory Management
  http://msdn.microsoft.com/en-us/library/f144e03t.aspx
- Fundamentals of Garbage Collection
  https://msdn.microsoft.com/en-us/library/ee787088(v=vs.110).aspx
- Common Type System
  http://msdn.microsoft.com/en-us/library/zcx1eb1e.aspx
- .Net Core and .Net Standard Platform
  http://andrewlock.net/understanding-net-core-netstandard-and-asp-net-core/

Resources

- Microsoft Developer Network: http://msdn.microsoft.com/
- Good sites for .NET code, discussions, etc:
  - **http://stackoverflow.com/**
  - http://www.asp.net/
  - http://www.codeproject.com