Principles and Architecture

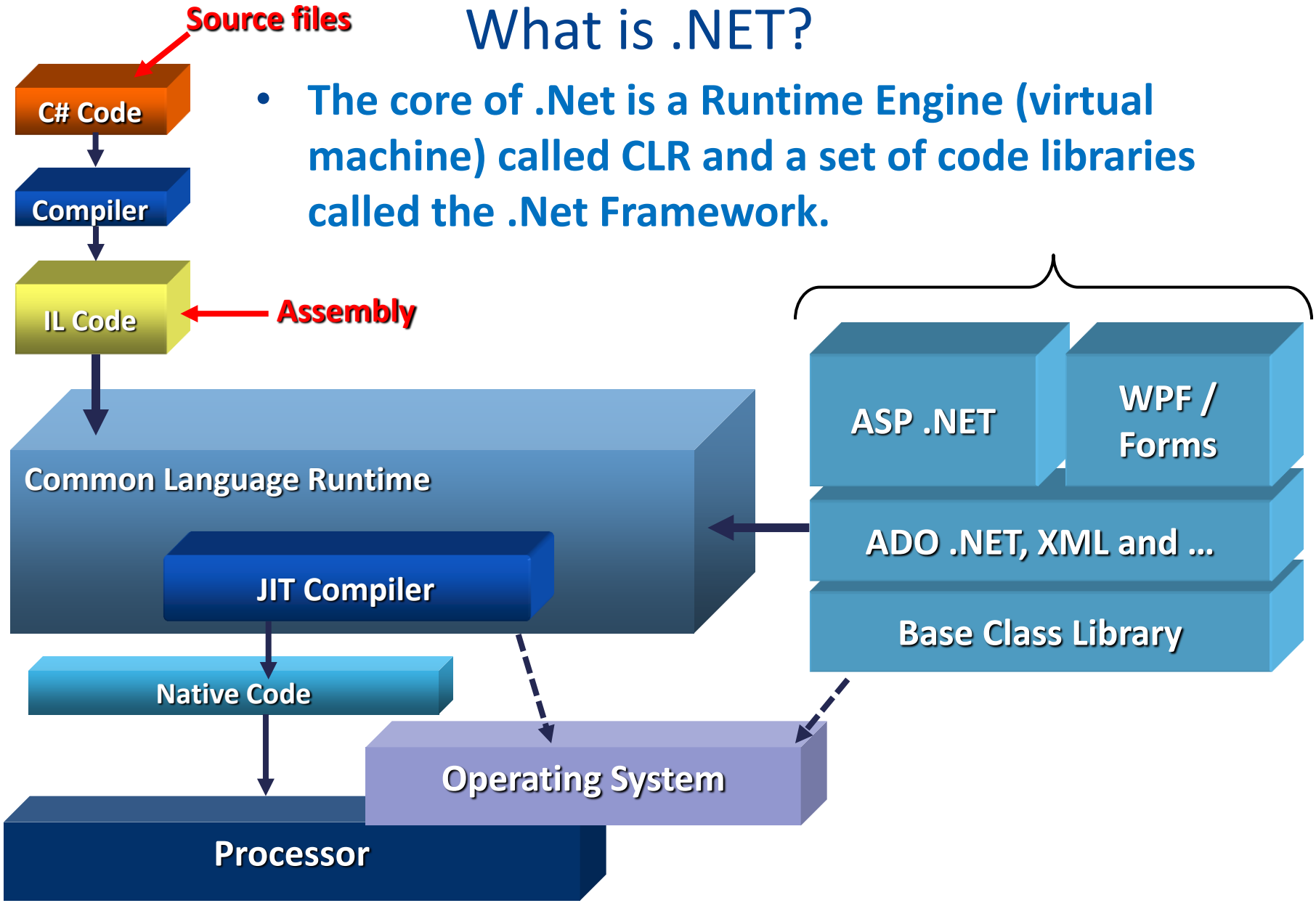
Agenda

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

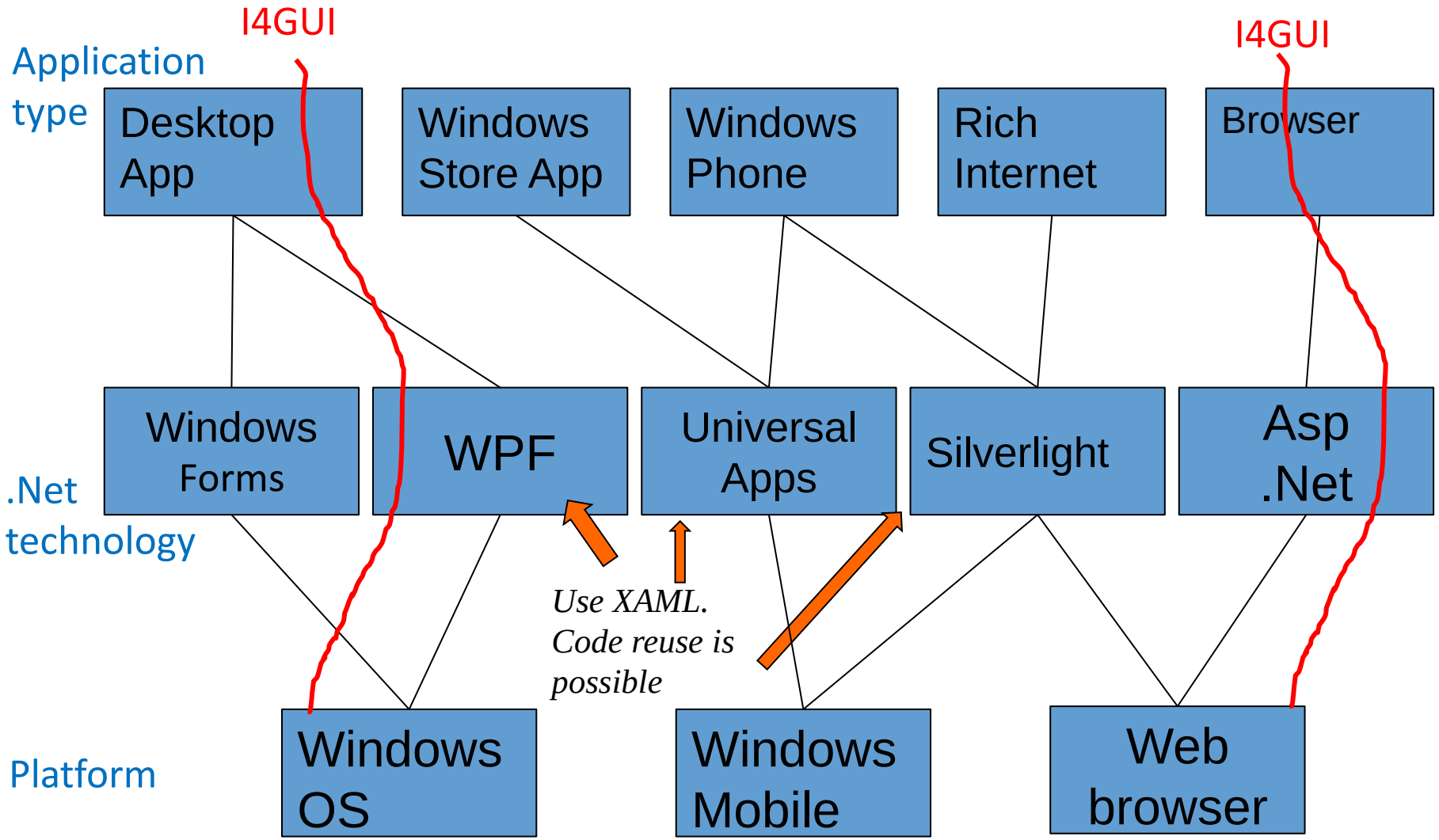
Læringsmål:
Redegøre for principperne i .Net frameworket og dets overordnede arkitektur.

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



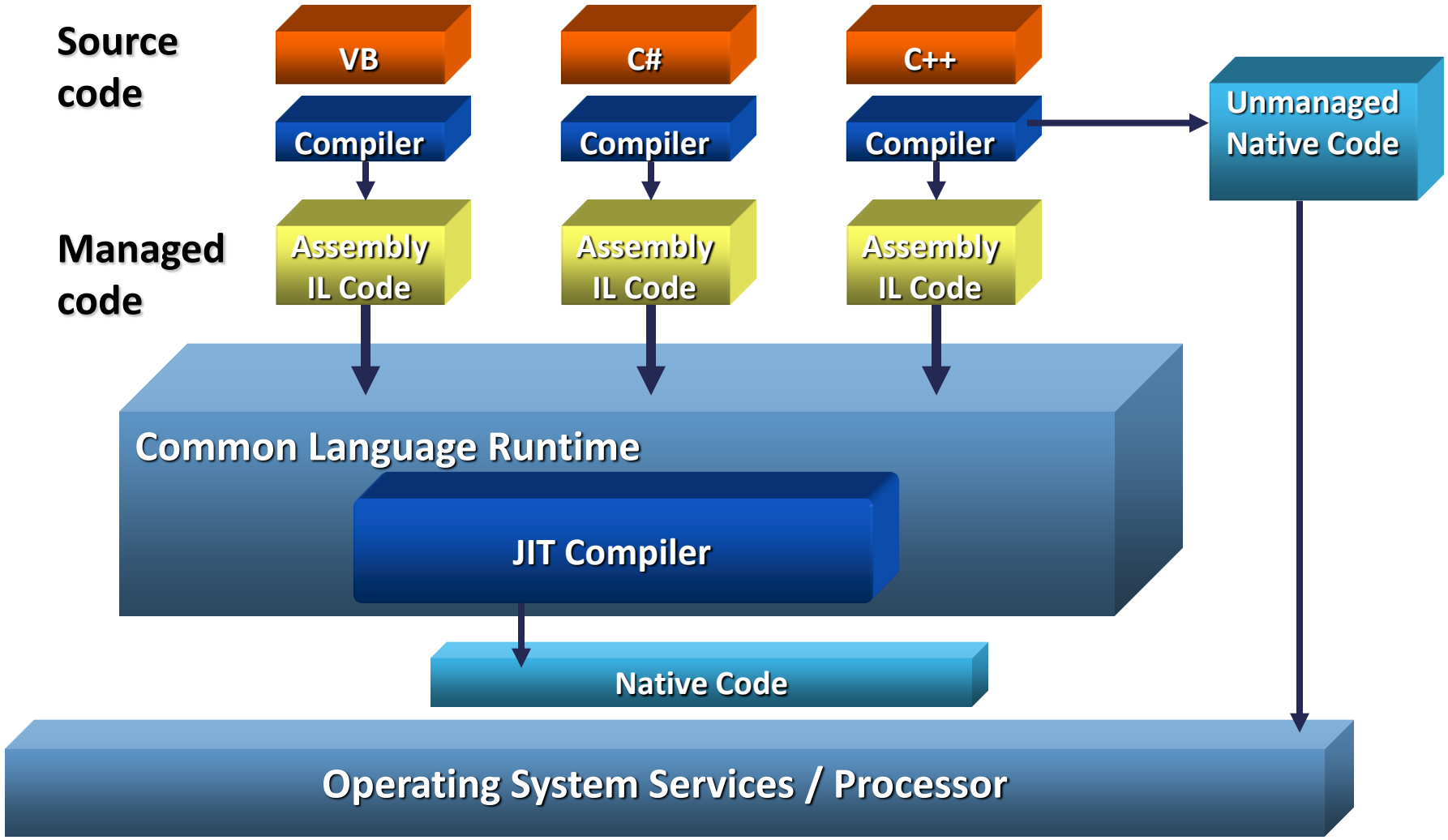
.NET on Small Devices

Ikke her i I4GUI, men det i lærer her kan genbruges på de håndholdte

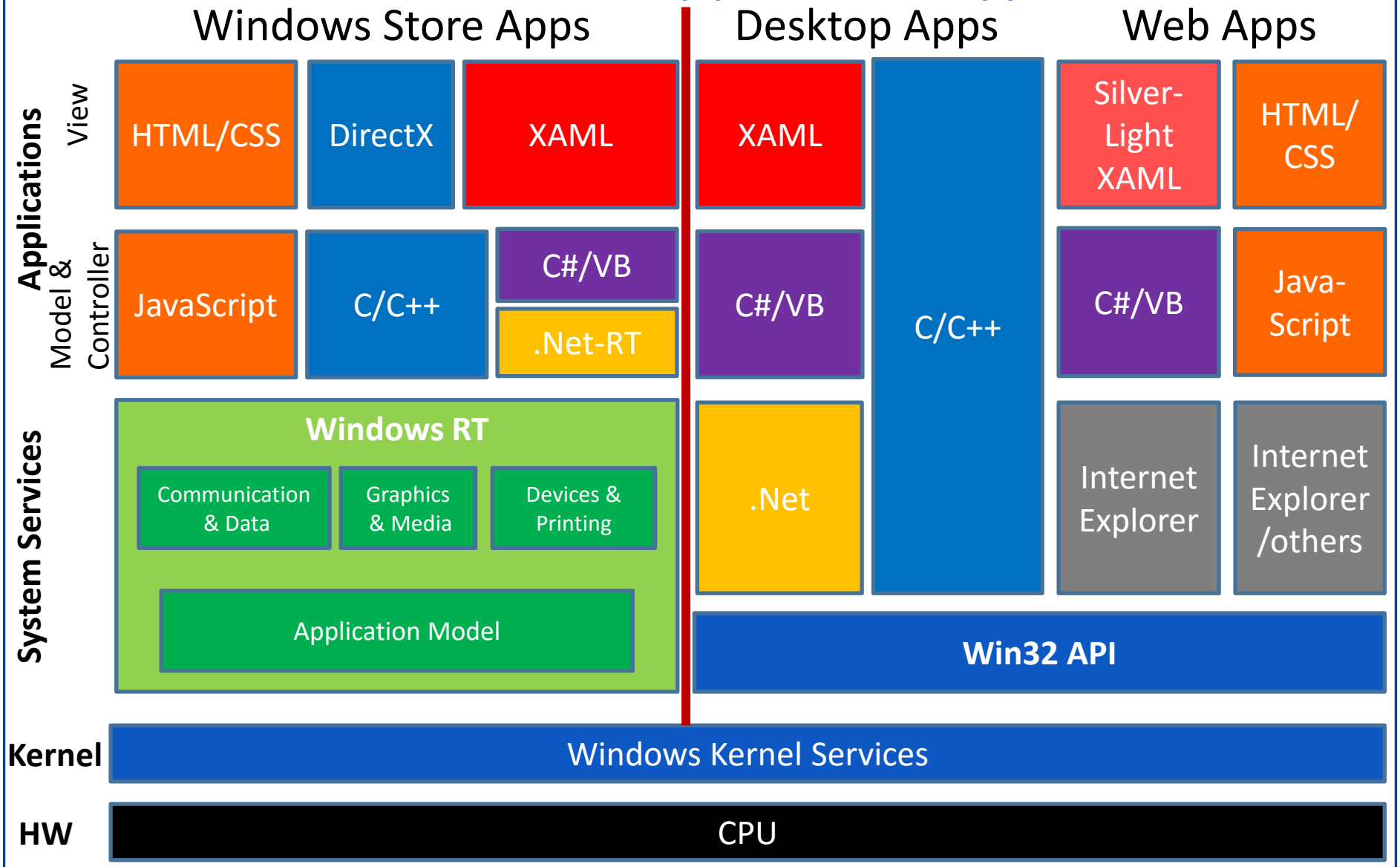
- Other Interfaces
  - .NET Compact Framework
  - Windows Mobile
  - .NET Micro Framework

Architectural Overview of the .NET Framework

.Net Framework Execution Model



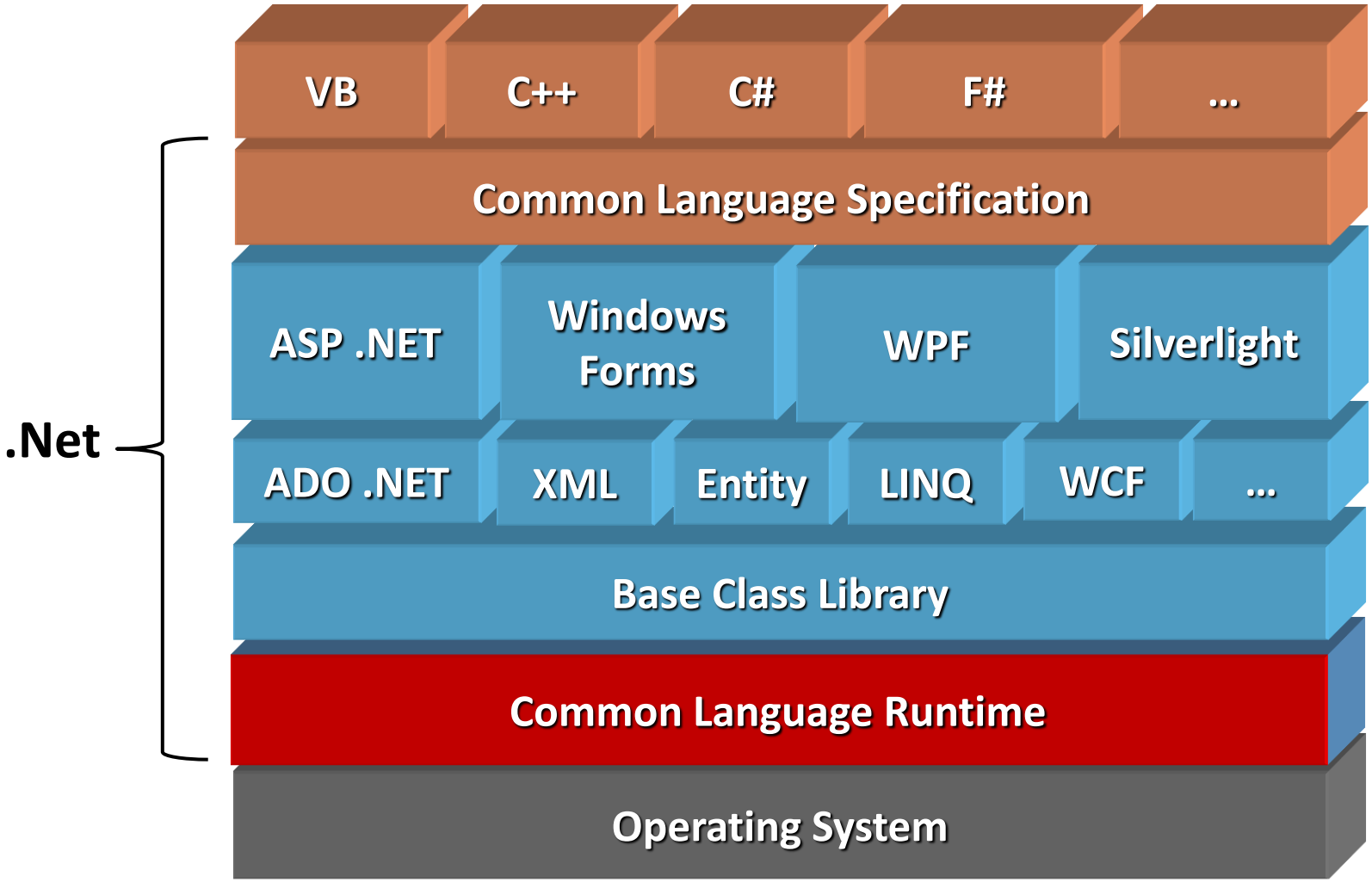
Windows 10 Application Types



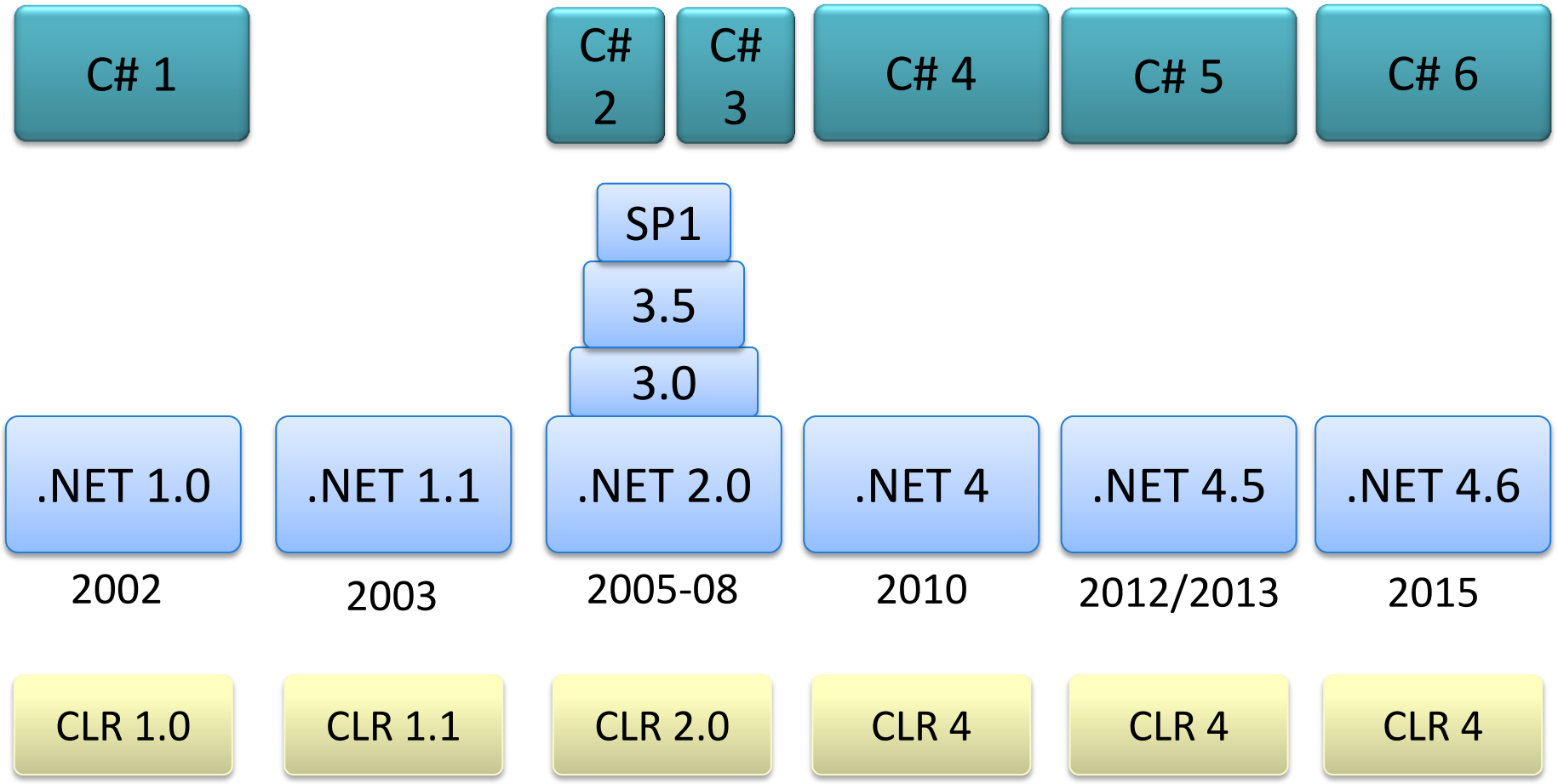
.NET Native

- 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

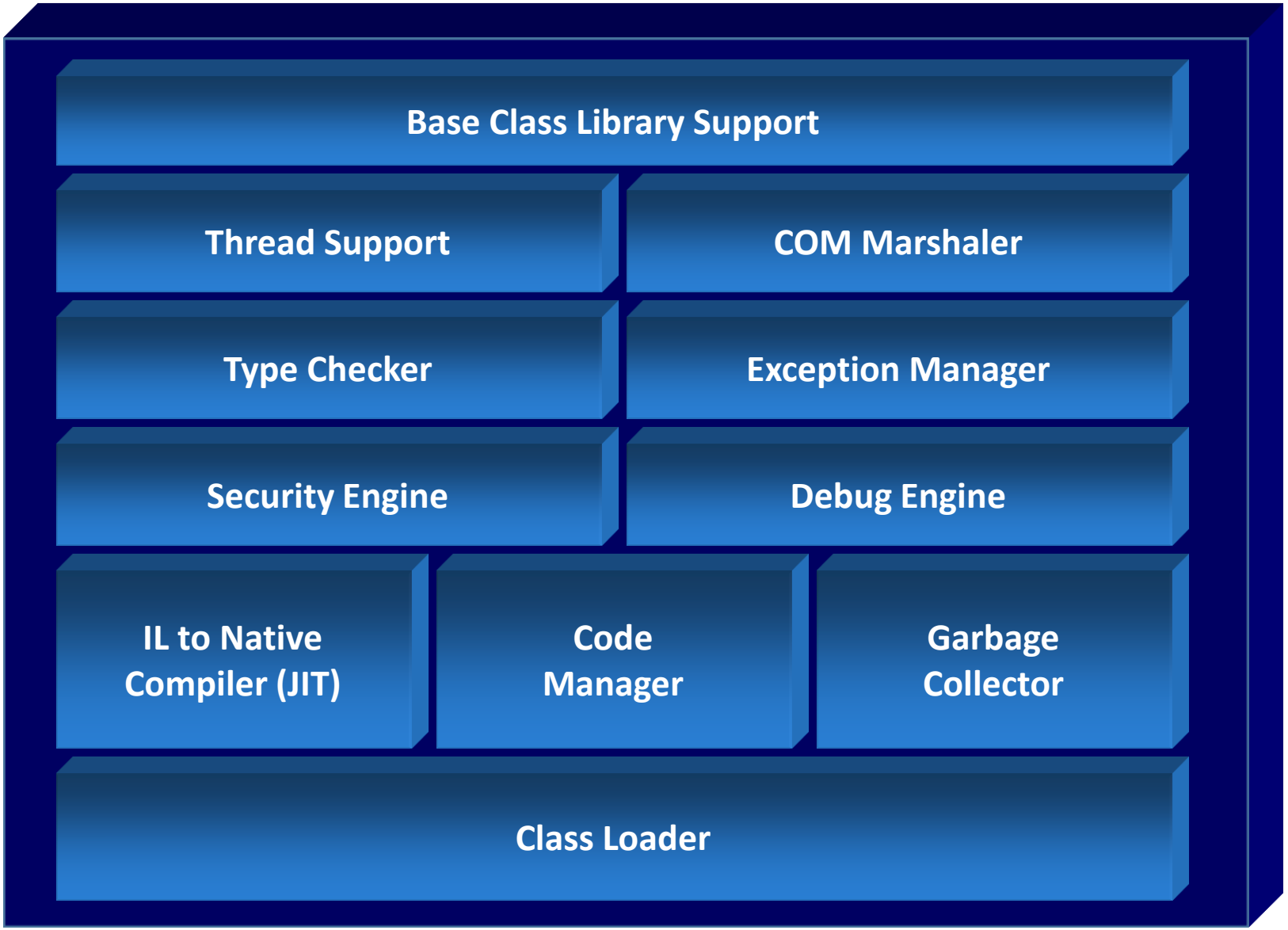
.NET Framework Architecture



A Look Back…


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

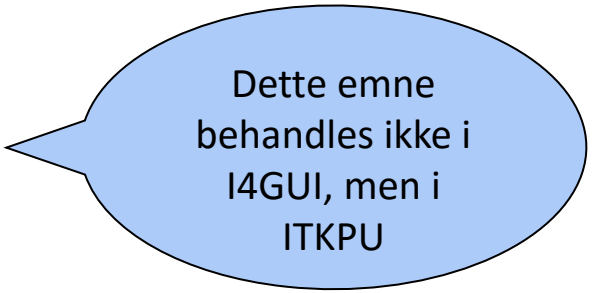
- **Native code (UWP apps)**
  - Fast execution times
  - Consistently speedy startup times
  - Low deployment and update costs
  - Optimized app memory usage

.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

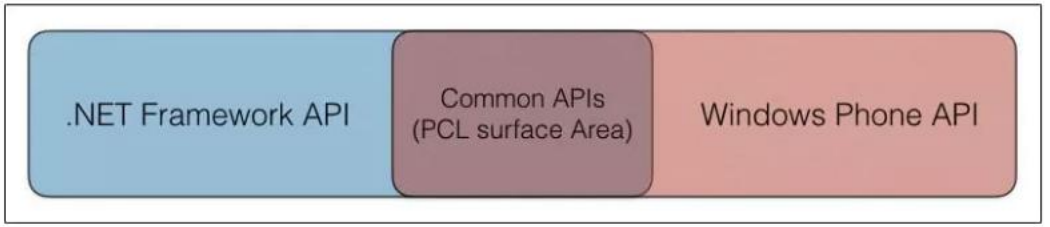
- The .NET Platform is Language Neutral
  - All .NET languages are first class players
- Common Language Specification
  - Consumer Languages (Script languages): Can use the .NET Framework
  - Extender Languages: Can extend the .NET Framework
- Microsoft are providing
  - VB, C++, C#, F# (+ Iron Python,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

.NET is Portable?

- Much of .NET is ECMA standardized
- Available on a variety of platforms:
  - various flavors of Windows (including CE and Mobile versions)
  - Linux / OS X:
    - ***Mono*** **project** **http://www.mono-project.com/**
    - MonoMac for building Cocoa applications on OSX using Mono
  - Unix:
    - *dotGNU* (much less mature) http://www.dotgnu.org/
  - FreeBSD / OS X:
    - *Rotor / SSCLI*
    - Microsoft's shared-source release of .NET for research purposes
    - http://msdn.microsoft.com/net/sscli
  - **iPhone, iPad and Android**
    - **Xamarin http://xamarin.com/platform**

Multiple .NET platforms

- On windows PC:
  - The full .NET Framework
  - The Windows 8/8.1 platform
  - The Universal Windows Platform
  - Mono
- On phones:
  - Windows Phone 8.1 platform
  - Windows Phone Silverlight platform
  - The Xamarin platforms for iOS and Android
- The list goes on:
  - Mono on Linux
  - Silverlight
  - .NET CF
  - .NET Micro

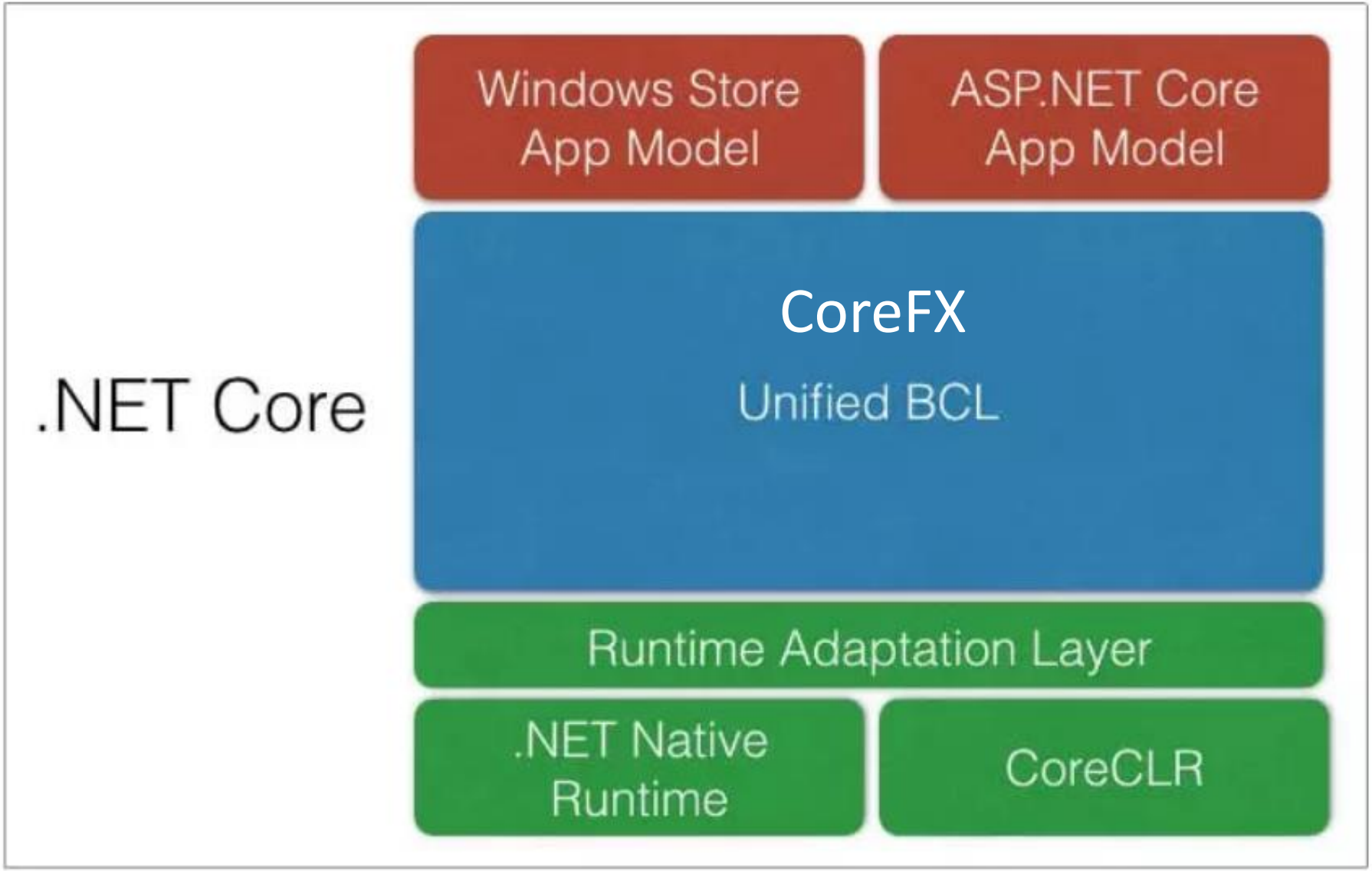


.NET Core

- 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 and Linux
- To build cross platform mobil apps that runs on ios, Android and Windows Phone (requires use of Xamarin too)

.NET Core Architecture



. NETStandard

- Will allow new platforms that meet the required specifications to be supported without re-compilation of existing code

Target Platform Name	**Alias**						
.NET Platform Standard	netstandard	1.0	1.1	1.2	1.3	1.4	1.5
.NET Core	netcoreapp	→	→	→	→	→	1.0
.NET Framework	net	→	→	→	→	→	4.6.2
		→	→	→	→	4.6.1	
		→	→	→	4.6		
		→	→	4.5.2			
		→	→	4.5.1			
		→	4.5				
Universal Windows Platform	uap	→	→	→	→	10.0	
Windows	win	→	→	8.1			
		→	8.0				
Windows Phone	wpa	→	→	8.1			
Windows Phone Silverlight	wp	8.1					
		8.0					
Mono/Xamarin Platforms		→	→	→	→	→	*
Mono		→	→	*			

The NETStandard framework provides the interface

ASSEMBLIES

Assemblies

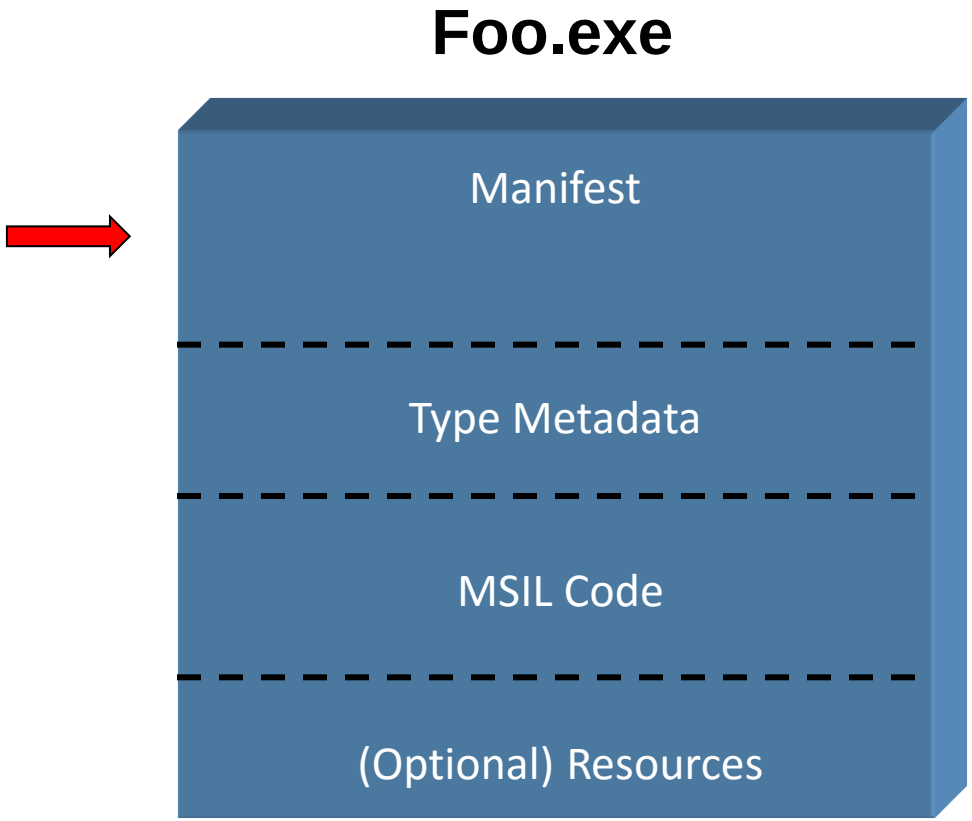
- Unit of deployment
  - One or more files, independent of packaging
  - Self-describing via metadata and manifest
- Versioning
  - Captured by compiler
- Security boundary
  - Assemblies are granted permissions
  - Methods can demand proof that a permission has been granted to entire call chain
- Mediate type import and export
  - Types named are relative to assembly

Applications

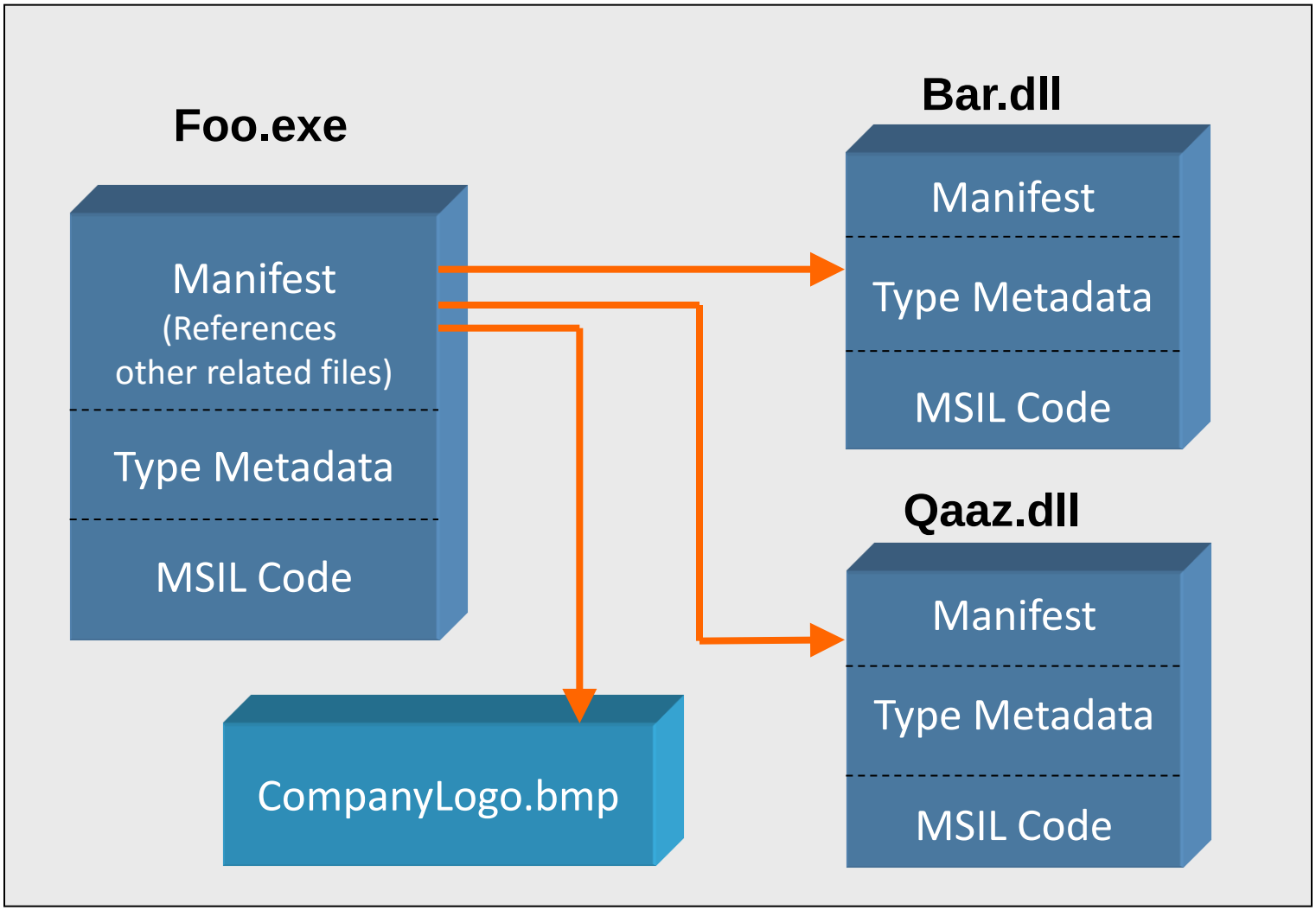
- Applications are configurable units
  - Consists of one or more assemblies
  - Application-specific files or data
- Assemblies are located based on…
  - Their logical name and
  - The application that loads them
- Applications can have private versions of assemblies
  - Private version preferred over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

A Single File Application

Assembly

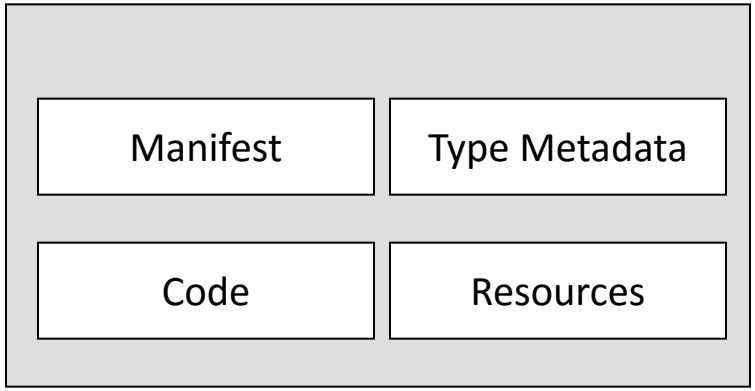


A Multi File Application

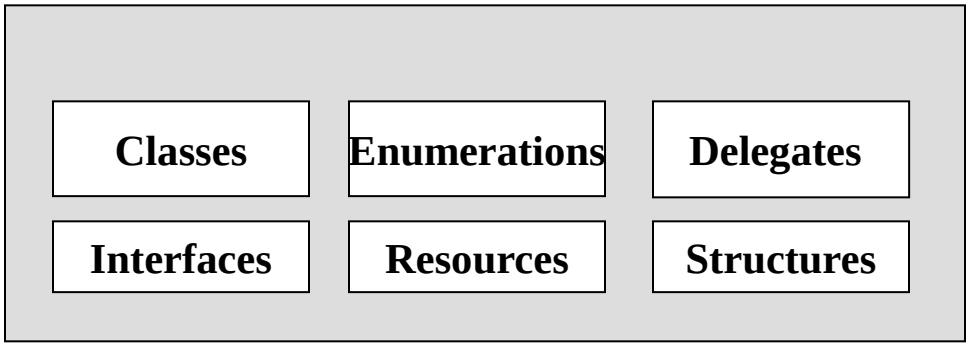


Two conceptual 'views'

Physical view of an Assembly



Logical view of an Assembly



Garbage Collection

AKA

Managed Heap

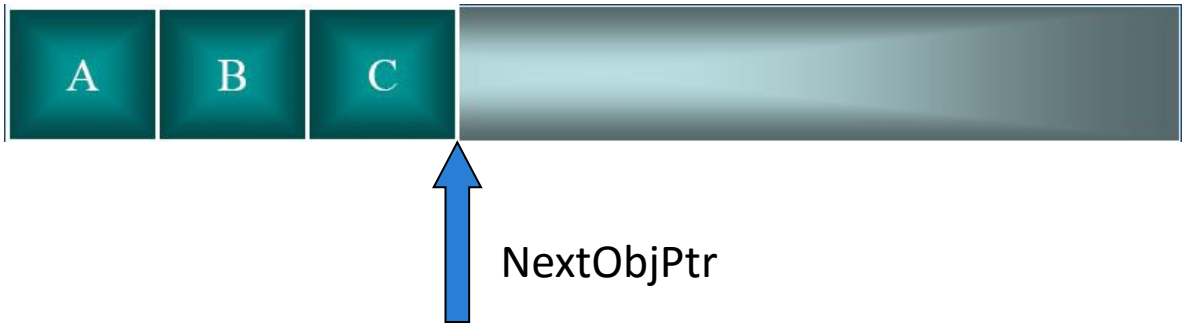
http://channel9.msdn.com/posts/Maoni-Stephens-CLR-45-Server-Background-GC

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 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.



The GC Algorithm Overview

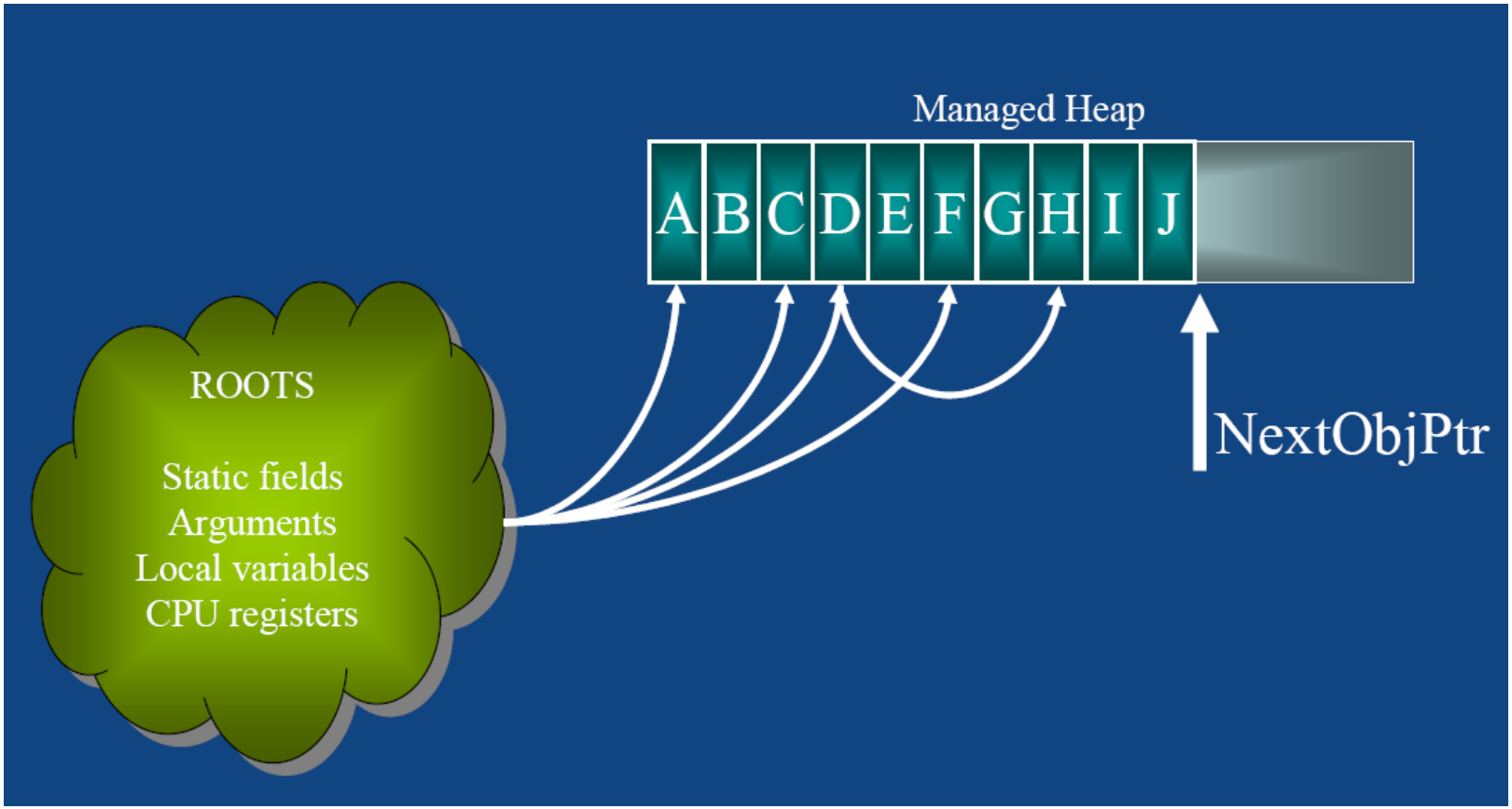
- Allocating objects:
  - new operator always allocates objects at the end
  - Almost as fast as a stack allocation
  - Much faster than unmanaged new/malloc/HeapAlloc
  - Large objects are allocated from a special heap
    - Large objects aren't moved in memory
    - Large objects are >= 85,000 bytes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

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

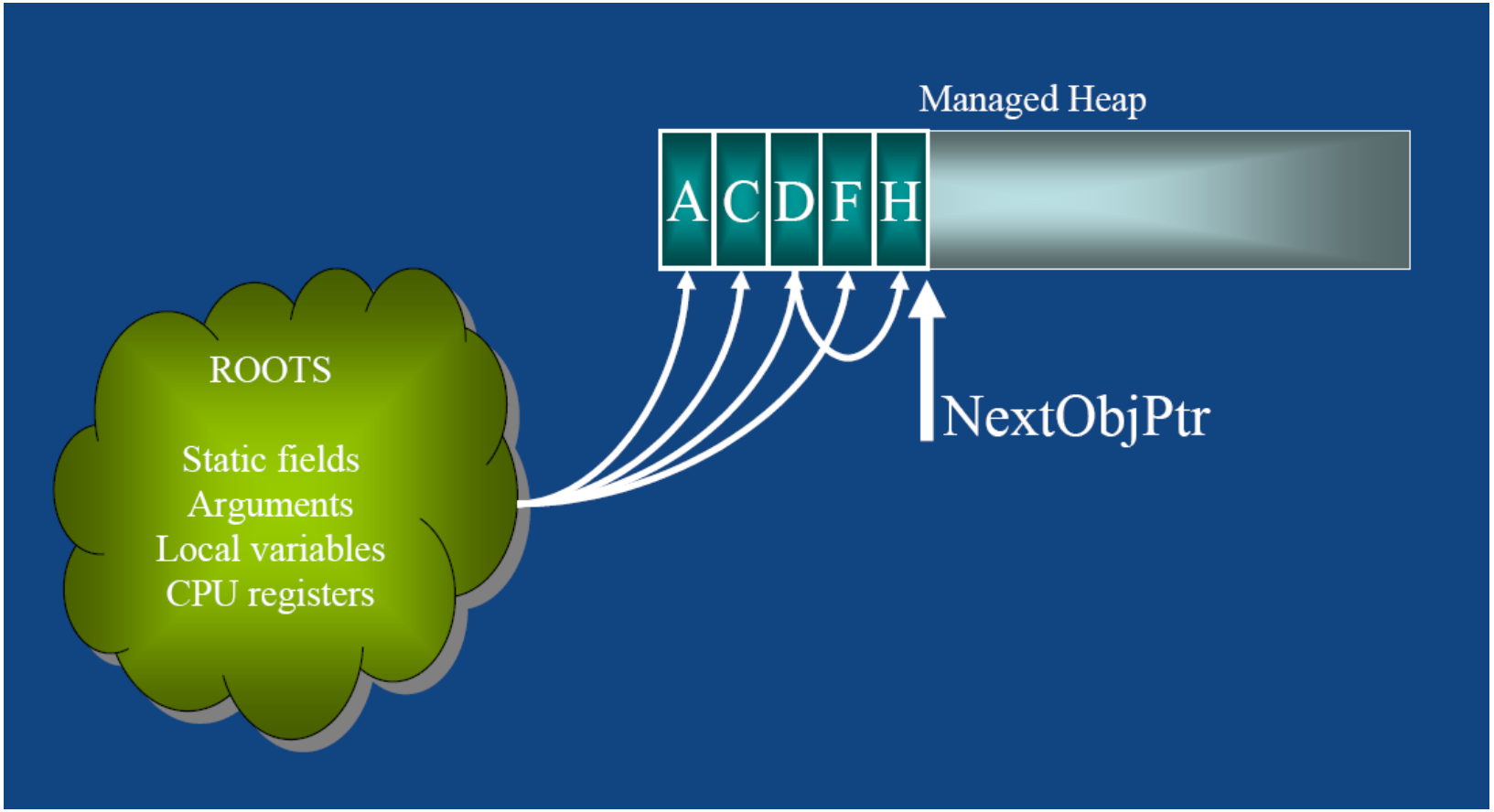
Using Roots to Mark Objects

- 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

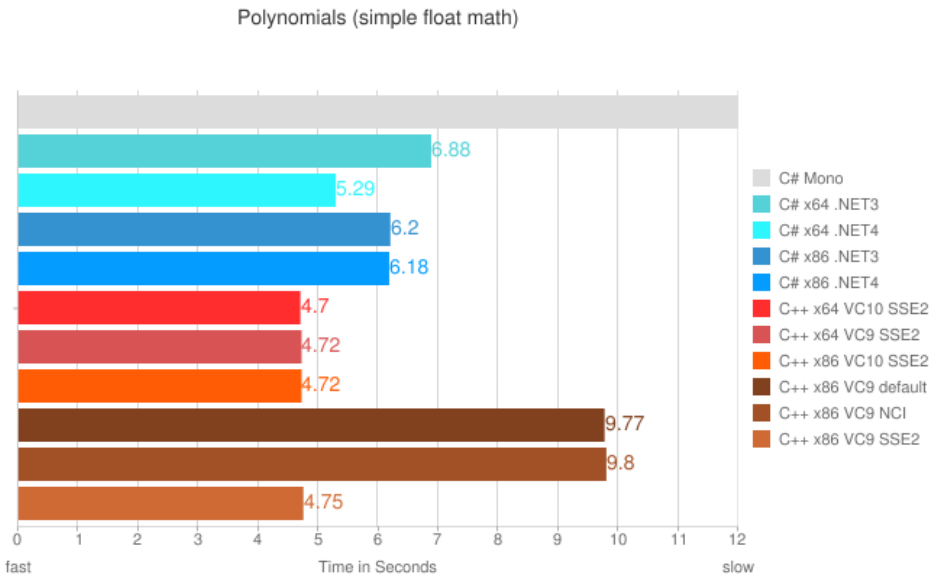
Improves Performance!

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.
  - Download from http://MSDN.Microsoft.com
- Search for:
  "Writing High-Performance Managed Applications :
  A Primer" by Gregor Noriskin
  - Article has a link to download the CLR Profiler
- 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://wpfdisciples.wordpress.com/
  - http://www.codeproject.com