Overview of the .NET

Overview

- Compilation and interpretation
- Virtual machines
- Simple C# program
- CIL, ildasm util
- CLR
- .NET Framework
- JIT, NGEN
- CLS
- .NET 6
- Compare C ++, C # (.NET) method call performance

Compilation (Ahead-of-Time) and interpretation

- A program written in a high level language can run in two ways
  - Compiled into a program in the native machine language and then run on the target machine.
  - Directly interpreted and the execution is simulated within an interpreter.

Compilation and interpretation

- How is a C++ program executed on linprog?
  - *cl try.cpp* compiling the program into machine code
  - Try.exe running the machine code
- How is a JavaScript program executed?
  - *cscript.exe* try.js
  - The program just runs, no compilation phase
  - The program *cscript* is the software environment that understands JavaScript language. The program try.js is executed (interpreted) within the environment.
- In general, which approach is more efficient?

Compilation and interpretation

- In general, which approach is more efficient?
  - A[i][j] = 1;

Compilation:

```
mov eax, DWORD PTR _i$[ebp]
imul eax, 20
lea ecx, DWORD PTR _A$[ebp+eax]
mov edx, DWORD PTR _j$[ebp]
mov DWORD PTR [ecx+edx*4], 1
```

Interpretation:

- create a software environment that understand the language
- put 1 in the array entry A[i][j];

Compilation and interpretation

- In general, which approach is more efficient?
  - A[i][j] = 1;

Compilation:

```
mov eax, DWORD PTR _i$[ebp]
imul eax, 20
lea ecx, DWORD PTR _A$[ebp+eax]
mov edx, DWORD PTR _j$[ebp]
mov DWORD PTR [ecx+edx*4], 1
```

Interpretation:

- create a software environment that understand the language
- put 1 in the array entry A[i][j];
- For the machine to put 1 in the array entry A[i][j], that code sequence still needs to be executed.
- Most interpreter does a little more than the barebone "real work."

- Compilation is always more efficient!!
- Interpretation provides more functionality. E.g. for debugging

One can modify the value of a variable during execution.

Compilers versus Interpreters

- Compilers “try to be as smart as possible” to fix decisions that can be taken at compile time to avoid to generate code that makes this decision at run time
  - Type checking at compile time vs. runtime
  - Static allocation
  - Static linking
  - Code optimization
- Compilation leads to better performance in general
  - Allocation of variables without variable lookup at run time
  - Aggressive code optimization to exploit hardware features

Compilers versus Interpreters

- Benefit of interpretation?
  - Interpretation facilitates interactive debugging and testing
    - Interpretation leads to better diagnostics of a programming problem
    - Procedures can be invoked from command line by a user
    - Variable values can be inspected and modified by a user
  - Some programming languages cannot be purely compiled into machine code alone
    - Some languages allow programs to rewrite/add code to the code base dynamically
    - Some languages allow programs to translate data to code for execution (interpretation)
    - JavaScript Eval() function

```
var x = 10;
var y = 20;
var a = eval("x * y") + " ";
var b = eval("2 + 2") + " ";
var c = eval("x + 17") + " ";
var res = a + b + c;
```

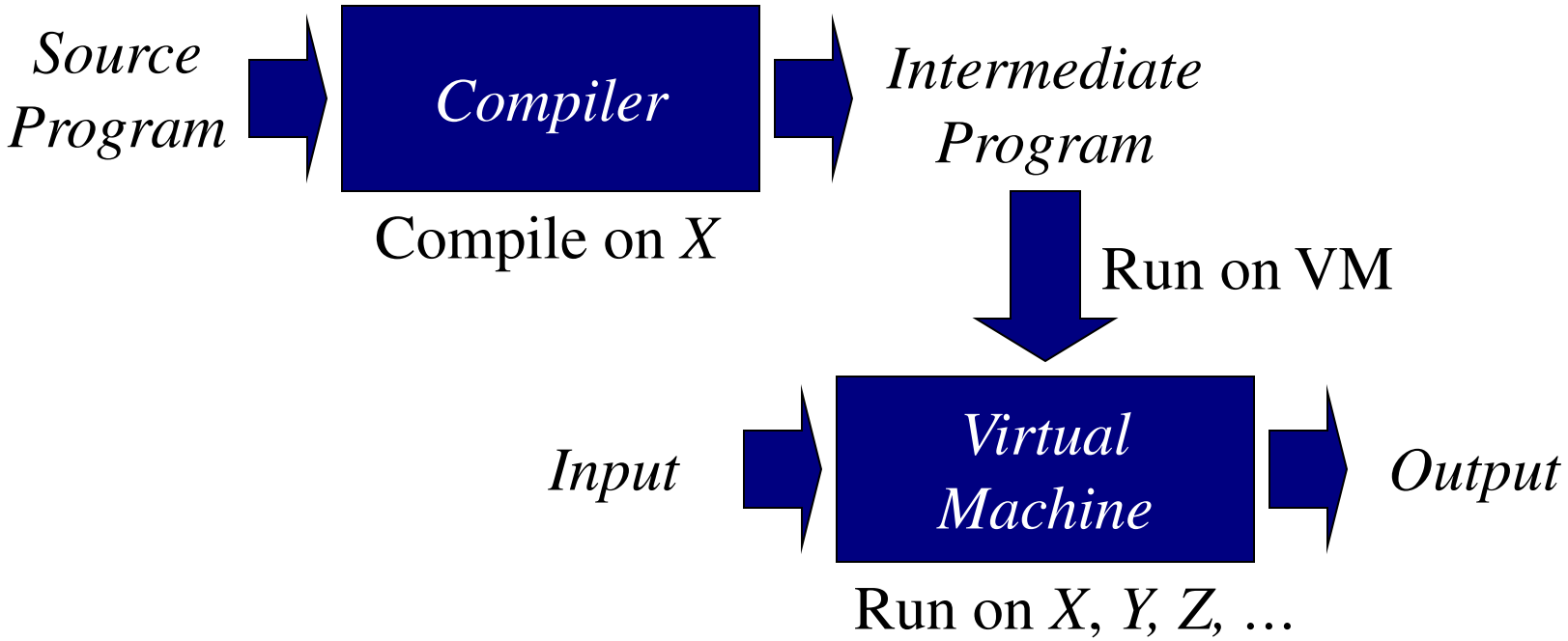
The result of res will be: "200 4 27 "

Virtual Machines (for programming language)

- A virtual machine executes an instruction stream in software
- Adopted by Pascal, Java, Smalltalk-80, C#, functional and logic languages, and some scripting languages
  - Pascal compilers generate P-code that can be interpreted or compiled into object code
  - Java compilers generate bytecode that is interpreted by the Java virtual machine (JVM)
  - C#, VB.NET compilers generate CIL (**Common Intermediate Language**) that is interpreted by the CLR virtual machine
  - The CLR may translate CIL into machine code by just-in-time (JIT) compilation

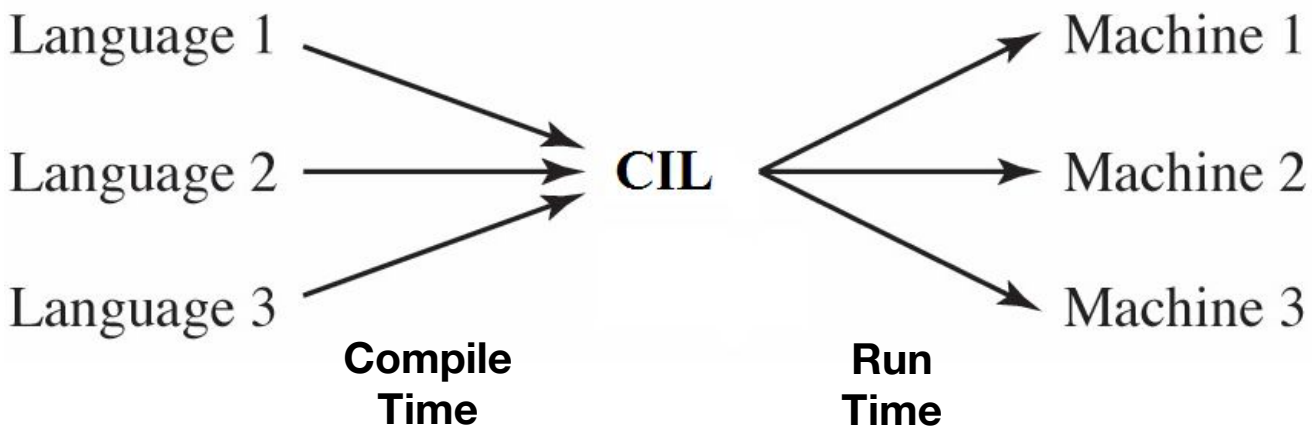
Compilation and Execution on Virtual Machines

- Compiler generates intermediate program
- Virtual machine interprets the intermediate program



Two Steps Compilation Process

- Compilation is done in two steps:
  - At compile time: compile each language (C#,VB.Net, C++, etc) to Common Intermediate Language (CIL)
  - At runtime: Common Language Runtime (CLR) uses a Just In Time (JIT) compiler to compile the CIL code to the native code for the device used



Simple C# program

```
namespace SimpleConsoleApplication
{
   class Program
    {
        static void Main(string[] args)
        {
            int init =10;
            int rate =5;
            int pos = init + rate * 60;
            System.Console.WriteLine(pos);
        }
    }
}
```

C# -> CIL Using ildasm

```
.method private hidebysig static void  Main(string[] args) cil managed
{  .entrypoint
  .maxstack  3
  .locals init ([0] int32 'init', [1] int32 rate, [2] int32 pos)
  ldc.i4.s   10
  stloc.0
  ldc.i4.5
  stloc.1
  ldloc.0
  ldloc.1
  ldc.i4.s   60
  mul
  add
  stloc.2
  ldloc.2
  call       void [mscorlib]System.Console::WriteLine(int32)
  ret }
```

.maxstack 3

.locals init ([0] int32 'init', [1] int32 rate, [2] int32 pos)

Local Variables		
0 (init)	int	0
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
unused	

ldc.i4.s 10

Local Variables		
0 (init)	int	0
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
10	int

Local Variables		
0 (init)	int	0
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
10	int

stloc.0

Local Variables		
0 (init)	int	10
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
unused	

Local Variables		
0 (init)	int	10
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
unused	

ldc.i4.5

Local Variables		
0 (init)	int	10
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
5	int

Local Variables		
0 (init)	int	10
1 (rate)	int	0
2 (pos)	int	0

Stack	
unused	
unused	
5	int

stloc.1

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
unused	
unused	

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
unused	
unused	

ldloc.0

ldloc.1

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
5	Int
10	int

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
5	int
10	int

ldc.i4.s 60

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
60	int
5	int
10	int

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
60	int
5	int
10	int

mul

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
300	int
10	int

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
300	int
10	int

add

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
unused	
310	int

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	0

Stack	
unused	
unused	
310	int

stloc.2

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	310

Stack	
unused	
unused	
unused	

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	310

Stack	
unused	
unused	
unused	

ldloc.2

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	310

Stack	
unused	
unused	
310	int

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	310

Stack	
unused	
unused	
310	int

call void mscorlib]System.Console::WriteLine(int32)

ret

Local Variables		
0 (init)	int	10
1 (rate)	int	5
2 (pos)	int	310

Stack	
unused	
unused	
unused	

Common Intermediate Language (CIL)

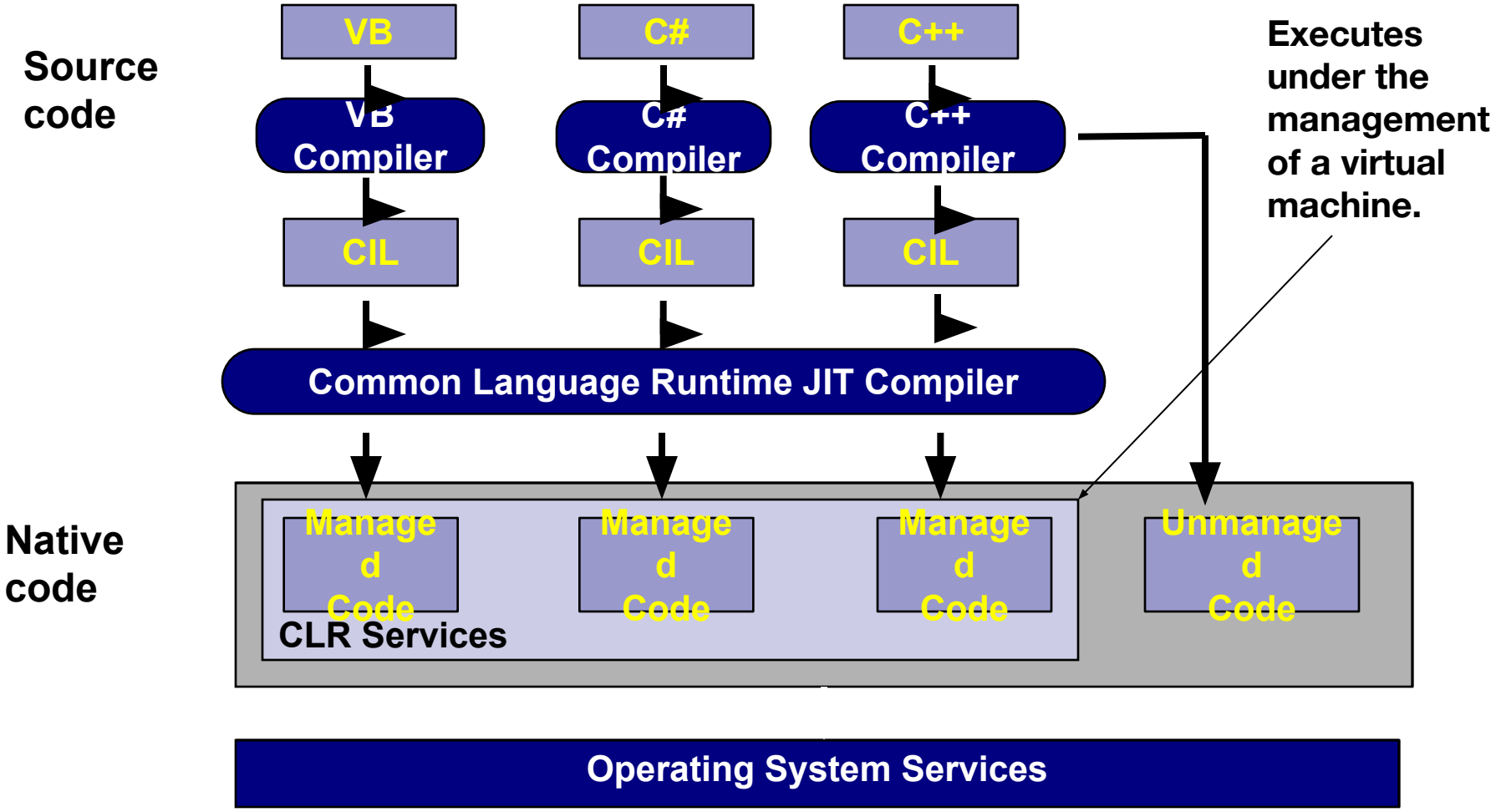
- Much like the native languages of devices.
- CIL was originally known as Microsoft Intermediate Language (MSIL).
- CIL is a CPU- and platform-independent instruction set.
- It can be executed in any environment supporting the .NET framework

Common Language Runtime (CLR)

- The Common Language Runtime (CLR) manages the execution of code.
- CLR uses Just-In-Time (JIT) compiler to compile the CIL code to the native code for device used.
- Through the runtime compilation process CIL code is verified for safety during runtime, providing better security and reliability than natively compiled binaries.
- Native image generator compilation (NGEN) can be used to produces a native binary image for the a specific environment. What is the point?

Compilation Process

So if we have 3 programming languages and 3 devices, how many compilers do we need?



Platform and Language Independent

- What we have described so far will lead us to Platform independent environment. How?
- Can we use compiled classes written in X language in a program written in Y language?
- VB.NET + C#.NET code

Language interoperability

- All .NET languages can interoperate

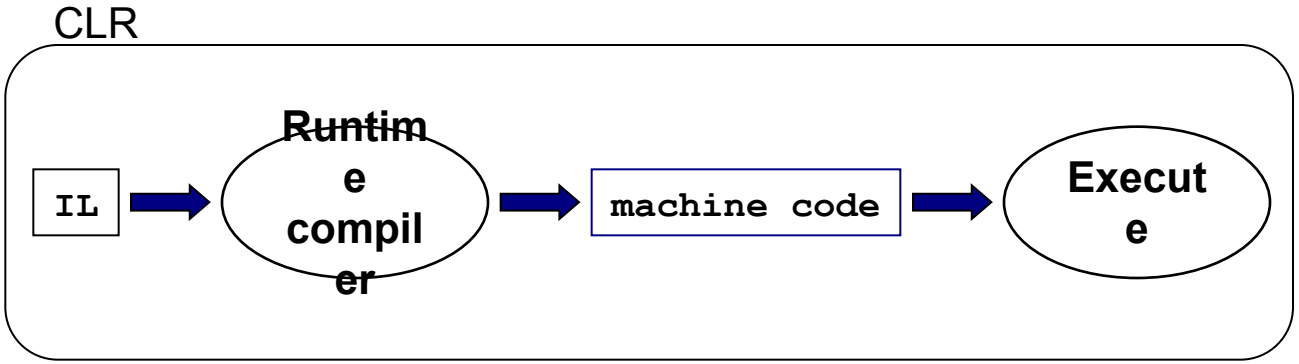
C# calling VB.NET →

```
class Hello
{
  static void Main()
  {
    System.Console.WriteLine(Greeting.Message());
  }
}
```

```
Class Greeting
  Shared Function Message() As String
    Return "hello"
  End Function
End Class
```

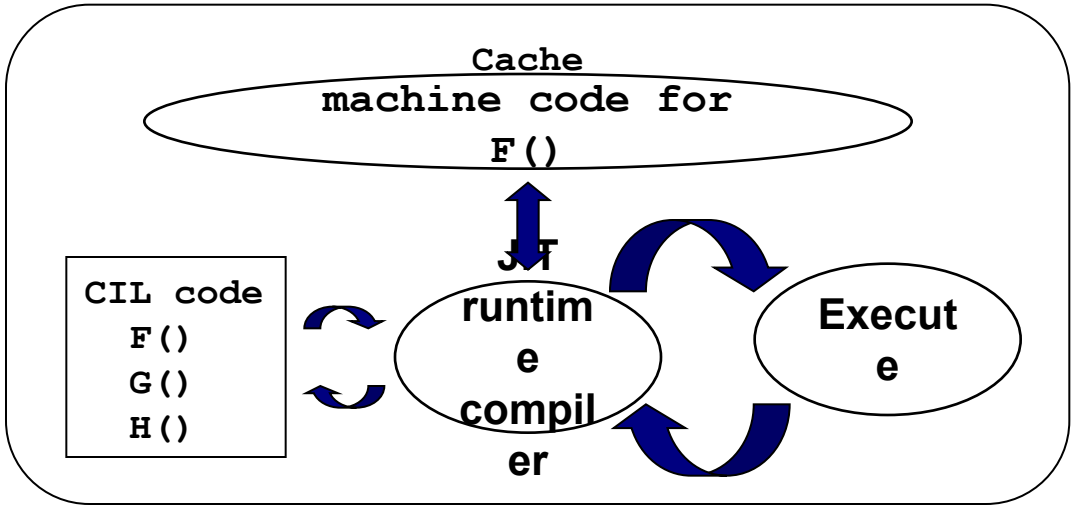
Execution engine

- *Common Language Runtime* (CLR) is the execution engine
  - loads IL
  - compiles IL
  - executes resulting machine code



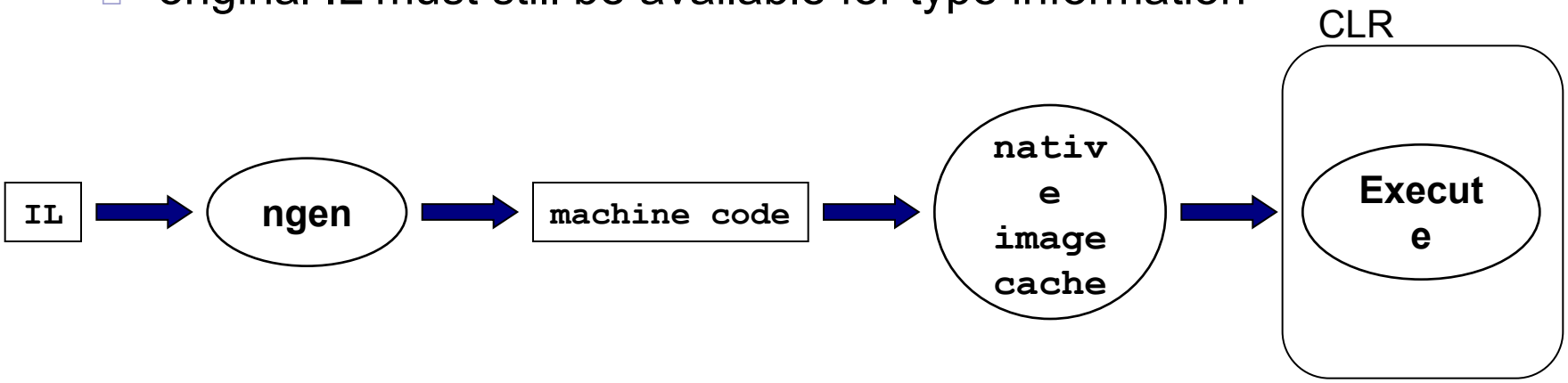
JIT runtime compile

- CIL is compiled into machine code at runtime by the CLR
  - compiles methods as needed
  - called *just in time* (JIT) compile
- JIT compilation model:
  - first time method is called the IL is compiled and optimized
  - compiled machine code is cached in transient memory
  - cached copy used for subsequent calls



NGEN install time compile

- Can compile CIL into machine code when app installed
  - use native image generator **`ngen.exe`**
  - can speed startup time since code pre-compiled
  - but cannot do as many optimizations
  - original IL must still be available for type information



Language variability

Not all .NET languages have exactly the same capabilities

differ in small but important ways

C#

```
class Hello
{
  static void Main()
  {
    int  i;
    uint u;
  }
}
```

signed integer →

unsigned integer →

VB.NET

```
Class Greeting
  Shared Sub Main()
    Dim i as Integer
  End Sub
End Class
```

signed integer only →

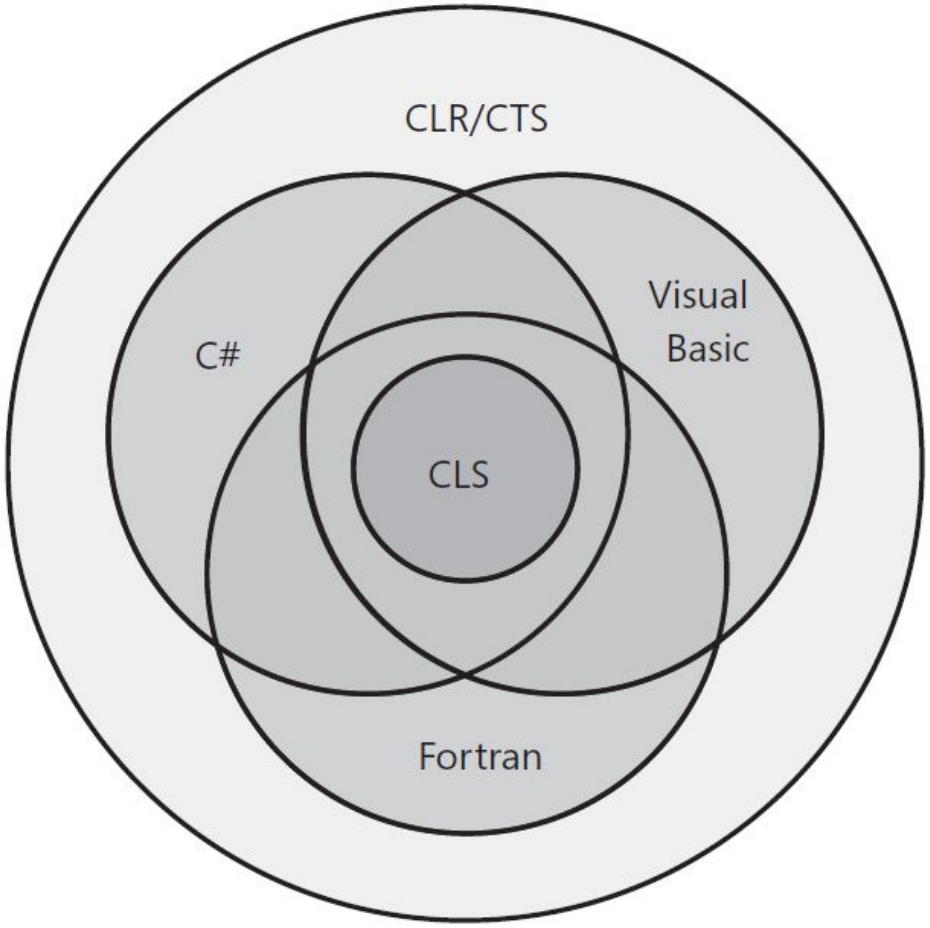
Common Language Specification

- Common Language Specification (CLS) defines type subset
  - required to be supported by all .NET languages
  - limiting code to CLS maximizes language interoperability
  - code limited to CLS called *CLS compliant*

not CLS compliant
to use **`uint`** in public
interface of public class →

```
public class Calculator
{
  public uint Add(uint a, uint b)
  {
    return a + b;
  }
}
```

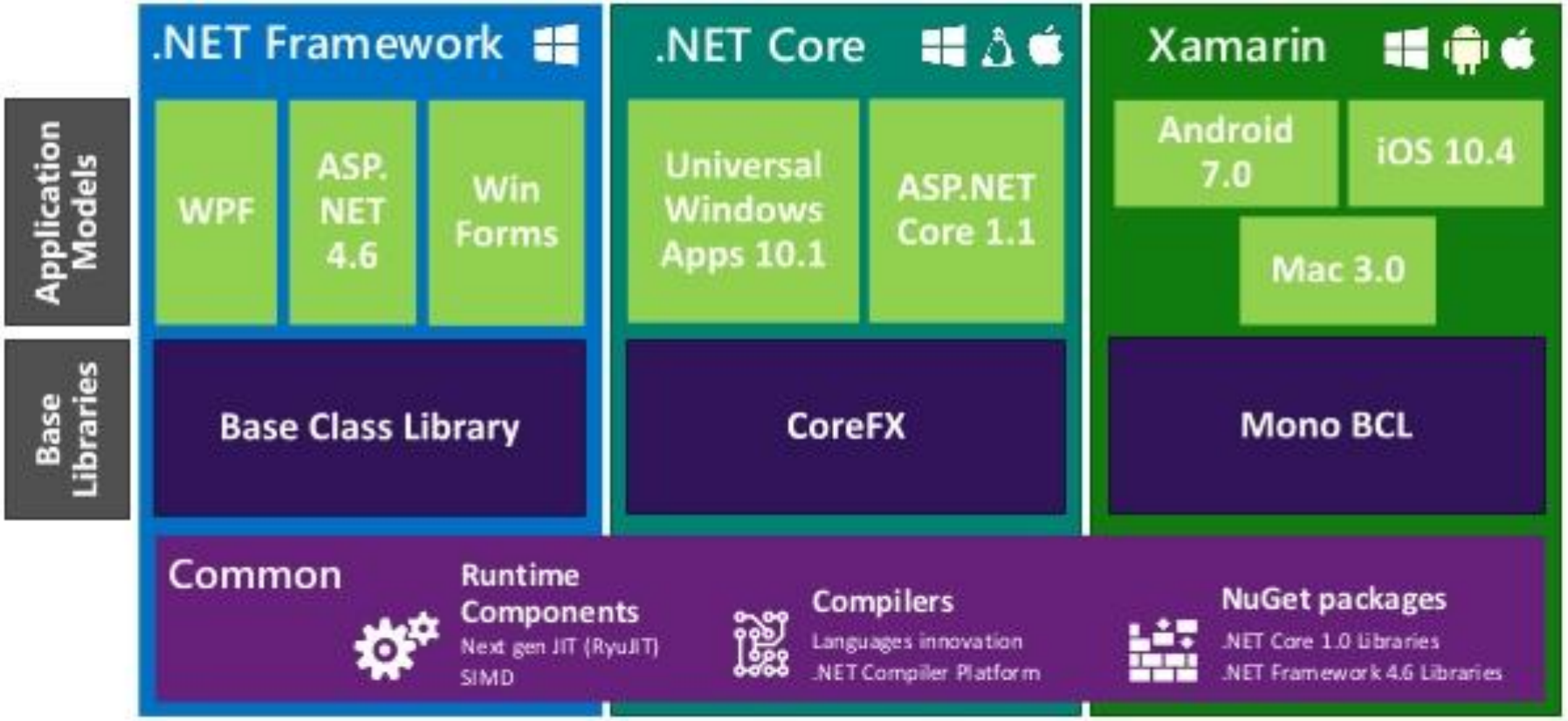
CLS,CLR/CTS & Languages



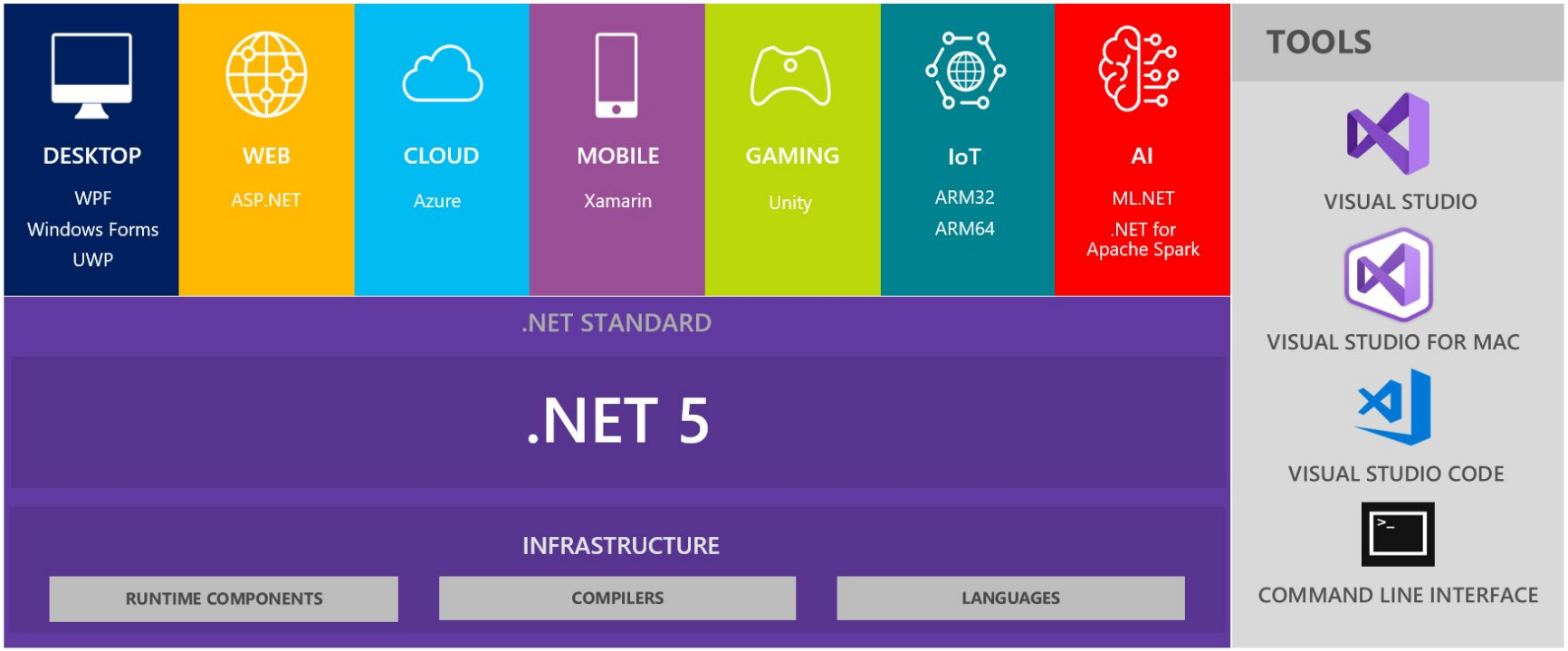
Languages offer a subset of the CLR/CTS and a superset of the CLS (but not necessarily the same superset).

The big picture of .NET Platforms

DOT NEXT



.NET – A unified platform



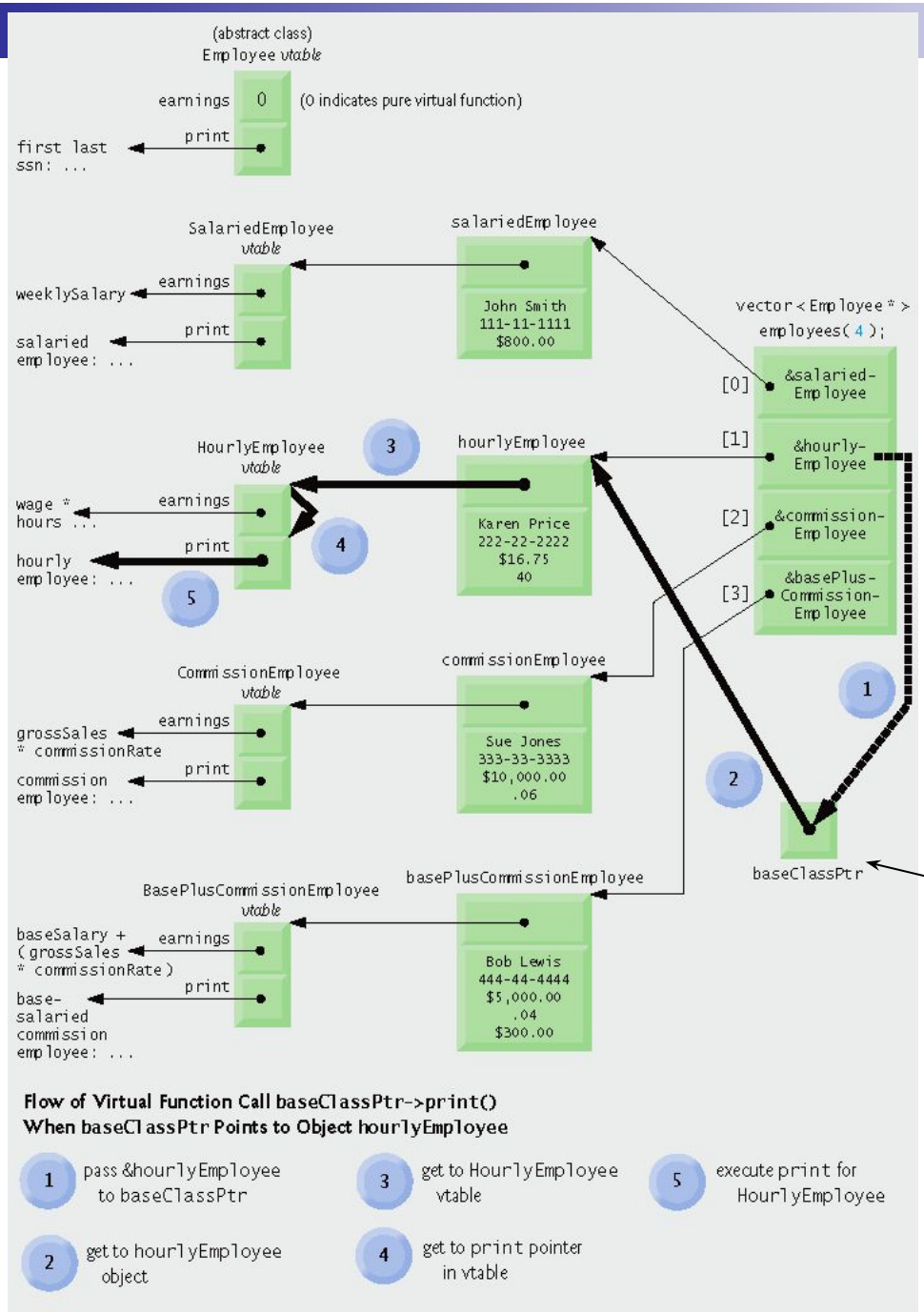
.NET Schedule

- .NET Core 3.0 release in September
- .NET Core 3.1 = Long Term Support (LTS)
- .NET 5.0 release in November 2020
- Major releases every year, LTS for even numbered releases
- Predictable schedule, minor releases if needed

Method call performance

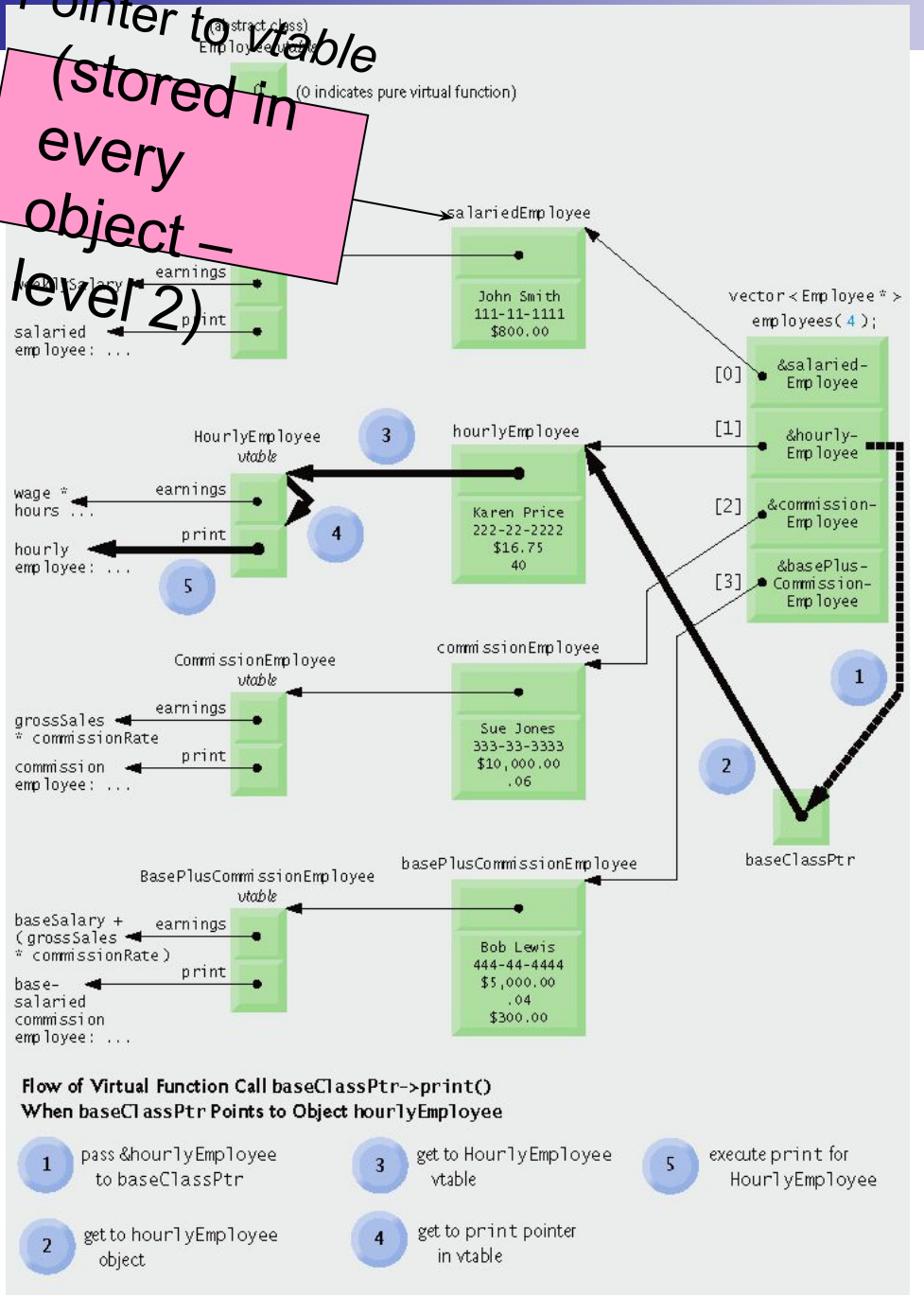
Let's compare C ++, C # (.NET) method call performance

- C++ Function
- C++ Virtual Function
- C# (.NET) Method

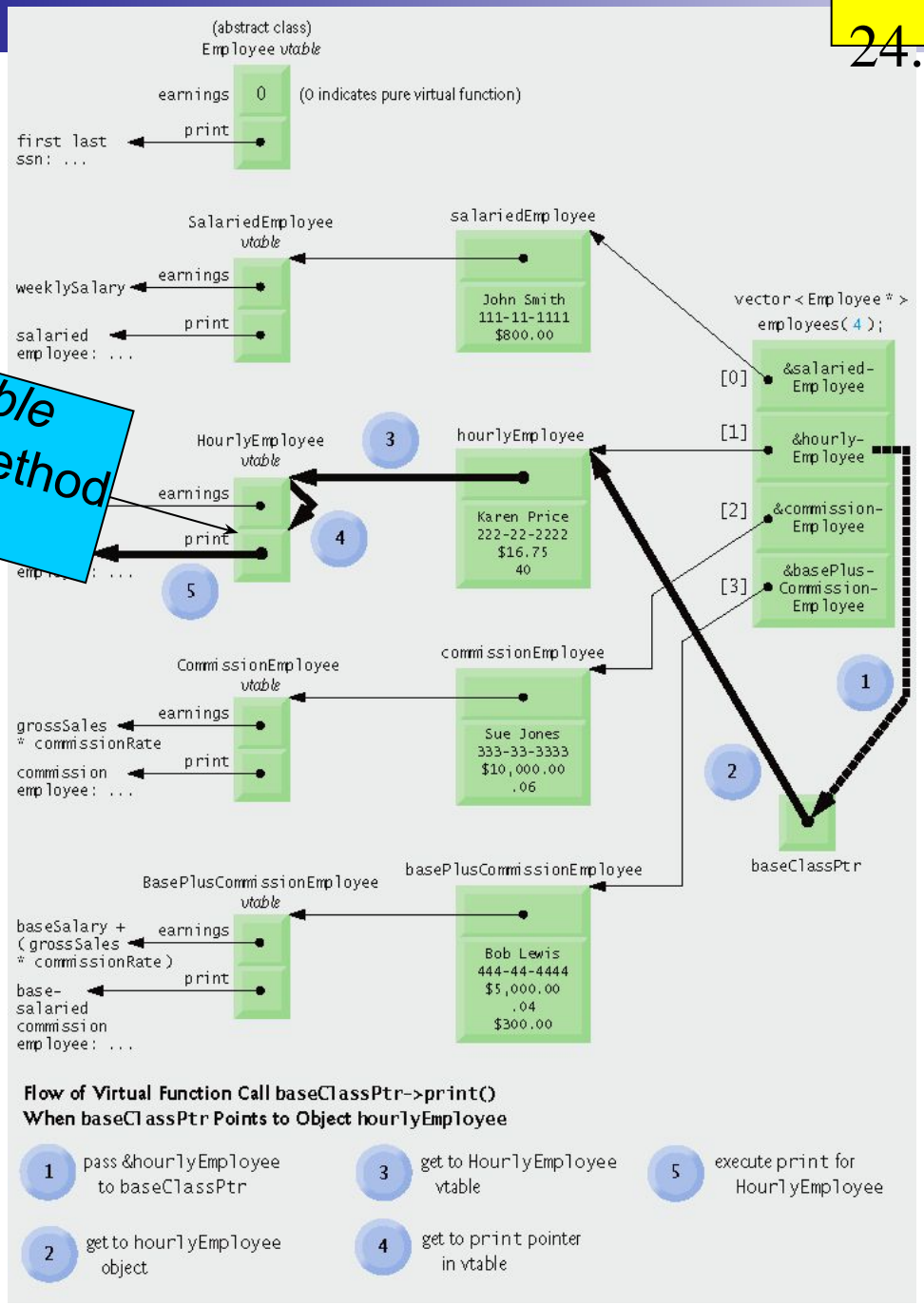


Pointer to object (level 1)

Pointer to vtable (stored in every object – level 2)

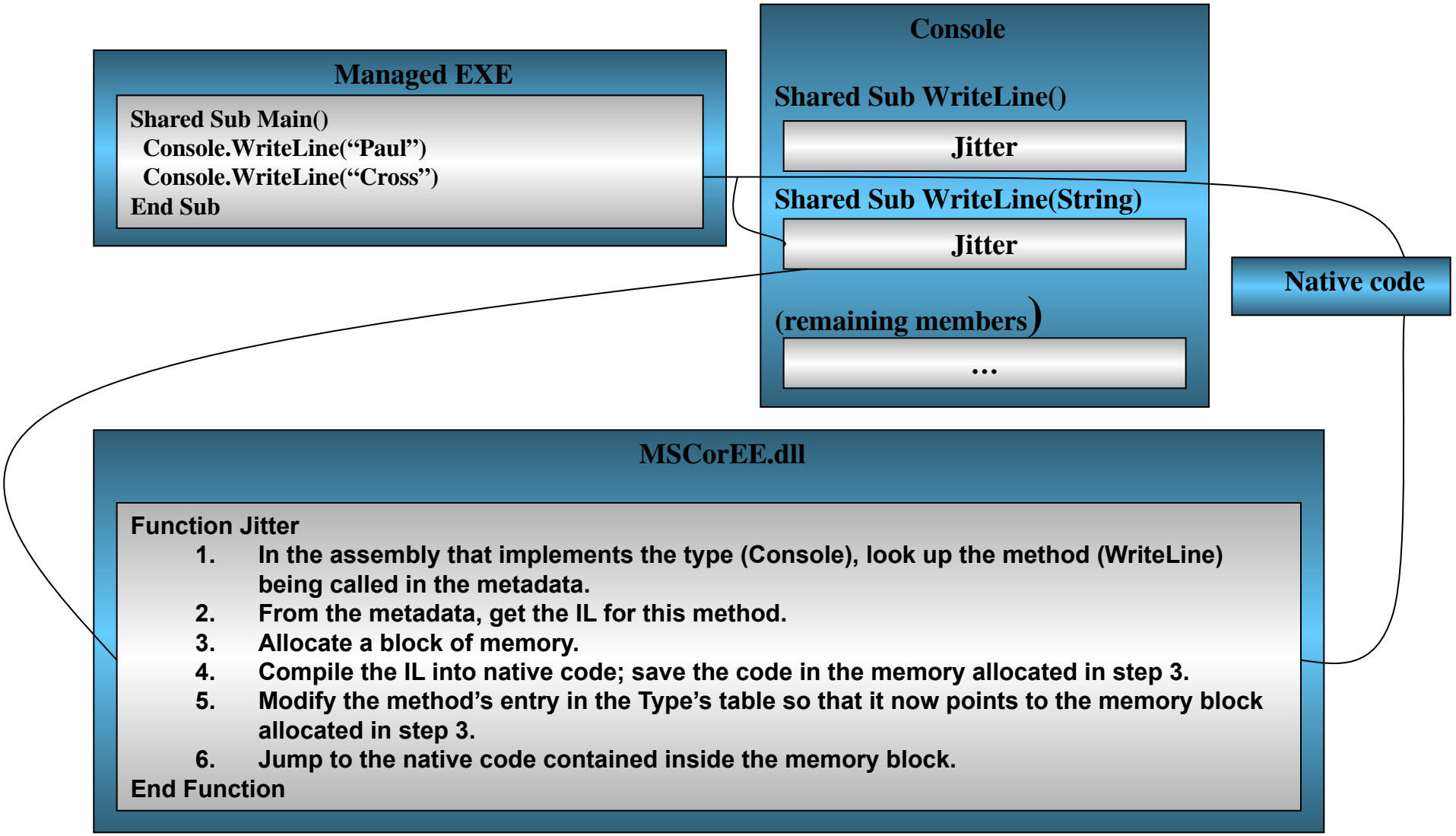


Deitel & Deitel, Fig 24.24



Index into *vtable* to access method (level 3)

Calling a method for the first time



Performance Impact

Call Number	C++	C++ Virtual	.NET
1	X	X + 2 pointers	X+ 2 pointers+ JIT compile
2,3…..	X	X + 2 pointers	X+ 2 pointers