MULTITHREADING

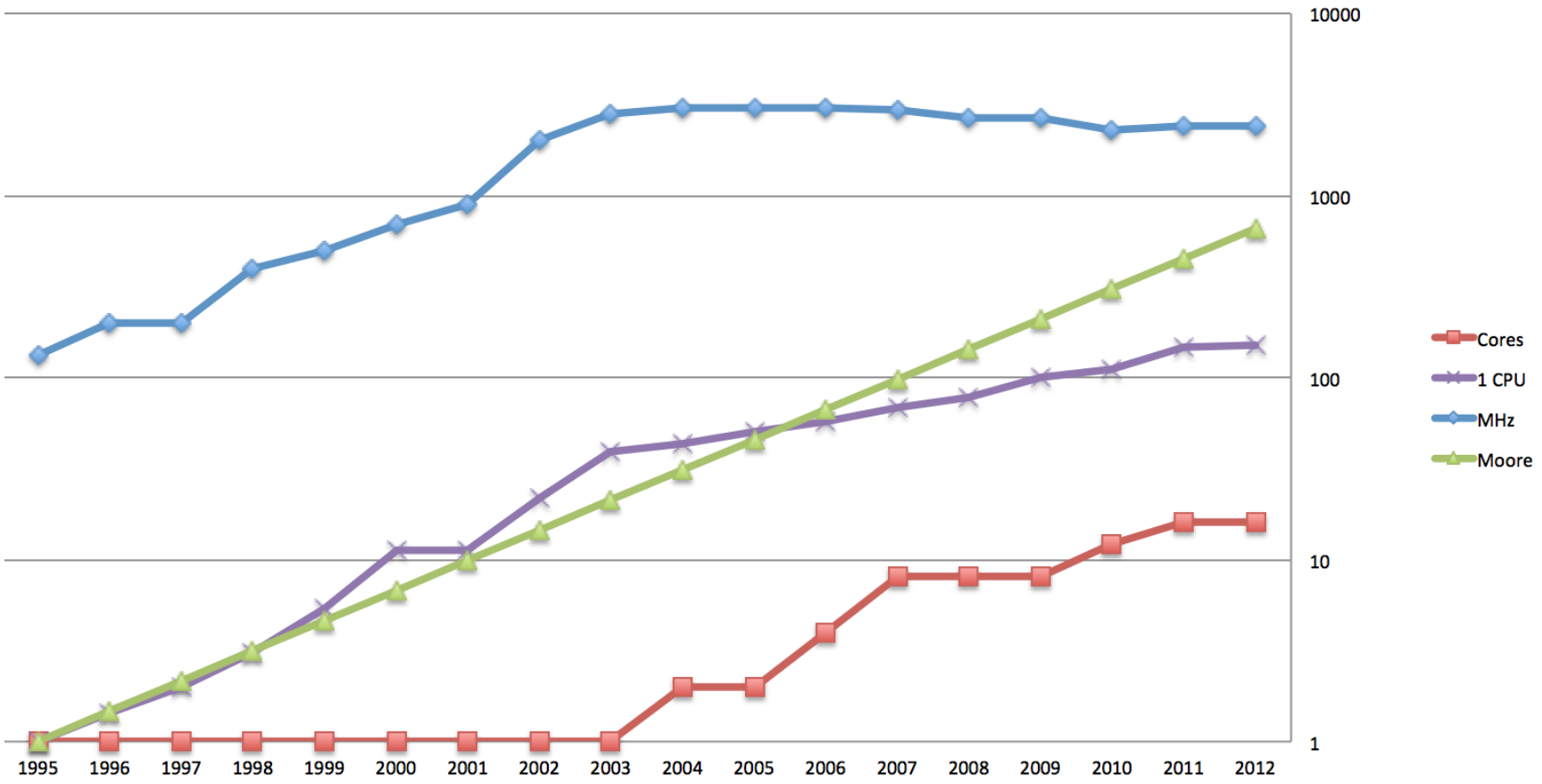
FAST PROGRAMS FOR MODERN COMPUTERS

I. Basics

WHAT?

- The art of doing multiple things at the same time

WHY?



HOW?

- TThread
- System.Threading [XE7]
- OmniThreadLibrary [Windows, VCL]

WHEN?

- Slow background process
- Background communication
- Executing synchronous API
- Multicore data processing
- Multiple clients

THREADING

- A thread is a line of execution through a program
  - There is always one thread
- Multitasking (and multithreading)
  - Cooperative
    - Win 3.x
  - Preemptive
    - Time slicing
    - Parallel execution

PROCESSES VS. THREADS

- Pros
  - Processes are isolated – data protection is simple
- Cons
  - Processes are isolated – data sharing is complicated
  - Processes are *heavy*, threads are *light*

PROBLEMS

- Data sharing
  - Messaging
  - Synchronization
- Synchronization causes
  - Race conditions
  - Deadlocking
  - Livelocking
- Slowdown

FOUR PATHS TO MULTITHREADING - 1

- The Windows Way
  - FHandle := **BeginThread**(nil, 0, @ThreadProc, Pointer(Self), 0, FThreadID);

FOUR PATHS TO MULTITHREADING - 2

- The Delphi Way
  - Focus on threads
  - TMyThread = class(**TThread**)
    procedure **Execute**; override;

FOUR PATHS TO MULTITHREADING - 3

- The XE7 Way
  - Focus on tasks
  - task := **TTask.Create**(procedure begin … end);
  - future := **TTask.Future**<Integer>(function: Integer …);
  - **TParallel.For**(1, Max, procedure (I: Integer) …);

FOUR PATHS TO MULTITHREADING - 4

- The OmniThreadLibrary Way
  - task := **CreateTask**(worker, 'name');
  - **Async**(procedure begin … end).**Await**(procedure …);
  - **Parallel.For**(1, 100000).**Execute**(procedure (i: integer) …);

THREAD VS. TASK

- *Task* is part of code that has to be executed
- *Thread* is the execution environment

THREAD POOLING

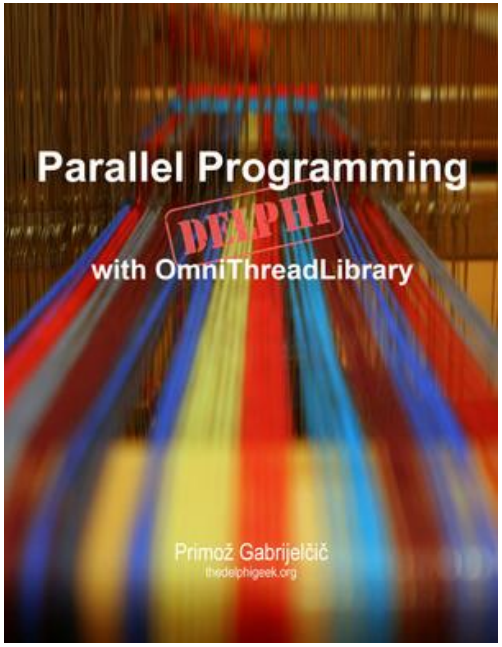
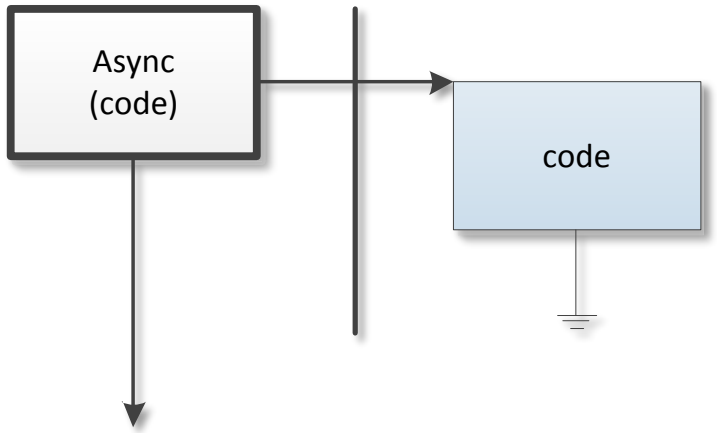
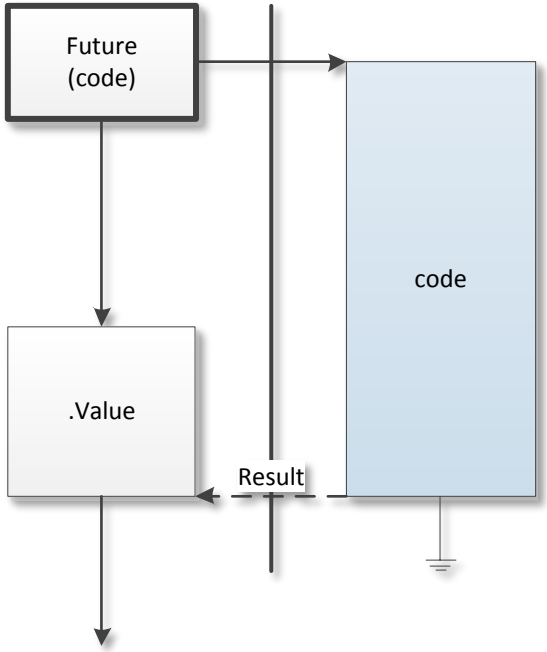
- Starting up a thread takes time
- Thread pool keeps threads alive and waits for tasks
- Automatic thread startup/shutdown

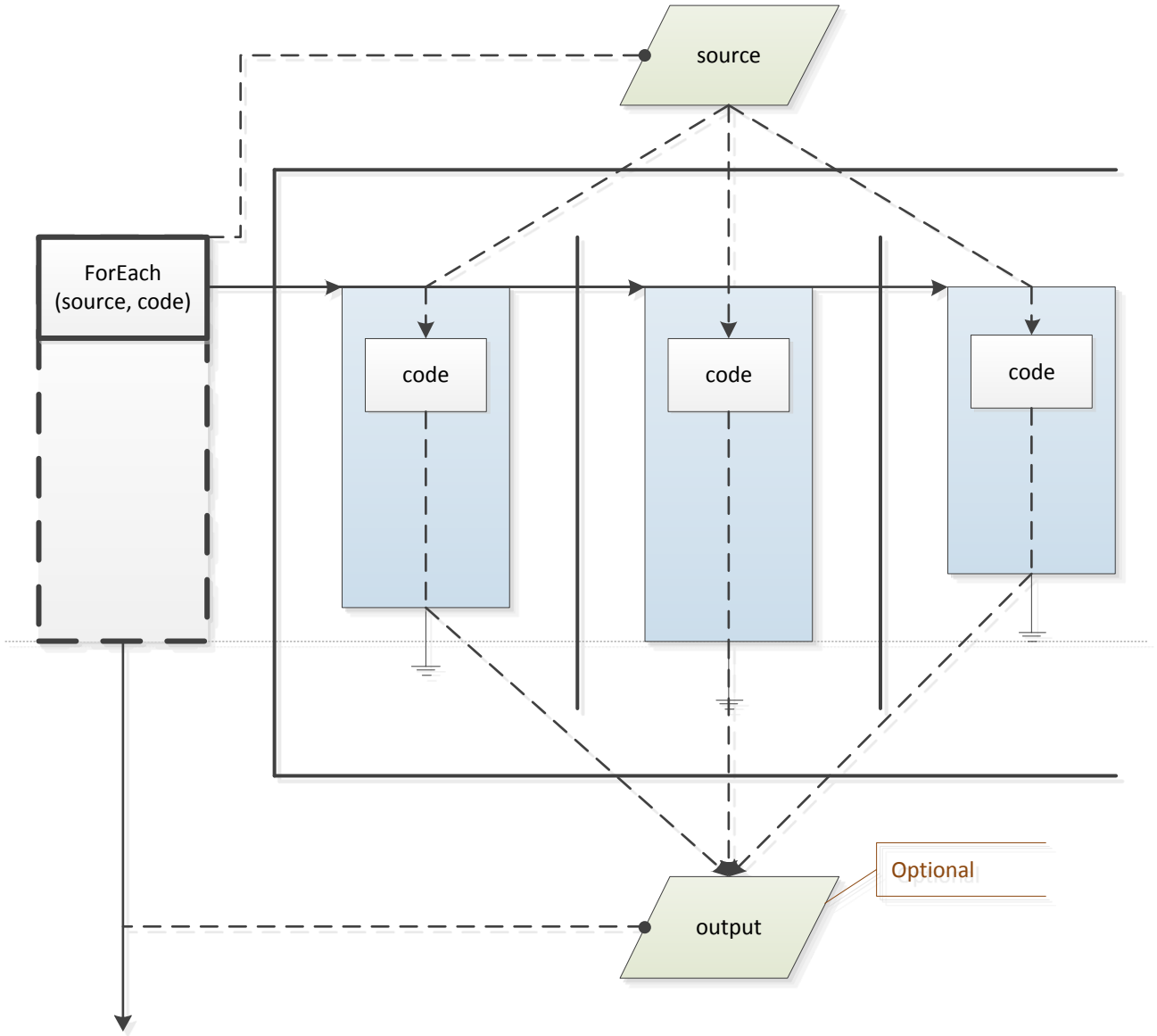
DELPHI 2 – XE6 DEMO

THREAD CREATION/TERMINATION

- ```
  FThread1 := TTestThread1.Create;
  ```

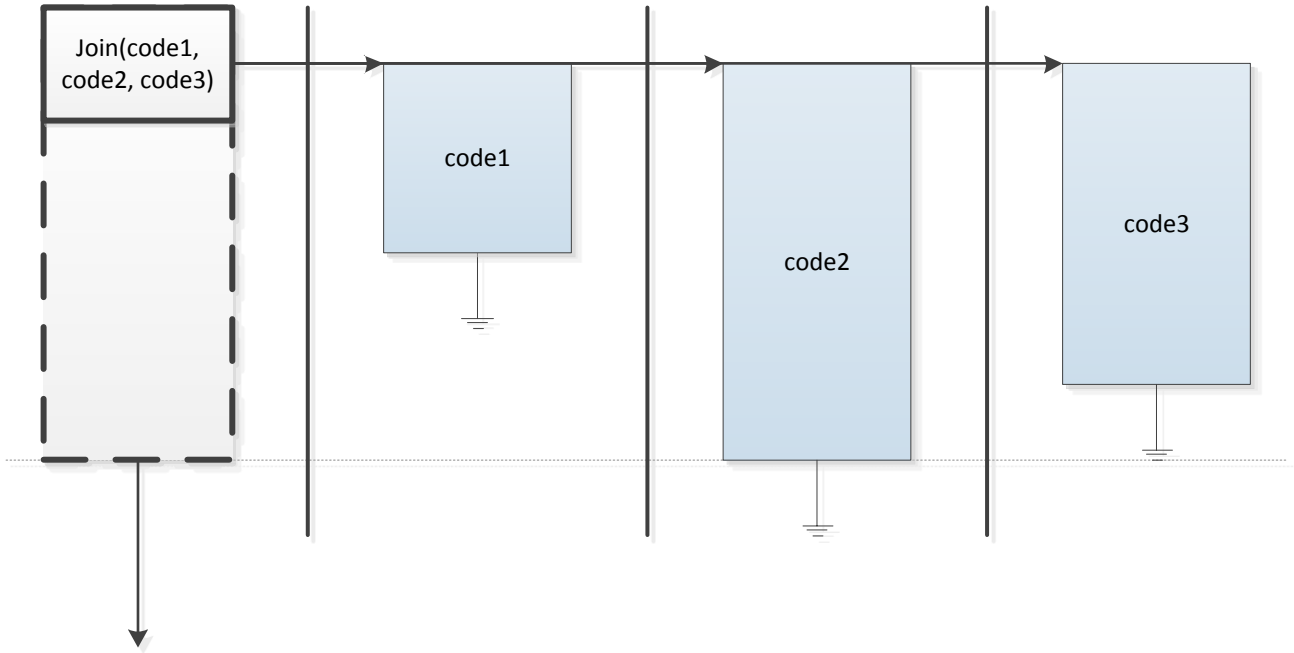
- ```
  FThread1.Terminate;
  FThread1.WaitFor;
  FreeAndNil(FThread1);
  ```

- ```
  FThread2 := TTestThread2.Create(true);
  FThread2.FreeOnTerminate := true;
  FThread2.OnTerminate := ReportThreadTerminated;
  ```
  ```

WORKER

```
procedure TTestThread1.Execute;
begin
  while not Terminated do begin
    // some real work could be done here
  end;
end;
```

TTHREAD EXTRAS

- CreateAnonymousThread
- Synchronize, Queue
- ReturnValue
- FatalException
- Handle, ThreadID, Priority

PROS AND CONS

- Pros
  - Low-level approach offers full execution speed
  - Multi-OS support
- Cons
  - Offers no help to simplify multithreading programming

DELPHI XE7 DEMO

TASK

- Encapsulates a *task* (a work to be done)
- Runs in a thread pool
- TTask.Create + ITask.Start
- TTask.Run
- ITask.Wait/TTask.WaitForAll/TTask.WaitForAny
- No *OnTerminate* notification

FUTURE

- Performs a computation in background and returns a result
- TTask.Future<ReturnType>
- IFuture<ReturnType>.Value
- IFuture<ReturnType>.Status

PARALLEL FOR

- TParallel.For(lowBound, highBound, workerProc);
- Watch for shared memory access!

PROS AND CONS

- Pros
  - Simple usage
  - Hard parts are already implemented
  - Multi-OS support
- Cons
  - Limited functionality
  - No messaging

II. Do's and Don't's

SHARED MEMORY

- Read / Modify / Write
  - Increment / Decrement
  - Simultaneously reading and writing into a list
    - TList, TStringList, TList<T>, …
  - Arrays are usually fine
    - Don’t access same element from two threads
    - Element size >= SizeOf(pointer)

ATOMIC CHANGES

- SyncObjs
- Locking
  - TCriticalSection
  - TSpinLock
  - TMultiReadExclusiveWriteSynchronizer / TMREWSync (SysUtils)
- “Interlocked” operations
  - TInterlocked

PROBLEMS CAUSED BY LOCKING

- Deadlocks
- Livelocks
- Slowdown

RTL

- SyncObjs
- TThreadList
- TThreadedQueue
- TMonitor
  - Be careful!

- `threadvar`

COMMUNICATION

MECHANISMS

- TEvent
- Messages [Windows]
- TCP
- Shared memory (with atomic changes)
  - Message queue

III. OmniThreadLibrary

OMNITHREADLIBRARY IS …

- … VCL for multithreading
  - Simplifies programming tasks
  - Componentizes solutions
  - Allows access to the bare metal
- … trying to make multithreading possible for mere mortals
- … providing *well-tested* components packed in *reusable* classes with *high-level* parallel programming support

PROJECT STATUS

- http://www.omnithreadlibrary.com
- Delphi 2007 →
- OpenBSD license
- Actively used
- https://leanpub.com/omnithreadlibrary
- http://otl.17slon.com/book
- http://www.omnithreadlibrary.com/webinars.htm
- Google+ community



INSTALLATION

- Checkout / Download + Unpack
- Add *path* & *path/src* to search path
- *uses Otl**

ABSTRACTION LAYERS

- Low-level
  - TThread replacement
  - Similar to TTask [XE7]
  - Communication
- High-level
  - Requires Delphi 2009
  - “Multithreading for mere mortals”
  - ‘Parallel for’ and much more

LOW-LEVEL MULTITHREADING

CREATING A TASK

- `CreateTask(`*`task_procedure`*`)`
- `CreateTask(`*`task_method`*` )`
- `CreateTask(`*`TOmniWorker_object`*`)`
- `CreateTask(`*`anonymous_procedure`*`)`

MESSAGING

- Messaging preferred to locking
- TOmniMessageQueue
- TOmniQueue
  - Dynamically allocated, O(1) enqueue and dequeue, threadsafe, microlocking queue
- TOmniBlockingCollection
- TOmniValue

FLUENT PROGRAMMING

```
FHelloTask := CreateTask(TAsyncHello.Create(), 'Hello')
  .SetParameter('Delay', 1000)
  .SetParameter('Message', 'Hello')
  .OnMessage(Self)
  .OnTerminated(
    procedure
    begin
      lbLog.Items.Add('Terminated');
    end)
  .Run;
```

LOW-LEVEL CLASSES

- OtlTask
  - IOmniTask
- OtlTaskControl
  - IOmniTaskControl
- OtlCommon
  - TOmniValue
  - Environment
- OtlContainers
  - TOmniBoundedStack
  - TOmniBoundedQueue
  - TOmniQueue
- OtlSync
  - TOmniCS
  - TOmniMREW
  - Locked<T>

IV. High-Level Mulithreading

ABSTRACTIONS

- Async/Await
- Async
- Future
- ForEach / For
- Join
- Parallel task
- Background worker
- Pipeline
- Fork/Join

AWAIT



- `Parallel.Async(code)`

ASYNC/AWAIT

- Simplified syntax
- Async(TProc).Await(TProc);

FUTURE

- Wikipedia
  - “They (futures) describe an object that acts as a proxy for a result that is initially not known, usually because the computation of its value has not yet completed.”
- Start background calculation, wait on result.

FUTURE

- `Future:= Parallel.Future<type> (calculation);`
- `Value := Future.Value;`



FOREACH / FOR

- ```
  Parallel.ForEach(from, to).Execute(
    procedure (const value: integer);
    begin
      //…
    end);
  ```
- ```
  Parallel.ForEach(source).Execute(
    procedure (const value: TOmniValue) …
  ```
- ```
  Parallel.ForEach<string>(source).Execute(
    procedure (const value: string) …
  ```
  ```


source
ForEach
(source, code)
code
code
code
Optional
output

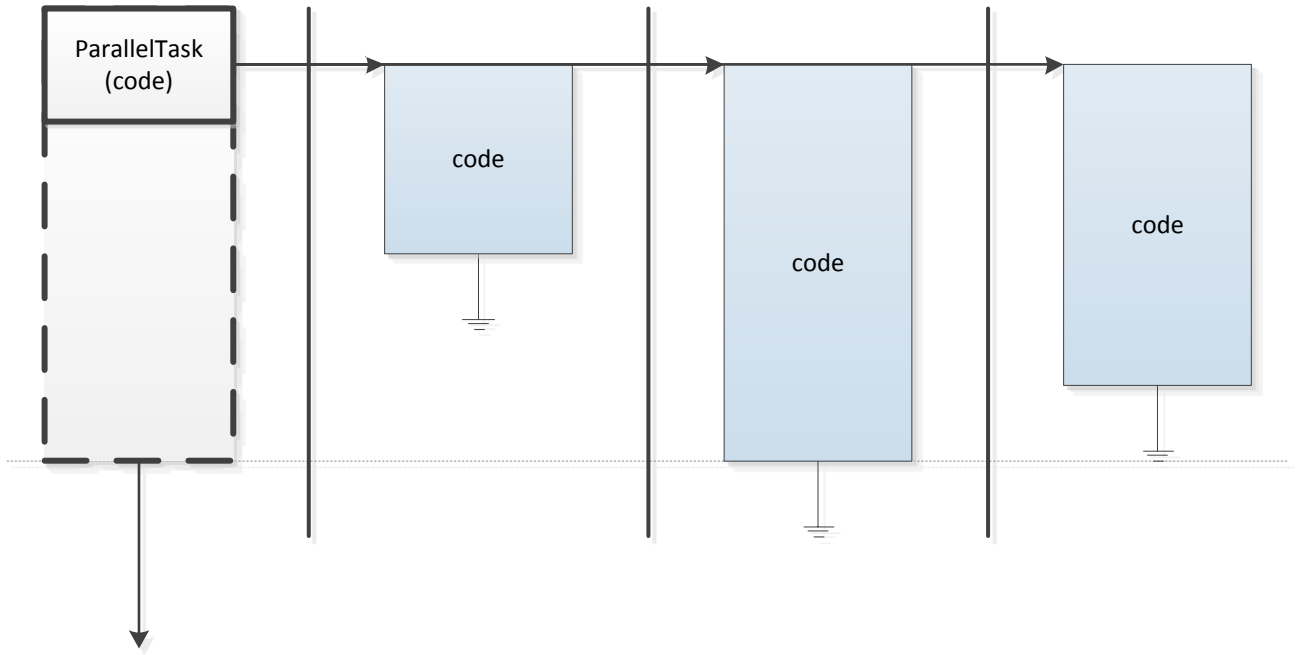
JOIN

- `Parallel.Join([task1, task2, task3, … taskN]).Execute`



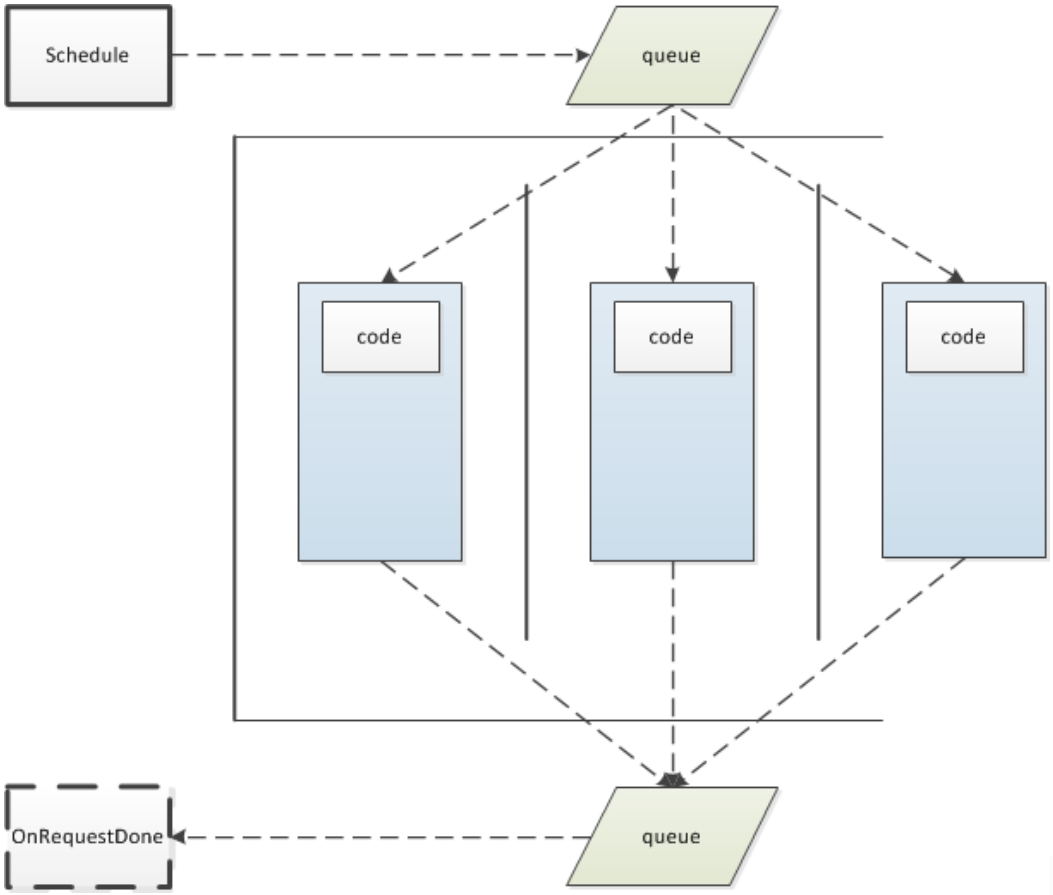
PARALLEL TASK

- `Parallel.ParallelTask.Execute(code)`



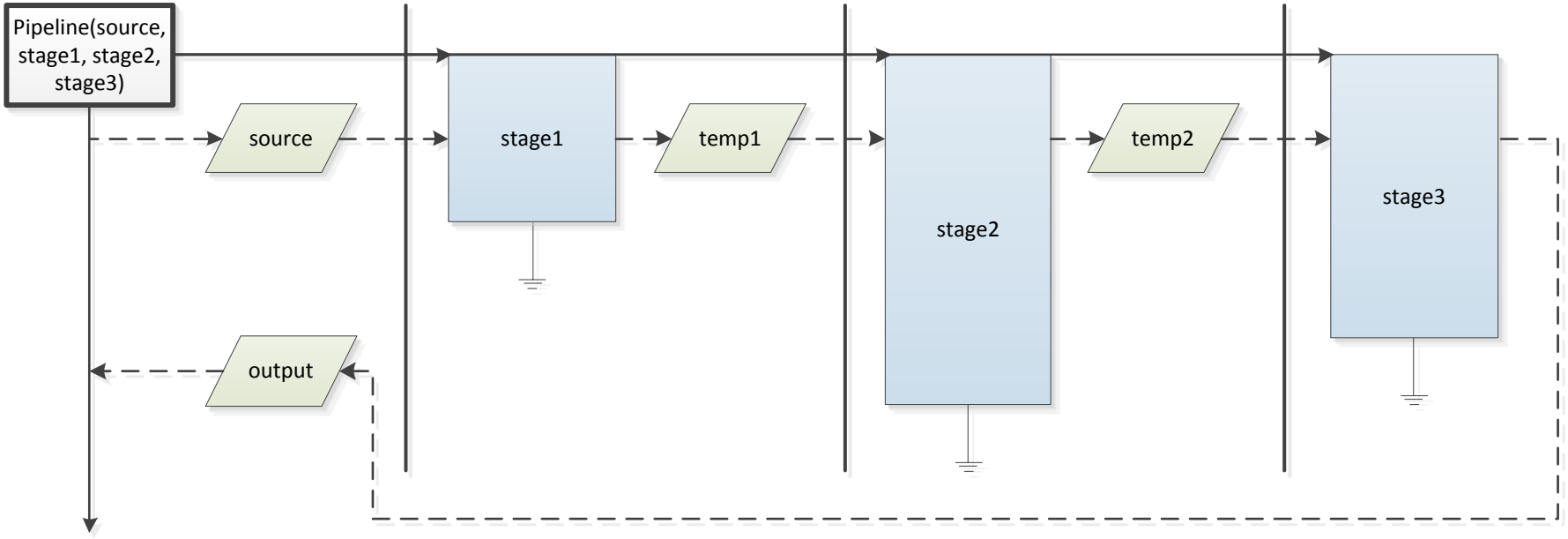
BACKGROUND WORKER

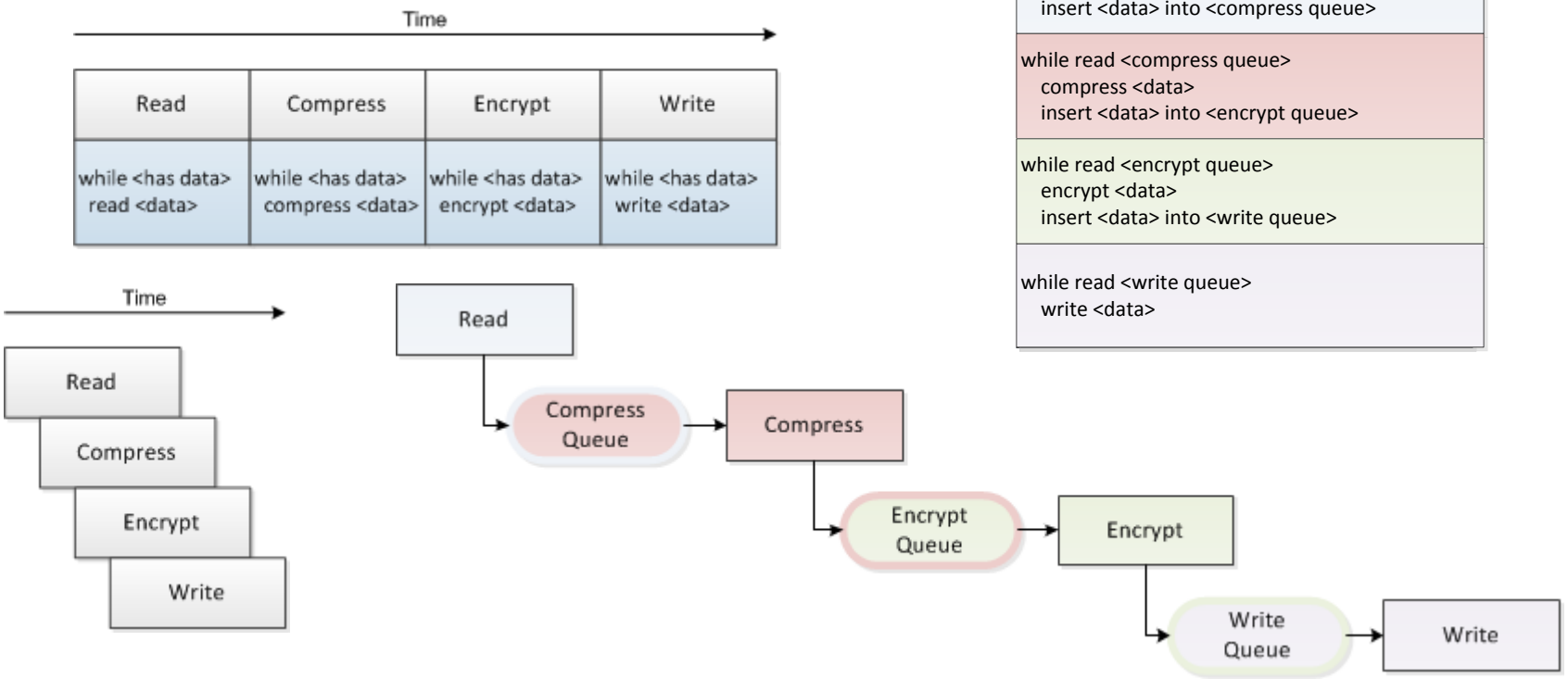
- Client/Server



PIPELINE

- Parallel.Pipeline([stage1, stage2, stage3]).Run



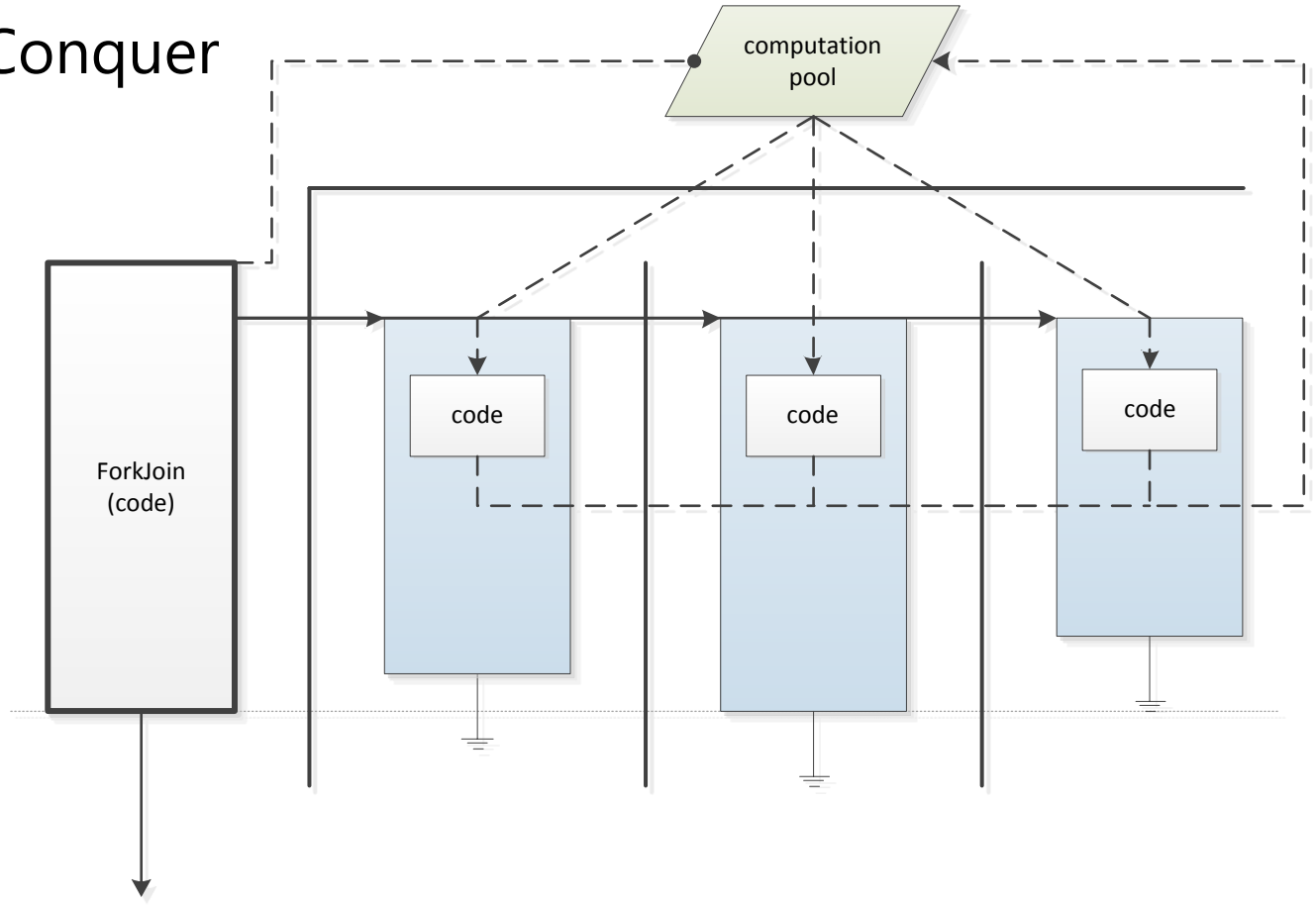

Time
Read
Compress
Encrypt
Write
while <has data>
read <data>
while <has data>
compress <data>
while <has data>
encrypt <data>
while <has data>
write <data>
Time
Read
Compress
Encrypt
Write
Read
Compress Queue
Compress
Encrypt Queue
Encrypt
Write Queue
Write
while <has data>
read <data>
insert <data> into <compress queue>
while read <compress queue>
compress <data>
insert <data> into <encrypt queue>
while read <encrypt queue>
encrypt <data>
insert <data> into <write queue>
while read <write queue>
write <data>

PIPELINE

```
var
  pipeOut: IOmniBlockingCollection;

pipeOut := Parallel.Pipeline
  .Stage(StageGenerate)
  .Stage(StageMult2)
  .Stage(StageSum)
  .Run;
```

FORK/JOIN

- Divide and Conquer



FORK/JOIN

```
max1 := forkJoin.Compute(
  function: integer begin
    Result := …
  end);

max1 := forkJoin.Compute(
  function: integer begin
    Result := …
  end);

Result := Max(max1.Value, max2.Value);
```

WORDS OF (HARD LEARNED) WISDOM

WORDS OF WISDOM

"New programmers
are drawn to multithreading
like moths to flame,
with similar results."

- Danny Thorpe

KEEP IN MIND

- Never use VCL from a background thread!
- Don’t parallelize everything
- Don’t create thousands of threads
- Rethink the algorithm
- Prove the improvements
- Test, test and test

BE AFRAID

- Designing parallel solutions is hard
- Writing multithreaded code is hard
- Testing multicore applications is hard
- Debugging multithreading code is pure insanity
  - Debugging high-level abstractions is just hard

QUESTIONS?