Experimental Evaluation of Distributed Middleware with a Virtualized Java Environment

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MW4SOC'11
December 12, 2011

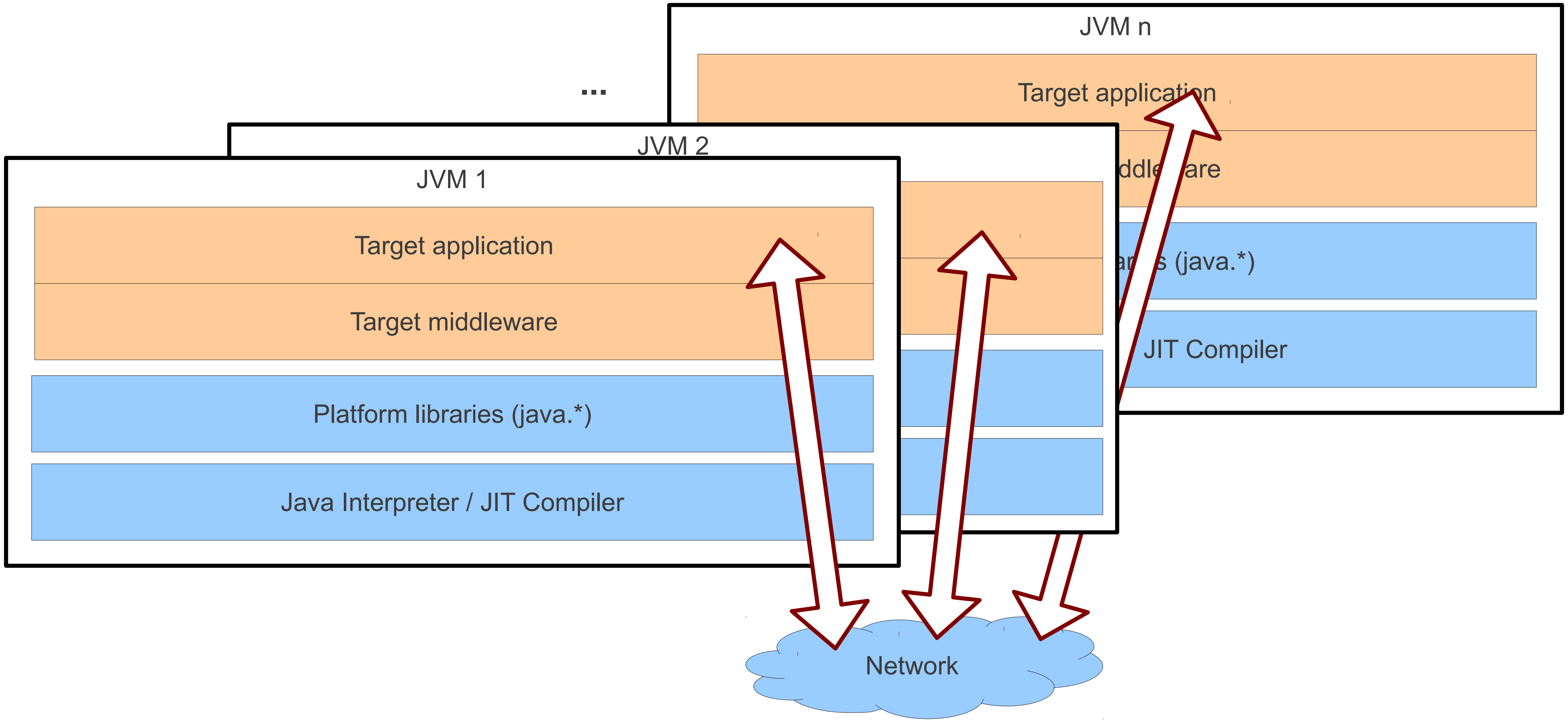
Motivation

- Service oriented architectures span a wide range of application scenarios
  - Geographically dispersed
  - Deployed outside enterprise information systems

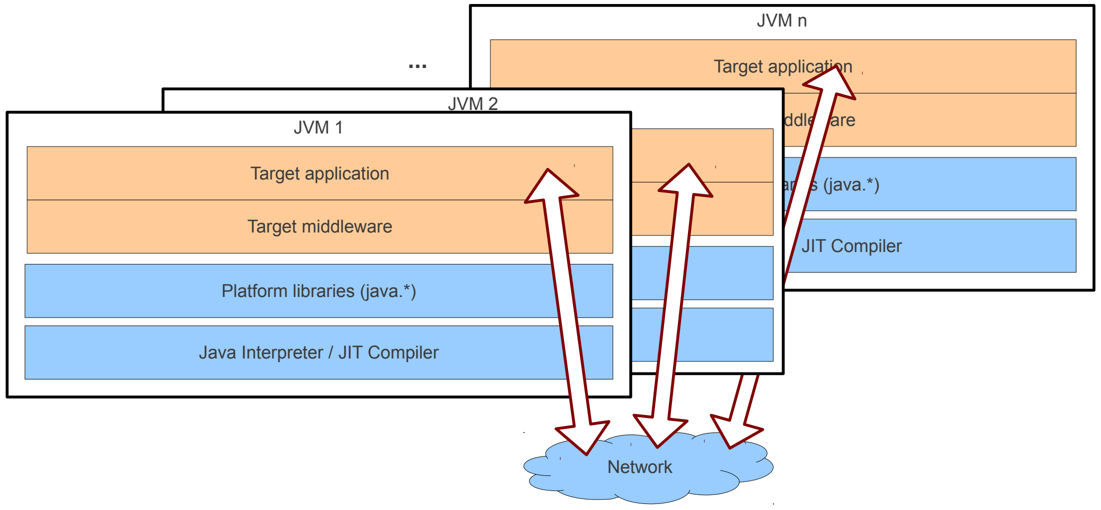
- Comprehensive evaluation requirements
  - Correctness
  - Performance

- Current evaluation solutions
  - **Simulation models**: useful while the whole system isn't available, but can only validate design and not the middleware and service implementation
  - **Actual deployment**: most realistic but costly and time consuming, also requires the availability of the entire system

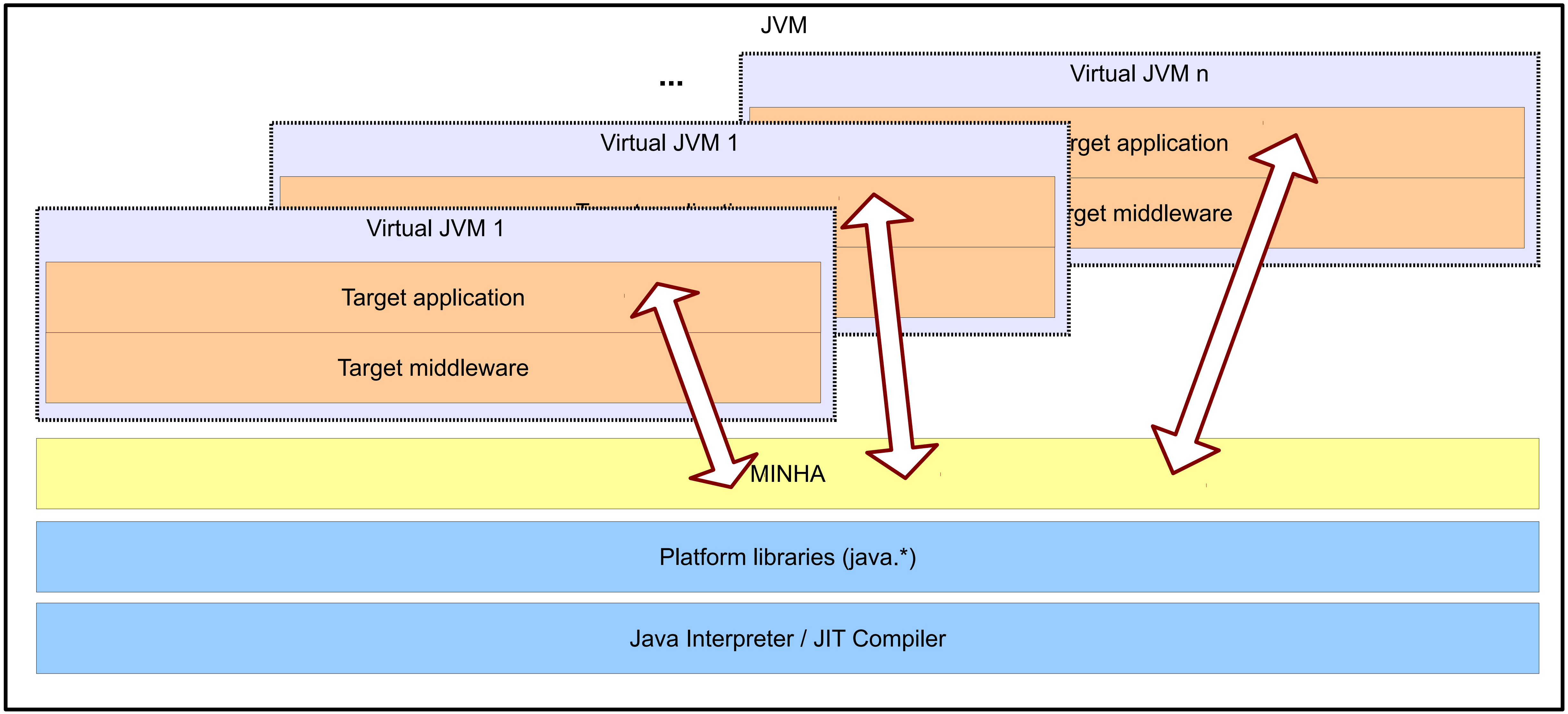
- Traditional experimental middleware evaluation



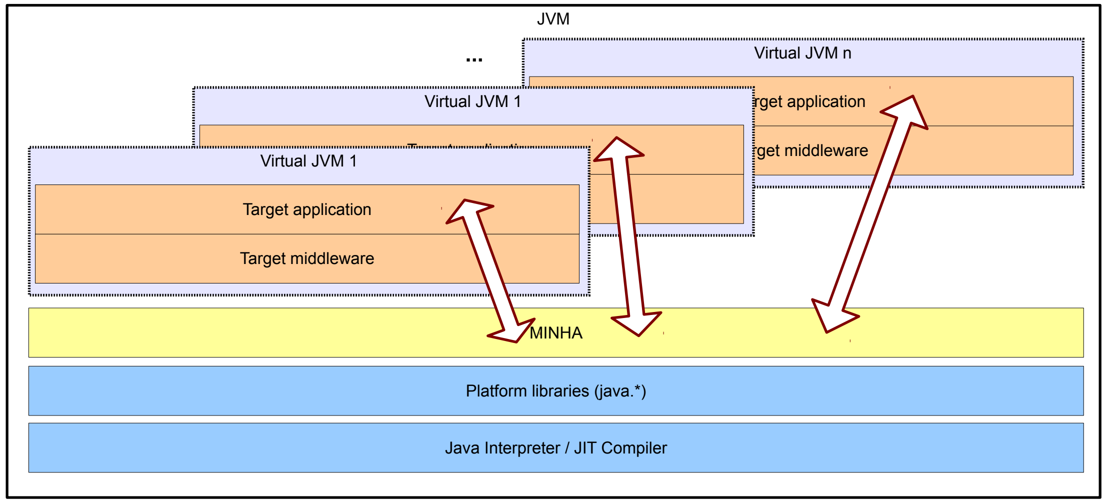
- Traditional experimental middleware evaluation
  - Multiple instances of an application are deployed in multiple JVMs
  - JVMs are scattered across multiple physical hosts
  - The amount of the required hardware resources is often prohibitive



Minha middleware evaluation

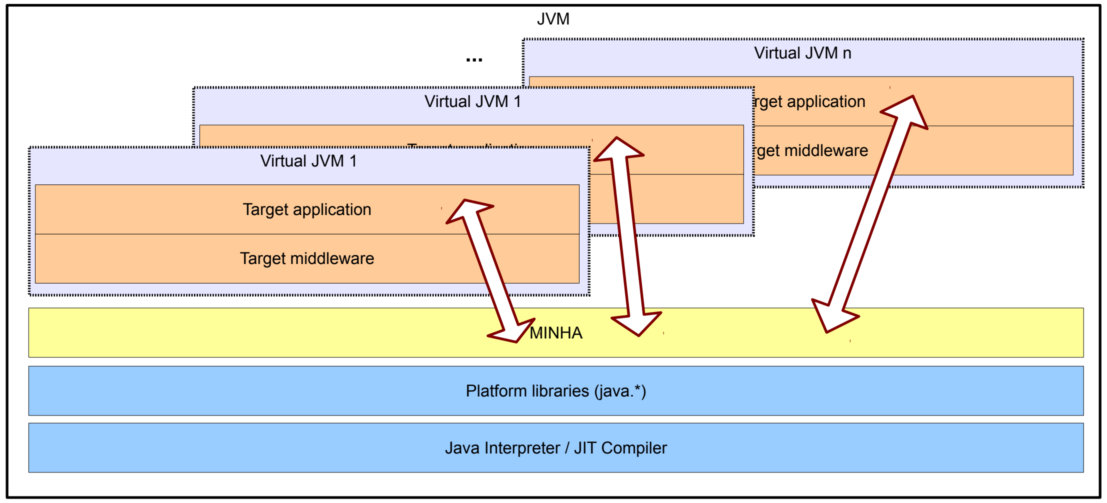


- Minha middleware evaluation
  - Reproduces the same distributed run within a single JVM
  - Application and middleware classes for each vJVM are automatically transformed
  - Some simulation models are developed from scratch, others are produced by translating native libraries



- MINHA middleware evaluation advantages

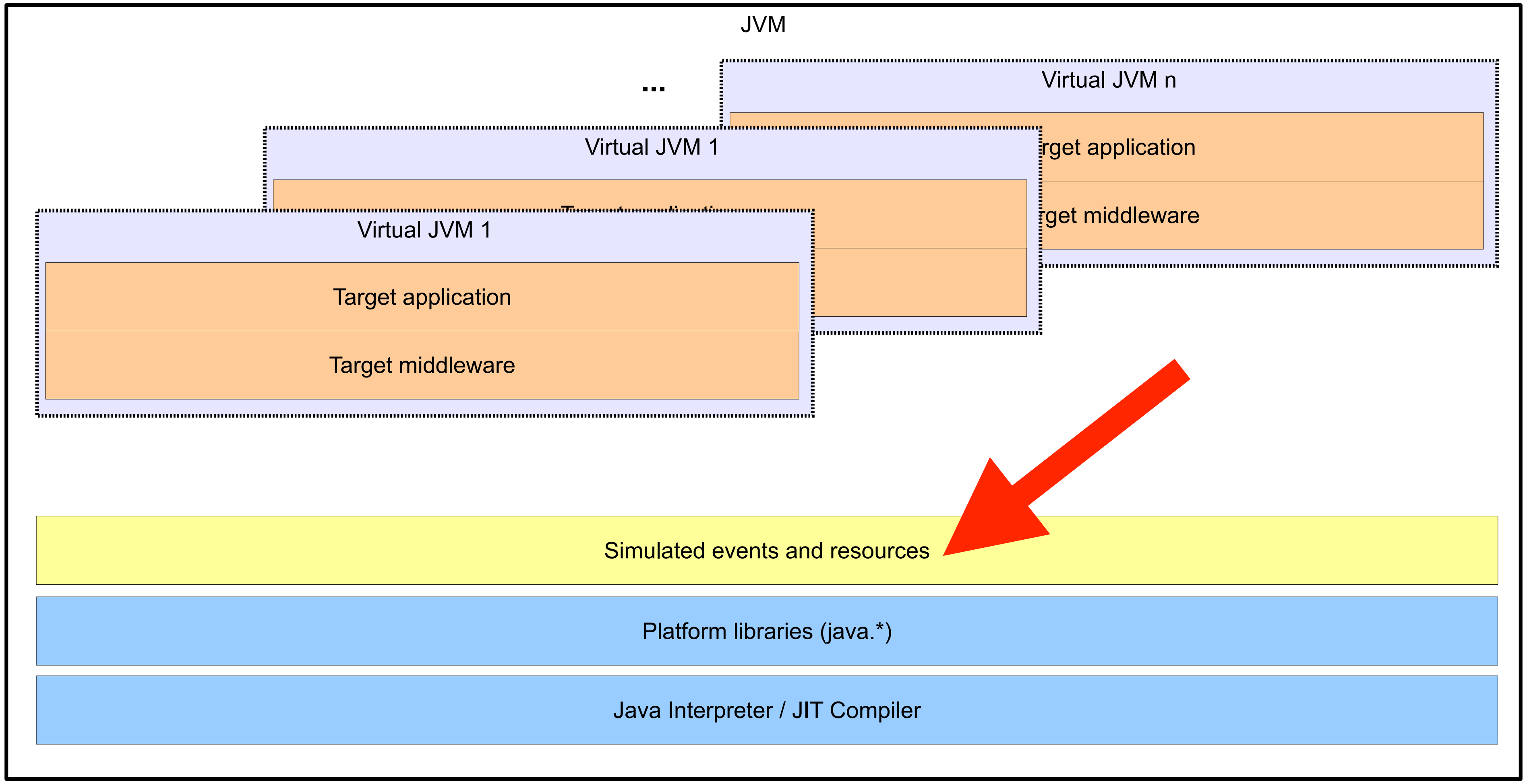
  - Global observation without interference
  - Simulated components
  - Large scale scenarios
  - Automated "What-If" analysis



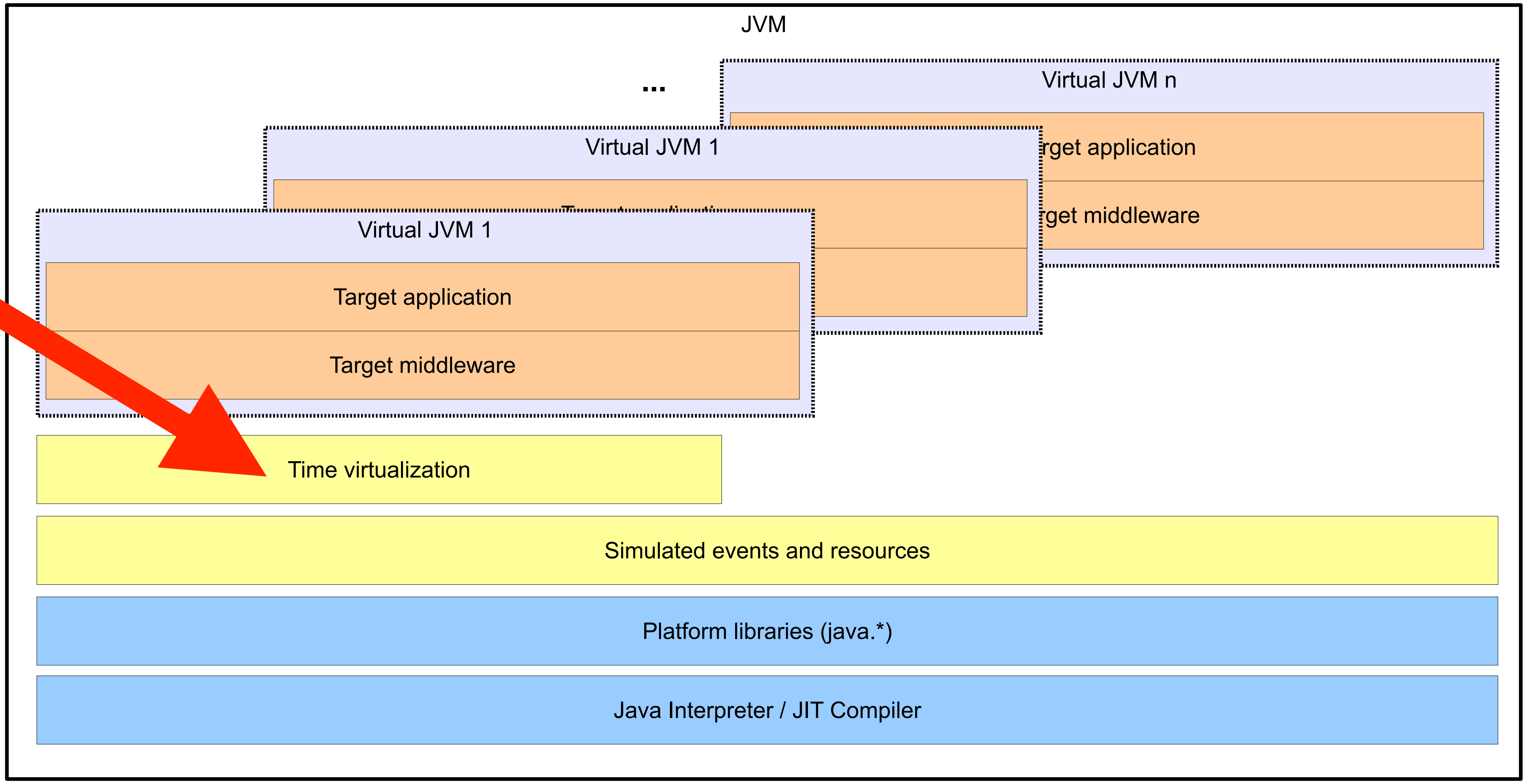
Agenda

- Simulation Kernel
- Virtualized JVM
- Input/Output Models
- Calibration
- Case Study

- **Event-based simulation kernel**
  - Abstract resource management primitives



- **Combination of real and simulated code**:
  - Measuring the time of execution and management of a simulated processor
  - Allowing sequential Java code to execute by eliminating the inversion of control resultant from the event simulation



Simulation Kernel

```
public class Foo {

    public static void main(...){
        int i = 0;
        while (i<100)
            i++;
    }

}
```

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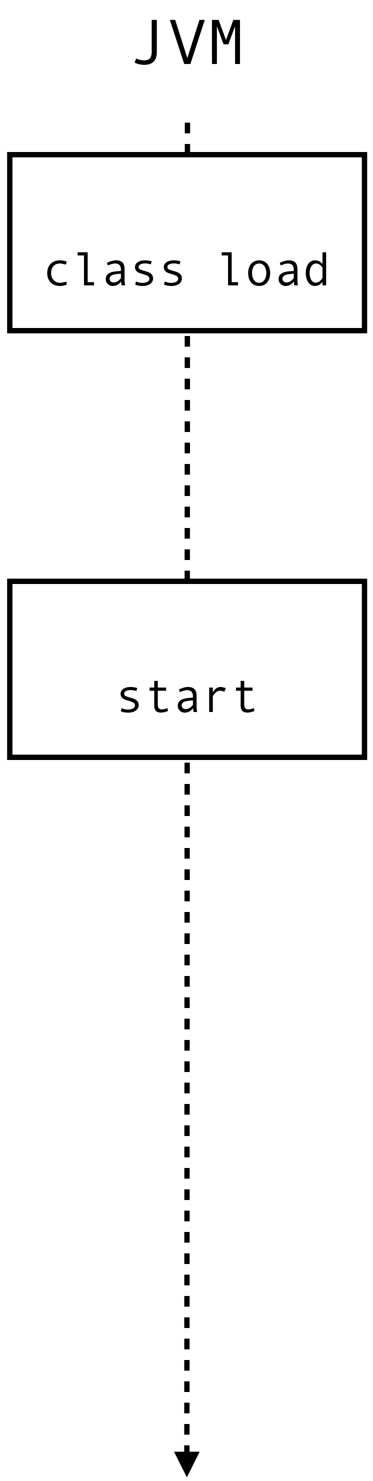


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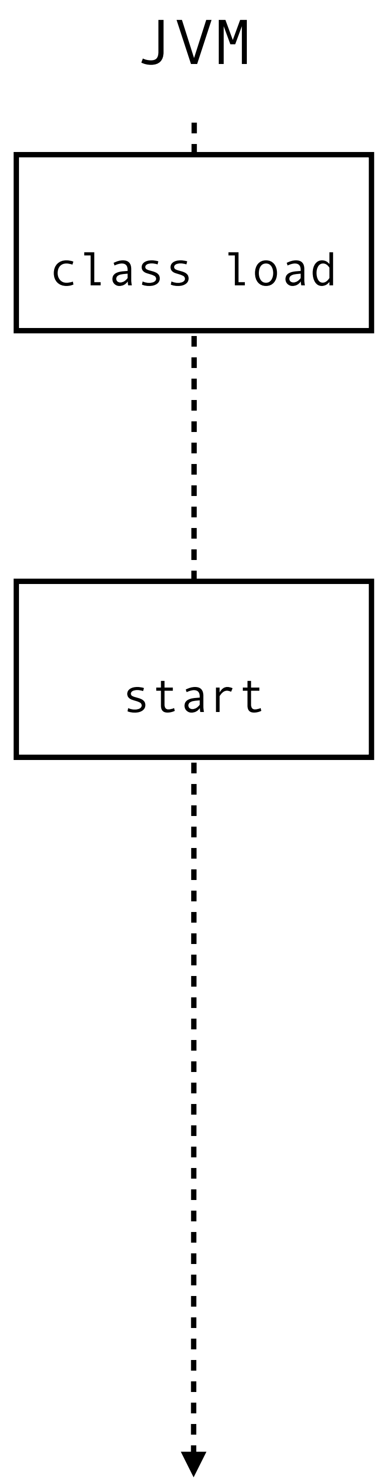


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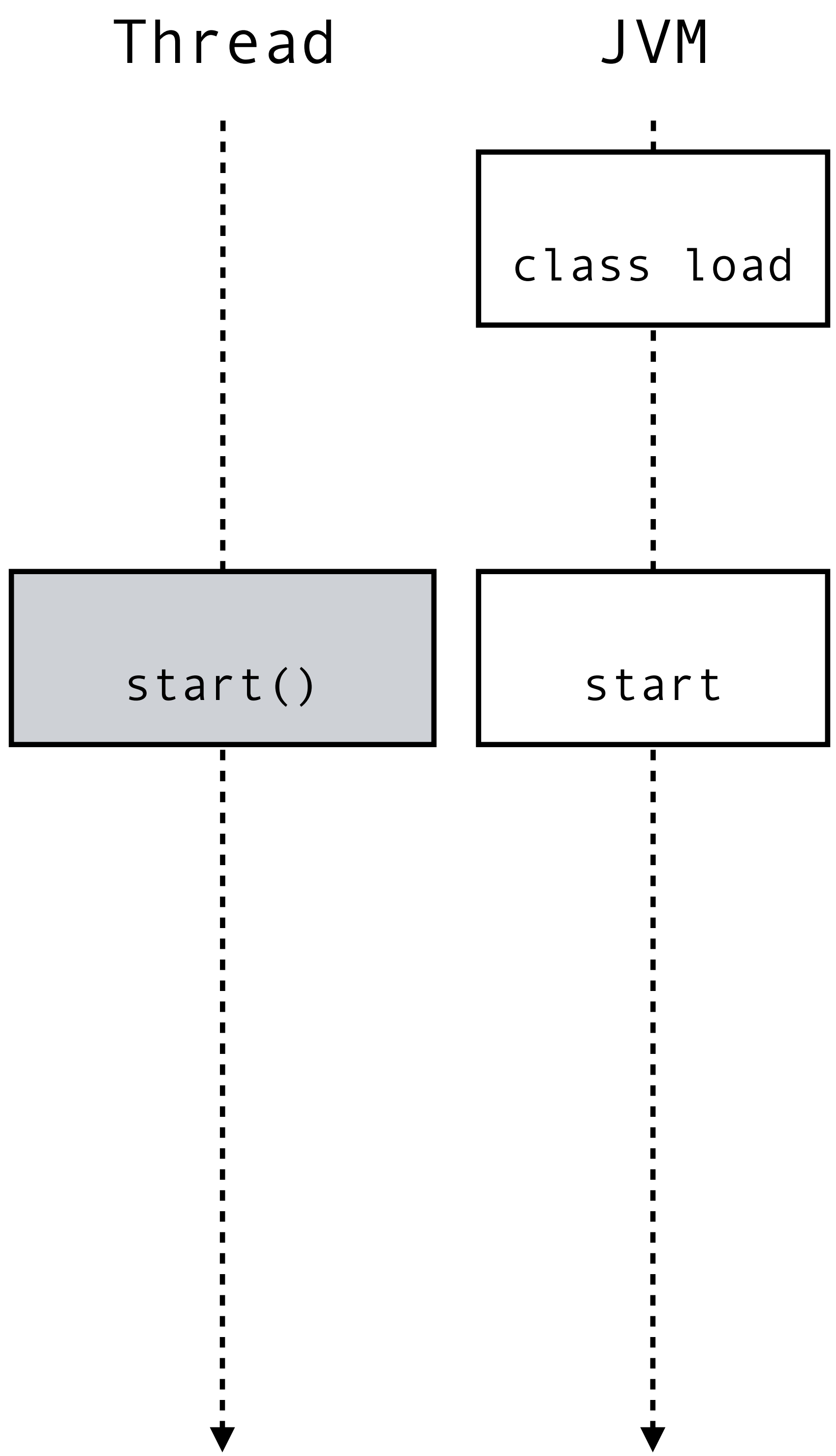
For simplicity, let's assume that this segment is a thread

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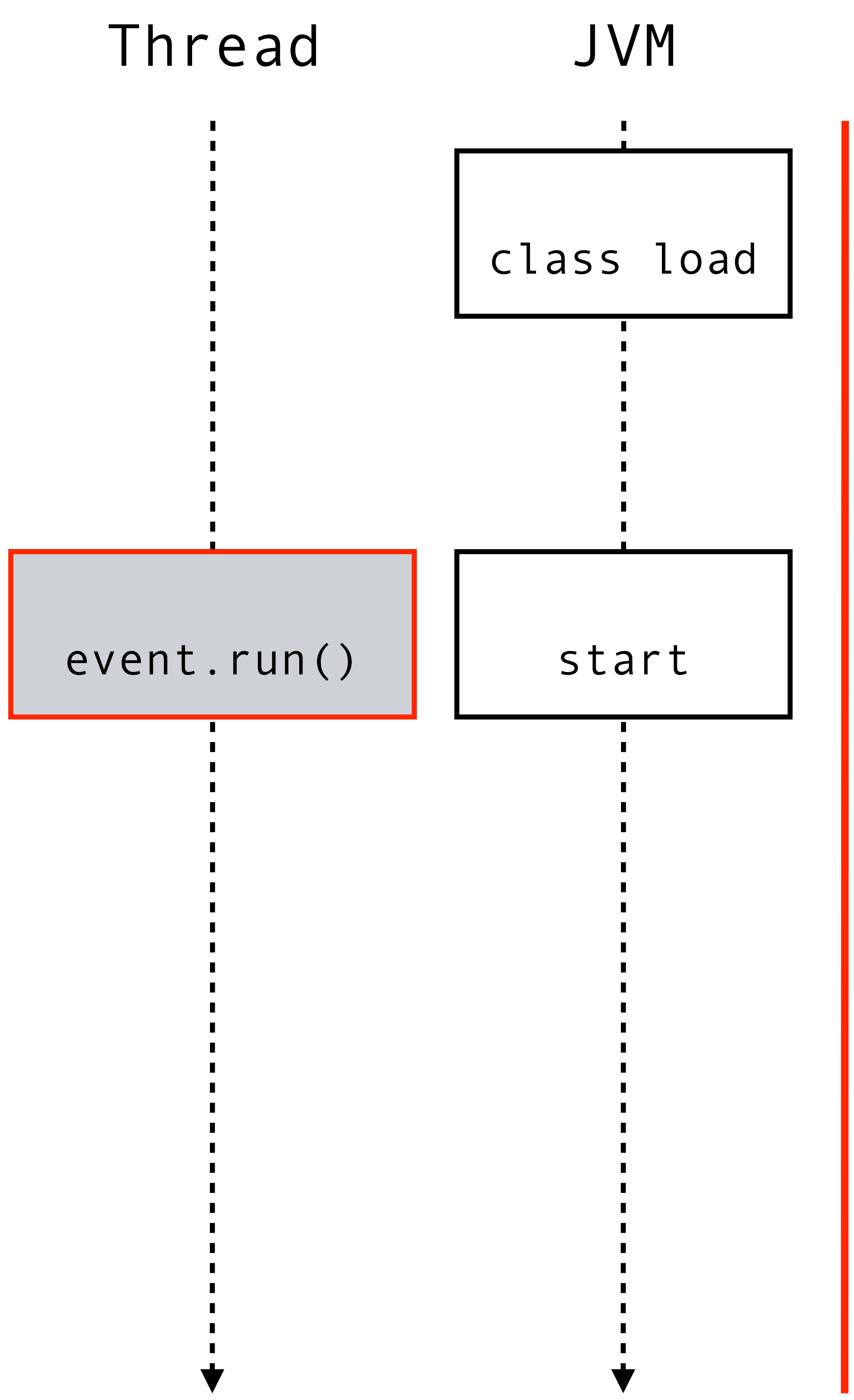


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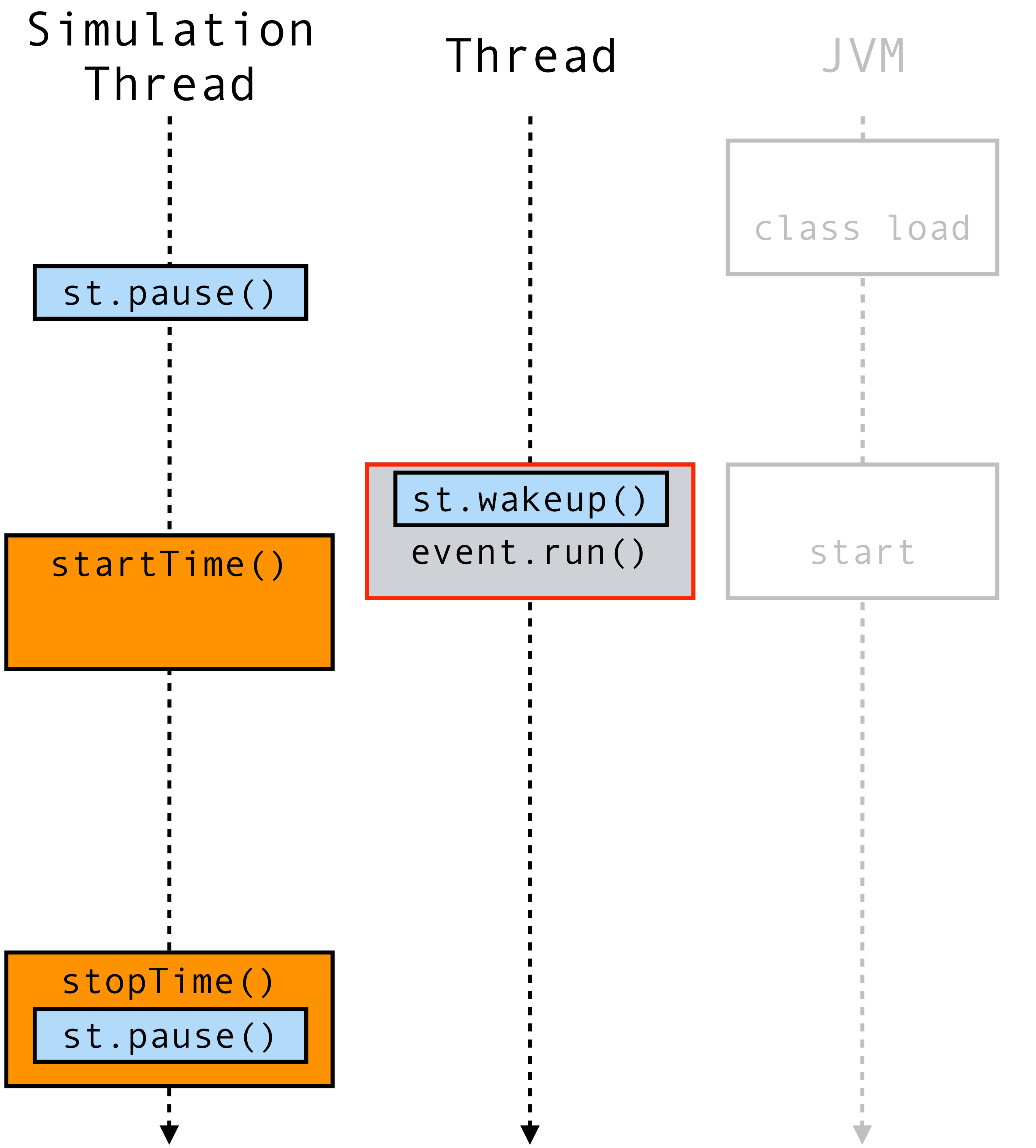


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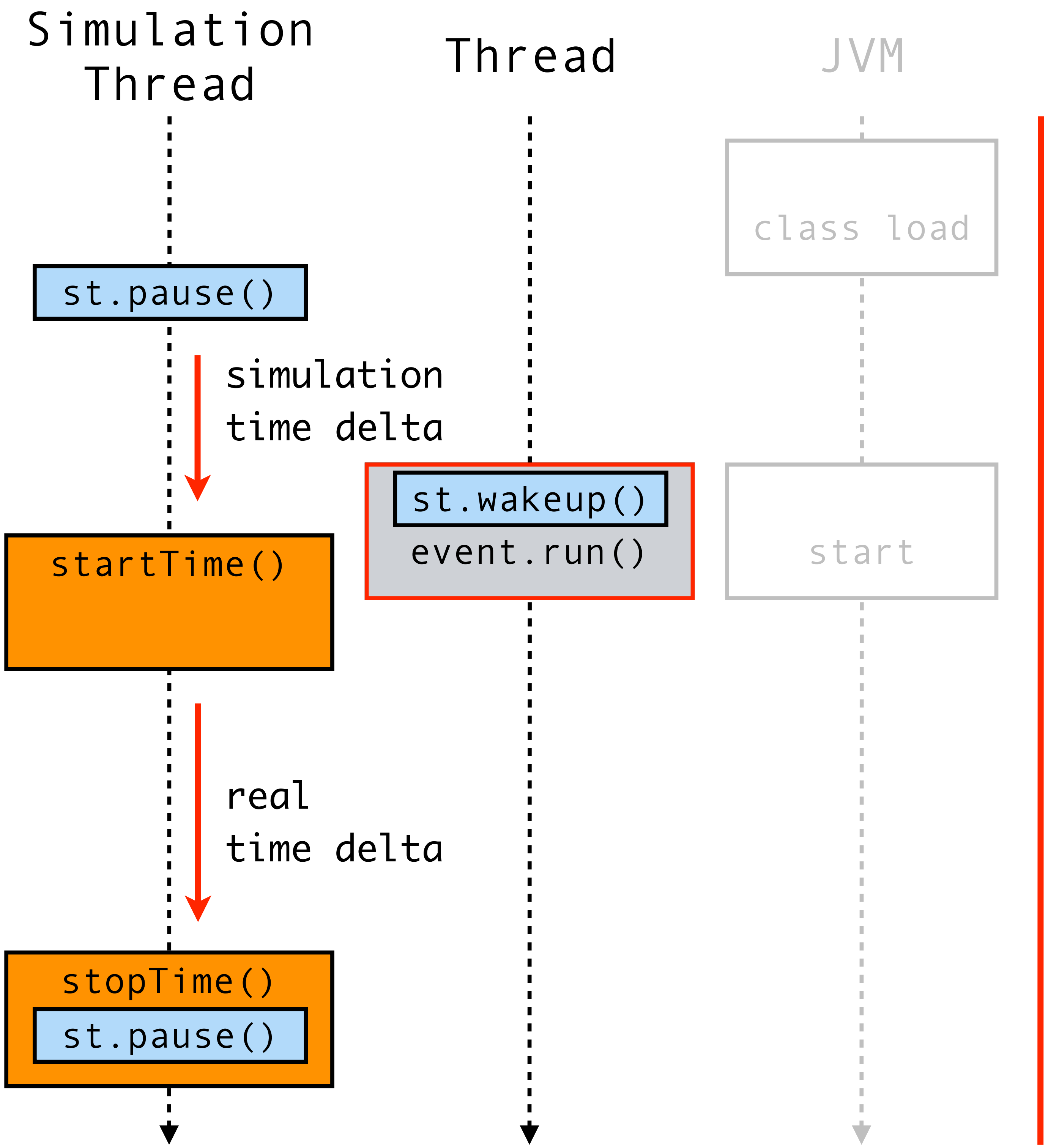


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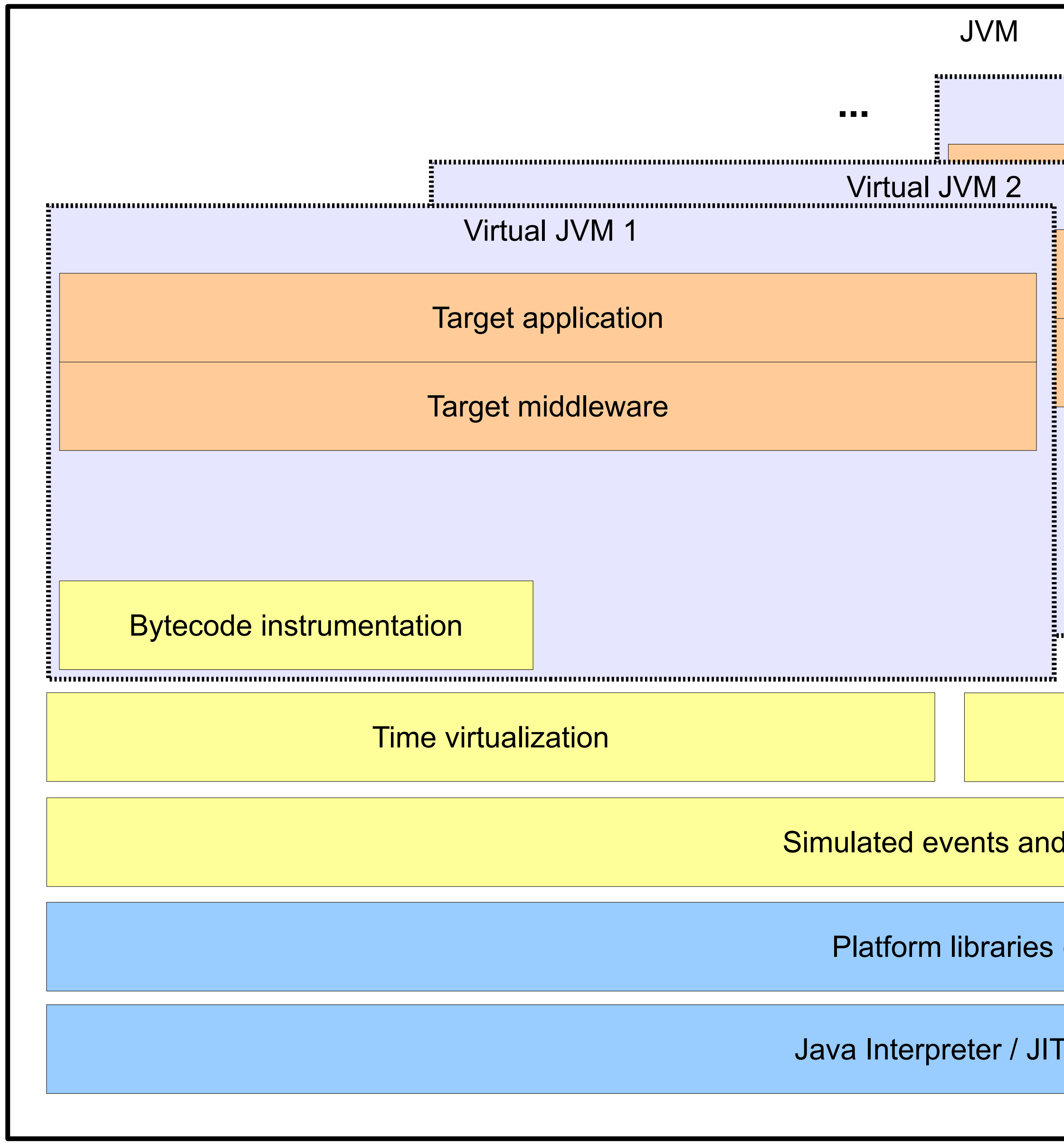
- Reflect real time of execution of a sequence of code in the occupation of a simulated processor
- Blocking operations (thread synchronization and I/O) must be intercepted and translated into corresponding simulation primitives
- Code executing in different virtual instances cannot interfere directly through shared variables

Virtualized JVM

- **Bytecode manipulation**: custom class loader that uses ASM Java bytecode manipulation and analysis framework to rewrite classes

- **Isolation**: each virtual JVM has its own separate instance of the class loader acting like a sandbox

- **Interaction**: A subset of classes, containing the simulation kernel and models, are kept global providing a controlled channel for virtual JVMs to interact



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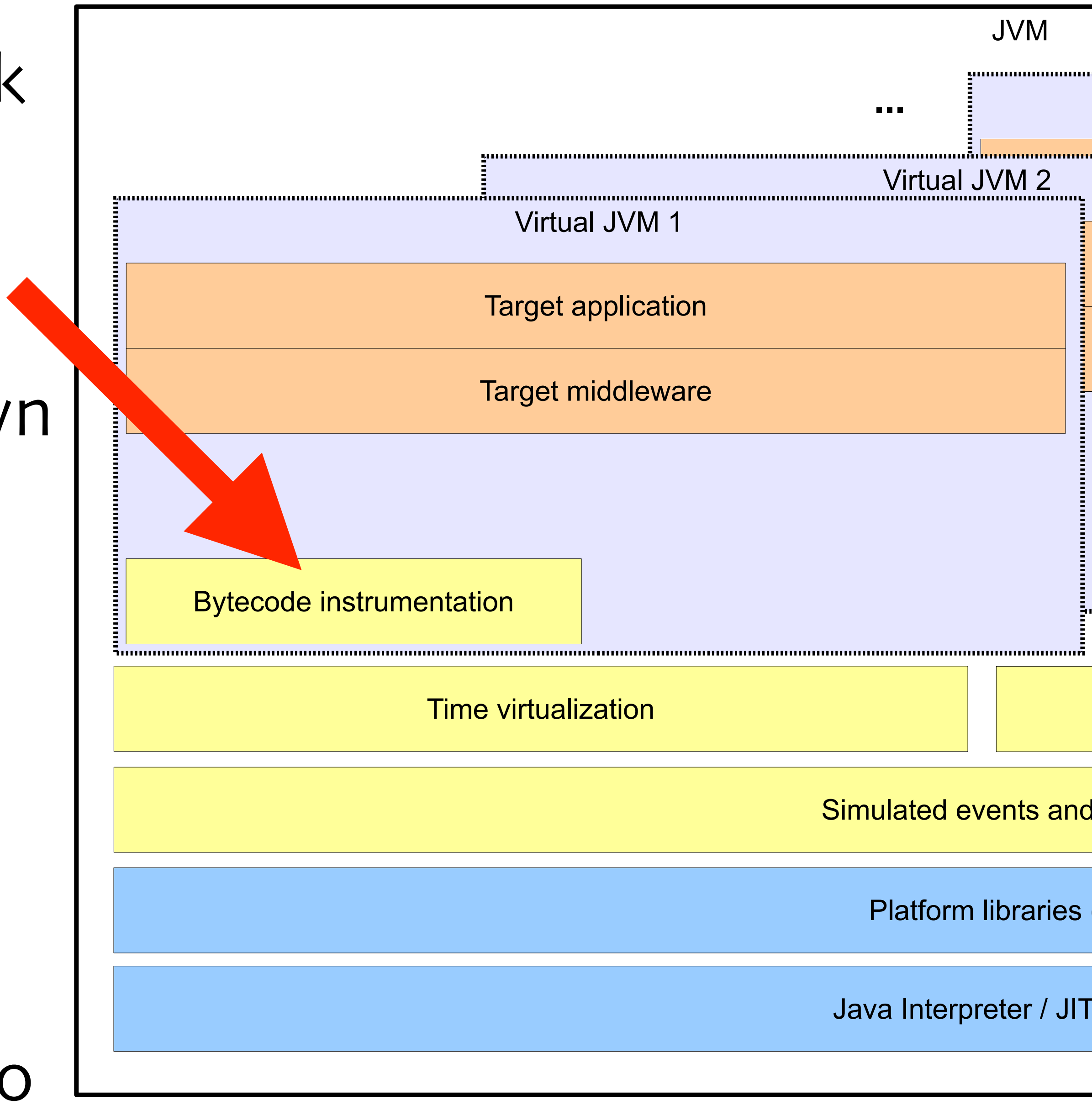

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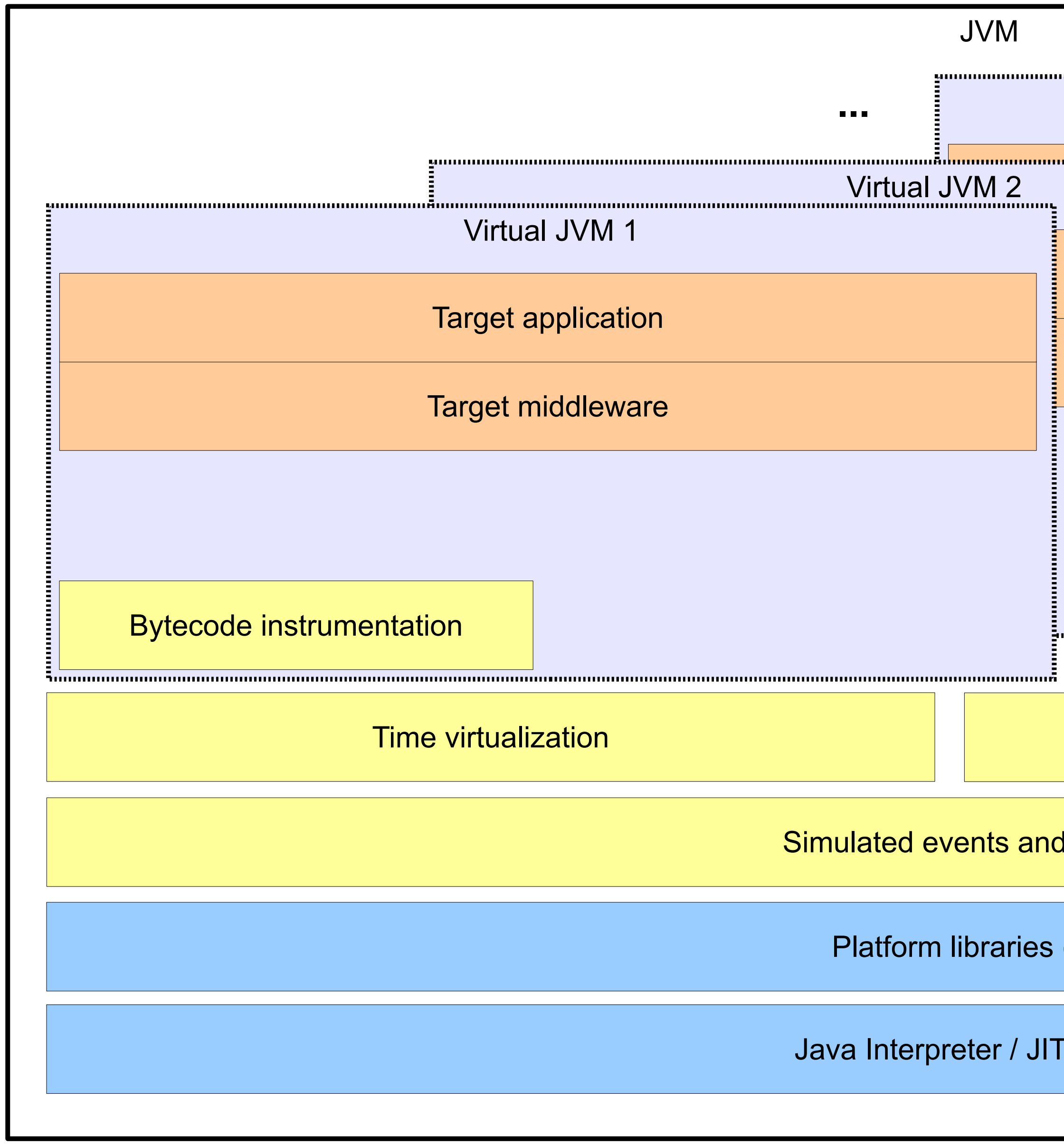

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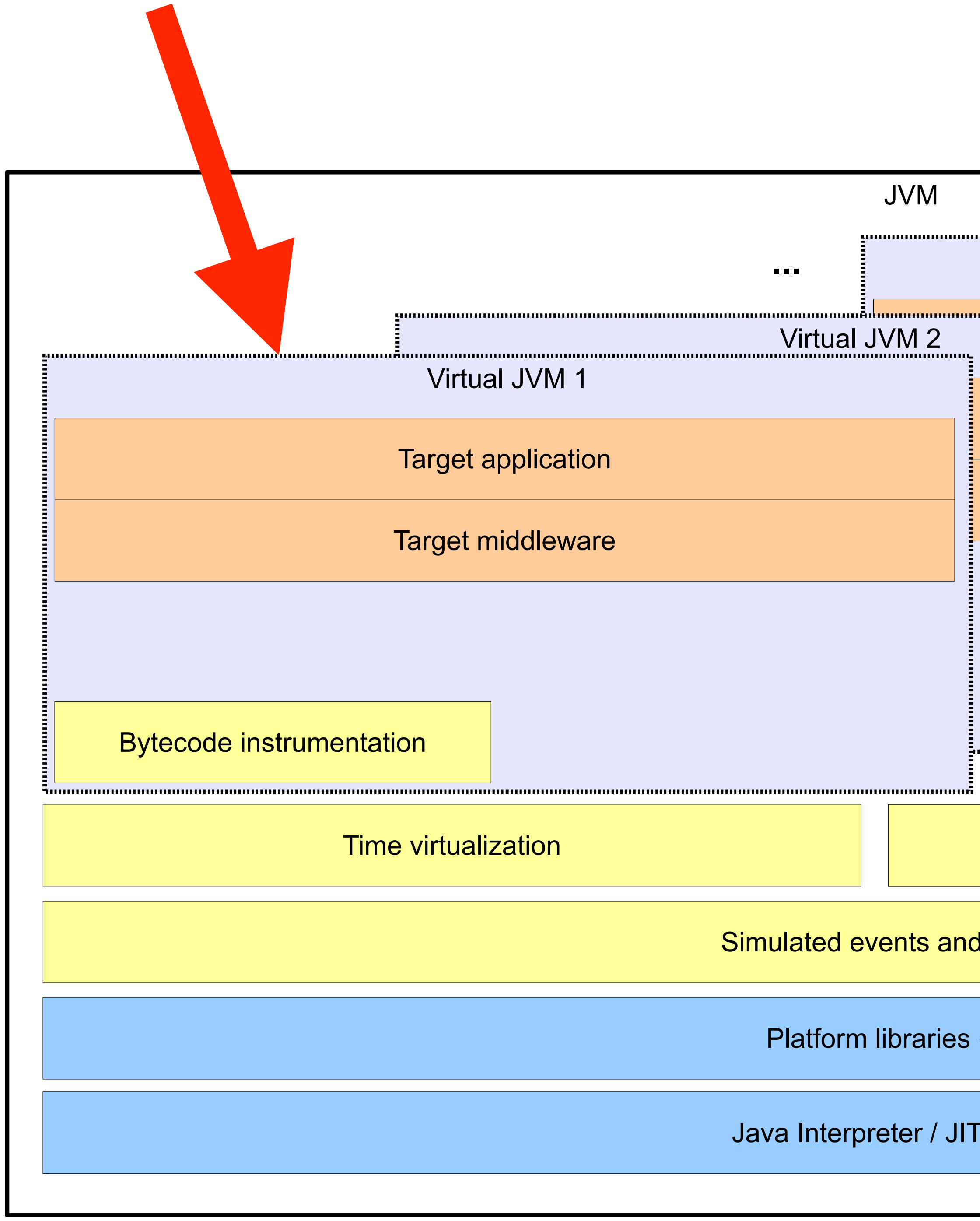

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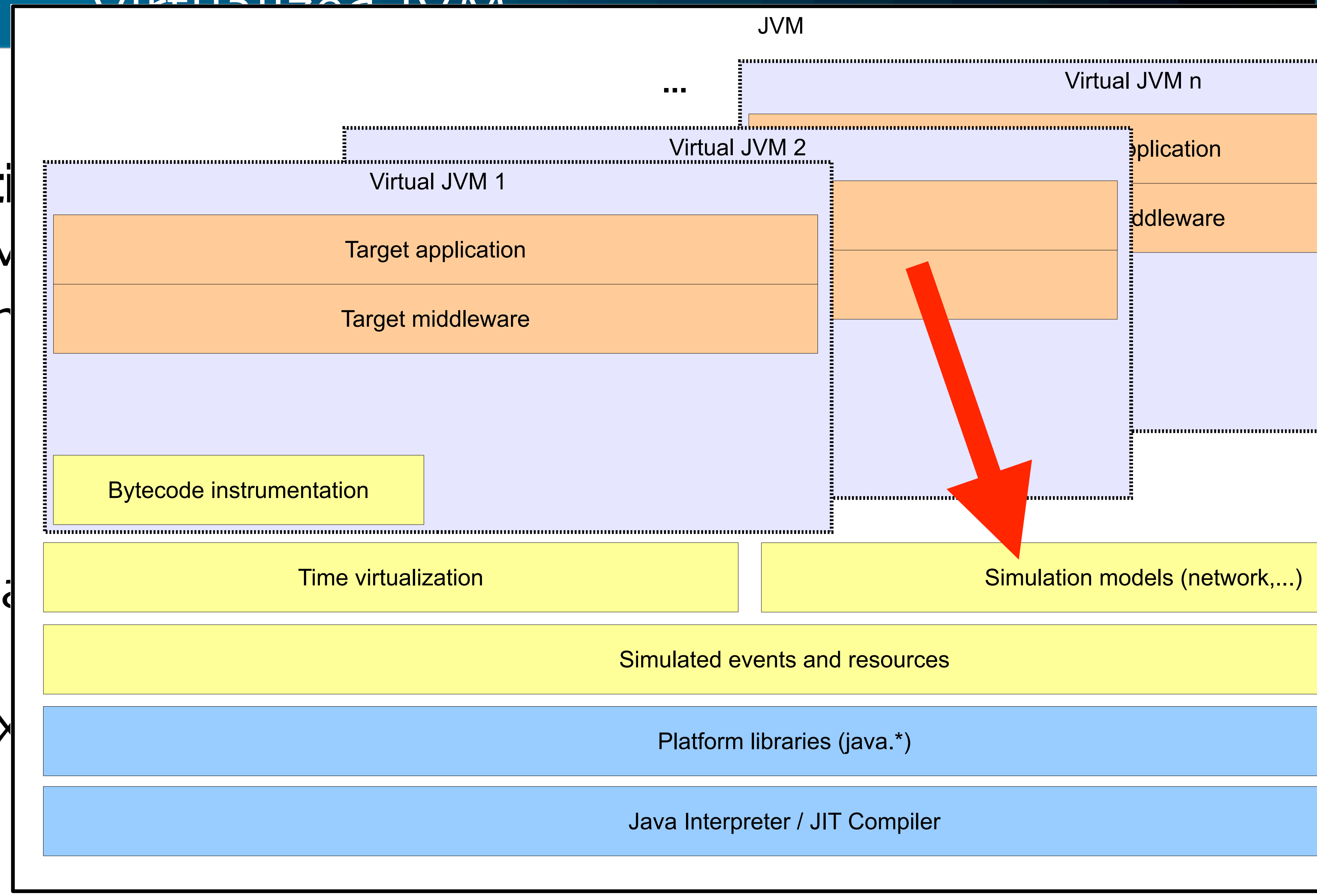

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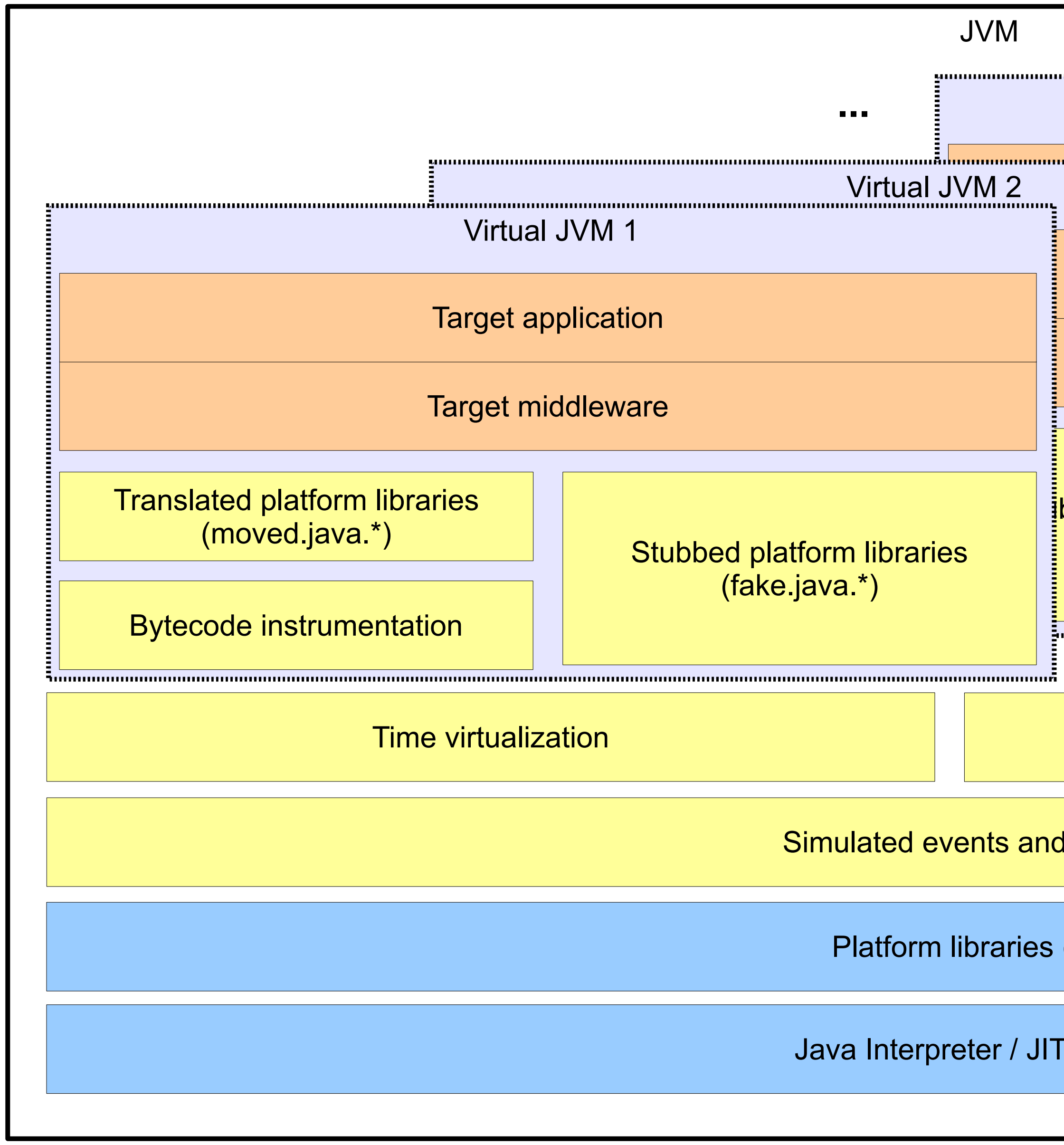
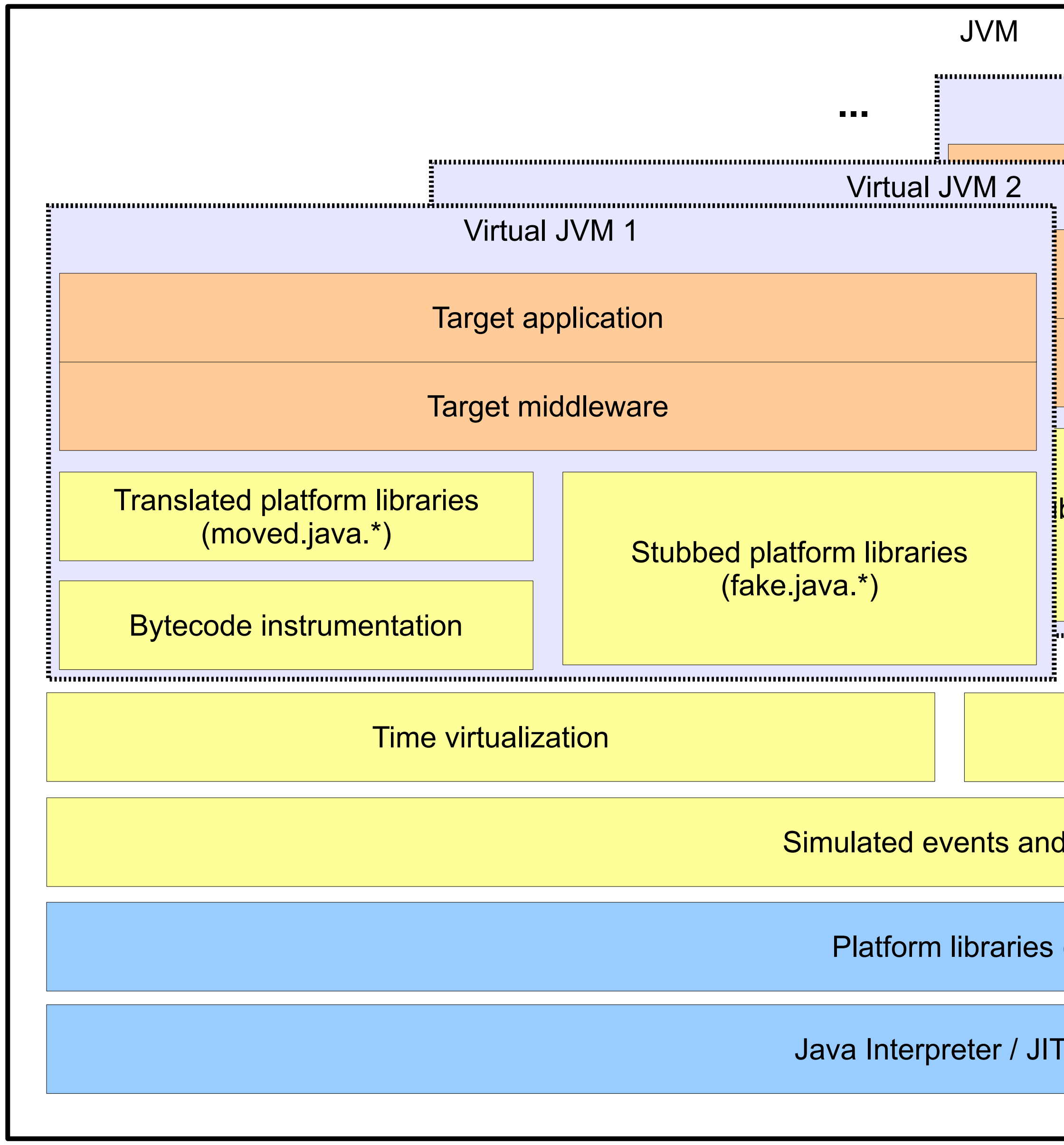
- **Platform libraries**
  - Java prohibits the transformation of classes under `java.*` package
  - Rewrite classes that contains native methods
  - Overwrite special static methods, like `System.nanoTime()`
  - The remaining classes are analyzed and processed automatically



- **Synchronization**
  - **Primitives in java.util.concurrent.***
  - Rewrite to `fake.*`
  - **Java monitor operations and implicit mutex/condition variables**
  - Inject a special `fake.java.lang.Object` ancestor on all translated classes and rewrite monitor operations to invocations to methods on this class
  - `static synchronized` methods are solved in a similar way with a singleton object

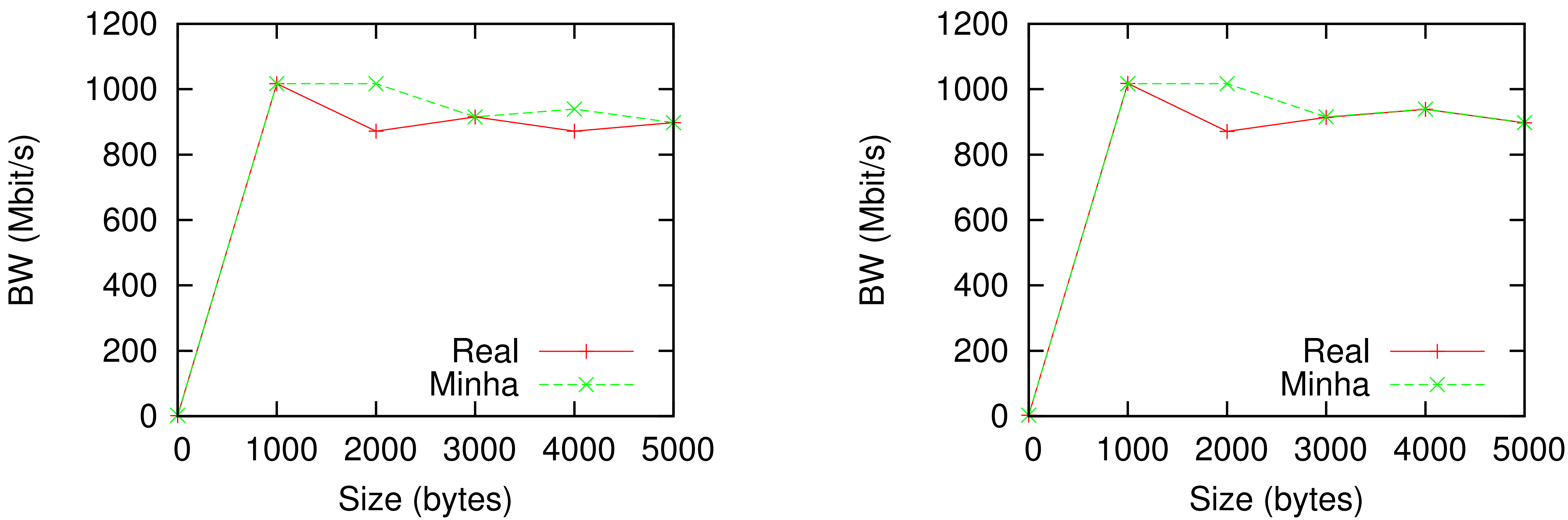


- **Filesystem**
  - Reads and writes are intercepted in order to avoid direct invocation of native methods, thus providing separate filesystems to different virtual JVMs

- **Network**
  - Modeled as a resource shared by all communication channels with a finite capacity
  - Access control is performed by the leaky bucket algorithm
  - TCP and UDP sockets, including Multicast, supported through the `java.net` API

- **Network**
  - Bandwidth
  - Sending and receiving overheads
  - Latency
- **Performed by running two benchmarks**:
  - Flood
  - Round-trip

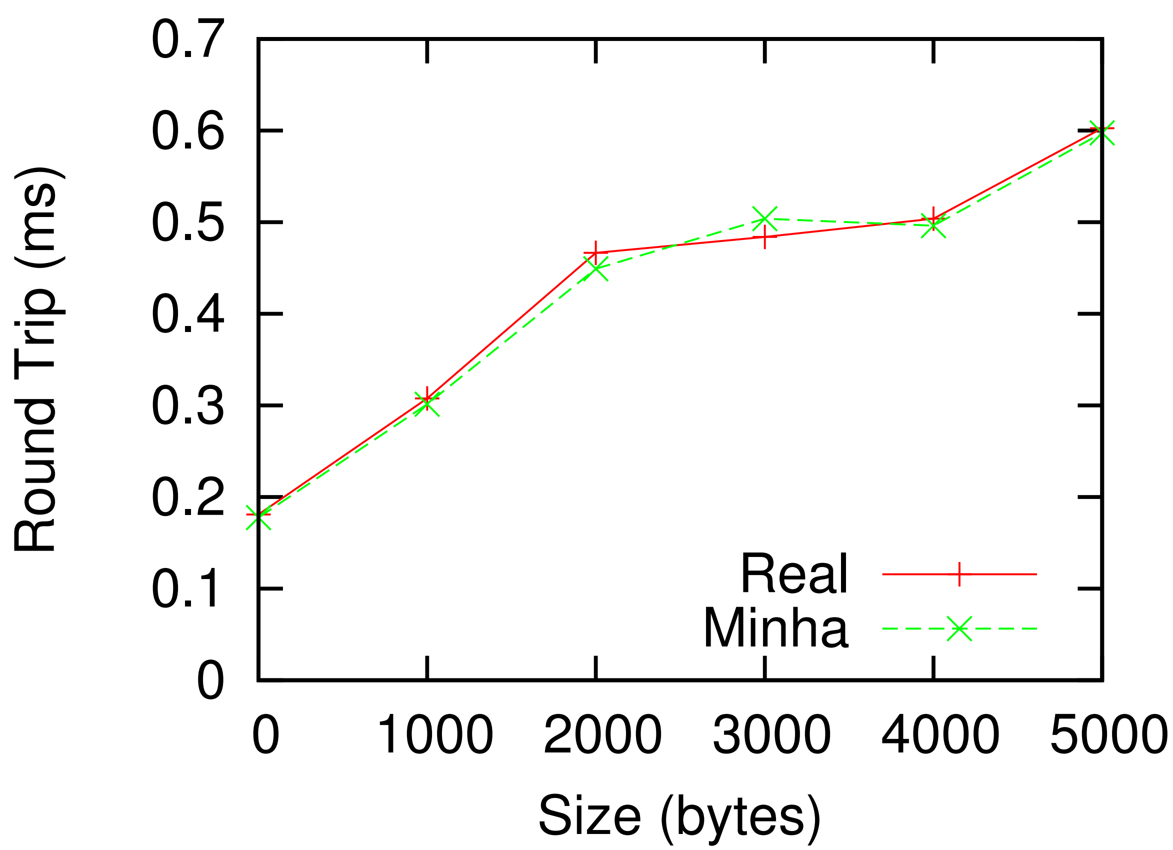
- Bandwidth with realistic behavior



a) Writing

b) Reading

- Latency with realistic behavior



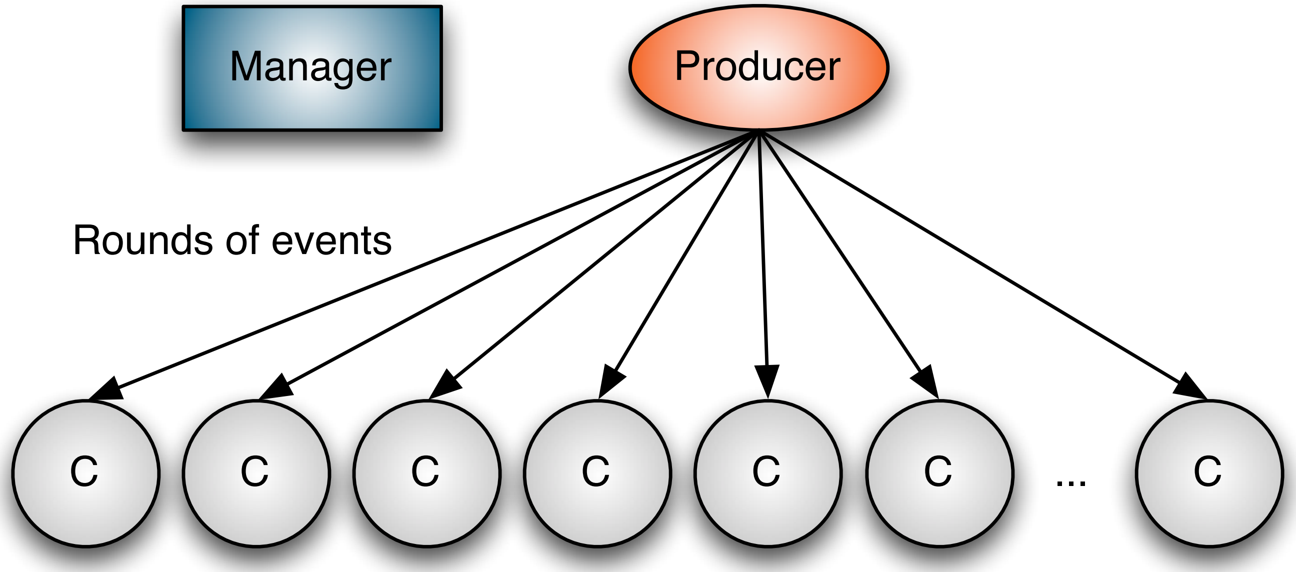
c) Latency

Case Study

- **Devices Profile for Web Services (DPWS)**
  - Standard that defines a set of protocols for devices to achieve seamless networking and interoperability through Web Services
  - Proposed as the base for large scale smart grids and safety critical medical devices
  - Used on recent operating systems, home automation, assembly lines and car industry

- **Web Services for Devices (WS4D-JMEDS)**
  - Framework that implements DPWS standard
  - Supports J2SE and J2ME

- **Membership notification**
  - Manager finds peers through multicast
  - Manager sends producers addresses to peers
  - Peers register themselves on producers
  - Producers initiate notification rounds
  - Number of peers go from 10 to 300



- **In a normal WS4D deploy we would have**
  - Each peer on a different device
  - Each device with only one CPU core

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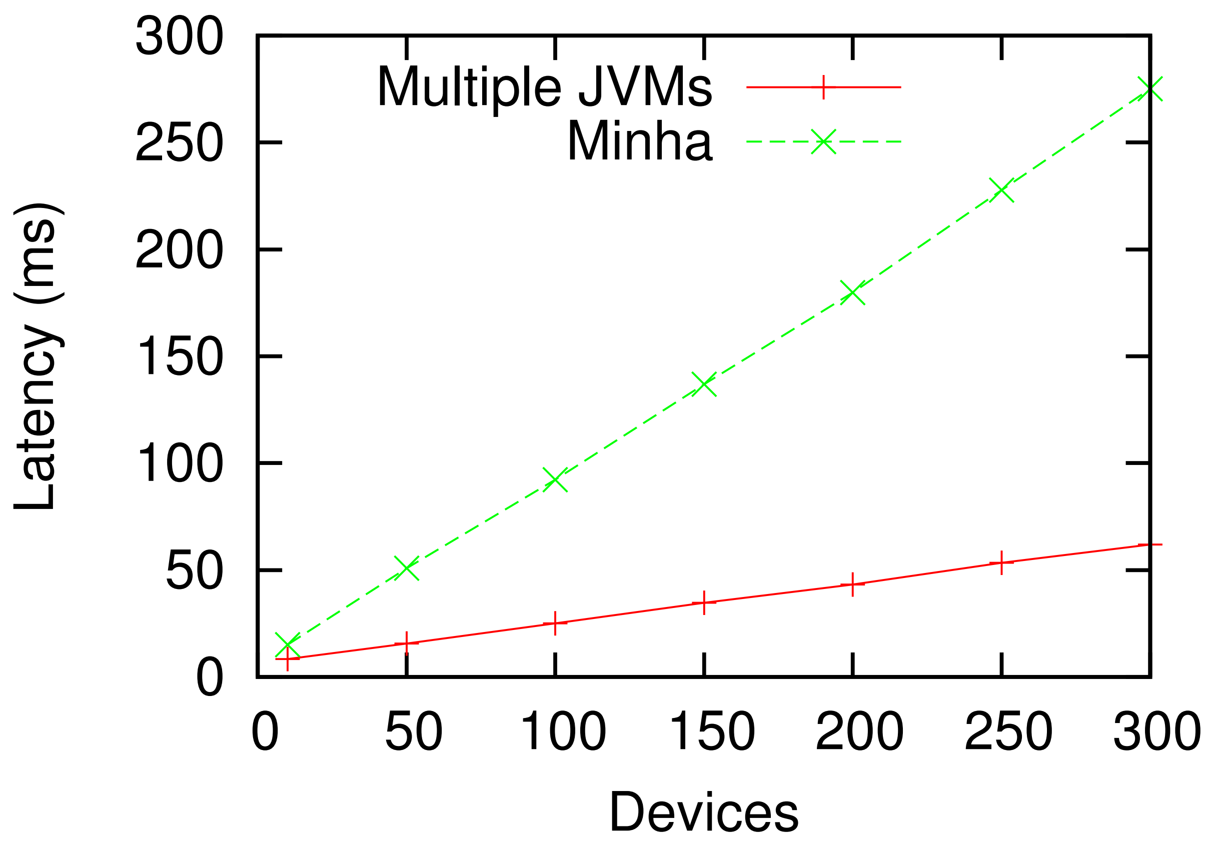
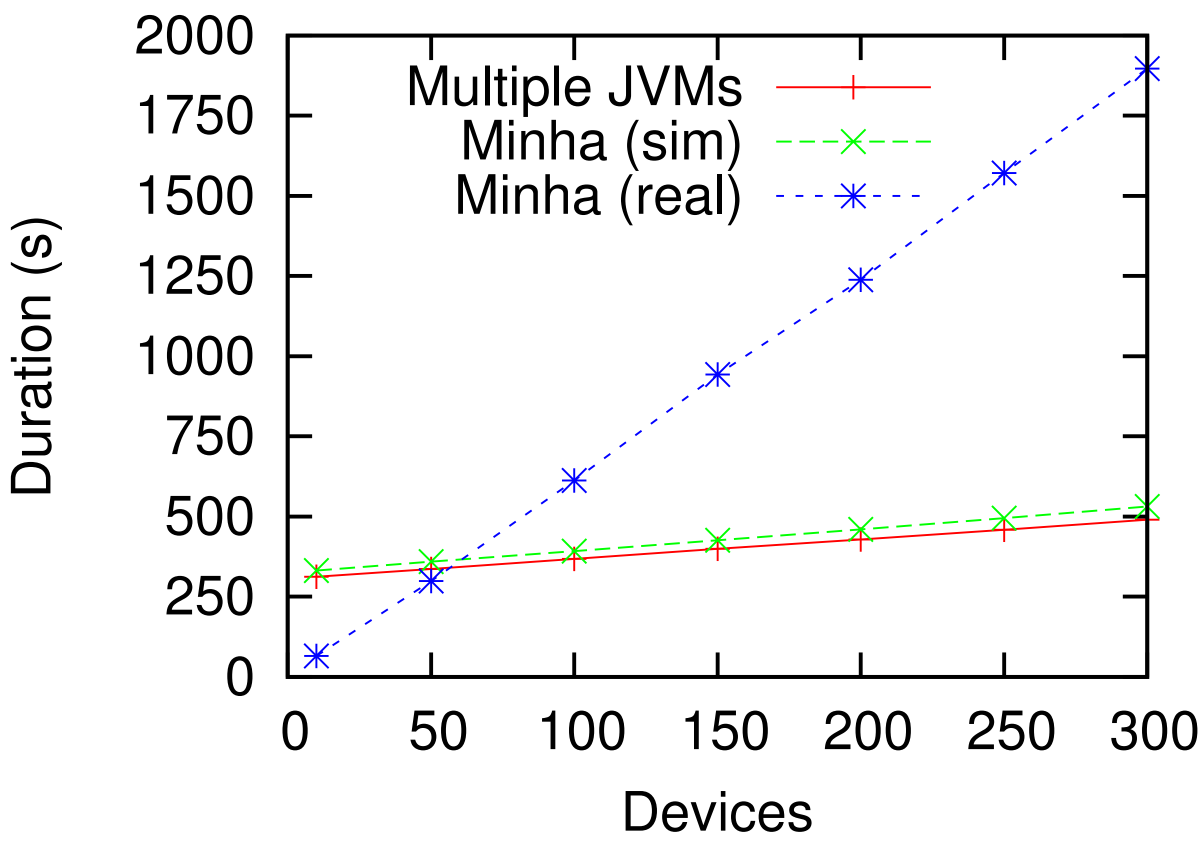
- **Due to hardware restrictions we deployed 300 devices on multiple JVMs on a single host with 24 CPU cores**
  - Localhost network with minimal latency
  - Producer can send up to 24 notifications in parallel (biasing the results)

- MINHA eliminates false latency when all peers run on a single host
- MINHA is faster than real deployments on I/O bound scenarios (up to 50 times)



a) Latency



b) Duration

Conclusion

- Allows off-the-shelf code (bytecode) to run unchanged including threading, concurrency control and networking
- Manages a simulated timeline which is updated using accurate measurements of time spent executing real code fragments
- Provides simulation models of networking primitives and an automatic calibrator
- Allows off-the-shelf middleware stack evaluation deployed on a large scale system with hundred of devices

http://gitorious.org/minha