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DEFCon: High-Performance Event Processing with Information Security

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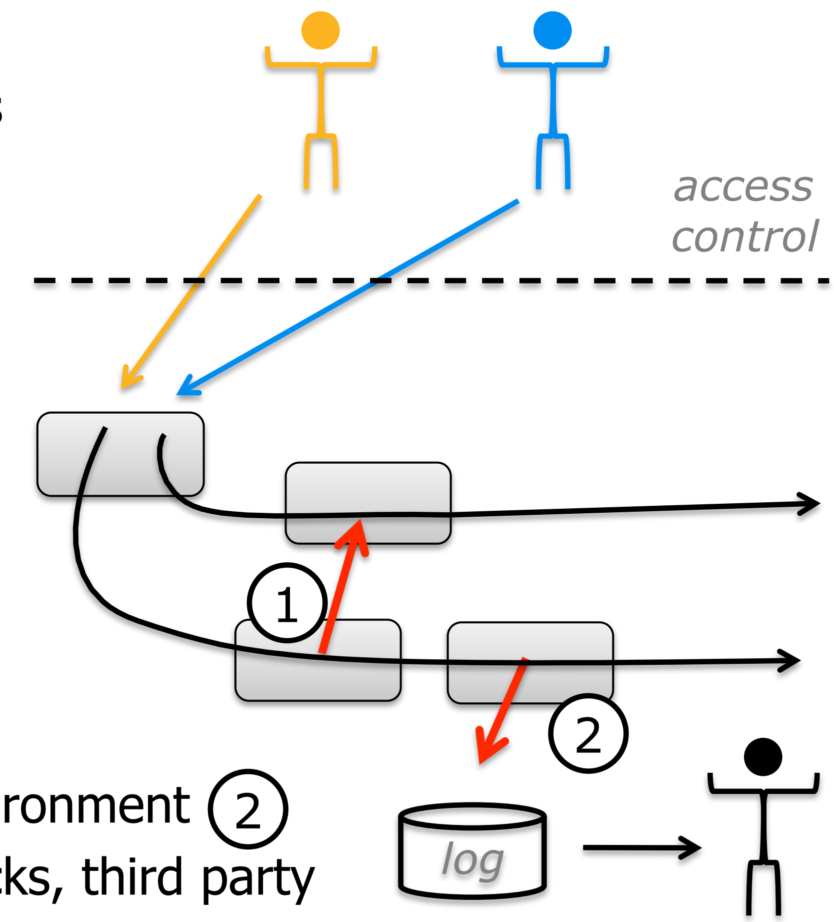
Event Stream Processing Needs Strong Security

Event processing

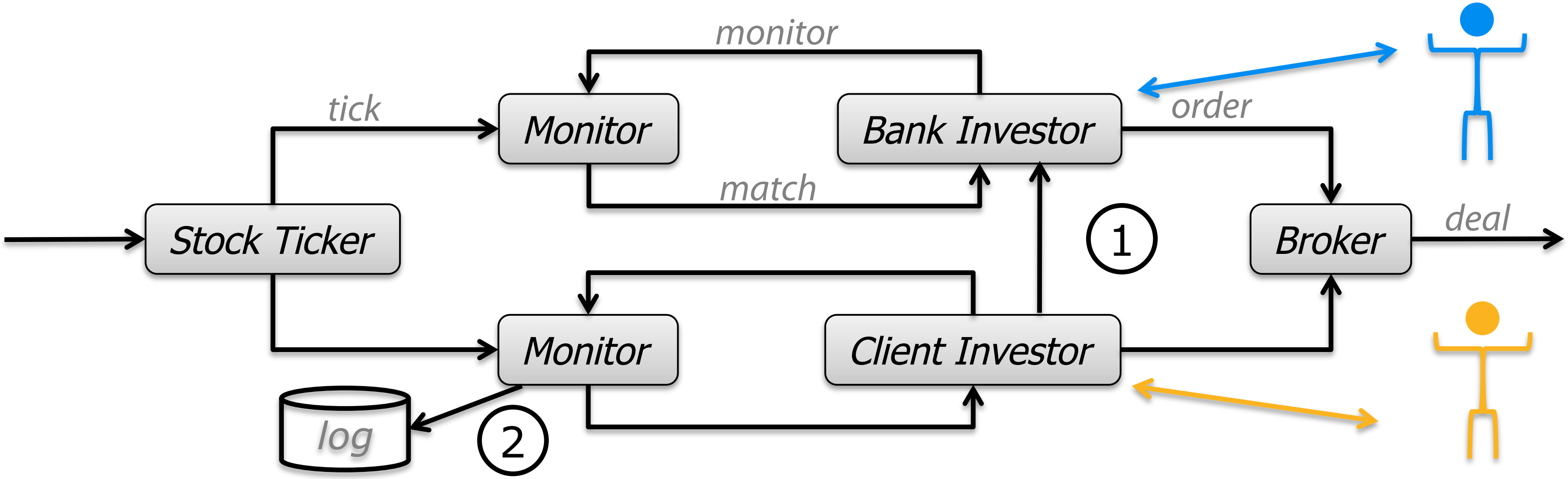
- Stream of messages transformed in near real-time by processing units
- Confidential information: healthcare, social networks, finance



Problem: incorrect event flows

- Lead to security violations
- Within application 1, with the environment 2
- Possible causes: bugs, security attacks, third party code, malicious code

Financial Processing: Security and Latency



market data processing and local brokering

Security is important

– Data is valuable: banks fined for exploiting client information

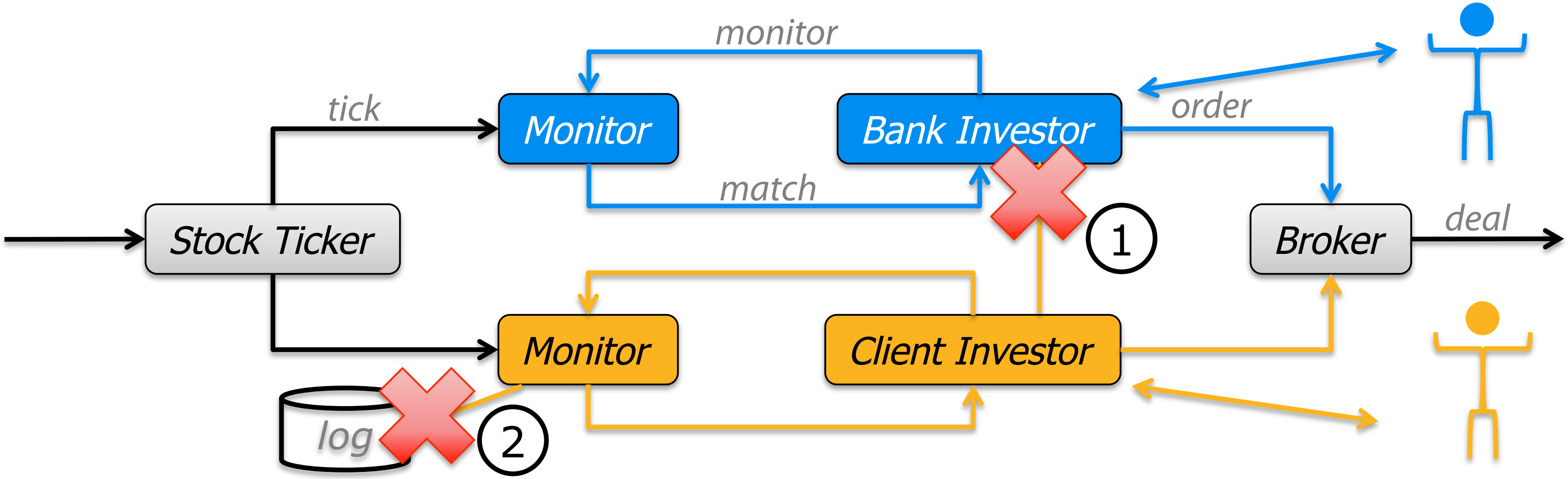
Performance constraints

– Latency, Throughput

Shared Platform

– Processing near stock exchanges costly:
  share resources, reduce entry costs for small firms
– Local brokering to avoid transaction fees and trade anonymously

Security Approach: Information Flow Control



Protect data end-to-end: Information Flow Control (IFC):

- Don't try to eliminate all bugs 1 and 2 (hard!)
- Track and control information flows in application
- Previously applied to operating systems and programming languages

Goal: apply IFC to current high-performance event processing systems

Contributions and Overview

Decentralized Event Flow Control (DEFC) model

– IFC applied to event processing

DEFCon high-performance implementation

– Safe and efficient event flows in Java

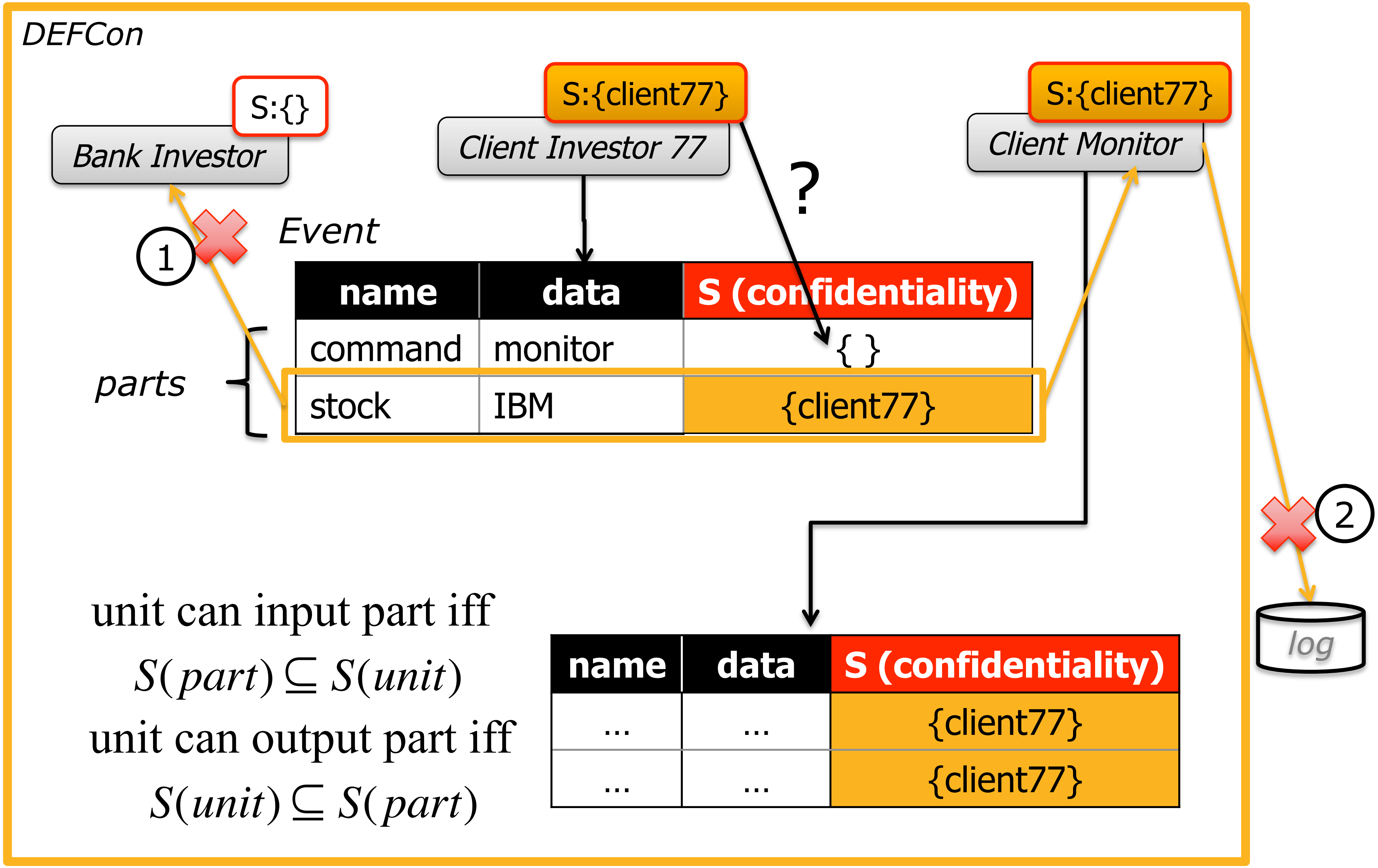
Practical isolation methodology

– Secure production-level language runtimes with low effort (OpenJDK 6)

Evaluation

– Throughput and latency overhead

Event Processing in DEFC



name	data	S (confidentiality)
command	monitor	{ }
stock	IBM	{client77}

unit can input part iff

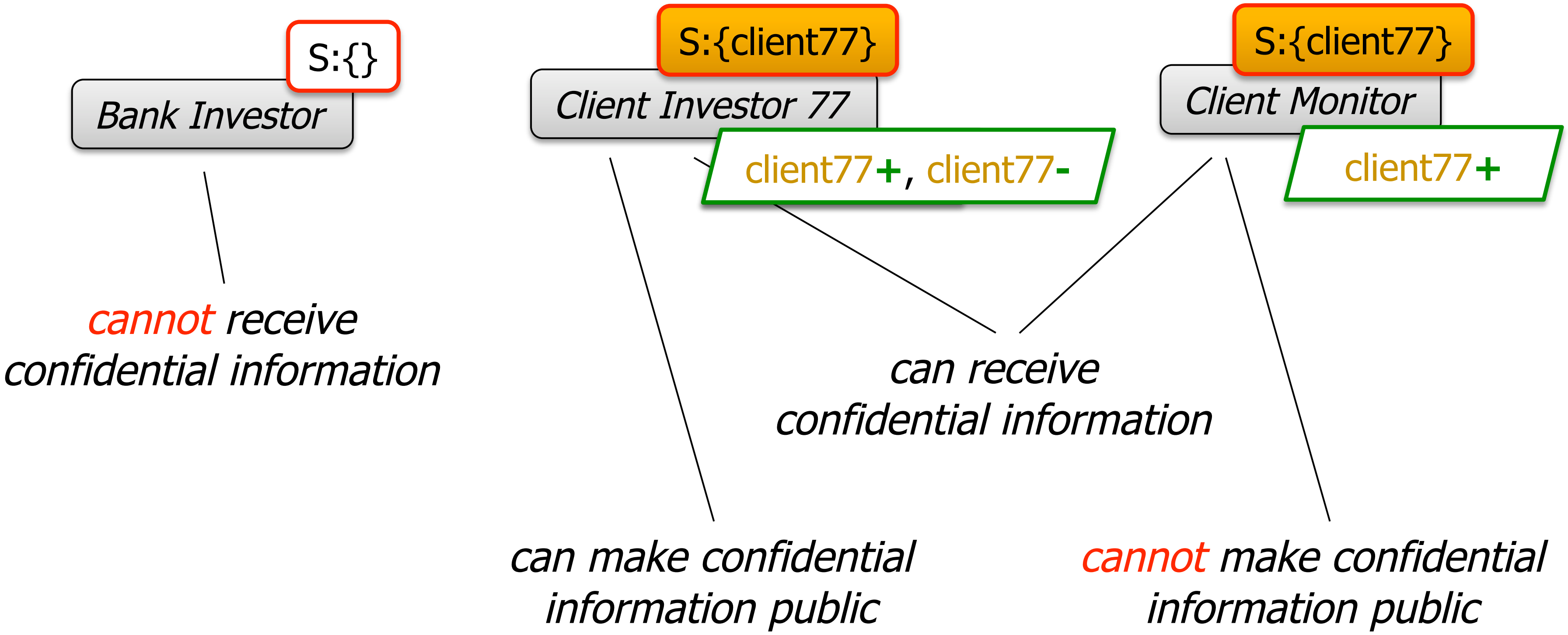
$$S(part) \subseteq S(unit)$$

unit can output part iff

$$S(unit) \subseteq S(part)$$

name	data	S (confidentiality)
…	…	{client77}
…	…	{client77}

DEFC Privileges



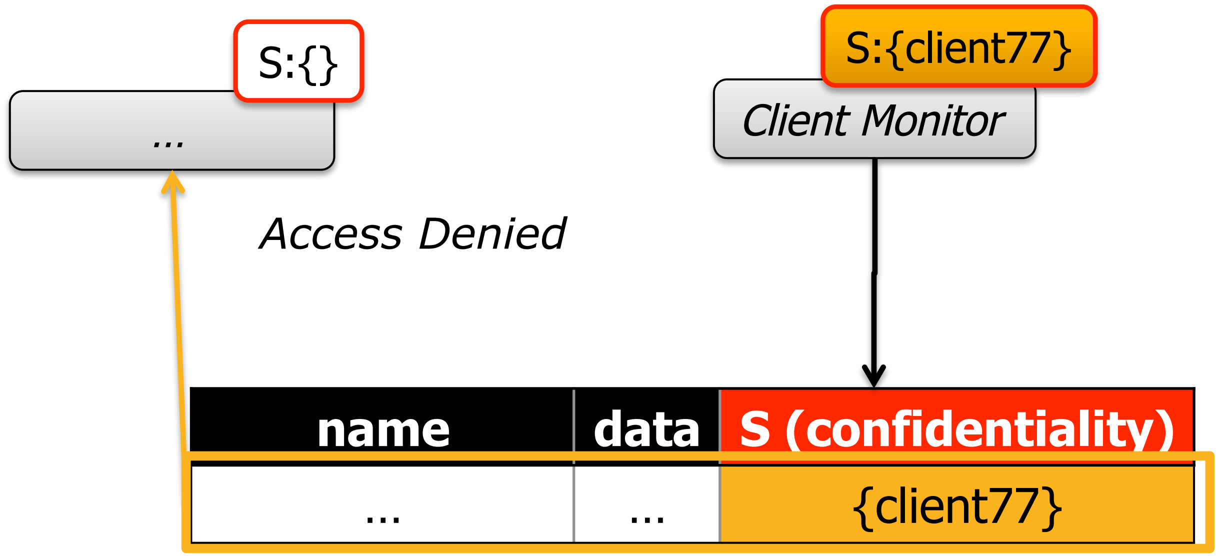
Clearance privilege: receiving confidential information client77+

– Allows units to add tag to its label

Declassification privilege: making confidential data public client77-

– Allows units to remove tag from its label

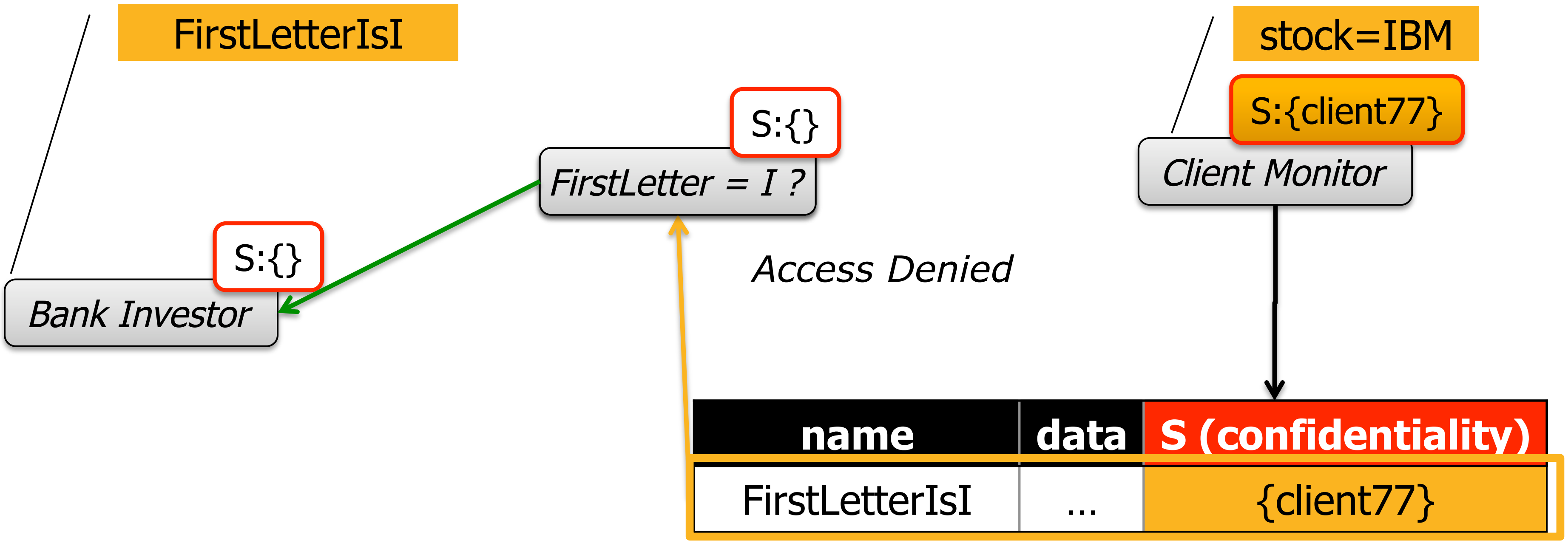
An Example of Leaks to Avoid



Untainted unit tries to read tainted part

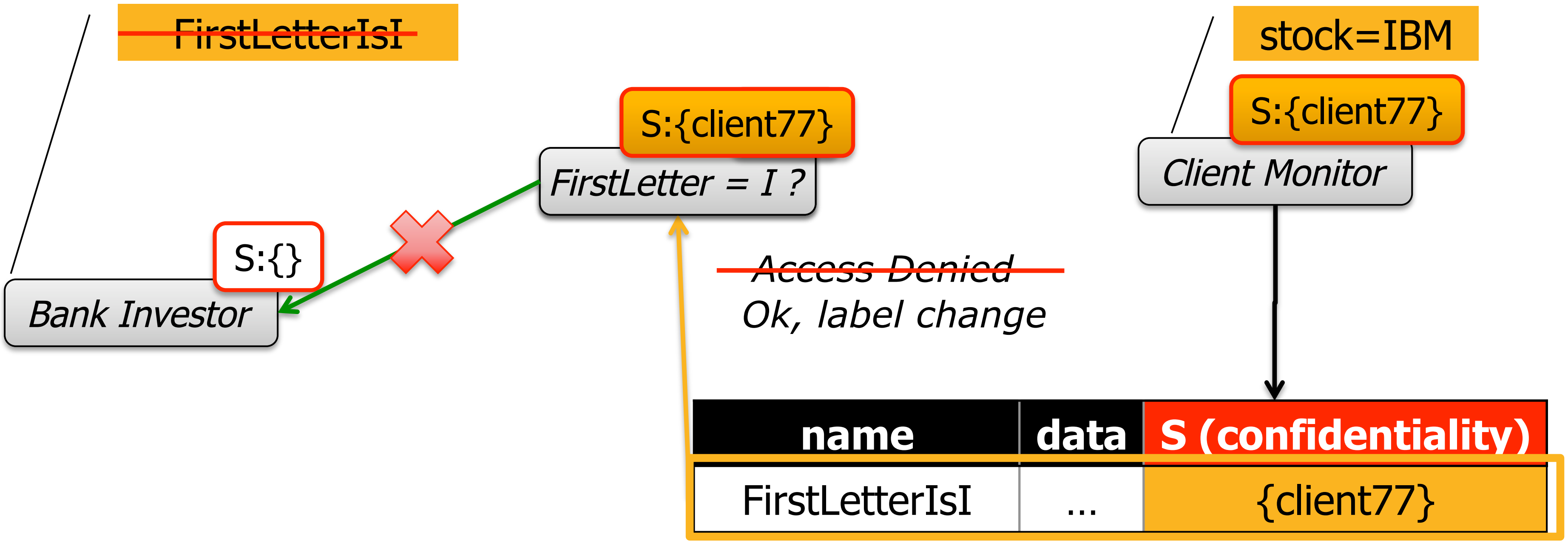
– First try: return access denied

An Example of Leaks to Avoid



- Untainted unit tries to read tainted part
  - First try: return access denied
    - Leaks name of secret parts

An Example of Leaks to Avoid



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- Second try: update unit label to part label

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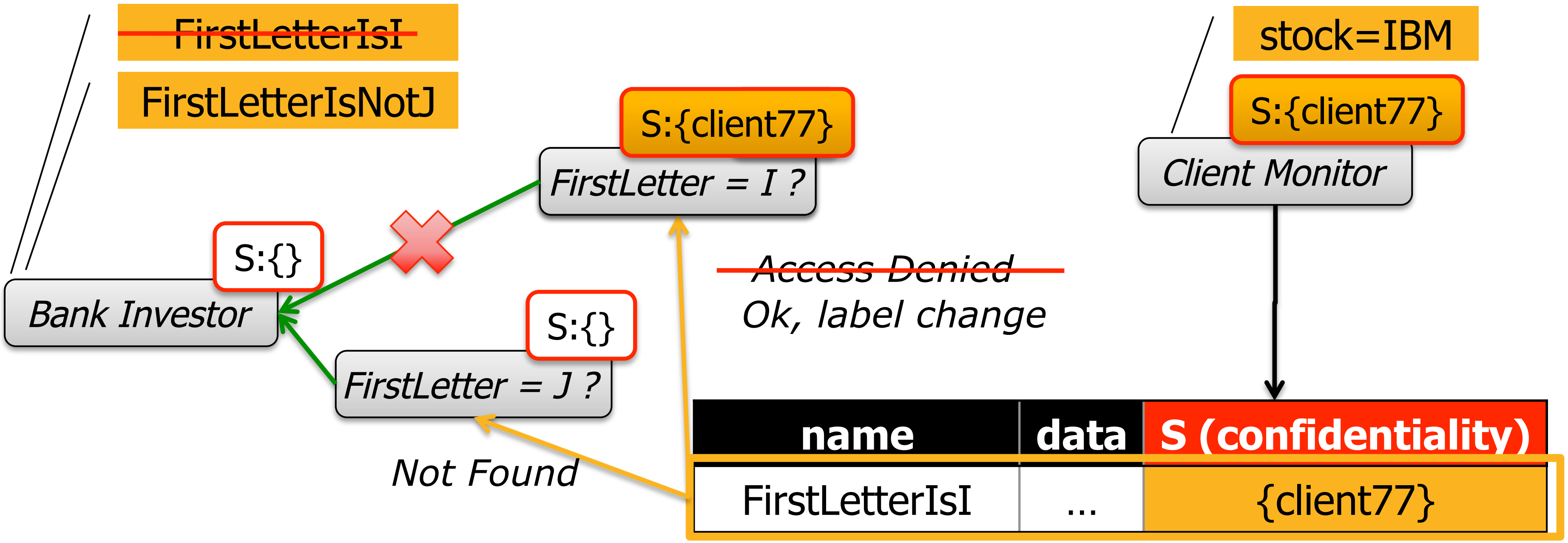

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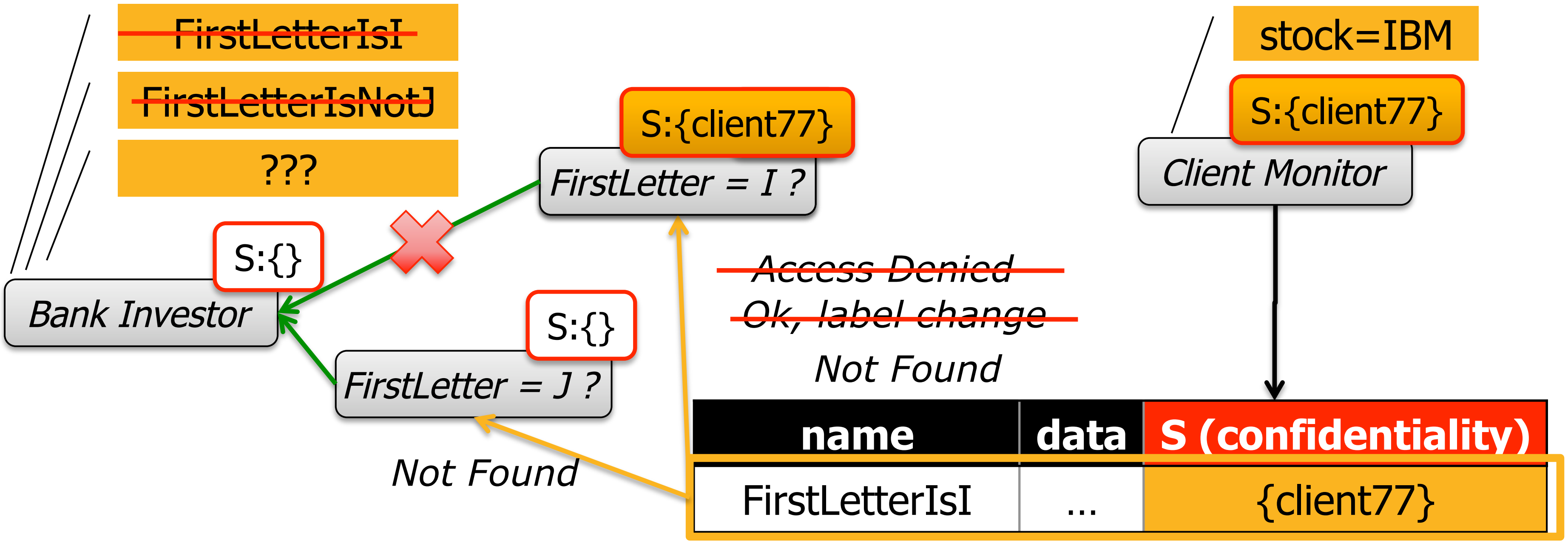

- Untainted unit tries to read tainted part
  - First try: return access denied
    - Leaks name of secret parts
  - Second try: update unit label to part label
    - Secret inferred by absence of communication
  - Solution: avoid implicit label changes, return part not found
- Result: all unit label changes must be explicit
  - First update label, then read part

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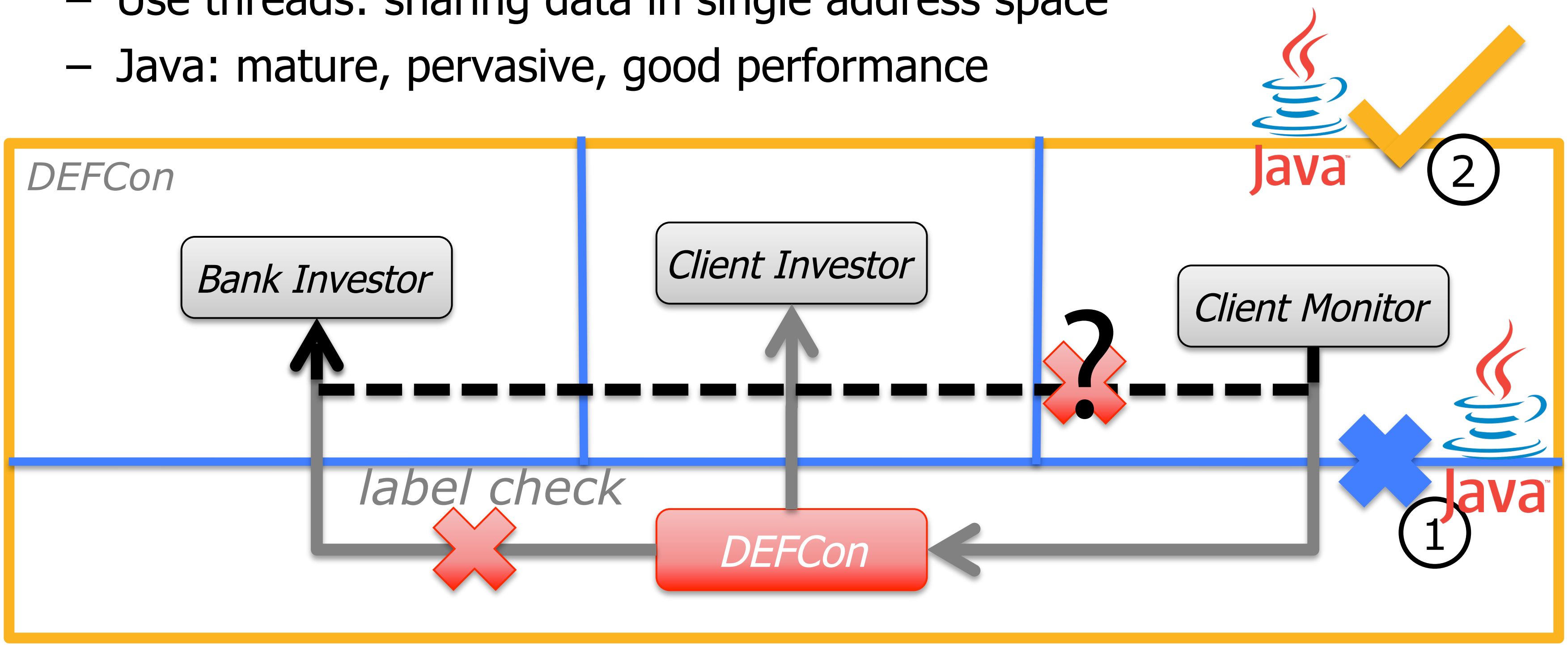
DEFCon: Controlling Event Flows

DEFC assumes units communicate through labelled events

How to control communication between units?

- VM or OS processes: heavy, require copying of data
- Use threads: sharing data in single address space
- Java: mature, pervasive, good performance



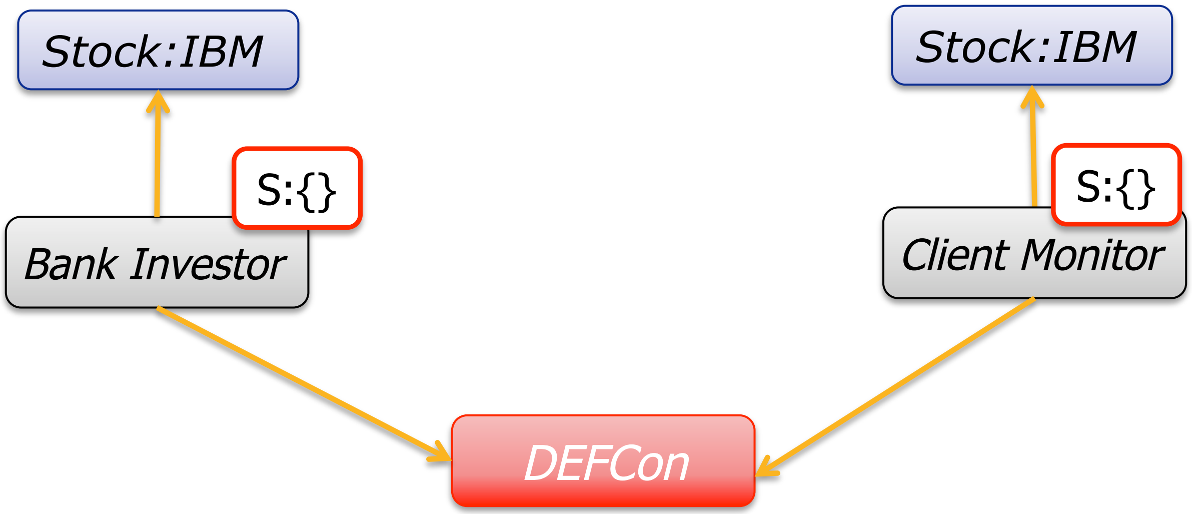
How to control communication between Java threads?

Communication: Threads Share Immutable Data

Unit Threads create new objects to put in events

Problem: how to deliver them to receiving units?

- Copy objects in events
  - Slow



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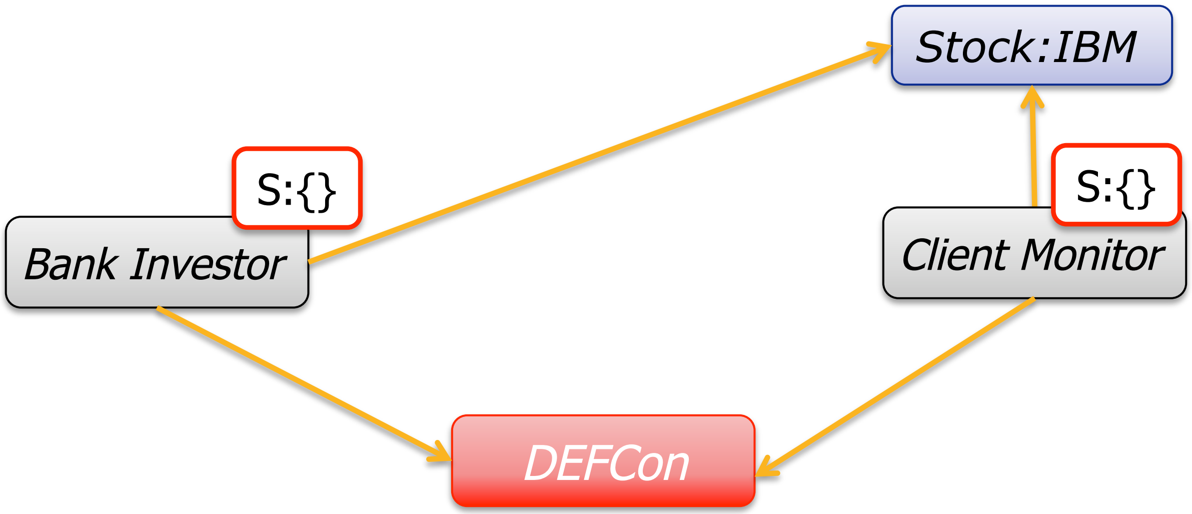

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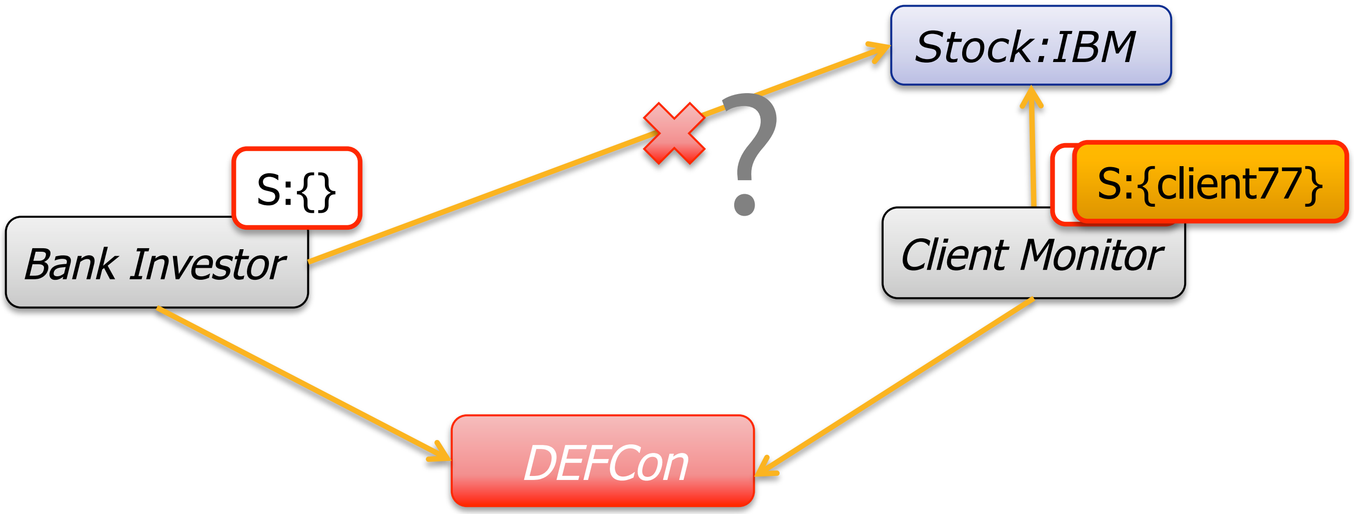

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Unit Threads create new objects to put in events

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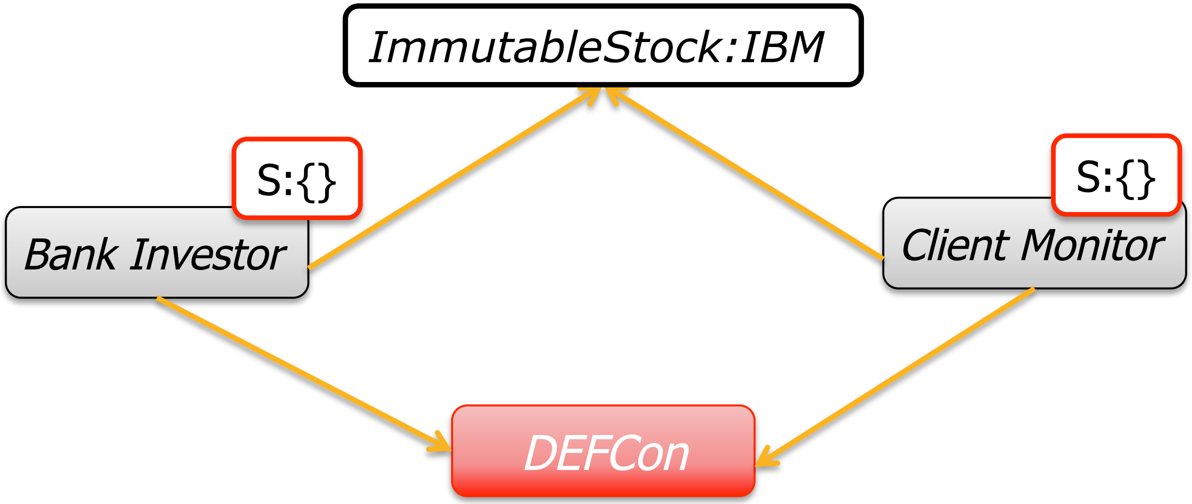
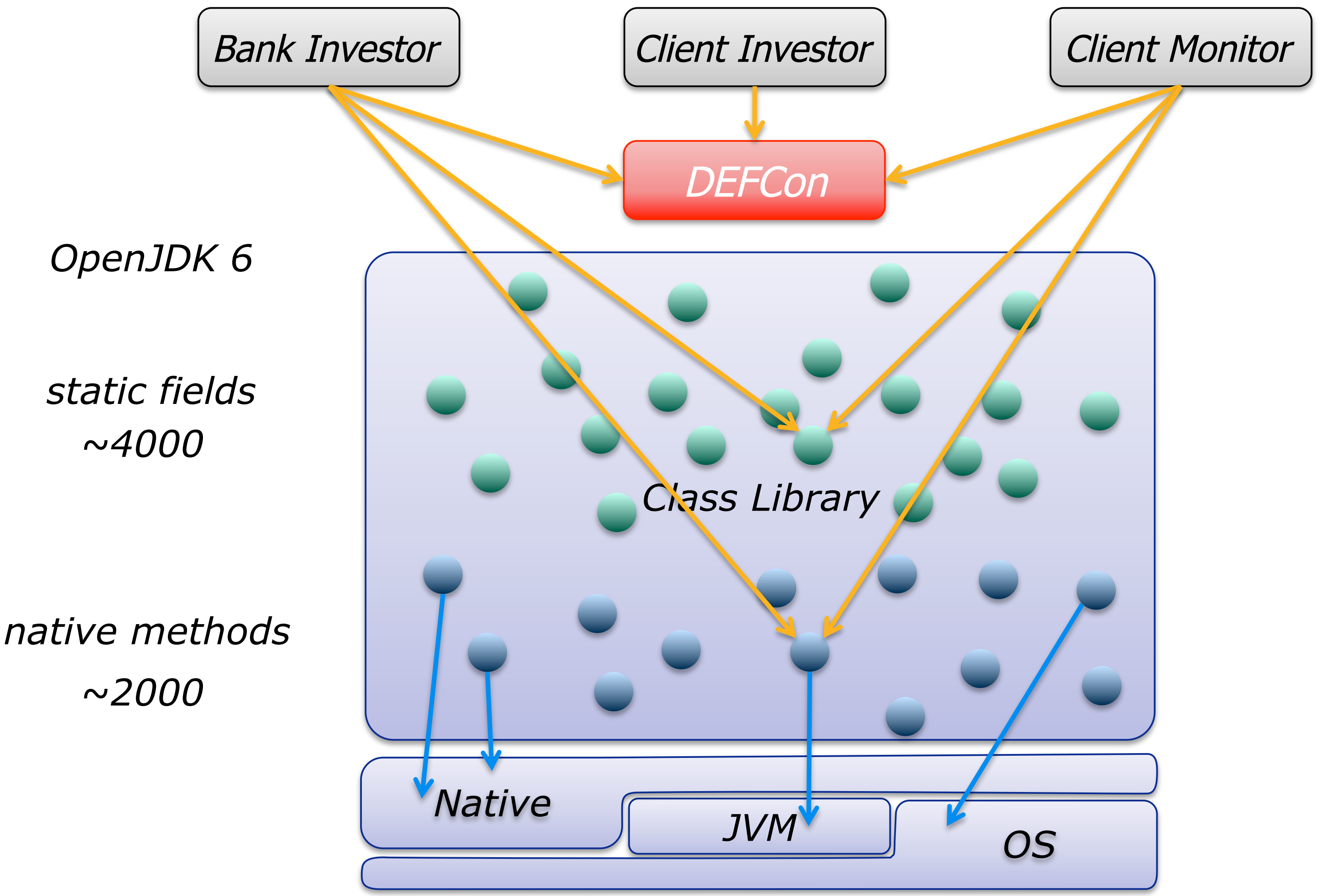
  - Problem if unit labels change

Shared state allows unrestricted communication

- Solution: only allow immutable objects in event parts



Communication: Shared State in Runtimes



Isolation Methodology Overview

Goal

- Provide isolation between Java Threads
- Secure potentially dangerous targets: static fields and native methods

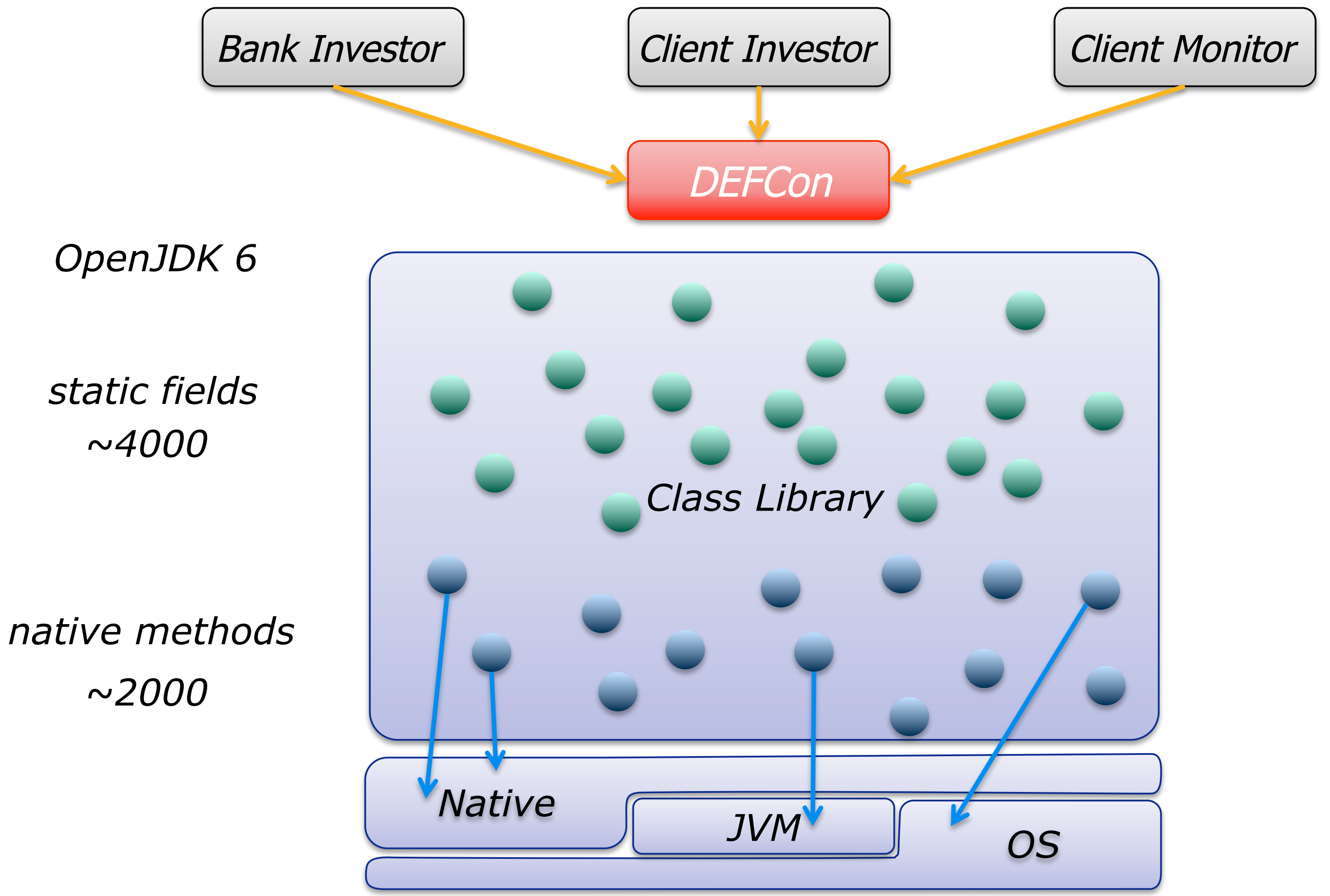
Previous Java isolation approaches

- Do not support fast message passing between isolates (MVM)
- Use custom Class Libraries and/or JVMs (I-JVM)
- Require extensive analysis of Class Library (KaffeOS, Joe-E)

Our approach

1. Identify potentially dangerous targets using static analysis
2. Modify runtime behaviour of targets using aspect oriented programming (AOP)
3. White-list safe targets

1. Static Analysis



1. Static Analysis

OpenJDK 6

static fields

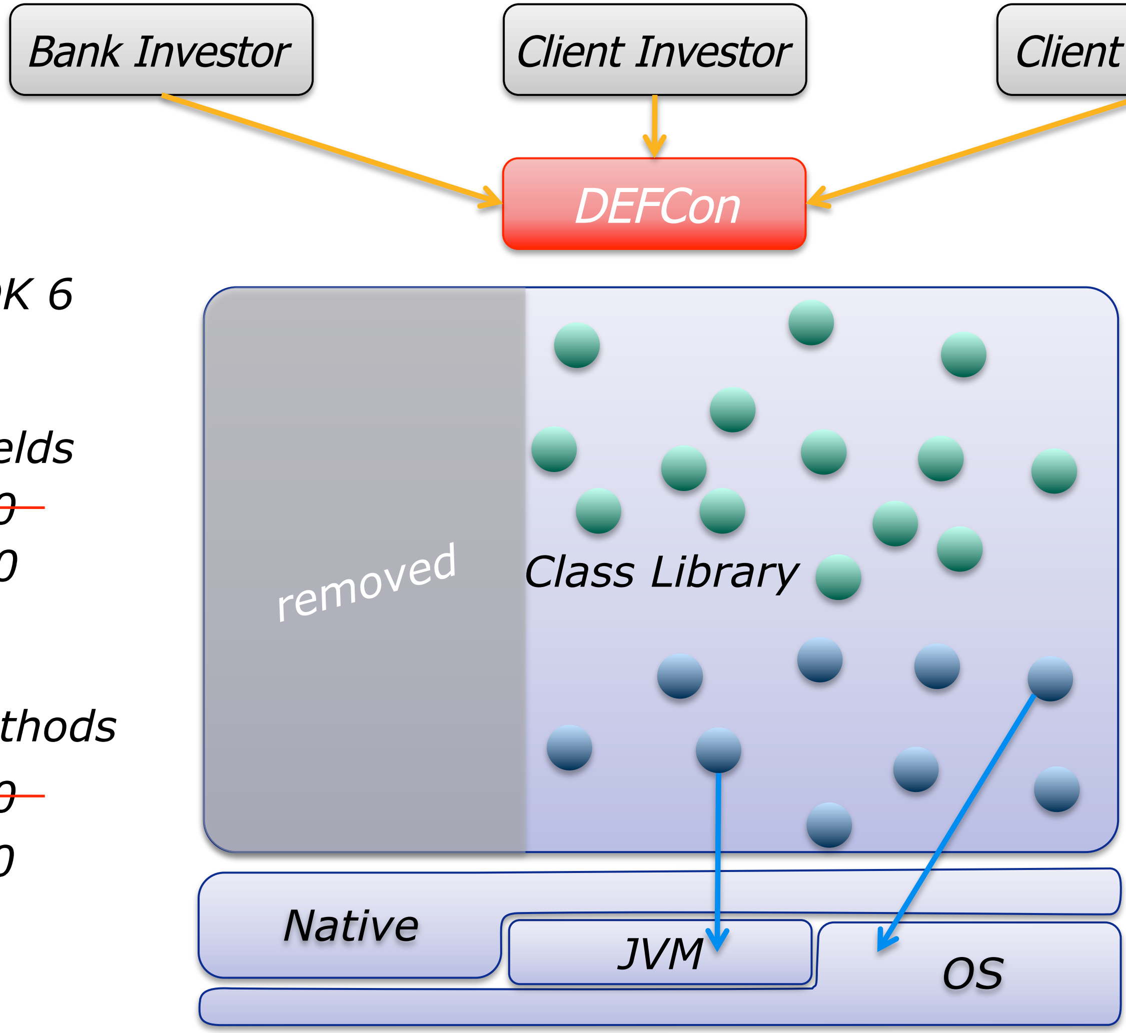
~~~4000~~

~2000

native methods

~~~2000~~

~1000



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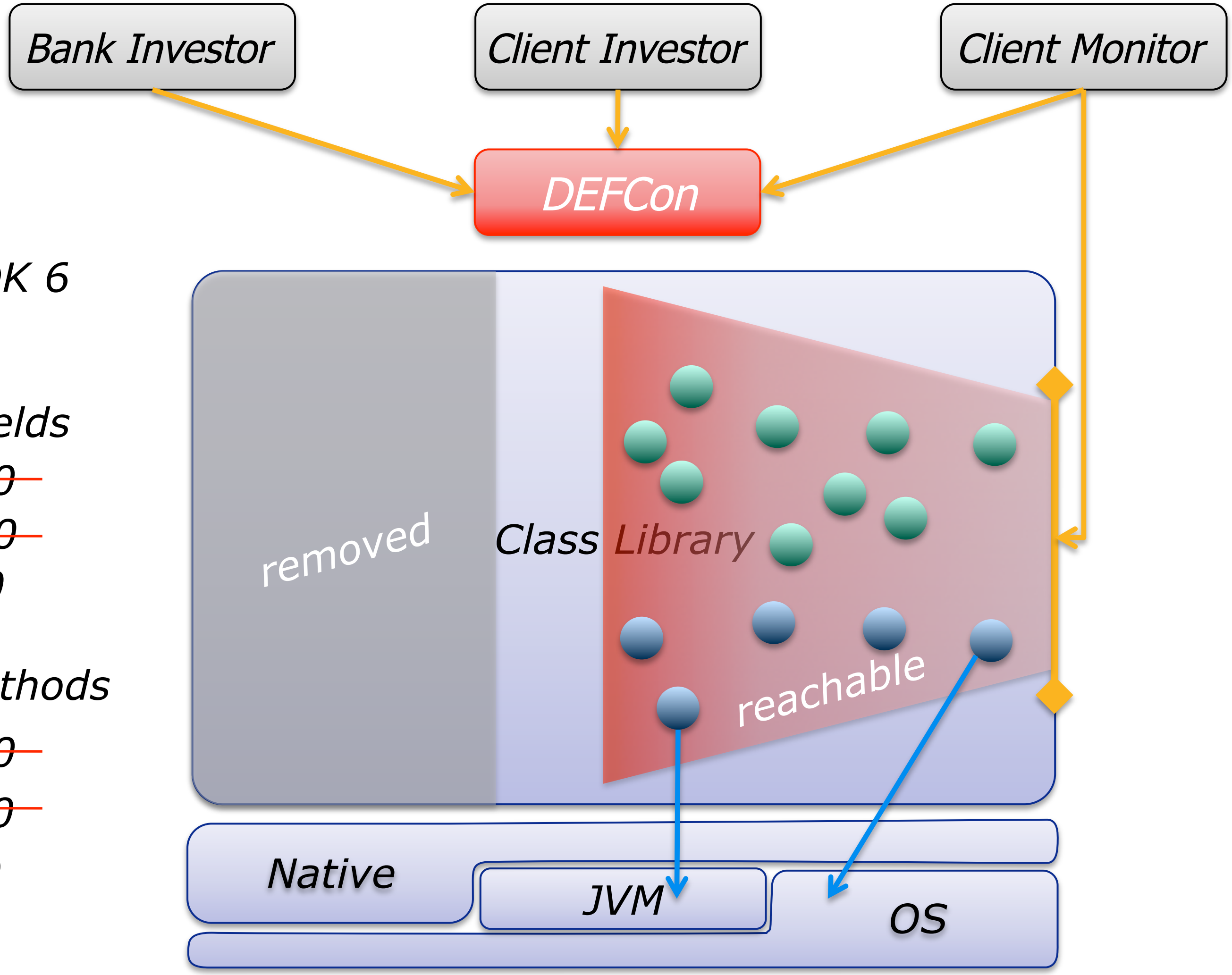


OpenJDK 6

static fields

~~~4000~~

~~~2000~~

~900

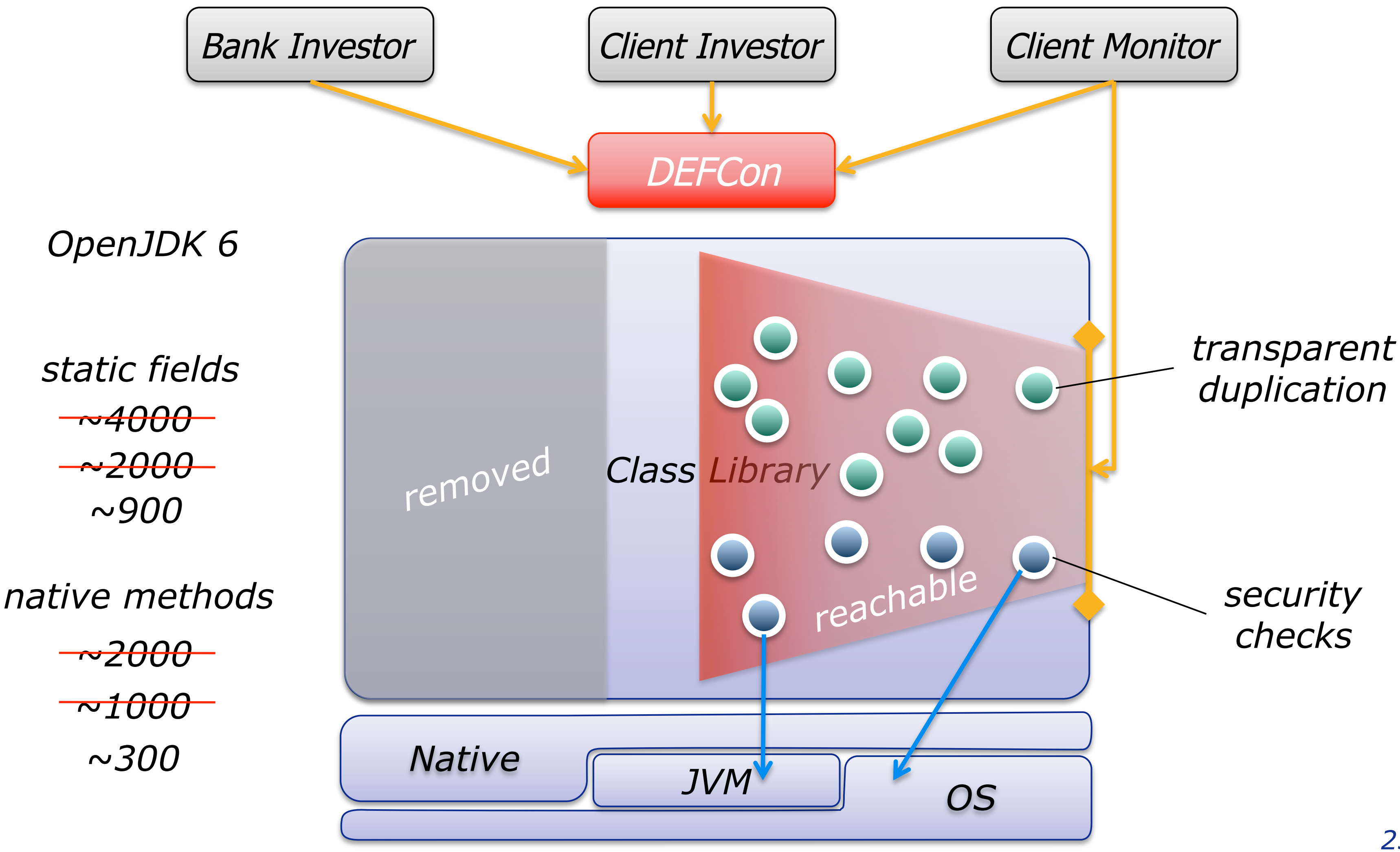
native methods

~~~2000~~

~~~1000~~

~300

2. AOP Runtime Injection



3. White-listing

OpenJDK 6

static fields

~~~4000~~

~~~2000~~

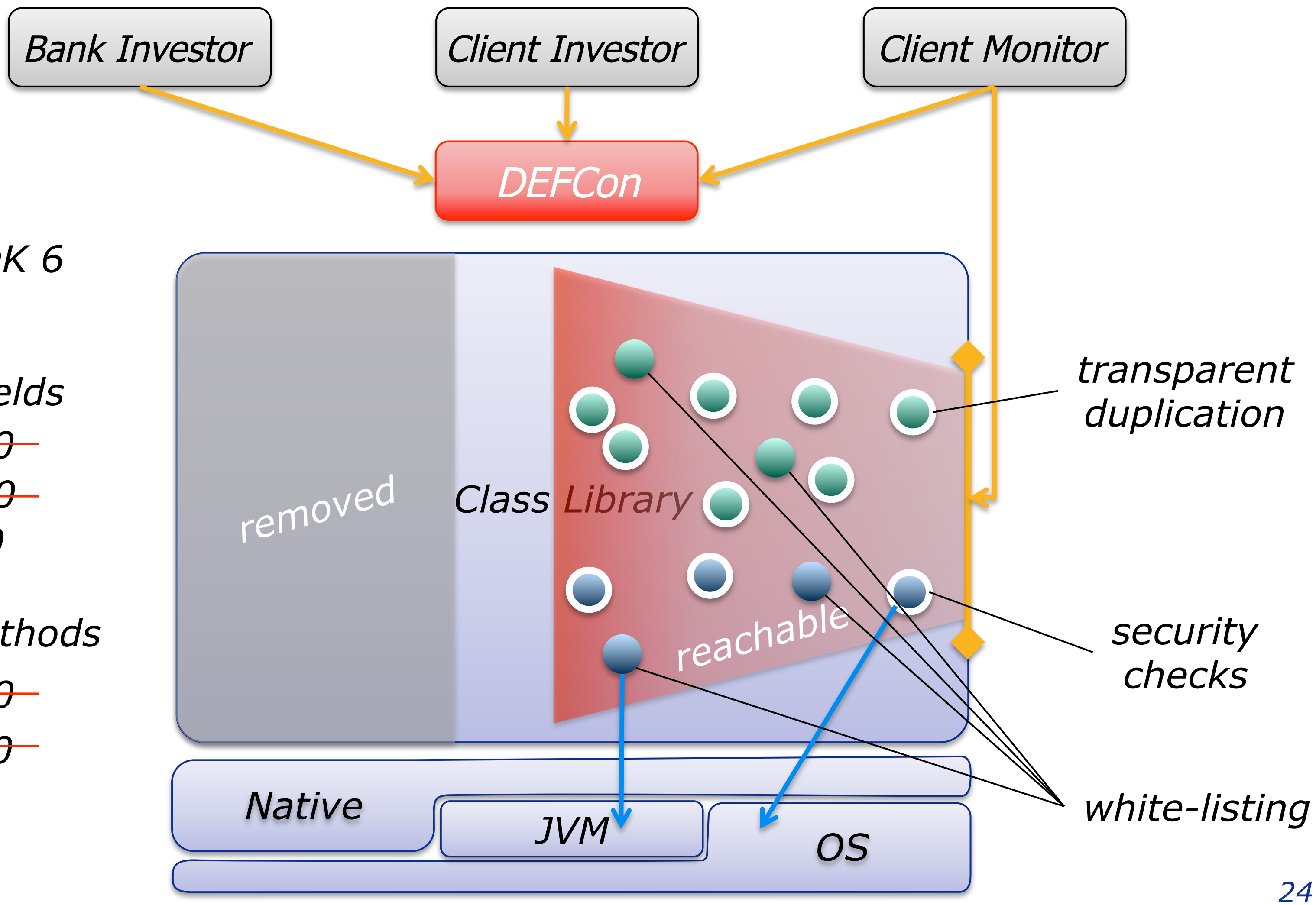
~900

native methods

~~~2000~~

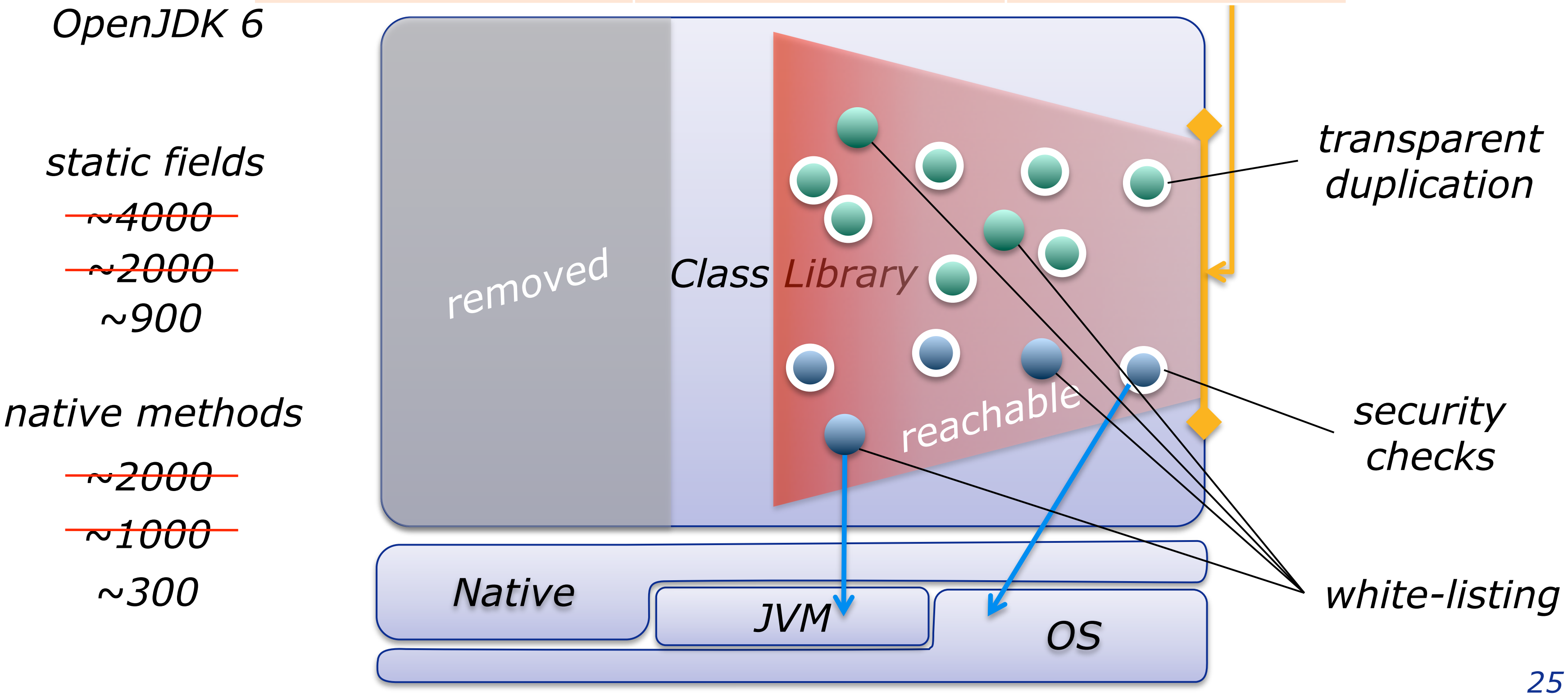
~~~1000~~

~300



3. White-listing

Target type	Manually white-listed	
	for unit execution	for performance
static fields	27	6
native methods	15	9



Isolation Summary

What we achieved

- Secured OpenJDK 6 for running financial scenario
- Required few days of manual work
- Easily applicable to new versions/different JDKs

Limitations

- Assumes knowledge of unit bytecode for static analysis
  - Might need additional effort for new units
- Manual code auditing subject to human errors

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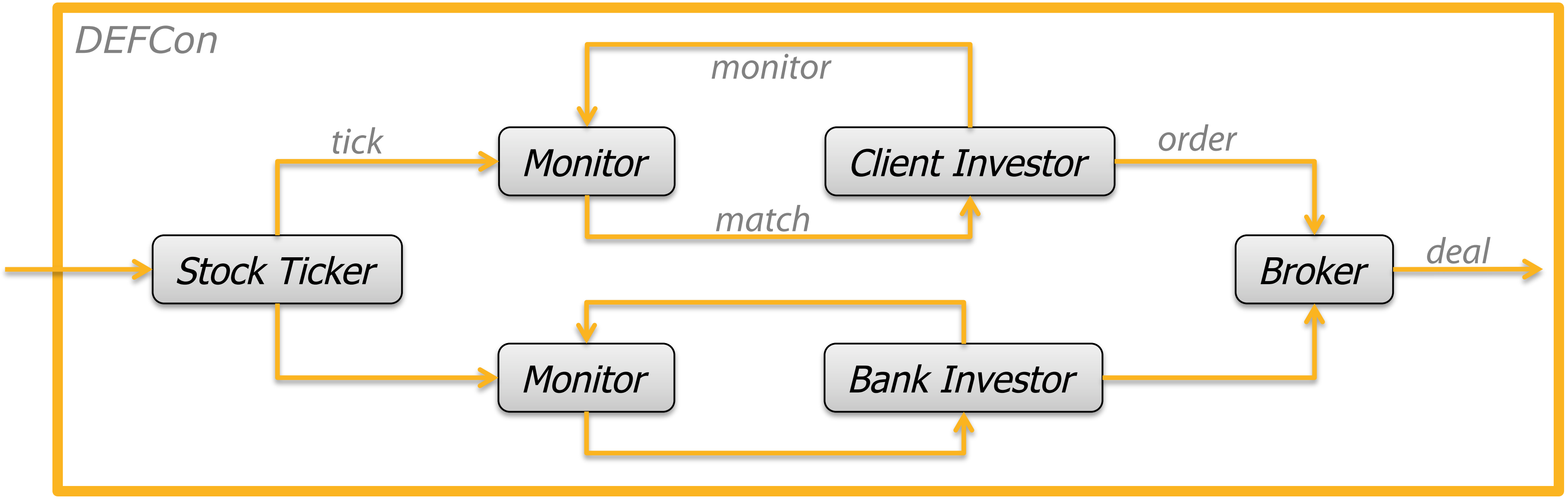
Evaluation: Performance Overhead



Measure overhead

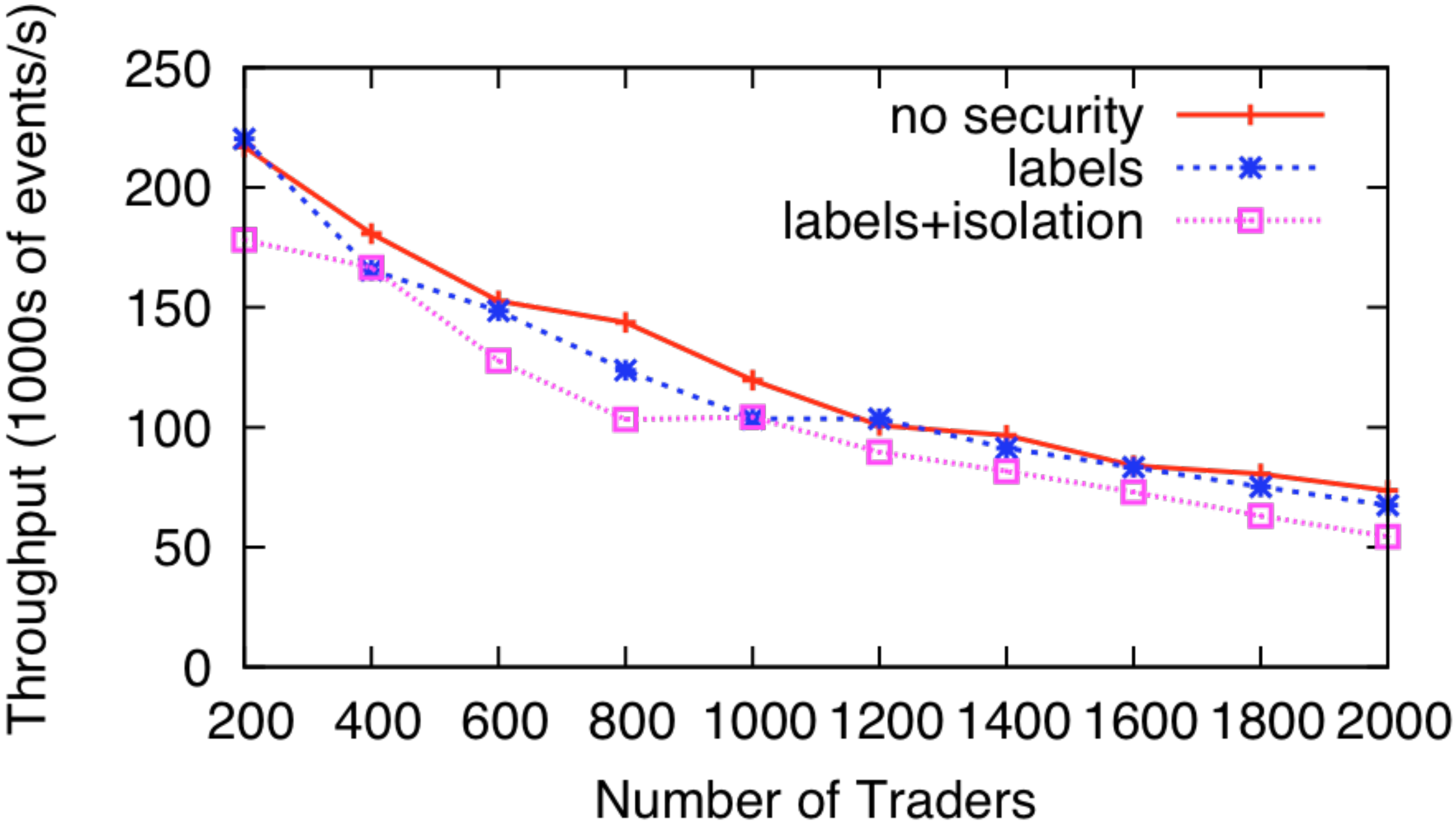
- Rate of processed ticks
- Latency of produced deals

Synthetic traces on 6k stock symbols

- Prices set to trigger a deal every 10 ticks

Experiments on dual Intel Xeon E5540 2.53GHz

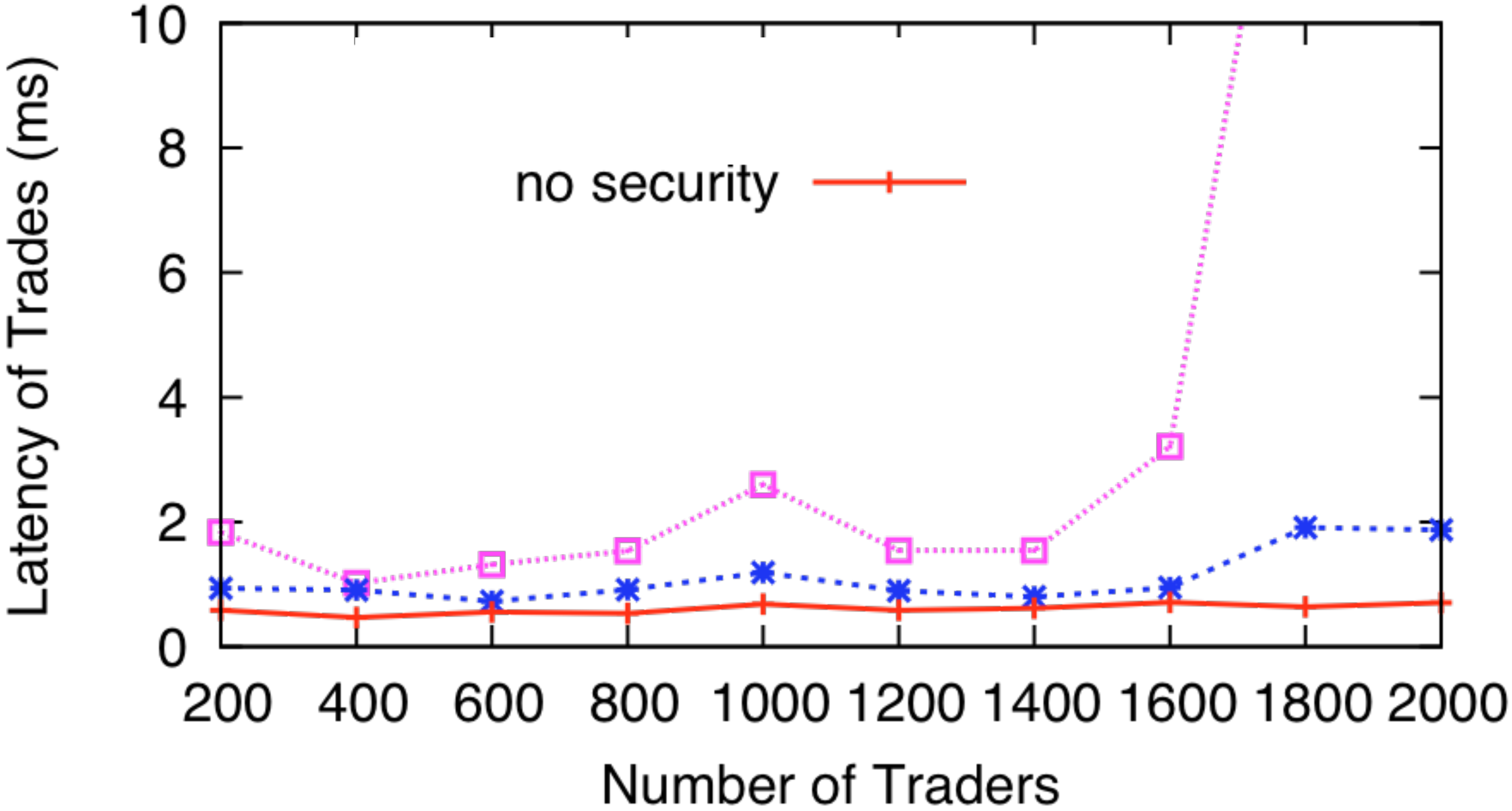
Acceptable Reduction on Throughput



Label checks: marginal overhead

Isolation: ~20% overhead

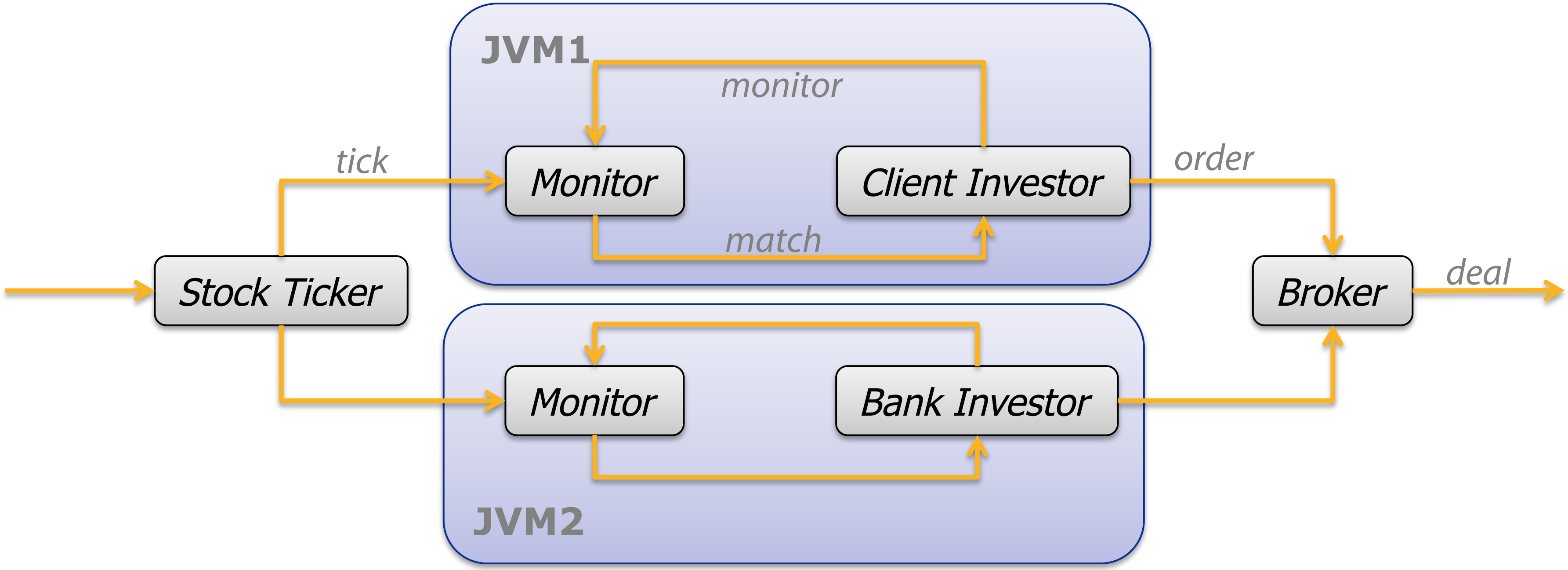
Low Impact on Latency



Label checks: ~0.5 ms overhead

Isolation: ~1ms overhead

Isolation with Separate JVMs



Comparison with Marketcetera (Open Source trading platform)

- One JVM per investor

Throughput:

- Comparable with DEFCon with few investors
- Does not scale

Latency: around 8 ms

Future Work

Distribution

- Performance limited by number of cores
- Scale DEFCon to multiple engines

Usability

- Correctly assigning labels is hard
- Tools to help design and automatically check labelling

Performance isolation

- Units compete for resources
- Prevent uncooperative behaviours

Conclusion

Event processing requires security and low latency

DEFC model

- Provides strong and fine-grained security by applying Information Flow Control to event processing

DEFCon implementation

- Processes events in single address space for performance
- Provides isolation on production-level language runtimes

Tracking and enforcing security of event flows can be done with reasonable overhead

Thank You! … Questions?

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