Explorations in the Grid/WS Computing Jungle

A Narrative of the Reverse-Engineering Attempts of a “New” Distributed Paradigm

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AT&T

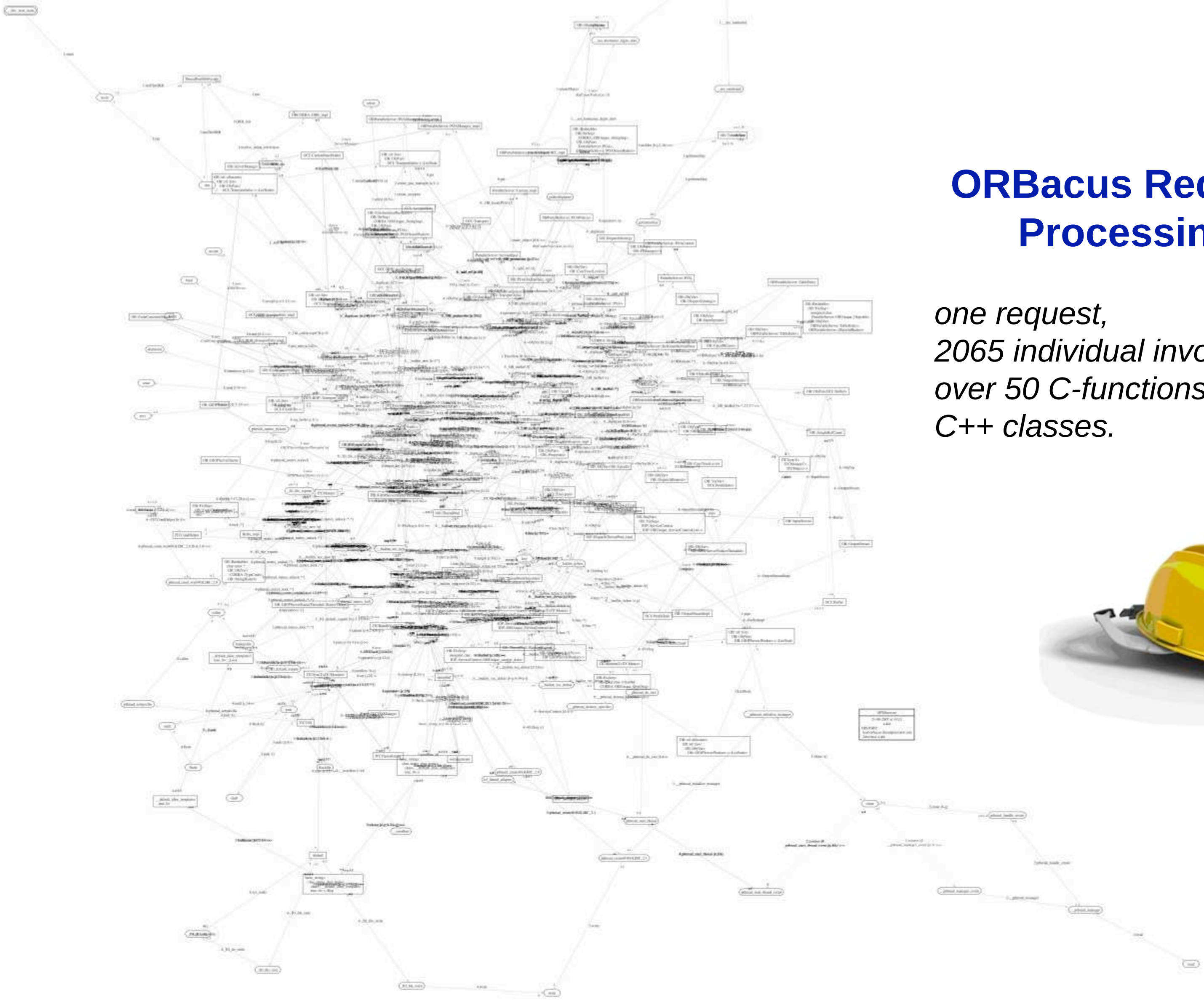
The world's networking company℠

Opera Talk, 6 May 2008, Comp. Dept., Cambridge University

The best and safest method of philosophizing seems to be, first to inquire diligently into the properties of things, and to establish those properties by experiences and then to proceed more slowly to hypotheses for the explanation of them. For hypotheses should be employed only in explaining the properties of things, but not assumed in determining them; unless so far as they may furnish experiments.

Isaac Newton

Context: Middleware Complexity



ORBacus Request Processing

one request,
2065 individual invocations,
over 50 C-functions and 140 C++ classes.

Web Services' Bright New World

- **Grid Computing:** federating resources
  Web Services: integrating services } over the Internet
- Globus (Argonne Lab.): reference implementation
- Large, complex, collaborative middleware (IBM, Apache,...)
- **Very poor performances:**
  - ➔ Up to **30s** to **create** a simple distributed object (counter)
  - ➔ Up to **2s** for a roundtrip remote **add** operation on this counter

- Where does it come from?
- Does it tell us something about modern mw development?

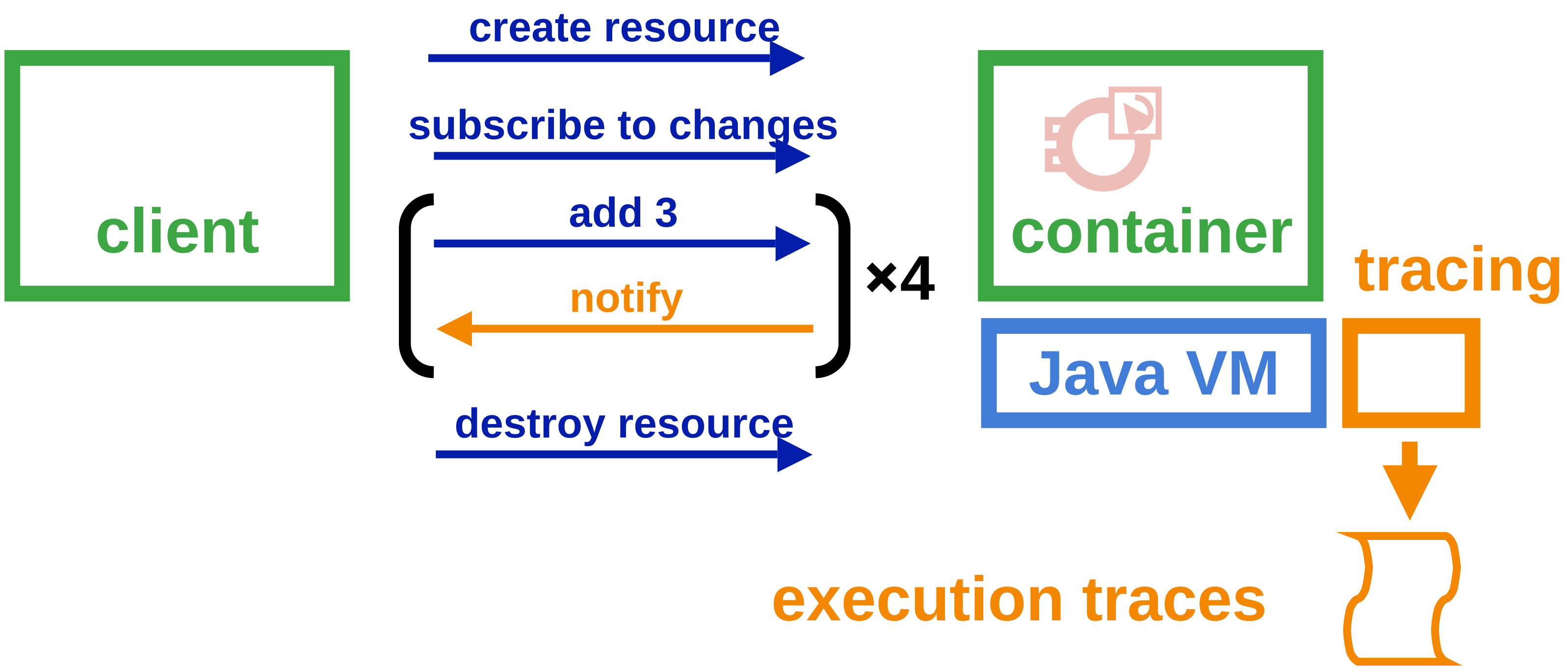
Globus

- **Reference Implementation** of the Grid Standards.
  - ➔ Developed by the “Globus alliance”, a partnership around Argonne National Laboratory.
- Globus is a **high level “middleware”** (software glue)
  - ➔ It offers services to share/ use remote distributed “resources” (CPU, memory, DB, bandwidth)
- Since version 3.9.x use **Web Service “connectivity”**
  - ➔ Web Services: “connectivity” middleware across the Internet
  - ➔ Integration of services across organizations
  - ➔ Related alphabet soup: SOAP, XML, WSDL, HTTP, .NET, *etc.*

Exploration Goals

- We wanted to **understand** Globus (at least its connectivity)
- Huge piece of software (3.9.x):
  - ➔ 123,839 lines in Java (without reused libraries)
  - ➔ 1,908,810 lines in C/C++ (including reused libraries)
- **Many libraries** / technologies involved:
  - ➔ XML, WSDL (Descr. Lang), WSRF (Resource Framework)
  - ➔ Axis (Java to SOAP), Xerces (XML Parsing), com.ibm.wsdl
- **How to understand that?**
- A typical **reverse engineering** problem

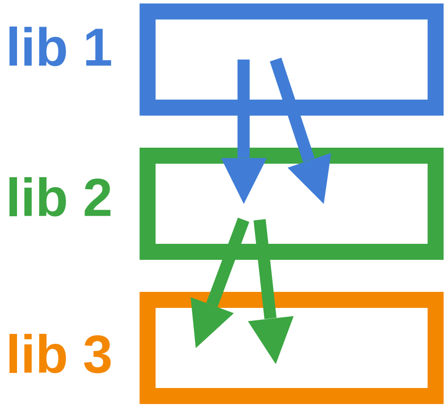
Methodology I + First Results



- First attempt: tracing everything (outside the JVM libs)
  - ➔ client : **1,544,734** local method call (sic)
  - ➔ server : **6,466,652** local method calls (sic) [+time out]
- **How to visualize such results?**

Program Visualization: a few Notions

- Problem studied for quite a long time now.
- Different aspect : collection, manipulation, visualization.
- Visualization some form of **projection** (many proposed).
- Our goal: understand software structure:

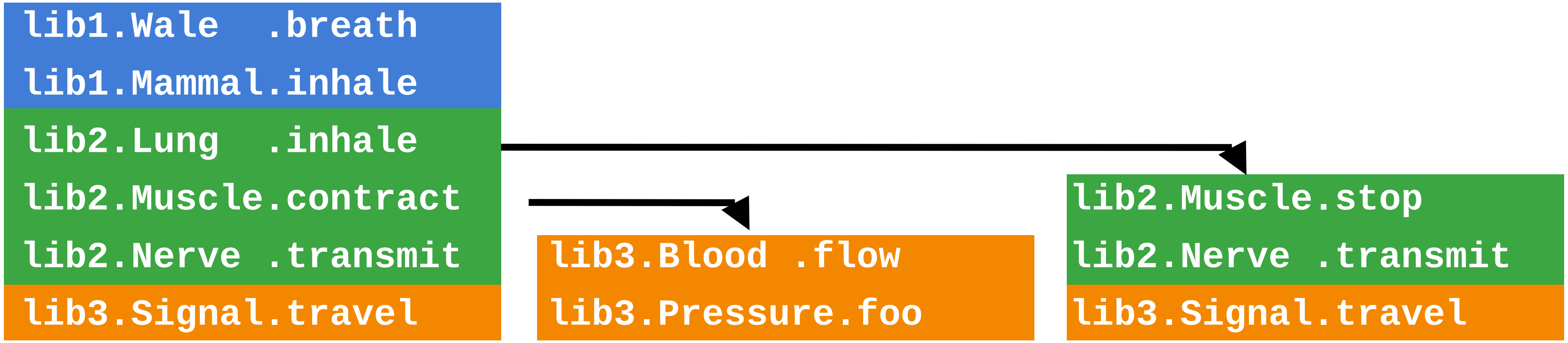


```
lib1.Wale  .breath
lib1.Mammal.inhale
lib2.Lung  .inhale
lib2.Muscle.contract
lib2.Nerve .transmit
lib3.Signal.travel
```

Growing Call Stack

- Tracing calls reveals the software structure.

Methodology I



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```
lib3.Blood .flow
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```
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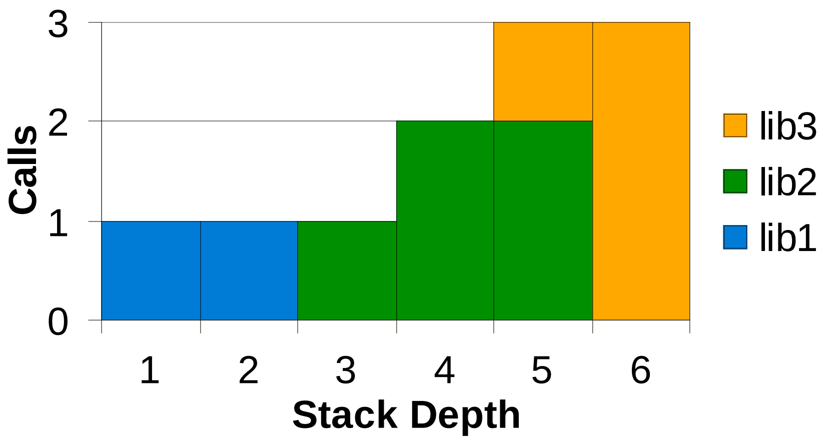
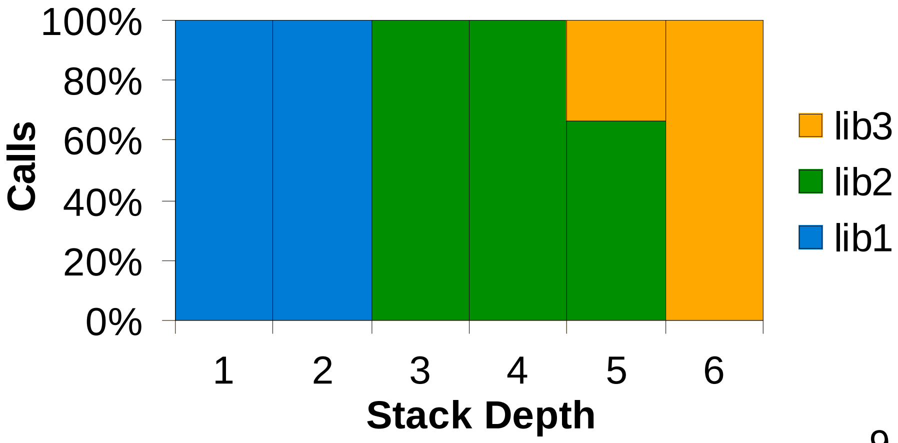
```

A call graph obtained by tracing

- ➔ Aggregates invocations of the same library.
- ➔ Chart w.r.t. position in call stack.





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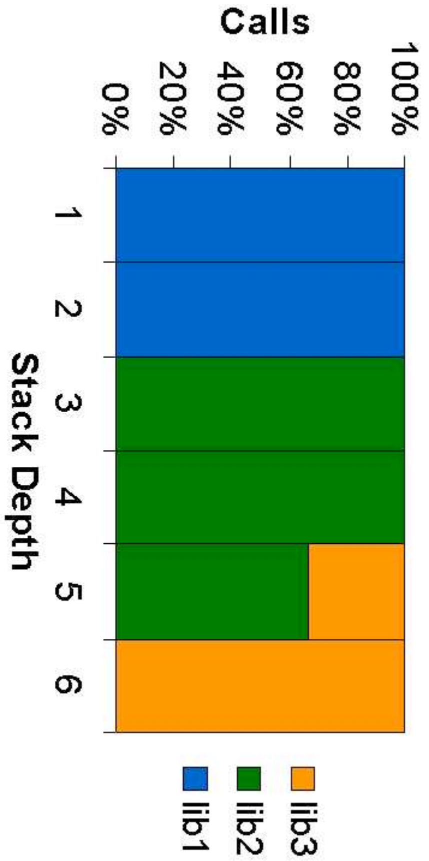
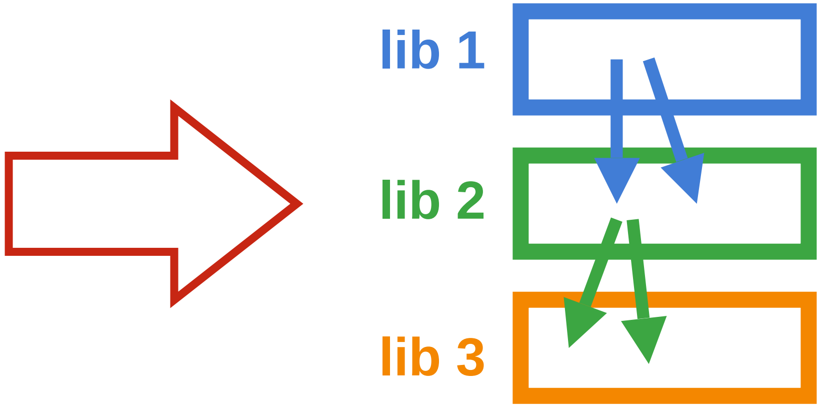


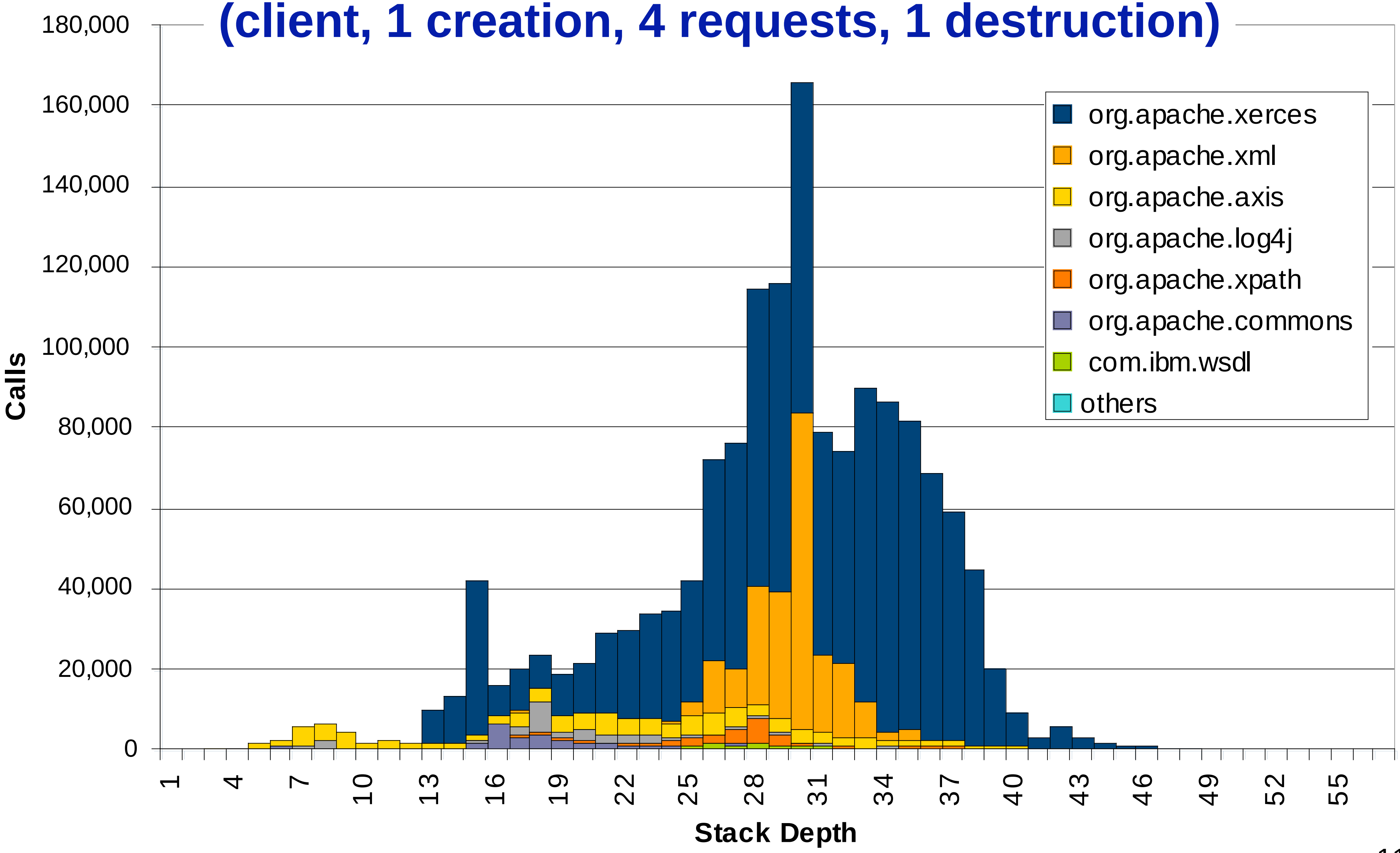
Package Activity vs. Stack Depth



Software Structure

Package Activity vs. Stack Depth

(client, 1 creation, 4 requests, 1 destruction)



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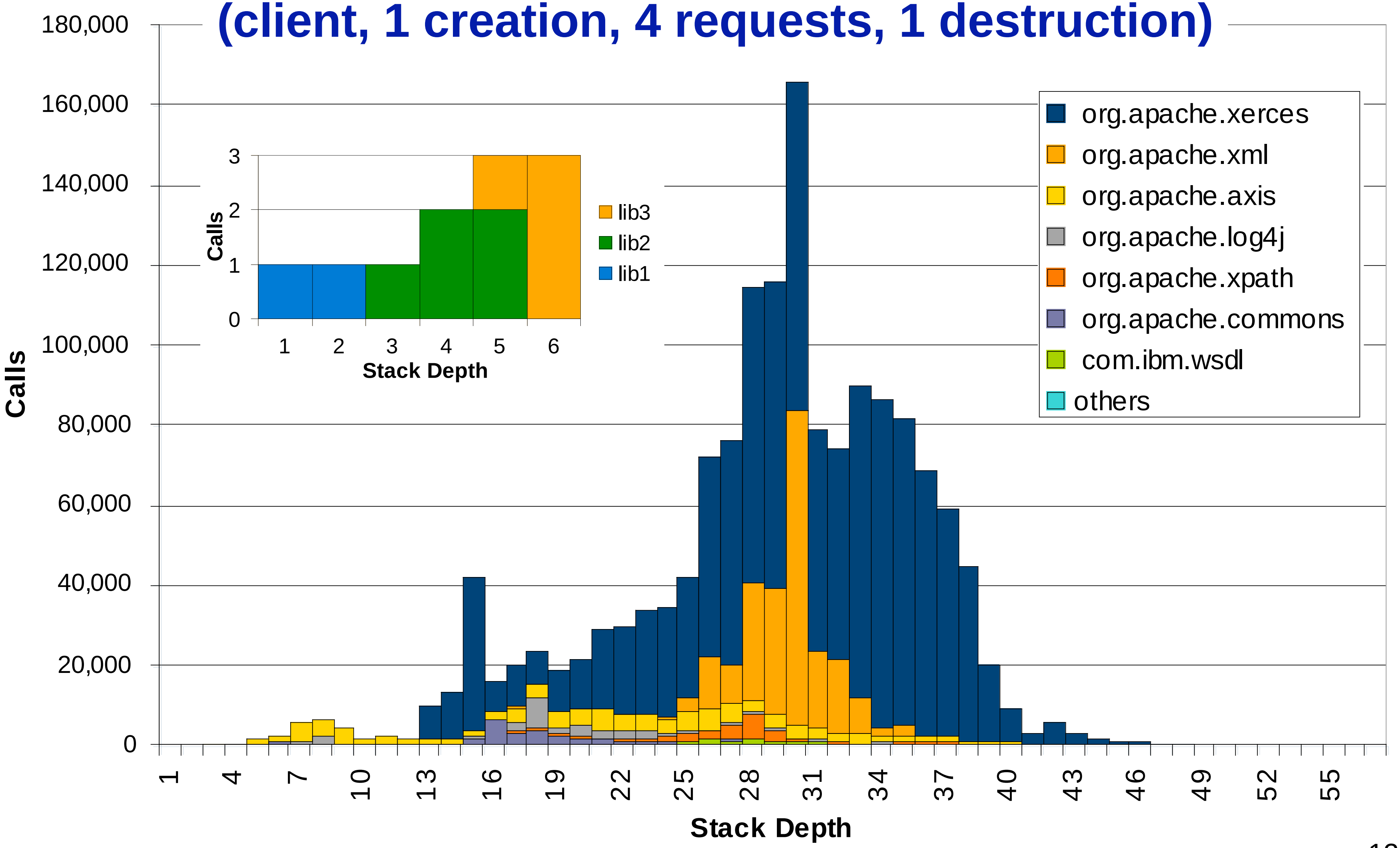

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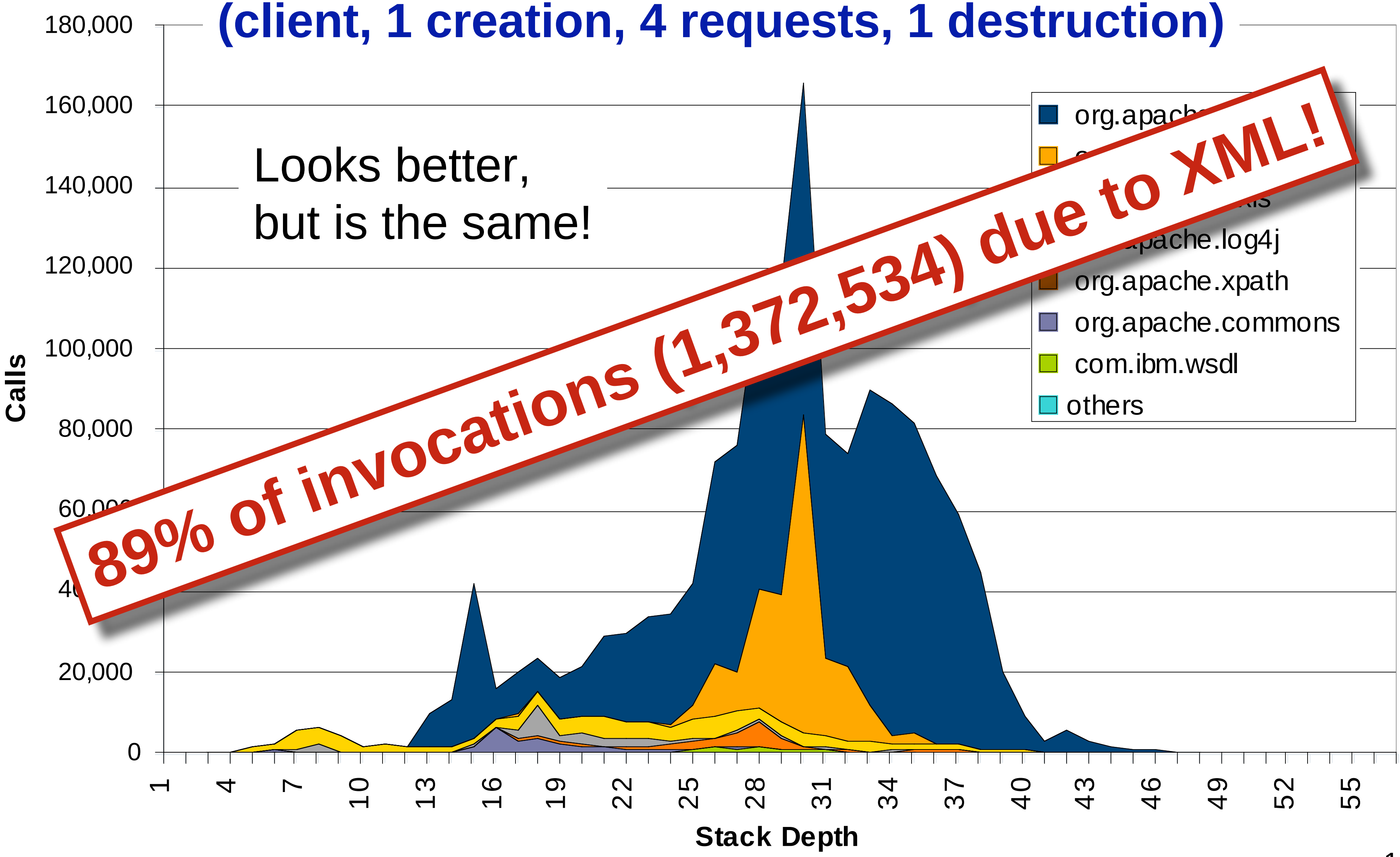
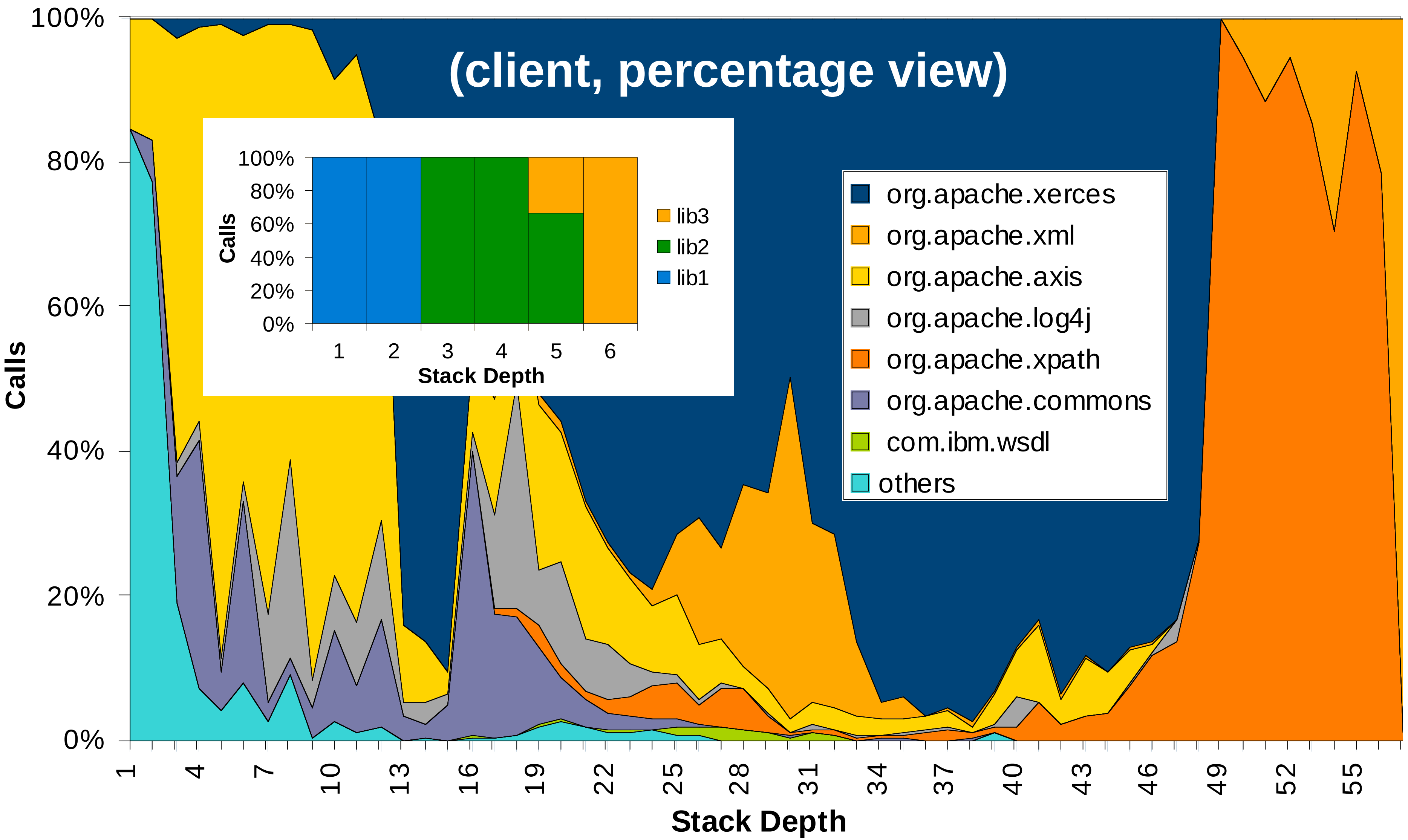


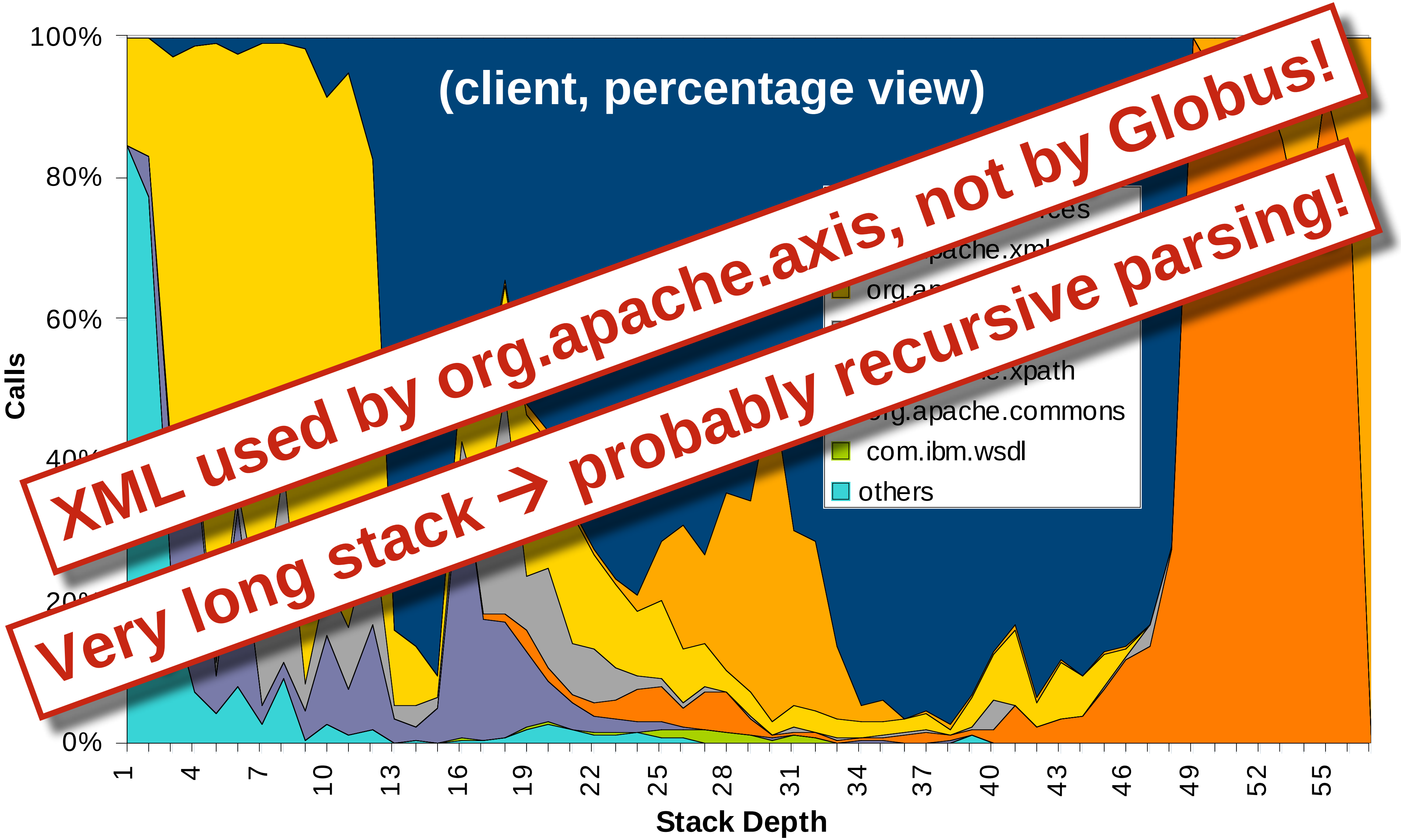
Looks better,
but is the same!

89% of invocations (1,372,534) due to XML!

Package Activity vs. Stack Depth



Package Activity vs. Stack Depth



XML used by org.apache.axis, not by Globus!

Very long stack → probably recursive parsing!

What does it tell us?

- Most of the **local invocations** (89%) are related to **XML** parsing (org.apache.xerces, org.apache.xml).
- The parsing is used by **Axis** (the SOAP/Java bridge from the apache foundation), not directly by Globus.
- The **very long stacks** we observe (up to 57 frames!) most probably reflect some **recursive parsing loop**, rather than the program structure.
- **Similar** findings on the **server** side (only more dramatic, stack depth up to 108 (sic), 4 times more invocations).

New Questions

More insight needed:

- Does invocation count reflect real performance?
- How “bad” is really the platform?
- Can we do the same kind of “structural” projection of profiling data?
- If yes, is it useful?

- Our choice: 2 step approach
  - ➔ (1) Black box profiling
  - ➔ (2) “Internal” profiling using sampling

Chosen Approach

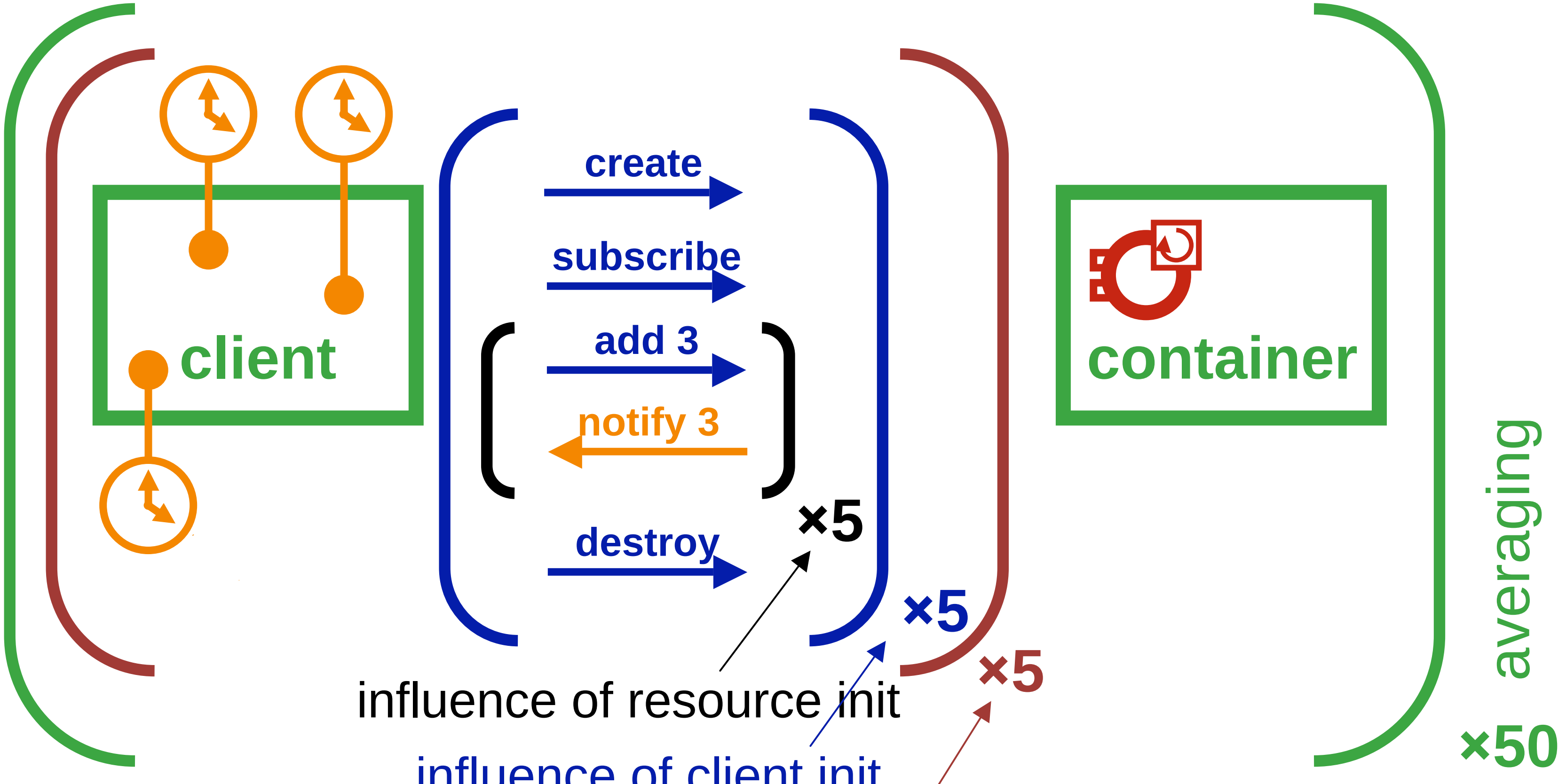
- 2 steps:
  1. **Black box profiling:** minimal interferences. Coarse results.
  2. **Sample based profiling:** less accurate but more detailed.

- We focused on the **connectivity** of the **WSRF** implementation of GT4-Java:
  - ➔ Low level "**plumbing**". No high level service involved
  - ➔ Motivation: profile the **founding bricks** of the Globus platform

- Experimental set-up:
  - ➔ **Standalone SMP** server running 4 Intel Xeon @ 1.6GHz
  - ➔ **No network cost** involved!
  - ➔ **Avoids context switching** overhead!
  - ➔ Globus **3.9.4** used (last GT4 alpha release, released Dec.04)

Black-Box Profiling: Approach

- Black Box Approach: Measure **externally** visible latencies
  - ➔ **Many** different situations to be considered!



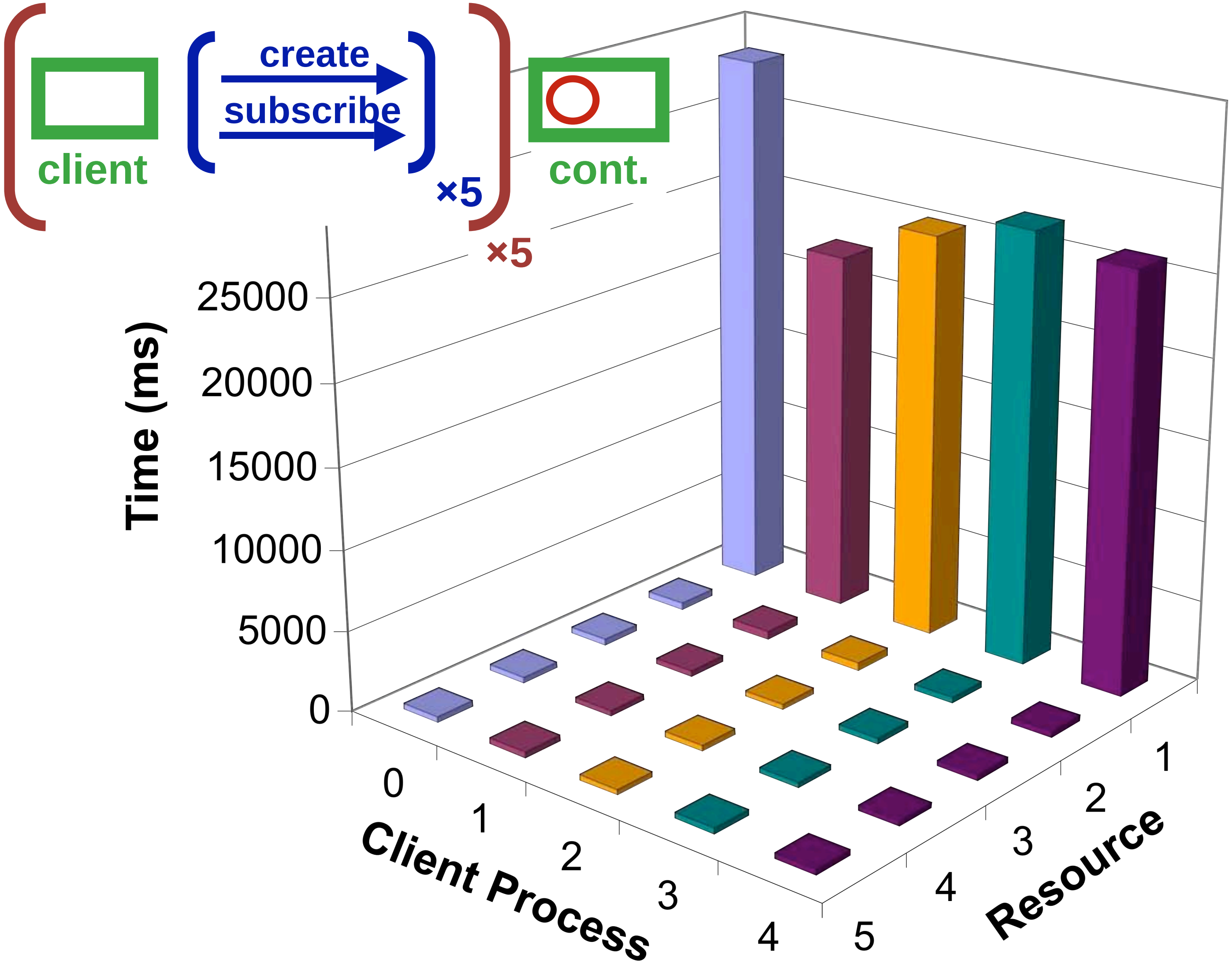
influence of resource init

influence of client init

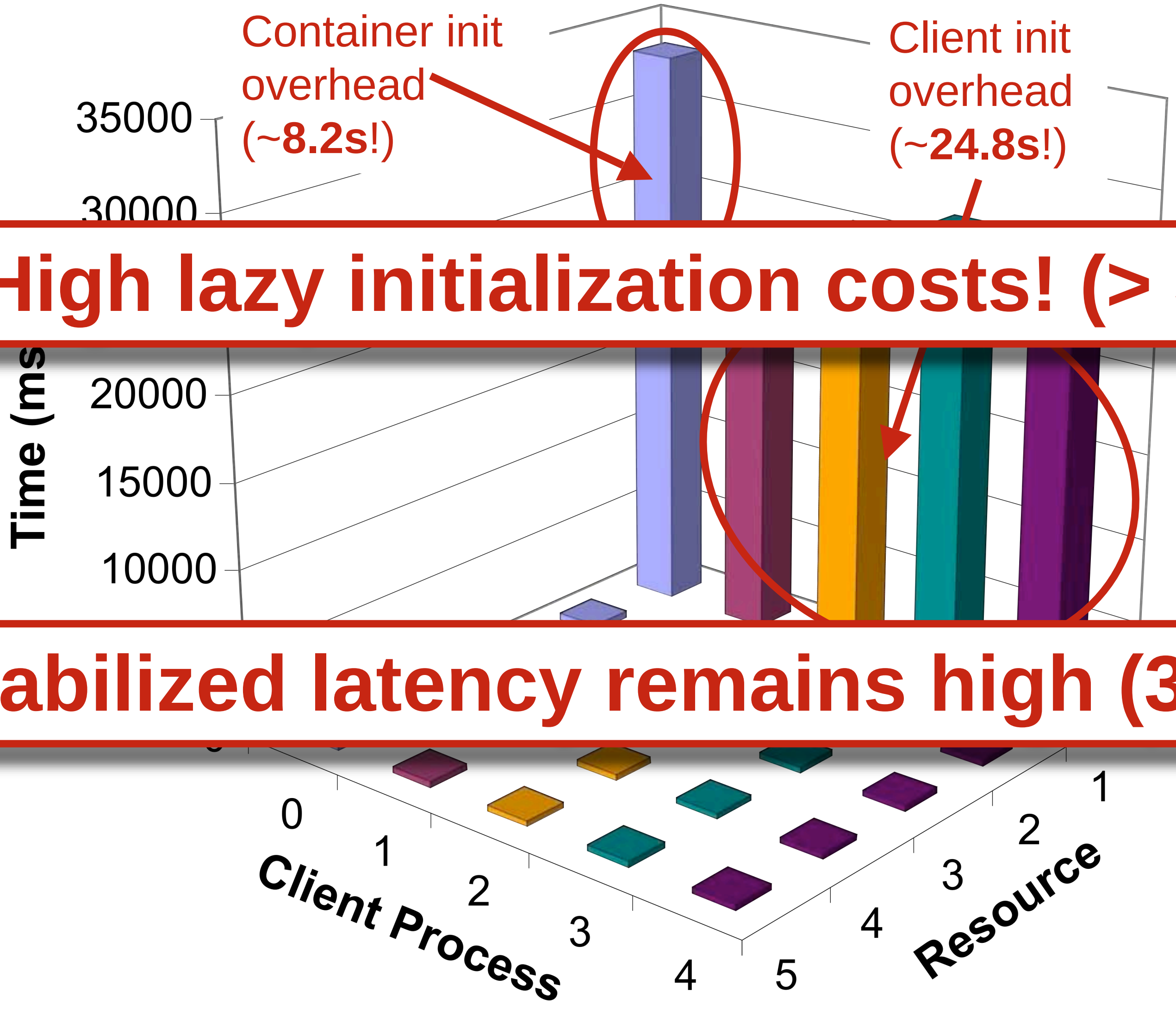
influence of container init

(10 000 invocations)

Resource Set-Up



Resource Set-Up



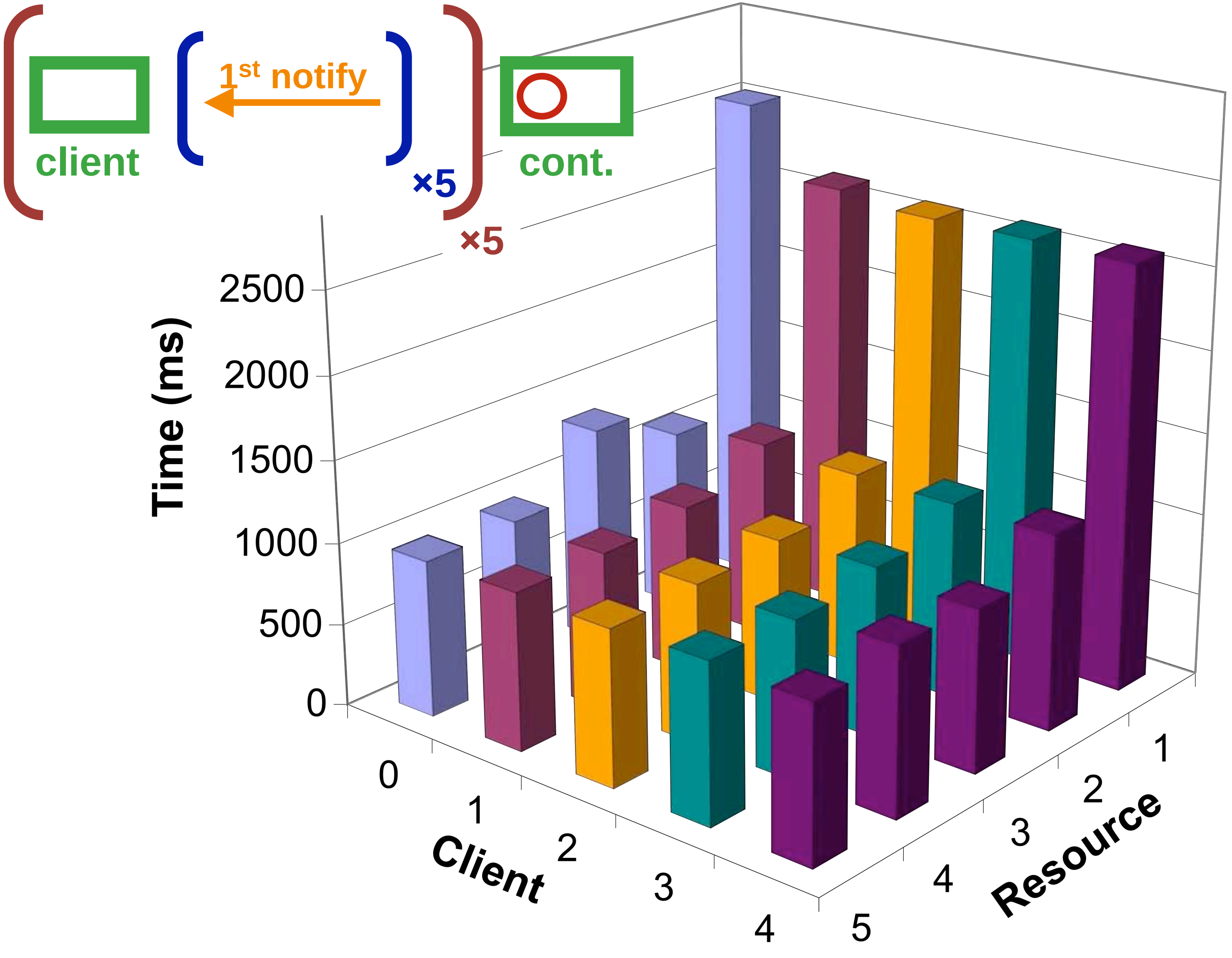
Container init overhead (~**8.2s**!)

Client init overhead (~**24.8s**!)

High lazy initialization costs! (> 30s!)

Stabilized latency remains high (380ms)

First Notification



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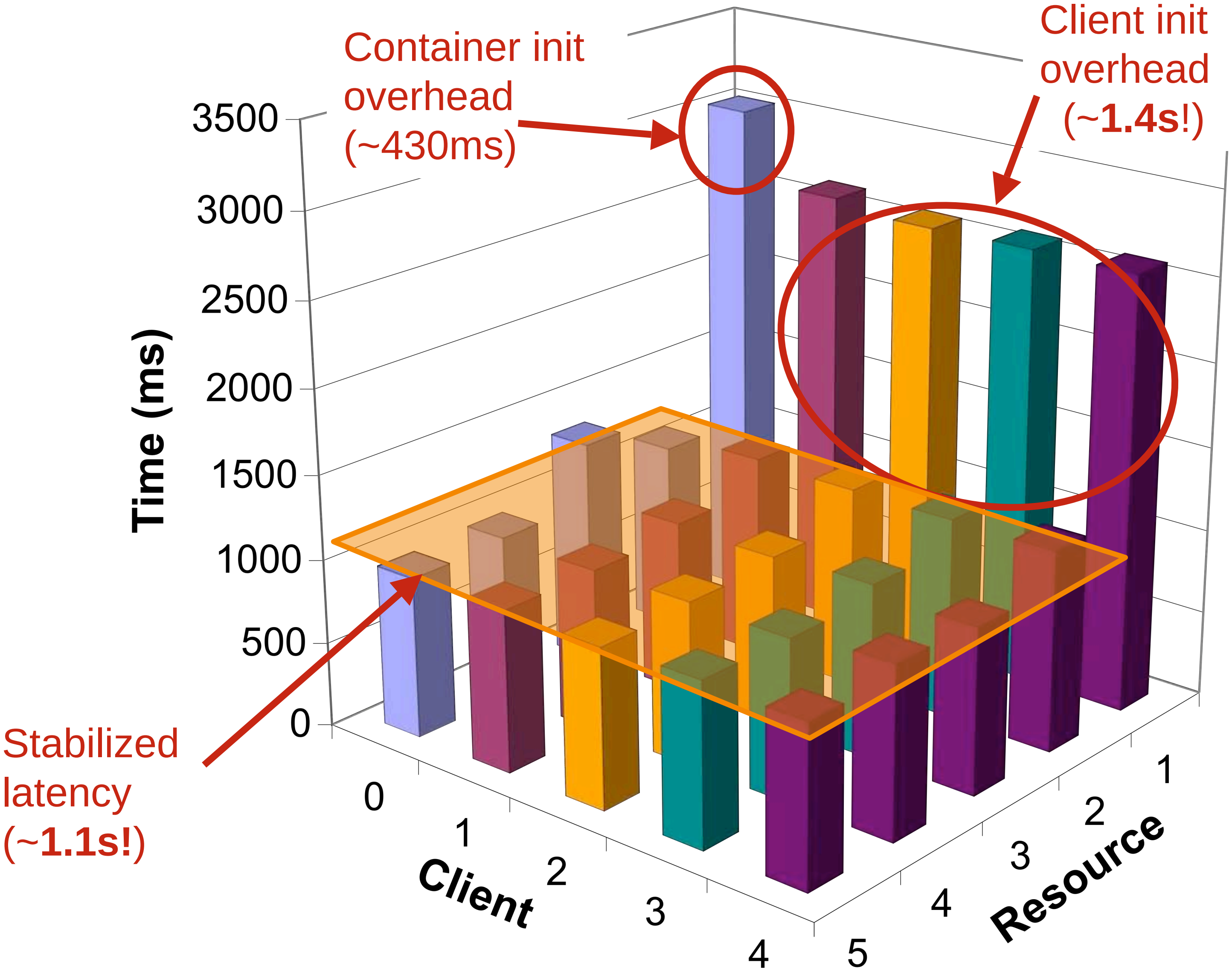
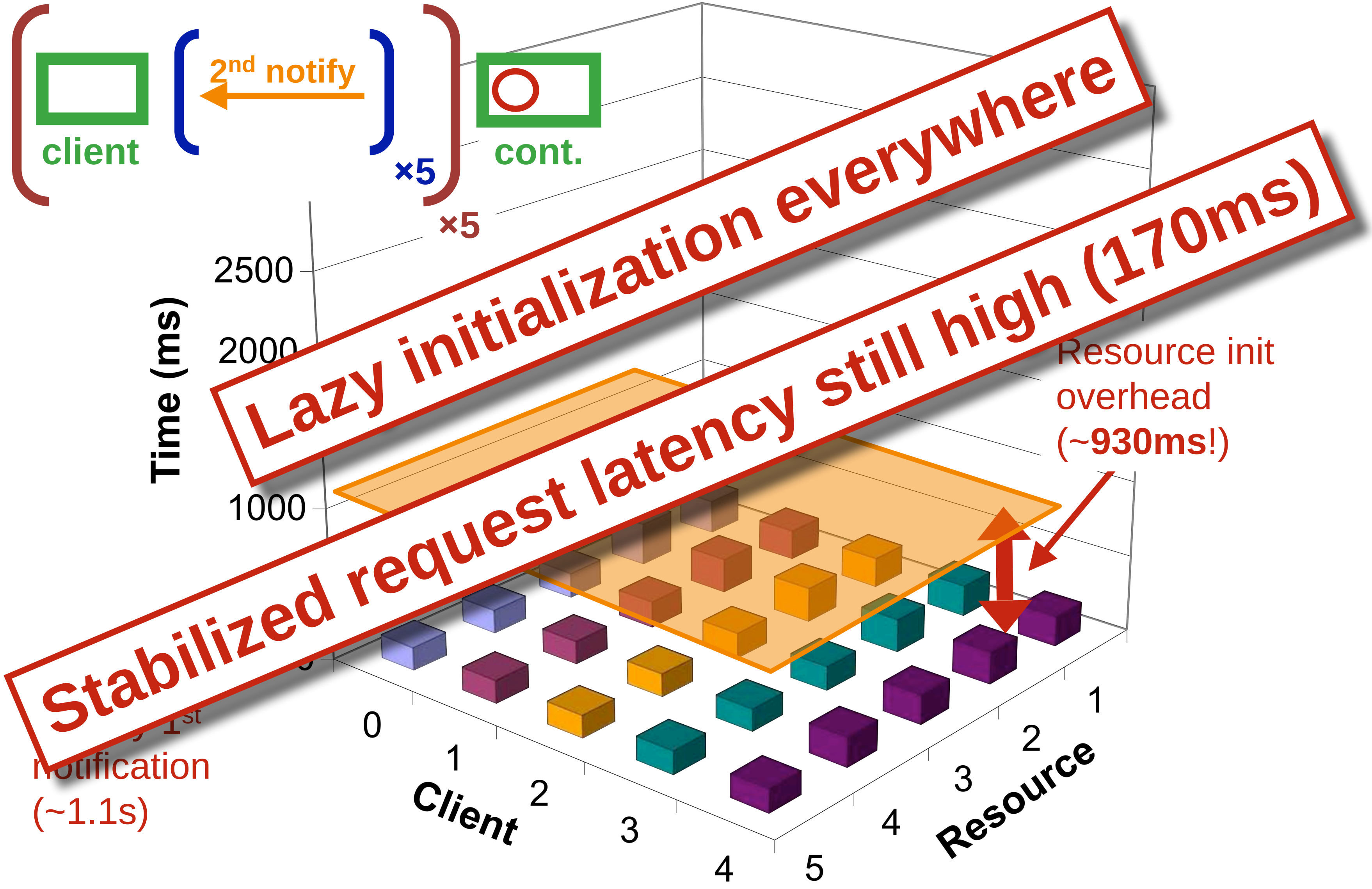


Container init overhead (~430ms)

Client init overhead (**~1.4s**!)

Stabilized latency (**~1.1s!**)

Second Notification



Resource init overhead (~**930ms**!)

y 1st notification (~1.1s)

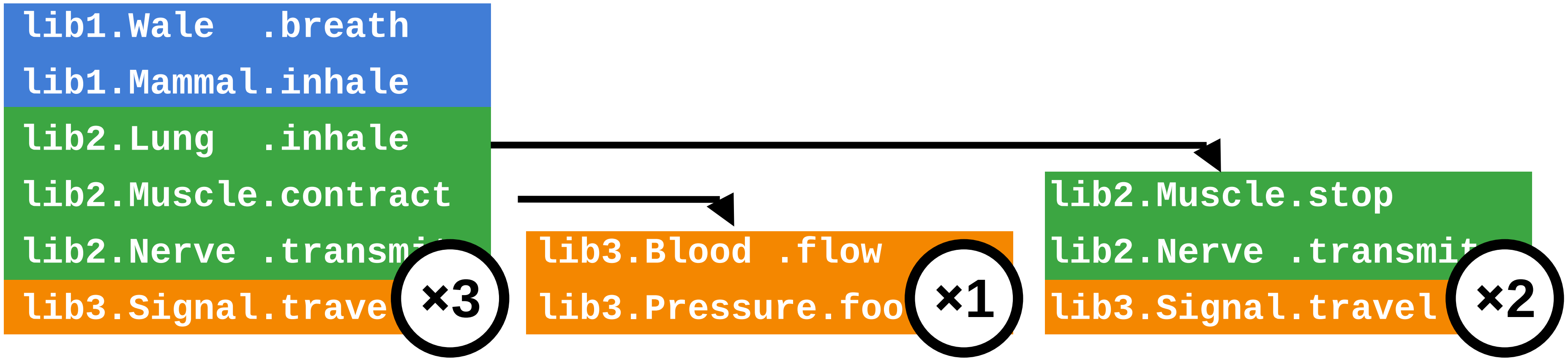
Lazy initialization everywhere

Stabilized request latency still high (170ms)

Internal Profiling: Basics

- **Profiling** data obtained through **sampling** (SUN hprof basic profiler on Java 1.4)
  - ➔ JVM periodically stopped. Stack of active thread is captured.
  - ➔ Result : A set of weighted stack traces. Weight = measures how often the stack was observed.
- **Visualization**: Set of weight stacks = **multi-dimensional object**
  - ➔ *Time* (represented by weights)
  - ➔ *Threads*: each trace belongs to a thread
  - ➔ *Control flow* (represented by stacks, reflects use relationships)
  - ➔ *Code Structure* (package organization, class hierarchy, *etc.*)
- **Projection** (aggregation / collapsing) required
- *Many* possibility. Our choice: **code structure + stack depth**

Methodology III



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lib3.Signal.trave
```

×3

```
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```

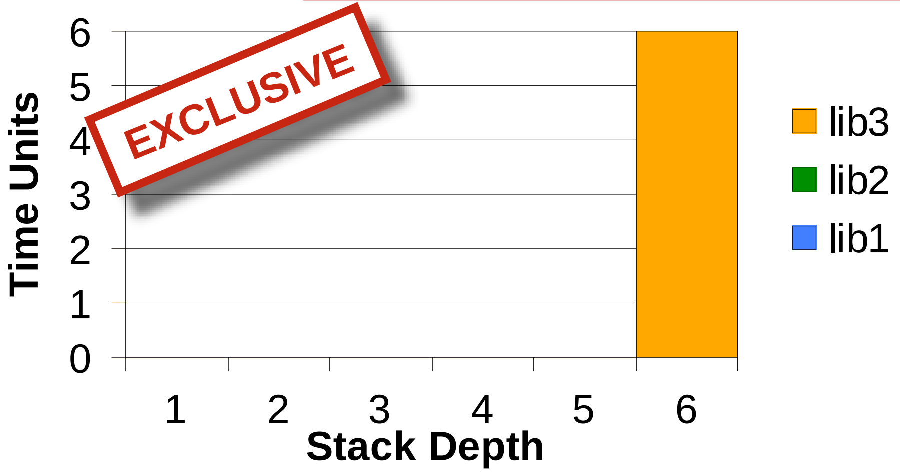
×1

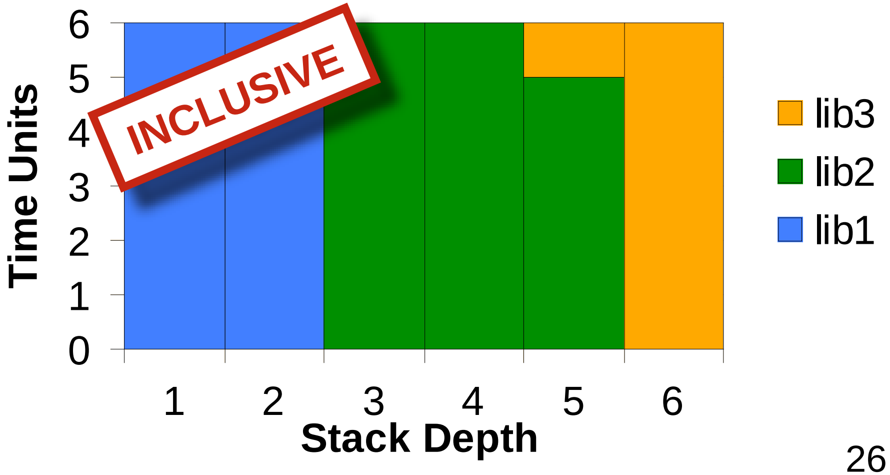
```
lib2.Muscle.stop
lib2.Nerve  .transmit
lib3.Signal.travel
```

×2

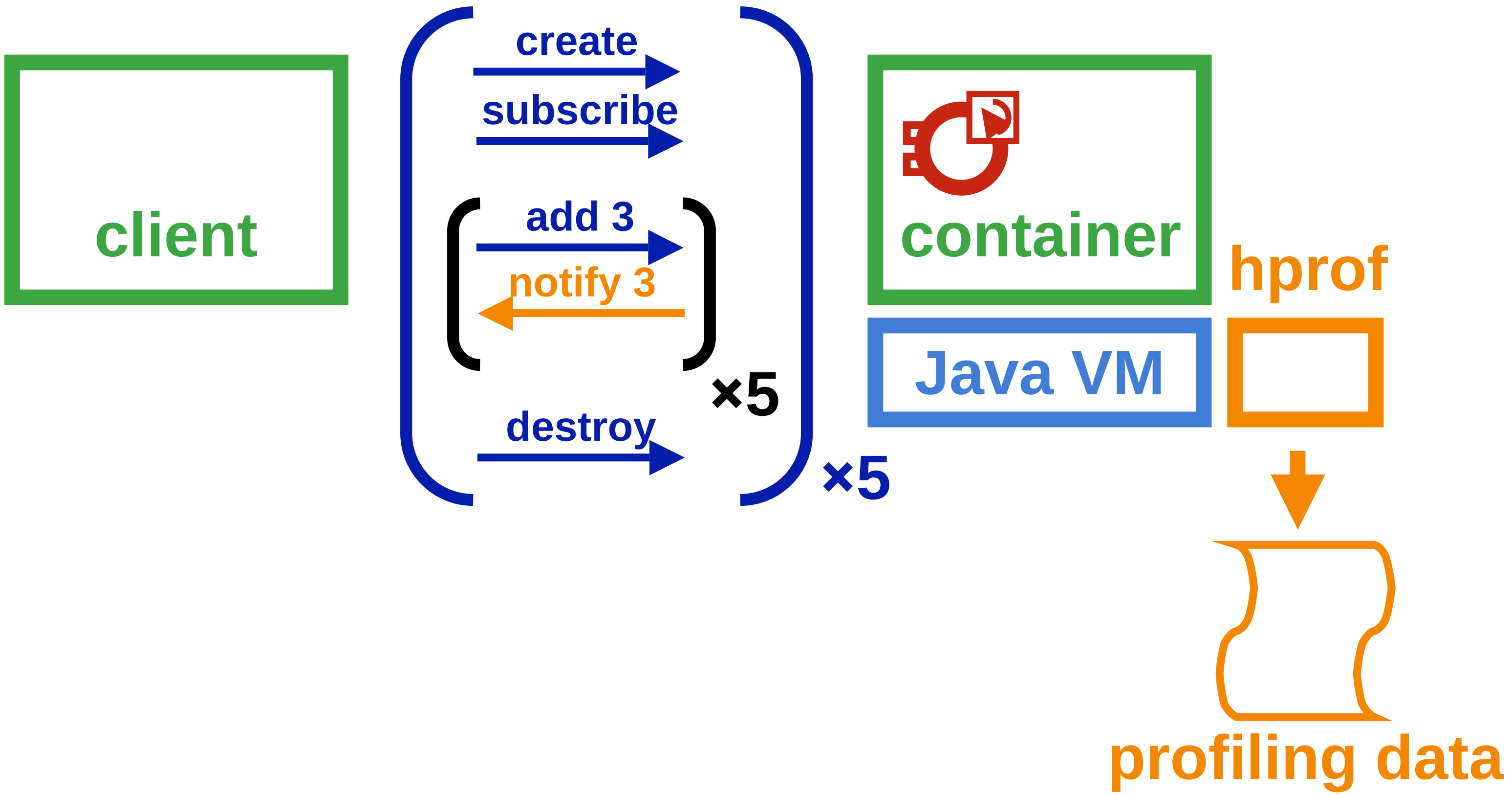
Sampling yields a set of weighted stack traces (weight reflects time spent)

- ➔ Aggregates invocations of the same library.
- ➔ Chart w.r.t. position in call stack.

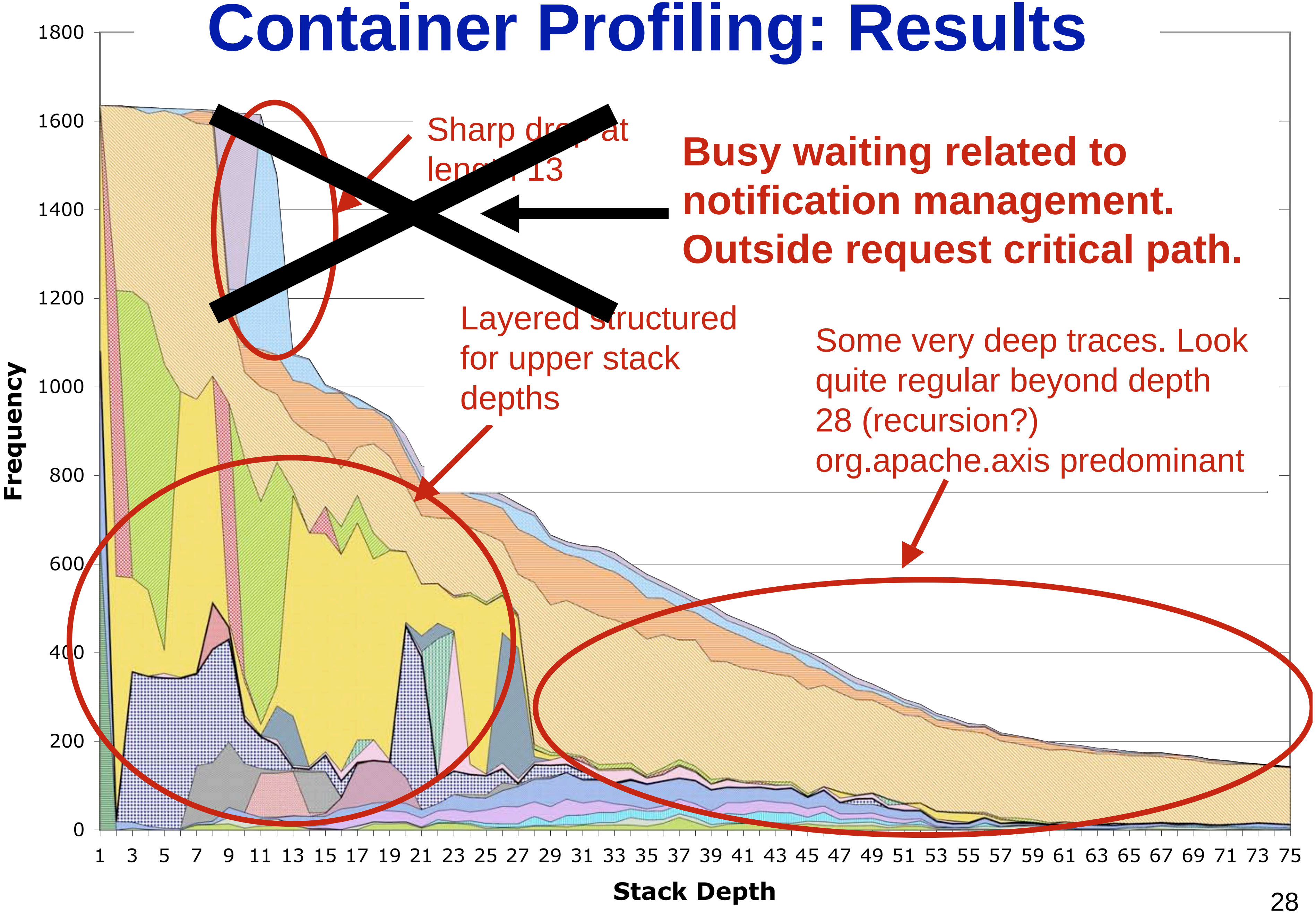




Experimental Set-Up



Container Profiling: Results



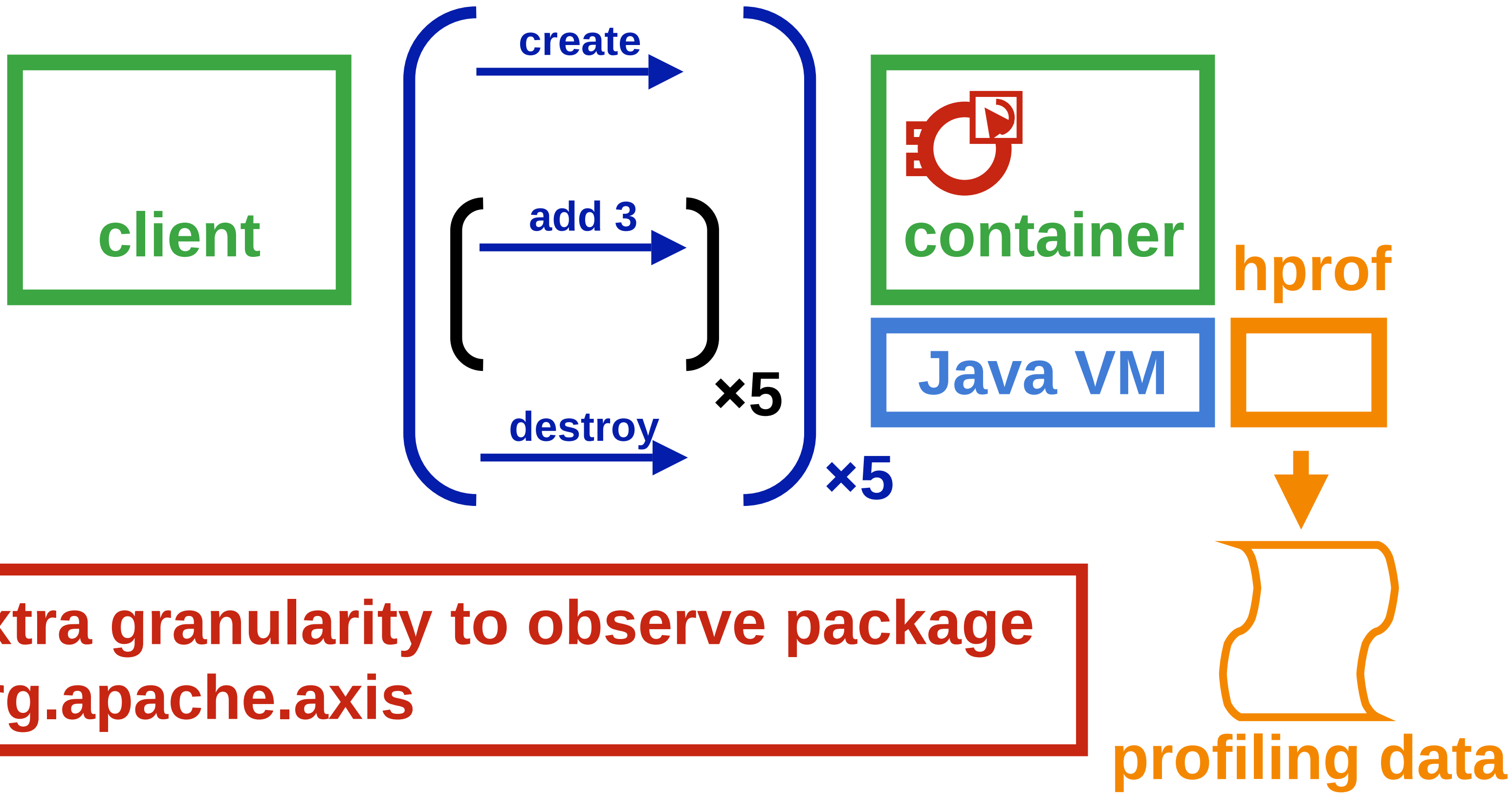
~~Sharp drop at length 13~~

Busy waiting related to notification management. Outside request critical path.

Layered structured for upper stack depths

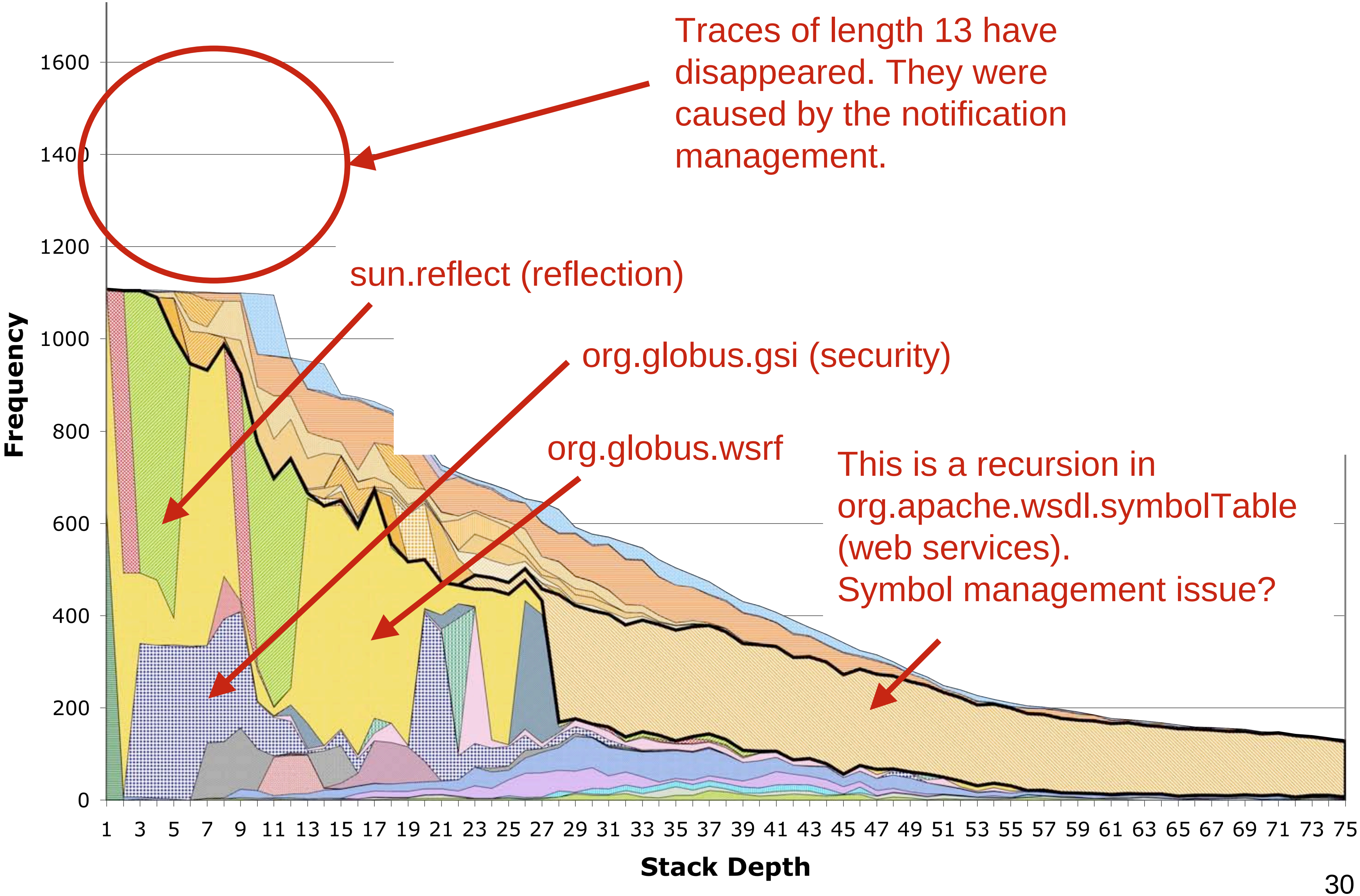
Some very deep traces. Look quite regular beyond depth 28 (recursion?) org.apache.axis predominant

New Experimental Set-Up



+ extra granularity to observe package org.apache.axis

New Results



Traces of length 13 have disappeared. They were caused by the notification management.

sun.reflect (reflection)

org.globus.gsi (security)

org.globus.wsrf

This is a recursion in org.apache.wsdl.symbolTable (web services).
Symbol management issue?

Profiling Breakdown

- Abstracts away **low level** packages (java.*, etc.)
- **Sample breakdown** among **“higher level”** packages:

Package Name	*Samples*	*%*
➔ org.apache.axis.wsdl	231	21%
➔ org.apache.axis.encoding	66	6%
➔ org.apache.axis (others)	113	10%
➔ org.globus.gsi	249	23%
➔ org.globus.wsrf	49	4%
➔ cryptix.provider.rsa	82	7%
➔ org.apache.xerces	78	7%
➔ others	237	21%

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SOAP + XML: 44%

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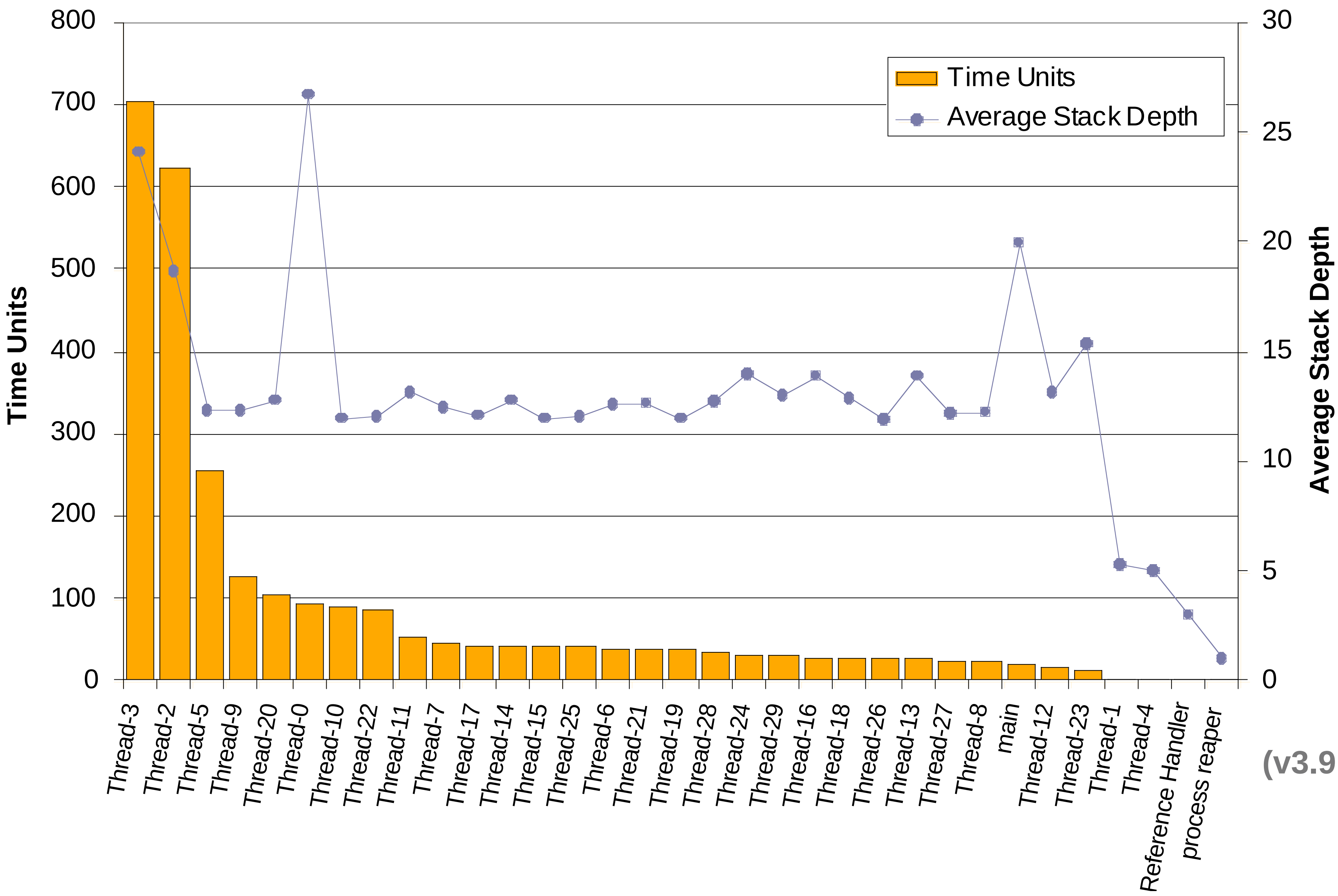
Security / Cryptography: 30%

Many Other Visualisation Ways



(v3.9.2)

Summing Up

- **Globus**
  - ➔ **Lazy optimisation**: very high latency on first invocation of operations (up to 30s to set up a resource on a new container!)
  - ➔ **Stabilized latencies** still high: ~ 160ms for a round trip request (with authentication turned on)
- No clear culprit. Technology overload: **WSDL, SOAP, security**
- Is **lazy optimisation** a **problem**? **Yes and No.**

Longer Term

- Platform and technology come and go
  - ➔ Globus is a moving target

- But experimental approaches stay
- And so do development practices

Middleware Practices:
Are we doomed?

- Lazy optimization → **flexibility paradox**
- Poor performance → **abstraction leaking**
- Reverse engineering → **Frankenstein’s** return?

- Can Cognitive-based Middleware save us?
  - → API are for real beings!

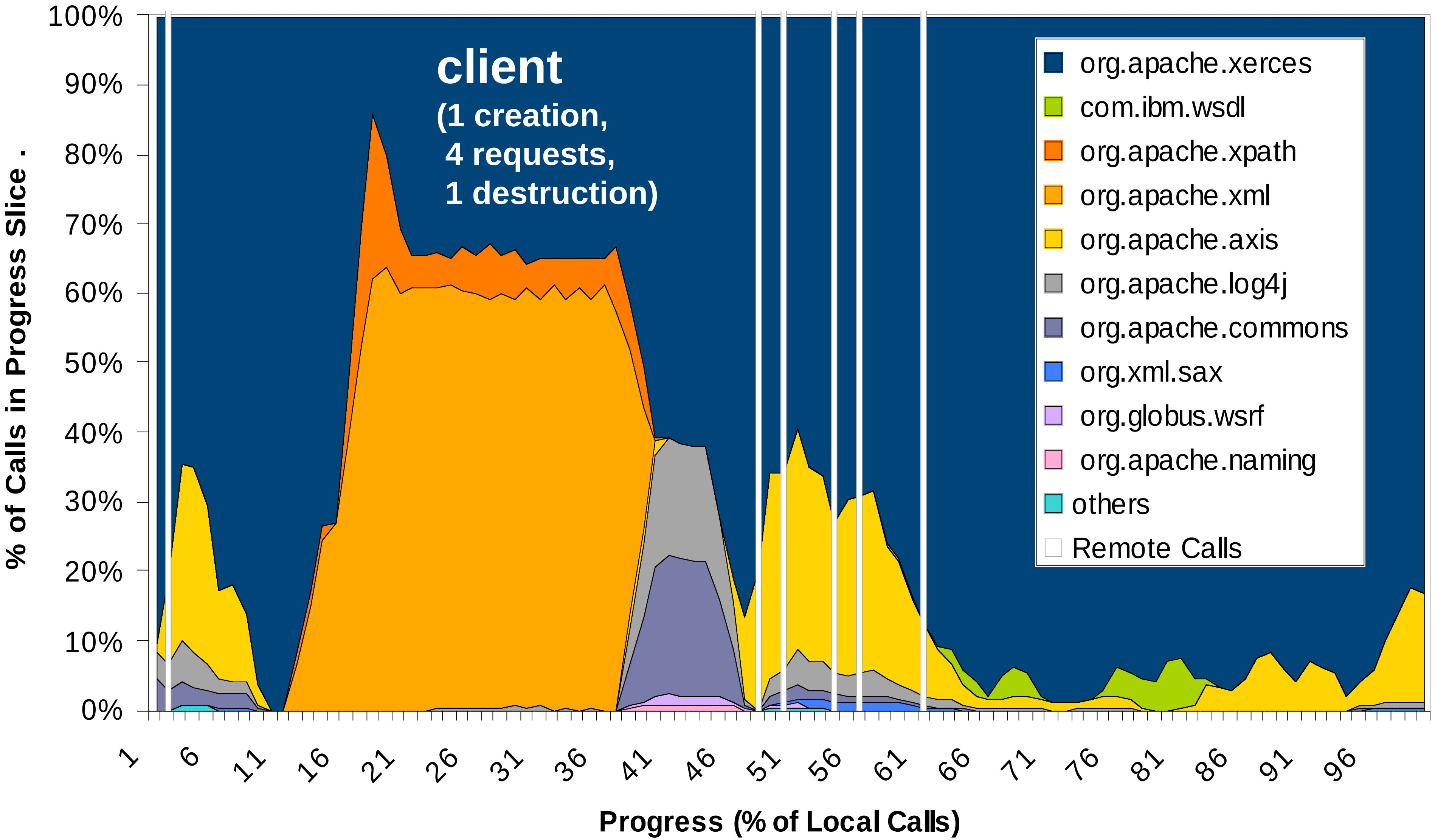
To look further

- Globus profiling
  - ➔ *The Impact of Web Service Integration on Grid Performance*, François Taïani, Matti Hiltunen, Rick Schlichting, HPDC-14, 2005
- Large graph reverse engineering
  - ➔ *CosmOpen: Dynamic reverse-engineering on a budget,* Francois Taiani, Marc-Olivier Killijian, Jean-Charles Fabre, TR COMP-002-2008, Lancaster University, 2008
  - ➔ http://ftaiani.ouvaton.org/7-software/index.html#CosmOpen
- Next Generation Middleware Group at Lancaster

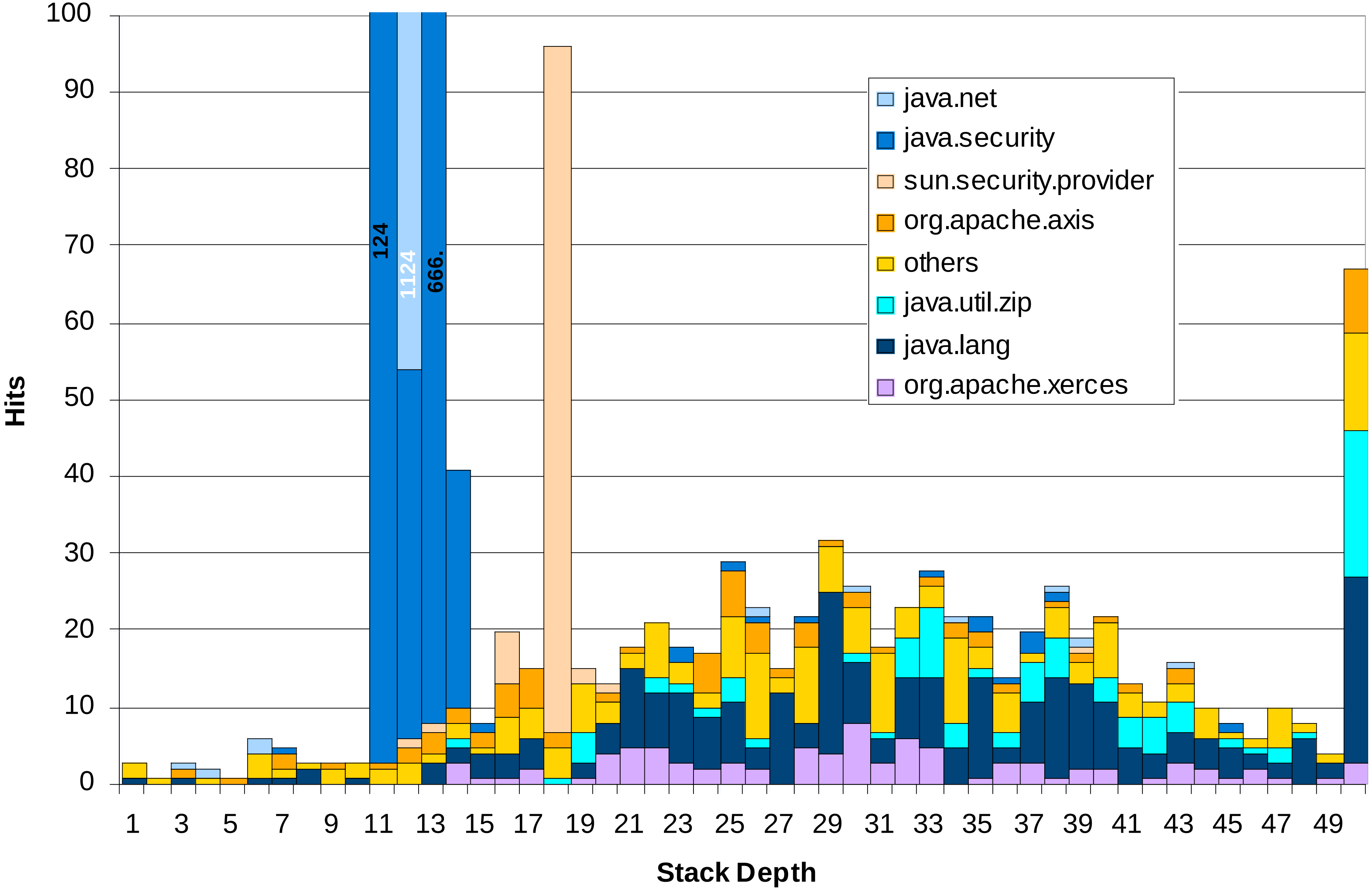
The End

(Thank you)

Package Activity vs. “Progress”



Profiling Results (Exclusive, Server)


Hits
java.net
java.security
sun.security.provider
org.apache.axis
others
java.util.zip
java.lang
org.apache.xerces
Stack Depth