Application-Level Debugging and Profiling: Gaps in the Tool Ecosystem

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For years instruction-level debuggers and profilers have improved in leaps and bounds. Similarly, system-level and network monitoring tools are increasingly ubiquitous. There is, however, a gulf between the two worlds which is widening as more and more processes and applications share system resources.

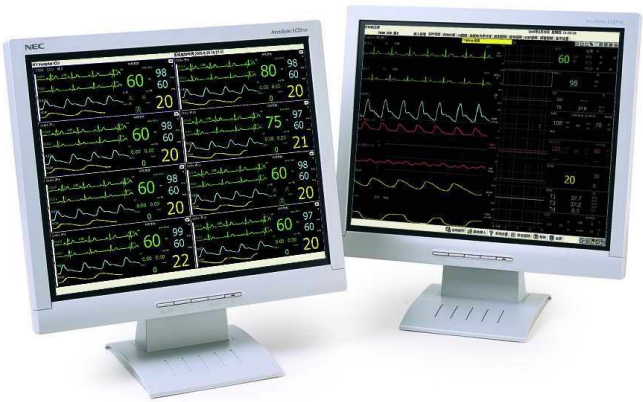
In this talk I will present the concepts of application-level tracing and what kind of information is available. I will run through the techniques for combining run-time data from different levels before moving onto some case studies. In particular I will present how a lack of application-level monitoring can lead to file-system bottlenecks and undetected network issues in distributed Linux HPC IT systems.

Application-level Tracing

Instruction-level code debugging

?

System-level monitoring of physical resources



Who am I?

PhD in Semiconductor Architecture and Electronic Design Automation (CAD)

Embedded Software and Digital Design

Too much time spent installing and configuring the CAD tools.

Too much time reading scripts.

Technical Director, Ellexus Ltd

Specialists in:
- Tracing Linux applications
- Profiling application file IO

We work out why your application doesn't work where it should.

We take the guess-work out of build issues and installation problems.

What am I going to talk about?

Profiling and debugging technologies

Our tools and how they work

Gaps in the tooling ecosystem

What the future might look like

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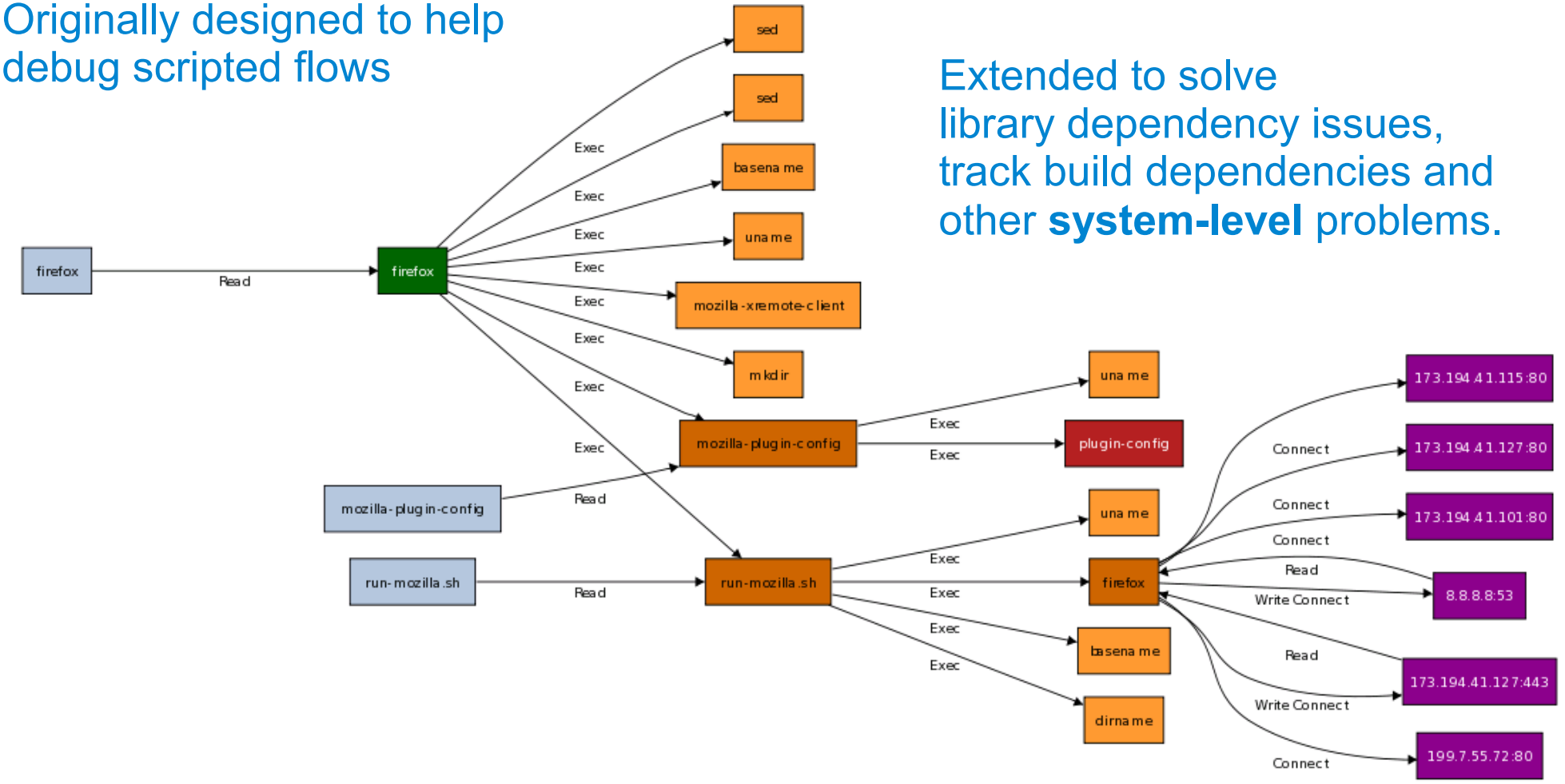
Breeze

Originally designed to help debug scripted flows



Extended to solve library dependency issues, track build dependencies and other **system-level** problems.

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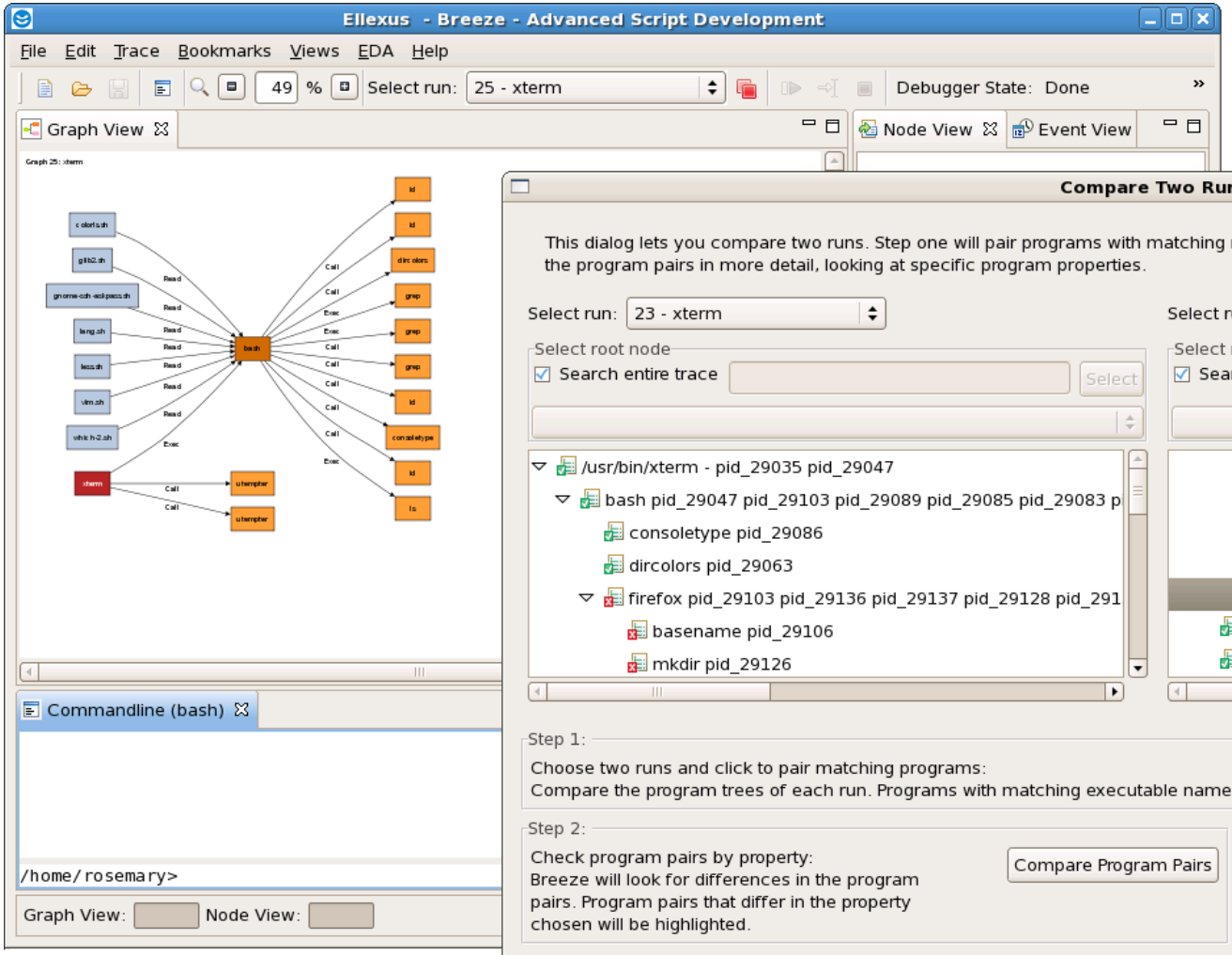
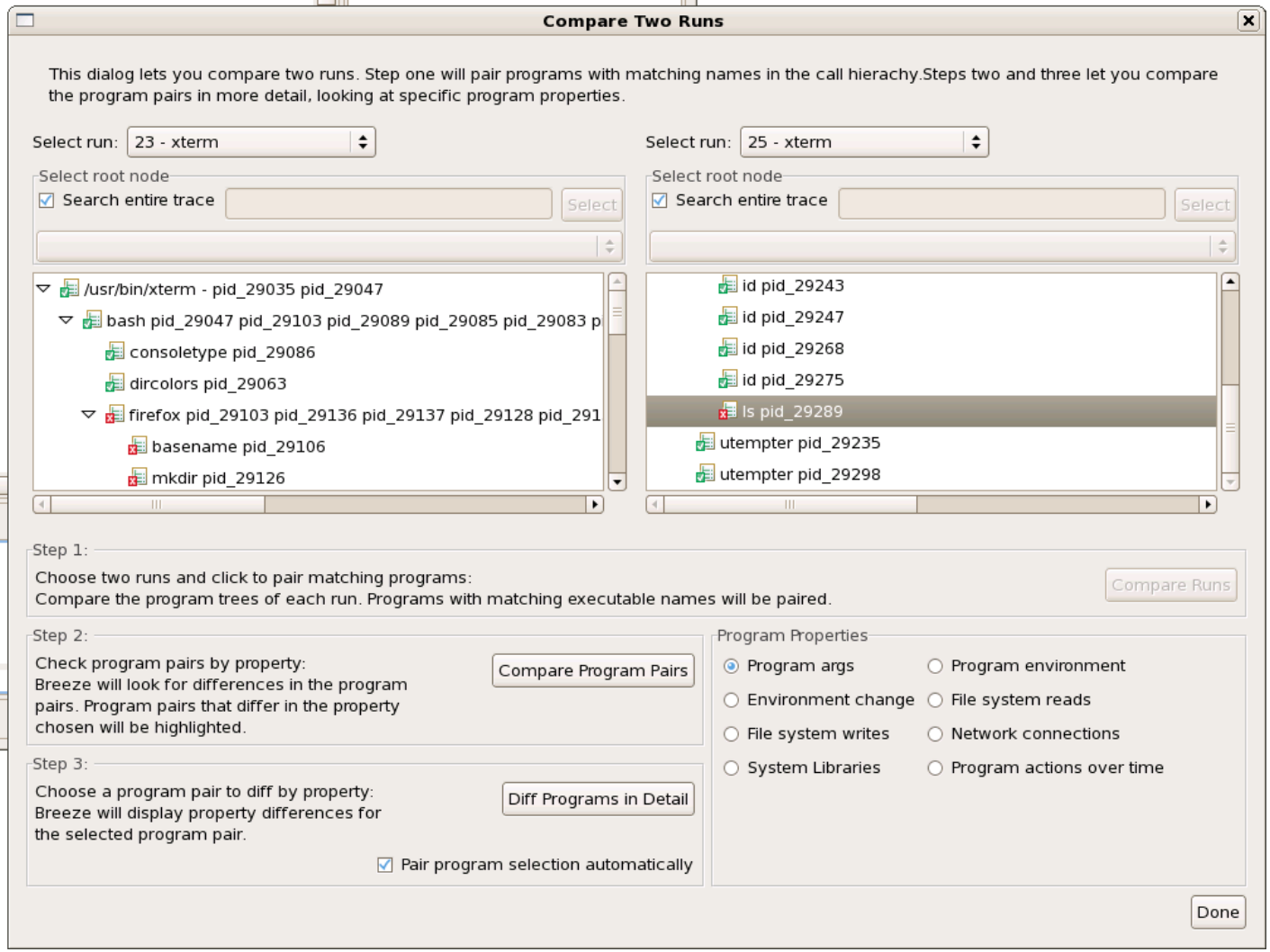
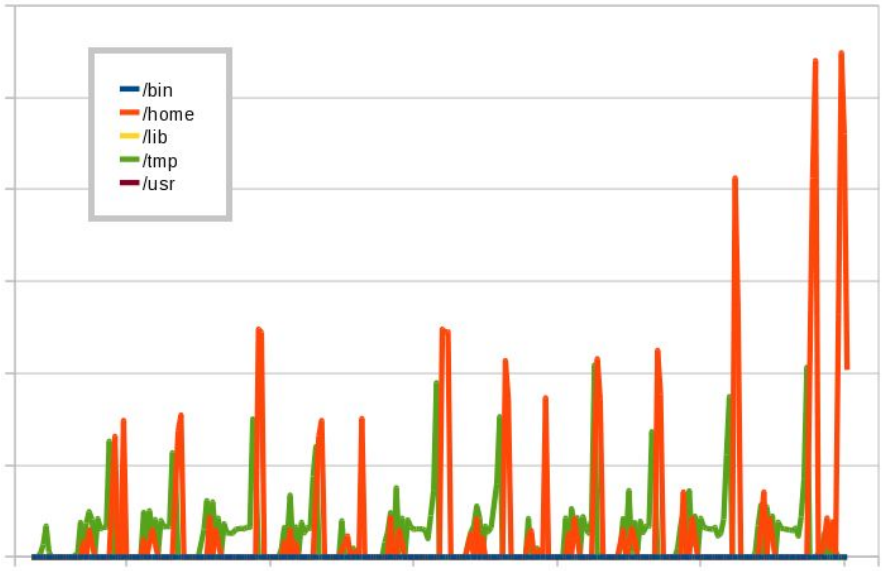
Breeze lets you compare applications





You can see what is different about a particular machine or user setting when it runs.

Breeze Profiling File IO



In 2012 we added file IO profiling for remote file systems.

We are increasingly being asked to solve file system, networking, power and memory issues.

Common factor: matching physical resource use with application stats

What else is available?

How does it work?

Instruction-level Debuggers

GDB swaps machine instructions for special 'breakpoint' instructions

Valgind rewrites the memory allocation code of your program

Lets you see the program in instruction-level detail

Difficult to get an overview

Measurement can change application behaviour

New Instruction-level Debuggers

UNDO takes snapshots so you can run your program backwards

Allinea DDT can debug parallel code across many machines

Debug symbols match the instructions to the code

Research into debug symbols continues to improve

Focus is on embedded, but what is embedded?

Application-level Debuggers: ptrace

Strace and Ltrace show system and library calls into the linux kernel

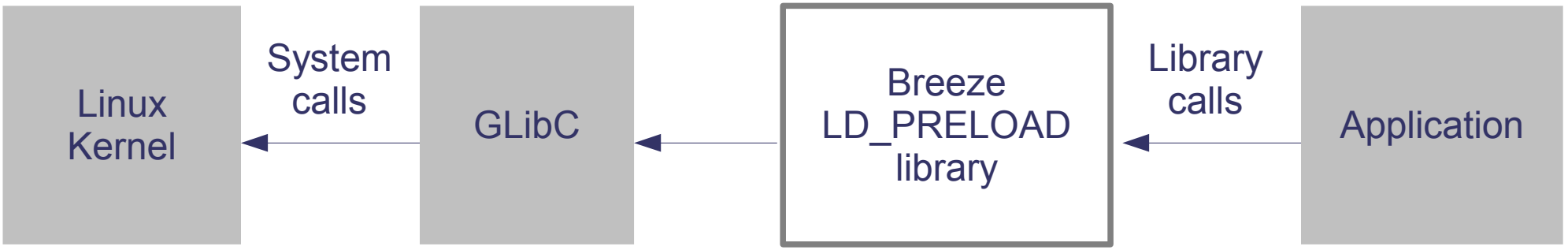
Both use a kernel facility called ptrace

They can solve some problems, but don't cope well with large applications

Application-level Debuggers: LD_PRELOAD

Breeze and others like it use LD_PRELOAD instead of ptrace
This is a technique that involves overriding library functions

Provides a powerful interface that can trace and control the application
Can easily be combined with other profiling data



LD_PRELOAD

Override library functions by matching the function signature
Use the dlsym function to get the next loaded library function with that name

```
int read(int fd, void *buf, int count)
{
   int (*next_read)(int fd, void *buf, int count)
   next_read = dlsym(RTLD_NEXT, "read")

   breeze_print(getpid(), "read", "%d", fd);

   return next_read(fd, buf, count);
}
```

Multi-machine LD_PRELOAD

Override exec() and re-write command arguements to modify remote jobs

```
ssh user@host ls -l /tmp
```

```
ssh user@host -o SendEnv=LD_PRELOAD ls -l /tmp
```

Switching file systems with LD_PRELOAD

Similar techniques can swap file systems, or suspend and resume jobs

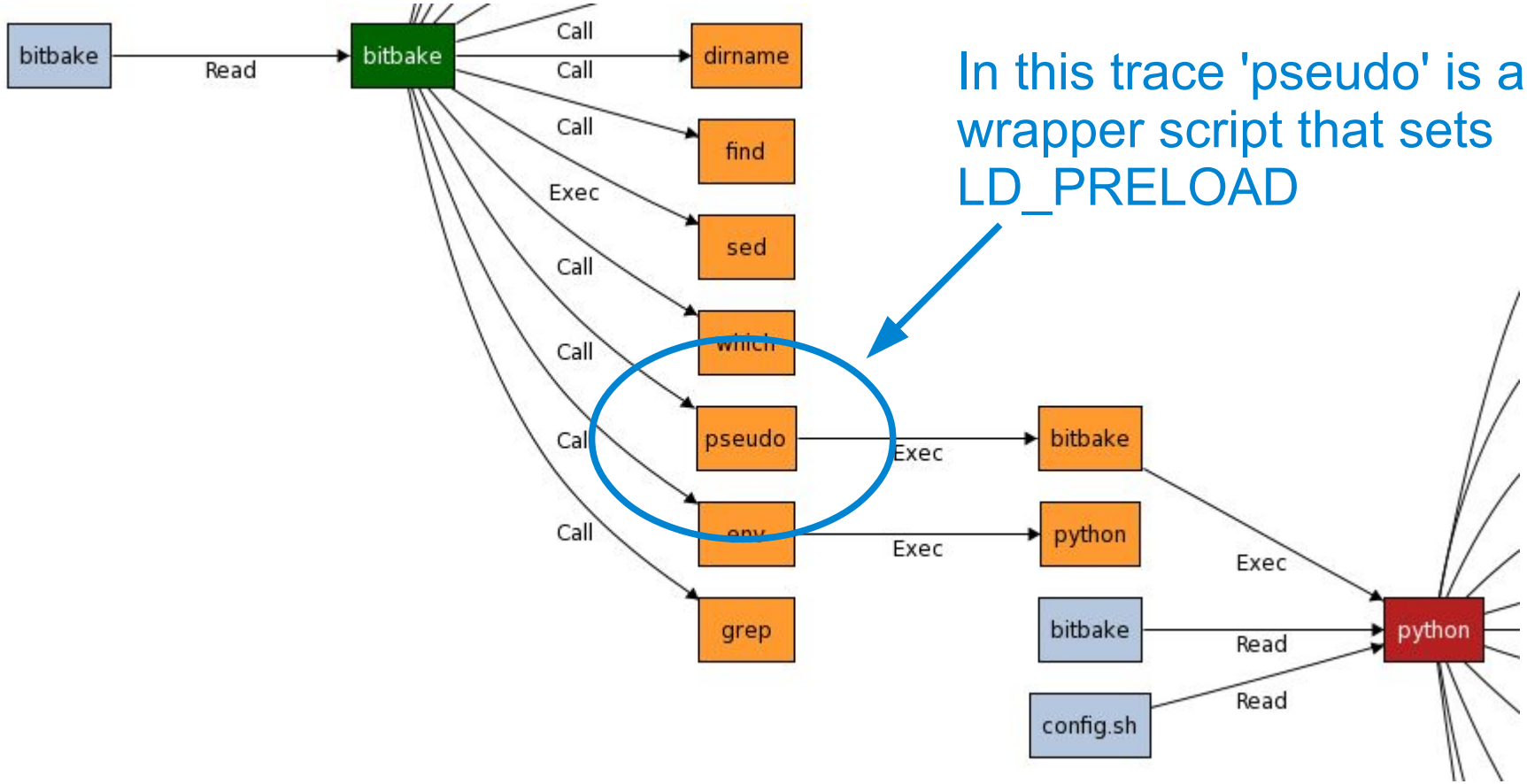
```
int open(const char *pathname, int flags)
{
   ...

   char *alt_pathname;
   asprintf(&alt_pathname, "%s/%s", "/alt", pathname);

   return next_open(alt_pathname, flags);
}
```

Yocto 'Pseudo'

Yocto is a Linux build system
It uses an LD_PRELOAD tool called Pseudo ('sudo') to fake root access

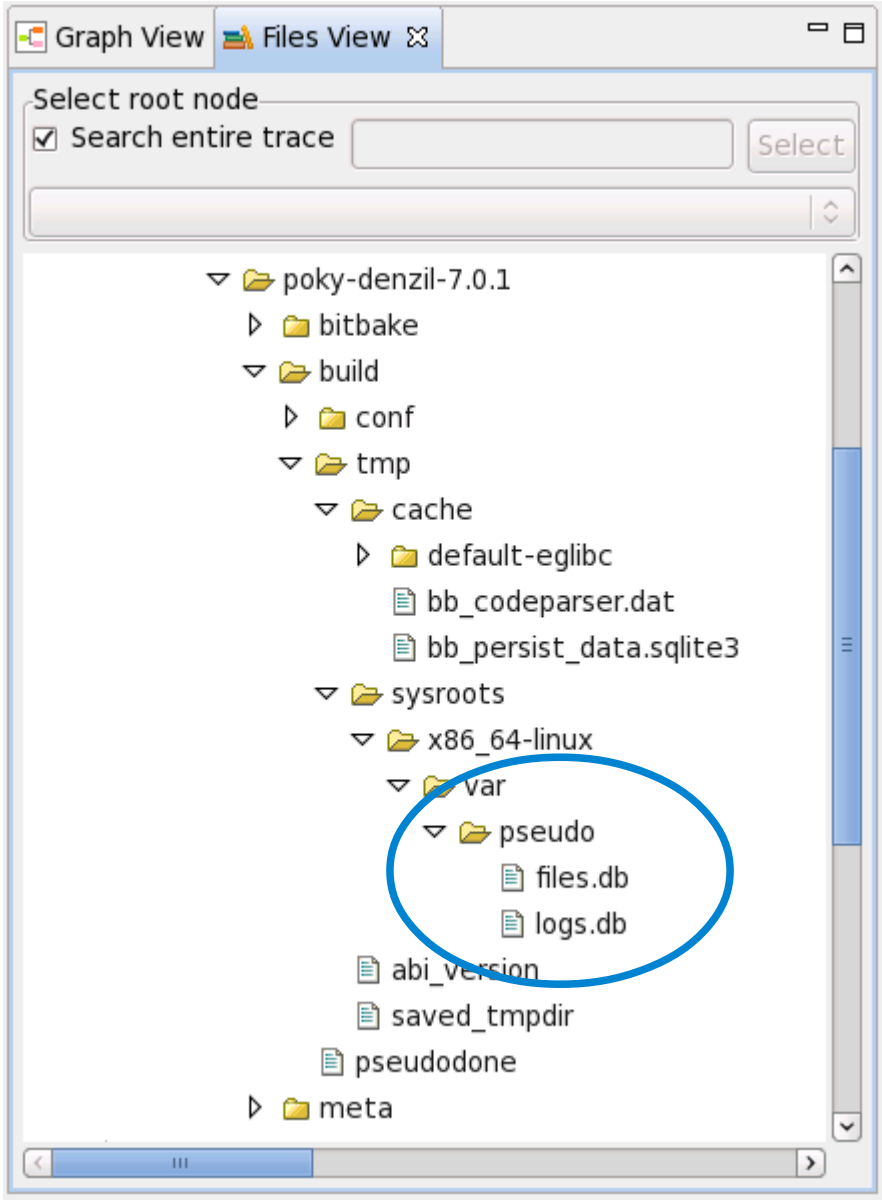


Yocto 'Pseudo' (2)

The LD_PRELOAD library redirects calls to open() read() and write() into a database.

The build thinks it is running as root and accessing the file system as normal.

In fact the build is modifying files in the database via the pseudo library.

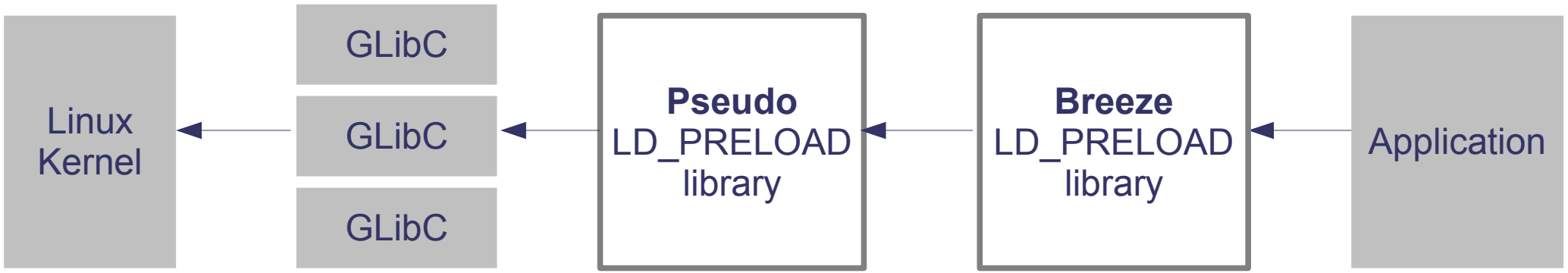


Getting it right

GlibC can have multiple versions of the same function.
This is even more complicated when another preload library is used.

It is important to preserve the original behaviour of the program.

Most of our code is involved in picking the right 'next' library version to use



Why should you care about application tracing?

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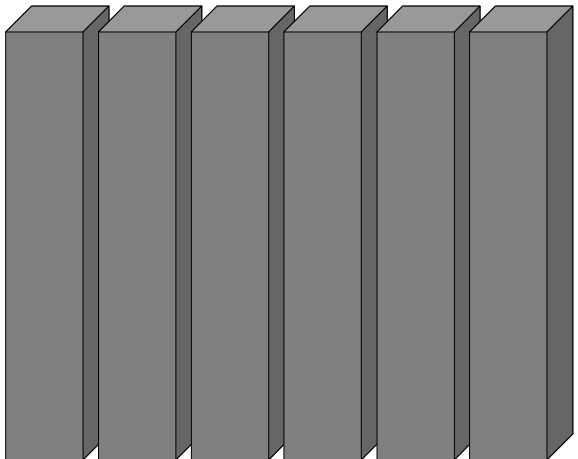
System Design

Job Scheduling

Virtualisation

Host OS



Multi-machine jobs

Suspend resume

Hierarchical file-systems

Virtualisation

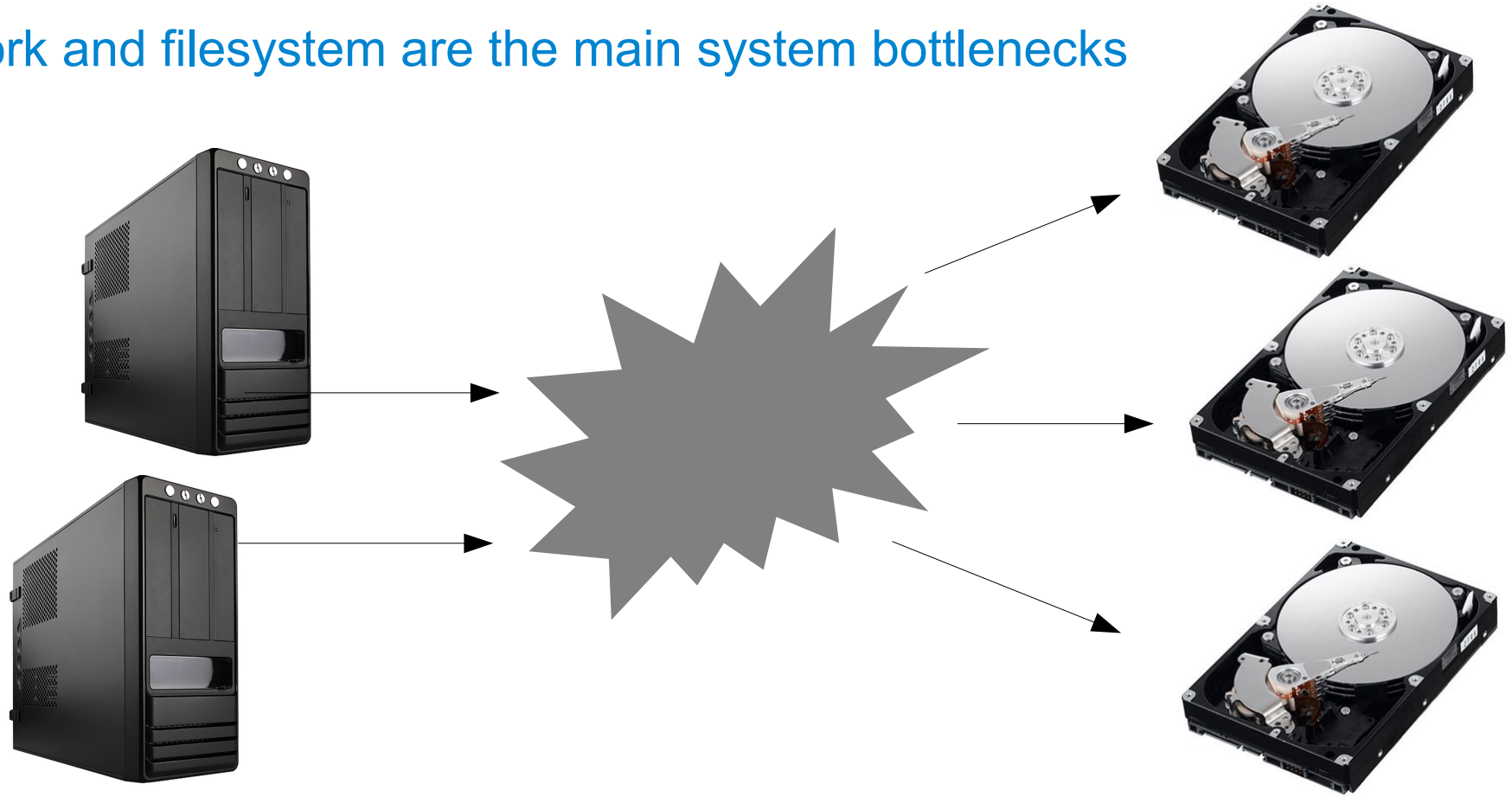
Homogenous hardware?
- not cost effective

Bromium – custom stack with one VM per app

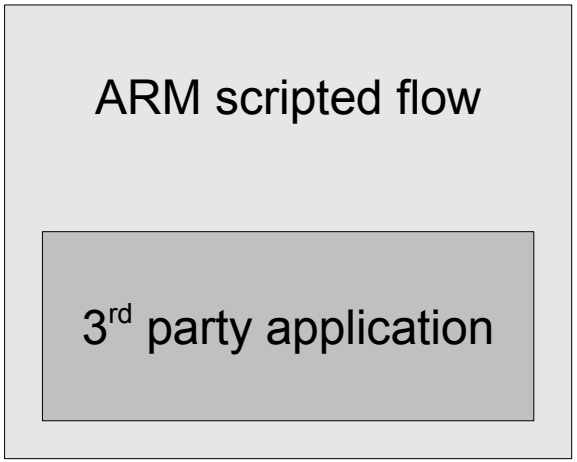
Case Study 1: ARM filesystem profiling

Networked filesystem with different performance for different areas

Network and filesystem are the main system bottlenecks



Case Study 1: ARM CAD Flow



Script dependencies

Application dependencies

License settings

Is everything being stored in the right place?

Case Study 1: Profiling file IO results

/scratch is medium-term storage and should only be used for results

We can see the writes at the end OK, but there are also lots of writes at the begining. This is a problem.

`/scratch`
is written to at the start of the trace

`/tmp`
is hardly used

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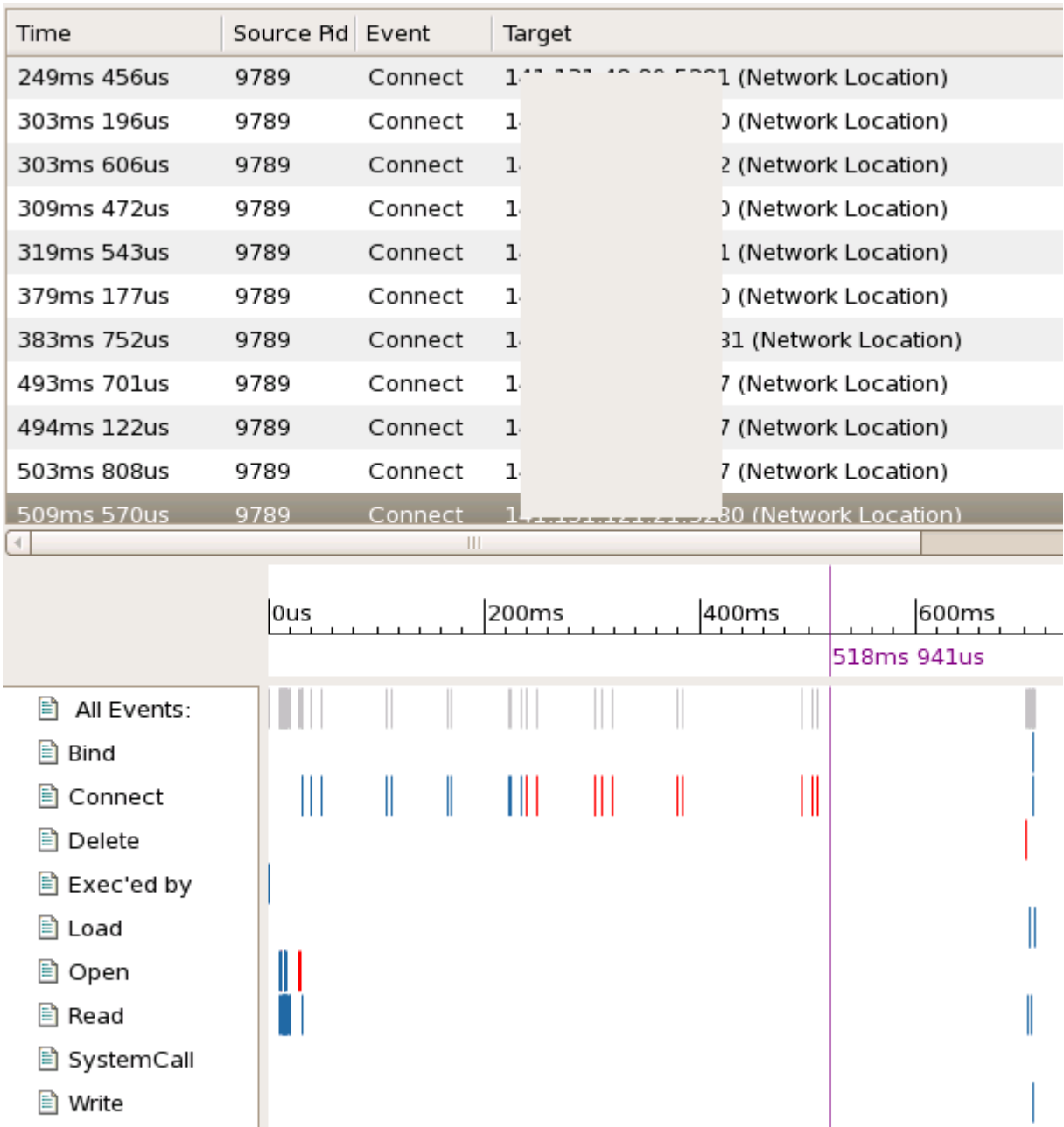
Case Study 2: Network IO

License server connections

This application spends
> 500ms connecting

Half of the connections fail
- it wastes 200ms



Case Study 3: Cadence Client Technology

One user couldn't type anything in new login systems

The IT manager traced a startx session for that user

Using Breeze he saw that xmbind was sourcing the wrong key bindings

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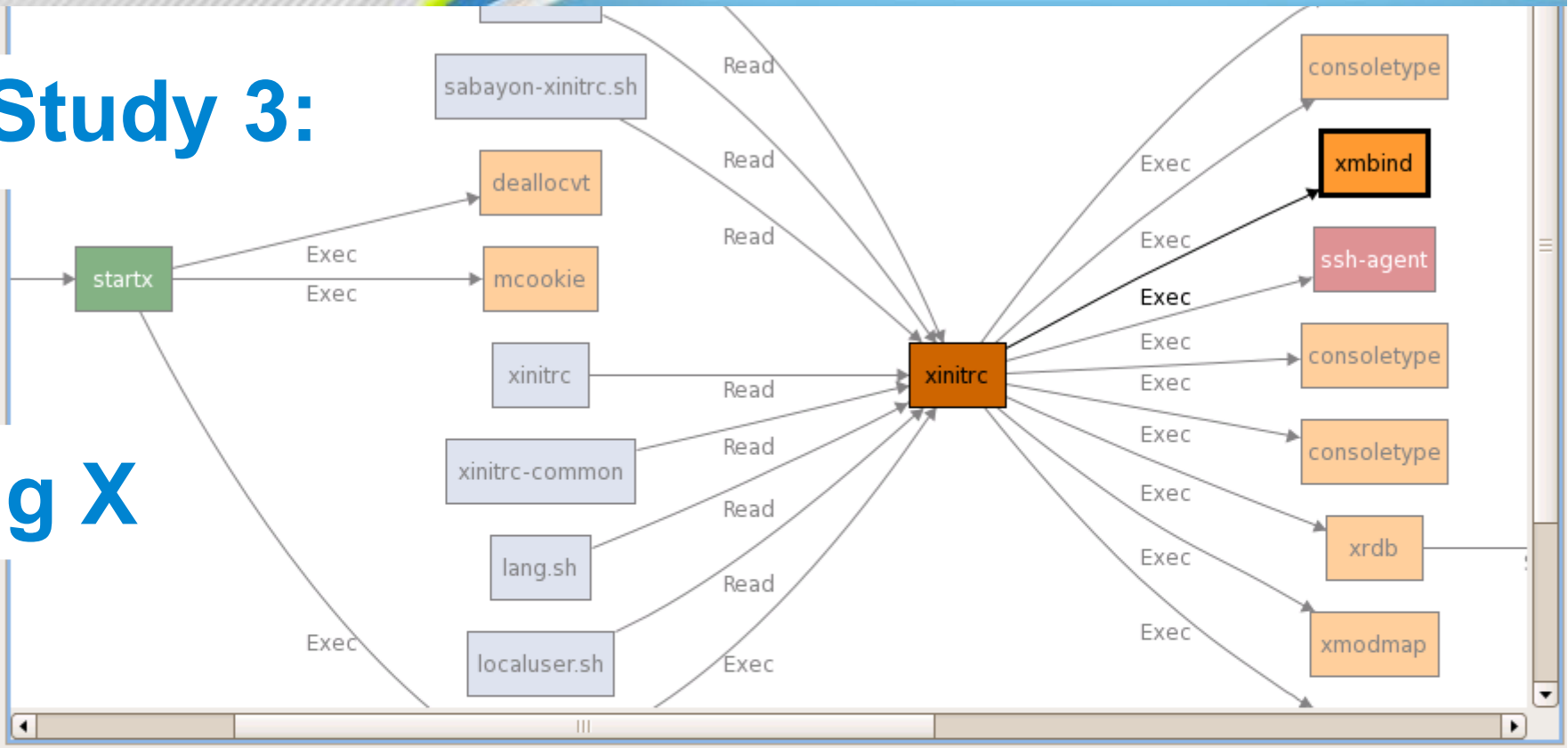
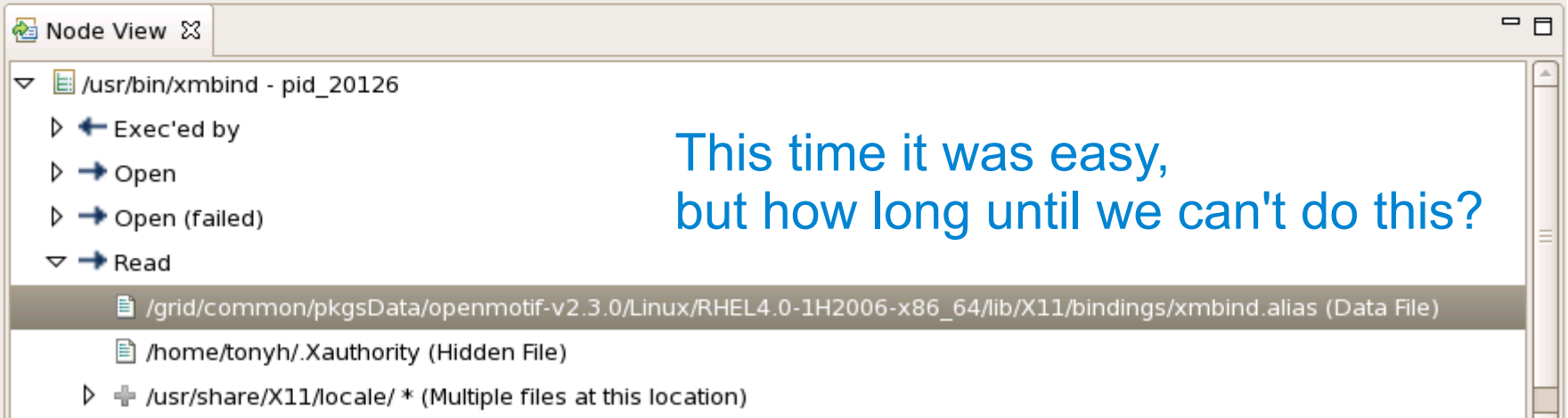
Case Study 3:

Tracing X

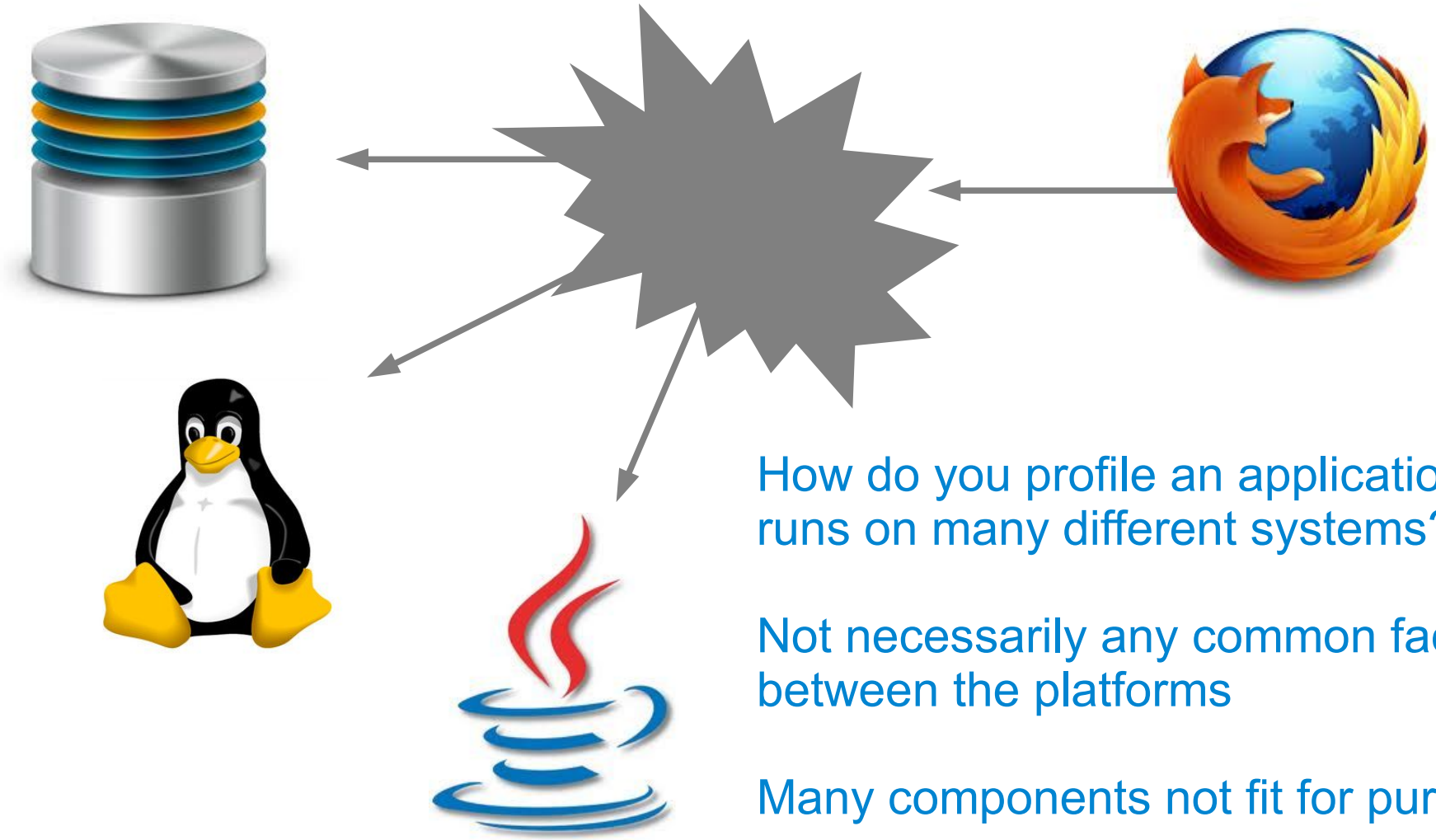




This time it was easy,
but how long until we can't do this?

Where do we go from here?

Problem 1: Distributed applications



How do you profile an application that runs on many different systems?

Not necessarily any common factors between the platforms

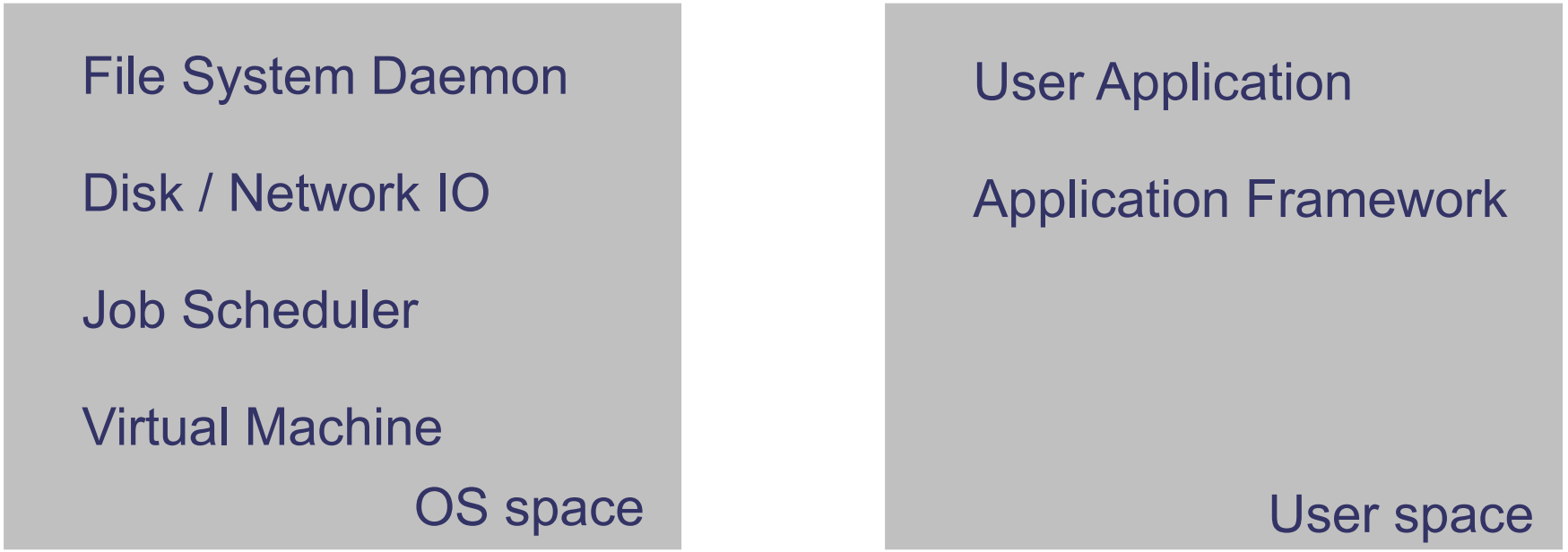
Many components not fit for purpose

Problem 2: What should we measure?

Hard to combine different data sets

We can't measure everything

We don't want to reverse engineer every system we need to profile



Solution: Design for Profiling?

We have all heard of Design For Test...

… introducing Design For Profiling

We can build programs with debug symbols and debug code

- This should be built into the high-level system design
- Profiling frameworks should be chosen at the start, not as an afterthought

Solution: Custom profiling frameworks

Breeze: *Trace

⇨ Customisable LD_PRELOAD framework

Jtrace : Java profiling and debugging

⇨ Open Source framework for inserting java snipppets into classes
Lets you instrument the java class libraries

… what next??

Big Data: Monitor everything and correlate

Grab information at all levels and look for trends

- Difficult to get fine-grain covereage without harming performance

Could be the only way to improve performance in very complex systems

- Cloud computing is only going to get more complicated

With enough data we could not only spot drops in performance, but we could predict resource needs such as memory consumption and power.

Now it's time for your ideas...

Thanks for listening

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