LISA 2015

# The Next Generation Cloud: Unleashing the Power of the Unikernel

Russell Pavlicek
Xen Project Evangelist
Russell.Pavlicek@XenProject.org

# About the Old, Fat Geek Up Front

- Linux user since 1995; became a Linux advocate immediately
- Delivered many early talks on Open Source Advocacy
- Former Open Source columnist for Infoworld, Processor magazines
- Former weekly panelist on “The Linux Show”
- Wrote one of the first books on Open Source: Embracing Insanity: Open Source Software Development
- 30 years in the industry; 20+ years in software services consulting
- Currently Evangelist for the Xen Project (employed by Citrix)
- Over 75 FOSS talks delivered; over 150 FOSS pieces published

# Why Am I Talking About This?

- I am not a unikernel implementer
- I am Evangelist for Xen Project, which is at the forefront of unikernel development
- There are a number of people implementing unikernels and discussing what they've done, but relatively few discussing the big picture
- This talk will attempt to examine both the forest and the trees:
  - We will discuss the value of the unikernel movement
  - We will examine several prominent unikernels and their uses
- The existence of these unikernels will alter the architecture of the cloud. Microservices will become smaller, faster, and more transient than today.

# Topic 1: The Forest

The importance of unikernels

# The Cloud We Know

- Field of innovation is in the orchestration
  - The Cloud Engine is paramount (OpenStack, CloudStack, etc.)
  - Workloads adapted to the cloud strongly resemble their non-cloud predecessors
    - Some basic adaptations to facilitate life in the cloud, but basically the same stuff that was used before the cloud
    - Applications with full stacks (operating system, utilities, languages, and apps) which could basically run on hardware, but are run on VMs instead.
    - VMs are beefy; large memory footprint, slow to start up
    - It all works, but its not overly efficient
    - 10s of VMs per physical host

# The Next Generation Cloud

- Turning the scrutiny to the workloads
  - Should be easier to deploy and manage
  - Smaller footprint, removing unnecessary duplication
  - Faster startup
  - Transient microservices
  - Higher levels of security
  - 1000s of VMs per host

# The New Stuff: Docker & Containers

- Makes deployment easier
- Smaller footprint by leveraging kernel of host
- Less memory needed to replicate shared kernel space
- Less disk needed to replicate shared executables
- Really fast startup times
- Higher number of VMs per host

# Docker Downsides

- Improvements, yes; but not without issues
  - Can't run any payload that can't use host kernel
  - Potential limits to scaleability
    - Linux not really optimized for 1000s of processes
  - Security
    - Security is a HUGE issue in clouds
    - Still working on security which brings containers up to the level of current solutions
      - We need to raise the bar *higher* in the cloud; status quo is not enough
    - As of 2014, Google & others ran Containers in VMs when they needed security

# The Unikernel: A Real Cloud Concept

- Very small
- Very efficient
- Very quick to boot
- And very, VERY secure!
- It's a Green (energy) technology which saves you green (cash); extremely important to foster adoption
- Many unikernels already exist, including MiniOS and MirageOS, a Xen Project Incubator Project

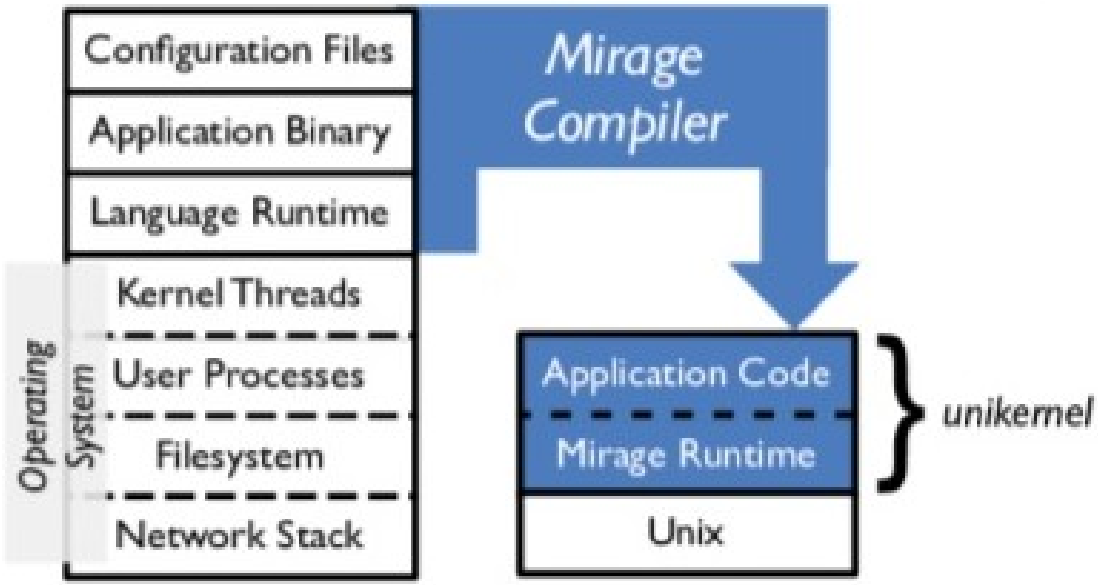
# What is a Unikernel? From MirageOS


***Unikernels*** *are specialised virtual machine images compiled from the modular stack of application code, system libraries and configuration*

# Unikernel Approach: MirageOS

Swap system libraries to target different platforms:

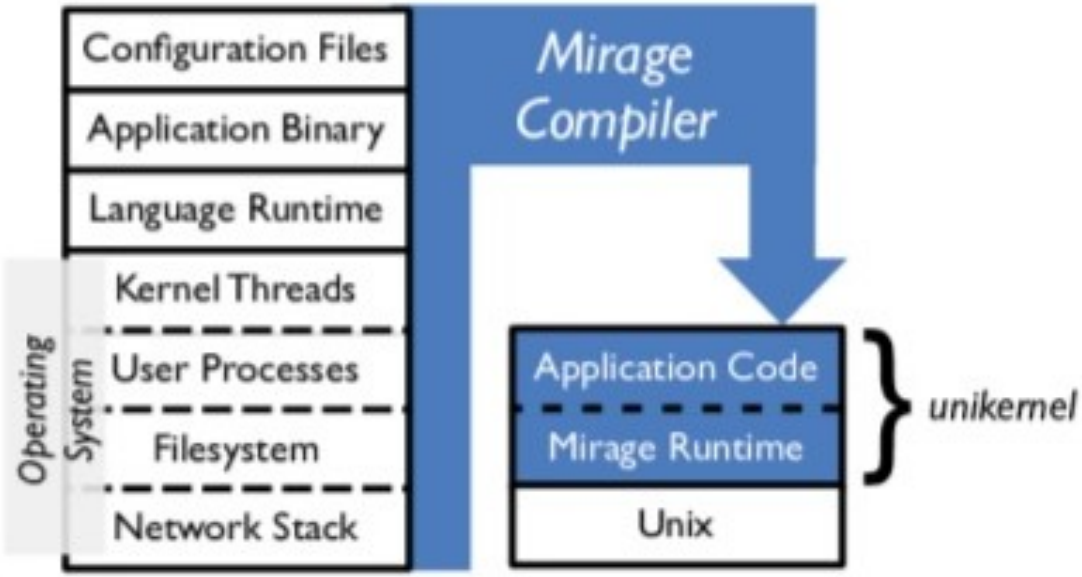
**develop application logic using native Unix.**



# Unikernel Approach: MirageOS

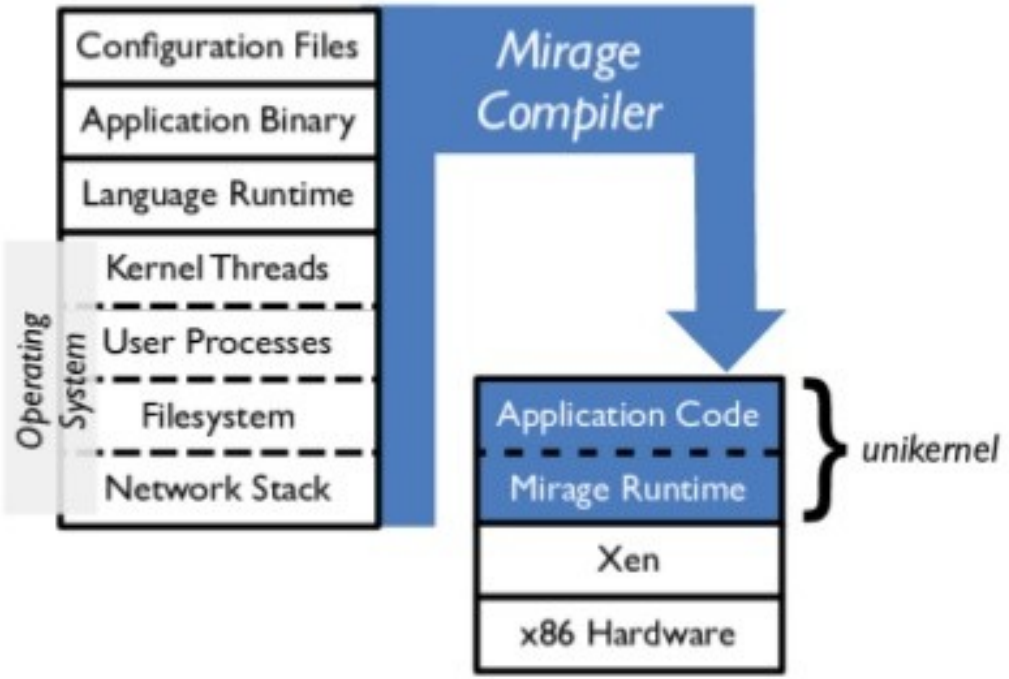
Swap system libraries to target different platforms:

**test unikernel using Mirage system libraries.**



# Unikernel Approach: MirageOS

Swap system libraries to target different platforms:
**deploy by specialising unikernel to Xen.**



# Unikernel Concepts

- Use just enough to do the job
  - No need for multiple users; one VM per user
  - No need for a general purpose operating system
  - No need for utilities
  - No need for a full set of operating system functions
- Lean and mean
  - Minimal waste
  - Tiny size

# Unikernel Concepts

- Similar to an embedded application development environment
  - Limited debugging available for deployed production system
    - You have exactly the tools you built into the stack
  - Instead, system failures are reproduced and analyzed on a full operating system stack and then encapsulated into a new image to deploy
  - Tradeoff is required for ultralight images

# What Do the Results Look Like?

- Mirage OS examples:
  - DNS Server: 449 KB
  - Web Server: 674 KB
  - OpenFlow Learning Switch: 393 KB
- LING metrics:
  - Boot time to shell in under 100ms
  - Erlangonxen.org memory usage: 8.7 MB
- ClickOS:
  - Network devices processing >5 million pkt/sec
  - 6 MB memory with 30 ms boot time

# What About Security?

- Type-Safe Solution Stack
  - Can be certified
  - Certification is crucial for certain highly critical tasks, like airplane fly-by-wire control systems
- Image footprints are unique to the image
  - Intruders cannot rely on always finding certain libraries
  - No utilities to exploit, no shell to manipulate

# Topic 2: The Trees

Some of the current leading unikernels

# What's Out There Right Now?

- MirageOS, from the Xen Project Incubator
- HaLVM, from Galois
- LING, from Erlang-on-Xen
- ClickOS, from NEC Europe Labs
- OSv, from Cloudius Systems
- Rumprun, from the Rump Kernel Project
- And that's just the beginning...

# MirageOS

- From the Xen Project Incubator
- Language support: Ocaml
- Hypervisor support: Xen Project
- V2.0 released in 2014
- General purpose devices
- Can be run on Amazon EC2
- http://www.openmirage.org/

# HaLVM

- Galois, Inc.
- Language support: Haskell
- Hypervisor support: Xen Project
- Originally designed to prototype operating system components
- Now suitable for creating network devices
- https://galois.com/project/halvm/

# LING

- Erlang-on-Xen project
- Language support: Erlang
- Hypervisor support: Xen Project
- Use cases include Zero-Footprint Cloud
- http://erlangonxen.org/

# ErlangOnXen.org Website

**System info:**

```
os_type:     ling
compat_rel:  17
wordsize:    4
smp_support: false
heap_type:   private
schedulers:  1
hipe_architecture: none
machine:     LING
```

**Modules:**

```
init
global_group
hipe_unified_loader
group
cow_http_hd
beam_dtl
clustering_dtl
iops_handler
contact_dtl
inet
 (and 140 more)
```

**Statistics:**

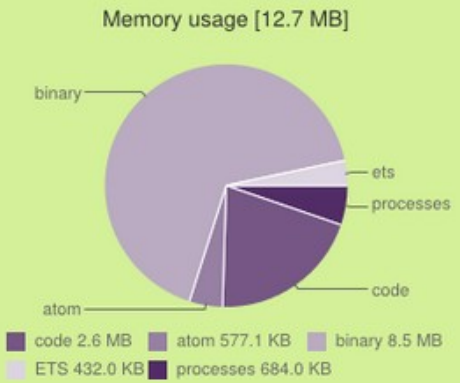
```
context_swithes: 1714004
GC, runs:        3267409
GC, reclaimed:   2.0 GB
reductions:      126941023
run_queue:       0
runtime:    134575
wall_clock: 518565825
```

**Processes:**

```
<0.73.0>
<0.74.0>
<0.57.0>
<0.52.0>
kernel_safe_sup
user_drv
user
<0.50.0>
<0.51.0>
standard_error_sup
 (and 50 more)
```

**Applications:**

```
crypto
webling
kernel
stdlib
cowlib
cowboy
ranch
```



# ErlangOnXen Zerg Demo

**300 sec** is how long it takes to launch a Linux instance to availability on Amazon EC2.

**50 sec** is the time between power on and the lock screen for an Android phone.

**0.4 sec** ago is when we received your request. Within this time we managed to create a new Xen instance, boot it, and run the application that rendered the page you are viewing. By the time you are done reading this, the instance will be gone.

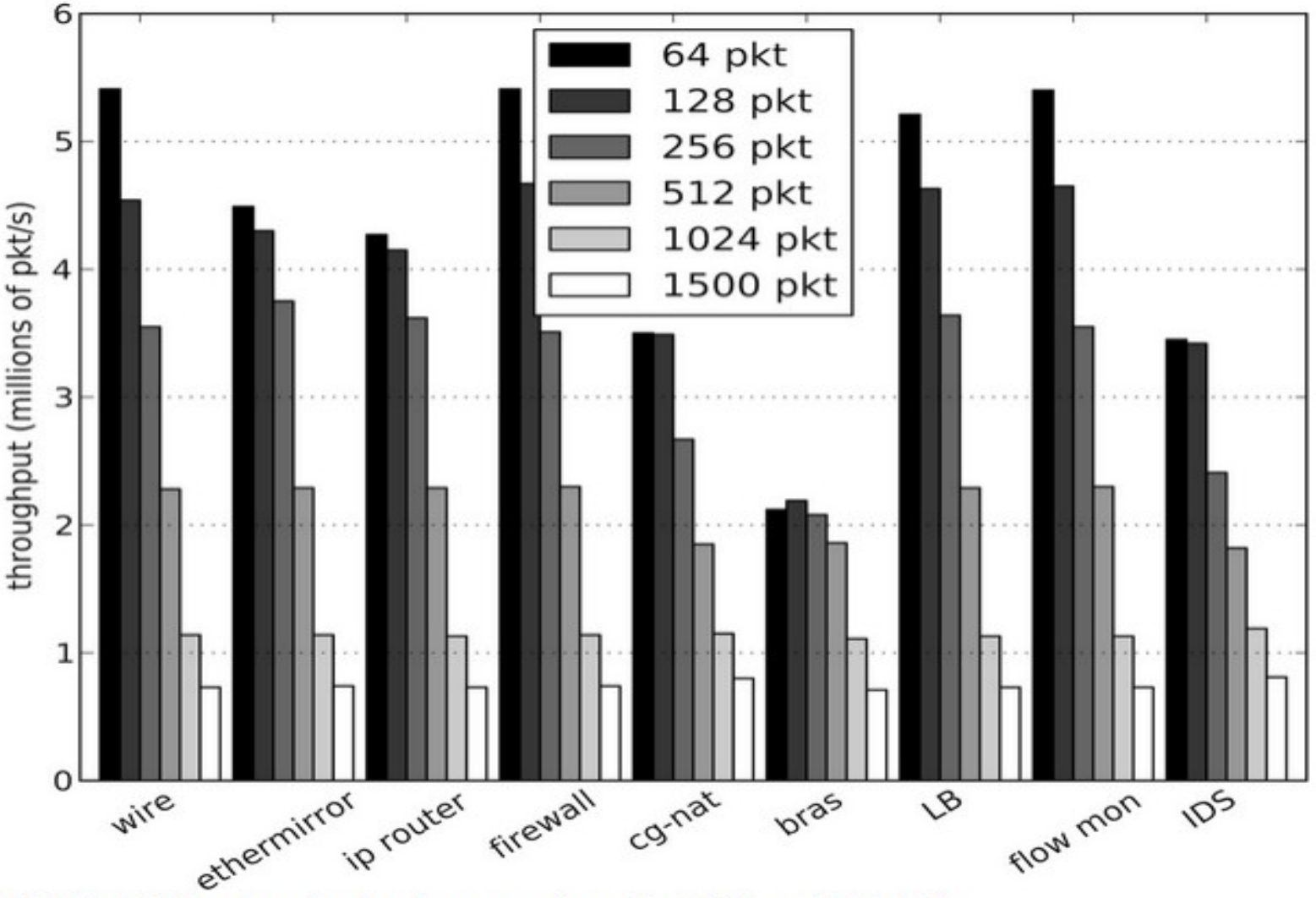
**Why is this important?** The fast startup is the cornerstone of the super-elastic clouds of the future. Think personal Facebook, personal Gmail, personal bank at the new level of privacy and security... more

This demo was made possible by Erlang on Xen.

# ClickOS

- NEC Europe Labs
- Language support: C, C++, Python
- Hypervisor support: Xen Project
- V0.2 released in 2014
- Suited for Network Function Virtualization (NFV) devices
- http://cnp.neclab.eu/clickos/

# ClickOS Throughput




ClickOS middlebox throughput performance using a single CPU core for the VM.

# OSv

- Cloudius Systems (now ScyllaDB)
  - Company may have moved on, but their Open Source project survives
  - Language support: C, C++, Java, Python, Javascript, Node.js, Ruby
- Hypervisor support: Xen Project, KVM, VMware
- Slightly different from “standard” unikernels
  - Kind of “fat”
  - Full Java JVM stack, minus multi-processes (threads yes, forks no)
  - Can run almost any JAR file
- NFV optimized
- http://osv.io/

# Rumprun

- A working product of the rump kernel ecosystem (which we'll discuss shortly)
- Under active development, rumprun does allow a growing number of programs to run as-is
  - Its goal is to a universal base for most unikernel-appropriate workloads for currently existing real-world POSIX-based applications
  - It has the potential to open the door to a *huge* number of functional unikernels
- http://repo.rumpkernel.org/rumprun

# What About the Unikernel Ecosystem?

- If this is more than just a few isolated experiments in unikernel concepts, we'd expect to see some advances in the general ecosystem
- The unikernel ecosystem is forming:
  - Jitsu (https://github.com/MagnusS/jitsu)
  - MiniOS (http://wiki.xenproject.org/wiki/Mini-OS)
  - Rump Kernels (http://rumpkernel.org/)
  - Xen Project itself

# Jitsu

The Jitsu Website says:

***Just-In-Time Summoning of Unikernels***

- *Jitsu is a forwarding DNS server that automatically starts virtual machines (VMs) on demand. When a DNS query is received, jitsu first checks for a local VM that is mapped to the requested domain. If a VM is found, the VM is started and its IP is returned to the client. Otherwise, the request is forwarded to the next DNS server. If no DNS requests are received for the VM within a given timeout period it is automatically stopped.*
- *Although Jitsu can be used with any VM that can be controlled with libvirt, it is mainly intended for use with unikernels that can be started quickly and be able to respond to the client request within the time it takes to send the DNS response.*

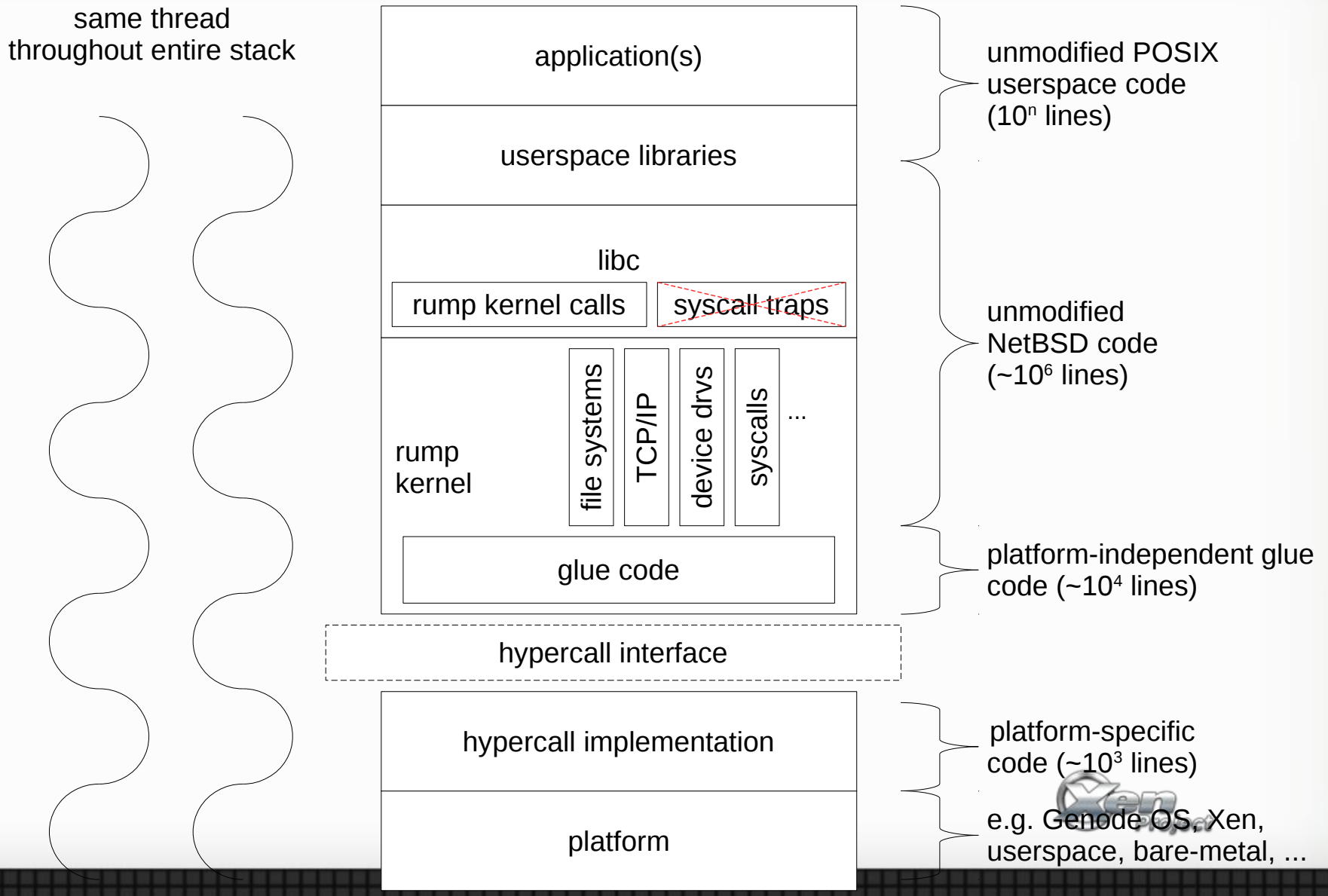
# MiniOS

- Small basic unikernel
- Distributed with Xen Project source
- Originally designed for driver disaggregation
- Base for others to build their unikernel projects
  - ClickOS, for example
  - Also the base for the earliest version of rumprun, which has advanced considerably since

# Rump Kernels

- Derived from the work of the NetBSD community
- Employs the notion of a kernel containing just enough code to get real work done
  - Concept is not limited to NetBSD, but existing work leverages NetBSD
- An open-ended framework containing production-quality drivers, currently manifesting itself in the *rumprun* unikernel
- Supports Xen Project, bare metal, userspace environments

# Rump Kernel Architecture



# THIS JUST IN...

**News Flash:** *The Fat Boy up front was **wrong**!*

*You **CAN** do databases as Unikernels!*

# BRAND NEW: The “RAMP” Stack!

- Just revealed in March: Nginx, MySQL, and PHP built on Rump Kernels!
- No rearchitecting the application; the work is in getting things to cross compile correctly (Nginx & MySQL)
- Working out usability and config kinks still
- Unikernel-compatible unmodified POSIX C and C++ applications “just work” on top of Rump Kernels, provided that they can be cross-compiled
  - Stacks on Rump Kernels are *always* cross-compiled, since the compiler *never* runs directly on the Rump Kernel
- Still in skunkworks stage; watch Twitter @rumpkernel for announcement when it is done

# More Rump Kernel & RAMP Info

- Rump Kernels contain the work of many BSD contributors, all the way back to the 1980s
- Antti Kantee leading the Rump Kernel project
- Martin Lucina leading the RAMP work
- Current Temporary Github repositories (will probably be replaced with a permanent Wiki page):
  - https://github.com/mato/rump-php
  - https://github.com/mato/rump-mysql
- Rump Kernel Mailing List:
  - http://www.freelists.org/list/rumpkernel-users
- Rump Kernel Twitter:
  - @rumpkernel

# Xen Project as Ecosystem Enabler

- Work proceeds on support for 1000s of VMs per host
  - Recent redesign of Event Channels removes obstacles to uncap VM growth (theoretically, into millions of VMs)
  - Currently, performance is strong up to around 600 VMs per host
  - Other areas identified and targeted to enable 2000-3000 VMs per host
- Paravirtualization makes creation of a unikernel much simpler
  - Simpler PV interfaces remove need for complex H/W drivers

# And Still More To Come...

- Arrakis (http://arrakis.cs.washington.edu/)
  - Derived from the Barrelfish operating system
- Clive (http://lsub.org/ls/clive.html)
  - Using the *go* language
- IncludeOS
  - C++ on KVM

# Are Unikernels a Panacea?

- Nope!
  - But it doesn't have to be a panacea to return value
  - There will always be really large databases and beefy apps which won't fit in this mold
  - The truth is that different problems are likely to require different optimal solutions for the foreseeable future
  - It is likely that the solution spectrum of the next few years will include a blend of unikernels, containers, and standard virtualization
  - But the arrival of unikernels means that the bar to efficiency has been raised to new heights

# What Does This Mean for Architecture?

- We like to talk about Microservices; we are witnessing the birth of *Transient Microservices*
  - Lifetimes possibly measured in fractions of second
  - Populations in the thousands per host
  - Now these aren't small just from an external standpoint, but internally as well
  - It's much easier manipulating smaller items than bigger ones, so what was once difficult to change becomes easier to change

# Open Source Leading the Way

- This is an example of how Open Source is working to expand horizons of the cloud
  - The closed source cloud just isn't the way to go
  - The real innovation in cloud is in Open Source
  - Xen Project is at the forefront of new cloud thinking, incubating and facilitating new technologies, including unikernels
  - Friends don't let friends go closed source in the cloud!

# The Xen Project Difference

- The Cloud is too critical to leave to hypervisors which are not working to create the future
  - If your hypervisor is just focused on yesterday's payloads, it won't help you get to the next generation cloud
  - Select a hypervisor which is innovating – and Open Source
  - Xen Project is busy moving the cloud forward

# More on Unikernels!

- We're having a Unikernels & More Day at SCALE 14X!
  - Southern California Linux Expo
  - January 22, 2016 in Pasadena, CA
  - We expect to have several speakers talking about the bits & bytes of running specific Unikernels
  - Join us!

# Stay Informed!

- Sign up for the Xen Project newsletter
  - One 4-minute read per month to learn what's happened and what's coming
    - Announcements
    - Blog posts
    - Upcoming events
  - Subscribe to the monthly newsletter here: http://xenproject.org/subscribe.html

# Questions?

Russell.Pavlicek@XenProject.org

Twitter: @RCPavlicek

*Thanks to the Mirage OS team and Antti Kantee of the Rump Kernel project for the use of their images. Thanks to NEC Europe Ltd (ClickOS) and ErlangOnXen (LING) for the use of images from their respective websites. Rights to same belong to the copyright holders.*

This presentation is available in the Presentations Section of XenProject.org