OpenBSD/sun4v: Porting OpenBSD to Sun's UltraSPARC T1 and T2 processors

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OpenBSD

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Outline

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Introduction

Just like BSD, SPARC is very undead!

- Oracle just unveiled the a new SPARC CPU
- World's Nr. 1 supercomputer is SPARC

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Short History of SPARC

- 32-bit SPARC V7/V8
  Lots of implementations
- 64-bit SPARC V9
  - Fully specified unpriviliged mode
  - Partly specifies priviliged mode

  First implemented by HAL/Fujitsu: SPARC64
  Sun followed with UltraSPARC (sun4u)
  - Priviliged mode differse between SPARC64 and UltraSPARC (MMU)

  Attempt to make SPARC64 and UltraSPARC more compatible: SPARC Joint Programming Specification (JPS1).
  - Fujitsu SPARC64-V
  - Sun UltraSPARC III

  Sun UltraSPARC IV: First SPARC multicore

  Sun UltraSPARC T1: Chip Multithreading, Hypervisor (sun4v)

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OpenBSD on SPARC V9

- OpenBSD/sparc64 runs on
  - Sun UltraSPARC I, II, III, IV, T1 and T2
  - Fujitsu SPARC64-V, SPARC64-VI and SPARC64-VII

  Almost all machines are supported (including laptops and E10000)
- Based on the NetBSD port by Eduardo Horvath
- Porting to OpenBSD started in 2001; mostly done by Jason Wright with help from Arthur Grabowski.
- Officially supported since OpenBSD 3.0
- OpenBSD 4.0 was the first release to run on UltraSPARC III
- OpenBSD 4.4 added support for Fujitsu SPARC64

OpenBSD is the only fully Open Source OS supporting Fujitsu SPARC64!

SPARC V9 “features”

- RISC
- Register windows
- Software TLB
- Fast traps
- Prioritized interrupts

Chip Multithreading

- Hyperthreading on steroids
  4 or 8 threads per core instead of just 2
- Modern CPUs spend a lot of time waiting for memory access
- Switch to another thread and continue to do useful work
- Multicore
  - Up to 64 virtual CPUs per chip.
  - Up to 4 chips per machine.
  - Up to 256 virtual CPUs per system (T5440).

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Step 1: OpenBSD on "bare metal"

Initial Hypervisor release had no domaining capabilities

CPU support

- Unpriviliged instruction set 100% compatible with SPARC V9
- Mostly compatible with older UltraSPARC processors
- MMU Translation Table Entries have diffrerent format
- sun4u: different sets (AG, IG, MG) of globals selected by trap type can be switched by modifying %pstate
- sun4v: different sets of globals selected by trap level; can be switched by modifying %gl

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Bootloader

- 1st stage bootloader written in Forth;
  no changes necessary
- 2nd stage bootloader written in C;
  calls OpenBOOT for all hardware access
  no changes necessary either
- Kernel needs lots of changes

Goal

Single kernel for sun4u and sun4v

Code patching

```
#define NORMAL_GLOBALS() \
999: wrpr      %g0, PSTATE_KERN, %pstate  ;\
      .section          .sun4v_patch, "ax" ;\
      .word    999b                        ;\
      wrpr     %g0, 0, %gl                 ;\
      .previous
```

```
struct sun4v_patch {
    u_int32_t addr;
    u_int32_t insn;
}
```

Also used to patch away cache flushes;
UltraSPARC T1/2 no longer has virtual cache aliasing

Traps

- SPARC V9 trap handling can be deep:
  - Register windows
  - Software TLB
- sun4u: 4 levels of nested trap levels
- sun4v: 4 leves, but 2 reserved for Hyperpriviliged mode
  - Hypervisor helps by doing some of the TLB handling
  - Still some trickery needed: ivert order in which traps are handled
- Seperate trap handlers for sun4u and sun4v

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System support

CPU support is not enough

Also need to be able to talk to the system hardware to do I/O.

Device drivers:

- vbus(4) virtual device bus
- vpci(4) virtual PCIe host bridge
- vrng(4) virtual random number generator
- vrtc(4) virtual real time clock

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PCI host bridge

Several generations of PCI host bridges un sun4u:

- **Psycho** UltraSPARC I/II/IIi; psycho(4)
- **Schizo** UltraSPARC III/IIIi/IV; schizo(4)
- **Fire** UltraSPARC IIIi, PCIe; pyro(4)

Host bridge handles:

- PCI config space access
- PCI interrupt management
- IOMMU management

sun4v Hypervisor provides these services; vpci(4) makes Hypervisor calls instead of direct hardware access

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Step 2: OpenBSD in a guest domain

Later Hypervisor added domaining capabilities

OpenBSD in a guest domain

Firmware upgrade for T1000/T2000 adds domaining capable Hypervisor

Allows creation of multiple domains. Domains get assigned resources for exclusive use:

- Virtual CPUs
- Memory
- Cryptographics resources
- IO devices

Control domain	Can configure the Hypervisor; has access to service processor
Service domain	Domain that provides virtual devices to other domains
IO domain	A domain with direct access to physical devices
Guest domain	A domain that uses virtual devices provided by a service domain

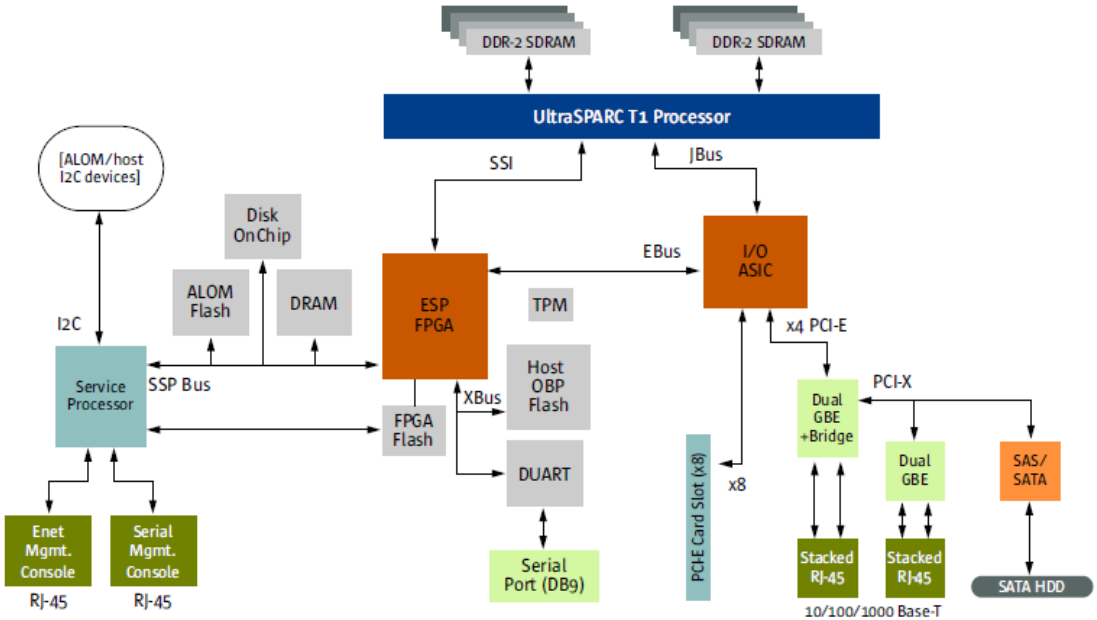
OpenBSD in a guest domain: device drivers

Device drivers implemented in this phase:

- cbus(4) channel device bus
- vnet(4) virtual network interface
- vdsk(4) virtual disk

Boostrapping OpenBSD in a Guest domain

Bootstrapping was done on T1000 server:



- Create control domain and IO domain using Solaris
- Boot diskless kernel (NFS root) using network interface in PCIe slot
- Hack on vnet(4) code; recompile kernel; repeat until it works
- Boot diskless kernel (NFS root) using vnet(4) interface
- Hack on vdsk(4) code; recompile kernel; repeat until it works
- Boot kernel from vdsk(4)

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Communication between domains

Logical domain channels (LDC)

- Hypervisor support:
  - send/receive 64-byte message (unreliable)
  - copy memory between domains
  - map another domain's pages
- Standard protocols defined by Sun:
  - LDC Transport Layer:
    Reliable data streams using 64-byte messages
  - Virtual IO (VIO) protocols:
    - ★ vDisk
    - ★ vNet

    Built on top of the LDC Transport Layer

Virtual Network Interfaces

Implements vNet virtual IO protocol

- Memory containing Tx packets needs to be exposed to other domain.
- Can't trust the other domain;
  don't expose mbufs to it!
- Dedicated memory pool for each interface;
  copy mbufs into pool before Tx

```
cbus0 at vbus0
vnet0 at cbus0 chan 0x0: ivec 0x200, 0x201, address 00:14:4f:f8:38:e7
```

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Virtual Disks

Implements client side of vDisk virtual IO protocol

- vdsk(4) emulates SCSI
  SCSI commands are converted into vDisk commands
- Expose buffers to other domain
  Domain providing storage has to be trusted anyway

```
cbus0 at vbus0
vdsk0 at cbus0 chan 0x2: ivec 0x204, 0x205
scsibus0 at vdsk0: 2 targets
sd0 at scsibus0 targ 0 lun 0: <SUN, Virtual Disk, 1.1> SCSI3 0/direct fixed
sd0: 2048MB, 512 bytes/sec, 4194304 sec total
vdsk1 at cbus0 chan 0x3: ivec 0x206, 0x207
scsibus1 at vdsk1: 2 targets
sd1 at scsibus1 targ 0 lun 0: <SUN, Virtual Disk, 1.1> SCSI3 0/direct fixed
sd1: 2048MB, 512 bytes/sec, 4194304 sec total
```

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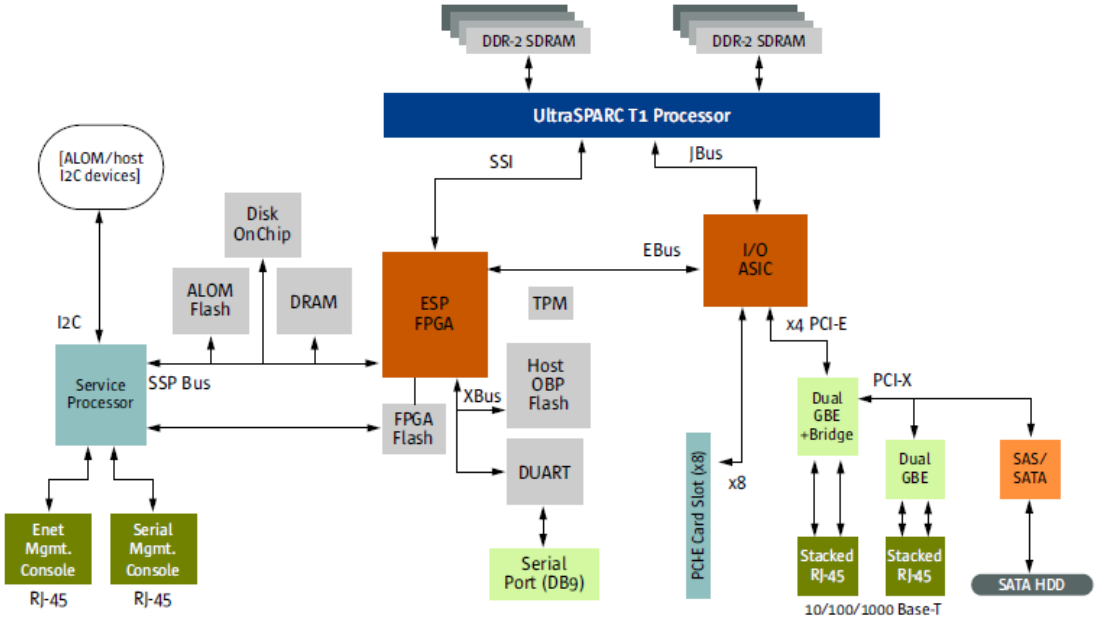
Use case: pf firewall in the box

For example on a T1000 server:



- Put a decent NIC into the PCI slot
- Configure vNet between domains

Step 3: OpenBSD in the primary domain

Device drivers:

- vcc(4) virtual console concentrator
- vcctty(4) virtual console device
- vsw(4) virtual switch
- vds(4) virtual disk server
- vdsp(4) virtual disk server port

Guest domain console access

```
vcc0 at cbus0
vcctty0 at vcc0 chan 0x19: ivec 0x232, 0x233 domain "svendsen"
vcctty1 at vcc0 chan 0x1e: ivec 0x23c, 0x23d domain "alfven"
vcctty2 at vcc0 chan 0x11: ivec 0x222, 0x223 domain "stenhammar"


# cu -l ttyV0
Connected

{0} ok
```

Virtual switch

Solaris has a virtual switch device driver

OpenBSD Philosophy

Avoid duplicating code!

bridge(4) already implements a layer 2 switch
Reuse by:

- Create a vnet(4) interface for each switch port
- Bridge them together using bridge(4)

Network configuration

```
vsw0 at cbus0
vnet0 at vsw0 chan 0x12: ivec 0x224, 0x225, address 00:00:00:00:00:00
vnet1 at vsw0 chan 0x1a: ivec 0x234, 0x235, address 00:00:00:00:00:00
vnet2 at vsw0 chan 0xb: ivec 0x216, 0x217, address 00:00:00:00:00:00
```

```
# ifconfig vnet0 -inet6 up
# ifconfig vnet1 -inet6 up
# ifconfig vnet2 -inet6 up
# ifconfig em1 up
# ifconfig bridge0 add vnet0 add vnet1 add vnet2 add em1 up
```

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Virtual Disk Server

Implements server side of vDisk virtual IO protocol

- Exports disk images as virtual disks to other domains
- Much like vnd(4)
- All memory is exported by the client to the server
  No security issues!

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Solaris as an OpenBSD guest

```
# cu -l ttyV2
Connected

{0} ok boot
Boot device: disk  File and args:
SunOS Release 5.11 Version snv_151a 64-bit
Copyright (c) 1983, 2010, Oracle and/or its affiliates. All rights reserved
Hostname: stenhammar

stenhammar console login: kettenis
Password:
Last login: Sat Jan  8 23:42:41 from nielsen.sibeliu
Oracle Corporation      SunOS 5.11      snv_151a        November 2010
kettenis@stenhammar:~$
```

Linux as an OpenBSD guest

- Only mainstream SPARC distro: Debian
- Doesn't seem to support sun4v by default
- Installer boots, but no virtual hardware seems to be detected
- Poor support for installation over serial console

Outline

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Domain Configuration

Currently only possible using Solaris:

- Reconfigure domains
- Start domains
- Stop domains

Needs to be possible from OpenBSD
Status:

- Start/Stop works; needs some cleanup.
- Reconfigure under investigation; lots of code still to be written

Meanwhile: Keep a Solaris disk around!

Domain Services

Hypervisor specification defines protocols to assist manageability:

domain-shutdown Request graceful shutdown

domain-panic Request panic

dr-cpu Dynamic reconfiguration for virtual CPUs

OpenBSD needs to implement these protocols... ...but currently doesn't.

Support for Neptune

Neptune is Sun's 10GigE network interface

- On-chip on UltraSPARC T2 (and SPARC T3?)
  - but 10GigE only (need XAUI card + XFP)
  - virtualizable
- Companion chip for UltraSPARC T2+
  - GigE or 10GigE (with XAUI card + XFP)

dlg@ needs to unslack!

Or if somebody could donate a XAUI card + XFP...

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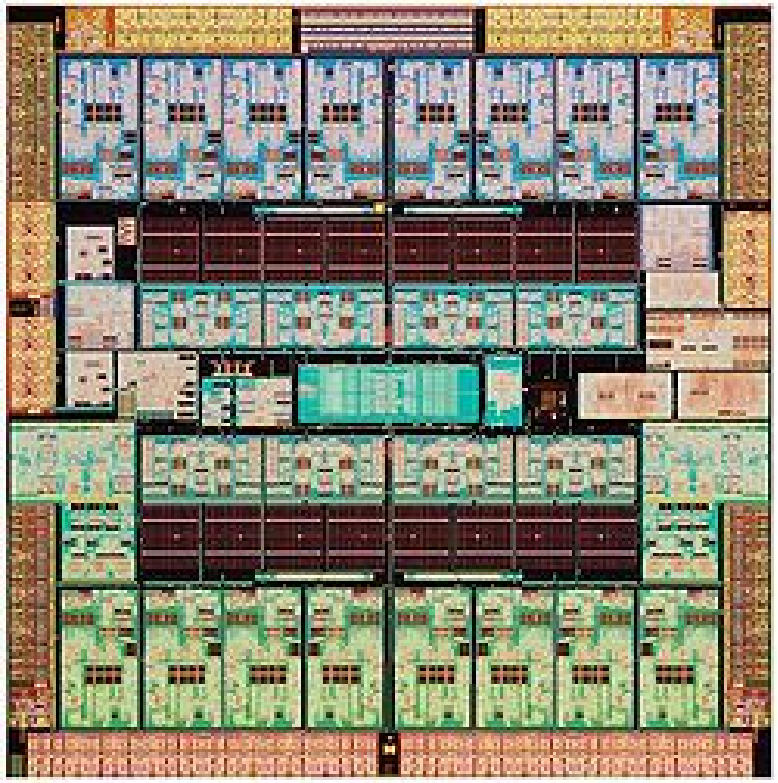
OpenBSD on Oracle SPARC T3?

SPARC T3 not radically different from UltraSPARC T2



OpenBSD should run, especially in a guest domain...
...but nobody tried this yet.
No chip-specific hardware documentation available
Hypervisor draft available

OpenBSD on Oracle SPARC T4?

- SPARC T4 has a new core
- Better single-thread performance
- OpenBSD might run, especially in a guest domain
- No chip-specific hardware documentation available

Acknowledgements

Sun Microsystems for providing the hardware that made this work possible

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