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 (particular the MMU)

  Attempt to make SPARC64 and UltraSPARC more compatible: SPARC Joint Programming Specification (JPS1).
  First JPS1 CPUs: Fujitsu SPARC64-V and Sun UltraSPARC III
  Sun UltraSPARC IV: First SPARC multicore
  Sun UltraSPARC T1: Chip Multithreading; SPARC 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!

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
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
sun4v: different sets of globals selected by trap level can be switched by modifying

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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
Only kernel needs to be changed;
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

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

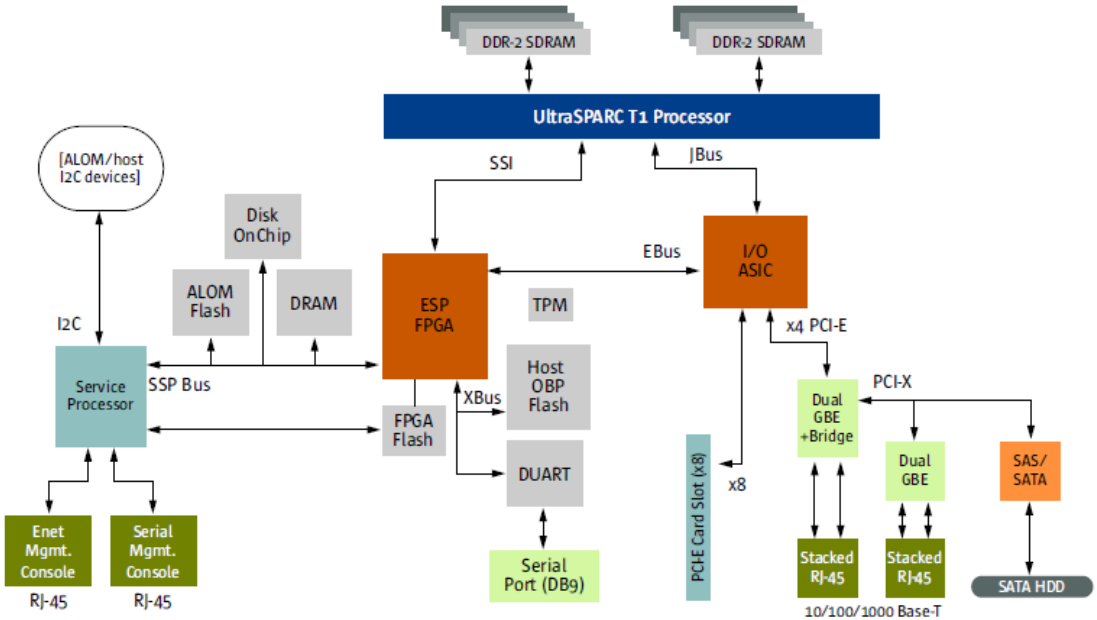
OpenBSD in a guest domain

Device drivers 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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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

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

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!

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

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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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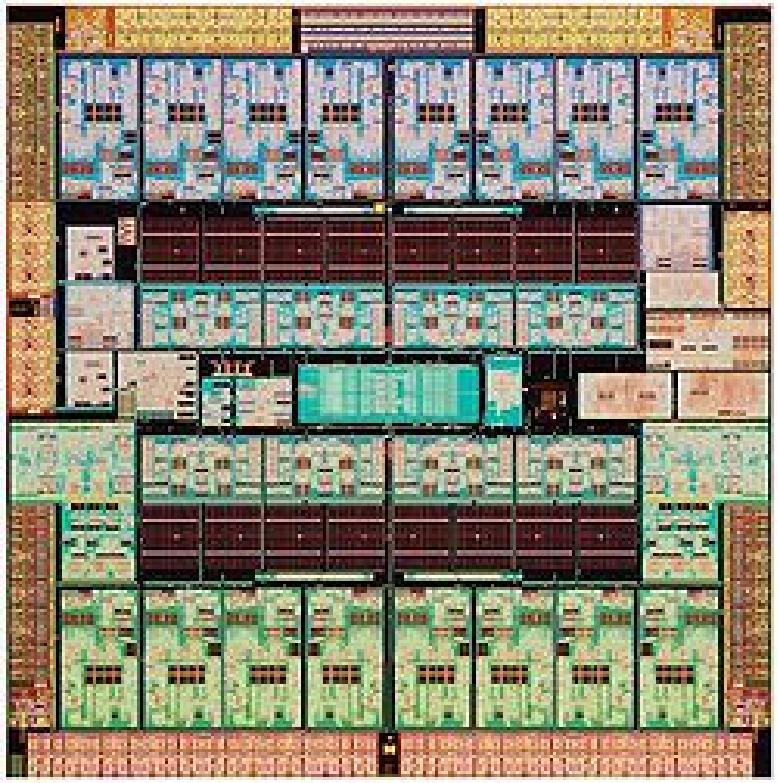
OpenBSD on Oracle SPARC T3?

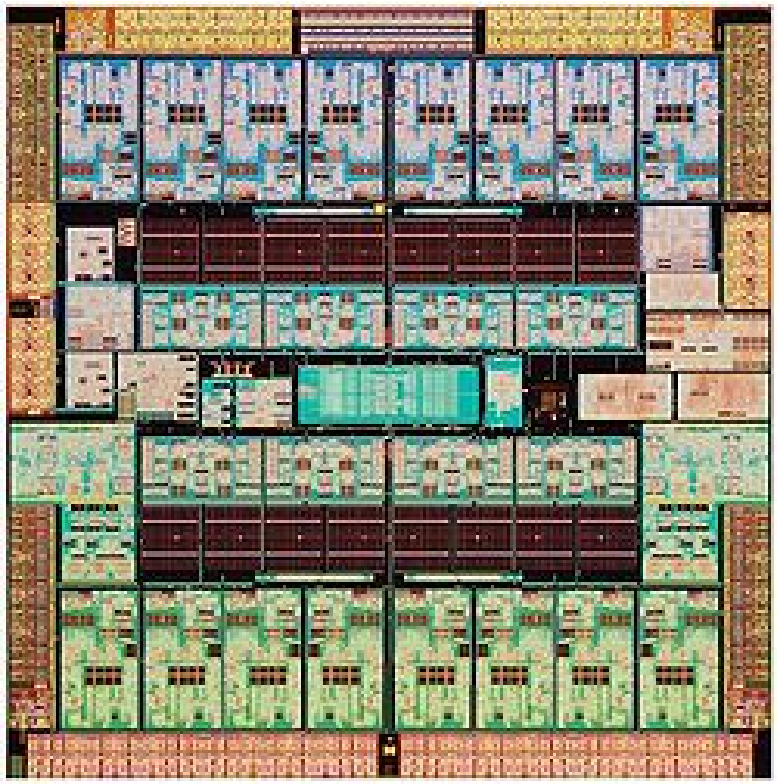
SPARC T3 not radically different from UltraSPARC T2



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