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Solaris 11 for Developers
Webinar Series #6

Writing Oracle Solaris 11 Device Drivers

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Solaris 11 for Developers Webinar Series

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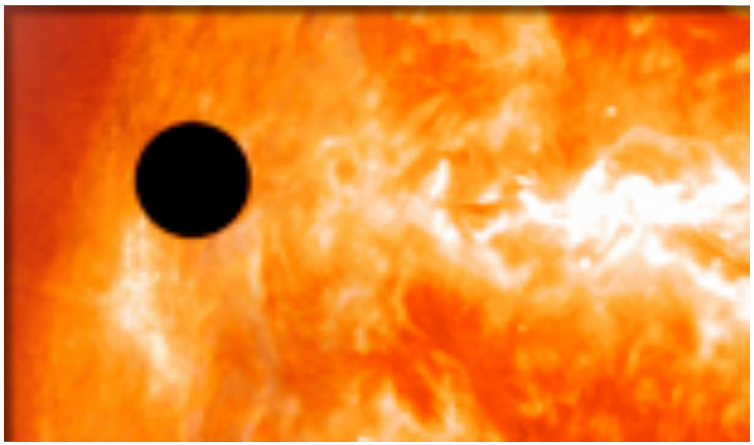
Webinar Series Topic	Date	Speaker
Modern Software Packaging for Enterprise Developers	03-27-12 @ 9am PT	Eric Reid
Simplify Your Development Environment with Zones, ZFS & More	04-10-12 @ 9am PT	Eric Reid & Stefan Schneider
Managing Application Services – Using SMF Manifests in Solaris 11	04-24-12 @ 9am PT	Matthew Hosanee
Optimize Your Applications on Solaris 11: The DTrace Advantage	05-08-12 @ 9am PT	Angelo Rajadurai
Maximize Application Performance and Reliability on Solaris 11	05-22-12 @ 9am PT	Vijay Taktar
Writing Solaris 11 Device Drivers	06-05-12 @ 9am PT	Bill Knoche
Publishing IPS Packaging	06-19-12 @ 9am PT	Eric Reid & Brock Pytlik
The World of IPS, Part 2: Tools and Commands	07-17-12 @ 9am PT	Eric Reid & Brock Pytlik
Oracle Solaris Remote Lab	07-31-12 @ 9am PT	Ron Larson & Angelo Rajadurai

Fun Fact for today

- Transit of Venus occurs today in the evening before sunset.
- It is rare. The next is on December 11, 2117
- They happen twice, 8 years apart, every 100 years or so.
- Please pay attention to safe viewing
- For more information: http://www.transitofvenus.org/



Goal

- A introduction to how devices and drivers work in Solaris
- Basic device driver construction
- Where to go for documentation and help

Disclaimer

- The kernel is a dangerous place
  - You can see and touch everything
  - Some things will break if you touch them
- Drivers are difficult to get right
  - Attention to details
  - Be rigorous about debugging your code
- Drivers can do really bad things
  - Panics, hangs, destroy an installed OS and even break hardware

What we will talk about

- What are drivers?
- Major driver types
- Devices and device tree
- Driver anatomy
- Compilation/linking
- Installation/loading
- Testing

What are drivers?

Drivers implement a set of standardized functions used by the kernel and user programs to manage and interact with devices, real and imagined.

- There is no main()
- In kernel address space – linked only to kernel routines
- Interrupt-able, pre-emptable

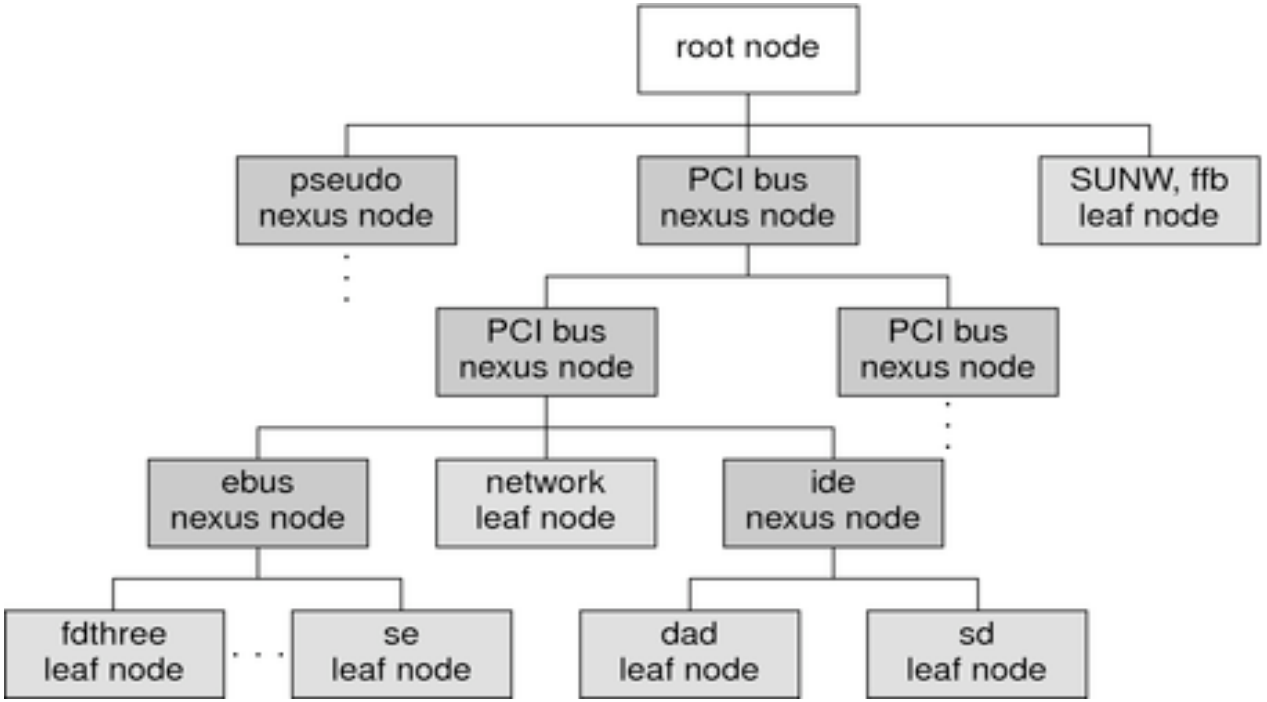
Major driver types

- Character – a sequential stream of bytes
- Block – a buffer at a time, addressable
- Streams – a subset of character device using the streamio package
- Drivers can be both Character and Block

Devices

- Devices are initially identified by the firmware (OpenBoot, BIOS)
- Solaris boots and reads the device tree – attempts to associate a driver for each device
- Solaris descends each branch (nexus) attempting to discover devices
- Solaris can add new devices at any time

Device tree



- libdevinfo, prtconf, /devices represent the device tree

Device identification

- Vendor ID and Device ID
  - PCI, PCIx, PCIe
- /etc/driver_aliases provides a mapping from device name/ compatible property to a driver name
- /etc/name_to_major lists major device numbers which correspond to a driver
- Each device in /devices has a major and minor device number and a name
  - Minor number managed by the driver

Device name, number, id

```
# ls -l /dev
/dev/dsk/c0t0d0s7 -> ../../devices/pci@1c,600000/scsi@2/sd@0,0:h

# ls -l /devices/pci@0,0:devctl
crw-------   1 root     sys       86,255 date time /devices/pci@0,0:devctl
```

ID -Persistent and unique device identifier (dev_t)

Use libdevid

Solaris kernel APIs

- Solaris has a stable device driver interface
- DDI - Device Driver Interface
- DKI - Device/Kernel Interface
- GLD – Generic LAN Driver

Anatomy of a simple driver

- Need some kernel specific header files
- Define some data structures
  - A handle
  - Device configuration operations
  - Character/block operations
  - Module load/unload operations
- Define some routines for the entry points
  - routines from cb_ops and dev_ops

Driver entry points

- Described in man pages 9e
- Loadable module interface (modlinkage, modldrv)
  - init, fini, info
- Auto configuration (dev_ops)
  - attach, detach, getinfo, probe, power
- Character
  - open, close, read, write, segmap, ioctl, chpoll
- Block
  - open, close, aread, awrite, strategy, print, etc

Driver entry points, cont.

- Memory mapped
  - devmap, devmap_access, devmap_map
- Streams
  - put, srv
- System
  - dump, quiesce

Kernel vs User device context

- Some entry points are callable by a user program: open, close, read, write, ioctls, etc
- Remember the drive is in kernel address space – do not attempt to access user space directly.
- Use ddi_copyin and ddi_copyout

Some header files

```
#include <sys/modctl.h>     /* used by modlinkage, modldrv, _init, _info, */
                            /* and _fini */
#include <sys/types.h>      /* used by open, close, read, write, prop_op, */
                            /* and ddi_prop_op */
#include <sys/file.h>       /* used by open, close */
#include <sys/errno.h>      /* used by open, close, read, write */
#include <sys/open.h>       /* used by open, close, read, write */
#include <sys/cred.h>       /* used by open, close, read */
#include <sys/uio.h>        /* used by read */
#include <sys/stat.h>       /* defines S_IFCHR used by ddi_create_minor_node */
#include <sys/cmn_err.h>    /* used by all entry points for this driver */
#include <sys/ddi.h>        /* used by all entry points for this driver */
                            /* also used by ddi_get_instance and */
                            /* ddi_prop_op */
#include <sys/sunddi.h>     /* used by all entry points for this driver */
                            /* also used by ddi_create_minor_node, */
                            /* ddi_get_instance, and ddi_prop_op */
```

Data Structures, dev_info_t

```
/*
* The entire state of each xx device.
*/
typedef struct {
dev_info_t *dip;
/* my devinfo handle */
} xx_devstate_t;
/*
* An opaque handle where our set of xx devices live
*/
static void *xx_state;
```

Data Structures, mod_ops

```
extern struct mod_ops mod_driverops;

static struct modldrv modldrv = {  /* see modldrv(9s) */
        &mod_driverops,
        "xx driver v1.0",
        &xx_ops
};


static struct modlinkage modlinkage = { /* see modlinkage(9s)
*//
        MODREV_1,
        &modldrv,
        0
};
```

Data Structures, dev_ops

```
static struct dev_ops xx_ops = { /* see dev_ops(9s) */
        DEVO_REV,
        0,          /* refcnt */
        xx_getinfo,
        nulldev,        /* identify */
        nulldev,        /* probe */
        xx_attach,
        xx_detach,
        nodev,          /* reset */
        &xx_cb_ops,
        (struct bus_ops *)0,
        nodev           /* power */
};
```

Data Structures, cb_ops

```
static struct cb_ops xx_cb_ops = { /* see cb_ops(9s) */
        xx_open,
        nulldev,          /* close */
        nodev,            /* strategy */
        nodev,            /* print */
        nodev,            /* dump */
        xx_read,
        xx_write,
        nodev,            /* ioctl */
        nodev,            /* devmap */
        nodev,            /* mmap */
        nodev,            /* segmap */
        nochpoll,         /* poll */
        ddi_prop_op,
        NULL,             /* streamtab */
        D_NEW | D_MP,
        CB_REV,
        nodev,            /* aread */
        nodev             /* awrite */
};
```

Data Structures, cb_ops

```
static struct cb_ops xx_cb_ops = { /* see cb_ops(9s) */
        xx_open,
        nulldev,          /* close */
        nodev,            /* strategy */
        nodev,            /* print */
        nodev,            /* dump */
        xx_read,
        xx_write,
        nodev,            /* ioctl */
        nodev,            /* devmap */
        nodev,            /* mmap */
        nodev,            /* segmap */
        nochpoll,         /* poll */
        ddi_prop_op,
        NULL,             /* streamtab */
        D_NEW | D_MP,
        CB_REV,
        nodev,            /* aread */
        nodev             /* awrite */
};
```

Routines

```
/* functions can be found in  man pages 9e */
/* and header file /usr/include/sys/devops.h */

static int xx_open(dev_t *devp, int flag, int otyp, cred_t *cred);
static int xx_read(dev_t dev, struct uio *uiop, cred_t *credp);
static int xx_write(dev_t dev, struct uio *uiop, cred_t *credp);
static int xx_getinfo(dev_info_t *dip, ddi_info_cmd_t infocmd, void *arg,
      void **result);
static int xx_attach(dev_info_t *dip, ddi_attach_cmd_t cmd);
static int xx_detach(dev_info_t *dip, ddi_detach_cmd_t cmd);
```

Routine, _init

```
static void *xxstatep;
int
_init(void)
{
    int error;
    const int max_instance = 20;    /* estimated max device
instances */

    ddi_soft_state_init(&xxstatep, sizeof (struct xxstate),
max_instance);
    error = mod_install(&xxmodlinkage);
    if (error != 0) {
        /*
         * Cleanup after a failure
         */
        ddi_soft_state_fini(&xxstatep);
    }
    return (error);
}
```

Routine, _fini

```
int
_fini(void)
{
    int error;
    error = mod_remove(&modlinkage);
    if (error != 0) {
        return (error);
    }
    /*
     * Cleanup resources allocated in _init()
     */
    ddi_soft_state_fini(&xxstatep);
    return (0);
}
```

Routine, _info

```
int
_info(struct modinfo *modinfop)
{
    return (mod_info(&xxmodlinkage, modinfop));
}
```

Routine, attach

```
static int /* called for each device instance, see attach(9e) */
xx_attach(dev_info_t *dip, ddi_attach_cmd_t cmd)
{
        int instance;
        xx_devstate_t *rsp;
        switch (cmd) {
        case DDI_ATTACH:
                instance = ddi_get_instance(dip);
                if (ddi_soft_state_zalloc(xx_state, instance)
                        != DDI_SUCCESS) {
                        cmn_err(CE_CONT, "%s%d: can't allocate state\n",
                                ddi_get_name(dip), instance);
                        return (DDI_FAILURE);
```

Routine, attach continued

```
                } else
                        rsp = ddi_get_soft_state(xx_state, instance);
                if (ddi_create_minor_node(dip, "xx", S_IFCHR,
                        instance, DDI_PSEUDO, 0) == DDI_FAILURE) {
                                ddi_remove_minor_node(dip, NULL);
                                goto attach_failed;
                }
                rsp->dip = dip;
                ddi_report_dev(dip);
                return (DDI_SUCCESS);
        default:
                return (DDI_FAILURE);
        }
attach_failed:
(void) xx_detach(dip, DDI_DETACH);
return (DDI_FAILURE);
}
```

Routine, detach

```
static int          /* see detach(9e) */
xx_detach(dev_info_t *dip, ddi_detach_cmd_t cmd)
{
        int instance;
        register xx_devstate_t *rsp;
        switch (cmd) {
        case DDI_DETACH:
                ddi_prop_remove_all(dip);
                instance = ddi_get_instance(dip);
                rsp = ddi_get_soft_state(xx_state, instance);
                ddi_remove_minor_node(dip, NULL);
                ddi_soft_state_free(xx_state, instance);
                return (DDI_SUCCESS);
        default:
                return (DDI_FAILURE);
        }
}
```

Routine, open

```
/*ARGSUSED*/
static int /* called on open(2), see open(9e) */
xx_open(dev_t *devp, int flag, int otyp, cred_t *cred)
{
        cmn_err(CE_NOTE, "Inside xx_open");
        if (otyp != OTYP_BLK && otyp != OTYP_CHR)
                return (EINVAL);
        if (ddi_get_soft_state(xx_state, getminor(*devp)) == NULL)
                return (ENXIO);
}
```

Routine, read

```
static int
xx_read(dev_t dev, struct uio *uiop, cred_t *credp)
{
int instance = getminor(dev);
xx_devstate_t *rsp = ddi_get_soft_state(xx_state, instance);
return(0);
}
```

Routine, write

```
/*ARGSUSED*/
static int
xx_write(dev_t dev, register struct uio *uiop, cred_t *credp)
{
        int instance = getminor(dev);
        xx_devstate_t *rsp = ddi_get_soft_state(xx_state, instance);
        return(0);
}
```

Compiling

For a 64-bit SPARC architecture using Sun Studio 12.1, use the -m64 option:

```
% cc -D_KERNEL -m64 -c mydriver.c
% ld -r -o mydriver mydriver.o
```

For a 64-bit x86 architecture using Sun Studio 12, use the -m64 option, and the -xmodel=kernel option:

```
% cc -D_KERNEL -m64 -xmodel=kernel -c mydriver.c
% ld -r -o mydriver mydriver.o
```

Compiling, continue

For a 64-bit SPARC architecture, use the following build commands for gcc:

```
% gcc -D_KERNEL -m64 -mcpu=v9 -mcmodel=medlow -fno-pic -mno-fpu \
    -ffreestanding -nodefaultlibs -c mydriver.c

% ld -r -o mydriver mydriver.o
```

For a 64-bit x86 architecture, use the following build commands for gcc:

```
% gcc -D_KERNEL -m64 -mcmodel=kernel -mno-red-zone –ffreestanding \
    -nodefaultlibs -c mydriver.c

% ld -r -o mydriver mydriver.o
```

Driver.conf

- If a device is not self identifying you may also need a driver.conf.
- It is located in the same directory along with the driver and is named xx.conf for a driver named xx.
- It contains any properties you might want to set property=value

Packaging

- IPS for Solaris 11 and later
- SVR4 packages for previous releases

Installation

cp mydriver.conf /usr/kernel/drv

add_drv mydriver

- _info(9E), _init(9E), and attach(9E) entry points are called in order.
- The driver is added to the /devices directory.
- The driver is the most recent module listed by modinfo(1M).
- The driver is the most recent module listed in the file /etc/name_to_major

Driver loading

modload(1M)

modunload(1M)

Testing

- Start simple, build incrementally
- cmn_err – similar to printf
- Use alternate boot environment
- kmdb, mdb - debuggers
- Watch for memory leaks, addressing errors
- Use ASSERT

To get help

- Join OPN
  http://www.oracle.com/partners/en/join-now/index.html
- Join Oracle Solaris Development Initiative
  http://www.oracle.com/partners/secure/support/oracle-solaris-development-494690.html
- Send me email:
  bill.knoche@oracle.com

To Learn More…

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Download Solaris 11
http://www.oracle.com/technetwork/server-storage/solaris11/downloads/

Learn more about Solaris 11 – the documentation
http://docs.oracle.com/cd/E23824_01/

Writing Device Drivers
http://docs.oracle.com/cd/E23824_01/html/819-3196/

Device Driver Tutorial
http://docs.oracle.com/cd/E19963-01/html/819-3159/

To Learn More…

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- man section 9e: DDI and DKI Driver Entry Points
http://docs.oracle.com/cd/E23824_01/html/821-1476/index.html

- man section 9f: DDI and DKI Kernel Functions
http://docs.oracle.com/cd/E23824_01/html/821-1477/index.html

- man section 9s: DDI and DKI Properties and Data Structures
http://docs.oracle.com/cd/E23824_01/html/821-1478/index.html

- Writing FCode 3.x Programs
http://download.oracle.com/docs/cd/E19253-01/806-1379-10/

To Learn More…

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- PCI special Interest group
http://www.pcisig.com/

- DLPI spec:
http://pubs.opengroup.org/onlinepubs/009618899/toc.htm

- TPI spec:
http://pubs.opengroup.org/onlinepubs/009618999/toc.htm

- OpenSolaris Device Driver Community
http://hub.opensolaris.org/bin/view/Community+Group+device_drivers/

Webinar Registration Page

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Oracle Solaris 11 Developer Webinar Series

Join us on April 24th for a complimentary webcast. In just one hour you will learn how to streamline your development process to maximize the performance of your application with Oracle Solaris 11. Access the Slides here.

- Learn why there is no more patching!
- Understand Oracle Solaris 11 cloud features
- Review how to maximize application reliability in Oracle Solaris 11
- Live Chat with Oracle Solaris 11 Engineers

Who should attend?

Application developers and administrators wanting a deep-dive on key features of Oracle Solaris 11 which you can exploit to make your applications superior to your competitors and easier to use.

Please note: (after registering) You will receive details on how to attend the meeting in a separate confirmation e-mail shortly before the webcast.

Next Webinar June 19th

Agenda - Next Sessions

- Click on event to register
- All webinars on Tuesday's 9-10am PT (Event will support VOIP)

Webinar Series Topic	Date	Speaker
Writing Oracle Solaris 11 Device Drivers	06-05-12 @ 9am PT	Bill Knoche (Principal Software Engineer)
Publishing IPS Packages	06-19-12 @ 9am PT	Eric Reid (Principal Software Engineer) and Brock Pytlik (Senior Software Engineer
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Oracle Solaris Remote Lab	07-31-12 @ 9am PT	Ron Larson (Project Manager, ISV Engineering) and Angelo Rajadurai (Principal Software Engineer)

Webinar Preview: http://education.oracle.com/education/downloads/solaris11/webinar/index.htm

Registration:
http://www.oracle.com/technetwork/server-storage/solaris11/overview/webinar-series-1563626.html

Questions

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