Kernel Debugging and Tracing

Jason Wessel

- Product Architect for Wind River Linux
- Kernel.org KDB/KGDB Maintainer

August 20th, 2014

Agenda

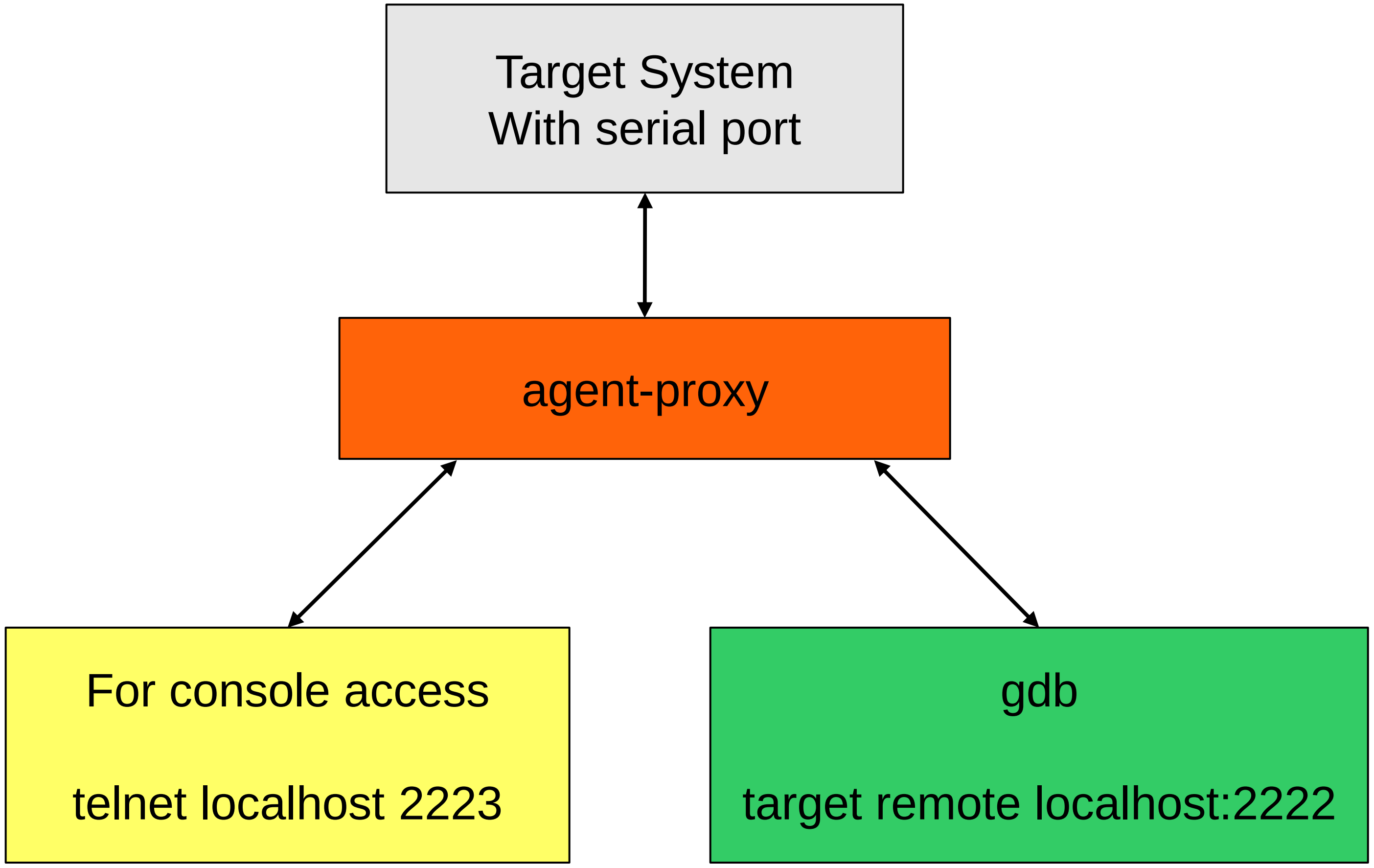
- Some debugger/tracing history
- Several demonstrations
- Given tools today, what do you need?

*** Presentation found at: http://kgdb.wiki.kernel.org ***

Kernel Debugger History

- Pre 2008-2010
  - KGDB core merged
  - KDB shell
  - Early debug with USB EHCI and VGA
  - Atomic KMS and ftrace support
  - Agent Proxy
- 2011~ today
  - Maintenance / bug fixes

Sharing the console - kgdboc



EHCI Debug Port

- Great for when you do not have rs232
- Higher speed than rs232
- Works with KGDB

  kgdbdbgp=0

- Use it as a Linux Console

  console=ttyUSB0 AND/OR earlyprintk=kdbgp0

- Read more in your kernel source tree:

  Documentation/x86/earlyprintk.txt

- You can buy one at

  http://www.semiconductorstore.com/cart/pc/viewPrd.asp?idproduct=12083

What is in the pipe?

- Merge for next window
  - KDB kiosk mode
  - FIQ debugger for ARM
- Experiments
  - Break point set from kernel command line

Volunteers?

- ARM HW break points, sw stepping?
- RFC'ed to death
  - KGDB for USB serial and USB keyboards
  - Maybe a kgdb over ethernet V2 (still needed?)

To Stop or Not to stop?

- KGDB is a stop mode debugger
  - One Way Trip to a reboot in may cases
- Most applications don’t want to stop

KGDB is not for production!

- Here is a video to show you why not to leave KGDB activated indefinitely.
- https://www.youtube.com/watch?v=gWXxeUZczNE

Play Video

How we got root? (1 of 4)

- .gdbinit file:

```
python
sys.path.insert(0, '/home/jwessel')
import offsets
end
```

How we got root? (2 of 4)

```
# /home/jwessel/offsets.py
import gdb
class HOffsets(gdb.Command):
    def __init__(self):
        super (HOffsets, self).__init__ ('hoffsets-of', gdb.COMMAND_DATA)

    def invoke(self, arg, from_tty):
        argv = gdb.string_to_argv(arg)
        if len(argv) != 1:
            raise gdb.GdbError('offsets-of takes exactly 1 argument.')

        stype = gdb.lookup_type(argv[0])

        gdb.write("%s {\n" % argv[0])
        for field in stype.fields():
            gdb.write("    %s => 0x%x\n" % (field.name, field.bitpos//8))
        gdb.write("}\n")

class Offsets(gdb.Command):
    def __init__(self):
        super (Offsets, self).__init__ ('offsets-of', gdb.COMMAND_DATA)

    def invoke(self, arg, from_tty):
        argv = gdb.string_to_argv(arg)
        if len(argv) != 1:
            raise gdb.GdbError('offsets-of takes exactly 1 argument.')

        stype = gdb.lookup_type(argv[0])

        gdb.write("%s {\n" % argv[0])
        for field in stype.fields():
            gdb.write("    %s => %d\n" % (field.name, field.bitpos//8))
        gdb.write("}\n")
Offsets()
HOffsets()
```

How we got root? (3 of 4)

- Lookup offsets with: gdb vmlinux
- hoffsets-of “struct task_struct”
  - real_cred => 0x480
- hoffsets-of “struct cred”
  - uid => 0x4
  - euid => 0x14

How we got root? (4 of 4)

- sysrq-g   # To enter the debugger
- ps
- md8c1 0xffff8800068907c0+0x480
  - Memory Display 8 byte words 1 column at hex offset 0x480
- mm4 0xffff880006878f00+0x4 0
  - Memory Modify 4 bytes at hex offset 4 for the uid
- mm4 0xffff880006878f00+0x14 0
  - Memory Modify 4 bytes at hex offset 14 for the euid

Better than KGDB?

- Good
  - KGDB / KDB
- Better
  - QEMU/KVM OR Virtual box OR vmware backend debugger
  - kdump/kexec
- Best
  - ICE / JTAG (usb or ethernet)
  - Simics - www.simics.com (because it has backward stepping)
- In a class by itself
  - printk() / trace_printk()   AND of course ftrace!

Debugging in 2014

- ftrace reins supreme! trace_printk + dumps
- Simulators and virtualization backends
- perf
- pstore / ramoops
- uprobes and systemtap
- kprobes
- gdb / KGDB / KDB
- lttng
- kdump

The kernel black box

- Kernel Args:
- ftrace=function ftrace_dump_on_oops ftrace_filter="EXPRESSION"
  - Where EXPRESSION might be *ata*

pstore / ramoops

- Kernel config options:
  - CONFIG_PSTORE=y CONFIG_PSTORE_CONSOLE=y CONFIG_PSTORE_FTRACE=y CONFIG_PSTORE_RAM=y
- Know your target HW for 128 megs ram (kernel args)
  - mem=127M
  - ramoops.mem_size=0xa0000
    - Do not use full final meg of ram
  - ramoops.mem_address=0x7f00000
- Collect ftrace
  - echo 1 > /sys/kernel/debug/pstore/record_ftrace

Booting with KVM / QEMU

- You can test this with KVM/qemu which does not re-write the RAM
- Assumes kernel is built with correct config options
- You can then use system_reset
- Example:

```
qemu-system-x86_64 -nographic -kernel arch/x86/boot/bzImage
"console=ttyS0,115200 ip=dhcp root=/dev/nfs
nfsroot=10.0.2.2:/space/exp/x86 rw acpi=force clock=pit UMA=1
kgdbts= mem=127M ramoops.mem_size=0x100000
ramoops.mem_address=0x7f00000" -m 128
```

Ramoops Rocks!

- Here is a video using pstore/ramoops to catch the console and ftrace logs
- https://www.youtube.com/watch?v=hUsm4vmYYWo

Play Video

What do tools do you need?

- Multi Virtual machine synced logs?
- CPU trace data?
- Complete function tracer for user space?
- Control ftrace ring buffer size from boot?
- Dtrace…………..
- I dream of a multi-queue ethernet device with a pipe for the debugger ☺

WIND RIVER

Backup Slides

EHCI Debug Port

- Great for when you do not have rs232
- Higher speed than rs232
- Works with KGDB

  kgdbdbgp=0
- Use it as a Linux Console

  console=ttyUSB0 AND/OR earlyprintk=kdbgp0
- Read more in your kernel source tree:

  Documentation/x86/earlyprintk.txt
- You can buy one at

  http://www.semiconductorstore.com/cart/pc/viewPrd.asp?idproduct=12083

KDB – kernel debug shell History

- The goal of the merge KDB and KGDB was simple:
  - Unify the fragmented kernel debugger communities
- KDB was a derived from from the 10 year old project:
  - ftp://oss.sgi.com/projects/kdb/download/v4.4/
- The merge work started in 2009 with many prototypes
  - Originally KDB was > 64,000 lines of changes for just x86
  - After some significant gutting of anything that was common, the result was a platform independent KDB hooked up to the same infrastructure (debug_core) that is used by KGDB.
  - The final KDB patch set was < 8500 lines of changes
- For more information about differences in SGI KDB vs mainline KDB
  - https://kgdb.wiki.kernel.org/index.php/KDB_FAQ

KDB – The in-kernel debug shell

- To use KDB you must meet one of following constraints
  - Use a non usb keyboard + vga text console
  - Use a serial port console
  - Use a USB EHCI debug port and debug dongle
- KDB is not a source debugger
  - However you can use it in conjunction with gdb and an external symbol file
- Maybe you don't need a kernel debugger, but you at least want a chance to see ftrace logs, dmesg, poke a stack trace or do one final sysrq.
  - KDB might still be the tool you are looking for

Loading KDB

Having KDB loaded allows you to trap the panic handler.

- For a serial port:

```
echo ttyS0 > /sys/module/kgdboc/kernel/kgdboc
```

- For the keyboard + vga text console

```
echo kbd > /sys/module/kgdboc/kernel/kgdboc
```

- Enter KDB with sysrq-g

```
echo g > /proc/sysrq-trigger
```

- Remember KDB is a stop mode debugger
  - Entering KDB means all the other processors skid to a stop
  - You can run some things like: lsmod, ps, kill, dmesg, bt
  - ftdump to dump ftrace logs (not merged to mainline yet)
  - You can also use hw breakpoints or modify memory

KDB “crash” course

- Simply loading KDB gives you the opportunity to stop and look at faults perhaps using external tools

```
echo ttyS0 > /sys/module/kgdboc/parameters/kgdboc
insmod test_panic.ko
echo 1 > /proc/test_panic/panic
```

- After the panic collect dmesg, ftdump, bt, and lsmod
- Use gdb to load the symbol file and kernel module

```
gdb ./vmlinux
add-symbol-file test_panic.ko ADDR_FROM_LSMOD
info line *0xADDR_FROM_BT
```

Pre-recorded Demonstration 1

- Example of a useless call to panic()
  - http://www.youtube.com/watch?v=V6Qc8ppJ_jc
- Example of finding the useless call to panic()
  - http://www.youtube.com/watch?v=LqAhY8K3XzI

KDB Demonstration 2 - breakpoints

- Load KDB and use a data write breakpoint

```
insmod test_panic.ko
echo ttyS0 > /sys/module/kgdboc/parameters/kgdboc
echo g > /proc/sysrq-trigger
bph tp_address_ref dataw
go
```

- Cause the problem and collect the data

```
echo 1 > /proc/test_panic/bad_access
bt
rd
lsmod
```

- Statically look at the source with gdb + module address

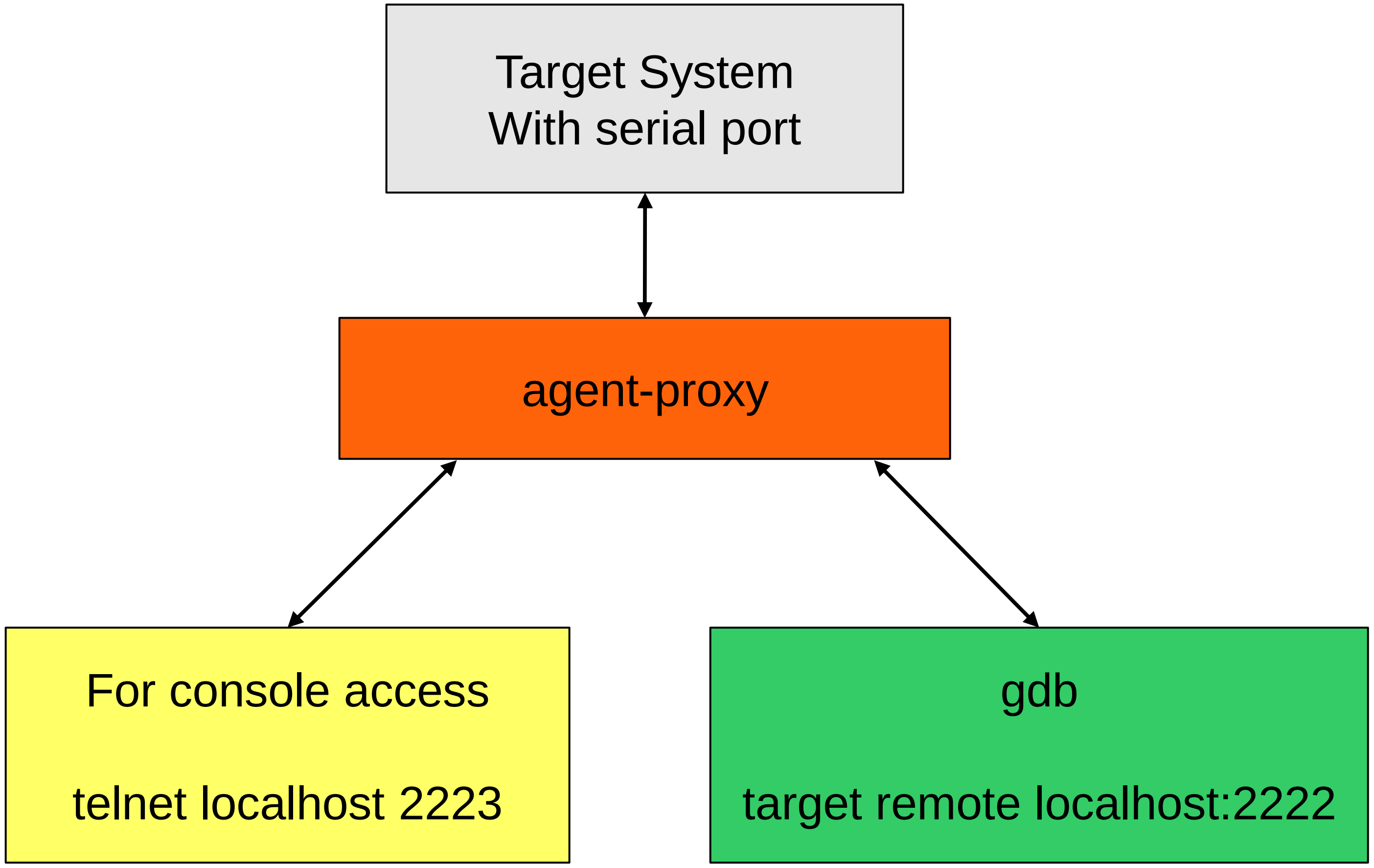
Pre-recorded Demonstration 2

- Example of a kernel bad paging request
  - http://www.youtube.com/watch?v=bBEh_UduX04
- Example of using HW breakpoint in kdb
  - http://www.youtube.com/watch?v=MfJU2E0aJwg

Remember KDB is KGDB too!

- If you only have a single serial port, it just got easier to use KGDB if you want to use it.
- Try the agent-proxy
- The agent-proxy is nothing more then a tty → tcp connection mux that can allow you to connect more than one client application to a tty
- You can even use the agent-proxy with the EHCI debug port device.

Sharing the console - kgdboc



KGDB demonstration setup

- Use a connection multiplexer
  - By default you can only connect one application at a time to the console
  - In the case of kgdboc you want an interactive console & a debug port

agent-proxy ***CONSOLE_PORT*****^DEBUG_PORT IP_ADDR PORT**

- More or less turns your local serial port into a terminal server

```
agent-proxy 2223^2222 0 /dev/ttyS0,115200
```

- Use it to multiplex a remote terminal server or simulator connection

```
agent-proxy 2223^2222 128.224.50.38 8181
```

- The agent-proxy is now available:

```
git clone git://git.kernel.org/pub/scm/utils/kernel/kgdb/agent-proxy.git
cd agent-proxy ; make
```

KGDB demonstration

- On the target system
  ```
  echo ttyS0 > /sys/module/kgdboc/parameters/kgdboc
  insmod test_panic.ko
  ```
- In gdb
  ```
  tar remote localhost:2222
  break sys_sync
  c
  ```
- On the target
  ```
  sync
  ```
- In gdb
  ```
  awatch tp_address_ref
  inf br
  c
  ```
- On the target
  ```
  echo 1 > /proc/test_panic/bad_access
  ```
- Back to gdb where we can pass along the exception
  ```
  signal 9
  ```

Pre-recorded Demonstration 3

- Start up the agent-proxy and connect and hit a breakpoint a sys_sync
  - http://www.youtube.com/watch?v=sWiHV5mt8_k
- Data Access breakpoint on tp_address_ref
  - http://www.youtube.com/watch?v=nnopzcwvLTs

References

- KGDB/KDB Website

  http://kgdb.wiki.kernel.org

- KGDB/KDB Mailing list
  - kgdb-bugreport@lists.sourceforge.net
  - https://lists.sourceforge.net/lists/listinfo/kgdb-bugreport
- Source code used in this presentation
  - The 2.6.36 kernel was used
  - The kernel module code can be found at:

http://kernel.org/pub/linux/kernel/people/jwessel/dbg_webinar/crash_mod.tar.bz2

KGDB facts

- KGDB and KDB use the same debug backend
- kgdboe (KGDB over ethernet) is not always reliable
  - kgdboe in the current form WILL NOT BE MAINLINED
  - Linux IRQs can get preempted and hold locks making it unsafe or impossible for the polled ethernet driver to run
  - Some ethernet drivers are so complex with separate kernel thread that the polled mode ethernet can hang due to locking or unsafe HW resource access
  - If you really want to attempt use kgdboe successfully, use a dedicated interface if you have one and do not use kernel soft or hard IRQ preemption.
- kgdboc is slow but the most reliable
- The EHCI debug port is currently the fastest KGDB connection

WIND RIVER