
Subject: [PATCH 1/2][cryo] Save/restore state of unnamed pipes
Posted by [Sukadev Bhattiprolu](#) on Tue, 24 Jun 2008 03:25:36 GMT
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>From e513f8bc0fe808425264ad01210ac610f6453047 Mon Sep 17 00:00:00 2001
From: Sukadev Bhattiprolu <sukadev@linux.vnet.ibm.com>
Date: Mon, 16 Jun 2008 18:41:05 -0700
Subject: [PATCH] Save/restore state of unnamed pipes

Design:

Current Linux kernels provide ability to read/write contents of FIFOs using /proc. i.e 'cat /proc/pid/fd/read-side-fd' prints the unread data in the FIFO. Similarly, 'cat foo > /proc/pid/fd/read-side-fd' appends the contents of 'foo' to the unread contents of the FIFO.

So to save/restore the state of the pipe, a simple implementation is to read the from the unnamed pipe's fd and save to the checkpoint-file. When restoring, create a pipe (using PT_PIPE()) in the child process, read the contents of the pipe from the checkpoint file and write it to the newly created pipe.

Its fairly straightforward, except for couple of notes:

- when we read contents of '/proc/pid/fd/read-side-fd' we drain the pipe such that when the checkpointed application resumes, it will not find any data. To fix this, we read from the 'read-side-fd' and write it back to the 'read-side-fd' in addition to writing to the checkpoint file.
- there does not seem to be a mechanism to determine the count of unread bytes in the file. Current implmentation assumes a maximum of 64K bytes (PIPE_BUFS * PAGE_SIZE on i386) and fails if the pipe is not fully drained.

Changelog:[v1]:

- [Serge Hallyn]: use || instead of && in ensure_fifo_has_drained
- [Serge Hallyn, Matt Helsley]: Use dup2() to restore fds and remove assumptions about order of read and write fds (addressed in PATCH 2/2).

Some unit-testing done at this point (using tests/pipe.c).

TODO:

- Additional testing (with multiple-processes and multiple-pipes)
- Named-pipes

```
---
cr.c | 217 ++++++-----
1 files changed, 205 insertions(+), 12 deletions(-)
```

```
diff --git a/cr.c b/cr.c
```

```
index c7e3332..716cc86 100644
```

```
--- a/cr.c
```

```
+++ b/cr.c
```

```
@@ -88,6 +88,11 @@ typedef struct fdinfo_t {
    char name[128]; /* file name. NULL if anonymous (pipe, socketpair) */
} fdinfo_t;
```

```
+typedef struct fifoinfo_t {
+ int fi_fd; /* fifo's read-side fd */
+ int fi_length; /* number of bytes in the fifo */
+} fifofdinfo_t;
+
+typedef struct memseg_t {
+ unsigned long start; /* memory segment start address */
+ unsigned long end; /* memory segment end address */
@@ -499,6 +504,129 @@ out:
    return rc;
}
```

```
+static int estimate_fifo_unread_bytes(pinfo_t *pi, int fd)
+{
+ /*
+ * Is there a way to find the number of bytes remaining to be
+ * read in a fifo ? If not, can we print it in fdinfo ?
+ *
+ * Return 64K (PIPE_BUFS * PAGE_SIZE) for now.
+ */
+ return 65536;
+}
+
+static void ensure_fifo_has_drained(char *fname, int fifo_fd)
+{
+ int rc, c;
+
+ errno = 0;
+ rc = read(fifo_fd, &c, 1);
+ if (rc != -1 || errno != EAGAIN) {
+ ERROR("FIFO '%s' not drained fully. rc %d, c %d "
+ "errno %d\n", fname, rc, c, errno);
+ }
+
+}
+
+}
```

```

+static int save_process_fifo_info(pinfo_t *pi, int fd)
+{
+ int i;
+ int rc;
+ int nbytes;
+ int fifo_fd;
+ int pbuf_size;
+ pid_t pid = pi->pid;
+ char fname[256];
+ fdinfo_t *fi = pi->fi;
+ char *pbuf;
+ fifofdinfo_t fifofdinfo;
+
+ write_item(fd, "FIFO", NULL, 0);
+
+ for (i = 0; i < pi->nf; i++) {
+ if (! S_ISFIFO(fi[i].mode))
+ continue;
+
+ DEBUG("FIFO fd %d (%s), flag 0x%x\n", fi[i].fdnum, fi[i].name,
+ fi[i].flag);
+
+ if (!(fi[i].flag & O_WRONLY))
+ continue;
+
+ pbuf_size = estimate_fifo_unread_bytes(pi, fd);
+
+ pbuf = (char *)malloc(pbuf_size);
+ if (!pbuf) {
+ ERROR("Unable to allocate FIFO buffer of size %d\n",
+ pbuf_size);
+ }
+ memset(pbuf, 0, pbuf_size);
+
+ sprintf(fname, "/proc/%u/fd/%u", pid, fi[i].fdnum);
+
+ /*
+ * Open O_NONBLOCK so read does not block if fifo has fewer
+ * bytes than our estimate.
+ */
+ fifo_fd = open(fname, O_RDWR|O_NONBLOCK);
+ if (fifo_fd < 0)
+ ERROR("Error %d opening FIFO '%s'\n", errno, fname);
+
+ nbytes = read(fifo_fd, pbuf, pbuf_size);
+ if (nbytes < 0) {
+ if (errno != EAGAIN) {
+ ERROR("Error %d reading FIFO '%s'\n", errno,

```

```

+   fname);
+ }
+ nbytes = 0; /* empty fifo */
+ }
+
+ /*
+  * Ensure FIFO has been drained.
+  *
+  * TODO: If FIFO has not fully drained, our estimate of
+  * unread-bytes is wrong. We could:
+  *
+  * - have kernel print exact number of unread-bytes
+  *   in /proc/pid/fdinfo/<fd>
+  *
+  * - read in contents multiple times and write multiple
+  *   fifobufs or assemble them into a single, large
+  *   buffer.
+  */
+ ensure_fifo_has_drained(fname, fifo_fd);
+
+ /*
+  * Save FIFO data to checkpoint file
+  */
+ fifofdinfo.fi_fd = fi[i].fdnum;
+ fifofdinfo.fi_length = nbytes;
+ write_item(fd, "fifofdinfo", &fifofdinfo, sizeof(fifofdinfo));
+
+ if (nbytes) {
+   write_item(fd, "fifobufs", pbuf, nbytes);
+
+   /*
+    * Restore FIFO's contents so checkpointed application
+    * won't miss a thing.
+    */
+   errno = 0;
+   rc = write(fifo_fd, pbuf, nbytes);
+   if (rc != nbytes) {
+     ERROR("Wrote-back only %d of %d bytes to FIFO, "
+          "error %d\n", rc, nbytes, errno);
+   }
+ }
+
+ close(fifo_fd);
+ free(pbuf);
+ }
+
+ write_item(fd, "END FIFO", NULL, 0);
+

```

```

+ return 0;
+}
+
static int save_process_data(pid_t pid, int fd, lh_list_t *ptree)
{
    char fname[256], exe[256], cwd[256], *argv, *env, *buf;
@@ -618,6 +746,8 @@ static int save_process_data(pid_t pid, int fd, lh_list_t *ptree)
}
    write_item(fd, "END FD", NULL, 0);

+ save_process_fifo_info(pi, fd);
+
    /* sockets */
    write_item(fd, "SOCK", NULL, 0);
    for (i = 0; i < pi->ns; i++)
@@ -870,6 +1000,29 @@ int restore_fd(int fd, pid_t pid)
    }
    if (pfd != fdinfo->fdnum) t_d(PT_CLOSE(pid, pfd));
}
+ } else if (S_ISFIFO(fdinfo->mode)) {
+     int pipefds[2] = { 0, 0 };
+
+     /*
+      * We create the pipe when we see the pipe's read-fd.
+      * Just ignore the pipe's write-fd.
+      */
+     if (fdinfo->flag == O_WRONLY)
+         continue;
+
+     DEBUG("Creating pipe for fd %d\n", fdinfo->fdnum);
+
+     t_d(PT_PIPE(pid, pipefds));
+     t_d(pipefds[0]);
+     t_d(pipefds[1]);
+
+     if (pipefds[0] != fdinfo->fdnum) {
+         DEBUG("Hmm, new pipe has fds %d, %d "
+             "Old pipe had fd %d\n", pipefds[0],
+             pipefds[1], fdinfo->fdnum); getchar();
+         exit(1);
+     }
+     DEBUG("Done creating pipefds[0] %d\n", pipefds[0]);
+ }

    /*
@@ -878,20 +1031,8 @@ int restore_fd(int fd, pid_t pid)
    ret = PT_FCNTL(pid, fdinfo->fdnum, F_SETFL, fdinfo->flag);
    DEBUG("---- restore_fd() fd %d setfl flag 0x%x, ret %d\n",

```

```

    fdinfo->fdnum, fdinfo->flag, ret);
-
-
    free(fdinfo);
}
- if (1) {
- /* test: force pipe creation */
- static int first = 1;
- int pipe[2] = { 0, 0 };
- if (! first) return 0;
- else first = 0;
- t_d(PT_PIPE(pid, pipe));
- t_d(pipe[0]);
- t_d(pipe[1]);
- }
    return 0;
error:
    free(fdinfo);
@@ -1286,6 +1427,56 @@ int restore_sig(pid_t pid, struct sigaction *sigact, sigset_t *sigmask,
sigset_t
    return 0;
}

+int restore_fifo(int fd, pid_t pid)
+{
+ char item[64];
+ void *buf = NULL;
+ size_t bufsz;
+ int ret;
+ int fifo_fd;
+ char fname[64];
+ int nbytes;
+ fifofdinfo_t *fifofdinfo = NULL;
+
+ for(;;) {
+ ret = read_item(fd, item, sizeof(item), &buf, &bufsz);
+ DEBUG("restore_fifo() read item '%.12s'\n", item);
+ if ITEM_IS("END FIFO")
+ break;
+ else ITEM_SET(fifofdinfo, fifofdinfo_t);
+ else if ITEM_IS("fifobufs") {
+ DEBUG("restore_fifo() bufsz %d, fi_fd %d, length %d\n",
+ bufsz, fifofdinfo->fi_fd,
+ fifofdinfo->fi_length);
+
+ if (!fifofdinfo->fi_length)
+ continue;
+

```

```

+ sprintf(fname, "/proc/%u/fd/%d", pid,
+   fifofdinfo->fi_fd);
+
+   fifo_fd = open(fname, O_WRONLY|O_NONBLOCK);
+   if (fifo_fd < 0) {
+       ERROR("Error %d opening FIFO '%s'\n", errno,
+         fname);
+   }
+
+   errno = 0;
+   nbytes = write(fifo_fd, buf, bufsz);
+   if (nbytes != bufsz) {
+       ERROR("Wrote %d of %d bytes to FIFO '%s', "
+         "errno %d\n", nbytes, bufsz,
+         fname, errno);
+   }
+   close(fifo_fd);
+ } else
+   ERROR("Unexpected item, '%s'\n", item);
+ }
+ DEBUG("restore_fifo() fd %d, len %d, got 'END FIFO'\n",
+   fifofdinfo->fi_fd, fifofdinfo->fi_length);
+ return 0;
+}
+
static int process_restart(int fd, int mode)
{
    char item[64];
@@ -1369,6 +1560,8 @@ static int process_restart(int fd, int mode)
    ptrace_set_thread_area(npid, ldt);
    if (cwd) PT_CHDIR(npid, cwd);
    restore_fd(fd, npid);
+ } else if (ITEM_IS("FIFO")) {
+   restore_fifo(fd, npid);
+ } else if (ITEM_IS("SOCK")) {
    restore_sock(fd, npid);
+ } else if (ITEM_IS("SEMUNDO")) {
--

```

1.5.2.5

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