Subject: [RFC][PATCH][cryo] Save/restore state of unnamed pipes
Posted by Sukadev Bhattiprolu on Tue, 17 Jun 2008 21:29:50 GMT
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>From fd13986de32af31621b1badbcf7bfb5626648e0e 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-sid-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.

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

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

Signed-off-by: Sukadev Bhattiprolu <sukadev@us.ibm.com>
---
 cr.c | 215 ++----
 1 files changed, 203 insertions(+), 12 deletions(-)

diff --git a/cr.c b/cr.c
index 5163a3d..0cb9774 100644

```
--- a/cr.c
+++ b/cr.c
@@ -84,6 +84,11 @@ 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 */
@@ -468,6 +473,128 @@ 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;
+
+ 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;
@@ -587,6 +714,8 @@ 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++)
@@ -839,6 +968,29 @@ 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]);
   }

   /*
@@ -847,20 +999,8 @@ 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);
@@ -1231,6 +1371,55 @@ 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("Error %d writing to FIFO '%s'\n",
+      errno, fname);
+   }
+   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];
@@ -1314,6 +1503,8 @@ 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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