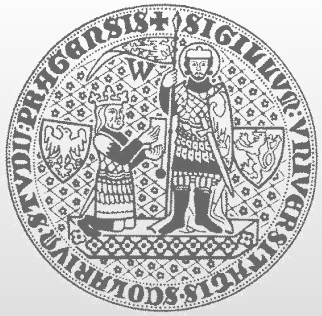
Deadlocks and Hangs

Crash Dump Analysis 2015/2016



CHARLES UNIVERSITY IN PRAGUE

faculty of mathematics and physics

Department of Distributed and Dependable Systems

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Overview

- **Deadlock**
  - "Cycle in resource waiting chain"
    - Coffman conditions
    - Various resources: mutexes, rwlocks, condition variables, implicit resources
- **Hang**
  - "No forward progress"
    - Using deadman timer

Deadlock

- **More formal definition**
  - Configuration in which two or more **activities** uninterruptibly block waiting for **resources** held by the others in the blocking chain
    - **Activities** can be processes, threads, interrupts
    - **Resources** can be synchronization primitives, but also generic resources

Coffman conditions

- **Necessary conditions for deadlock**
  1) One **resource** can be owned by only one **activity** at a time
  2) An **activity** can request additional **resources** even if it already owns some
  3) A **resource** cannot be forcibly revoked from an **activity**
  4) A cycle exists in the **activity-resource** waiting chain

Deadlock example

P1:

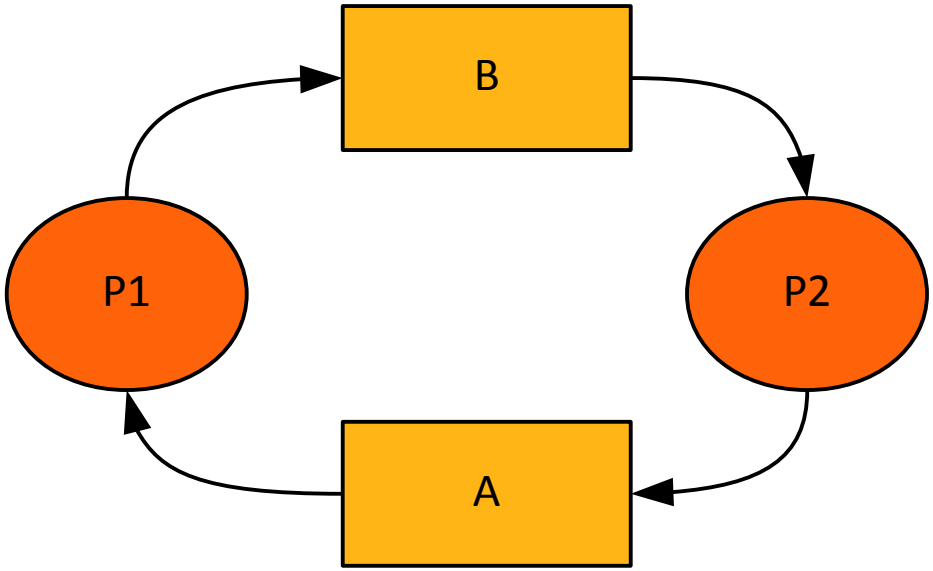
lock(A); ✔

lock(B); ☜

P2:

lock(B); ✔

lock(A); ☜



Synchronization primitives

- **Protection against race conditions**
  - Usually figure as resources in deadlocks
  - In Solaris
    - Mutexes
    - Readers-Writer Locks
    - Condition Variables

Mutex

- **Mutual exclusion from critical sections**
  - Solaris kernel: `kmutex_t`
  - ::mutex

```
mutex_enter(&pidlock);
retval = p->p_pgrp;
mutex_exit(&pidlock);
```

```
> ffffff02e10356e0::mutex
            ADDR  TYPE             HELD MINSPL OLDSPL WAITERS
ffffff02e10356e0 adapt ffffff02d5848980      -      -      no
```

Readers-Writer Lock

- **Critical sections for multiple readers or one writer**
  - Solaris kernel: krwlock_t
  - ::rwlock

```
rw_enter(&nvf_list_lock, RW_READER);
rval = nvlist_lookup_nvlist(nvf_list, id, &list);
rw_exit(&nvf_list_lock);

rw_enter(&nvf_list_lock, RW_WRITER);
rval = nvlist_add_uint32(nvf_list, id, value);
rw_exit(&nvf_list_lock);
```

```
> ffffff00e93ece80::rwlock
            ADDR      OWNER/COUNT FLAGS          WAITERS
ffffff00e93ece80 ffffff00f1947b20  B100
                                    |
                 WRITE_LOCKED ------+
```

Condition Variables

- **Waiting for a condition to become true**
  - The condition is indicated by `cv_signal()` or `cv_broadcast()`
    - Condition tested and changed under the protection of a a mutex
  - Solaris kernel: kcondvar_t
  - ::wchaninfo

```
mutex_enter(&as->a_contents);
while (AS_ISCLAIMGAP(as))
     cv_wait(&as->a_cv, &as->a_contents);
AS_SETCLAIMGAP(as);
mutex_exit(&as->a_contents);
```

```
> ffffff00e8cc6dfa::wchaninfo -v
ADDR             TYPE NWAITERS   THREAD           PROC
ffffff00e8cc6dfa cond         1:  ffffff00e91aa0a0 Xorg
```

What runs in the system?

- **Crash dumps taken on a deadlocked or hung system may not exhibit the culprit directly**
  - Need to look further and deeper
    - ::cpuinfo
    - ::threadlist
    - ::findstack
    - Find arguments on the stack or use WCHAN as shown by ::threadlist

::cpuinfo & ::threadlist

```
> ::cpuinfo -v
 ID ADDR             FLG NRUN BSPL PRI RNRN KRNRN SWITCH THREAD           PROC
  0 ffffffffbc34aa0  1b    1   10  -1   no    no t-3    ffffff0002805c80 (idle)
                      |    |    |
            RUNNING <--+    |    +--> PIL THREAD
              READY         |           10 ffffff00028c5c80
             EXISTS         |            5 ffffff00028bfc80
             ENABLE         |
                            +-->  PRI THREAD           PROC
                                   60 ffffff0002e30c80 sched


> ffffff00028c5c80::threadlist -v
            ADDR             PROC              LWP CLS PRI            WCHAN
ffffff00028c5c80 ffffffffbc29c30                0   0 109 ffffffffbcd6340
  PC: resume_from_intr+0xb4    THREAD: unix`thread_create_intr()
  stack pointer for thread ffffff00028c5c80: ffffff00028c59a0
  [ ffffff00028c59a0 resume_from_intr+0xb4() ]
    swtch+0x90()
    turnstile_block+0x75b()
    mutex_vector_enter+0x261()
    clock+0x64f()
```

Interpretation of WCHAN

- **Various means**
  - Using ::whatis
  - Guessing the type from the stack trace
  - Need to investigate what is the holder doing

```
> ffffffffbcd6340::whatis
ffffffffbcd6340 is tod_lock+0 in genunix's bss
> ffffffffbcd6340::mutex
            ADDR  TYPE             HELD MINSPL OLDSPL WAITERS
ffffffffbcd6340 adapt ffffff00e91aa0a0      -      -     yes
```

Useful queries

- **Is someone waiting on e.g. a rwlock?**
  - `::threadlist -v ! less`
  - `/rw_enter`
- **::findlocks**
  - Can detect wait cycles
  - Needs ::typegraph
  - “nota bene: locks may be held”

Deadlock appearance

- **A deadlocked system will either**

  (a) Crash because the kernel detects the cycle in the waiting chain

  (b) Appear hung and unresponsive

  - Eventually crash due to `deadman` timer, if the `lbolt` variable does not change

  (c) Appear working, if the resources involved in the deadlock are not vital

Dealing with hangs

- **Goal: Force the system to crash**
  - In order to find the culprit in the crash dump
  - It may be illustrative to explore the hung system using kmdb before forcing the crash dump
    - Using breakpoints and binary search to find the top-level function which loops (if any)
      - The only option if the hang occurs too early before a dump can be generated

Binary search on a stack trace

1. Break into kmdb
2. $C
3. Pick the return address in the middle of the stack trace
4. :c
   - If the breakpoint **was hit**, clear all breakpoints (:z) and repeat the search on the lower half of the stack trace
   - If the breakpoint **was not hit**, clear all breakpoints (:z) and repeat the search on the upper half of the stack trace
     - It is possible that the stack trace starts with the top-level function. In that case, try to put a breakpoint to a function called from it and see if it gets called

Enforcing crash dump

- If you can still use the system shell
  - `hald -d`
  - `reboot -d`
  - `uadmin 5 1`
- If kmdb is loaded and you can break into it (F1+A, Stop+A, Ctrl+] se)
  - `$<systemdump`
- If you can break into OBP prompt on SPARC (Stop+A, Ctrl+] se)
  - `sync`

Enforcing crash dump (2)

- **Using a button**
  - NMI/XIR buttons on server machines
  - Three times the power button
- **Deadman timer**

Deadman timer

- **Periodic activity**
  - Wakes up each second and monitors the system `lbolt` variable*
  - Needs to be enabled in /etc/system
    - `set snooping=1`
  - If "`lbolt`" does not change for a pre-configured amount of time (default is 50 s), the system dump is generated

** lbolt variable was removed from Solaris 11 in favor of ddi_get_lbolt()*