SCC.211 Operating Systems

Session 7

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Overview

- Summary/ recap of:
  - Topic 5: Multi-process Systems
    - Real-Time Systems and Real-Time Scheduling
  - Topic 6: File-systems
- Brief Introduction to
  - Topic 7: Memory Protection

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5. Multi-process Systems

Summary/ Recap

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Recap

- Types of multi-process system
- Difference between dispatchers and schedulers
  - Scheduler makes choice, dispatcher actions that choice
- Schedulers
  - Seen examples and comparison/ common metrics for
    - First Come First Served
    - Round Robin

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Real-Time Systems

- Real-time process
  - Process that delivers results of processing in a given time-span
- Real-time system
  - System in which correctness of computation depends not only on obtaining the right result, but also upon providing the result on time
- Deadline
  - Deadline represents latest acceptable time for
    - Processing result to be considered correct, or…
    - Presentation of result to be valid

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Real-Time Processes

- Soft Real-Time
  - Deadlines may be broken
    e.g. High-end, professional multimedia
- Hard Real-Time
  - Deadlines critical
    e.g. Embedded/ Control Systems
    - May require safety conformance certification (proof it will <u>always</u> meet deadlines)

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Real-Time Scheduling

- Driven by events/ deadlines
  - Periodic events …*predictable*
  - Aperiodic events …*unpredictable* -- *beware!*
- Must ensure work can <u>always</u> be scheduled even in <u>worst possible case</u>
  - Never take on too much work …*requires* ***admission-control***
  - Utilisation of resources (including CPU) must never be greater than 100%
    - This must also consider context switching overheads

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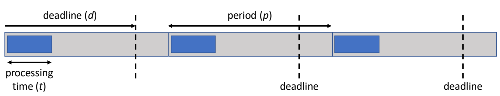
Periodic Tasks

- Rate = 1/ *period*
- Need to check
  - Processing time for process must be < process deadline
  - Total processing time per cycle must be < period

…Much harder with multiple tasks, periods, and deadlines



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Pre-emptive Real-Time Schedulers

- Rate Monotonic (RM)
  - Fixed, repeating schedule for worst possible case …*pre-emptive version of last slide*
  - Priority inversely proportional to required work period …*more frequent = higher priority*
  - Assume processes have same amount of work (CPU processing/ burst time) each cycle
- Earliest Deadline First (EDF)
  - Dynamic scheduling scheme
  - Each process has sequence of deadlines …*schedule process with closest deadline*

Recall: we saw EDF with disk scheduling

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6. File-Systems

Summary/ Recap

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Overview

- Approaches to storing files
- Common file-systems
  - FAT, traditional Unix, e.g., ext2
- Journaling and Locking
- New approaches

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FAT Schemes

- Simple filesystems
- Common on small disks/ consumer products
- Limited capacity
  - Need to scan full sector/ block list to find any point in file
    - List held in File Allocation Table (typically multiple copies for resilience)
  - To be efficient, whole FAT must be in-memory

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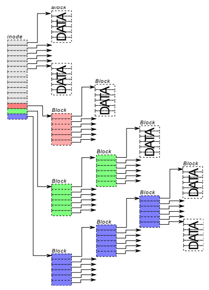
Unix index-node (inode)

- Combined index scheme
  - Random access – can jump to any point in file
  - Index levels/ depth vary with file size
    - Supports very large files
    - Efficient for small files
- Supports sparse files
  - No need to store empty (all zero) blocks
    - Data blocks or index blocks



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Creating a Sparse File

```c
const char * message = "Hello World\n";

int
main( ) {
        FILE * stream = fopen( "testfile.txt", "w" );

        if( stream == NULL ) { /* Handle error */ }

        fwrite( message, sizeof( char ), strlen( message ), stream );

        fseek( stream, 1024 * 1024 * 1024, SEEK_SET ); // Make hole

        fwrite( message, sizeof( char ), strlen( message ), stream );

        fclose( stream );
}
```

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Program Output

```
$ gcc hole.c -o hole
$ ./hole
$ ls -l
total 32
-rwxrwxr-x 1 acs acs      17000 Oct 13 21:35 hole
-rw-rw-r-- 1 acs acs        453 Oct 13 21:34 hole.c
-rw-rw-r-- 1 acs acs 1073741836 Oct 13 21:35 testfile.txt
$
```

~ 1GB in size

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Program Output II

```
$ gcc hole.c -o hole
$ ./hole
$ ls -l
total 32
-rwxrwxr-x 1 acs acs      17000 Oct 13 21:35 hole
-rw-rw-r-- 1 acs acs        453 Oct 13 21:34 hole.c
-rw-rw-r-- 1 acs acs 1073741836 Oct 13 21:35 testfile.txt
$ du -k *
20      hole
4       hole.c
8       testfile.txt
$ od testfile.txt
0000000   H   e   l   l   o       W   o   r   l   d  \n  \0
0000020  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0
*
10000000000   H   e   l   l   o       W   o   r   l   d  \n
10000000014
```

~ 1GB in size

Only 8KB on disk (2 x 4K blocks)

Notice the hole

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Journaling File Systems

- Examples: NTFS, ext3, …
- File-system updates written as *transactions* to journal/ log
  - Transactions periodically flushed to disk
  - Entries only removed from log when confirmed written/ flushed
- Fast as decouples file writes from disk head movement
  - Flush operation can do in-order sector (block) writes
  - Transaction log could be on faster disk/ media
- Resilient as log can be ‘replayed’ in event of system failure
  - Transactions must be ***atomic*** and ***idempotent***

Atomic: All or no subparts of transaction must be completed
Idempotent: Can be repeated any number of times and still give same result

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Journaling

- (Circular) Transaction log of filesystem updates
  - Can be replayed in event of system failure
  - If committed all updates must done, else none
  - Depending on filesystem, log can be held on same disk or fast SSD

Start (Metadata)	Update	Update	Update	Commit

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POSIX File Locking: *fcntl( ), lockf( )*

- Often only way to coordinate unrelated applications
- Shared Lock
  - Any number of shared locks possible
  - Cannot include any data byte under an exclusive lock
- Exclusive Lock
  - Fails if any requested byte subject to existing lock
- API allows blocking and non-blocking lock requests
  - Blocking lock request hangs until bytes available (no other locks)

Note: a process can only have one type of lock on a file at any point

Early systems often locked at file descriptor (whole file) level, see (BSD style) flock( ) -- now mainly used for process/ thread synchronisation, but note that threads must explicitly open( ) file to get new descriptor… i.e. not inherit via fork( ), or via dup( ).

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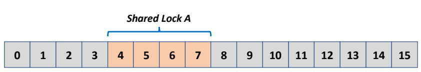
POSIX File Locking



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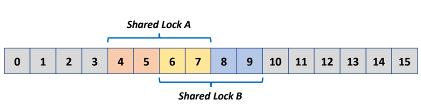
POSIX File Locking



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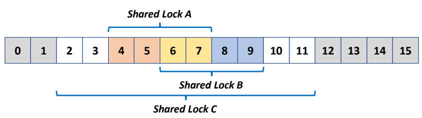
POSIX File Locking



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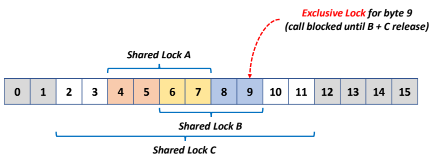
POSIX File Locking



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New filesystems: *extents and delayed writes*

- Portions of file stored as contiguous set of disk blocks
  - Makes file reads more efficient
    - Less meta-data (block pointers and indexes, etc.) to process
    - Less fragmentation
    - Less head movement
  - Delay (collate) writes, or applications can use *pre-allocation* with *fallocate( )*
- File information contains list of extents:

Logical Block address (start of extent in file)
Number of contiguous disk blocks in extent
Block address of first disk block in extent

Used in ext4 and similar *Cluster Run* scheme used in NTFS

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Other Improvements

- Fine grained timestamps
  - Granularity of 1 sec no longer acceptable… use *ns*
- Database technology in filesystems
  - Database style (H or B+ based) indexes for
    - Directories
    - Accessing tree of extents
  - Databases as a filesystem
    - Very powerful
    - Problematic due to semantics of/ expected result common operations
      - No longer simple tree of files and directories expected by users and applications

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7. Memory Protection

Introduction

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Memory Protection

- Basic approach
  - Memory Management Unit (MMU)
- Segmentation
  - Variable length scheme
- Paging
  - Fixed length scheme

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