

Operating Systems

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Lecture 8b

Memory management

- Virtual memory
- Addressing and address spaces
- Partitioning and segmentation
- Paging & Page replacement

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Recap: Questions

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Recap questions

1. How can we avoid page faults when a process starts?
2. How can thrashing be controlled?
3. What is a working set?
4. What is the significance of the reference bit in the page table?
5. What is the main problem of the FIFO page replacement policy?
6. What information is required to operate the LRU policy?

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Files

- Persistent storage **Assignment Project Exam Help**
- Formats, access, operations **<https://powcoder.com>**
- Attributes & permissions
- Implementation **Add WeChat powcoder**

Files

- Persistent storage of data
- Named
- Byte-wise access
- Access protection
- Consistency guarantees

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Operating system duties:

- Manage efficient access (e.g. caching)
- Protect storage device from being damaged/corrupted
- Provide uniform interface for heterogeneous devices

Basic terminology

- **Bit**: 0, 1
- **Byte**: typically 8 bits
- **Word**: the number of bits a processor can operate on at once
- **Character**: maps one or more bytes to letters, digits, etc
- **Character set**: defines the mapping system (e.g. ASCII, Unicode)
- **Field**: a group of characters
- **Record**: a group of fields
- **File**: a group of related records
- **Volume**: a unit of data storage holding multiple files
- **File system**: the way the OS organises files and manages access

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- Human-readable name to identify a file
- Maps to an internal identifier in the file system
- Length of the file name
 - MS-DOS: 8 characters + extension
 - Modern OS: 255 characters
- Relevance of upper/lower case, allowed characters
 - Unix distinguishes between upper/lower case, unlike Windows
- File name extensions
 - MS-DOS: separate from the file name
 - Modern OS: convention, multiple extensions possible

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- Regular files
 - Text files: interpretation as characters
 - Binary files: interpretation application-specific
e.g. executables, pictures
- Directories: hierarchy of files
- Special files for I/O devices

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Define how the data is organised within a file

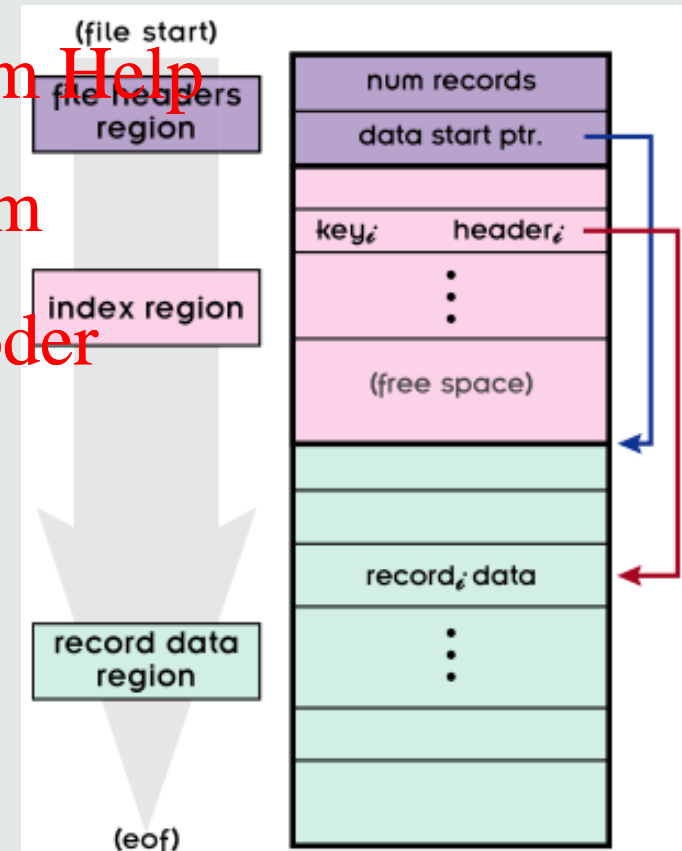
- Fixed-length records
- Variable-length records
- Indexed records
- Trees: XML, JSON

record 0	10101	Srinivasan	Comp. Sci.	65000
record 1	12121	Wu	Finance	90000
record 2	15151	Mozart	Music	40000
record 3	22222	Einstein	Physics	95000
record 4	32343	El Said	History	60000

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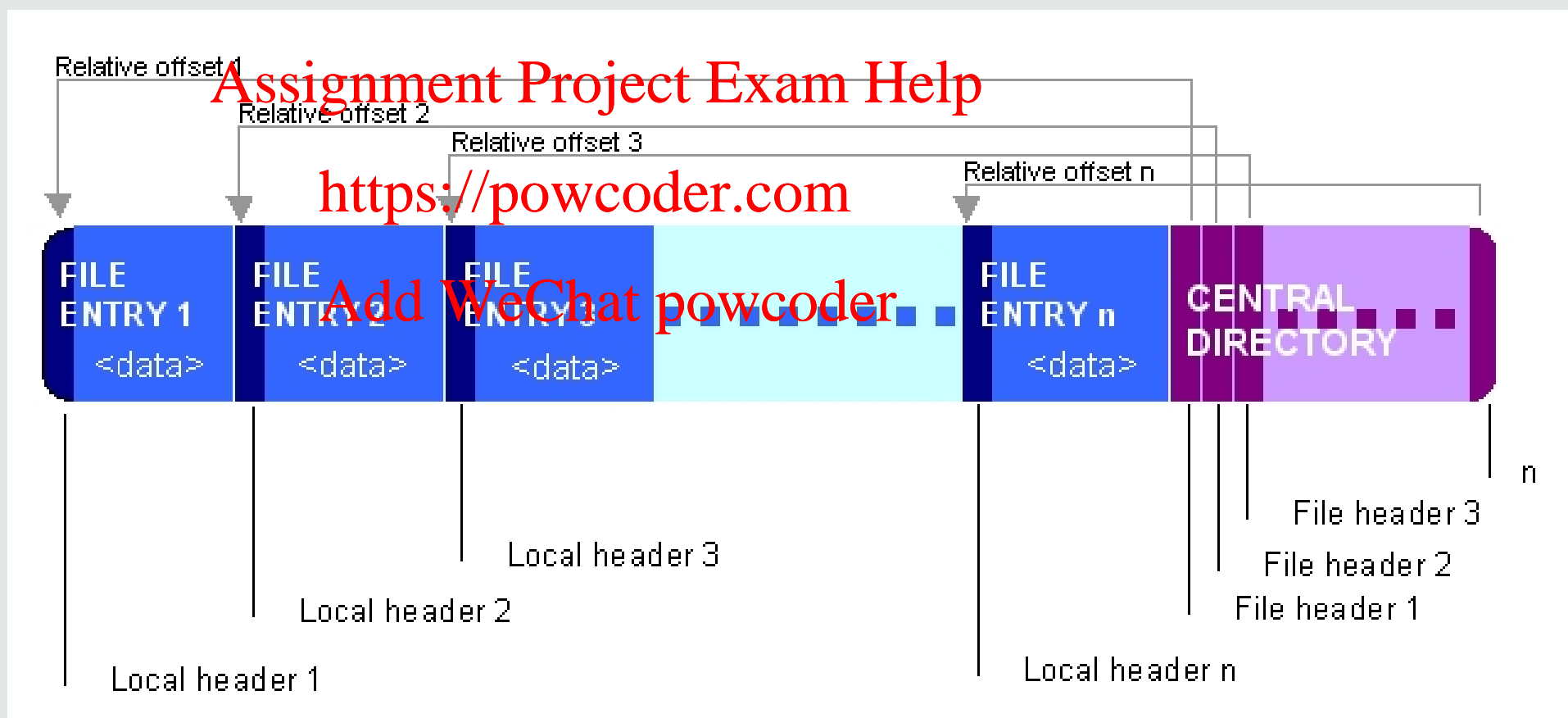
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File formats

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Example: ZIP format



Example: ZIP format

[illegible]

File formats

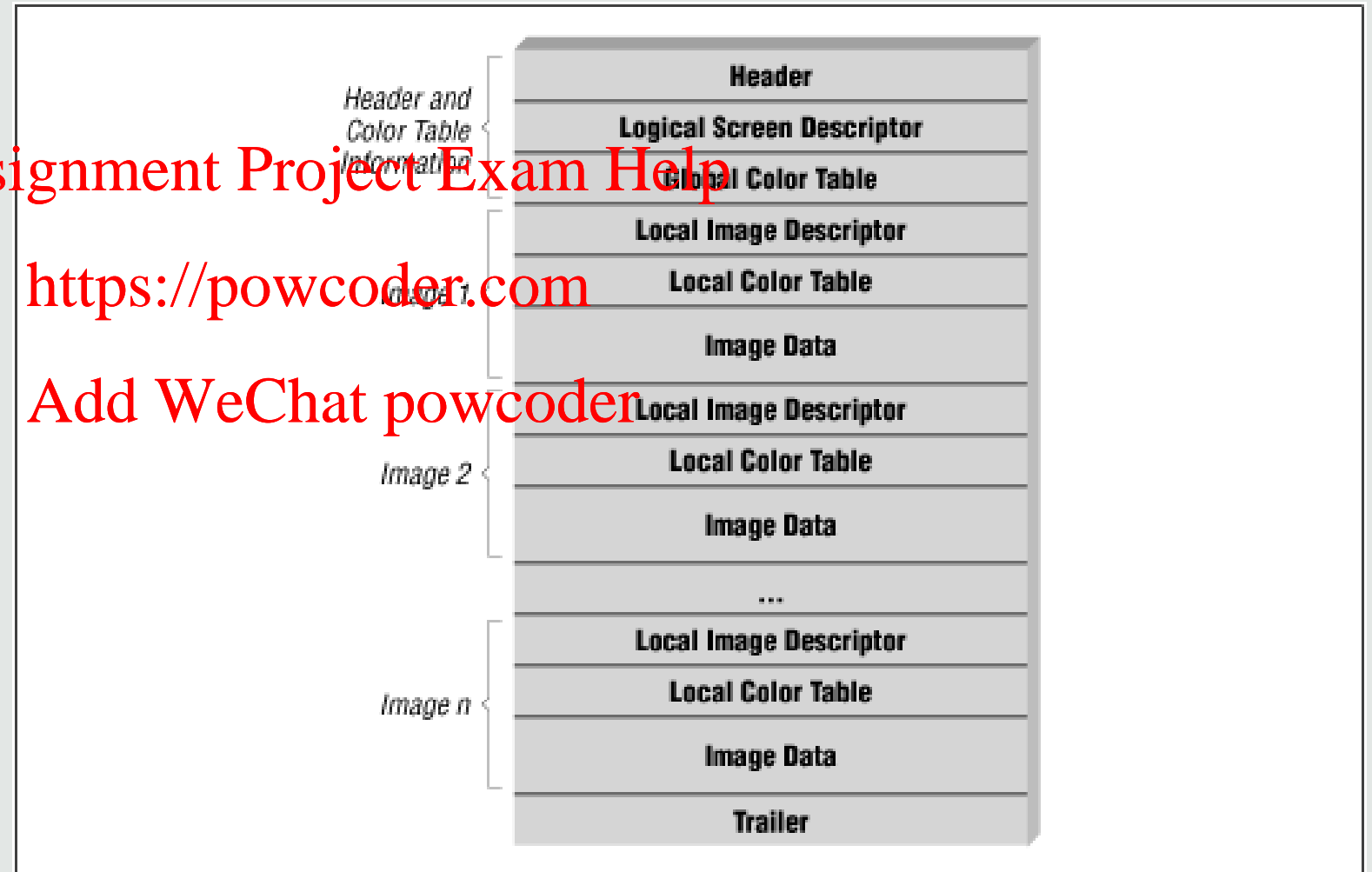
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Example: GIF format

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Example: GIF format

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	ASCII
00000000	47	49	46	38	39	61	18	01	5A	00	E6	00	00	FF	FF	FF	GIF89a..Z.ж..яяя
00000010	F7	E2	51	EA	D8	58	D9	B4	0B	00	00	00	F5	E0	50	E8	чвQкШХЩг....хаРи
00000020	D6	57	FA	1			4D										ЦWъштпШМК°FвОТХN°
00000030	40	EA	D2	4			E5										ѢкТКЮЙQeTVЭГЕШЙнь
00000040	DD	CC	9A	D4	BC	4B	F2	DC									ЭМЪфjКтЬOrKGD\$Хе
00000050	C7	3B	D9	BD	42	BD	A1	5C	E3	D5	26	DC	C7	50	DF	CB	з+ЩSBSŸ\yX&bЗРЯЛ
00000060	52	EB	B5	4C	E9	D7	58	DB	C5	64	E7	BC	0A	FE	D5	00	РнХЛЙчХЭEdsj.юХ.
00000070	E0	CC	52	D3	B6	40	D7	C4	8F	C6	A5	39	B5	97	3A	F6	амРУѢ@чДЦЖГ9μ-:ц
00000080	E2	24	FF	FE	00	CD	B4	48	D1	B3	3F	FF	E9	00	BF	9E	в\$яю.НгHci?яй.іћ
00000090	30	14	BE	60	FE	EE	24	09	C2	4E	D6	B2	18	F7	F3	E6	6Фіцo\$ЩВNЦІ.чуж
000000A0	BB	9E	3E	ED	DE	97	D5	C0	69	DB	BE	36	E3	D3	9C	D7	»ћ>нЮ-ХАiЫs6гУньч
000000B0	B6	35	DD	CA	6E	D9	BE	3C	E8	CE	08	E6	D9	9A	E7	D2	Ѣ5ЭKnЩs<иО.жЩъэТ
000000C0	68	DB	C1	22	C1	9F	36	B7	98	3B	DE	CF	9F	D4	B0	25	іЫБ2Вц6..;ЮЦф°%
000000D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
000000E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
000000F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000100	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000110	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000120	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000130	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000140	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000150	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000160	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000170	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.....
00000180	00	00	00	00	00	00	00	00	00	00	00	00	00	21	F9	04	.....!щ.
00000190	00	00	00	00	00	2C	00	00	00	00	18	01	5A	00	00	07	.....Z...
000001A0	FF	80	00	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E€%Љ< ЪЌѢ
000001B0	8F	90	91	92	93	94	95	96	97	98	99	9A	9B	9C	9D	9EѢ > ѢЌћ

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Width: 280 pixels

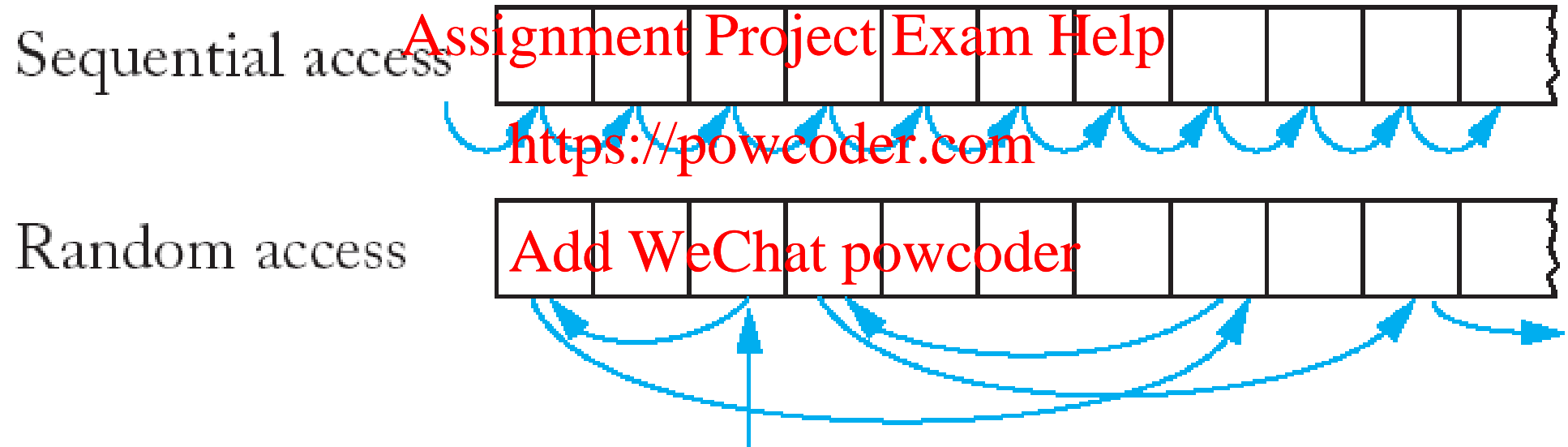
Height: 90 pixels

Flags: 11100110

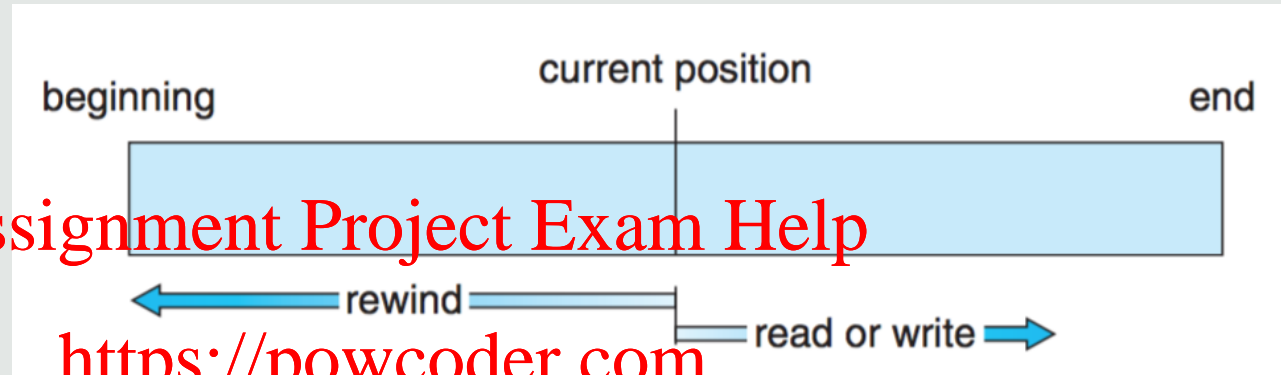
First data block (extension block)

Image's first sub-block size: 255

Flags: 00000111

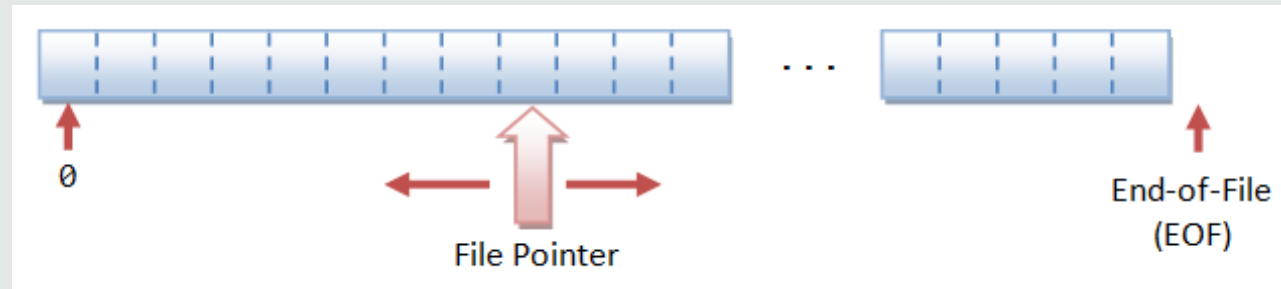


Sequential access:



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Random access:



Typical operations:

- Create, Delete, Rename
- Open, Close
- Read, Write, Append, Truncate
- Seek
- Get Attributes, Set Attributes
- Lock, Unlock

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File operations

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Example: POSIX System calls

int open(const char *filename, int flags, mode_t mode);

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O_RDONLY	open for reading only
O_WRONLY	open for writing only
O_RDWR	open for reading and writing

O_APPEND	append on each write
O_CREAT	create file if it does not exist: REQUIRES mode
O_TRUNC	truncate size to 0

```
// example:  
int fd = open("myfile.txt", O_WRONLY | O_CREAT, 0644);  
if (fd < 0) switch(errno) { ... }
```

File operations

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Example: POSIX System calls

```
ssize_t read(int fd, void *buf, size_t count);
```

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// example:

```
char buffer[BUF_SIZE];  
ssize_t bytes read = read(fd, buffer, BUF_SIZE);
```

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Example: POSIX System calls

```
ssize_t write(int fd, void *buf, size_t count);
```

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// example:

```
char buffer[BUF_SIZE];  
ssize_t bytes_written = write(fd, buffer, BUF_SIZE);
```

File operations

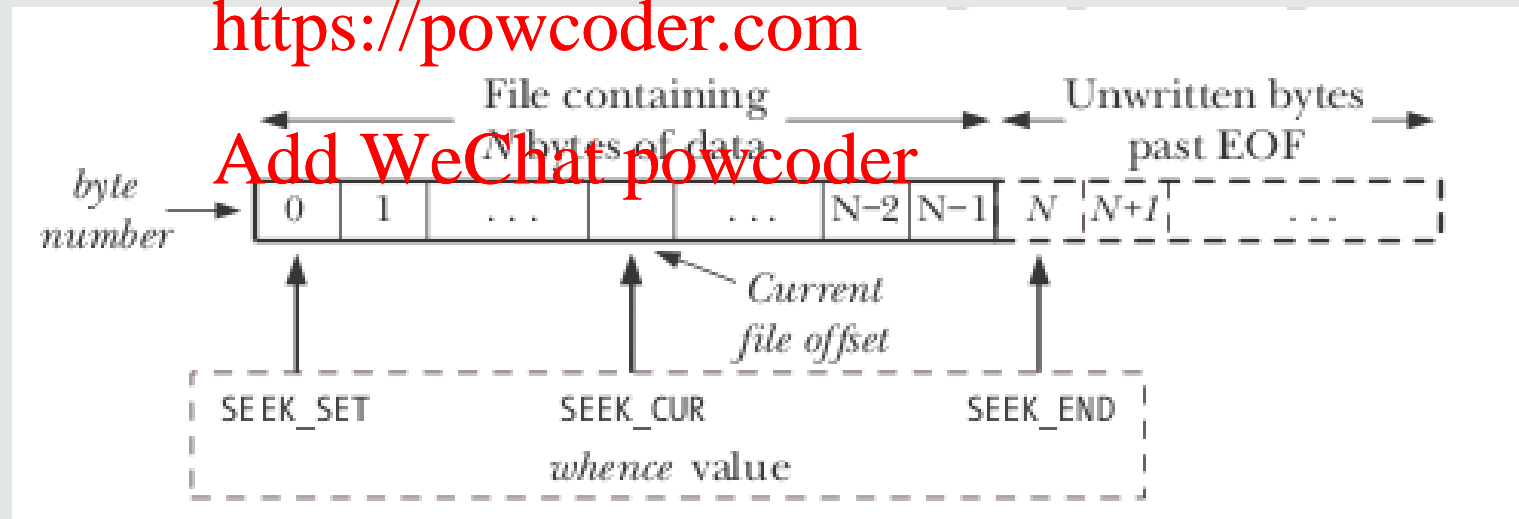
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Example: POSIX System calls

```
ssize_t lseek(int fd, off_t offset, int whence);
```

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```
// example:  
off_t pos = lseek(fd, 0, SEEK_CUR);
```

File operations

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Example: POSIX System calls

```
int close(int fd);
```

```
int unlink(const char *pathname);
```

```
int fcntl(int fd, int cmd, ... /* args */ );
```

File operations

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Example: POSIX System calls

`int stat(const char *filename, struct stat *buf);`

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```
struct stat {  
    dev_t    st_dev;      /* ID of device containing file */  
    ino_t    st_ino;      /* inode number */  
    mode_t   st_mode;     /* protection */  
    nlink_t  st_nlink;    /* number of hard links */  
    uid_t    st_uid;      /* user ID of owner */  
    gid_t    st_gid;      /* group ID of owner */  
    dev_t    st_rdev;     /* device ID (if special file) */  
    off_t    st_size;     /* total size, in bytes */  
    blksize_t st_blksize; /* blocksize for file system I/O */  
    blkcnt_t st_blocks;   /* number of 512B blocks allocated */  
    time_t   st_atime;     /* time of last access */  
    time_t   st_mtime;     /* time of last modification */  
    time_t   st_ctime;     /* time of last status change */  
};
```

Typical metadata:

- Creator, Owner, Owner Group, Protection, Password
- Read-only flag, Write flag, Executable flag, Hidden flag, System flag, Archive flag, ASCII/binary flag, Random access flag, Temporary flag, Lock flags
- Creation time, Time of last access, Time of last change
- Record length, Key position, Key length
- Current size, Maximum size

Example: UNIX file attributes

permissions		user	group	size	date	file/directory
drwxr-xr-x	2	paul	users	1024	Jan 2 23:50	..
drwxr-xr-x	6	root	root	1024	Jan 2 22:51	..
drwxr-xr-x	3	paul	users	1024	Jan 8 11:42	grassdata
lrwxrwxrwx	1	paul	users	13	May 6 1998	latex -> /d2/lt
drwx-----	2	paul	users	1024	Mar 8 17:30	mail
drwx-----	2	paul	users	1024	Feb 4 81:09	projects
-rw-r--r--	1	paul	users	844344	Dec 9 1998	nations.ps
-rw-rw-r--	1	paul	users	21438	Mar 2 21:47	ps4mf.txt

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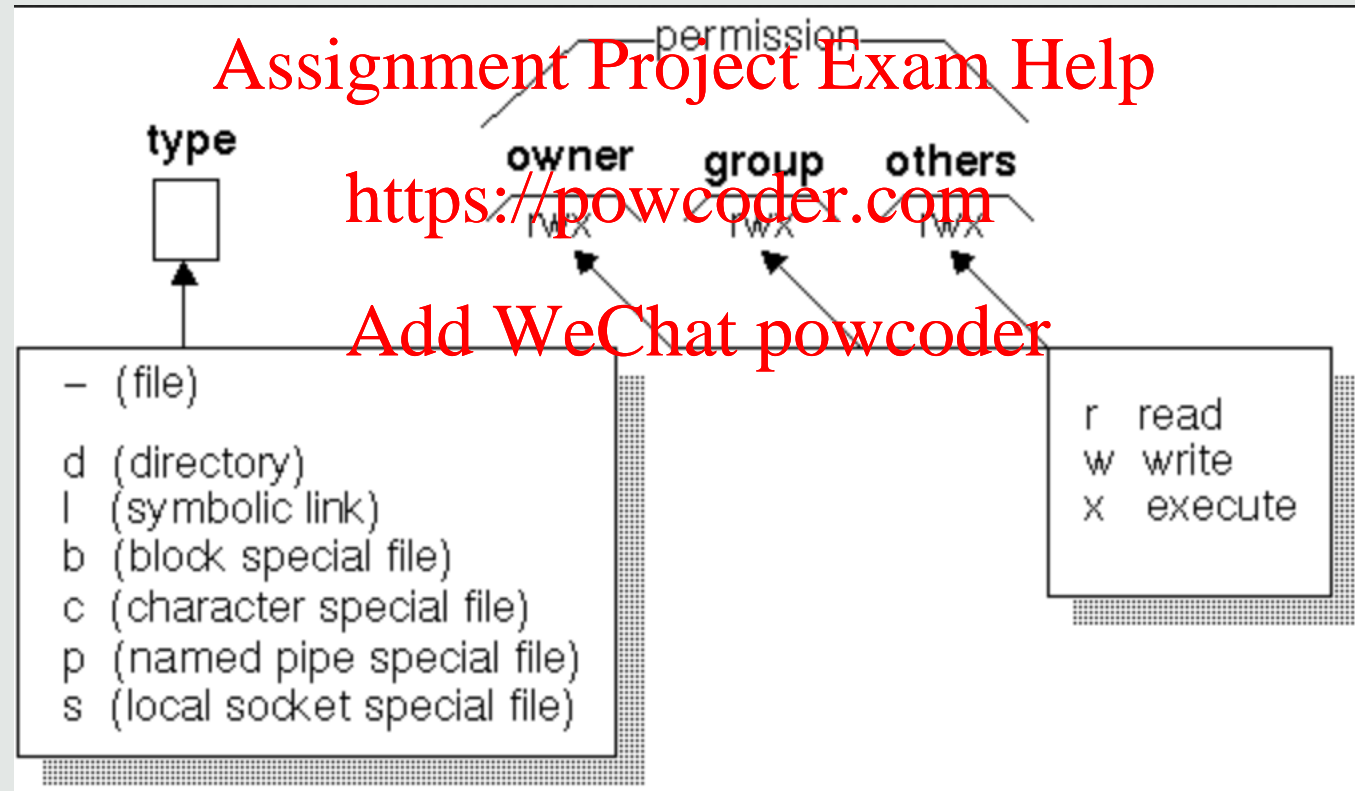
The diagram illustrates the structure of UNIX permissions. It shows three arrows pointing from the first three characters of the permission string to their respective categories: the first character for user permissions, the second for group permissions, and the third for other (world) permissions. A legend defines the letters: 'r' for read, 'w' for write, and 'x' for execute. A hyphen '-' indicates a permission not set. Below this, another legend defines the first character of the permission string: 'd' for directory, '-' for file, and 'l' for link (to other file/directory).

other (world) permissions
group permissions
user permissions

r : read permission
w : write permission
x : execute permission (programm)
- : permission not set

d : directory
- : file
l : link (to other file/directory)

Example: UNIX file permissions



Example: UNIX file permissions

	File	Directory
Read	Read	Ignored
Write	Write	Allowed to create files in the directory
Execute	Execute	Allowed to view files in the directory
Set UID	Allows all users to execute the file with the permissions of the owner	Ignored
Set GID	Allows all users to execute the file with the permissions of the group	All new files created in the directory are set to the same group as the directory
Sticky Bit	Ignored	Prohibits non-owners from deleting or renaming a file

Example:

`java.io.File`

`File(String pathname)`

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```
boolean exists()
boolean createNewFile()
boolean renameTo(File dest)
boolean delete()
long length()
long lastModified()
boolean canRead()
boolean canWrite()
boolean canExecute()
boolean setReadable(boolean readable,
boolean ownerOnly)
boolean setWritable(boolean writable,
boolean ownerOnly)
boolean setExecutable(boolean executable,
boolean ownerOnly)
. . .
```

Example:

```
java.io.RandomAccessFile
```

```
RandomAccessFile(String name, String mode)  
throws FileNotFoundException
```

```
void close()  
int read(byte[] b)  
int write(byte[] b)  
void seek(long pos)  
long getFilePointer()  
void setLength(long newLength)  
String readLine()  
double readDouble()  
.  
.  
.  
  
throw  
    IOException,  
    EOFException,  
    SecurityException,  
    .  
    .  
    .
```

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Example:

java.io Streams and Readers/Writers

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`FileInputStream(File file)`

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```
int read(byte[] buf)
void close()
```

`FileOutputStream(File file)`

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```
int write(byte[] buf)
void close()
```

`FileReader(File file)`

```
int read(char[] cbuf)
void close()
```

`FileWriter(File file)`

```
int write(char[] cbuf)
void close()
```

- How files are stored

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- How storage space is managed

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- Performance

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- Reliability

Files

- Naming: human-readable identification
- Attributes: permissions, ownership, dates, . . .
- Access: open - read / write - close
- Unified interface for access to a variety of devices
- Examples: POSIX, Java

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- Tanenbaum & Bos., Modern Operating Systems

- Chapter 4

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- Silberschatz et al., Operating System Concepts

- Chapters 10 & 11

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- Introduction
- Operating System Architectures
- Processes
- Threads - Programming
- Process Scheduling - Evaluation
- Process Synchronisation
- Deadlocks
- Memory Management
- **File Systems (continued)**
- Input / Output
- Security and Virtualisation

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