(Midterm Exam Problem 3)

Review: File Descriptor Behavior

COMP 321

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Opening a File

```
int  open(const char *pathname,  int flags);
```

Opens a file for the indicated (i.e., flags) type of accesses

- Set flags to one of
  - O_RDONLY: open the file for reading from only
  - O_WRONLY: open the file for writing to only
  - O_RDWR: open the file for reading from and/or writing to
- Returns the ***lowest numbered*** file descriptor number that is not currently open in this process to something else
- Returns -1 on any error and sets global variable errno to indicate which error

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Opening a File

```
int  open(const char *pathname,  int flags);
```

The flags argument may also include other bits, such as

- O_APPEND: On each write() to this open fd, always move to the end of the file first (every write() only appends to the file)
- O_TRUNC: If the file exists (and if possible), truncate the file to empty on the open()

- Specify flags as the "or" of what you need, e.g.,
  - open(name, O_RDWR | O_APPEND)
  - open(name, O_WRONLY | O_TRUNC)

Writing a File

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

Writes into the contents of a file from memory beginning at address buf

- The file must already be open – fd specifies which file to write to
- File data is transferred sequentially from buf, starting at fd current position
- The maximum number of bytes to write is given by count
  - Tries to write requested count, returns the number of bytes actually written
  - Number written may be less than requested (a "***short count***")
  - This is ***not*** an error! We'll talk more about this later
- Returns -1 on any error and sets global variable errno to indicate which error

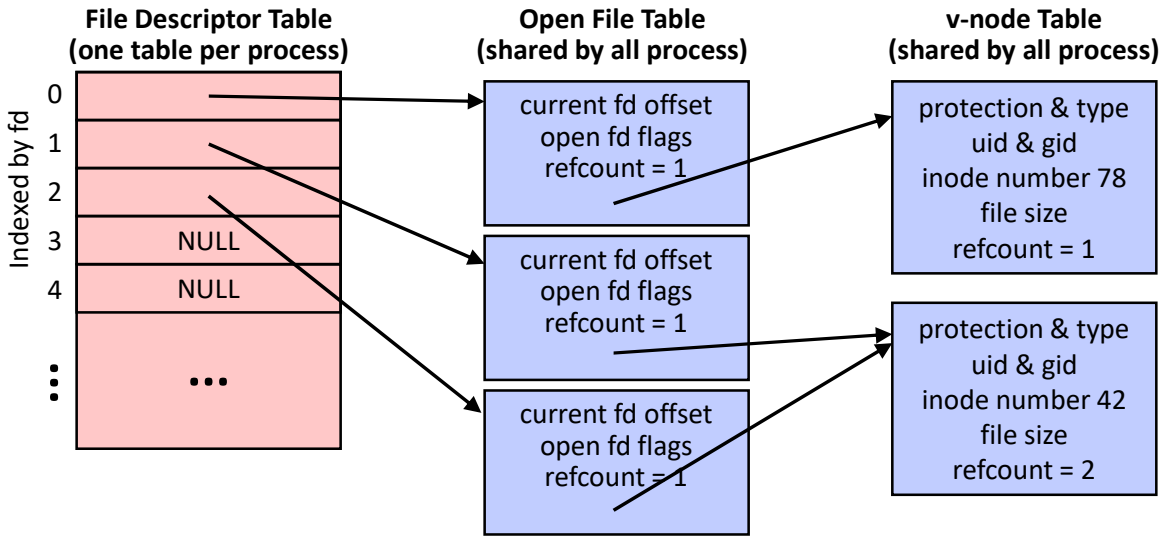
Explicitly Moving a File Descriptor's File Offset

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

Changes current offset for file descriptor fd to new position in the file's data

- The new fd offset is set to "offset" number of bytes relative to "whence"
  - SEEK_SET: fd offset is set to offset bytes (absolute)
  - SEEK_CUR: fd offset is set to current position plus offset bytes
  - SEEK_END: fd offset is set to the size (bytes) of the file plus offset bytes
- In general, "offset" may be negative (e.g., offset = -100, whence = SEEK_CUR)
- Returns
  - The fd's new file offset, on success
  - -1 on any error and sets global variable errno to indicate which error

Kernel Data Structures Help Define the Behavior



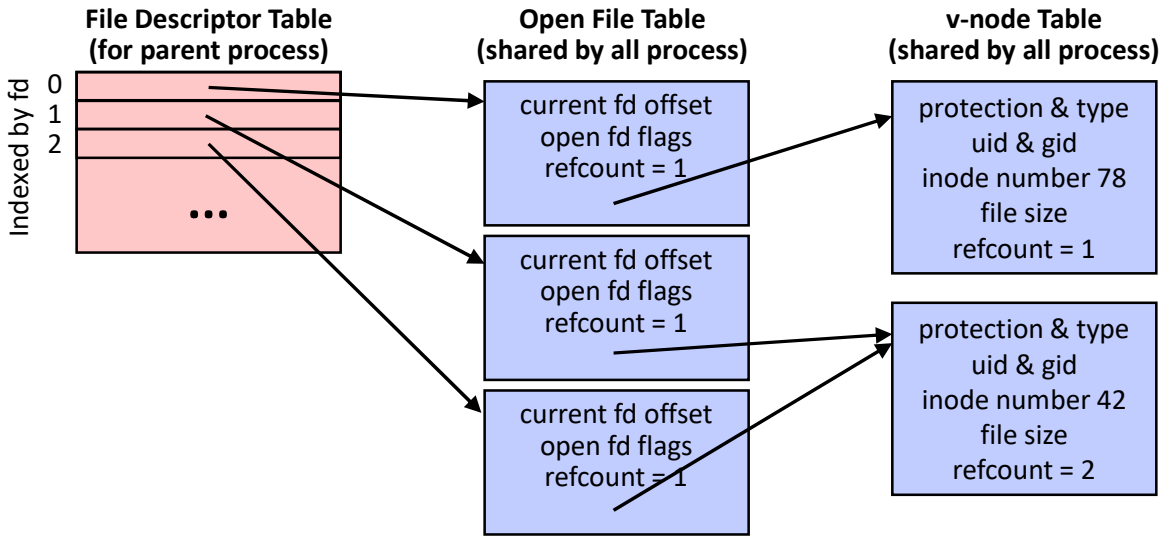
Creating a New Process

```
pid_t  fork(void);
```

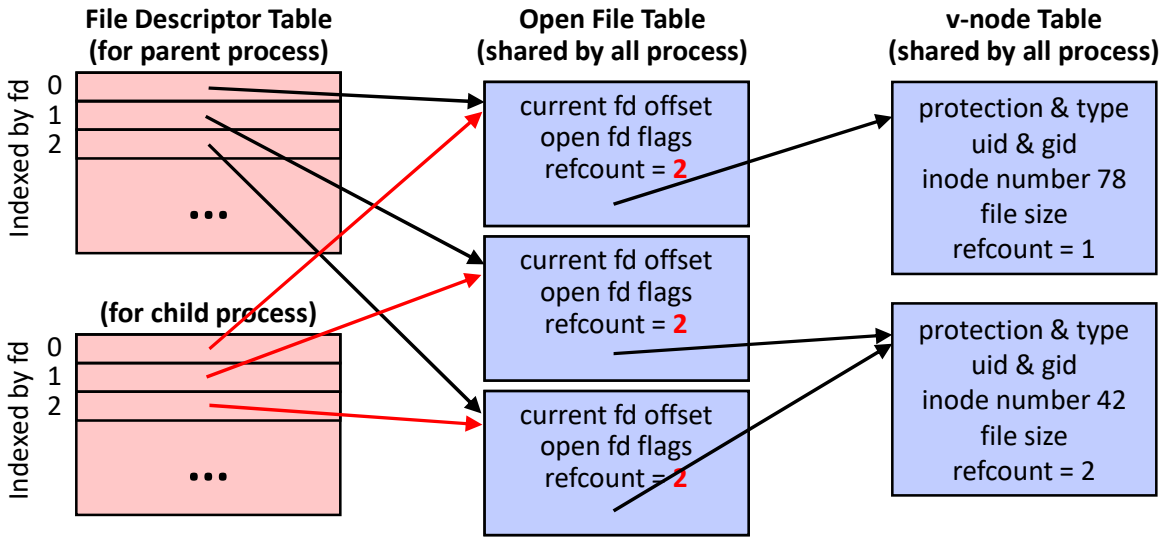
Creates a new process as an identical "clone" of the calling process

- Kernel creates a new PCB for the new process, substantially as a copy of the calling process's existing PCB
- Kernel assigns new process a new pid, remembered in the kernel in child's PCB
  - pids assigned in ascending order, wrapping around, skipping those in use
- Child address space is created as a ***copy*** of the calling process's address space
  - Child thus ***appears*** to have called fork(), since the parent did call fork()
  - So fork() returns **twice**
    - Once (as normal) in the ***parent***: returns the new child's pid
    - And once (appearing to be normal) in the ***child*** process: returns 0

Kernel File Data Structures Before the Fork



Kernel File Data Structures After the Fork



Midterm Exam Problem 3

Consider the following C program (you should assume that all kernel calls and procedure calls in it always succeed).

- If the file "data" is initially an empty file before executing this program, how many characters are in the file after completion of the program's execution? Enter a single number only.
- What are the complete contents of the file "data" after the completion of this execution of the program as described above? *Clearly* write out the complete file contents below.

We'll walk through the program's execution step by step . . .

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

(empty)


```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

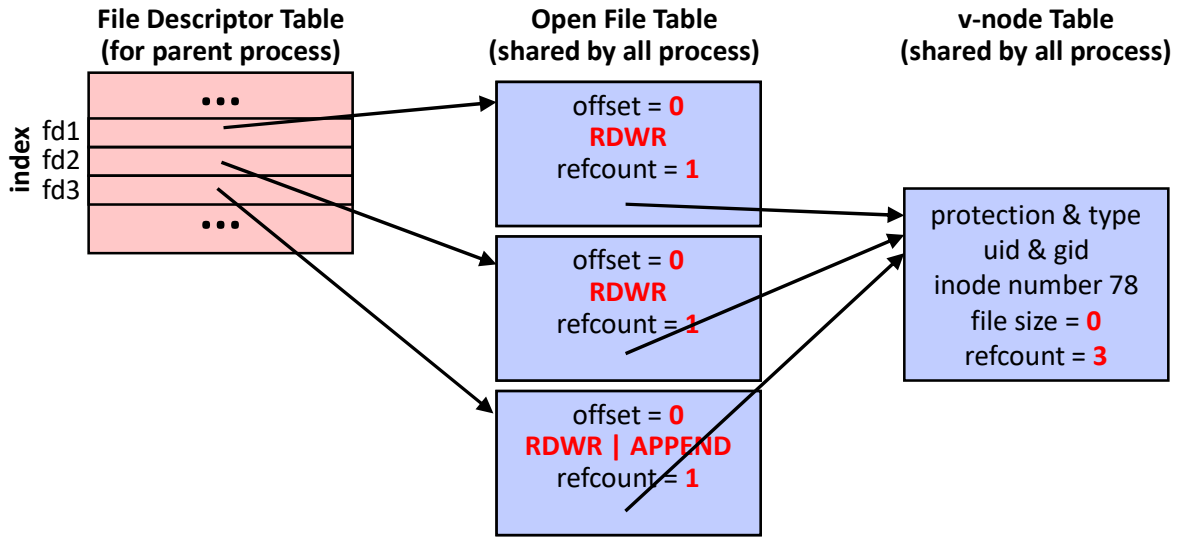
```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

(empty)

fd1 offset = 0
fd2 offset = 0
fd3 offset = 0

Kernel File Data Structures



13

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

fd1 offset = 0 (before) **fd1 offset = 26 (after)**

fd2 offset = 0

fd3 offset = 0

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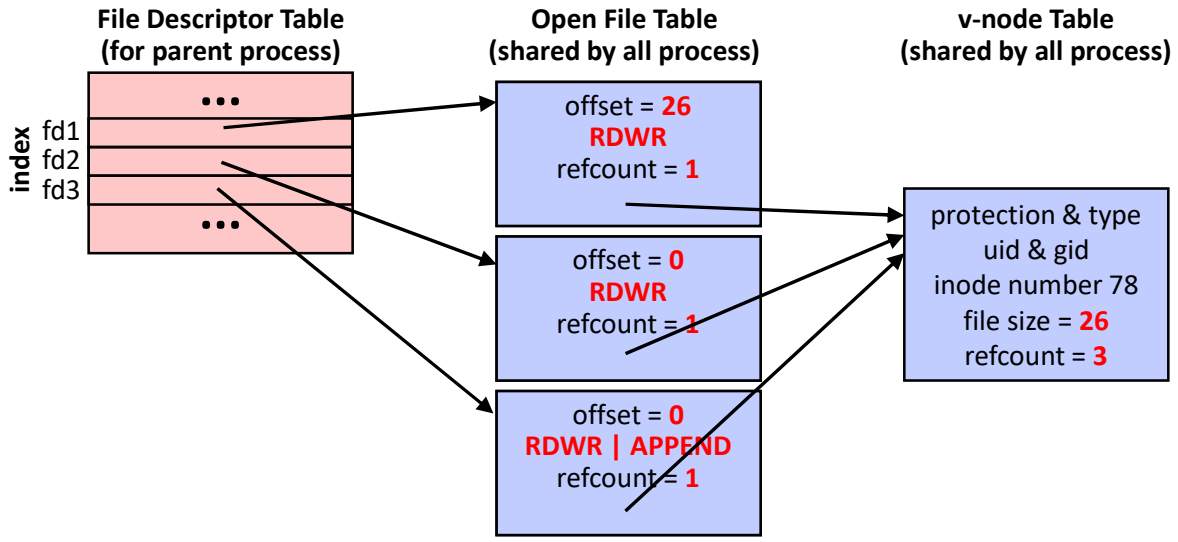
Kernel File Data Structures



15

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

fd2 offset = 0 (before)

fd2 offset = 5 (after)

fd1 offset = 26

fd3 offset = 0

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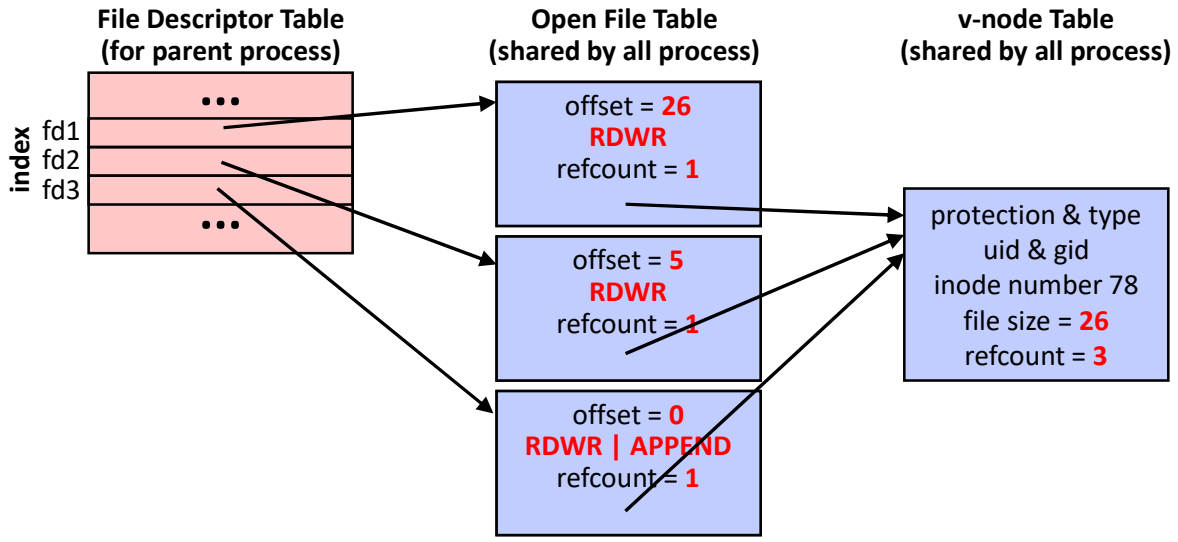
Kernel File Data Structures



17

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

fd2 offset = 5

fd1 offset = 26

fd3 offset = 0 (before)

fd3 offset = 31 (after)

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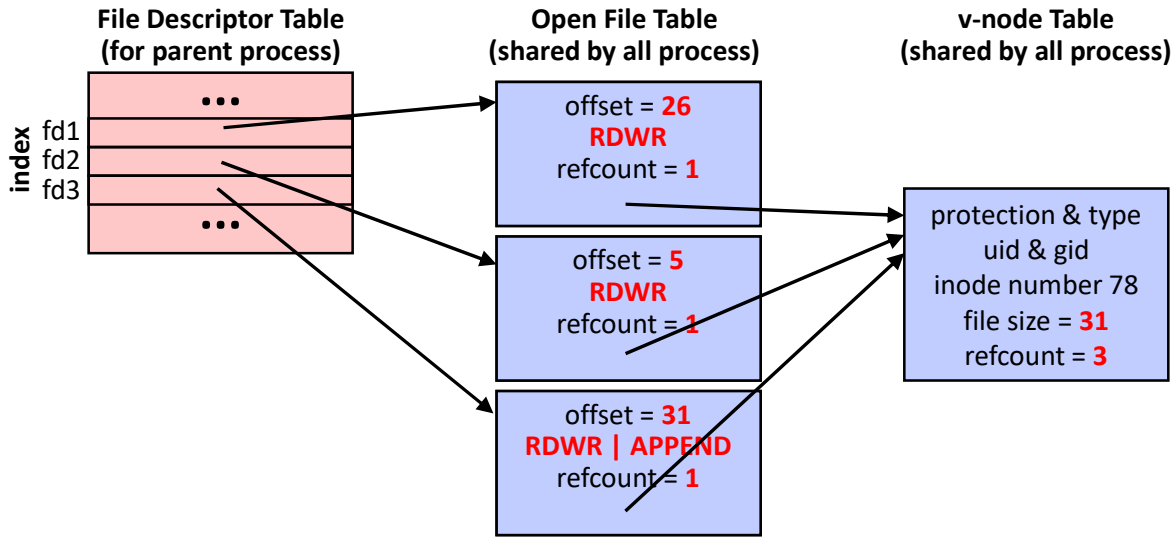
Kernel File Data Structures



19

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

fd2 offset = 5

fd1 offset = 26

fd3 offset = 0 (after)

fd3 offset = 31 (before)

20

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
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}
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```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

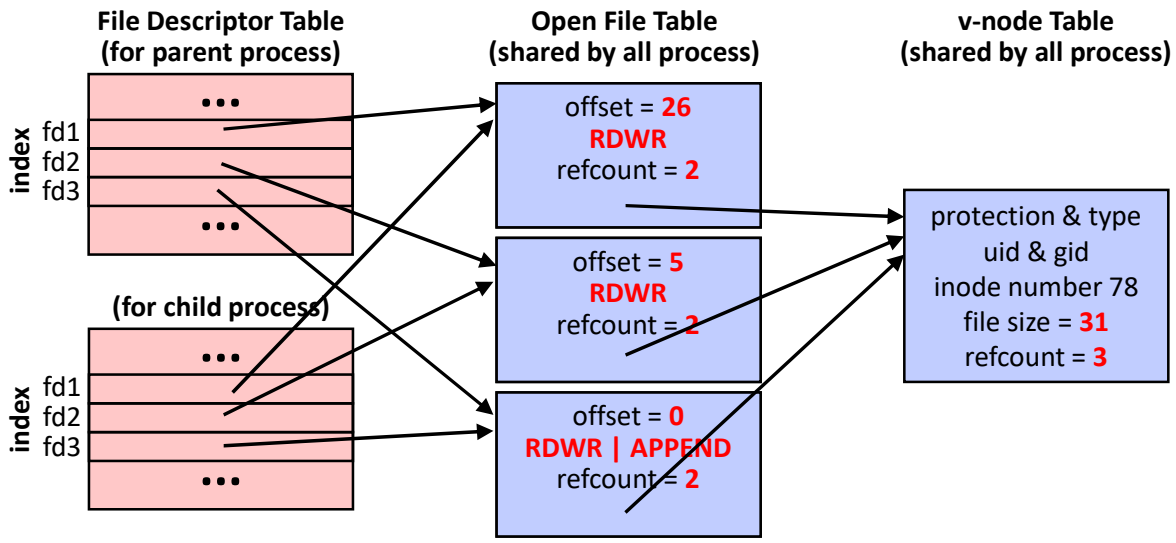
fd3 offset = 0

fd2 offset = 5

fd1 offset = 26

21

Kernel File Data Structures



22

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

fd1 offset = 26

fd2 offset = 5 (before) **fd2 offset = 15 (after)**

fd3 offset = 0


```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

fd1 offset = 26

fd2 offset = 15

fd3 offset = 0

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
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if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd1 offset = 26

fd2 offset = 15

fd3 offset = 0 (before)

fd3 offset = 38 (after)

25

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
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```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	p	q	r	s	t	u	v	w	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd1 offset = 16 (after)

fd1 offset = 26 (before)

fd2 offset = 15

fd3 offset = 38

26

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
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if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	p	C	O	M	P	3	2	1	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd2 offset = 15

fd1 offset = 16 (before)

fd1 offset = 23 (after)

fd3 offset = 38

27

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
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if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
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    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	P	3	2	1	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd2 offset = 15 (before)

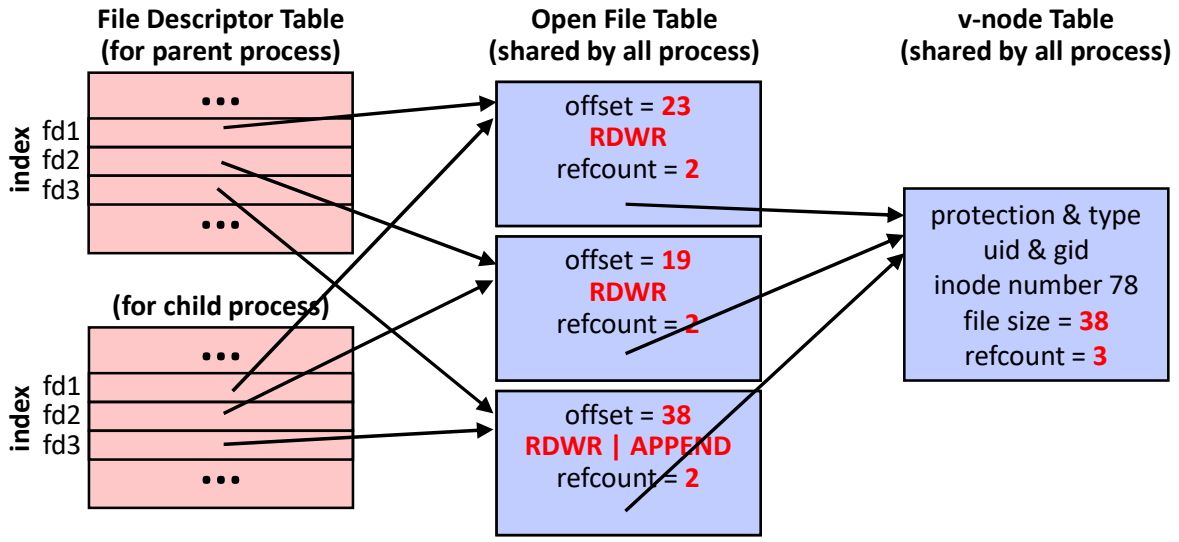
fd2 offset = 19 (after)

fd1 offset = 23

fd3 offset = 38

28

Kernel File Data Structures

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fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

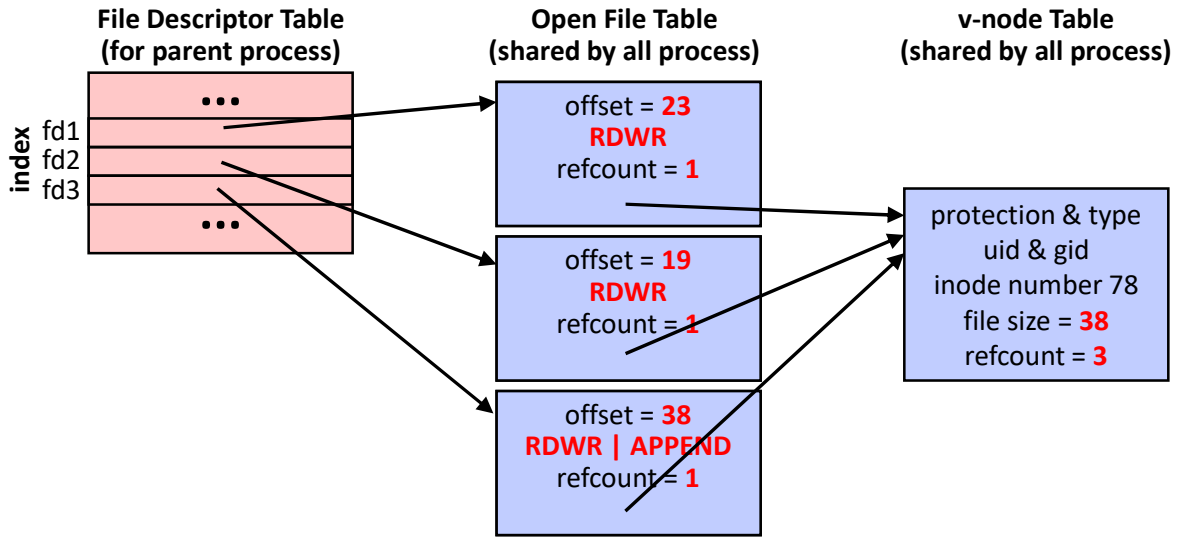
H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	P	3	2	1	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd2 offset = 19

fd1 offset = 23

fd3 offset = 38

Kernel File Data Structures



31

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	P	3	2	1	x	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd2 offset = 19

fd1 offset = 23

fd3 offset = 38

32

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	P	3	2	1	-	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd2 offset = 19

fd1 offset = 23 (before)

fd1 offset = 24 (after)

fd3 offset = 38


```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	.	3	2	1	-	y	z	W	O	R	L	D	H	o	u	s	t	o	n
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

fd1 offset = 24

fd2 offset = 19 (before)

fd2 offset = 20 (after)

fd3 offset = 38

```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents

H	E	L	L	O	9	8	7	6	5	4	3	2	1	0	R	i	c	e	.	3	2	1	-	y	z	W	O	R	L	D	H	o	u	s	t	o	n	/
00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38

fd2 offset = 20

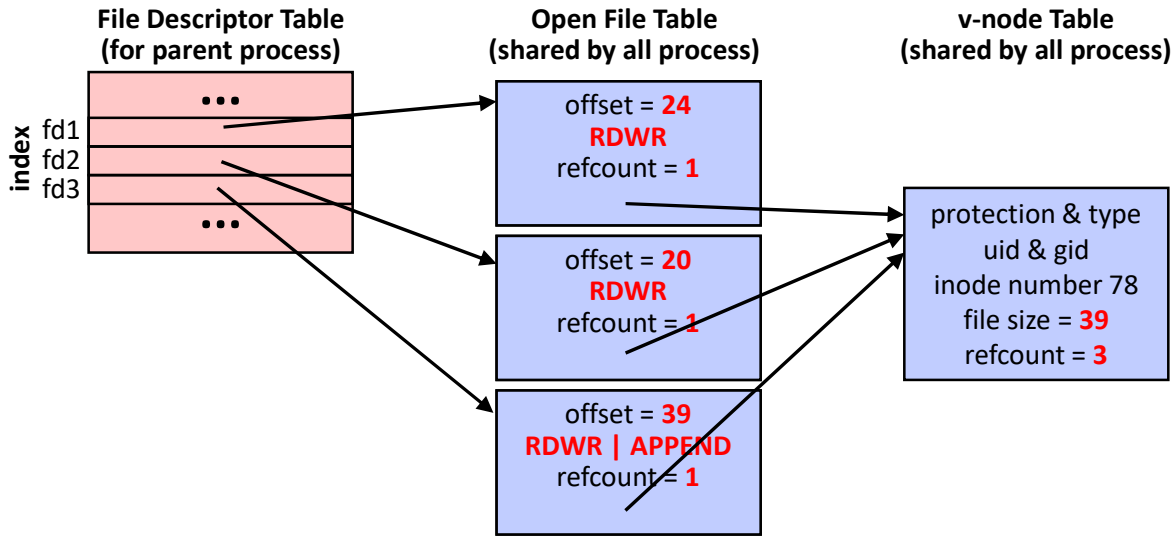
fd1 offset = 24

fd3 offset = 38 (before)

fd3 offset = 39 (after)

35

Kernel File Data Structures



36

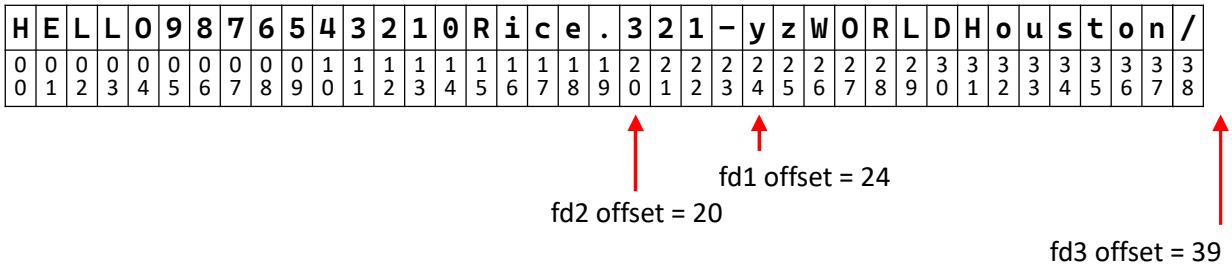
```
fd1 = open("data", O_RDWR | O_TRUNC);
fd2 = open("data", O_RDWR);
fd3 = open("data", O_RDWR | O_APPEND);

write(fd1, "abcdefghijklmnopqrstuvwxyz", 26);
write(fd2, "HELLO", 5);
write(fd3, "WORLD", 5);
lseek(fd3, 0, SEEK_SET);
```

```
if ((pid = fork()) == 0) {
    write(fd2, "9876543210", 10);
    lseek(fd3, -1, SEEK_CUR);
    write(fd3, "Houston", 7);
    lseek(fd1, -10, SEEK_CUR);
    write(fd1, "COMP321", 7);
    write(fd2, "Rice", 4);
}
```

```
else {
    waitpid(pid, NULL, 0);
    write(fd1, "-", 1);
    write(fd2, ".", 1);
    write(fd3, "/", 1);
}
exit(0);
```

File Contents



Midterm Exam Problem 3 – The Answers

File Size = 39

File Contents