

Assignment 2

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Answer 3

1. pThread-server.c

```
atif@atif-PC:~/Desktop/HTOP$ ./pthreadServer
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7
Integer received on the server side is 8
Integer received on the server side is 9
Integer received on the server side is 10
Integer received on the server side is 11
Integer received on the server side is 12
Integer received on the server side is 13
Integer received on the server side is 14
Integer received on the server side is 15
Integer received on the server side is 16
Integer received on the server side is 17
Integer received on the server side is 18
Integer received on the server side is 19
Integer received on the server side is 20
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7
Integer received on the server side is 8
Integer received on the server side is 9
Integer received on the server side is 10
Integer received on the server side is 11
Integer received on the server side is 12
Integer received on the server side is 13
Integer received on the server side is 14
Integer received on the server side is 15
Integer received on the server side is 16
Integer received on the server side is 17
Integer received on the server side is 18
Integer received on the server side is 19
Integer received on the server side is 20
Integer received on the server side is 1

atif@atif-PC:~/Desktop/HTOP$ bash script.sh
Elapsed time: 3803353 ns

atif@atif-PC:~/Desktop/HTOP$
```

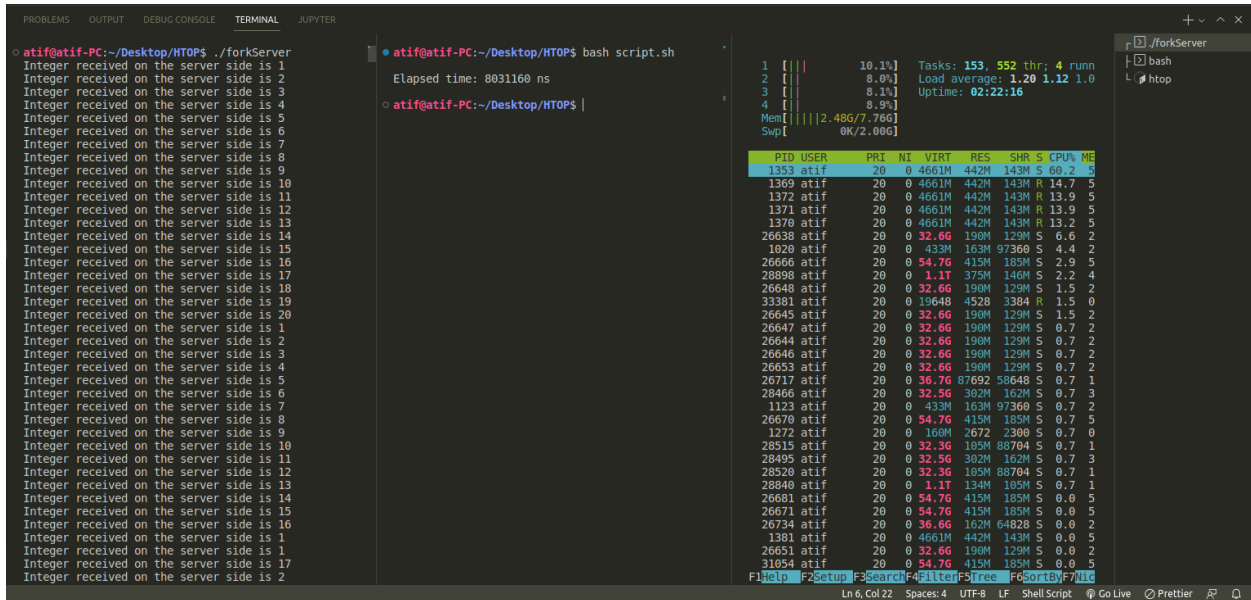
PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%
26638	atif	20	0	32.6G	184M	122M	S	12.7
1353	atif	20	0	4648M	423M	131M	S	9.4
26666	atif	20	0	54.7G	399M	185M	S	4.0
26645	atif	20	0	32.6G	184M	129M	S	3.4
1370	atif	20	0	4648M	423M	131M	S	2.7
26648	atif	20	0	32.6G	184M	129M	S	2.7
26646	atif	20	0	32.6G	184M	129M	S	2.7
1371	atif	20	0	4648M	423M	131M	S	2.0
1372	atif	20	0	4648M	423M	131M	S	2.0
1369	atif	20	0	4648M	423M	131M	S	2.0
26644	atif	20	0	32.6G	184M	129M	S	2.0
26647	atif	20	0	32.6G	184M	129M	S	2.0
28126	atif	20	0	19428	4264	3304	R	1.3
1020	atif	20	0	319M	119M	66796	S	0.7
26653	atif	20	0	32.6G	184M	129M	S	0.7
26681	atif	20	0	54.7G	399M	185M	S	0.7
26670	atif	20	0	54.7G	399M	185M	S	0.7
26651	atif	20	0	32.6G	184M	129M	S	0.7
1123	atif	20	0	319M	119M	66796	S	0.0
26704	atif	20	0	44.6G	133M	98M	S	0.0
1272	atif	20	0	160M	2672	2300	S	0.0
26671	atif	20	0	54.7G	399M	185M	S	0.0
26717	atif	20	0	36.6G	83028	58648	S	0.0
1263	atif	20	0	160M	2672	2300	S	0.0
1487	atif	20	0	489M	26492	20080	S	0.0
26683	atif	20	0	54.7G	399M	185M	S	0.0
26684	atif	20	0	54.7G	399M	185M	S	0.0
26734	atif	20	0	36.6G	161M	64764	S	0.0
26672	atif	20	0	54.7G	399M	185M	S	0.0
28243	atif	20	0	724M	43736	34716	S	0.0
26607	atif	20	0	36.8G	150M	111M	S	0.0
26738	atif	20	0	36.6G	161M	64764	S	0.0

a) Elapsed Time:- 6803393 ns

b) CPU cores utilization was initially 3-5%. As soon as the clients are run, the CPU utilization shoots up to 10-15%.

c) Memory utilization was 1.54G/7.76G previously. As soon as the clients are run, the memory utilization goes to 1.55G/7.76G.

2. fork-server.c



```
atif@atif-PC:~/Desktop/HTOPS$ ./forkServer
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7
Integer received on the server side is 8
Integer received on the server side is 9
Integer received on the server side is 10
Integer received on the server side is 11
Integer received on the server side is 12
Integer received on the server side is 13
Integer received on the server side is 14
Integer received on the server side is 15
Integer received on the server side is 16
Integer received on the server side is 17
Integer received on the server side is 18
Integer received on the server side is 19
Integer received on the server side is 20
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7
Integer received on the server side is 8
Integer received on the server side is 9
Integer received on the server side is 10
Integer received on the server side is 11
Integer received on the server side is 12
Integer received on the server side is 13
Integer received on the server side is 14
Integer received on the server side is 15
Integer received on the server side is 16
Integer received on the server side is 1
Integer received on the server side is 1
Integer received on the server side is 17
Integer received on the server side is 2
```

```
atif@atif-PC:~/Desktop/HTOPS$ bash script.sh
Elapsed time: 8031160 ns
atif@atif-PC:~/Desktop/HTOPS$
```

PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%	MEM
1353	atif	20	0	4661M	442M	143M	S	60.2	5
1369	atif	20	0	4661M	442M	143M	R	14.7	5
1372	atif	20	0	4661M	442M	143M	R	13.9	5
1371	atif	20	0	4661M	442M	143M	R	13.2	5
1370	atif	20	0	4661M	442M	143M	R	13.2	5
26638	atif	20	0	32.6G	190M	129M	S	0.6	2
1020	atif	20	0	433M	163M	97360	S	4.4	2
26666	atif	20	0	54.7G	415M	185M	S	2.9	5
28898	atif	20	0	1.1T	375M	140M	S	2.2	4
26648	atif	20	0	32.6G	190M	129M	S	1.5	2
33381	atif	20	0	1964B	452B	3384	R	1.5	0
26645	atif	20	0	32.6G	190M	129M	S	1.5	2
26647	atif	20	0	32.6G	190M	129M	S	0.7	2
26644	atif	20	0	32.6G	190M	129M	S	0.7	2
26646	atif	20	0	32.6G	190M	129M	S	0.7	2
26653	atif	20	0	32.6G	190M	129M	S	0.7	2
26717	atif	20	0	36.7G	87692	58648	S	0.7	1
28466	atif	20	0	32.5G	382M	162M	S	0.7	3
1123	atif	20	0	433M	163M	97360	S	0.7	2
26670	atif	20	0	54.7G	415M	185M	S	0.7	5
1272	atif	20	0	169M	2672	2380	S	0.7	0
28515	atif	20	0	32.3G	185M	88704	S	0.7	1
28495	atif	20	0	32.5G	382M	162M	S	0.7	3
28520	atif	20	0	32.3G	185M	88704	S	0.7	1
28840	atif	20	0	1.1T	134M	105M	S	0.7	1
26681	atif	20	0	54.7G	415M	185M	S	0.6	5
26671	atif	20	0	54.7G	415M	185M	S	0.6	5
26734	atif	20	0	36.6G	162M	64828	S	0.6	2
1381	atif	20	0	4661M	442M	143M	S	0.6	5
26651	atif	20	0	32.6G	190M	129M	S	0.6	2
31854	atif	20	0	54.7G	415M	185M	S	0.6	5

a) Elapsed Time:- 8031160 ns

b) CPU cores utilization was initially 5-10%. As soon as the clients are run, the CPU utilization shoots up to 20-25%.

c) Memory utilization was 2.48G/7.76G previously. As soon as the clients are run, the memory utilization goes to 2.52G/7.76G.

3. select-server.c

The screenshot shows a terminal window with two panes. The left pane displays the output of a program named `selectServer`, which repeatedly prints "Integer received on the server side is" followed by a number from 1 to 20. The right pane shows a terminal prompt where a script `bash script.sh` has been executed, resulting in the message "Elapsed time: 5318726 ns".

Overlaid on the right side of the terminal is a system monitor window. It displays system statistics: Tasks: 153, 547 thr; 1 run; Load average: 1.14, 0.72, 0.9; Uptime: 02:29:52; Mem: 2.49G/7.76G; Swap: 0K/2.00G. Below this is a table of process statistics:

PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%
1353	atif	20	0	467M	464M	144M	S	75.4
1371	atif	20	0	467M	464M	144M	S	18.0
1369	atif	20	0	467M	464M	144M	S	17.2
1370	atif	20	0	467M	464M	144M	S	17.2
1372	atif	20	0	467M	464M	144M	S	16.5
26638	atif	20	0	32.6G	196M	135M	S	6.5
1020	atif	20	0	440M	177M	102M	S	3.6
35810	atif	20	0	19588	4300	3260	R	2.2
26666	atif	20	0	50.7G	365M	193M	S	1.4
26640	atif	20	0	32.6G	196M	135M	S	1.4
26647	atif	20	0	32.6G	196M	135M	S	1.4
26644	atif	20	0	32.6G	196M	135M	S	1.4
26681	atif	20	0	50.7G	365M	193M	S	1.4
31770	atif	20	0	1.1T	217M	102M	S	1.4
1123	atif	20	0	440M	177M	102M	S	0.7
26646	atif	20	0	32.6G	196M	135M	S	0.7
26645	atif	20	0	32.6G	196M	135M	S	0.7
26717	atif	20	0	36.7G	86524	58648	S	0.7
26653	atif	20	0	32.6G	196M	135M	S	0.7
35559	atif	20	0	50.7G	365M	193M	S	0.7
35600	atif	20	0	50.7G	365M	193M	S	0.7
28898	atif	20	0	1.1T	380M	145M	S	0.7
1263	atif	20	0	160M	2672	2300	S	0.7
28520	atif	20	0	32.3G	105M	88764	S	0.7
26671	atif	20	0	50.7G	365M	193M	S	0.0
26607	atif	20	0	36.8G	152M	111M	S	0.0
26704	atif	20	0	44.6G	137M	98M	S	0.0
29152	atif	20	0	876M	74508	49280	S	0.0
26683	atif	20	0	50.7G	365M	193M	S	0.0
26684	atif	20	0	50.7G	365M	193M	S	0.0
35681	atif	20	0	50.7G	365M	193M	S	0.0

a) Elapsed Time:- 5318726 ns

b) CPU cores utilization was initially 10-15%. As soon as the clients are run, the CPU utilization shoots up to 20-25%.

c) Memory utilization was 2.49G/7.76G previously. As soon as the clients are run, the memory utilization goes to 2.50G/7.76G.

4. poll-server.c

The screenshot shows a terminal window with the following content:

```
o atif@atif-PC:~/Desktop/HTOP$ ./pollServer
Time Out
: Success
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 1
Integer received on the server side is 1
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 2
Integer received on the server side is 6
Integer received on the server side is 2
Integer received on the server side is 1
Integer received on the server side is 8
Integer received on the server side is 4
Integer received on the server side is 2
Integer received on the server side is 2
Integer received on the server side is 9
Integer received on the server side is 5
Integer received on the server side is 3
Integer received on the server side is 10
Integer received on the server side is 3
Integer received on the server side is 11
Integer received on the server side is 6
Integer received on the server side is 4
Integer received on the server side is 4
Integer received on the server side is 12
Integer received on the server side is 7
Integer received on the server side is 5
Integer received on the server side is 5
Integer received on the server side is 13
Integer received on the server side is 8
Integer received on the server side is 5
Integer received on the server side is 14
Integer received on the server side is 9
Integer received on the server side is 6
Integer received on the server side is 15
Integer received on the server side is 10
```

On the right side of the terminal, there is a window titled "pollServer" showing system resource usage:

```
Tasks: 155 543 thr: 1 run
Load average: 0.94 0.79 0.
Uptime: 02:31:46
Mem[|||||]2.57G/7.76G
Swp[|||||]0K/2.00G
```

Below the resource usage, there is a table showing the top processes:

PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%
1353	atif	20	0	4675M	463M	143M	S	17.6
26638	atif	20	0	32.6G	200M	132M	S	7.5
1372	atif	20	0	4675M	463M	143M	S	4.1
1369	atif	20	0	4675M	463M	143M	S	4.1
1371	atif	20	0	4675M	463M	143M	S	3.4
1370	atif	20	0	4675M	463M	143M	S	3.4
26666	atif	20	0	50.7G	423M	189M	S	2.0
26647	atif	20	0	32.6G	200M	132M	S	2.0
26646	atif	20	0	32.6G	200M	132M	S	2.0
26640	atif	20	0	32.6G	200M	132M	S	1.4
26644	atif	20	0	32.6G	200M	132M	S	1.4
26645	atif	20	0	32.6G	200M	132M	S	1.4
1020	atif	20	0	439M	176M	101M	S	1.4
36807	atif	20	0	19600	4240	3304	R	1.4
26653	atif	20	0	32.6G	200M	132M	S	0.7
28898	atif	20	0	1.1T	414M	159M	S	0.7
26717	atif	20	0	36.7G	86856	58648	S	0.7
1272	atif	20	0	160M	2672	2300	S	0.7
26681	atif	20	0	50.7G	423M	189M	S	0.0
1263	atif	20	0	169M	2672	2300	S	0.0
28520	atif	20	0	32.3G	105M	88760	S	0.0
26651	atif	20	0	32.6G	200M	132M	S	0.0
35600	atif	20	0	50.7G	423M	189M	S	0.0
35601	atif	20	0	50.7G	423M	189M	S	0.0
26704	atif	20	0	44.6G	137M	98M	S	0.0
26734	atif	20	0	36.6G	163M	64820	S	0.0
1123	atif	20	0	439M	176M	101M	S	0.0
28466	atif	20	0	32.5G	302M	162M	S	0.0
28515	atif	20	0	32.3G	105M	88760	S	0.0
37026	atif	20	0	724M	43076	34132	S	0.0
35559	atif	20	0	50.7G	423M	189M	S	0.0

a) Elapsed Time:- 4877701 ns

b) CPU cores utilization was initially 5-10%. As soon as the clients are run, the CPU utilization shoots up to 15-20%.

c) Memory utilization was 2.57G/7.76G previously. As soon as the clients are run, the memory utilization goes to 2.58G/7.76G.

5. epoll-server.c

The screenshot shows a terminal window with two panes. The left pane shows the output of the `./epollServer` command, which repeatedly prints "Integer received on the server side is" followed by a number from 1 to 20. The right pane shows the output of the `bash script.sh` command, which displays system statistics: "Elapsed time: 4835783 ns". Below this, a system monitor window is visible, showing a table of process statistics. The table has columns for PID, USER, PRI, NI, VIRT, RES, SHR, S, and CPU%. The first row of the table is highlighted in blue and shows the following values: PID 1353, USER atif, PRI 20, NI 0, VIRT 4677M, RES 472M, SHR 145M, S 93.8, CPU% 12.7%. The table continues with many other rows, showing various processes and their resource usage.

```
o atif@atif-PC:~/Desktop/HTOPS ./epollServer
Integer received on the server side is 1
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7
Integer received on the server side is 6
Integer received on the server side is 8
Integer received on the server side is 7
Integer received on the server side is 9
Integer received on the server side is 8
Integer received on the server side is 10
Integer received on the server side is 9
Integer received on the server side is 11
Integer received on the server side is 10
Integer received on the server side is 12
Integer received on the server side is 13
Integer received on the server side is 11
Integer received on the server side is 14
Integer received on the server side is 15
Integer received on the server side is 12
Integer received on the server side is 16
Integer received on the server side is 17
Integer received on the server side is 13
Integer received on the server side is 18
Integer received on the server side is 19
Integer received on the server side is 20
Integer received on the server side is 1
Integer received on the server side is 2
Integer received on the server side is 3
Integer received on the server side is 4
Integer received on the server side is 5
Integer received on the server side is 6
Integer received on the server side is 7

o atif@atif-PC:~/Desktop/HTOPS bash script.sh
Elapsed time: 4835783 ns

1 [||||| 12.7%] Tasks: 161, 555 thr; 1 run
2 [||||| 16.4%] Load average: 1.20 0.85 0.
3 [||||| 13.7%] Uptime: 02:34:15
4 [||||| 13.0%]
Mem[||||| 2.73G/7.76G]
Swp[||||| 0K/2.00G]

PID USER PRI NI VIRT RES SHR S CPU%
1353 atif 20 0 4677M 472M 145M S 93.8
1369 atif 20 0 4677M 472M 145M S 21.2
1370 atif 20 0 4677M 472M 145M S 21.2
1371 atif 20 0 4677M 472M 145M S 20.4
1372 atif 20 0 4677M 472M 145M S 20.4
26638 atif 20 0 32.6G 207M 130M S 7.6
1020 atif 20 0 441M 178M 103M S 6.0
26666 atif 20 0 50.7G 542M 192M S 3.0
1123 atif 20 0 441M 178M 103M S 1.5
26644 atif 20 0 32.6G 207M 130M S 1.5
26647 atif 20 0 32.6G 207M 130M S 1.5
38042 atif 20 0 19616 4344 3296 R 1.5
26646 atif 20 0 32.6G 207M 130M S 1.5
26717 atif 20 0 36.8G 87236 58648 S 1.5
26653 atif 20 0 32.6G 207M 130M S 0.8
26645 atif 20 0 32.6G 207M 130M S 0.8
26681 atif 20 0 50.7G 542M 192M S 0.8
26648 atif 20 0 32.6G 207M 130M S 0.8
28898 atif 20 0 1.1T 430M 164M S 0.8
35559 atif 20 0 50.7G 542M 192M S 0.8
35680 atif 20 0 50.7G 542M 192M S 0.8
1272 atif 20 0 160M 2672 2308 S 0.8
1263 atif 20 0 160M 2672 2308 S 0.8
38395 atif 20 0 724M 42968 34024 S 0.0
26683 atif 20 0 50.7G 542M 192M S 0.0
28515 atif 20 0 32.3G 105M 88768 S 0.0
28883 atif 20 0 1.1T 158M 109M S 0.0
3251 atif 20 0 418M 32484 25836 S 0.0
26684 atif 20 0 50.7G 542M 192M S 0.0
26607 atif 20 0 36.8G 156M 113M S 0.0
26671 atif 20 0 50.7G 542M 192M S 0.0
```

a) Elapsed Time:- 2835783 ns

b) CPU cores utilization was initially 10-15%. As soon as the clients are run, the CPU utilization shoots up to 25-30%.

c) Memory utilization was 2.73G/7.76G previously. As soon as the clients are run, the memory utilization goes to 2.74G/7.76G.

Answer 4

It is evident from the results that the server with `fork()` process is the heaviest. It is because as soon as a new client request connects to the server, `fork()` creates a new process for executing it, and creating a process is heavy.

On the other hand, a thread is lightweight and can be managed independently by the scheduler. It also increases the performance of the program, as evident by the results.

For the results of poll() vs epoll() vs select() we see that:-

1. select()

- a) We are building each set for each call to the server for each client connection.
- b) For checking the set bit, it may take up to $O(n)$ operations, as it runs a for-loop to check the set bit.
- c) Its performance is similar to the poll() server.

2. poll()

- a) poll() does not require that the user calculate the value of the highest-numbered file descriptor.
- b) Better than select() in terms of operations performed.

3. epoll()

- a) Best performance as it performs $O(1)$ operations in the I/O list instead of $O(n)$
- b) The execution time is the least compared to the other two operations.
- c) epoll() can behave as level triggered or edge triggered.