Московский Авиационный Институт

(Национальный Исследовательский Университет) Институт №8 “Компьютерные науки и прикладная математика”

Кафедра №806 “Вычислительная математика и программирование”

Лабораторная работа №2 по курсу

**«Операционные системы»**

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Постановка задачи

**Цель работы:**

**Целью является приобретение практических навыков в:**

* **Управление потоками в ОС**
* **Обеспечение синхронизации между потоками Задание:**

**Составить программу на языке Си, обрабатывающую данные в многопоточном режиме. При обработки использовать стандартные средства создания потоков операционной системы (Windows/Unix). Ограничение максимального количества потоков, работающих в один момент времени, должно быть задано ключом запуска вашей программы. Так же необходимо уметь продемонстрировать количество потоков, используемое вашей программой с помощью стандартных средств операционной системы. В отчете привести исследование зависимости ускорения и эффективности алгоритма от входных данных и количества потоков. Получившиеся результаты необходимо объяснить.**

**Вариант 3) Отсортировать массив целых чисел при помощи параллельной сортировки**

Общий метод и алгоритм решения

Использованные системные вызовы:

* ssize\_t write(int fd, const void \* buf, size\_t n); – Записывает N байт из буфер(BUF) в файл (FD). Возвращает количество записанных байт или -1.
* void exit(int status); – выполняет немедленное завершение программы. Все используемые программой потоки закрываются, и временные файлы удаляются, управление возвращается ОС или другой программе.
* int pthread\_create(pthread\_t \* restrict newthread, const pthread\_attr\_t \* restrict attr, void \*(\*start\_routine)(void \*), void \*restrict arg) — создаёт поток с

рутиной (стартовой функцией) и заданными аргументами

* int pthread\_join(pthread\_t th, void \*\*thread\_return) — дожидается завершения потока.

Для mutex реализации были использованы:

pthread\_mutex\_t – тип данных;

int pthread\_mutex\_init(pthread\_mutex\_t \*mutex, const pthread\_mutexattr\_t \*mutexattr) – инициализация мьютекса;

int pthread\_mutex\_lock(pthread\_mutex\_t \*mutex) – блокировка мьютекса;

int pthread\_mutex\_unlock(pthread\_mutex\_t \*mutex) – разблокировка мьютекса; int pthread\_mutex\_destroy(pthread\_mutex\_t \*mutex) – удаление мьютекса;

Программа запускается с аргументами – количество элементов массива и число потоков, которые могут работать одновременно. Это число используется для управления созданием потоков.

Инициализируется мьютекс, который будет использоваться для синхронизации доступа к данным.

Создается структура TASK для работы с потоками. Массив из случайных чисел разбивается на несколько диапазонов и в массив потоков передаеются начала и окончания этих диапазонов. Число элементов в каждом массиве определяется по формуле len = MAX\_ARRAY\_ELEMENTS / MAX\_THREADS.

Если количество активных потоков достигает MAX\_THREADS, программа ждёт завершения всех этих потоков перед созданием новых.

После завершения всех вычислений выполняется ожидание завершения оставшихся запущенных потоков. Программа измеряет и выводит затраченное время на выполнение умножения матриц. Это время рассчитывается с помощью стандартной структуры timespec и clock\_gettime.

Уничтожение мьютекса после использования.

Узнаем количество логических ядер

irina@Irina-VivoBook src % sysctl -n hw.logicalcpu

4

|  |  |  |  |
| --- | --- | --- | --- |
| Число потоков | Время выполнения | Ускорение | Эффективность |
| 1 | 49344 | 1,00 | 1,00 |
| 2 | 27614 | 1,79 | 0,895 |
| 3 | 25148 | 1,96 | 0,653 |
| 4 | 22725 | 2,17 | 0,542 |
| 5 | 21403 | 2,31 | 0,462 |
| 6 | 20896 | 2,36 | 0,393 |
| 7 | 19226 | 2,57 | 0,367 |
| 8 | 16373 | 3,01 | 0,376 |

Код программы

**main.c:**

#include <stdio.h>

#include <stdlib.h>

#include <time.h>

#include <stdint.h>

#if defined (WIN32) || (\_WIN64)

#include <windows.h>

#define pthread\_t DWORD

#define pthread\_create(THREAD\_ID\_PTR, ATTR, ROUTINE, PARAMS) CreateThread(NULL,0,(LPTHREAD\_START\_ROUTINE)ROUTINE,(void\*)PARAMS,0,THREAD\_ID\_PTR)

#define sleep(ms) Sleep(ms)

#else // Linux

#include <pthread.h>

#include <unistd.h>

#endif

typedef struct TASK

{

int low;

int high;

int busy;

int\* a;

}TASK;

void merge(int\* a, int low, int mid, int high)

{

int n1 = mid - low + 1;

int n2 = high - mid;

int\* left = (int\*)malloc(n1 \* sizeof(int));

int\* right = (int\*)malloc(n2 \* sizeof(int));

int i;

int j;

for (i = 0; i < n1; i++)

left[i] = a[i + low];

for (i = 0; i < n2; i++)

right[i] = a[i + mid + 1];

int k = low;

i = j = 0;

while (i < n1 && j < n2)

{

if (left[i] <= right[j])

a[k++] = left[i++];

else

a[k++] = right[j++];

}

while (i < n1)

a[k++] = left[i++];

while (j < n2)

a[k++] = right[j++];

free(left);

free(right);

}

void merge\_sort(int\* a, int low, int high)

{

int mid = low + (high - low) / 2;

if (low < high)

{

merge\_sort(a, low, mid);

merge\_sort(a, mid + 1, high);

merge(a, low, mid, high);

}

}

void\* merge\_sort\_thread(void\* arg)

{

TASK\* task = (TASK\*)arg;

int low;

int high;

low = task->low;

high = task->high;

int mid = low + (high - low) / 2;

if (low < high)

{

merge\_sort(task->a, low, mid);

merge\_sort(task->a, mid + 1, high);

merge(task->a, low, mid, high);

}

task->busy = 0;

return 0;

}

int main(int argc, char\*\* argv)

{

char\* sz;

int MAX\_ARRAY\_ELEMENTS = 100000000;

int MAX\_THREADS = 1;

char msg[1024];

uint32\_t msg\_len;

if (argc < 3) {

msg\_len = snprintf(msg, sizeof(msg) - 1, "usage: %s array\_count thread\_count\n", argv[0]);

write(STDERR\_FILENO, msg, msg\_len);

exit(EXIT\_SUCCESS);

}

if (argc == 3)

{

MAX\_ARRAY\_ELEMENTS = atoi(argv[1]);

MAX\_THREADS = atoi(argv[2]);

}

float time\_sec = (float)clock() / CLOCKS\_PER\_SEC;

long int start\_time;

start\_time = time(NULL);

msg\_len = snprintf(msg, sizeof(msg) - 1, "Now time is: %s", ctime(&start\_time));

write(STDERR\_FILENO, msg, msg\_len);

msg\_len = snprintf(msg, sizeof(msg) - 1, "Array[%d]\nThreads[%d]\n", MAX\_ARRAY\_ELEMENTS, MAX\_THREADS);

write(STDERR\_FILENO, msg, msg\_len);

int\* array = (int\*)malloc(sizeof(int) \* MAX\_ARRAY\_ELEMENTS);

clock\_t time\_start = clock();

srand(time\_start);

int i;

for (i = 0; i < MAX\_ARRAY\_ELEMENTS; i++)

array[i] = rand();

msg\_len = snprintf(msg, sizeof(msg) - 1, "Array Randomized\n");

write(STDERR\_FILENO, msg, msg\_len);

pthread\_t\* threads = (pthread\_t\*)malloc(sizeof(pthread\_t) \* MAX\_THREADS);

TASK\* tasklist = (TASK\*)malloc(sizeof(TASK) \* MAX\_THREADS);

int len = MAX\_ARRAY\_ELEMENTS / MAX\_THREADS;

TASK\* task;

int low = 0;

for (i = 0; i < MAX\_THREADS; i++, low += len)

{

task = &tasklist[i];

task->a = array;

task->busy = 1;

task->low = low;

task->high = low + len - 1;

if (i == (MAX\_THREADS - 1))

task->high = MAX\_ARRAY\_ELEMENTS - 1;

pthread\_create(&threads[i], 0, merge\_sort\_thread, task);

}

#if defined (WIN32) || (\_WIN64)

// ожидаем выполнение всех потоков для windows

for (i = 0; i < MAX\_THREADS; i++)

while (tasklist[i].busy)

sleep(10);

#else // Linux

// ожидаем выполнение всех потоков

// wait for all threads

for(i = 0; i < MAX\_THREADS; i++)

pthread\_join(threads[i], NULL);

#endif

TASK\* taskm = &tasklist[0];

for (i = 1; i < MAX\_THREADS; i++)

{

TASK\* task = &tasklist[i];

merge(taskm->a, taskm->low, task->low - 1, task->high);

}

int last = 0;

for (i = 0; i < MAX\_ARRAY\_ELEMENTS; i++)

{

if (array[i] < last)

{

msg\_len = snprintf(msg, sizeof(msg) - 1, "Array is not sorted!\n");

write(STDERR\_FILENO, msg, msg\_len);

return 0;

}

last = array[i];

}

long int end\_time = time(NULL);

msg\_len = snprintf(msg, sizeof(msg) - 1, "Now time is: %s", ctime(&end\_time));

write(STDERR\_FILENO, msg, msg\_len);

msg\_len = snprintf(msg, sizeof(msg) - 1, "Array sorted in %ld Seconds\n", time(NULL) - start\_time);

write(STDERR\_FILENO, msg, msg\_len);

free(tasklist);

free(threads);

return 0;

}

Протокол работы программы

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ gcc merge\_sort.c

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out

usage: ./a.out array\_count thread\_count

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 1

Now time is: Tue Dec 3 11:08:25 2024

Array[100000000]

Threads[1]

Array Randomized

Now time is: Tue Dec 3 11:09:14 2024

Array sorted in 49344 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 2

Now time is: Tue Dec 3 11:09:21 2024

Array[100000000]

Threads[2]

Array Randomized

Now time is: Tue Dec 3 11:09:48 2024

Array sorted in 27614 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 3

Now time is: Tue Dec 3 11:09:53 2024

Array[100000000]

Threads[3]

Array Randomized

Now time is: Tue Dec 3 11:10:18 2024

Array sorted in 25148 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 4

Now time is: Tue Dec 3 11:10:23 2024

Array[100000000]

Threads[4]

Array Randomized

Now time is: Tue Dec 3 11:10:45 2024

Array sorted in 22725 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 5

Now time is: Tue Dec 3 11:10:49 2024

Array[100000000]

Threads[5]

Array Randomized

Now time is: Tue Dec 3 11:11:11 2024

Array sorted in 21403 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 6

Now time is: Tue Dec 3 11:11:15 2024

Array[100000000]

Threads[6]

Array Randomized

Now time is: Tue Dec 3 11:11:37 2024

Array sorted in 20896 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 7

Now time is: Tue Dec 3 11:11:41 2024

Array[100000000]

Threads[7]

Array Randomized

Now time is: Tue Dec 3 11:12:04 2024

Array sorted in 19226 ms

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ ./a.out 100000000 8

Now time is: Tue Dec 3 11:12:08 2024

Array[100000000]

Threads[8]

Array Randomized

Now time is: Tue Dec 3 11:12:31 2024

Array sorted in 16373 ms

**Strace:(сортировка 100000000 элементов массива в 8 потоках)**

irina@Irina-VivoBook:~/Prog/Prog\_C/Kurs2/LabOS/Lab02$ strace -f ./a.out 100000000 8

**execve**("./a.out", ["./a.out", "100000000", "8"], 0x7ffd9625e418 */\* 46 vars \*/*) = 0

**brk**(NULL)                               = 0x646e9edab000

**arch\_prctl**(0x3001 */\* ARCH\_??? \*/*, 0x7ffede0fd860) = -1 **EINVAL** (Недопустимый аргумент)

**mmap**(NULL, 8192, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf0422cb000

**access**("/etc/ld.so.preload", R\_OK)      = -1 **ENOENT** (Нет такого файла или каталога)

**openat**(AT\_FDCWD, "/etc/ld.so.cache", O\_RDONLY|O\_CLOEXEC) = 3

**newfstatat**(3, "", {st\_mode=S\_IFREG|0644, st\_size=63951, ...}, AT\_EMPTY\_PATH) = 0

**mmap**(NULL, 63951, PROT\_READ, MAP\_PRIVATE, 3, 0) = 0x7cf0422bb000

**close**(3)                                = 0

**openat**(AT\_FDCWD, "/lib/x86\_64-linux-gnu/libc.so.6", O\_RDONLY|O\_CLOEXEC) = 3

**read**(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832

**pread64**(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784

**pread64**(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0"..., 48, 848) = 48

**pread64**(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0I\17\357\204\3$\f\221\2039x\324\224\323\236S"..., 68, 896) = 68

**newfstatat**(3, "", {st\_mode=S\_IFREG|0755, st\_size=2220400, ...}, AT\_EMPTY\_PATH) = 0

**pread64**(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784

**mmap**(NULL, 2264656, PROT\_READ, MAP\_PRIVATE|MAP\_DENYWRITE, 3, 0) = 0x7cf042000000

**mprotect**(0x7cf042028000, 2023424, PROT\_NONE) = 0

**mmap**(0x7cf042028000, 1658880, PROT\_READ|PROT\_EXEC, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x28000) = 0x7cf042028000

**mmap**(0x7cf0421bd000, 360448, PROT\_READ, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x1bd000) = 0x7cf0421bd000

**mmap**(0x7cf042216000, 24576, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x215000) = 0x7cf042216000

**mmap**(0x7cf04221c000, 52816, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_FIXED|MAP\_ANONYMOUS, -1, 0) = 0x7cf04221c000

**close**(3)                                = 0

**mmap**(NULL, 12288, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf0422b8000

**arch\_prctl**(ARCH\_SET\_FS, 0x7cf0422b8740) = 0

**set\_tid\_address**(0x7cf0422b8a10)         = 3456

**set\_robust\_list**(0x7cf0422b8a20, 24)     = 0

**rseq**(0x7cf0422b90e0, 0x20, 0, 0x53053053) = 0

**mprotect**(0x7cf042216000, 16384, PROT\_READ) = 0

**mprotect**(0x646e9ebbf000, 4096, PROT\_READ) = 0

**mprotect**(0x7cf042305000, 8192, PROT\_READ) = 0

**prlimit64**(0, RLIMIT\_STACK, NULL, {rlim\_cur=8192\*1024, rlim\_max=RLIM64\_INFINITY}) = 0

**munmap**(0x7cf0422bb000, 63951)           = 0

**clock\_gettime**(CLOCK\_PROCESS\_CPUTIME\_ID, {tv\_sec=0, tv\_nsec=2310418}) = 0

**getrandom**("\x99\x7d\x2c\xf5\x15\x51\xfd\x83", 8, GRND\_NONBLOCK) = 8

**brk**(NULL)                               = 0x646e9edab000

**brk**(0x646e9edcc000)                     = 0x646e9edcc000

**openat**(AT\_FDCWD, "/etc/localtime", O\_RDONLY|O\_CLOEXEC) = 3

**newfstatat**(3, "", {st\_mode=S\_IFREG|0644, st\_size=1535, ...}, AT\_EMPTY\_PATH) = 0

**newfstatat**(3, "", {st\_mode=S\_IFREG|0644, st\_size=1535, ...}, AT\_EMPTY\_PATH) = 0

**read**(3, "TZif2\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\21\0\0\0\21\0\0\0\0"..., 4096) = 1535

**lseek**(3, -927, SEEK\_CUR)                = 608

**read**(3, "TZif2\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\21\0\0\0\21\0\0\0\0"..., 4096) = 927

**close**(3)                                = 0

**write**(2, "Now time is: Tue Dec  3 11:12:55"..., 38Now time is: Tue Dec  3 11:12:55 2024

) = 38

**write**(2, "Array[100000000]\nThreads[8]\n", 28Array[100000000]

Threads[8]

) = 28

**mmap**(NULL, 400003072, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf02a200000

**clock\_gettime**(CLOCK\_PROCESS\_CPUTIME\_ID, {tv\_sec=0, tv\_nsec=2952002}) = 0

**write**(2, "Array Randomized\n", 17Array Randomized

)      = 17

**rt\_sigaction**(SIGRT\_1, {sa\_handler=0x7cf042091870, sa\_mask=[], sa\_flags=SA\_RESTORER|SA\_ONSTACK|SA\_RESTART|SA\_SIGINFO, sa\_restorer=0x7cf042042520}, NULL, 8) = 0

**rt\_sigprocmask**(SIG\_UNBLOCK, [RTMIN RT\_1], NULL, 8) = 0

**mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7cf029800000

**mprotect**(0x7cf029801000, 8388608, PROT\_READ|PROT\_WRITE) = 0

**rt\_sigprocmask**(SIG\_BLOCK, ~[], [], 8)   = 0

**clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf02a000910, parent\_tid=0x7cf02a000910, exit\_signal=0, stack=0x7cf029800000, stack\_size=0x7fff00, tls=0x7cf02a000640}strace: Process 3457 attached

 => {parent\_tid=[3457]}, 88) = 3457

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3457] **rseq**(0x7cf02a000fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3456] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3457] <... rseq resumed>)         = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0 <unfinished ...>

[pid  3457] **set\_robust\_list**(0x7cf02a000920, 24 <unfinished ...>

[pid  3456] <... mmap resumed>)         = 0x7cf028e00000

[pid  3457] <... set\_robust\_list resumed>) = 0

[pid  3456] **mprotect**(0x7cf028e01000, 8388608, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3457] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3456] <... mprotect resumed>)     = 0

[pid  3457] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[],  <unfinished ...>

[pid  3457] **mmap**(NULL, 134217728, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0 <unfinished ...>

[pid  3456] <... rt\_sigprocmask resumed>[], 8) = 0

[pid  3457] <... mmap resumed>)         = 0x7cf020e00000

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf029600910, parent\_tid=0x7cf029600910, exit\_signal=0, stack=0x7cf028e00000, stack\_size=0x7fff00, tls=0x7cf029600640} <unfinished ...>

[pid  3457] **munmap**(0x7cf020e00000, 52428800strace: Process 3458 attached

) = 0

[pid  3456] <... clone3 resumed> => {parent\_tid=[3458]}, 88) = 3458

[pid  3458] **rseq**(0x7cf029600fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3457] **munmap**(0x7cf028000000, 14680064 <unfinished ...>

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3458] <... rseq resumed>)         = 0

[pid  3456] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3457] <... munmap resumed>)       = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0 <unfinished ...>

[pid  3458] **set\_robust\_list**(0x7cf029600920, 24 <unfinished ...>

[pid  3456] <... mmap resumed>)         = 0x7cf028400000

[pid  3457] **mprotect**(0x7cf024000000, 135168, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3456] **mprotect**(0x7cf028401000, 8388608, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3458] <... set\_robust\_list resumed>) = 0

[pid  3456] <... mprotect resumed>)     = 0

[pid  3457] <... mprotect resumed>)     = 0

[pid  3458] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[],  <unfinished ...>

[pid  3458] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3458] **mmap**(NULL, 134217728, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0) = 0x7cf01c000000

[pid  3458] **munmap**(0x7cf020000000, 67108864) = 0

[pid  3458] **mprotect**(0x7cf01c000000, 135168, PROT\_READ|PROT\_WRITE) = 0

[pid  3456] <... rt\_sigprocmask resumed>[], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf028c00910, parent\_tid=0x7cf028c00910, exit\_signal=0, stack=0x7cf028400000, stack\_size=0x7fff00, tls=0x7cf028c00640}strace: Process 3459 attached

 => {parent\_tid=[3459]}, 88) = 3459

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3459] **rseq**(0x7cf028c00fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3456] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3459] <... rseq resumed>)         = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7cf023600000

[pid  3459] **set\_robust\_list**(0x7cf028c00920, 24 <unfinished ...>

[pid  3456] **mprotect**(0x7cf023601000, 8388608, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] <... set\_robust\_list resumed>) = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[],  <unfinished ...>

[pid  3459] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3456] <... rt\_sigprocmask resumed>[], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf023e00910, parent\_tid=0x7cf023e00910, exit\_signal=0, stack=0x7cf023600000, stack\_size=0x7fff00, tls=0x7cf023e00640} <unfinished ...>

[pid  3459] <... rt\_sigprocmask resumed>NULL, 8) = 0

strace: Process 3460 attached

[pid  3456] <... clone3 resumed> => {parent\_tid=[3460]}, 88) = 3460

[pid  3459] **mmap**(0x7cf020000000, 67108864, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0 <unfinished ...>

[pid  3460] **rseq**(0x7cf023e00fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3459] <... mmap resumed>)         = 0x7cf018000000

[pid  3456] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3460] <... rseq resumed>)         = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0 <unfinished ...>

[pid  3459] **mprotect**(0x7cf018000000, 135168, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3456] <... mmap resumed>)         = 0x7cf022c00000

[pid  3460] **set\_robust\_list**(0x7cf023e00920, 24 <unfinished ...>

[pid  3459] <... mprotect resumed>)     = 0

[pid  3456] **mprotect**(0x7cf022c01000, 8388608, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3460] <... set\_robust\_list resumed>) = 0

[pid  3456] <... mprotect resumed>)     = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[], [], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf023400910, parent\_tid=0x7cf023400910, exit\_signal=0, stack=0x7cf022c00000, stack\_size=0x7fff00, tls=0x7cf023400640} => {parent\_tid=[3461]}, 88) = 3461

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7cf022200000

[pid  3456] **mprotect**(0x7cf022201000, 8388608, PROT\_READ|PROT\_WRITE) = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[], [], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf022a00910, parent\_tid=0x7cf022a00910, exit\_signal=0, stack=0x7cf022200000, stack\_size=0x7fff00, tls=0x7cf022a00640} => {parent\_tid=[3462]}, 88) = 3462

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7cf021800000

[pid  3456] **mprotect**(0x7cf021801000, 8388608, PROT\_READ|PROT\_WRITE) = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[], [], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf022000910, parent\_tid=0x7cf022000910, exit\_signal=0, stack=0x7cf021800000, stack\_size=0x7fff00, tls=0x7cf022000640} => {parent\_tid=[3463]}, 88) = 3463

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3456] **mmap**(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7cf020e00000

[pid  3456] **mprotect**(0x7cf020e01000, 8388608, PROT\_READ|PROT\_WRITE) = 0

[pid  3456] **rt\_sigprocmask**(SIG\_BLOCK, ~[], [], 8) = 0

[pid  3456] **clone3**({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7cf021600910, parent\_tid=0x7cf021600910, exit\_signal=0, stack=0x7cf020e00000, stack\_size=0x7fff00, tls=0x7cf021600640} => {parent\_tid=[3464]}, 88) = 3464

[pid  3456] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3456] **futex**(0x7cf02a000910, FUTEX\_WAIT\_BITSET|FUTEX\_CLOCK\_REALTIME, 3457, NULL, FUTEX\_BITSET\_MATCH\_ANYstrace: Process 3461 attached

 <unfinished ...>

[pid  3461] **rseq**(0x7cf023400fe0, 0x20, 0, 0x53053053) = 0

[pid  3461] **set\_robust\_list**(0x7cf023400920, 24) = 0

[pid  3461] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3461] **mmap**(NULL, 134217728, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0) = 0x7cf010000000

[pid  3461] **munmap**(0x7cf014000000, 67108864) = 0

[pid  3461] **mprotect**(0x7cf010000000, 135168, PROT\_READ|PROT\_WRITE) = 0

strace: Process 3464 attached

strace: Process 3463 attached

strace: Process 3462 attached

[pid  3460] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3462] **rseq**(0x7cf022a00fe0, 0x20, 0, 0x53053053) = 0

[pid  3460] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3462] **set\_robust\_list**(0x7cf022a00920, 24) = 0

[pid  3462] **rt\_sigprocmask**(SIG\_SETMASK, [], NULL, 8) = 0

[pid  3462] **mmap**(0x7cf014000000, 67108864, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0) = 0x7cf00c000000

[pid  3460] **mmap**(0x7cf014000000, 67108864, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0 <unfinished ...>

[pid  3462] **mprotect**(0x7cf00c000000, 135168, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] <... mmap resumed>)         = 0x7cf008000000

[pid  3460] **mprotect**(0x7cf008000000, 135168, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3463] **rseq**(0x7cf022000fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3464] **rseq**(0x7cf021600fe0, 0x20, 0, 0x53053053 <unfinished ...>

[pid  3460] <... mprotect resumed>)     = 0

[pid  3463] <... rseq resumed>)         = 0

[pid  3464] <... rseq resumed>)         = 0

[pid  3464] **set\_robust\_list**(0x7cf021600920, 24 <unfinished ...>

[pid  3463] **set\_robust\_list**(0x7cf022000920, 24 <unfinished ...>

[pid  3464] <... set\_robust\_list resumed>) = 0

[pid  3463] <... set\_robust\_list resumed>) = 0

[pid  3464] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3463] **rt\_sigprocmask**(SIG\_SETMASK, [],  <unfinished ...>

[pid  3464] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3463] <... rt\_sigprocmask resumed>NULL, 8) = 0

[pid  3464] **mmap**(NULL, 134217728, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0 <unfinished ...>

[pid  3463] **mmap**(NULL, 134217728, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_NORESERVE, -1, 0 <unfinished ...>

[pid  3464] <... mmap resumed>)         = 0x7cf000000000

[pid  3463] <... mmap resumed>)         = 0x7ceff8000000

[pid  3464] **munmap**(0x7cf004000000, 67108864 <unfinished ...>

[pid  3463] **munmap**(0x7ceffc000000, 67108864 <unfinished ...>

[pid  3464] <... munmap resumed>)       = 0

[pid  3463] <... munmap resumed>)       = 0

[pid  3464] **mprotect**(0x7cf000000000, 135168, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3463] **mprotect**(0x7ceff8000000, 135168, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3464] <... mprotect resumed>)     = 0

[pid  3463] <... mprotect resumed>)     = 0

[pid  3458] **mprotect**(0x7cf01c021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **openat**(AT\_FDCWD, "/proc/sys/vm/overcommit\_memory", O\_RDONLY|O\_CLOEXEC) = 3

[pid  3458] **read**(3, "0", 1)             = 1

[pid  3458] **close**(3)                    = 0

[pid  3458] **madvise**(0x7cf01c022000, 65536, MADV\_DONTNEED) = 0

[pid  3461] **mprotect**(0x7cf010021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3461] **madvise**(0x7cf010022000, 65536, MADV\_DONTNEED) = 0

[pid  3457] **mprotect**(0x7cf024021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 65536, MADV\_DONTNEED) = 0

[pid  3462] **mprotect**(0x7cf00c021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **madvise**(0x7cf00c022000, 65536, MADV\_DONTNEED <unfinished ...>

[pid  3461] **madvise**(0x7cf010022000, 65536, MADV\_DONTNEED) = 0

[pid  3461] **mmap**(NULL, 196608, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf042288000

[pid  3461] **mmap**(NULL, 196608, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf042258000

[pid  3462] <... madvise resumed>)      = 0

[pid  3461] **munmap**(0x7cf042288000, 196608) = 0

[pid  3461] **munmap**(0x7cf042258000, 196608) = 0

[pid  3458] **mprotect**(0x7cf01c032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **madvise**(0x7cf01c022000, 262144, MADV\_DONTNEED) = 0

[pid  3459] **mprotect**(0x7cf018021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **mprotect**(0x7cf008021000, 69632, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **mprotect**(0x7ceff8021000, 69632, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3457] **mprotect**(0x7cf024032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 262144, MADV\_DONTNEED) = 0

[pid  3463] <... mprotect resumed>)     = 0

[pid  3462] **mprotect**(0x7cf00c032000, 196608, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3464] **mprotect**(0x7cf000021000, 69632, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3462] <... mprotect resumed>)     = 0

[pid  3461] **mprotect**(0x7cf010032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] <... mprotect resumed>)     = 0

[pid  3462] **madvise**(0x7cf00c022000, 262144, MADV\_DONTNEED <unfinished ...>

[pid  3461] **madvise**(0x7cf010022000, 262144, MADV\_DONTNEED <unfinished ...>

[pid  3462] <... madvise resumed>)      = 0

[pid  3461] <... madvise resumed>)      = 0

[pid  3461] **mmap**(NULL, 393216, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf042258000

[pid  3461] **mmap**(NULL, 393216, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf041fa0000

[pid  3461] **munmap**(0x7cf042258000, 393216) = 0

[pid  3461] **munmap**(0x7cf041fa0000, 393216) = 0

[pid  3458] **mprotect**(0x7cf01c062000, 389120, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **mprotect**(0x7ceff8032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **mprotect**(0x7cf00c062000, 389120, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **mprotect**(0x7cf008032000, 196608, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3459] **mprotect**(0x7cf018032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] <... mprotect resumed>)     = 0

[pid  3457] **mprotect**(0x7cf024062000, 389120, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3464] **mprotect**(0x7cf000032000, 196608, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] <... mprotect resumed>)     = 0

[pid  3464] **mprotect**(0x7cf000062000, 389120, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **mmap**(NULL, 782336, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf02a141000

[pid  3458] **munmap**(0x7cf02a141000, 782336 <unfinished ...>

[pid  3463] **mprotect**(0x7ceff8062000, 389120, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3458] <... munmap resumed>)       = 0

[pid  3463] <... mprotect resumed>)     = 0

[pid  3459] **mprotect**(0x7cf018062000, 389120, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **mprotect**(0x7cf008062000, 389120, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3461] **mprotect**(0x7cf010062000, 389120, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3460] <... mprotect resumed>)     = 0

[pid  3461] <... mprotect resumed>)     = 0

[pid  3461] **mprotect**(0x7cf0100c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3461] **madvise**(0x7cf010022000, 1433600, MADV\_DONTNEED) = 0

[pid  3464] **mprotect**(0x7cf0000c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] **madvise**(0x7cf000022000, 1433600, MADV\_DONTNEED) = 0

[pid  3462] **mprotect**(0x7cf00c0c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **mprotect**(0x7cf0240c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 1433600, MADV\_DONTNEED <unfinished ...>

[pid  3462] **madvise**(0x7cf00c022000, 1433600, MADV\_DONTNEED) = 0

[pid  3457] <... madvise resumed>)      = 0

[pid  3463] **mprotect**(0x7ceff80c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] **mprotect**(0x7cf0180c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **madvise**(0x7ceff8022000, 1433600, MADV\_DONTNEED) = 0

[pid  3459] **madvise**(0x7cf018022000, 1433600, MADV\_DONTNEED) = 0

[pid  3460] **mprotect**(0x7cf0080c1000, 782336, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3464] **madvise**(0x7cf000022000, 1433600, MADV\_DONTNEED <unfinished ...>

[pid  3460] <... mprotect resumed>)     = 0

[pid  3464] <... madvise resumed>)      = 0

[pid  3464] **mmap**(NULL, 1564672, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf02a082000

[pid  3464] **mmap**(NULL, 1564672, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf029682000

[pid  3460] **madvise**(0x7cf008022000, 1433600, MADV\_DONTNEED) = 0

[pid  3464] **munmap**(0x7cf02a082000, 1564672) = 0

[pid  3464] **munmap**(0x7cf029682000, 1564672) = 0

[pid  3461] **mprotect**(0x7cf010180000, 1560576, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **mprotect**(0x7cf01c0c1000, 782336, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **mprotect**(0x7cf01c180000, 1560576, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **mprotect**(0x7cf024180000, 1560576, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3460] **mprotect**(0x7cf008180000, 1560576, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3457] <... mprotect resumed>)     = 0

[pid  3460] <... mprotect resumed>)     = 0

[pid  3462] **mprotect**(0x7cf00c180000, 1560576, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] **mprotect**(0x7cf000180000, 1560576, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3463] **mprotect**(0x7ceff8180000, 1560576, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3464] <... mprotect resumed>)     = 0

[pid  3459] **mprotect**(0x7cf018180000, 1560576, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3463] <... mprotect resumed>)     = 0

[pid  3459] <... mprotect resumed>)     = 0

[pid  3464] **mmap**(NULL, 3125248, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf020a00000

[pid  3464] **munmap**(0x7cf020a00000, 3125248) = 0

[pid  3457] **mprotect**(0x7cf0242fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 6119424, MADV\_DONTNEED) = 0

[pid  3458] **mprotect**(0x7cf01c2fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **madvise**(0x7cf01c022000, 6119424, MADV\_DONTNEED) = 0

[pid  3461] **mprotect**(0x7cf0102fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3461] **madvise**(0x7cf010022000, 6119424, MADV\_DONTNEED) = 0

[pid  3460] **mprotect**(0x7cf0082fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **mprotect**(0x7ceff82fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **madvise**(0x7cf008022000, 6119424, MADV\_DONTNEED) = 0

[pid  3462] **mprotect**(0x7cf00c2fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **madvise**(0x7ceff8022000, 6119424, MADV\_DONTNEED) = 0

[pid  3464] **mprotect**(0x7cf0002fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] **mprotect**(0x7cf0182fd000, 3125248, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **madvise**(0x7cf00c022000, 6119424, MADV\_DONTNEED) = 0

[pid  3464] **madvise**(0x7cf000022000, 6119424, MADV\_DONTNEED) = 0

[pid  3464] **mmap**(NULL, 6250496, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf020800000

[pid  3464] **mmap**(NULL, 6250496, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf020200000

[pid  3459] **madvise**(0x7cf018022000, 6119424, MADV\_DONTNEED) = 0

[pid  3464] **munmap**(0x7cf020800000, 6250496) = 0

[pid  3464] **munmap**(0x7cf020200000, 6250496) = 0

[pid  3458] **mprotect**(0x7cf01c5f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **mprotect**(0x7cf0245f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **madvise**(0x7cf01c022000, 12369920, MADV\_DONTNEED) = 0

[pid  3463] **mprotect**(0x7ceff85f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 12369920, MADV\_DONTNEED) = 0

[pid  3463] **madvise**(0x7ceff8022000, 12369920, MADV\_DONTNEED) = 0

[pid  3461] **mprotect**(0x7cf0105f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **mprotect**(0x7cf00c5f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3461] **madvise**(0x7cf010022000, 12369920, MADV\_DONTNEED) = 0

[pid  3462] **madvise**(0x7cf00c022000, 12369920, MADV\_DONTNEED) = 0

[pid  3459] **mprotect**(0x7cf0185f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **mprotect**(0x7cf0085f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] **madvise**(0x7cf018022000, 12369920, MADV\_DONTNEED) = 0

[pid  3460] **madvise**(0x7cf008022000, 12369920, MADV\_DONTNEED) = 0

[pid  3458] **madvise**(0x7cf01c022000, 12369920, MADV\_DONTNEED) = 0

[pid  3458] **mmap**(NULL, 12500992, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf020200000

[pid  3458] **mmap**(NULL, 12500992, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf017400000

[pid  3464] **mprotect**(0x7cf0005f8000, 6250496, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] **madvise**(0x7cf000022000, 12369920, MADV\_DONTNEED) = 0

[pid  3464] **mmap**(NULL, 12500992, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf016800000

[pid  3464] **mmap**(NULL, 12500992, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015c00000

[pid  3458] **munmap**(0x7cf020200000, 12500992) = 0

[pid  3458] **munmap**(0x7cf017400000, 12500992) = 0

[pid  3461] **mprotect**(0x7cf010bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] **munmap**(0x7cf016800000, 12500992) = 0

[pid  3464] **munmap**(0x7cf015c00000, 12500992) = 0

[pid  3461] **madvise**(0x7cf010022000, 24870912, MADV\_DONTNEED) = 0

[pid  3457] **mprotect**(0x7cf024bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **mprotect**(0x7cf00cbee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **madvise**(0x7cf00c022000, 24870912, MADV\_DONTNEED) = 0

[pid  3463] **mprotect**(0x7ceff8bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024022000, 24870912, MADV\_DONTNEED) = 0

[pid  3463] **madvise**(0x7ceff8022000, 24870912, MADV\_DONTNEED) = 0

[pid  3459] **mprotect**(0x7cf018bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] **madvise**(0x7cf018022000, 24870912, MADV\_DONTNEED) = 0

[pid  3460] **mprotect**(0x7cf008bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **madvise**(0x7cf008022000, 24870912, MADV\_DONTNEED) = 0

[pid  3461] **madvise**(0x7cf010022000, 24870912, MADV\_DONTNEED) = 0

[pid  3461] **mmap**(NULL, 25001984, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf016800000

[pid  3461] **mmap**(NULL, 25001984, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

[pid  3461] **munmap**(0x7cf016800000, 25001984) = 0

[pid  3461] **munmap**(0x7cf015000000, 25001984) = 0

[pid  3461] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3461] **madvise**(0x7cf022c00000, 8368128, MADV\_DONTNEED) = 0

[pid  3461] **exit**(0)                     = ?

[pid  3461] +++ exited with 0 +++

[pid  3462] **mprotect**(0x7cf00d7da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **mprotect**(0x7cf0257da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3462] **madvise**(0x7cf00c021000, 49872896, MADV\_DONTNEED <unfinished ...>

[pid  3458] **mprotect**(0x7cf01cbee000, 12500992, PROT\_READ|PROT\_WRITE <unfinished ...>

[pid  3462] <... madvise resumed>)      = 0

[pid  3458] <... mprotect resumed>)     = 0

[pid  3462] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3462] **madvise**(0x7cf022200000, 8368128, MADV\_DONTNEED) = 0

[pid  3462] **exit**(0)                     = ?

[pid  3462] +++ exited with 0 +++

[pid  3464] **mprotect**(0x7cf000bee000, 12500992, PROT\_READ|PROT\_WRITE) = 0

[pid  3457] **madvise**(0x7cf024021000, 49872896, MADV\_DONTNEED) = 0

[pid  3457] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3457] **madvise**(0x7cf029800000, 8368128, MADV\_DONTNEED) = 0

[pid  3457] **exit**(0)                     = ?

[pid  3457] +++ exited with 0 +++

[pid  3456] <... futex resumed>)        = 0

[pid  3456] **futex**(0x7cf029600910, FUTEX\_WAIT\_BITSET|FUTEX\_CLOCK\_REALTIME, 3458, NULL, FUTEX\_BITSET\_MATCH\_ANY <unfinished ...>

[pid  3458] **mprotect**(0x7cf01d7da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3464] **mprotect**(0x7cf0017da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3458] **madvise**(0x7cf01c021000, 49872896, MADV\_DONTNEED) = 0

[pid  3458] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3458] **madvise**(0x7cf028e00000, 8368128, MADV\_DONTNEED) = 0

[pid  3458] **exit**(0)                     = ?

[pid  3458] +++ exited with 0 +++

[pid  3456] <... futex resumed>)        = 0

[pid  3456] **futex**(0x7cf028c00910, FUTEX\_WAIT\_BITSET|FUTEX\_CLOCK\_REALTIME, 3459, NULL, FUTEX\_BITSET\_MATCH\_ANY <unfinished ...>

[pid  3464] **madvise**(0x7cf000021000, 49872896, MADV\_DONTNEED) = 0

[pid  3464] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3464] **madvise**(0x7cf020e00000, 8368128, MADV\_DONTNEED) = 0

[pid  3464] **exit**(0)                     = ?

[pid  3464] +++ exited with 0 +++

[pid  3459] **mprotect**(0x7cf0197da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3463] **mprotect**(0x7ceff97da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3459] **madvise**(0x7cf018021000, 49872896, MADV\_DONTNEED) = 0

[pid  3459] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3459] **madvise**(0x7cf028400000, 8368128, MADV\_DONTNEED) = 0

[pid  3459] **exit**(0)                     = ?

[pid  3456] <... futex resumed>)        = 0

[pid  3459] +++ exited with 0 +++

[pid  3456] **futex**(0x7cf023e00910, FUTEX\_WAIT\_BITSET|FUTEX\_CLOCK\_REALTIME, 3460, NULL, FUTEX\_BITSET\_MATCH\_ANY <unfinished ...>

[pid  3463] **madvise**(0x7ceff8021000, 49872896, MADV\_DONTNEED) = 0

[pid  3463] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3463] **madvise**(0x7cf021800000, 8368128, MADV\_DONTNEED) = 0

[pid  3463] **exit**(0)                     = ?

[pid  3463] +++ exited with 0 +++

[pid  3460] **mprotect**(0x7cf0097da000, 24997888, PROT\_READ|PROT\_WRITE) = 0

[pid  3460] **madvise**(0x7cf008021000, 49872896, MADV\_DONTNEED) = 0

[pid  3460] **rt\_sigprocmask**(SIG\_BLOCK, ~[RT\_1], NULL, 8) = 0

[pid  3460] **madvise**(0x7cf023600000, 8368128, MADV\_DONTNEED) = 0

[pid  3460] **exit**(0)                     = ?

[pid  3460] +++ exited with 0 +++

<... futex resumed>)                    = 0

**munmap**(0x7cf029800000, 8392704)         = 0

**munmap**(0x7cf028e00000, 8392704)         = 0

**munmap**(0x7cf028400000, 8392704)         = 0

**munmap**(0x7cf023600000, 8392704)         = 0

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf005000000

**munmap**(0x7cf015000000, 50003968)        = 0

**munmap**(0x7cf005000000, 50003968)        = 0

**mmap**(NULL, 100003840, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7ceff2000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7ceff2000000, 100003840)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**mmap**(NULL, 150003712, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cefef000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7cefef000000, 150003712)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**mmap**(NULL, 200003584, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cefec000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7cefec000000, 200003584)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**mmap**(NULL, 250003456, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cefe9000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7cefe9000000, 250003456)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**mmap**(NULL, 300003328, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cefe6000000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7cefe6000000, 300003328)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**mmap**(NULL, 350003200, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cefe3200000

**mmap**(NULL, 50003968, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7cf015000000

**munmap**(0x7cefe3200000, 350003200)       = 0

**munmap**(0x7cf015000000, 50003968)        = 0

**newfstatat**(AT\_FDCWD, "/etc/localtime", {st\_mode=S\_IFREG|0644, st\_size=1535, ...}, 0) = 0

**write**(2, "Now time is: Tue Dec  3 11:13:18"..., 38Now time is: Tue Dec  3 11:13:18 2024

) = 38

**write**(2, "Array sorted in 23 Seconds\n", 27Array sorted in 23 Seconds

) = 27

**exit\_group**(0)                           = ?

+++ exited with 0 +++

Вывод

В ходе написания данной лабораторной работы я научилась создавать программы, работающие с несколькими потоками, а также синхронизировать их между собой. В результате тестирования программы, я проанализировала каким образом количество потоков влияет на эффективность и ускорение работы программы. Оказалось, что большое количество потоков даёт хорошее ускорение на больших количествах входных данных, но эффективность использования ресурсов находится на приемлемом уровне только на небольшом количестве потоков, не превышающем количества логических ядер процессора. Лабораторная работа была довольно интересна, так как я впервые работал с многопоточностью и синхронизацией на СИ.