Parallel Loop Constructs and Clauses

- Loop
-

Please send corrections (or suggestions) to youngwlim@hotmail.com.

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Clauses (14)

schedule (type)
Specifies how iterations of the for loop are divided among available threads. Acceptable values for type are:

auto
With auto, scheduling is delegated to the compiler and runtime system. The compiler and runtime system can choose any possible mapping of iterations to threads (including all possible valid schedules) and these may be different in different loops.

dynamic
Iterations of a loop are divided into chunks of size ceiling(number_of_iterations/number_of_threads).

Chunks are dynamically assigned to active threads on a "first-come, first-do" basis until all work has been assigned.

dynamic,n
As above, except chunks are set to size n. n must be an integral assignment expression of value 1 or greater.

https://www.ibm.com/docs/en/xl-c-aix/13.1.2?topic=processing-pragma-omp-section-pragma-omp-sections

Clauses (15)

guided

Chunks are made progressively smaller until the default minimum chunk size is reached. The first chunk is of size ceiling(number_of_iterations/number_of_threads). Remaining chunks are of size ceiling(number_of_iterations_left/number_of_threads).

The minimum chunk size is 1.

Chunks are assigned to active threads on a "first-come, first-do" basis until all work has been assigned.

guided,n

As above, except the minimum chunk size is set to n; n must be an integral assignment expression of value 1 or greater.

https://www.ibm.com/docs/en/xl-c-aix/13.1.2?topic=processing-pragma-omp-section-pragma-omp-sections

Clauses (16)

runtime

Scheduling policy is determined at run time. Use the OMP_SCHEDULE environment variable to set the scheduling type and chunk size.

static

Iterations of a loop are divided into chunks of size ceiling(number_of_iterations/number_of_threads). Each thread is assigned a separate chunk.

This scheduling policy is also known as block scheduling.

static,n

Iterations of a loop are divided into chunks of size n. Each chunk is assigned to a thread in round-robin fashion.

n must be an integral assignment expression of value 1 or greater.

This scheduling policy is also known as block cyclic scheduling.

https://www.ibm.com/docs/en/xl-c-aix/13.1.2?topic=processing-pragma-omp-section-pragma-omp-sections

Parallel region

An important difference between **OpenMP** and **MPI** is
that parallelism in **OpenMP** is **dynamically activated**
by a **thread spawning** a **team** of **threads**.

Furthermore, the **number** of **threads** used
can differ between **parallel regions**,
and **threads** can create **threads** recursively.

This is known as as **dynamic mode** .

By contrast, in an **MPI** program
the **number** of running processes is
(mostly) constant throughout the run,
and determined by factors external to the program.

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-parallel.html

Loop parallelism

OpenMP parallel loops are an example of
OpenMP `worksharing' constructs

take an amount of work and
distribute it over the available threads
in a parallel region.

The parallel execution of a loop
can be handled a number of different ways.

For instance, you can create
a parallel region around the loop,
and adjust the **loop bounds**:

```
#pragma omp parallel
{
  int threadnum = omp_get_thread_num(),
      numthreads = omp_get_num_threads();

  int low = N*threadnum/numthreads,
      high = N*(threadnum+1)/numthreads;

  for (i=low; i<high; i++)
    // do something with i
}
```

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop parallelism

use the **parallel for** pragma:

```
#pragma omp parallel
#pragma omp for
for (i=0; i<N; i++) {
  // do something with i
}
```

you don't have to calculate
the loop bounds for the threads yourself,

but you can also tell OpenMP
to assign the loop iterations
according to different schedules

```
#pragma omp parallel
{
  code1();
  #pragma omp for
  for (i=1; i<=4*N; i++) {
    code2();
  }
  code3();
}
```

The code before and after the loop is
executed identically in each thread; t

he loop iterations are spread
over the four threads.

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop parallelism

#pragma omp parallel spawns a group of threads, while #pragma omp for divides loop iterations between the spawned threads. You can do both things at once with the fused #pragma omp parallel for directive.

#pragma omp for only delegates portions of the loop for different threads in the current team. A team is the group of threads executing the program. At program start, the team consists only of a single member: the master thread that runs the program.

To create a new team of threads, you need to specify the parallel keyword. It can be specified in the surrounding context:

```
#pragma omp parallel
{
  #pragma omp for
  for(int n = 0; n < 10; ++n)
  printf(" %d", n);
}
```

https://stackoverflow.com/questions/1448318/omp-parallel-vs-omp-parallel-for

Loop parallelism

The difference between parallel, parallel for and for is as follows:

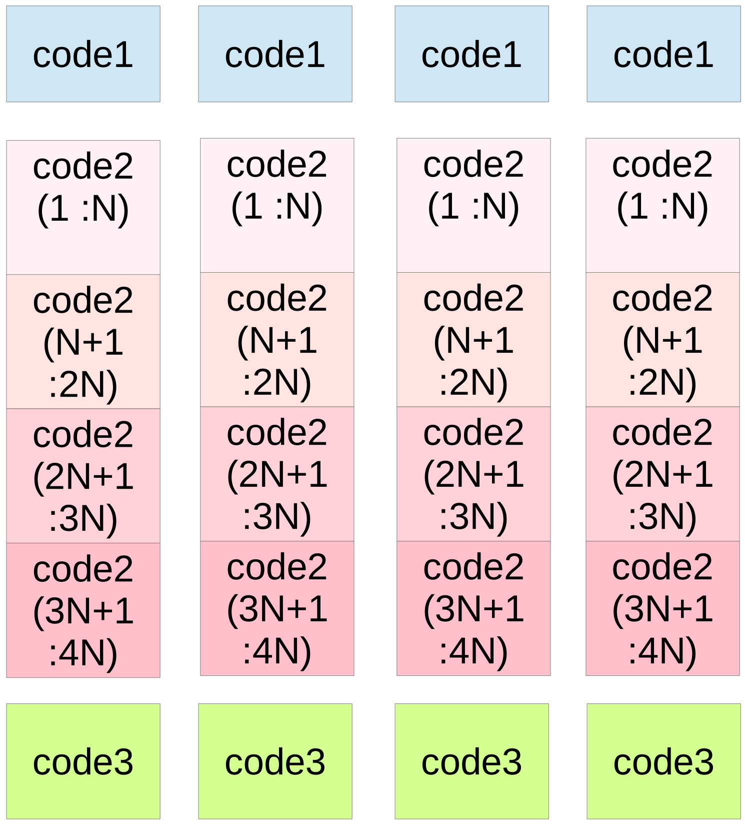
A team is the group of threads that execute currently. At the program beginning, the team consists of a single thread. A parallel construct splits the current thread into a new team of threads for the duration of the next block/statement, after which the team merges back into one. for divides the work of the for-loop among the threads of the current team.

It does not create threads, it only divides the work amongst the threads of the currently executing team. parallel for is a shorthand for two commands at once: parallel and for. Parallel creates a new team, and for splits that team to handle different portions of the loop. If your program never contains a parallel construct, there is never more than one thread; the master thread that starts the program and runs it, as in non-threading programs.

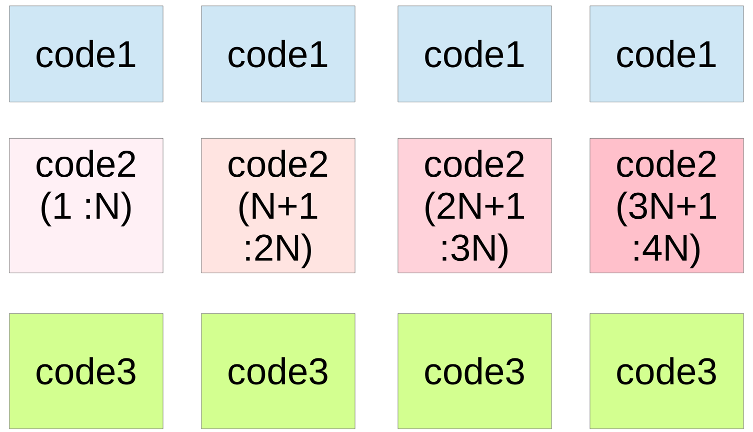
https://stackoverflow.com/questions/1448318/omp-parallel-vs-omp-parallel-for

Loop parallelism

Without #pragma omp **for**



With #pragma omp **for**



https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop parallelism

Note that the **parallel do** and **parallel for** pragmas
do not create a team of threads:
they take the team of threads that is active,
and divide the loop iterations over them.

This means that the **omp for** or **omp do** directive
needs to be inside a **parallel region**.
It is also possible to have a combined
omp parallel for or **omp parallel do** directive.

If your parallel region only contains a loop,
you can combine the pragmas for the parallel region
and distribution of the loop iterations:

```
#pragma omp parallel for
  for (i=0; .....
```

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Loop parallelism

Note that the **parallel do** and **parallel for** pragmas
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Loop Schedules (1)

more **iterations** in a loop than **threads**
several ways to assign loop **iterations** to the **threads**
OpenMP lets you specify this with the **schedule clause**.

#pragma omp **for schedule**(....)

Static schedules
the **iterations** are assigned purely
based on the number of **iterations**
and the number of **threads**
(and the **chunk parameter**; see later).

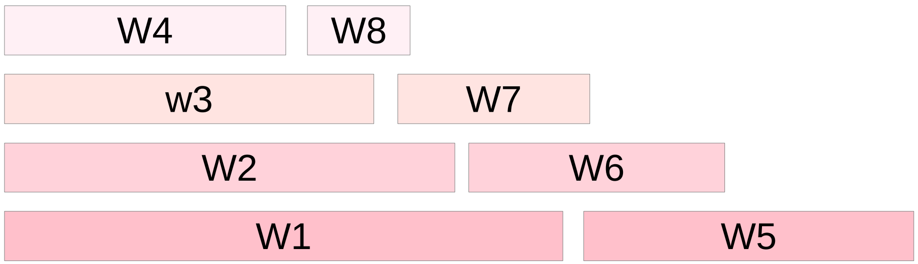
Dynamic schedules
iterations are assigned
to **threads** that are unoccupied.

when iterations take an unpredictable amount of time,
so **load balancing** is needed.

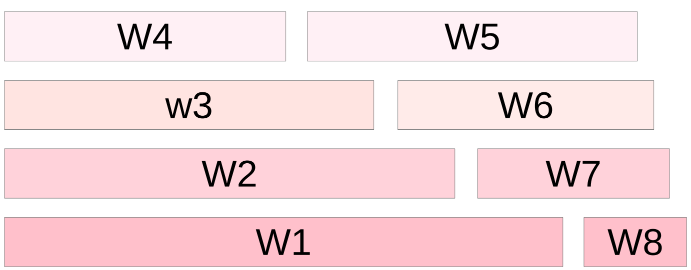
https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop Schedules (2)

Static round robin scheduling



Dynamic scheduling



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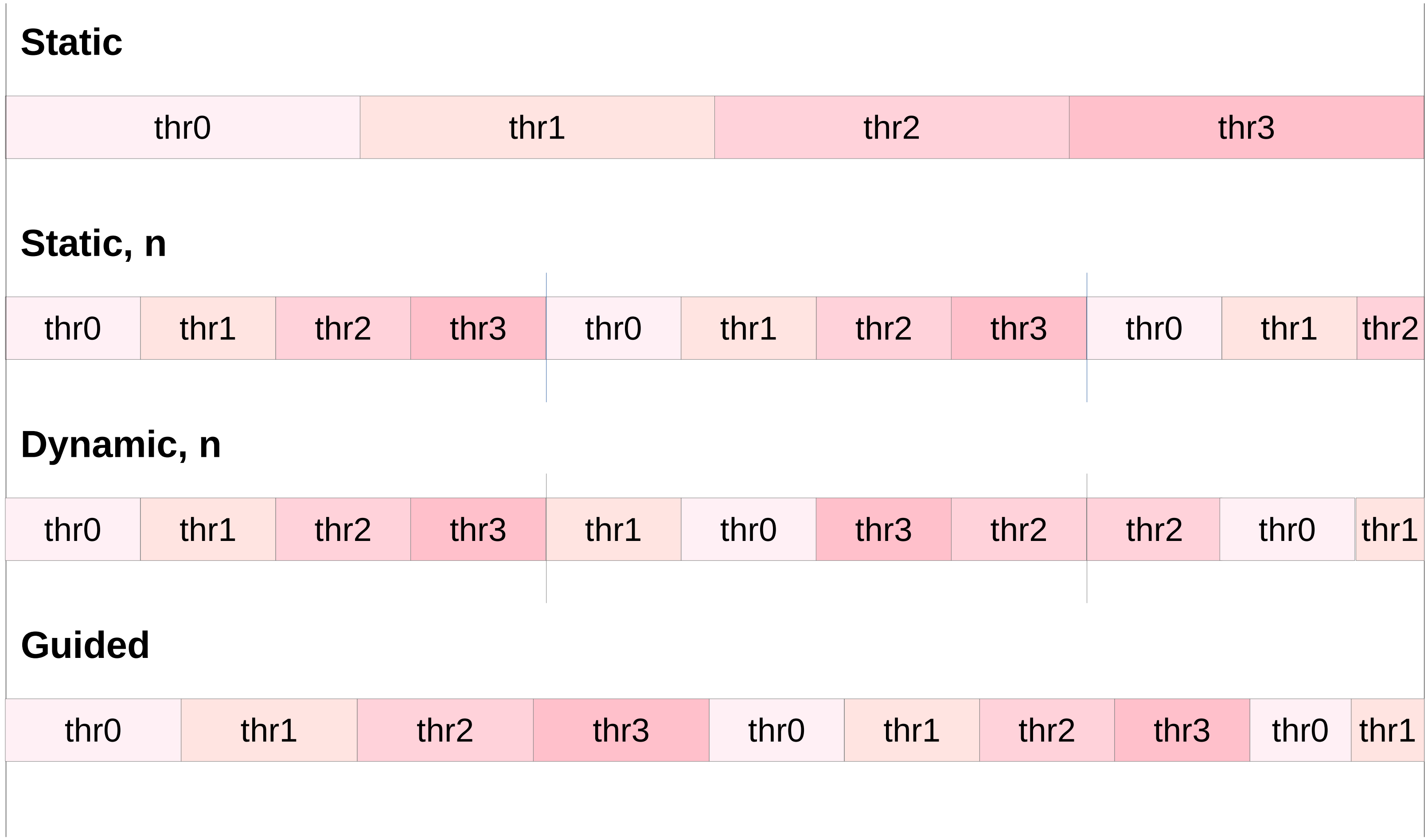
Loop Schedules (3)



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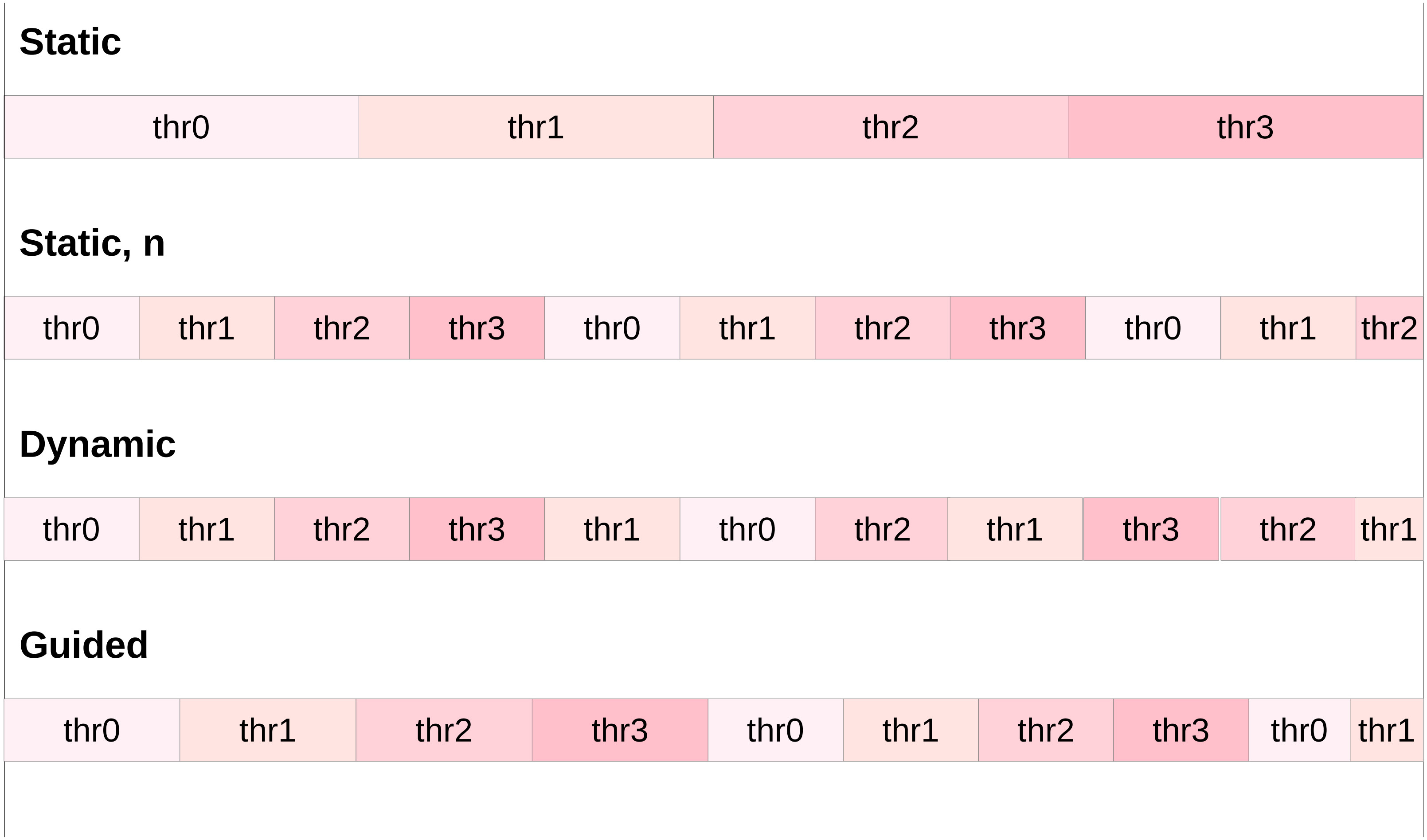
Loop Schedules (3)



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Loop Schedules (4)

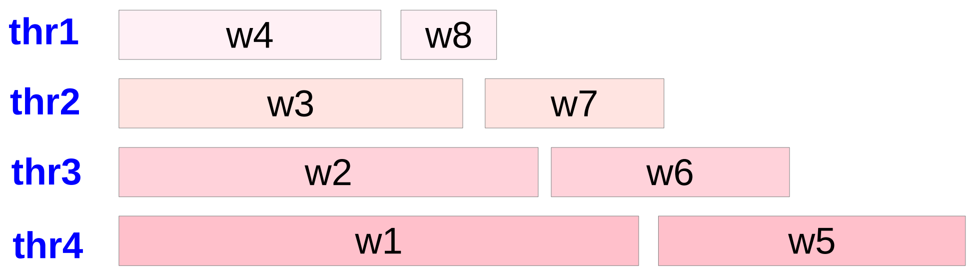
assume that each core gets assigned
two (blocks of) iterations and
these blocks take gradually
less and less time.

thread 1 gets two fairly long blocks,
whereas thread 4 gets two short blocks,

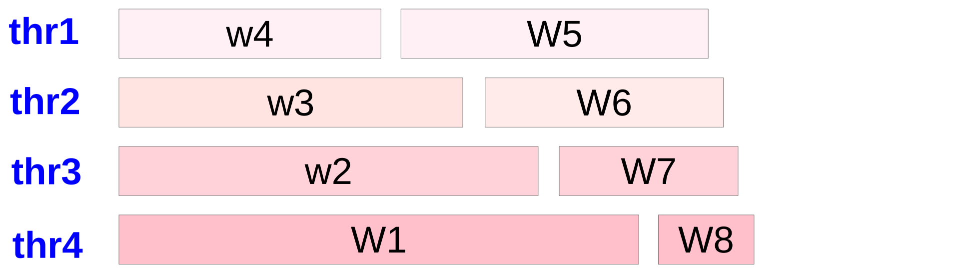
Thread 1 finishes much earlier.
Imbalance : unequal amounts of work

load balancing
thread 4 gets block 5,
since it finishes the first set of blocks early.
The effect is a perfect

Static round robin scheduling



Dynamic scheduling



https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop Schedule – Static (1)

The **default static schedule** is
to assign one consecutive **block**
of **iterations** to each **thread**.

#pragma omp **for schedule(static)**
#pragma omp **for schedule(static, chunk)**

With **static scheduling**, the compiler
will split up the loop iterations at compile time,

When the iterations take roughly
the same amount of time,
this is the most efficient at runtime.

Static

thr0	thr1	thr2	thr3

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

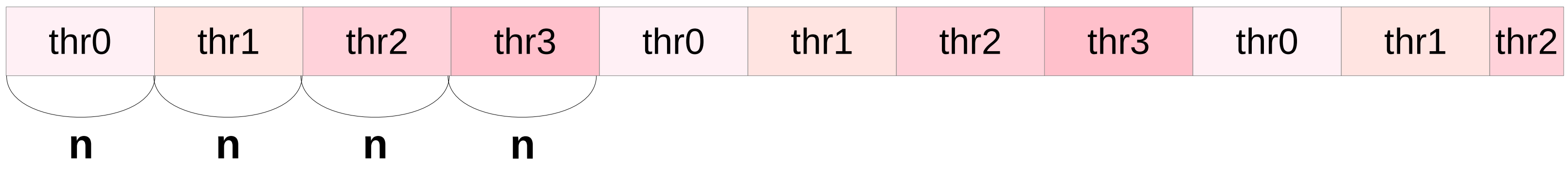
Loop Schedule – Static (2)

#pragma omp **for schedule(static,chunk)**

If you want <u>different</u> <u>sized blocks</u>
you can defined a **chunk size chunk**

The choice of a **chunk size** is often
a balance between the **low overhead**
of having only <u>a few chunks</u>, (big chunks)
versus the **load balancing effect**
of having <u>smaller chunks</u>. (many chunks)

Static, n



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Loop Schedule – Static (3)

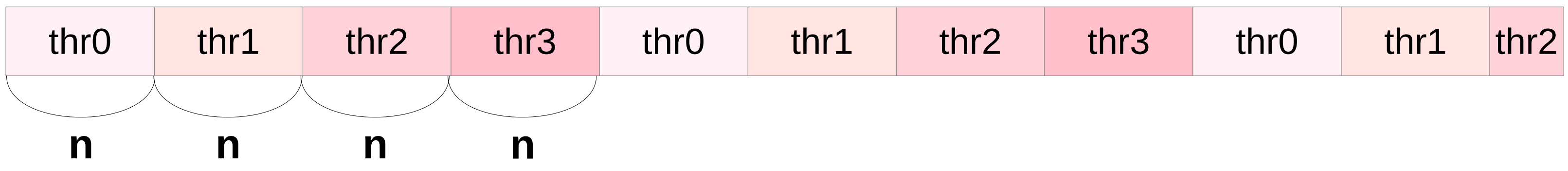
#pragma omp **for schedule(static,chunk)**

OpenMP divides the iterations
into chunks of size chunk-size

distributes the chunks to **threads**
in a circular order.

When no chunk-size is specified,
OpenMP divides iterations into chunks
that are approximately equal in size and
distributes at most one **chunk** to each **thread**.

Static, n



http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Static (4)

Static scheduling is used
when you know that each thread will do
the approximately same amount of work
at the **compile time**.

the following code can be parallelized
using OMP. (assume only 4 threads)

```
float A[100][100];

for(int i = 0; i < 100; i++)
{
   for(int j = 0; j < 100; j++)
   {
      A[i][j] = 1.0f;
   }
}
```

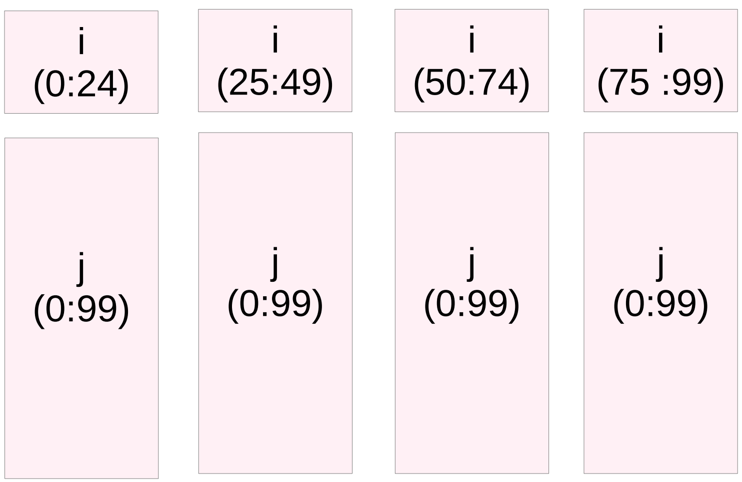
100 * 100 iterations
10000 / 4 iterations / thread

https://stackoverflow.com/questions/15508128/using-omp-schedule-with-pragma-omp-for-parallel-scheduleruntime

Loop Schedule – Static (5)

```
float A[100][100];

#pragma omp for schedule(static)
for(int i = 0; i < 100; i++)
{
   for(int j = 0; j < 100; j++)
   {
      A[i][j] = 1.0f;
   }
}
```



to use the default static scheduling,
place pragma on the outer for loop,

then each thread will do
25% of the outer loop (i) work
and eqaul amount of inner loop (j) work

Hence, the total amount of work done
by each thread is same.

Hence, we could simply stick
with the default static scheduling
to give optimal load balancing.

https://stackoverflow.com/questions/15508128/using-omp-schedule-with-pragma-omp-for-parallel-scheduleruntime

Loop Schedule – Static (6)

Assume : a for loop with 64 iterations and 4 threads

schedule(static)

OpenMP divides iterations into 4 chunks of size 16
and it distributes them to four threads.

64 iterations and 4 threads → 64 / 4 = 16

the 1st tread executes iterations 1, 2, 3, …, 15 and 16.

the 2nd thread executes iterations 17, 18, 19, …, 31, 32.

schedule(static, 4) and **schedule(static, 8)**

OpenMP divides iterations into chunks of size 4 and 8, respectively.

- when all iterations have the same computational cost.

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Static (6)

schedule**(static, 4)**

0	1	2	3	16	17	18	19	32	33	34	35	48	49	50	51
4	5	6	7	20	21	22	23	36	37	38	39	52	53	54	55
8	9	10	11	24	25	26	27	40	41	42	43	56	57	58	59
12	13	14	15	28	29	30	31	44	45	46	47	60	61	62	63

schedule**(static, 8)**

0	1	2	3	4	5	6	7	32	33	34	35	36	37	38	39
8	9	10	11	12	13	14	15	40	41	42	43	44	45	46	47
16	17	18	19	20	21	22	23	48	49	50	51	52	53	54	55
24	25	26	27	28	29	30	31	56	57	58	59	60	61	62	63

schedule**(static)**

0	1	2	3	4	5	6	7	8	9	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	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Dynamic (1)

In **dynamic scheduling** OpenMP will
put **blocks** of iterations in a **task queue**,
(the **default chunk size** is **1**)
and the **threads** take one of these tasks
whenever they are finished with the previous.

#pragma omp for schedule(dynamic[,chunk])

While this schedule may give **good load balancing**
if the iterations take very differing amounts of time to execute,
it does carry **runtime overhead**
for managing the **queue** of iteration tasks.

Dynamic

thr0	thr1	thr2	thr3	thr1	thr0	thr3	thr2	thr2	thr0	thr1

arbitrary thread assignment

fixed chunk size except the last

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop Schedule – Dynamic (2)

large **chunks** carry the least **overhead**,
but smaller chunks are better for **load balancing**.

If you don't want to decide on a schedule in your code,
you can specify the schedule will then **at runtime**
be read from the OMP_SCHEDULE environment variable.

You can even just leave it to the runtime library by specifying
omp_set_schedule.

Dynamic

thr0	thr1	thr2	thr3	thr1	thr0	thr3	thr2	thr2	thr0	thr1

arbitrary thread assignment

fixed chunk size except the last

https://pages.tacc.utexas.edu/~eijkhout/pcse/html/omp-loop.html

Loop Schedule – Dynamic (3)

for schedule(dynamic, chunk-size)
the dynamic scheduling type

OpenMP divides the **iterations**
into chunks of size chunk-size.

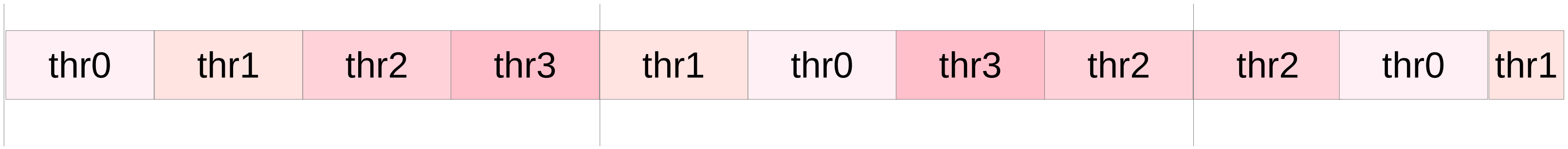
Each thread *executes*
a chunk of **iterations** and
then *requests* another chunk
until there are no more chunks available.

There is no particular order
in which the chunks are distributed
to the **threads**.

The order changes each time
when we execute the for loop.

If we do not specify **chunk-size**,
it defaults to one.

Dynamic



arbitrary thread assignment

fixed chunk size except the last

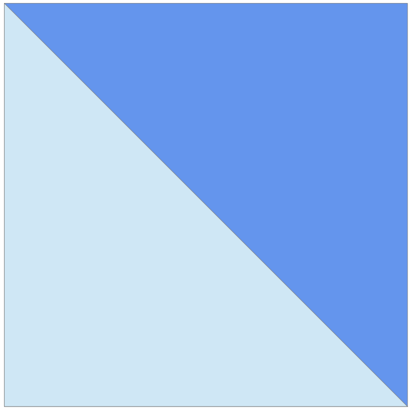
http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Dynamic (4)

Dynamic scheduling is used when you know that each thread will <u>not</u> do <u>same</u> amount of work by using **static scheduling**.

```
float A[100][100];

for(int i = 0; i < 100; i++)
{
   for(int j = 0; j < i; j++)
   {
      A[i][j] = 1.0f;
   }
}
```



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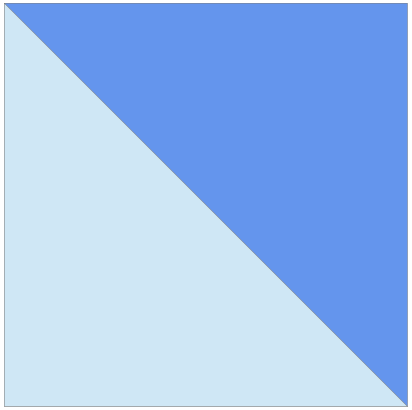
Loop Schedule – Dynamic (5)

```
float A[100][100];

for(int i = 0; i < 100; i++)
{
   for(int j = 0; j < i; j++)
   {
      A[i][j] = 1.0f;
   }
}
```



The inner loop variable **j** is dependent on the **i**.

the **default static scheduling**,

- the outer loop (i) work might be divided equally between the 4 threads,
- but the inner loop (j) work will be large for some threads.

- not equal amount of work
- not optimal **load balancing**

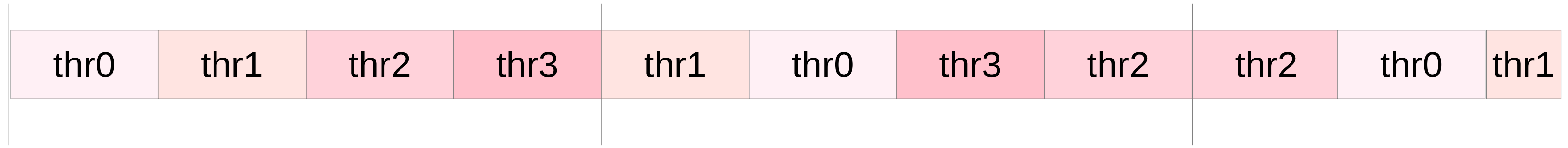
https://stackoverflow.com/questions/15508128/using-omp-schedule-with-pragma-omp-for-parallel-scheduleruntime

Loop Schedule – Dynamic (6)

the dynamic scheduling is done at the run time
can make sure optimal **load balance**.

can specify the chunk_size for scheduling
which depends on the **loop size**.

Dynamic



arbitrary thread assignment

fixed chunk size except the last

https://stackoverflow.com/questions/15508128/using-omp-schedule-with-pragma-omp-for-parallel-scheduleruntime

Loop Schedule – Dynamic (7)

schedule(dynamic) and **schedule(dynamic, 1)**
OpenMP determines similar scheduling.
the size of chunks is equal to **1** in both instances.

the distribution of chunks between the threads is arbitrary.

schedule(dynamic, 4) and **schedule(dynamic, 8)**
OpenMP divides iterations into chunks of size **4** and **8**, respectively.

the distribution of chunks to the threads has no pattern (abitrary)

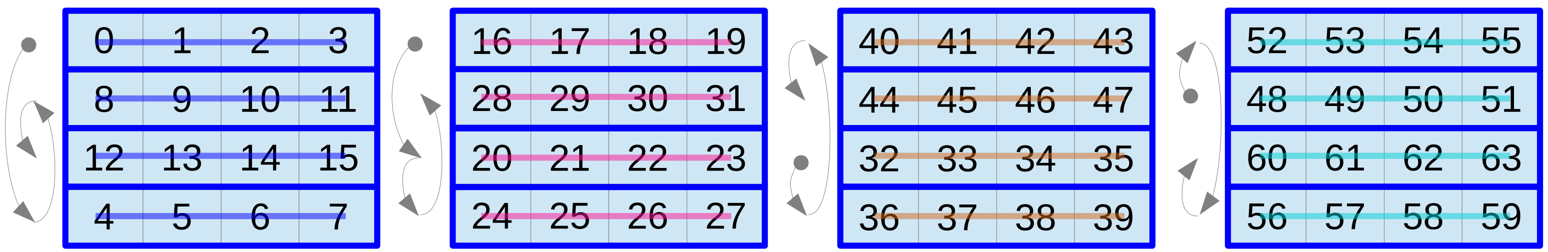
- when the iterations require different computational costs.
- when the iterations are poorly balanced between each other.

- higher **overhead** than the static scheduling type
  because it dynamically distributes the iterations during the runtime.

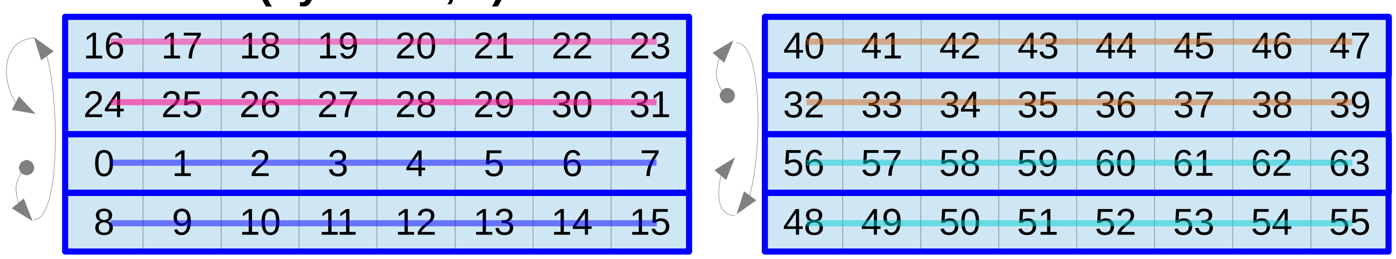
http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Dynamic (6)

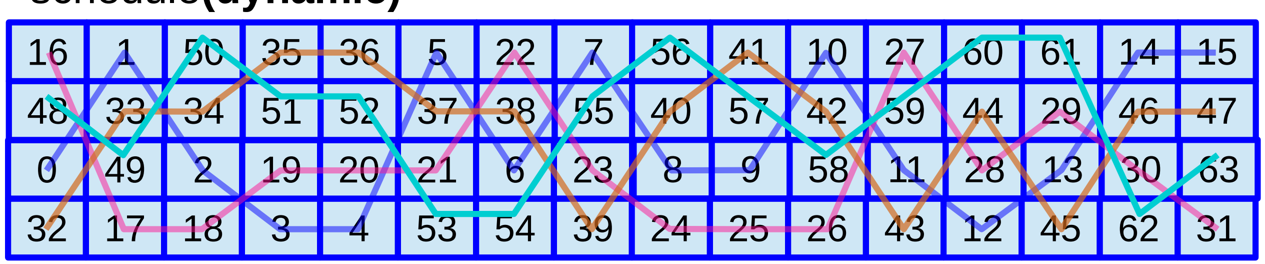
schedule**(dynamic, 4)**



schedule**(dynamic, 8)**



schedule**(dynamic)**



http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Guided (1)

The **guided** scheduling type is similar to the **dynamic** scheduling type.

OpenMP again divides the iterations into chunks.

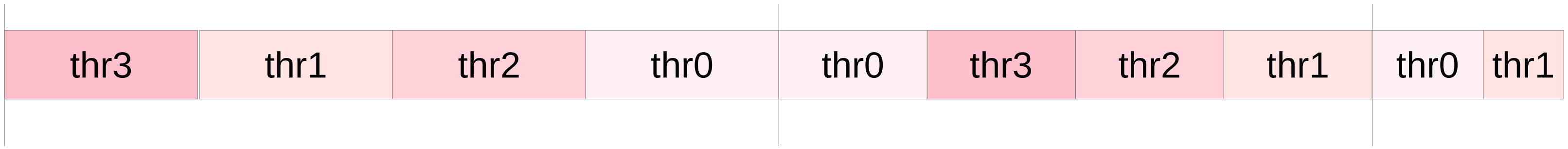
Each thread executes a chunk of iterations and then requests another chunk until there are no more chunks available.

The difference is in **the size of chunks**.

The size of a chunk is proportional to the **number of unassigned iterations** divided by the **number of the threads**.

Therefore **the size of the chunks** decreases as the execution goes on

Guided



arbitrary thread assignment

decreasing chunk size

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Guided (2)

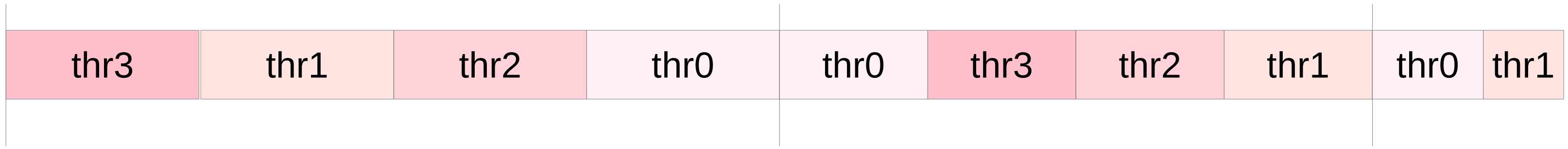
The **minimum size of a chunk**
is set by '**chunk-size'**
in the scheduling clause:

for schedule(guided, chunk-size).

the chunk which contains the last iterations
may have smaller size than chunk-size.

If we do not specify **chunk-size**,
it defaults to **one**.

Guided



arbitrary thread assignment

decreasing chunk size

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Guided (3)

the **size** of the **chunks** is decreasing.

1st chunk has always 16 iterations. 64 iterations / 4 threads → 64 / 4 = 16

2nd chunk has always 12 iterations. (64-16) iterations / 4 threads → 48 / 4 = 12

3rd chunk has always 9 iterations. (48-12) iterations / 4 threads → 36 / 4 = 9

the **minimum chunk size** is determined in the schedule clause.
The only exception is the **last chunk**.
Its size might be lower then the prescribed minimum size.

The guided scheduling type is appropriate
when the iterations are poorly balanced between each other.

The initial chunks are larger, because they reduce overhead.
The smaller chunks fills the schedule towards the end of the computation
and improve load balancing.
This scheduling type is especially appropriate
when poor load balancing occurs toward the end of the computation.

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Guided (3)

schedule(guided)

64	64 / 4 = 16
(64-16)	48 / 4 = 12
(48-12)	36 / 4 = 9
(36-9)	27 / 4 = 7
(27-7)	20 / 4 = 5
(20-5)	15 / 4 = 4
(15-4)	11 / 4 = 3
(11-3)	8 / 4 = 2
(8-2)	6 / 4 = 2
(6-2)	4 / 4 = 1
(4-1)	3 / 4 = 1
(3-1)	2 / 4 = 1
(2-1)	1 / 4 = 1

schedule(guided, 4)

64	64 / 4 = 16	
(64-16)	48 / 4 = 12	
(48-12)	36 / 4 = 9	
(36-9)	27 / 4 = 7	
(27-7)	20 / 4 = 5	
(20-5)	15 / 4 = 4	
(15-4)	11 / 4 = 3 < 4	
(11-4)	7	4
(7-4)	3	3
(3-3)	0	

schedule(guided, 8)

64	64 / 4 = 16	
(64-16)	48 / 4 = 12	
(48-12)	36 / 4 = 9	
(36-9)	27 / 4 = 7 < 8	
(27-8)	19	8
(19-8)	11	8
(11-8)	3	3
(3-3)	0	

unassigned iterations / threads

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Static (6)

schedule**(static)**

0	1	2	3	4	5	6	7	8	9	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	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	44	45	46	47	48	58	59	63
16	17	18	19	20	21	22	23	24	25	26	27	49	50	51	52	60							
28	29	30	31	32	33	34	35	36	53	54	55	61											
37	38	39	40	41	42	43	56	57	62														

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	63
16	17	18	19	20	21	22	23	24	25	26	27	53	54	55	60	
28	29	30	31	32	33	34	35	36	49	50	51	52	56	57	61	
37	38	39	40	41	42	43	44	45	46	47	48	58	59	62		

schedule(guided)

64	64 / 4 = 16
(64-16)	48 / 4 = 12
(48-12)	36 / 4 = 9
(36-9)	27 / 4 = 7
(27-7)	20 / 4 = 5
(20-5)	15 / 4 = 4
(15-4)	11 / 4 = 3
(11-3)	8 / 4 = 2
(8-2)	6 / 4 = 2
(6-2)	4 / 4 = 1
(4-1)	3 / 4 = 1
(3-1)	2 / 4 = 1
(2-1)	1 / 4 = 1

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Static (6)

schedule(**static**)

0	1	2	3	4	5	6	7	8	9	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	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	44	45	46	47	48	61
16	17	18	19	20	21	22	23	24	25	26	27	49	50	51	52	62					
28	29	30	31	32	33	34	35	36	53	54	55	56	63								
37	38	39	40	41	42	43	57	58	59	60											

schedule(guided, 4)

64	64 / 4 = 16	
(64-16)	48 / 4 = 12	
(48-12)	36 / 4 = 9	
(36-9)	27 / 4 = 7	
(27-7)	20 / 4 = 5	
(20-5)	15 / 4 = 4	
(15-4)	11 / 4 = 3 < 4	
(11-4)	7	4
(7-4)	3	3
(3-3)	0	

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Auto

The auto scheduling type delegates
the decision of the scheduling
to the **compiler** and/or **runtime** system.

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedule – Runtime

The schedule(runtime) clause tells it
to set the schedule using the environment variable.

The environment variable can be set
to any other scheduling type.

It can be set by

setenv OMP_SCHEDULE “dynamic,5”

https://stackoverflow.com/questions/15508128/using-omp-schedule-with-pragma-omp-for-parallel-scheduleruntime

Loop Schedules – Runtime

The **runtime** scheduling type defers
the decision about the scheduling
until the **runtime**.

different ways of specifying
the scheduling type in this case.

One option is with the environment variable
OMP_SCHEDULE

and the other option is
with the function
omp_set_schedule.

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

Loop Schedules – Runtime

If the scheduling-type (in the schedule clause of the loop construct) is equal to runtime then OpenMP determines the scheduling by the internal control variable run-sched-var. We can set this variable by setting the environment variable OMP_SCHEDULE to the desired scheduling type. For example, in bash-like terminals, we can do

```
$ export OMP_SCHEDULE=sheduling-type
```

Another way to specify run-sched-var is to set it with omp_set_schedule function.

```
...
omp_set_schedule(sheduling-type);
...
```

http://jakascorner.com/blog/2016/06/omp-for-scheduling.html

for construct

```
#pragma omp for [clause ...]  newline

            schedule (type [,chunk])
            ordered
            private (list)
            firstprivate (list)
            lastprivate (list)
            shared (list)
            reduction (operator: list)
            collapse (n)
            nowait

  for_loop
```

https://hpc.llnl.gov/openmp-tutorial#WorkSharing

Nested Parallelism (1)

```
void fun1()
{
   for (int i=0; i<80; i++)
      ...
}

main()
{
  #pragma omp parallel
  {
     #pragma omp for
     for (int i=0; i<100; i++)
        ...

     #pragma omp for
     for (int i=0; i<10; i++)
        fun1();
   }
}
```

the 2nd loop in **main**
can only be distributed to **10** threads

80 loop iterations in **fun1**
which will be called **10** times in **main** loop.

total **800** iterations in **fun1** and the **main** loop

This gives much more parallelism potential
if parallelism can be added in both levels.

https://software.intel.com/content/www/us/en/develop/articles/exploit-nested-parallelism-with-openmp-tasking-model.html

Nested Parallelism (2)

```
void fun1()
{
  #pragma omp parallel for
  for (int i=0; i<80; i++)
     ...
}

main
{
  #Pragma omp parallel
  {
     #pragma omp for
     for (int i=0; i<100; i++)
        …

     #pragma omp for
     for (int i=0; i<10; i++)
        fun1();
  }
}
```

may either have insufficient threads for the 1st main loop
as it has larger loop count, or

create exploded number of threads for the 2nd main loop
when OMP_NESTED=TRUE.

The simple solution is to split the parallel region in main and
create separate ones for each loop
with a distinct thread number specified.

https://software.intel.com/content/www/us/en/develop/articles/exploit-nested-parallelism-with-openmp-tasking-model.html

Nested Parallelism (3)

```
void fun1()
{
  #pragma omp taskloop
  for (int I = 0; i<80; i++)
     ...
}

main
{
  #pragma omp parallel
  {
     #pragma omp for
     for (int i=0; i<100; i++)
        ...

     #pragma omp for
     for (int i=0; i<10; i++)
        fun1();
  }
}
```

don't have to worry about the thread number changes
in 1st and 2nd main loops.

Even though you still have a small amount of (10) threads
allocated for 2nd main loop,
the rest available threads will be able
to be distributed through omp **taskloop** in fun1.

https://software.intel.com/content/www/us/en/develop/articles/exploit-nested-parallelism-with-openmp-tasking-model.html

Nested Parallelism (4)

nested parallel regions is
a way to distribute **tasks** by creating / forking more **threads**.

parallel region is the only construct
determines **execution thread number**
and controls **thread affinity**

Using **nested parallel regions** means
each **thread** in **parent region**
will yield multiple **threads** in enclosed regions,
which in turn create a product of **thread number**.

https://software.intel.com/content/www/us/en/develop/articles/exploit-nested-parallelism-with-openmp-tasking-model.html

Nested Parallelism (5)

omp tasking shows another way
to explore parallelism by adding
more **tasks**, instead of **threads**.

though the **thread number** is unchanged
as specified at the entry of the **parallel region**,
the increased **tasks** from the **nested tasking** constructs
can be distributed and executed by any available/idle **threads**
in the current team of the same parallel region.

This gives opportunities to fully use all threads' capability,
and improve balance of workloads automatically.

https://software.intel.com/content/www/us/en/develop/articles/exploit-nested-parallelism-with-openmp-tasking-model.html

References

[1] en.wikipedia.org
[2] M Harris, http://beowulf.lcs.mit.edu/18.337-2008/lectslides/scan.pdf