



# *Arquitectura de Computadores Avançada*

*Performance Analysis*

António Rui Borges

## *Factors affecting program execution*

Program execution is affected by multiple factors. Some of them are controlled by the programmer, but some are not.

Among the most important, one may highlight

- at hardware level
  - internal processor organization (instruction scheduling and execution patterns)
  - processor to main memory path (access times)
- at software level
  - code organization (algorithmic design)
  - match of code generation to processor architecture (compilation procedure)
  - operating system (scheduling policy / power management)

## *Quad-core processor characterization*

```
[ruib@ruib-laptop ~]$ lscpu
```

```
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
Address sizes:         39 bits physical, 48 bits virtual
CPU(s):                8
On-line CPU(s) list:   0-7
Thread(s) per core:    2
Core(s) per socket:    4
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 142
Model name:            Intel(R) Core(TM) i7-8565U CPU @ 1.80GHz
Stepping:              11
CPU MHz:               900.002
CPU max MHz:           4600,0000
CPU min MHz:           400,0000
BogoMIPS:              3999.93
Virtualization:        VT-x
L1d cache:             128 KiB
L1i cache:             128 KiB
L2 cache:              1 MiB
L3 cache:              8 MiB
NUMA node0 CPU(s):     0-7
```

## *Dual-core processor characterization*

```
[ruib@ruib-laptop2 ~]$ lscpu
```

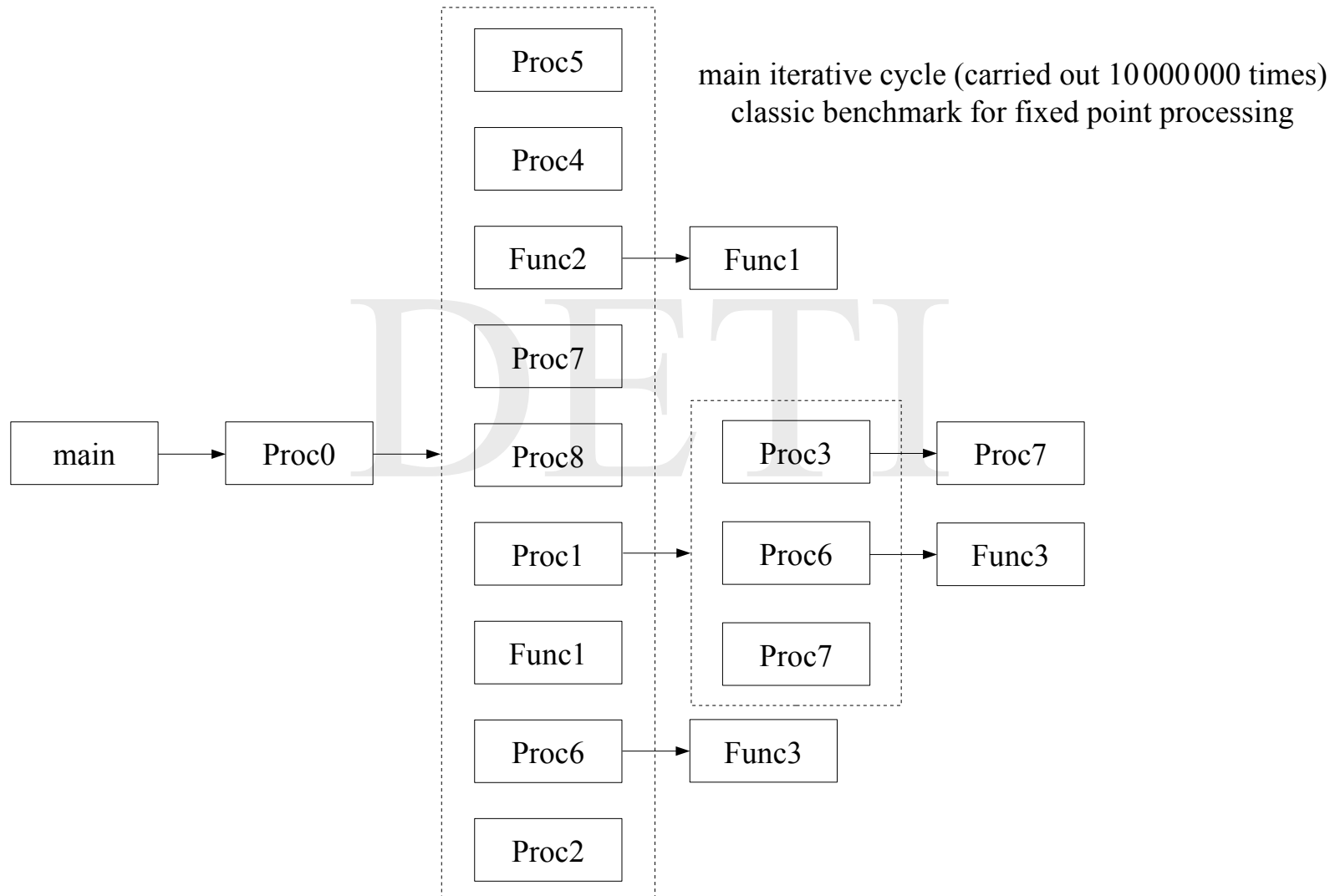
```
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    2
Core(s) per socket:    2
Socket(s):             1
NUMA node(s):         1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                78
Model name:            Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz
Stepping:              3
CPU MHz:               2787.223
CPU max MHz:           2800,0000
CPU min MHz:           400,0000
BogoMIPS:              4800.00
Virtualization:        VT-x
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              3072K
NUMA node0 CPU(s):     0-3
```

...

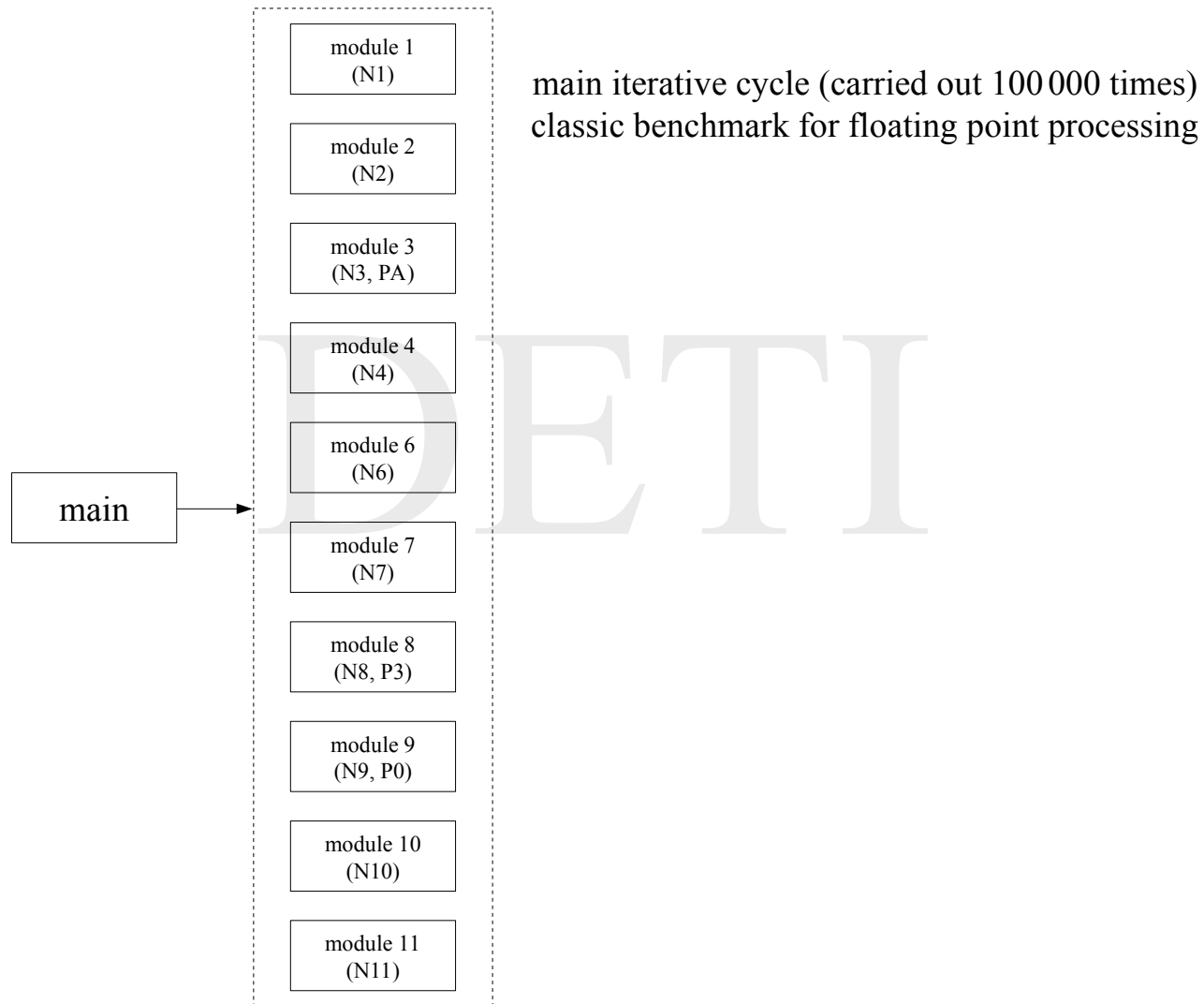
# *Compiler optimization*

- without optimization
  - to reduce the compilation cost
  - to make debugging produce the expected results
- with optimization
  - to improve performance and/or code size at the expense of compilation time and the ability to debug the program
- options (GNU)
  - [-O0] almost no code optimization takes place (default situation)
  - [-O1 ... -O3] performance optimization (degree increases with the number used)
  - [-Os] code size optimization
  - [-Og] debugging optimization

# *Dhrystone*



# *Whetstone*



## *Prime (v1 and v2)*

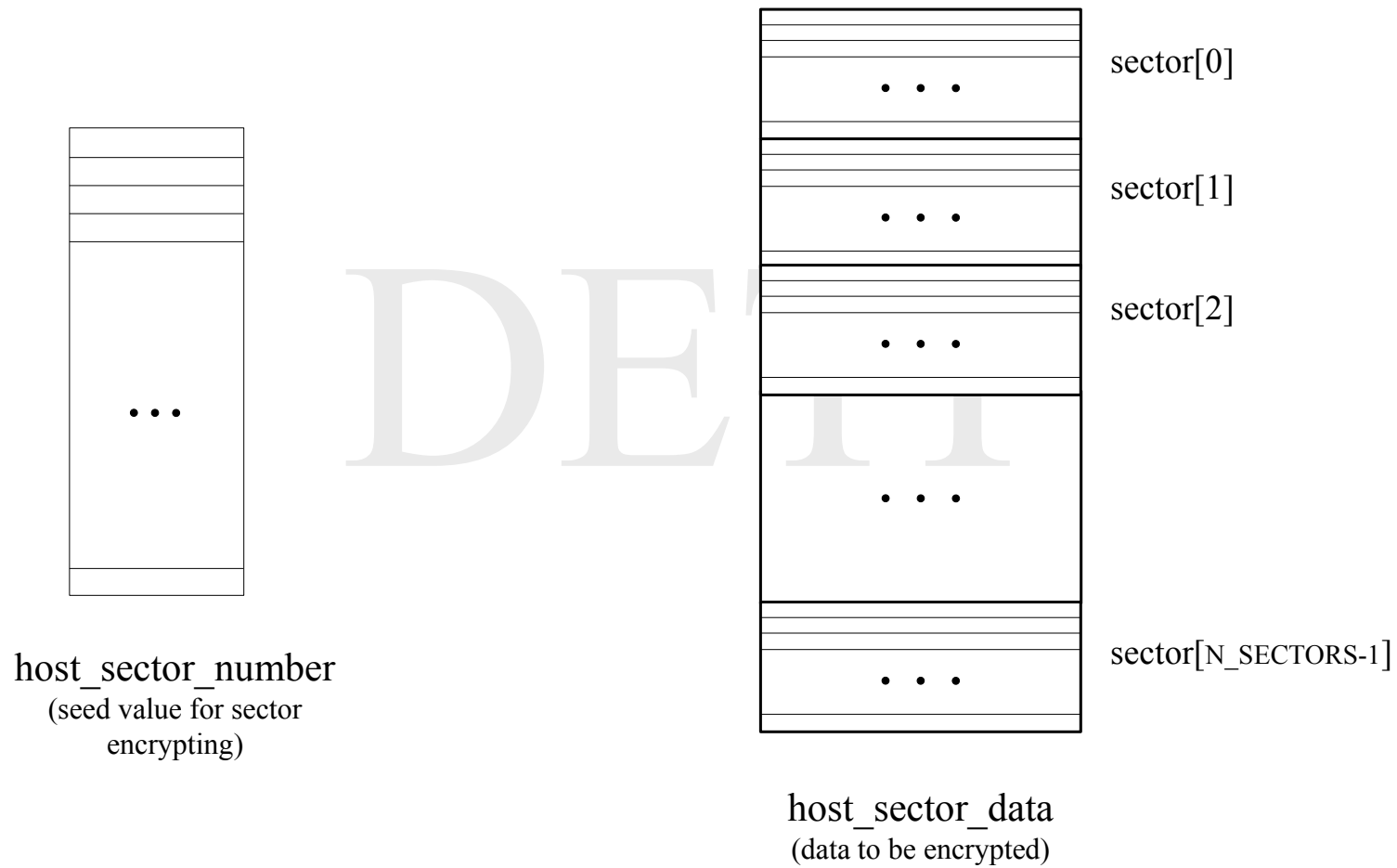
- computation of the number of primes up to a given limit
- version 1 (limit =  $10^7$ )
  - each odd number  $n$  in the range from 3 to limit is selected in turn to check if it is a multiple of an odd number in the range from 3 to  $n$
  - computational intensive with small memory use
- version 2 (limit =  $10^9$ )
  - modified Eratosthenes algorithm
  - large memory use



# *Crypt - 1*

- sector encryption
  - each sector is encrypted with a different seed
  - there are  $2^{21}$  sectors, each 512 bytes long
  - sectors are encrypted sequentially, 4 bytes at a time
  - each sector occupies a contiguous portion of memory

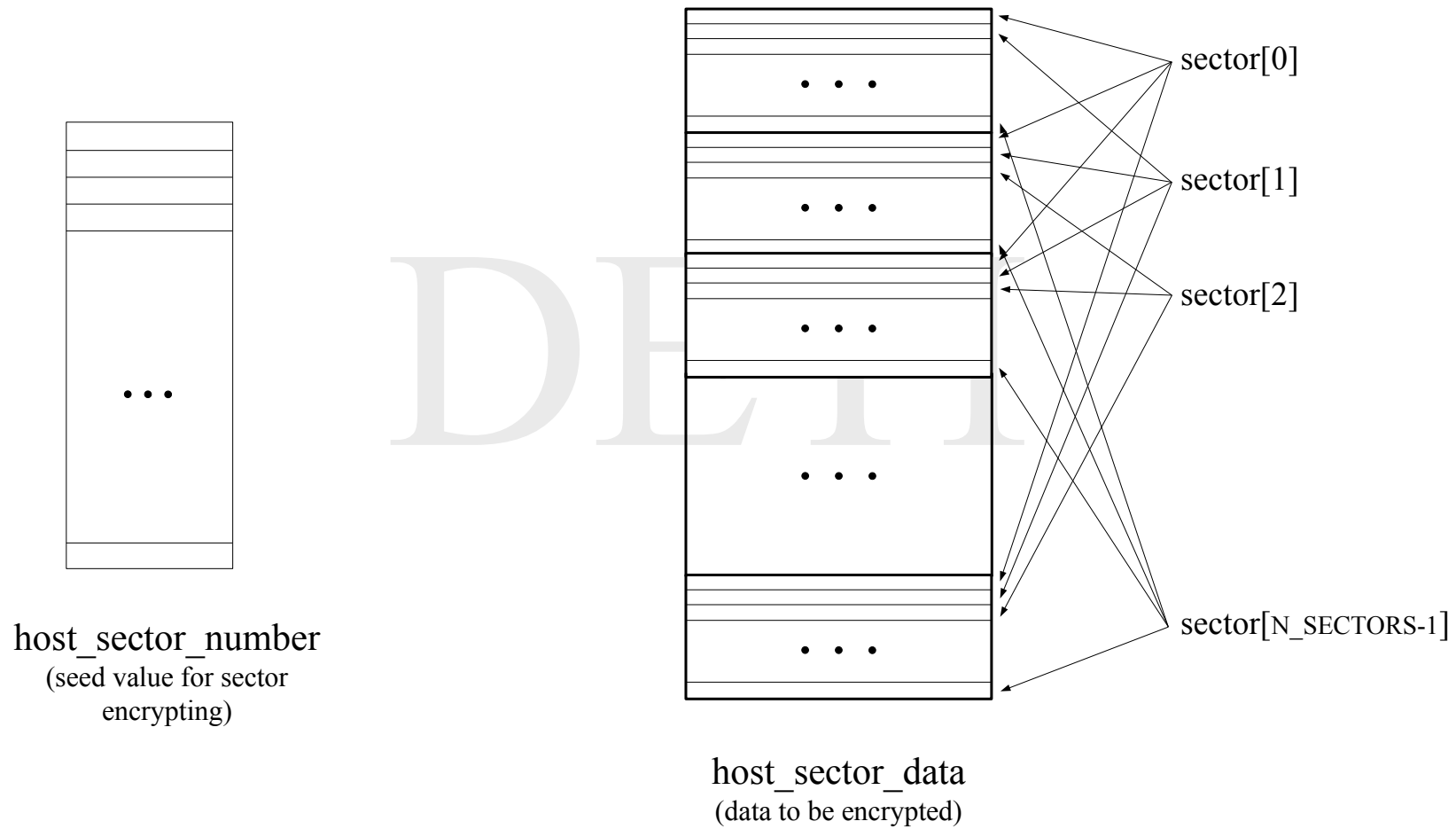
## *Crypt - 2*



## *NewCrypt - 1*

- sector encryption
  - each sector is encrypted with a different seed
  - there are  $2^{21}$  sectors, each 512 bytes long
  - sectors are encrypted sequentially, 4 bytes at a time
  - each sector is scattered in memory
  - each 4 bytes group is separated from any other by a  $2^{21}$  byte distance

## *NewCrypt - 2*



# Collected data - 1

Comp Config		Intel(R) Core(TM) i7-8565U CPU @ 1.80GHz												
Operating System	Gcc version	dhrystone												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	0,503	0,499	0,507	0,507	0,514	<b>0,506</b>	0,158	0,159	0,157	0,158	0,157	<b>0,158</b>	<b>3,2</b>
Operating System	Gcc version	whetstone												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	1,306	1,309	1,319	1,314	1,305	<b>1,311</b>	0,382	0,381	0,384	0,387	0,389	<b>0,385</b>	<b>3,4</b>
Operating System	Gcc version	prime1												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	1,974	1,995	2,002	2,085	1,989	<b>2,009</b>	1,611	1,610	1,653	1,611	1,608	<b>1,619</b>	<b>1,2</b>
Operating System	Gcc version	prime2												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	5,759	5,779	5,783	5,796	5,799	<b>5,783</b>	4,093	4,101	4,088	4,099	4,083	<b>4,093</b>	<b>1,4</b>
Operating System	Gcc version	crypt												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	0,563	0,558	0,574	0,576	0,577	<b>0,570</b>	0,293	0,286	0,274	0,287	0,291	<b>0,286</b>	<b>2,0</b>
Operating System	Gcc version	newCRIPT												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
linux 5.8.11	10.2.1	2,307	2,324	2,275	2,301	2,329	<b>2,307</b>	1,724	1,732	1,755	1,794	1,706	<b>1,742</b>	<b>1,3</b>

## Collected data - 2

Comp Config		Intel(R) Core(TM) 4 x i5-6200U CPU @ 2.30GHz / 8GB												
Operating System	Gcc version	dhrystone												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
windows 10	6.4.0	0,843	0,798	0,812	0,798	0,798	<b>0,810</b>	0,140	0,140	0,140	0,140	0,140	<b>0,140</b>	<b>5,8</b>
linux 4.12.9	6.4.1	0,821	0,817	0,826	0,824	0,822	<b>0,822</b>	0,252	0,249	0,259	0,252	0,252	<b>0,253</b>	<b>3,3</b>
linux 4.18.5	8.1.1	0,844	0,838	0,859	0,836	0,853	<b>0,846</b>	0,284	0,288	0,289	0,290	0,285	<b>0,287</b>	<b>2,9</b>
linux 4.18.8	8.1.1	0,920	1,047	0,992	0,926	0,931	<b>0,963</b>	0,274	0,264	0,264	0,265	0,264	<b>0,266</b>	<b>3,6</b>
linux 5.0.16	8.3.1	0,842	0,966	0,958	0,955	0,868	<b>0,918</b>	0,256	0,254	0,259	0,254	0,274	<b>0,259</b>	<b>3,5</b>
Operating System	Gcc version	whetstone												
		no opt						opt						
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	speed up
windows 10	6.4.0	3,218	3,187	3,156	3,203	3,187	<b>3,190</b>	0,578	0,562	0,562	0,578	0,578	<b>0,572</b>	<b>5,6</b>
linux 4.12.9	6.4.1	2,359	2,346	2,348	2,339	2,337	<b>2,346</b>	0,902	0,918	0,902	0,900	0,898	<b>0,904</b>	<b>2,6</b>
linux 4.18.5	8.1.1	2,190	2,173	2,182	2,171	2,197	<b>2,183</b>	0,738	0,730	0,739	0,716	0,737	<b>0,732</b>	<b>3,0</b>
linux 4.18.8	8.1.1	2,217	2,225	2,253	2,217	2,222	<b>2,227</b>	0,730	0,772	0,774	0,766	0,768	<b>0,762</b>	<b>2,9</b>
linux 5.0.16	8.3.1	2,272	2,297	2,462	2,463	2,271	<b>2,353</b>	0,744	0,717	0,717	0,741	0,744	<b>0,733</b>	<b>3,2</b>

## Collected data - 3

Operating System	Gcc version	primev1												
		no opt						opt						speed up
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	
windows 10	6.4.0	3,406	3,406	3,406	3,406	3,406	<b>3,406</b>	3,031	3,031	3,031	3,015	3,031	<b>3,028</b>	<b>1,1</b>
linux 4.12.9	6.4.1	3,253	3,287	3,291	3,283	3,260	<b>3,275</b>	2,929	2,941	2,932	2,930	2,928	<b>2,932</b>	<b>1,1</b>
linux 4.18.5	8.1.1	3,277	3,307	3,264	3,254	3,277	<b>3,276</b>	2,621	2,628	2,632	2,621	2,624	<b>2,625</b>	<b>1,2</b>
linux 4.18.8	8.1.1	3,899	3,343	3,914	3,352	3,334	<b>3,568</b>	2,681	2,679	2,954	2,678	2,922	<b>2,783</b>	<b>1,3</b>
linux 5.0.16	8.3.1	3,322	3,292	3,309	3,311	3,386	<b>3,324</b>	2,664	2,640	2,714	2,647	2,658	<b>2,665</b>	<b>1,2</b>
Operating System	Gcc version	primev2												
		no opt						opt						speed up
		run 1	run 2	run 3	run 4	run 5	aver	run 1	run 2	run 3	run 4	run 5	aver	
windows 10	6.4.0	9,187	9,187	9,124	9,203	9,375	<b>9,215</b>	6,374	6,328	6,327	6,358	6,375	<b>6,352</b>	<b>1,5</b>
linux 4.12.9	6.4.1	8,098	8,153	8,093	8,089	8,124	<b>8,111</b>	5,488	5,488	5,484	5,489	5,488	<b>5,487</b>	<b>1,5</b>
linux 4.18.5	8.1.1	10,992	11,059	11,088	11,158	11,161	<b>11,092</b>	5,358	5,404	5,356	5,416	5,361	<b>5,379</b>	<b>2,1</b>
linux 4.18.8	8.1.1	11,636	11,694	11,571	12,113	11,980	<b>11,799</b>	5,696	5,593	5,660	5,623	5,611	<b>5,637</b>	<b>2,1</b>
linux 5.0.16	8.3.1	11,244	11,253	11,349	11,160	11,278	<b>11,257</b>	5,375	5,334	5,317	5,338	5,316	<b>5,336</b>	<b>2,1</b>

## Collected data - 4

Operating System	Gcc version	<i>crypt</i>												
		no opt						opt						
		<i>run 1</i>	<i>run 2</i>	<i>run 3</i>	<i>run 4</i>	<i>run 5</i>	<i>aver</i>	<i>run 1</i>	<i>run 2</i>	<i>run 3</i>	<i>run 4</i>	<i>run 5</i>	<i>aver</i>	<i>speed up</i>
linux 4.18.5	8.1.1	0,889	0,890	0,889	0,895	0,888	<b>0,890</b>	0,388	0,397	0,386	0,398	0,393	<b>0,392</b>	<b>2,3</b>
linux 4.18.8	8.1.1	1,100	0,975	0,998	0,918	0,928	<b>0,984</b>	0,433	0,415	0,427	0,442	0,421	<b>0,428</b>	<b>2,3</b>
linux 5.0.16	8.3.1	0,904	0,899	0,896	0,899	0,900	<b>0,900</b>	0,402	0,388	0,394	0,399	0,385	<b>0,394</b>	<b>2,3</b>
Operating System	Gcc version	<i>newCrypt</i>												
		no opt						opt						
		<i>run 1</i>	<i>run 2</i>	<i>run 3</i>	<i>run 4</i>	<i>run 5</i>	<i>aver</i>	<i>run 1</i>	<i>run 2</i>	<i>run 3</i>	<i>run 4</i>	<i>run 5</i>	<i>aver</i>	<i>speed up</i>
linux 4.18.5	8.1.1	8,817	7,950	7,611	5,247	5,443	<b>7,014</b>	17,560	5,577	11,660	4,518	11,700	<b>10,203</b>	<b>0,7</b>
linux 4.18.8	8.1.1	4,981	9,318	5,628	3,772	4,582	<b>5,656</b>	6,739	8,343	4,286	8,586	7,829	<b>7,157</b>	<b>0,8</b>
linux 5.0.16	8.3.1	7,962	9,647	6,329	5,124	7,178	<b>7,248</b>	5,924	8,515	6,032	8,514	8,312	<b>7,459</b>	<b>1,0</b>



## ***gprof profile processing***

- generation of extra code to write profile information suitable for analysis by gprof
  - `gcc -pg <other options> <source files> -o <exec file>_gprof`
- run the program to collect profile information
  - `./<exec file>_gprof`
- produce the summarized results
  - `gprof <exec file>_gprof > <exec file>_gprof.out`

# ***Dhrystone execution profile - 1***

## **Execution profile of non-optimized version**

### **Flat profile:**

Each sample counts as 0.01 seconds.

<b>% time</b>	<b>cumulative seconds</b>	<b>self seconds</b>	<b>calls</b>	<b>self ms/call</b>	<b>total ms/call</b>	<b>name</b>
30.14	0.14	0.14	1	135.62	452.07	Proc0
23.44	0.24	0.11	10000000	0.00	0.00	Proc1
13.39	0.30	0.06	10000000	0.00	0.00	Proc8
8.93	0.34	0.04	30000000	0.00	0.00	Func1
8.93	0.38	0.04	30000000	0.00	0.00	Proc7
8.93	0.42	0.04	10000000	0.00	0.00	Func2
4.46	0.44	0.02	10000000	0.00	0.00	Proc3
2.23	0.45	0.01	10000000	0.00	0.00	Proc5
0.00	0.45	0.00	10000000	0.00	0.00	Func3
0.00	0.45	0.00	10000000	0.00	0.00	Proc2
0.00	0.45	0.00	10000000	0.00	0.00	Proc4
0.00	0.45	0.00	10000000	0.00	0.00	Proc6

## *Dhrystone execution profile - 2*

### Execution profile of optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
67.10	0.04	0.04				Proc0
33.55	0.06	0.02	10000000	2.01	2.01	Proc1

## *Whetstone execution profile - 1*

### Execution profile of non-optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
47.70	0.39	0.39				main
22.02	0.57	0.18	89900000	2.01	2.01	P3
22.02	0.75	0.18	1400000	128.96	128.96	PA
8.56	0.82	0.07	61600000	1.14	1.14	P0

## *Whetstone execution profile - 2*

### Execution profile of optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
-----------	-----------------------	-----------------	-------	-----------------	------------------	------

DETI

## *Crypt execution profile - 1*

### Execution profile of non-optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
60.10	1.27	1.27				main
40.22	2.13	0.85	2097152	406.63	406.63	modify_ sector_cpu_kernel
0.00	2.13	0.00	4	0.00	0.00	get_ delta_time

## *Crypt execution profile - 2*

### Execution profile of optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
-----------	-----------------------	-----------------	-------	-----------------	------------------	------

DETI

## *NewCrypt execution profile - 1*

### Execution profile of non-optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
74.92	2.35	2.35	2097152	1.12	1.12	modify
						_sector_cpu_kernel
26.04	3.17	0.82				main
0.00	3.17	0.00	4	0.00	0.00	get
						_delta_time



## *NewCrypt execution profile - 2*

### Execution profile of optimized version

#### Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
-----------	-----------------------	-----------------	-------	-----------------	------------------	------

DETI

## ***perf profile and event processing***

- run the program to collect profile information and store it in `perf.data`
  - `perf record <exec file>`
- display profile information collected by `perf record`
  - `perf report`
- run the program to collect performance statistics
  - `perf stat -d <exec file>`

# ***Dhrystone execution profile and event processing - 1***

## **Execution profile of non-optimized version**

**Samples: 2K of event 'cycles:u', Event count (approx.): 2222560500**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
26,81%	dhry	dhry	[.] Proc0
12,98%	dhry	dhry	[.] Proc8
10,48%	dhry	dhry	[.] Func1
10,35%	dhry	dhry	[.] Proc1
9,68%	dhry	libc-2.31.so	[.] __strcmp_avx2
7,75%	dhry	dhry	[.] Proc7
6,86%	dhry	dhry	[.] Func2
3,40%	dhry	dhry	[.] Proc6
3,21%	dhry	dhry	[.] Proc2
3,18%	dhry	dhry	[.] Proc3
2,19%	dhry	dhry	[.] Func3
1,84%	dhry	dhry	[.] Proc4
0,82%	dhry	dhry	[.] Proc5
0,44%	dhry	dhry	[.] strcmp@plt
0,01%	dhry	[unknown]	[k] 0xfffffffff82c00fe7
0,00%	dhry	ld-2.31.so	[.] _dl_sysdep_start

## *Dhrystone execution profile and event processing - 2*

### **Event processing of non-optimized version**

#### **Performance counter stats for './dhry':**

514,41 msec	task-clock:u	#	0,998 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
54	page-faults:u	#	0,105 K/sec	
2229040253	cycles:u	#	4,333 GHz	(49,82%)
5573361662	instructions:u	#	2,50 insn per cycle	(62,46%)
749450190	branches:u	#	1456,912 M/sec	(62,65%)
3593	branch-misses:u	#	0,00% of all branches	(62,69%)
2084810266	L1-dcache-loads:u	#	4052,817 M/sec	(62,71%)
4789	L1-dcache-load-misses:u	#	0,00% of all L1-dcache hits	(62,62%)
1442	LLC-loads:u	#	0,003 M/sec	(49,79%)
667	LLC-load-misses:u	#	46,26% of all LL-cache hits	(49,72%)

0,515189804 seconds time elapsed

0,510955000 seconds user

0,000989000 seconds sys

## ***Dhrystone execution profile and event processing - 3***

### **Execution profile of optimized version**

**Samples: 584 of event 'cycles:u', Event count (approx.): 632019100**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
66,42%	dhry_03	libc-2.31.so	[.] __strcmp_avx2
16,07%	dhry_03	dhry_03	[.] Proc0
15,70%	dhry_03	dhry_03	[.] Proc1
1,75%	dhry_03	dhry_03	[.] strcmp@plt
0,05%	dhry_03	ld-2.31.so	[.] _dl_load_cache_lookup
0,01%	dhry_03	[unknown]	[k] 0xffffffff82c00fe7

# *Dhrystone execution profile and event processing - 4*

## Event processing of optimized version

Performance counter stats for './dhry\_03':

149,91 msec	task-clock:u	#	0,994 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
54	page-faults:u	#	0,360 K/sec	
631177895	cycles:u	#	4,210 GHz	(49,32%)
959183555	instructions:u	#	1,52 insn per cycle	(61,99%)
139789059	branches:u	#	932,469 M/sec	(61,99%)
5405	branch-misses:u	#	0,00% of all branches	(62,60%)
269186917	L1-dcache-loads:u	#	1795,623 M/sec	(63,30%)
560	L1-dcache-load-misses:u	#	0,00% of all L1-dcache hits	(63,35%)
345	LLC-loads:u	#	0,002 M/sec	(50,06%)
277	LLC-load-misses:u	#	80,29% of all LL-cache hits	(49,38%)

0,150866342 seconds time elapsed

0,149167000 seconds user

0,000965000 seconds sys

# *Whetstone execution profile and event processing - 1*

## Execution profile of non-optimized version

Samples: 5K of event 'cycles:u', Event count (approx.): 5780646128

Overhead	Command	Shared Object	Symbol
34,23%	whet	whet	[.] main
22,74%	whet	whet	[.] P3
11,79%	whet	whet	[.] PA
7,51%	whet	whet	[.] P0
6,90%	whet	libm-2.31.so	[.] __ieee754_log_fma
5,32%	whet	libm-2.31.so	[.] __ieee754_exp_fma
2,66%	whet	libm-2.31.so	[.] __cos_fma
2,47%	whet	libm-2.31.so	[.] __atan_fma
2,02%	whet	libm-2.31.so	[.] __sqrt_finite@GLIBC_2.15
1,10%	whet	libm-2.31.so	[.] exp@@GLIBC_2.29
1,01%	whet	libm-2.31.so	[.] __sin_fma
0,39%	whet	libm-2.31.so	[.] __sqrt
0,39%	whet	libm-2.31.so	[.] log@@GLIBC_2.29
0,31%	whet	whet	[.] cos@plt
0,25%	whet	whet	[.] log@plt
0,19%	whet	whet	[.] sqrt@plt
0,18%	whet	whet	[.] atan@plt
0,15%	whet	whet	[.] exp@plt
0,15%	whet	libm-2.31.so	[.] 0x0000000000000f3a4
0,13%	whet	whet	[.] sin@plt
0,12%	whet	libm-2.31.so	[.] 0x0000000000000f2f4
0,01%	whet	ld-2.31.so	[.] _dl_setup_hash
0,00%	whet	ld-2.31.so	[.] _dl_sysdep_start
0,00%	whet	[unknown]	[k] 0xffffffff82c00fe7

## *Whetstone execution profile and event processing - 2*

### Event processing of non-optimized version

Performance counter stats for './whet':

1309,12	msec	task-clock:u	#	0,999	CPUs utilized	
0		context-switches:u	#	0,000	K/sec	
0		cpu-migrations:u	#	0,000	K/sec	
70		page-faults:u	#	0,053	K/sec	
5757284243		cycles:u	#	4,398	GHz	(49,89%)
10580098798		instructions:u	#	1,84	insn per cycle	(62,42%)
1167798406		branches:u	#	892,050	M/sec	(62,47%)
38659		branch-misses:u	#	0,00%	of all branches	(62,55%)
4491468135		L1-dcache-loads:u	#	3430,912	M/sec	(62,63%)
7086		L1-dcache-load-misses:u	#	0,00%	of all L1-dcache hits	(62,58%)
1078		LLC-loads:u	#	0,823	K/sec	(49,98%)
901		LLC-load-misses:u	#	83,58%	of all LL-cache hits	(49,90%)

1,310054073 seconds time elapsed

1,302868000 seconds user

0,000981000 seconds sys



## *Whetstone execution profile and event processing - 3*

### Execution profile of optimized version

**Samples: 1K of event 'cycles:u', Event count (approx.): 1651177492**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
51,39%	whet_03	whet_03	[.] main
23,19%	whet_03	libm-2.31.so	[.] __ieee754_log_fma
18,46%	whet_03	libm-2.31.so	[.] __ieee754_exp_fma
3,92%	whet_03	libm-2.31.so	[.] exp@@GLIBC_2.29
0,74%	whet_03	libm-2.31.so	[.] log@@GLIBC_2.29
0,61%	whet_03	libm-2.31.so	[.] 0x000000000000f2f4
0,60%	whet_03	whet_03	[.] log@plt
0,53%	whet_03	whet_03	[.] exp@plt
0,47%	whet_03	libm-2.31.so	[.] 0x000000000000f3a4
0,07%	whet_03	libc-2.31.so	[.] _IO_file_write@@GLIBC_2.2.5
0,02%	whet_03	ld-2.31.so	[.] _dl_cache_libcmp
0,00%	whet_03	[unknown]	[k] 0xffffffff82c00fe7

# *Whetstone execution profile and event processing - 4*

## Event processing of optimized version

Performance counter stats for './whet\_03':

422,84 msec	task-clock:u	#	0,999 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
67	page-faults:u	#	0,158 K/sec	
1657196158	cycles:u	#	3,919 GHz	(49,86%)
1624717675	instructions:u	#	0,98 insn per cycle	(62,40%)
259068224	branches:u	#	612,683 M/sec	(62,40%)
7276	branch-misses:u	#	0,00% of all branches	(62,41%)
324836740	L1-dcache-loads:u	#	768,222 M/sec	(62,59%)
4659	L1-dcache-load-misses:u	#	0,00% of all L1-dcache hits	(62,66%)
1781	LLC-loads:u	#	0,004 M/sec	(50,13%)
1595	LLC-load-misses:u	#	89,56% of all LL-cache hits	(49,94%)

0,423229358 seconds time elapsed

0,416980000 seconds user

0,000992000 seconds sys

# *Crypt execution profile and event processing - 1*

## **Execution profile of non-optimized version**

**Samples: 5K of event 'cycles:u', Event count (approx.): 5143354868**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
47,67%	crypt	crypt	[.] modify_sector_cpu_kernel
47,29%	crypt	crypt	[.] main
3,25%	crypt	[unknown]	[k] 0xffffffff82c00fe7
0,86%	crypt	libc-2.31.so	[.] __random_r
0,65%	crypt	libc-2.31.so	[.] __random
0,17%	crypt	libc-2.31.so	[.] rand
0,11%	crypt	crypt	[.] rand@plt
0,01%	crypt	libc-2.31.so	[.] _dl_addr
0,01%	crypt	ld-2.31.so	[.] _dl_cache_libcmp
0,00%	crypt	ld-2.31.so	[.] _dl_sysdep_start

## *Crypt execution profile and event processing - 2*

### **Event processing of non-optimized version**

**Performance counter stats for './crypt':**

1484,65 msec	task-clock:u	#	0,999 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
264247	page-faults:u	#	0,178 M/sec	
5108403156	cycles:u	#	3,441 GHz	(49,85%)
10308450742	instructions:u	#	2,02 insn per cycle	(62,38%)
607779880	branches:u	#	409,376 M/sec	(62,51%)
2235803	branch-misses:u	#	0,37% of all branches	(62,58%)
5480293319	L1-dcache-loads:u	#	3691,301 M/sec	(62,64%)
17055055	L1-dcache-load-misses:u	#	0,31% of all L1-dcache hits	(62,60%)
418133	LLC-loads:u	#	0,282 M/sec	(49,94%)
276924	LLC-load-misses:u	#	66,23% of all LL-cache hits	(49,88%)

1,485962366 seconds time elapsed

1,206725000 seconds user

0,266730000 seconds sys

## *Crypt execution profile and event processing - 3*

### **Execution profile of optimized version**

**Samples: 2K of event 'cycles:u', Event count (approx.): 1552736429**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
82,44%	crypt_03	crypt_03	[.] main
11,11%	crypt_03	[unknown]	[k] 0xffffffff82c00fe7
3,00%	crypt_03	libc-2.31.so	[.] __random_r
2,05%	crypt_03	libc-2.31.so	[.] __random
0,70%	crypt_03	libc-2.31.so	[.] rand
0,68%	crypt_03	crypt_03	[.] rand@plt
0,02%	crypt_03	ld-2.31.so	[.] strdup

# *Crypt execution profile and event processing - 4*

## Event processing of optimized version

Performance counter stats for './crypt\_03':

632,79 msec	task-clock:u	#	0,999 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
264247	page-faults:u	#	0,418 M/sec	
1491017075	cycles:u	#	2,356 GHz	(50,02%)
2126489266	instructions:u	#	1,43 insn per cycle	(62,55%)
369167269	branches:u	#	583,399 M/sec	(62,54%)
2227985	branch-misses:u	#	0,60% of all branches	(62,54%)
353223989	L1-dcache-loads:u	#	558,203 M/sec	(62,55%)
17147696	L1-dcache-load-misses:u	#	4,85% of all L1-dcache hits	(62,47%)
303176	LLC-loads:u	#	0,479 M/sec	(49,94%)
279632	LLC-load-misses:u	#	92,23% of all LL-cache hits	(49,94%)

0,633159520 seconds time elapsed

0,370175000 seconds user

0,256542000 seconds sys

# *NewCrypt execution profile and event processing - 1*

## **Execution profile of non-optimized version**

**Samples: 12K of event 'cycles:u', Event count (approx.): 12211478588**

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
78,33%	newCrypt	newCrypt	[.] modify_sector_cpu_kernel
19,48%	newCrypt	newCrypt	[.] main
1,45%	newCrypt	[unknown]	[k] 0xffffffff82c00fe7
0,35%	newCrypt	libc-2.31.so	[.] __random_r
0,32%	newCrypt	libc-2.31.so	[.] __random
0,04%	newCrypt	libc-2.31.so	[.] rand
0,02%	newCrypt	newCrypt	[.] rand@plt
0,00%	newCrypt	ld-2.31.so	[.] _dl_map_object_from_fd
0,00%	newCrypt	ld-2.31.so	[.] _dl_sysdep_start

## *NewCrypt execution profile and event processing - 2*

### Event processing of non-optimized version

Performance counter stats for './newCrypt':

3210,17 msec	task-clock:u	#	1,000 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
264247	page-faults:u	#	0,082 M/sec	
12438447384	cycles:u	#	3,875 GHz	(49,97%)
10312064290	instructions:u	#	0,83 insn per cycle	(62,49%)
613699245	branches:u	#	191,173 M/sec	(62,53%)
2244086	branch-misses:u	#	0,37% of all branches	(62,54%)
5492148756	L1-dcache-loads:u	#	1710,857 M/sec	(62,53%)
550191577	L1-dcache-load-misses:u	#	10,02% of all L1-dcache hits	(62,51%)
473432410	LLC-loads:u	#	147,479 M/sec	(49,96%)
6110025	LLC-load-misses:u	#	1,29% of all LL-cache hits	(49,95%)

3,211376212 seconds time elapsed

2,934441000 seconds user

0,255312000 seconds sys



## *NewCrypt execution profile and event processing - 3*

### **Execution profile of optimized version**

**Samples:** 8K of event 'cycles:u', Event count (approx.): 7495550730

<b>Overhead</b>	<b>Command</b>	<b>Shared Object</b>	<b>Symbol</b>
96,30%	newCrypt_03	newCrypt_03	[.] main
2,38%	newCrypt_03	[unknown]	[k] 0xfffffffff82c00fe7
0,62%	newCrypt_03	libc-2.31.so	[.] __random_r
0,50%	newCrypt_03	libc-2.31.so	[.] __random
0,13%	newCrypt_03	libc-2.31.so	[.] rand
0,07%	newCrypt_03	newCrypt_03	[.] rand@plt
0,00%	newCrypt_03	ld-2.31.so	[.] strdup
0,00%	newCrypt_03	ld-2.31.so	[.] _dl_sysdep_start

# *NewCrypt execution profile and event processing - 4*

## Event processing of optimized version

Performance counter stats for './newCrypt\_O3':

2089,64 msec	task-clock:u	#	1,000 CPUs utilized	
0	context-switches:u	#	0,000 K/sec	
0	cpu-migrations:u	#	0,000 K/sec	
264246	page-faults:u	#	0,126 M/sec	
7588582815	cycles:u	#	3,632 GHz	(50,00%)
2140828781	instructions:u	#	0,28 insn per cycle	(62,53%)
371156019	branches:u	#	177,617 M/sec	(62,53%)
2240063	branch-misses:u	#	0,60% of all branches	(62,53%)
354188450	L1-dcache-loads:u	#	169,498 M/sec	(62,53%)
833829604	L1-dcache-load-misses:u	#	235,42% of all L1-dcache hits	(62,49%)
441406756	LLC-loads:u	#	211,236 M/sec	(49,96%)
8964163	LLC-load-misses:u	#	2,03% of all LL-cache hits	(49,96%)

2,090489392 seconds time elapsed

1,835238000 seconds user

0,241205000 seconds sys