

Liquid Architecture

Microarchitecture Optimization for Embedded Systems

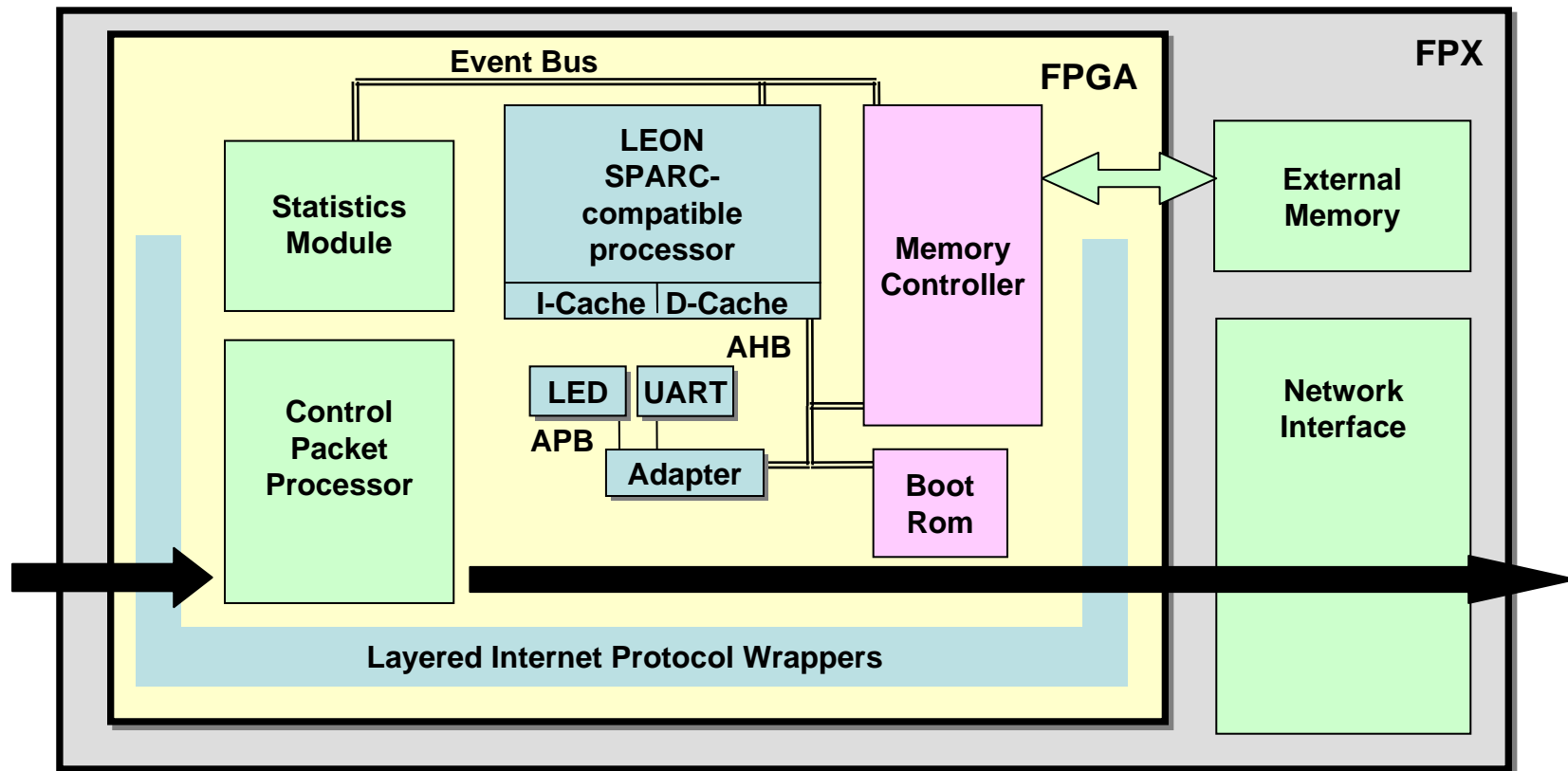
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Liquid Architecture

- Configurable architecture that can adapt to needs of particular application
- E.g., within an FPGA
 - Soft-core processors
- E.g., as an embedded processor
 - Tensilica supports configuration at fab time
 - Stretch support configuration at run time
- Today's discussion is on performance analysis and configuration choice

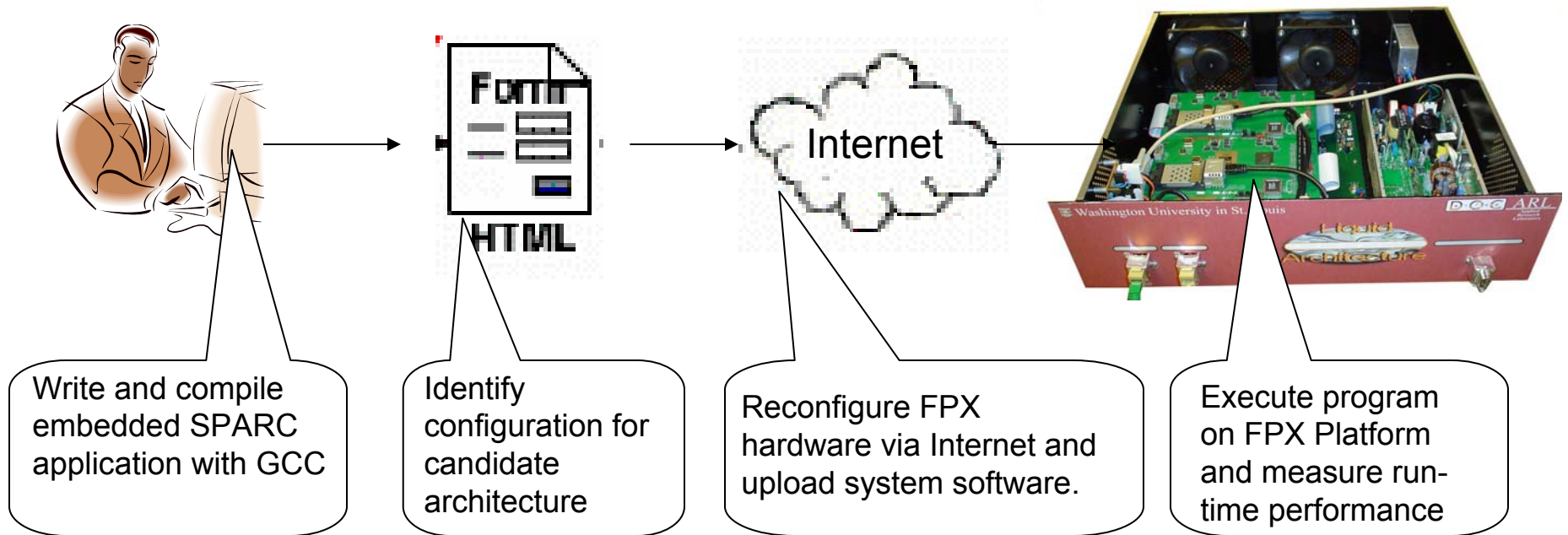
Block Diagram



Microarchitecture Configurability

- Instruction set
- Memory subsystem
 - Cache size (I and D)
 - Associativity
 - Cache line size
- Co-processor(s)
- Instruction pipeline
- Full HDL source is available

Design Flow

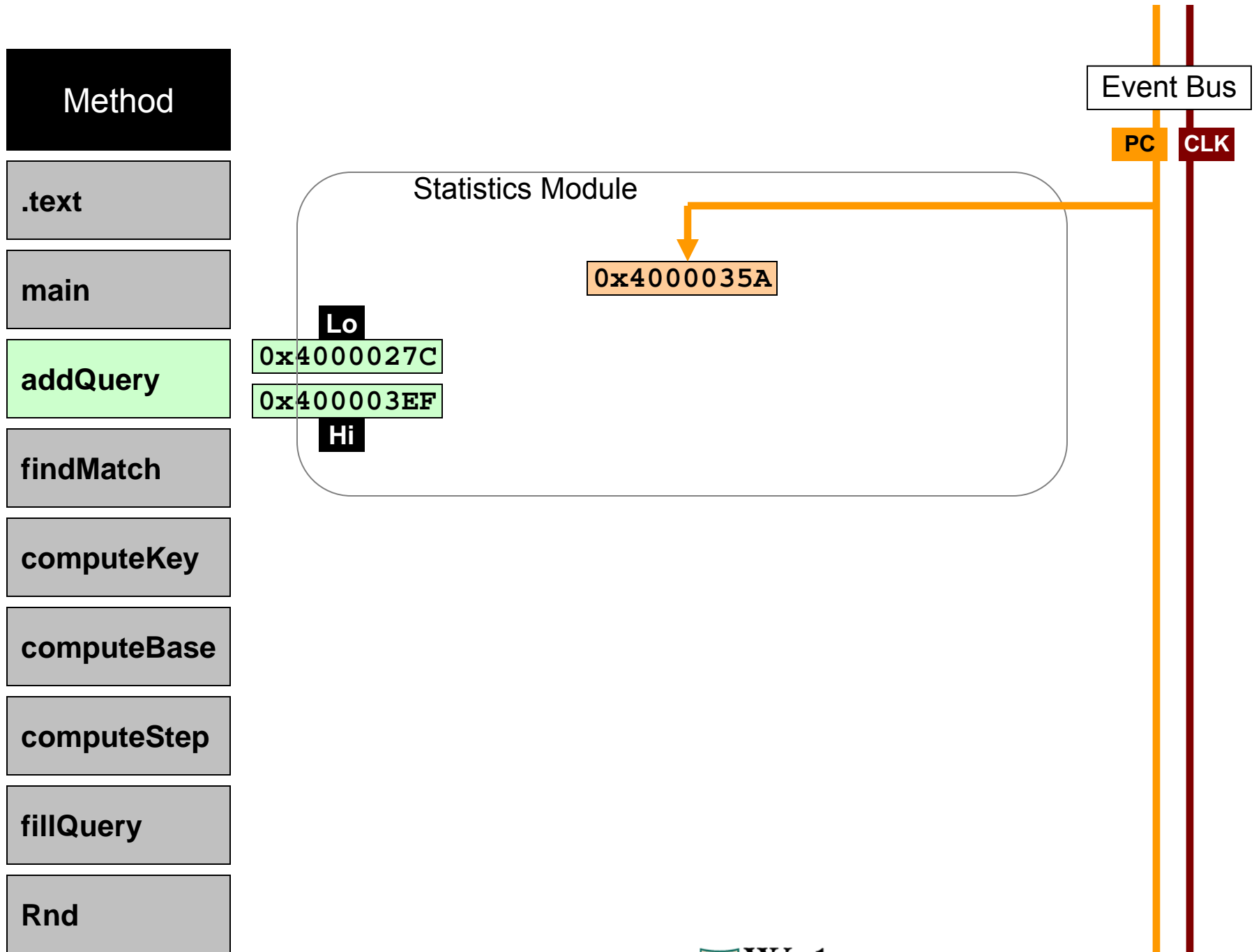


Cycle-accurate profiling

Method	Time / Cycles
.text	<input type="checkbox"/>
main	<input type="checkbox"/>
addQuery	<input checked="" type="checkbox"/>
findMatch	<input type="checkbox"/>
computeKey	<input type="checkbox"/>
computeBase	<input type="checkbox"/>
computeStep	<input checked="" type="checkbox"/>
fillQuery	<input type="checkbox"/>
Rnd	<input type="checkbox"/>

- Choose methods to profile from the user interface

Method	Address Range
.text	
main	
addQuery	<div style="text-align: center;"> Lo 0x4000027C 0x400003EF Hi </div>
findMatch	
computeKey	
computeBase	
computeStep	
fillQuery	
Rnd	



Function

.text

main

addQuery

findMatch

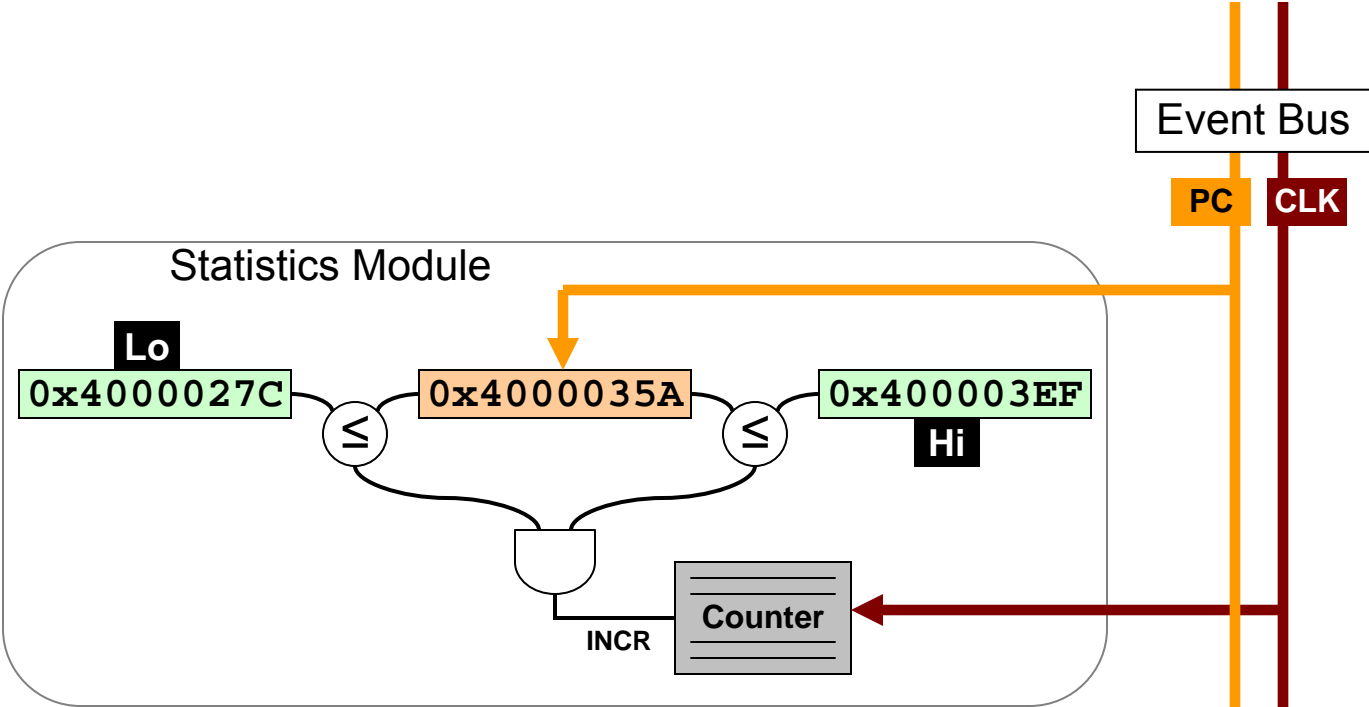
computeKey

computeBase

computeStep

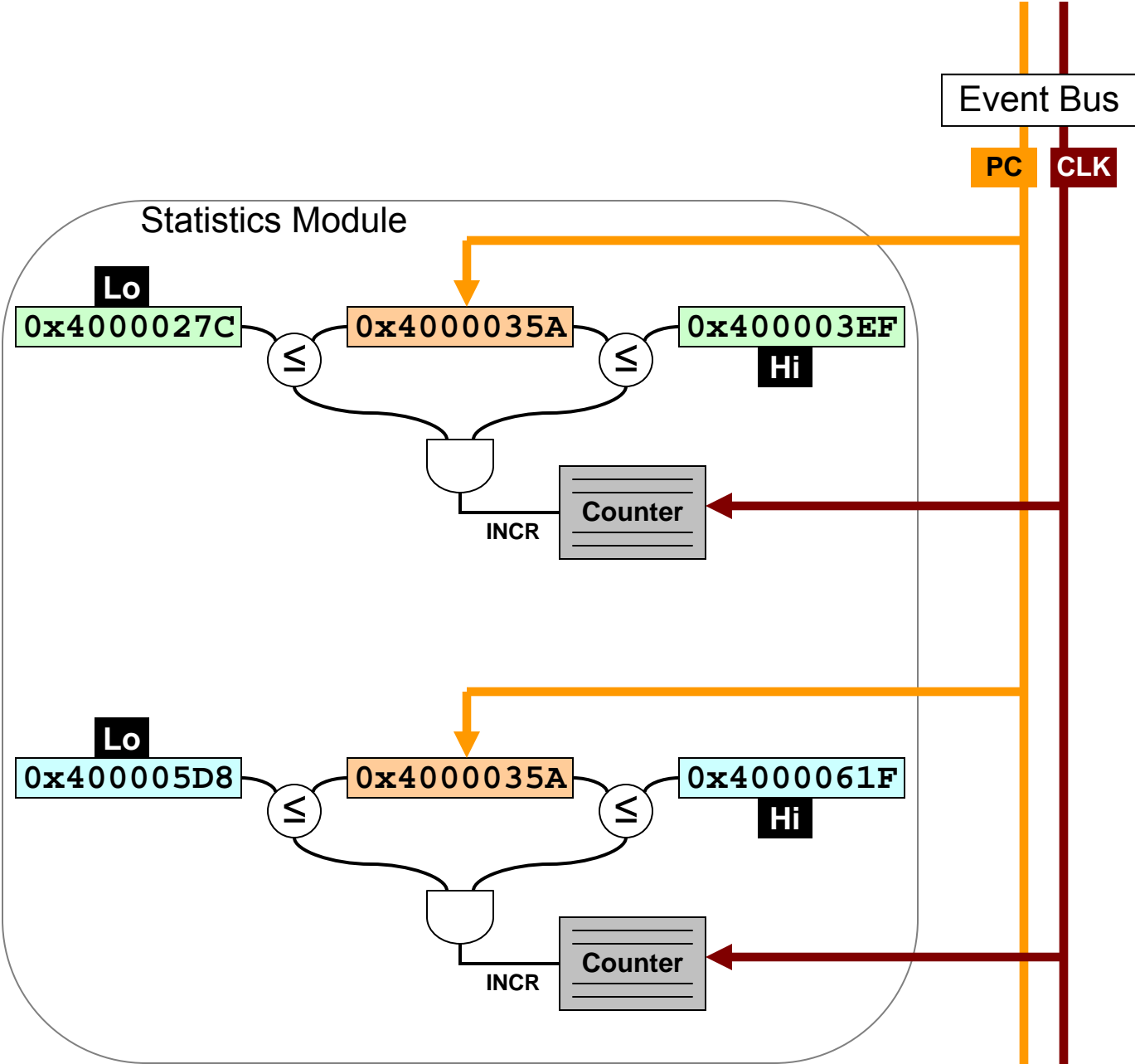
fillQuery

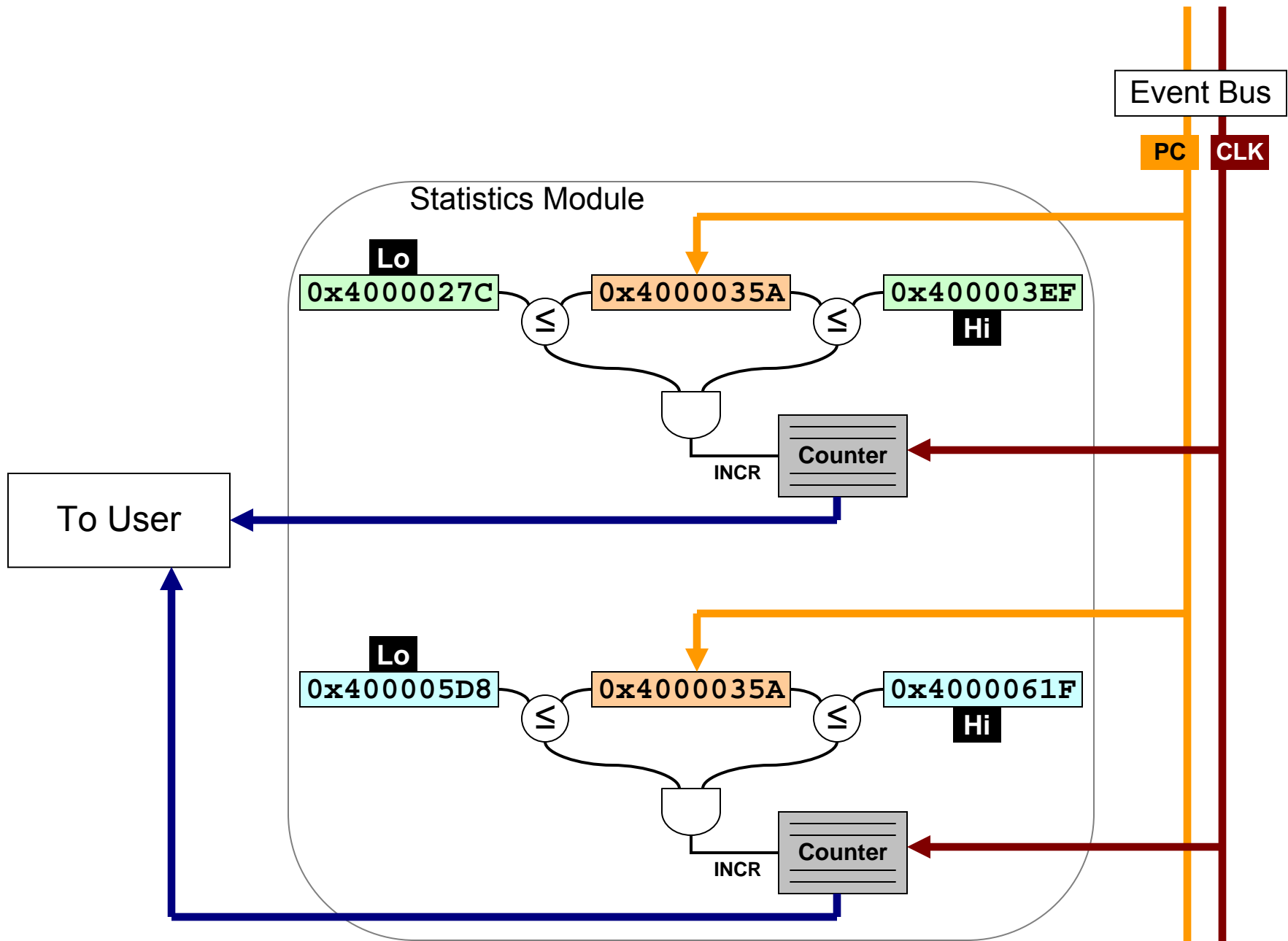
Rnd



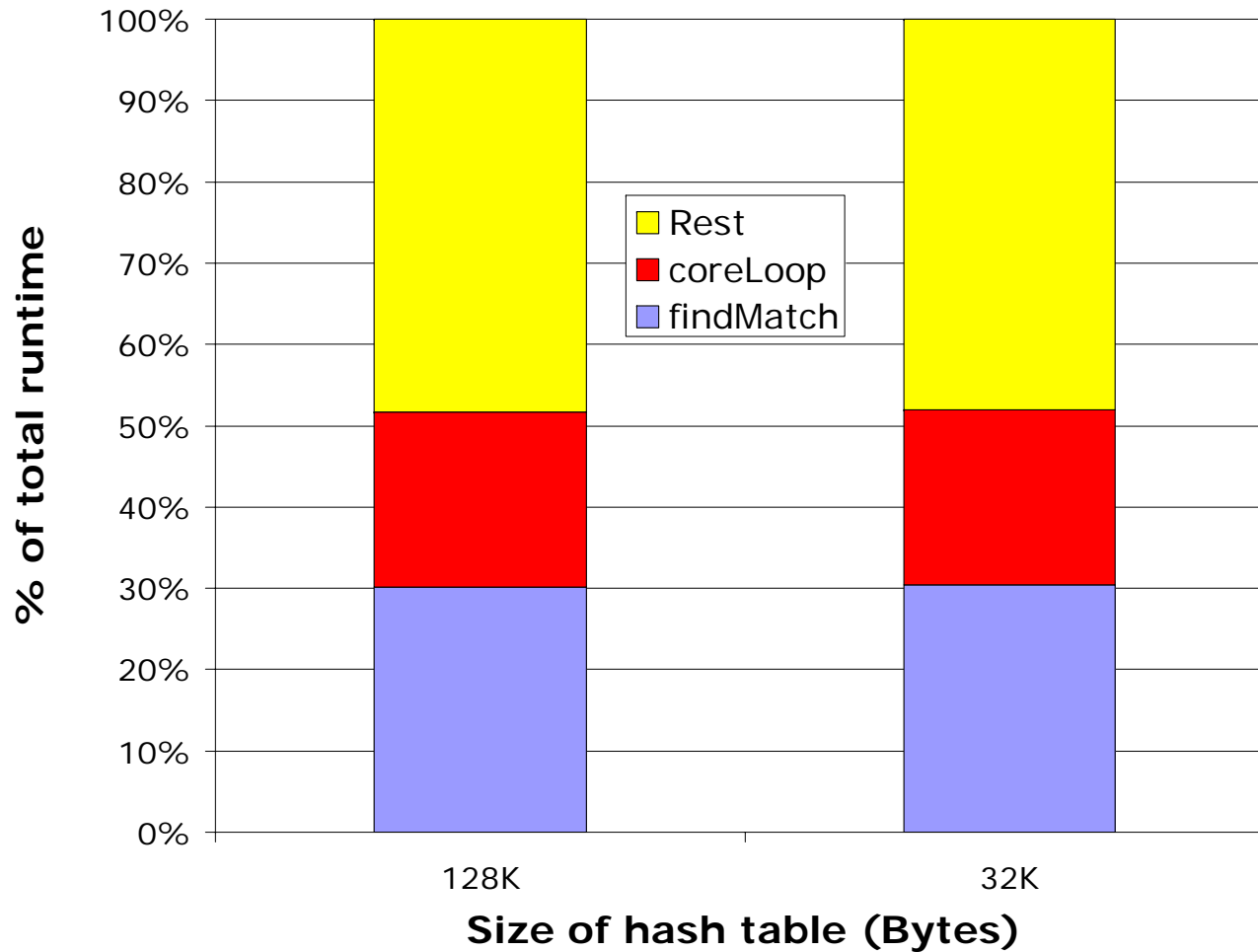
Function

- .text
- main
- addQuery
- findMatch
- computeKey
- computeBase
- computeStep
- fillQuery
- Rnd





Where is time spent?

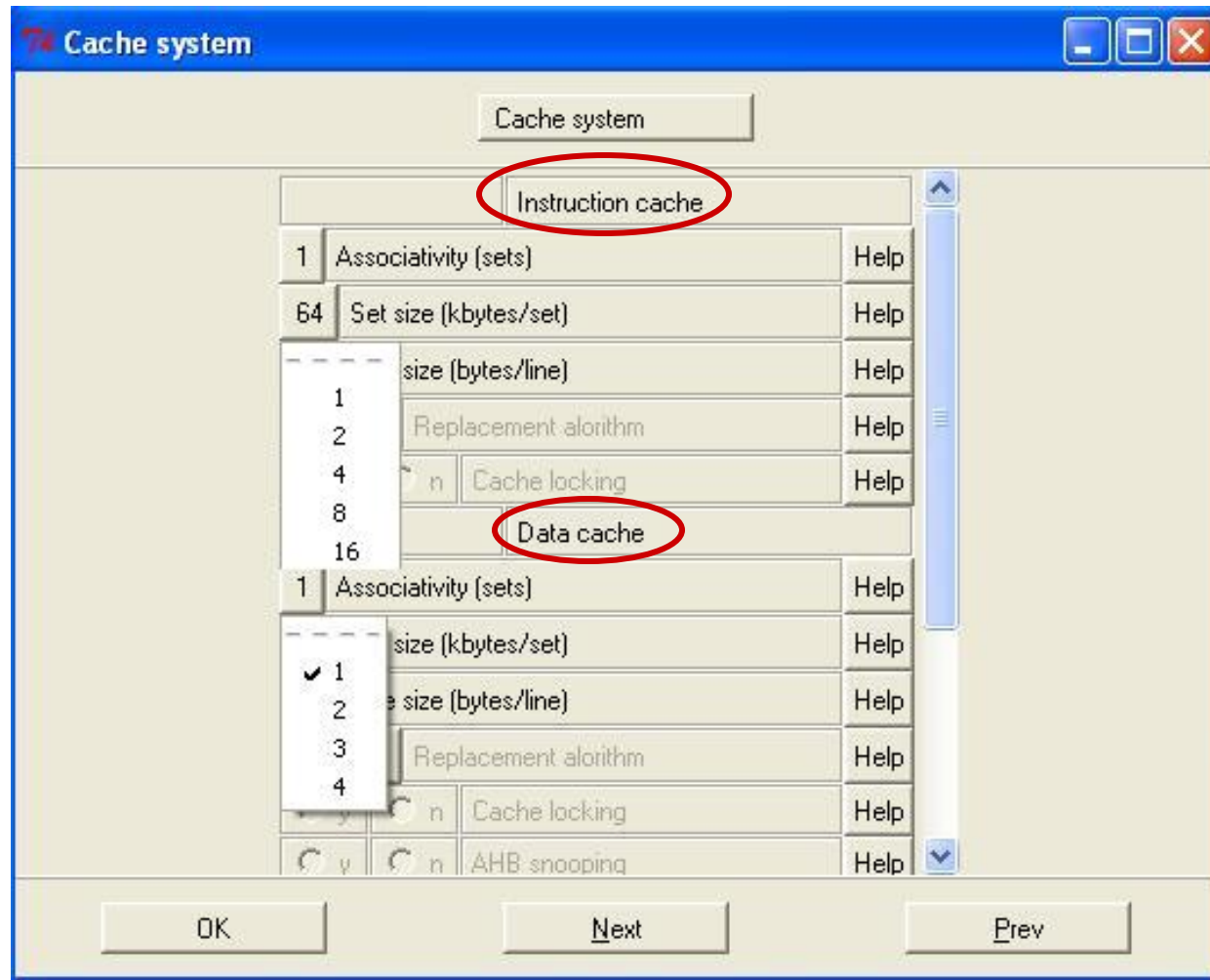


BLASTN
biosequence
search
application

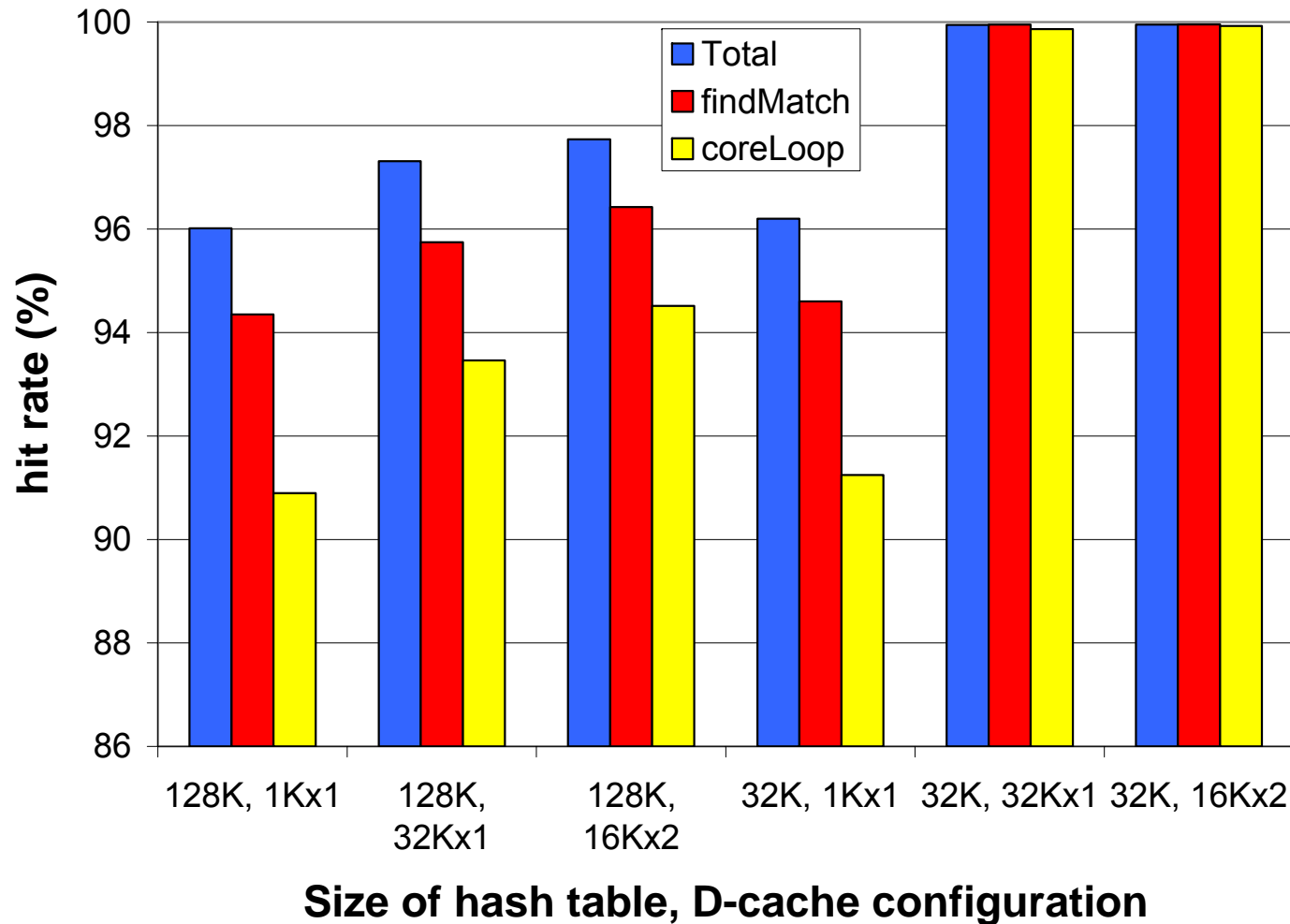
Function	Time / Cycles	Cache Hits / Misses	
		Read	Write
.text	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
main	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
addQuery	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
findMatch	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
computeKey	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
computeBase	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
computeStep	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
fillQuery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rnd	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Expand to
measure cache
hits/misses

Measure Several Configurations

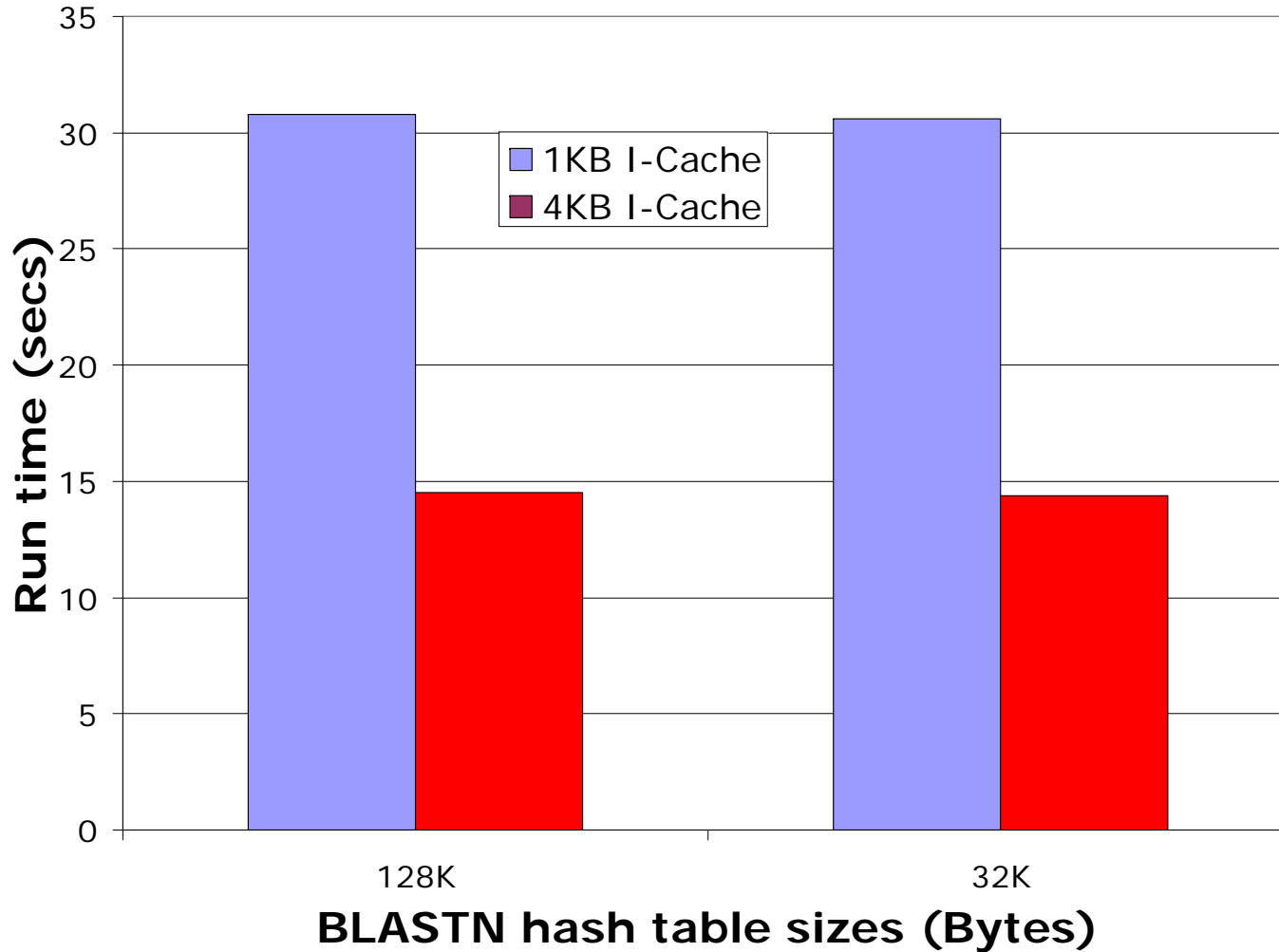


Impact of D-cache Configuration



BLASTN
biosequence
search
application

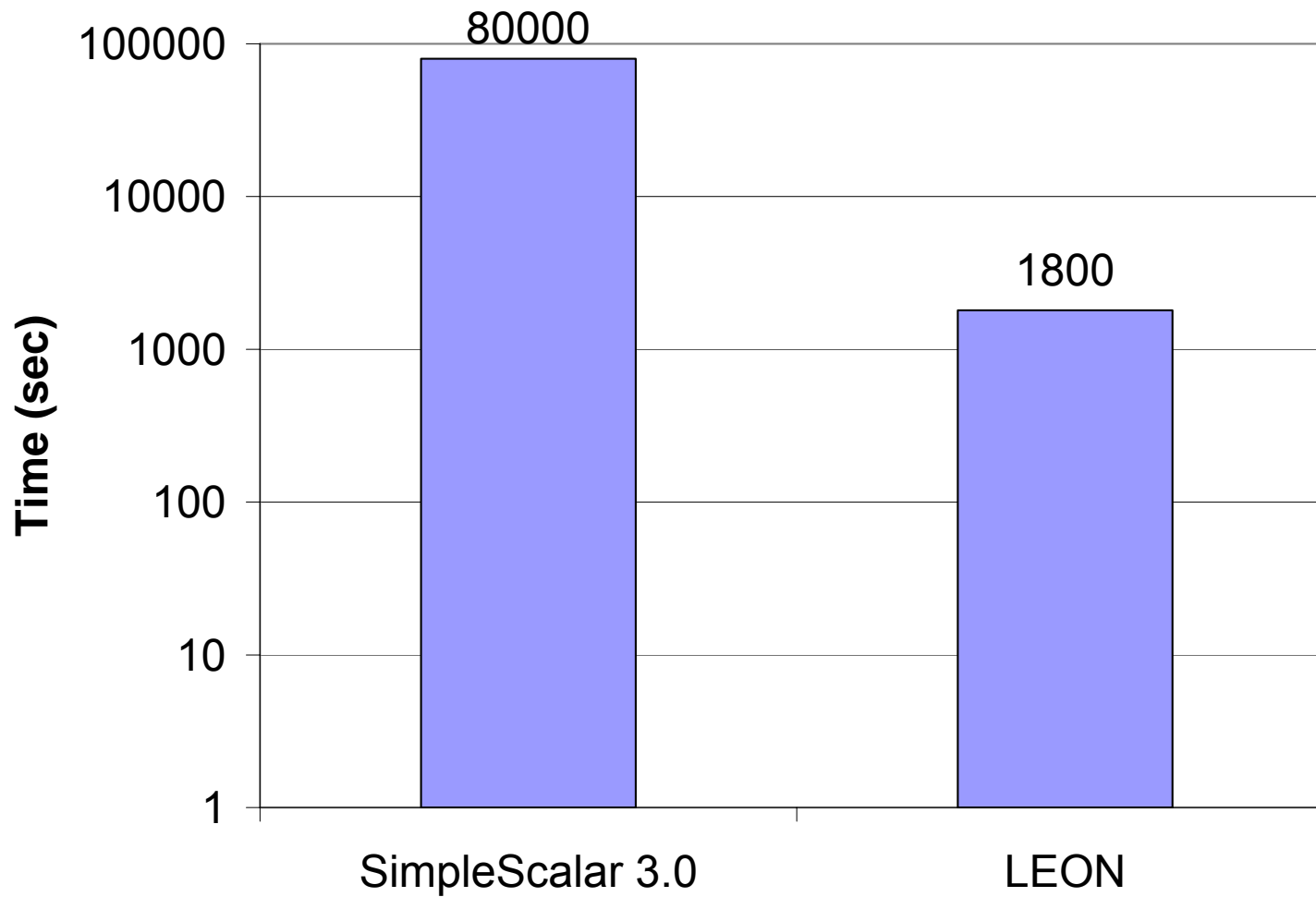
Impact of I-cache Configuration



BLASTN
biosequence
search
application

Function	Time / Cycles	Cache Hits / Misses		Pipeline Stalls	Branch Predict
		Read	Write		
.text	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
main	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
addQuery	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
findMatch	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
computeKey	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
computeBase	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
computeStep	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
fillQuery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rnd	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Time for Single Run

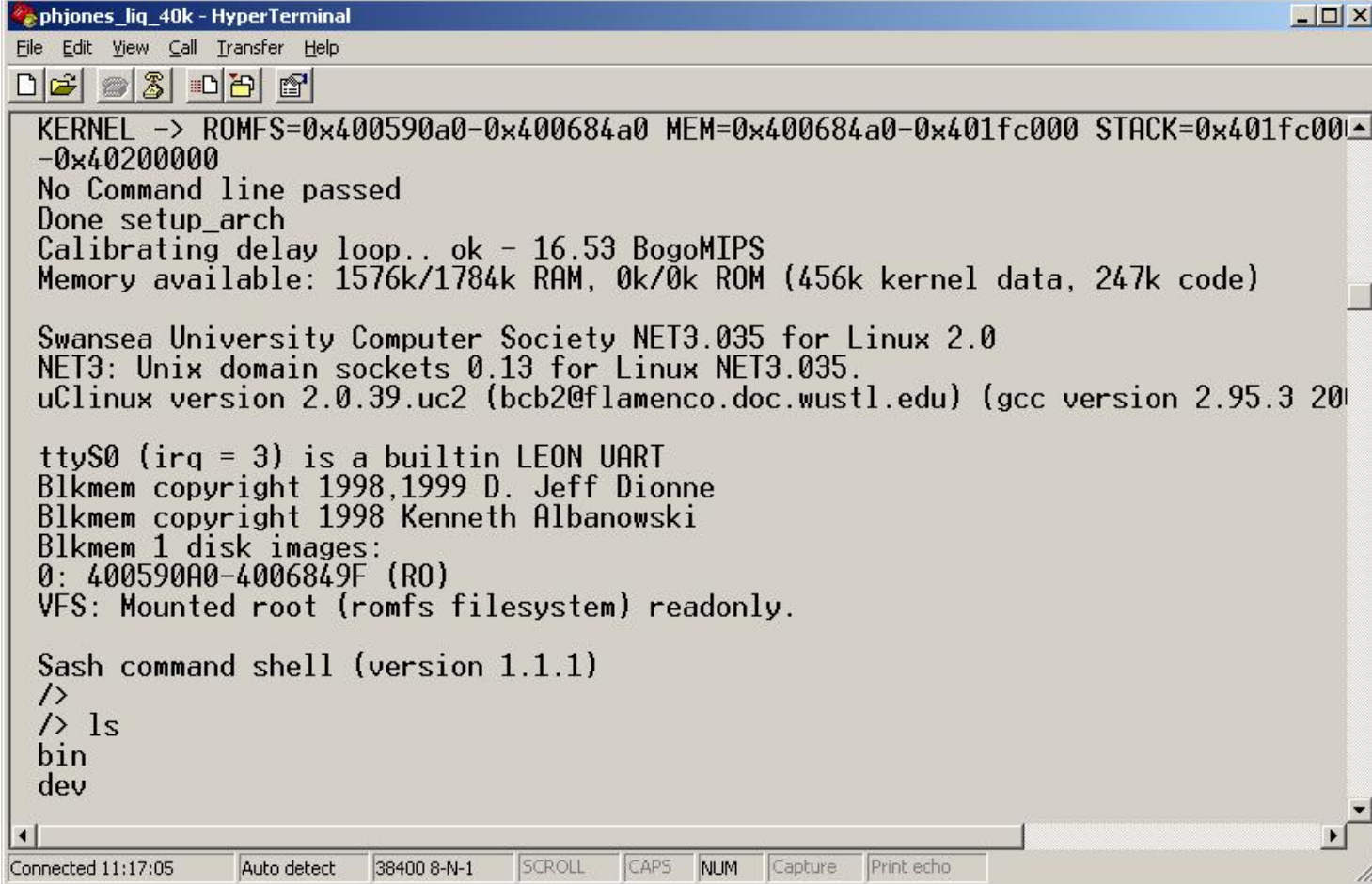


Almost 2 orders of magnitude faster than simulation

Implications of Slow Simulation

- Focus has historically been on measuring the performance of a single thread of a single application
- Real apps are often executed in a multitasking environment
 - Impacts cache behavior
 - Ignores OS (system call) performance
- Liquid architecture system enables direct measurement, including OS

OS Boot Sequence



```
phjones_liq_40k - HyperTerminal
File Edit View Call Transfer Help
[Icons]
KERNEL -> ROMFS=0x400590a0-0x400684a0 MEM=0x400684a0-0x401fc000 STACK=0x401fc000
-0x40200000
No Command line passed
Done setup_arch
Calibrating delay loop.. ok - 16.53 BogoMIPS
Memory available: 1576k/1784k RAM, 0k/0k ROM (456k kernel data, 247k code)

Swansea University Computer Society NET3.035 for Linux 2.0
NET3: Unix domain sockets 0.13 for Linux NET3.035.
uClinux version 2.0.39.uc2 (bcb2@flamenco.doc.wustl.edu) (gcc version 2.95.3 20030804)

ttyS0 (irq = 3) is a builtin LEON UART
Blkmem copyright 1998,1999 D. Jeff Dionne
Blkmem copyright 1998 Kenneth Albanowski
Blkmem 1 disk images:
0: 400590A0-4006849F (RO)
VFS: Mounted root (romfs filesystem) readonly.

Sash command shell (version 1.1.1)
/>
/> ls
bin
dev

Connected 11:17:05  Auto detect  38400 8-N-1  SCROLL  CAPS  NUM  Capture  Print echo
```

Summary

- Run-time reconfigurable processors will be available sooner rather than later
- Determining desired configuration is a difficult design task
 - Large search space
 - Depends on accurate performance data
- Liquid architecture system enables direct measurement of performance properties

Current and Future Work

- Evaluation of several arch. design ideas
- Automated search of the design space
- Characterizing performance analysis methods
 - Analytic models
 - Simulation models
 - Direct execution models
- Usable as is for evaluating soft-core procs
- Like to extend to higher-speed procs