AUTOMATING THE DESIGN OF MLUT MPSOPC FPGAS IN THE CLOUD

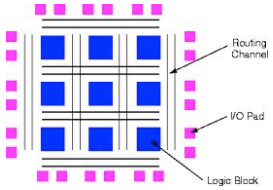
E. Cartwright, A. Fahkari, Sen Ma, C. Smith, M. Huang, Jason Agron[1], *D. Andrews*

CSCE Department University of Arkansas, Intel[1]

Agenda

- MPSoPC's == Opportunities ^ Challenges
- Automating Architecture Generation
- Enabling High Level Programming Models
- Conclusion

FPGAs: Accelerators -> MPSoPC's



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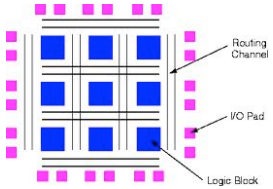

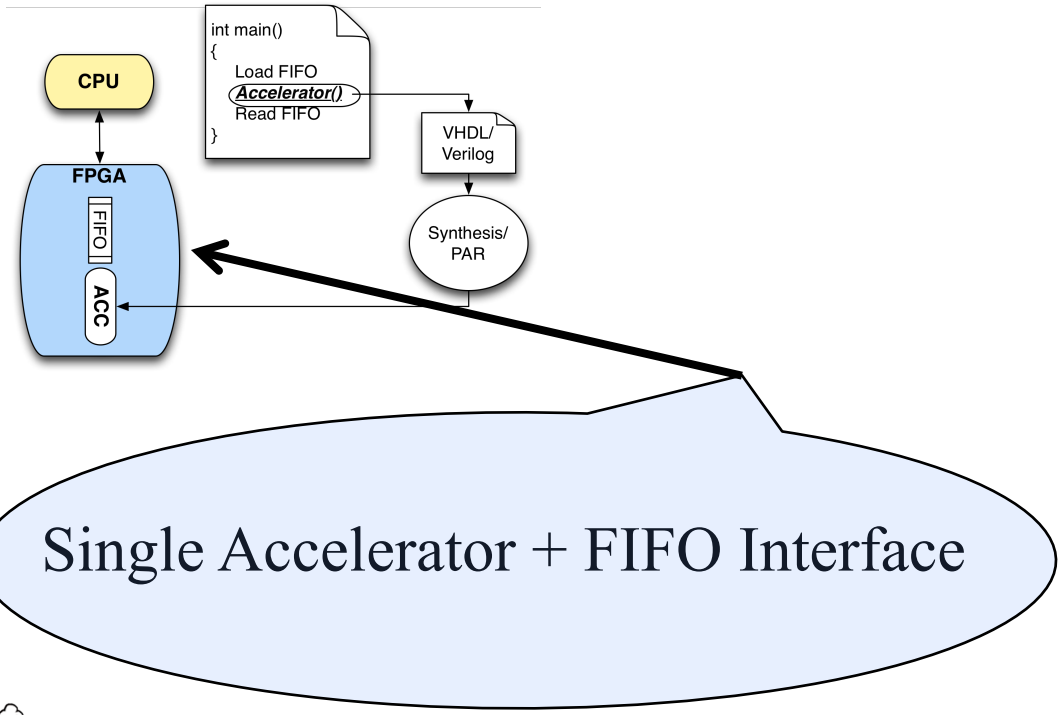

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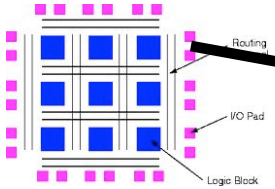
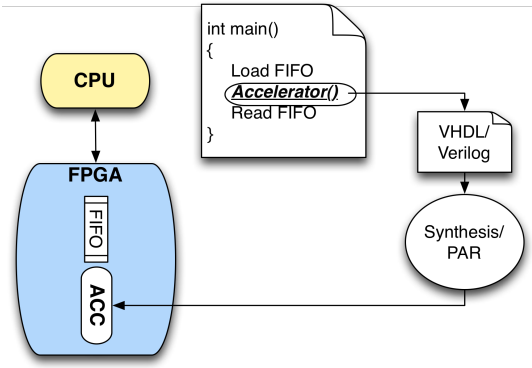
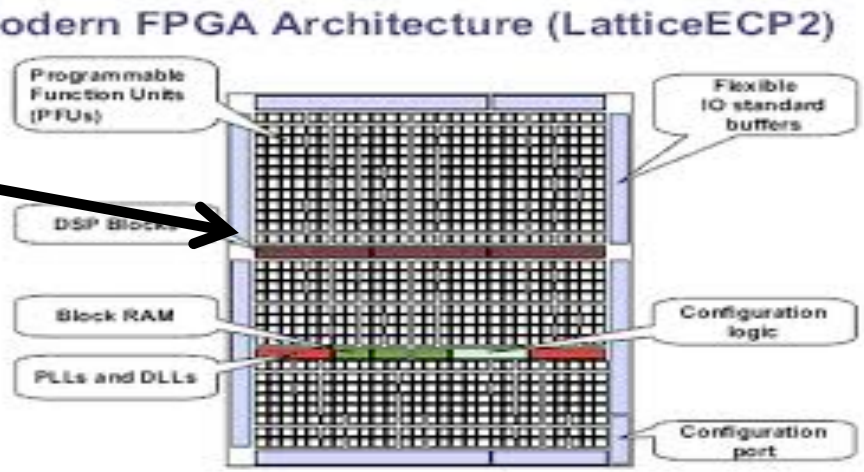


Moore's Law

M+ Luts





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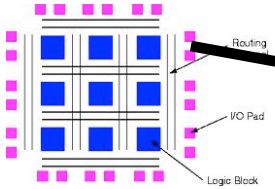

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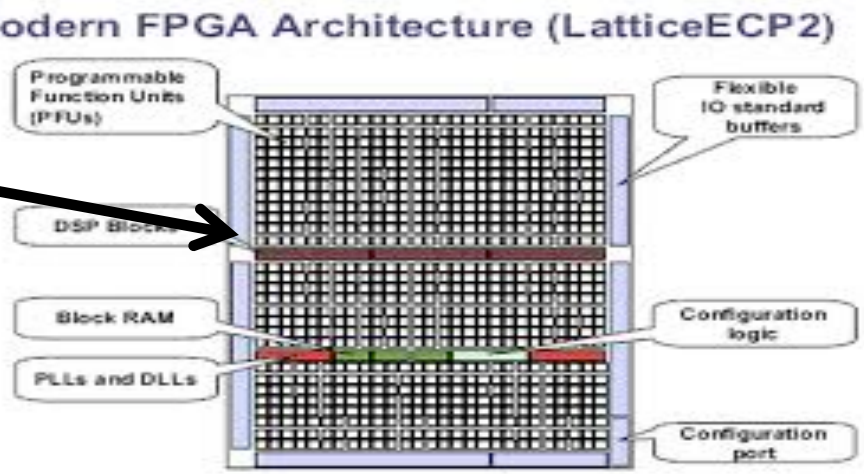
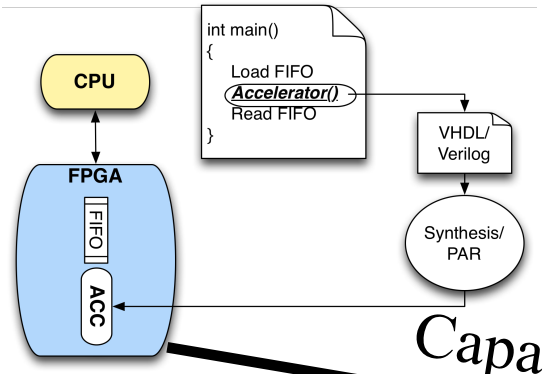
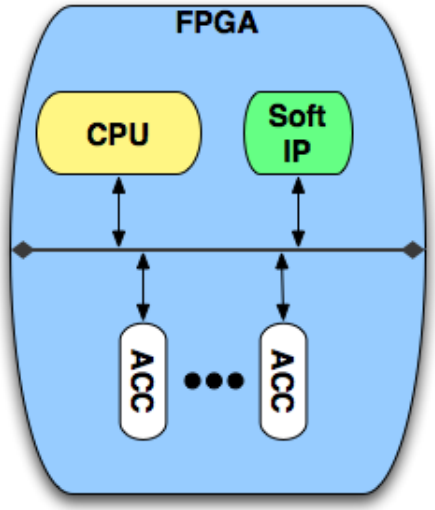




Capabilities

Gates to Architectures



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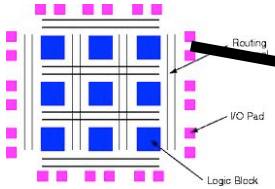

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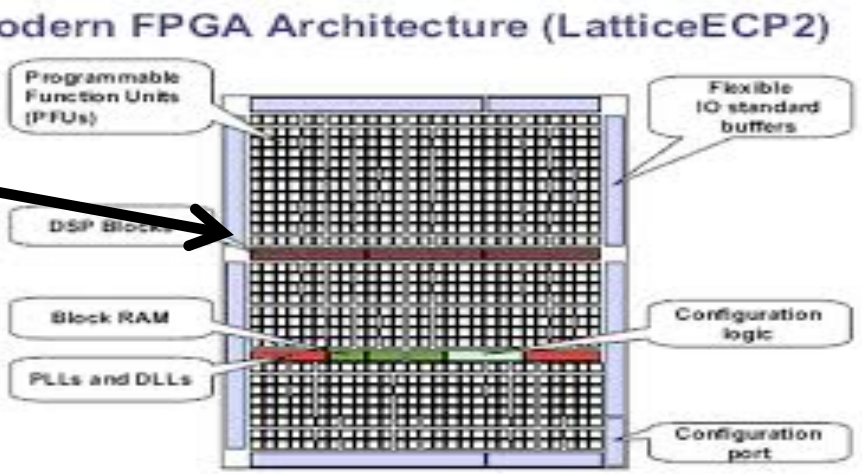

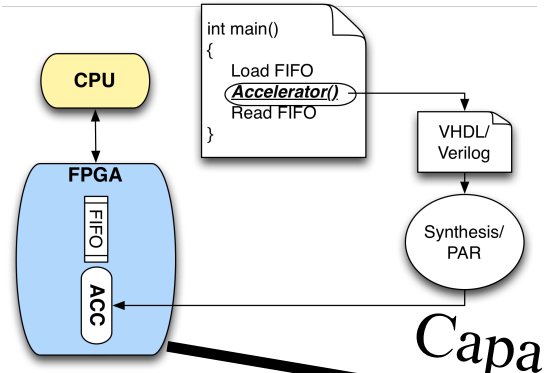

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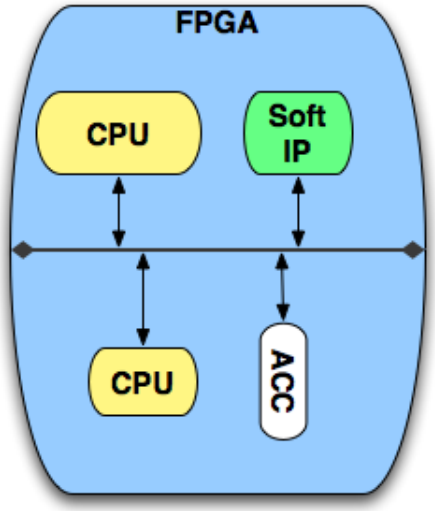

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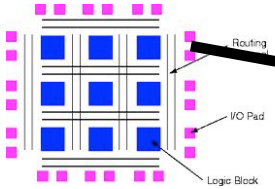

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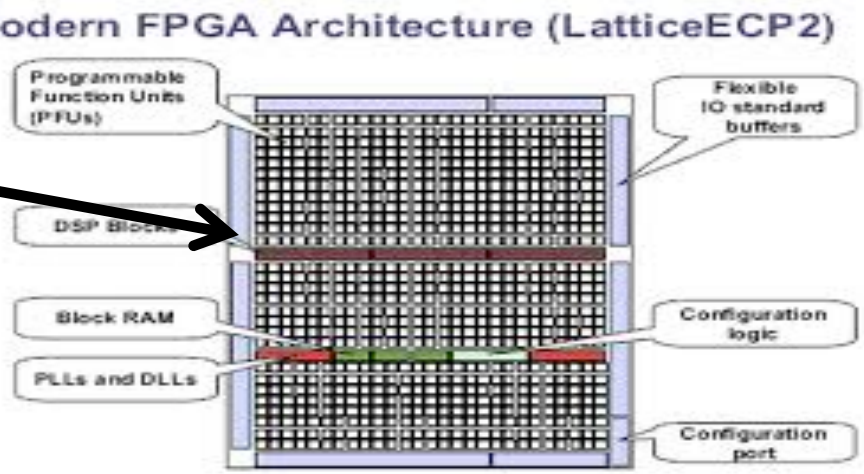

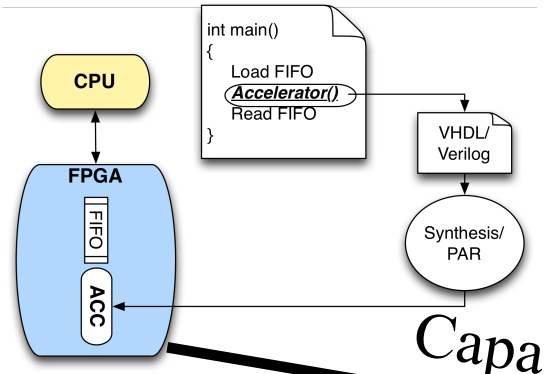

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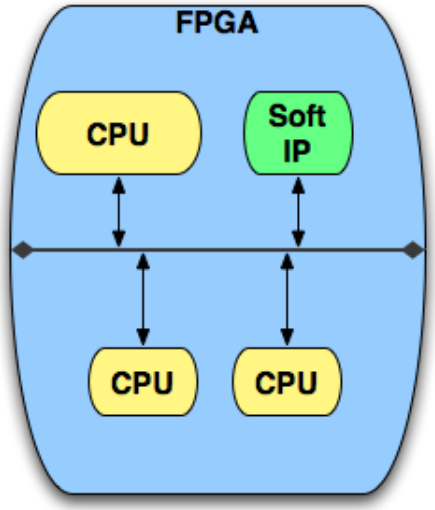

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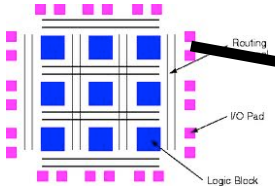

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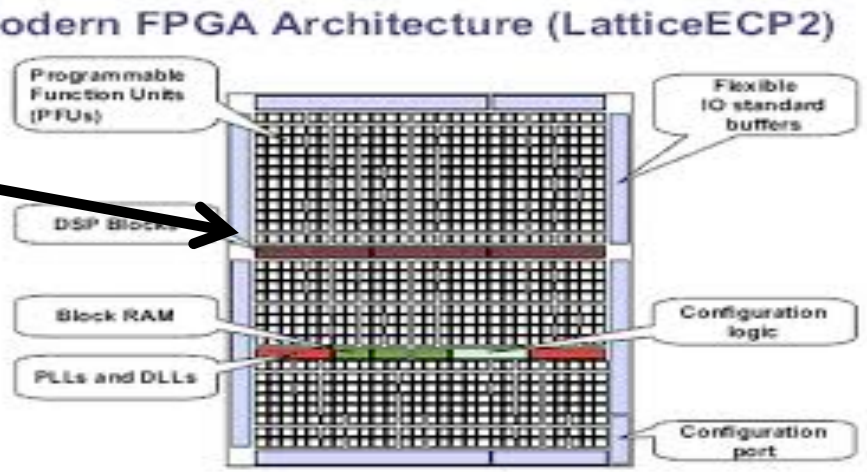

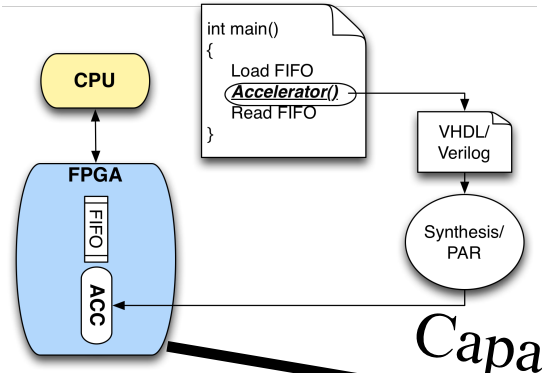

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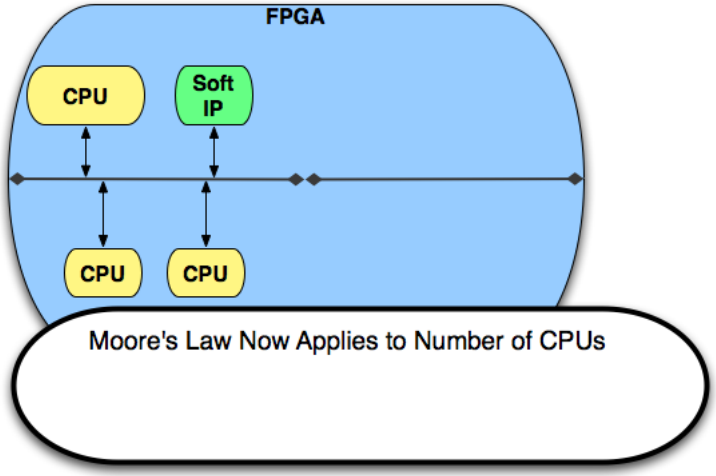

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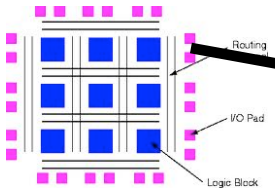

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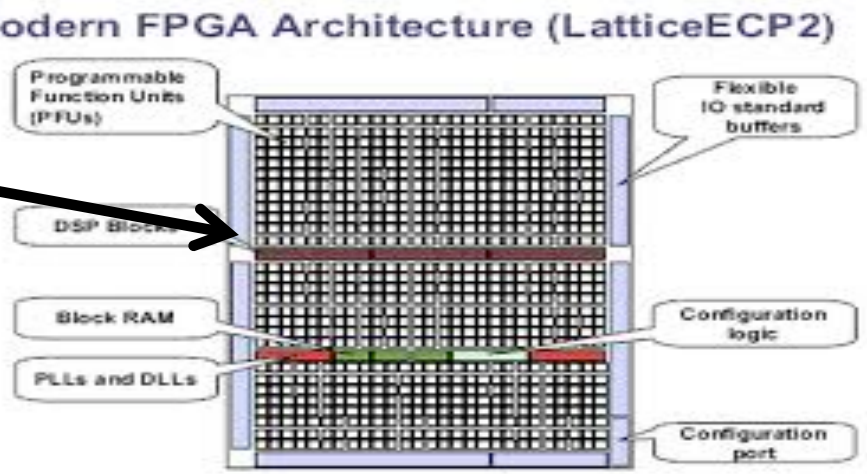

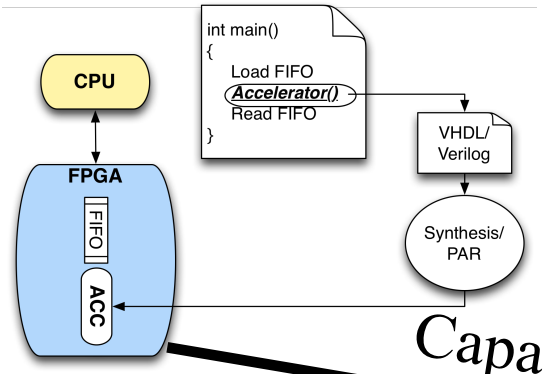

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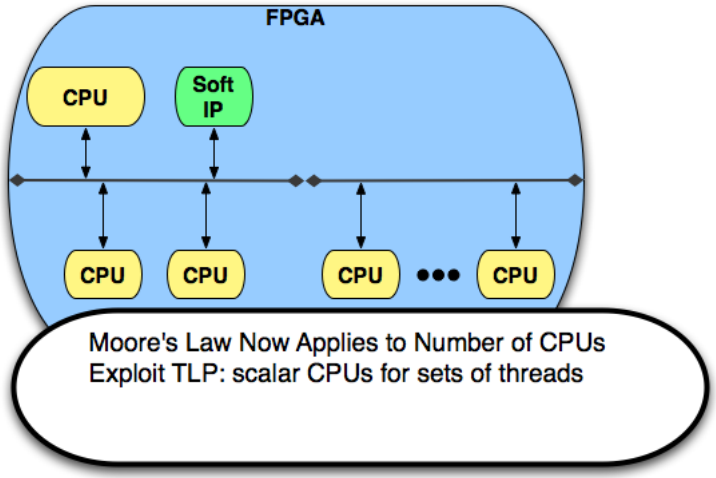

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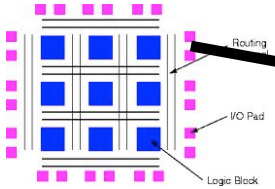

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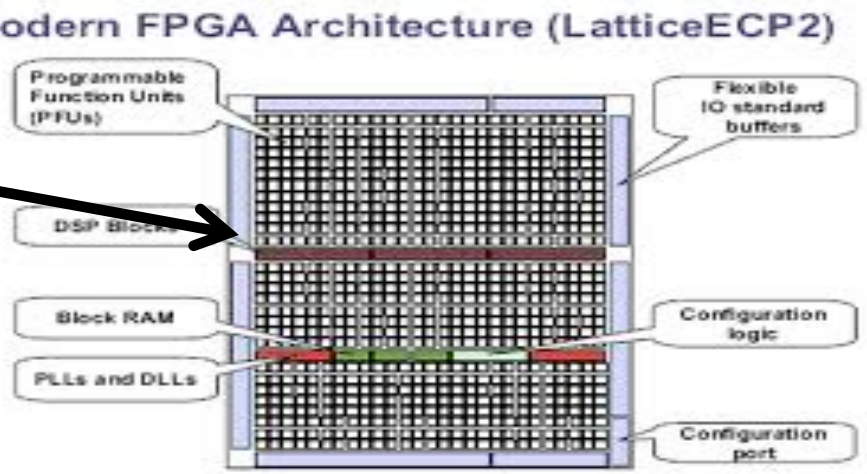

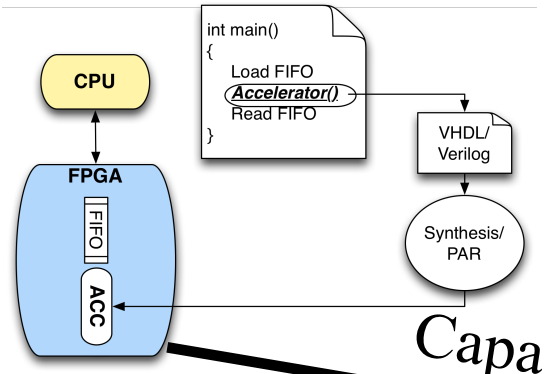

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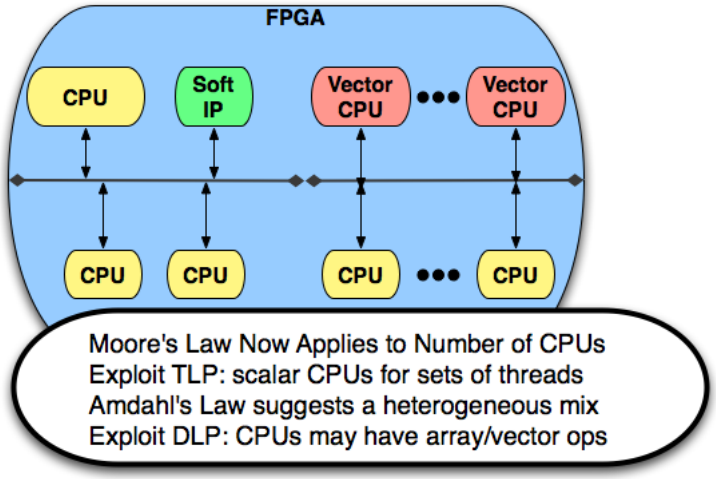

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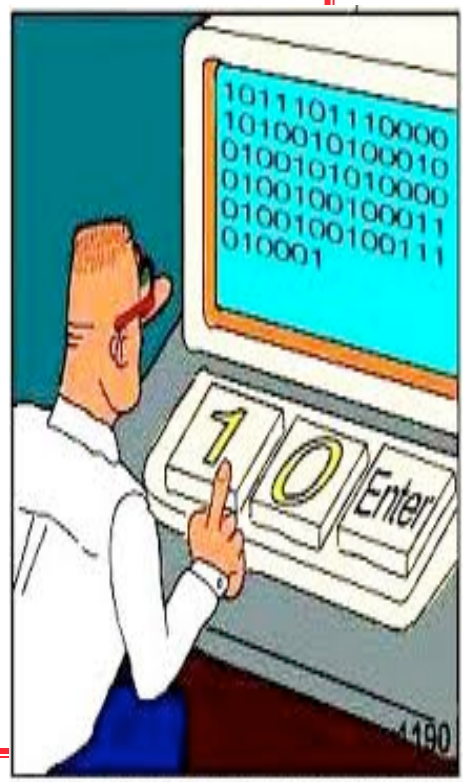
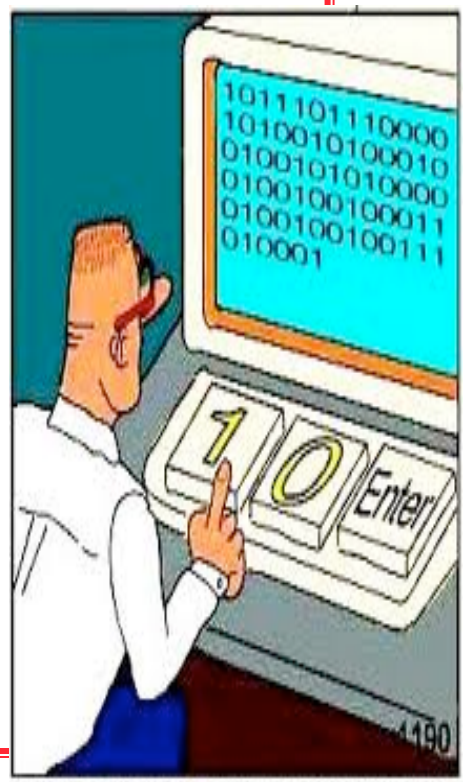


REAL Programmers code in BINARY.

New Capabilities Bring New Challenges

Required Designer Capabilities Changing:



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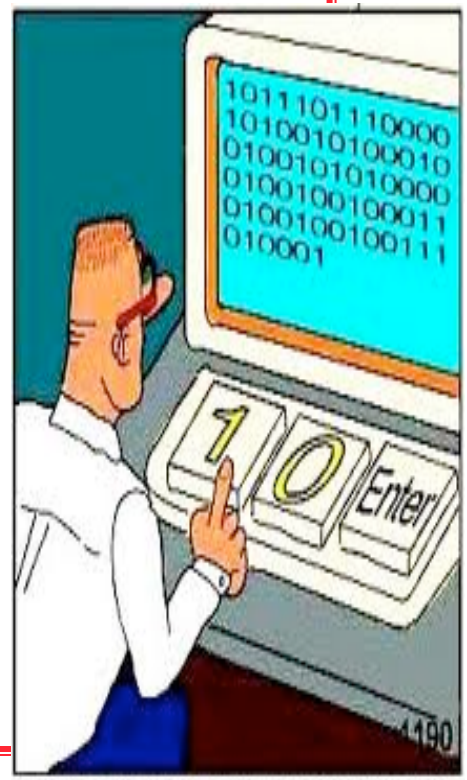

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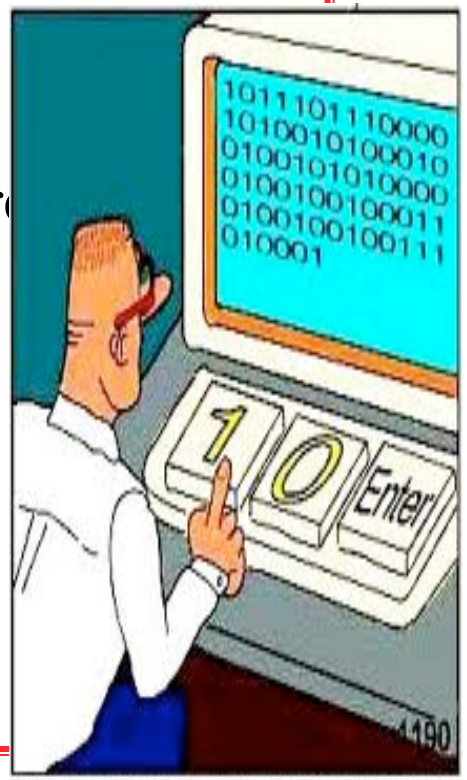
Senior Level Computer Architecture Knowledge Requir

- Parallel Architectures: SMP, NUMA
- Multi-Tiered Memory Hierarchy Design
- Cache Coherency Protocols
- "Beefier" Interconnects
- DMA's,Timers,UARTS,PICS,



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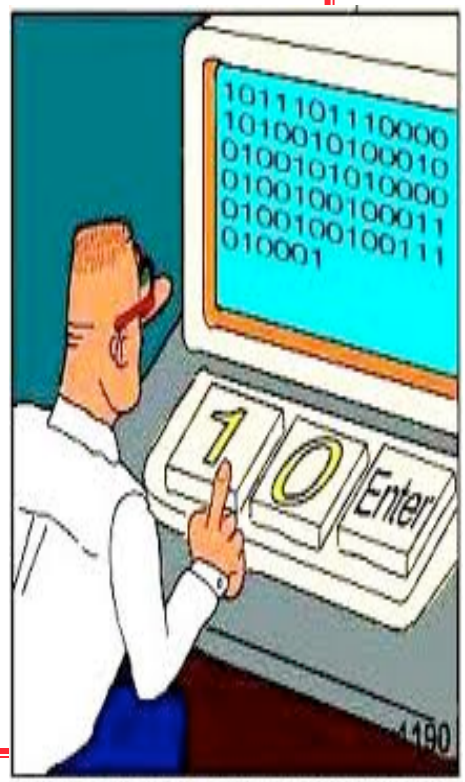

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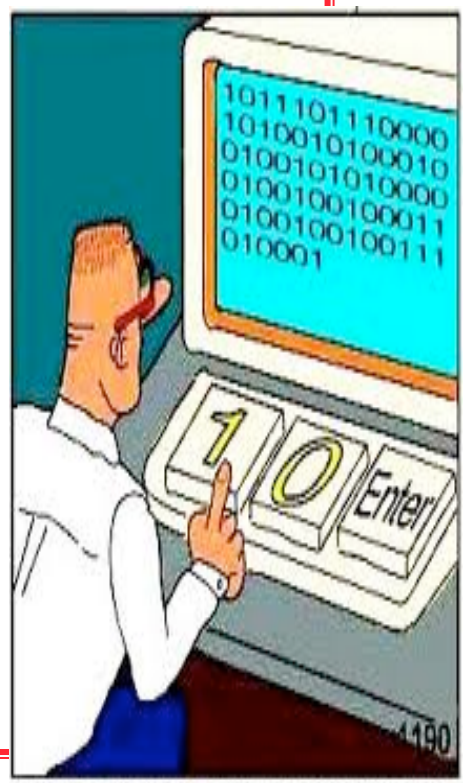

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Not Sufficient for Handling Complexities,
Error Prone, Time Consuming, Tedious,
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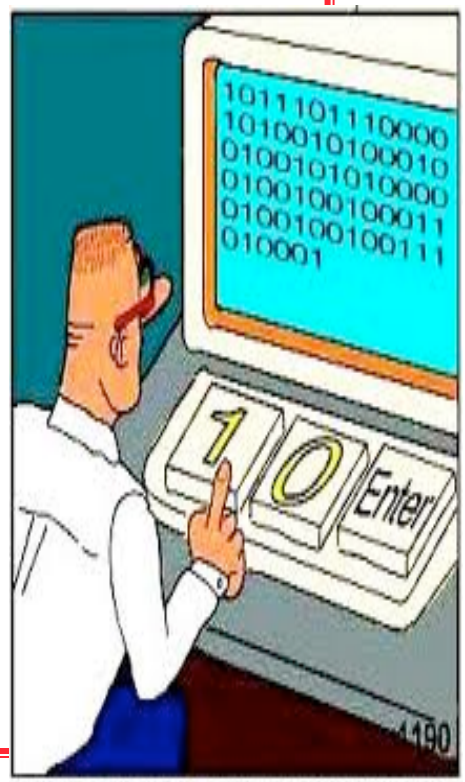

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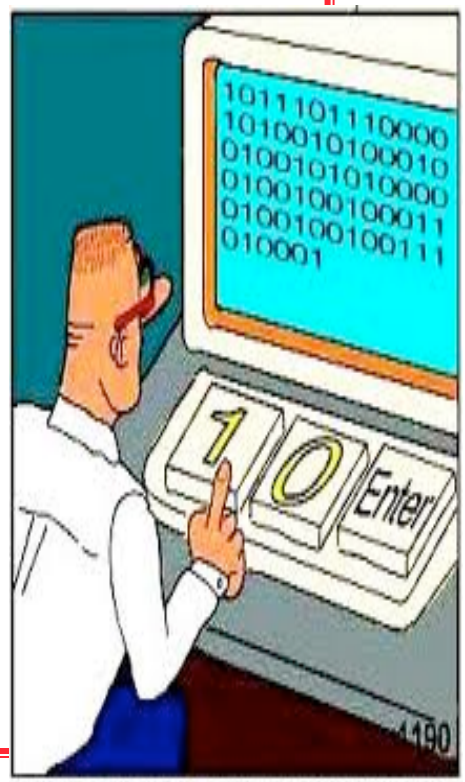
New: Architecture Synthesis
- Automate Integration of Soft IP Components
- Into "Base" Multiprocessor Systems



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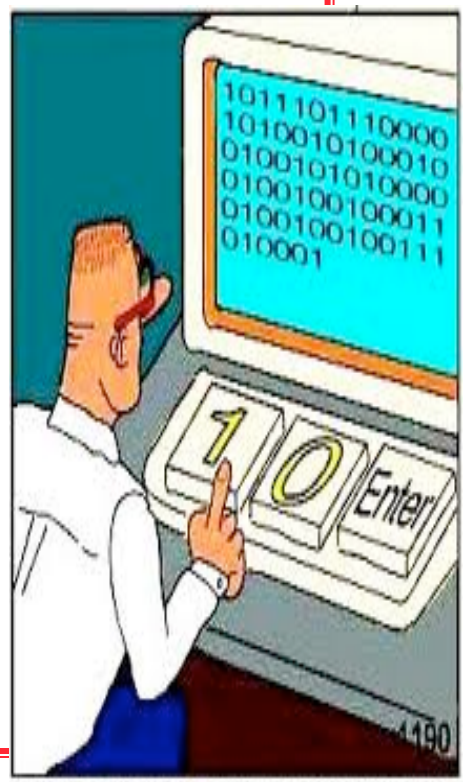

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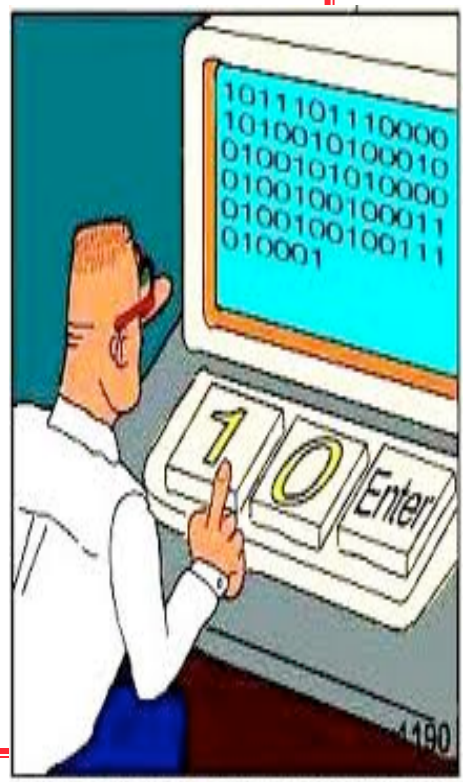

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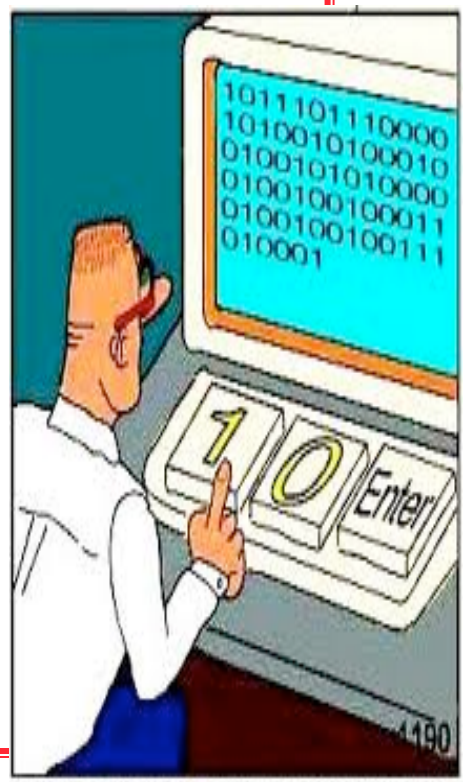
VHDL, State Machines for Accelerators



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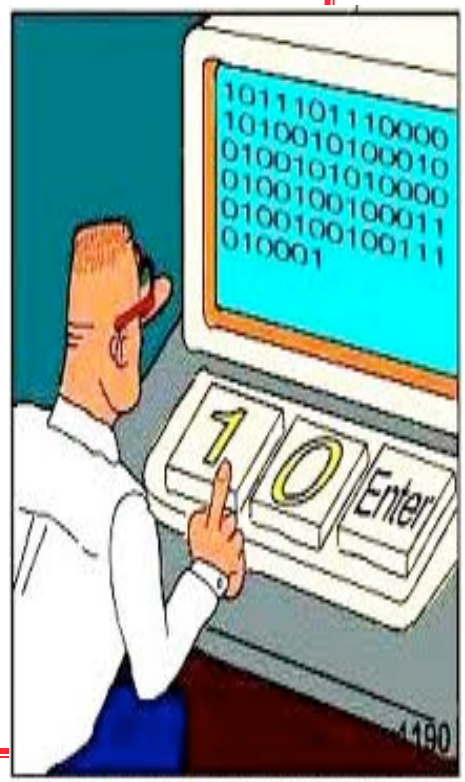
New: Scalable Parallel Programming Models
(Heterogeneous) Concurrency,
Threads,Vector,SPMT



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  - Allow Debug on PC, Cross Compile to Target Platform
  - Provide Hardware Microkernel Op Sys + Middleware
  - *Includes Transparent/Scalable Scheduling
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- Accessibility via Cloud
  - Architecture Overlay Created/Formatted for Vendor Tools
  - Compilation + Linking to OS

Architecture Generation

- What Should Designer See ?

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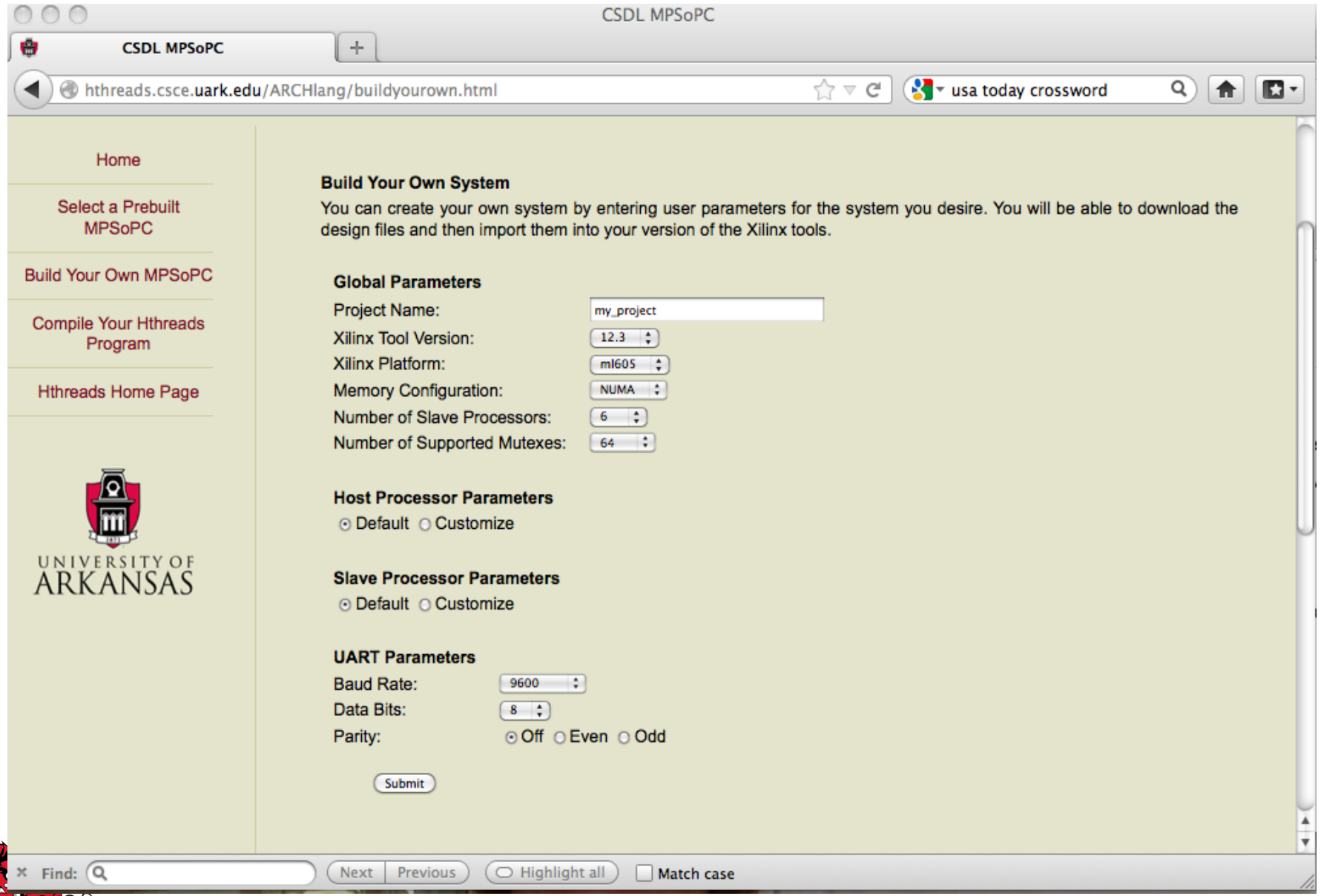
Architecture Generation

- What Should Designer See ?
- Simple Interface Such That….
  - No Need for having gotten "A" In Computer Architecture
    - In fact, no requirement for even having take Computer Architecture
- Free Designer from tedious, error prone assembly of advanced architecture concepts
  - For 80,000 Hardware Designers, Can then Modify
  - 1.2 M Software/Application Engineers Use As Is…..
- Lets see…..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usa today crossword
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Global Parameters
Project Name: my_project
Xilinx Tool Version: 12.3
Xilinx Platform: ml605
Memory Configuration: NUMA
Number of Slave Processors: 6
Number of Supported Mutexes: 64
Host Processor Parameters
Default Customize
Slave Processor Parameters
Default Customize
UART Parameters
Baud Rate: 9600
Data Bits: 8
Parity: Off Even Odd
Submit
Find:
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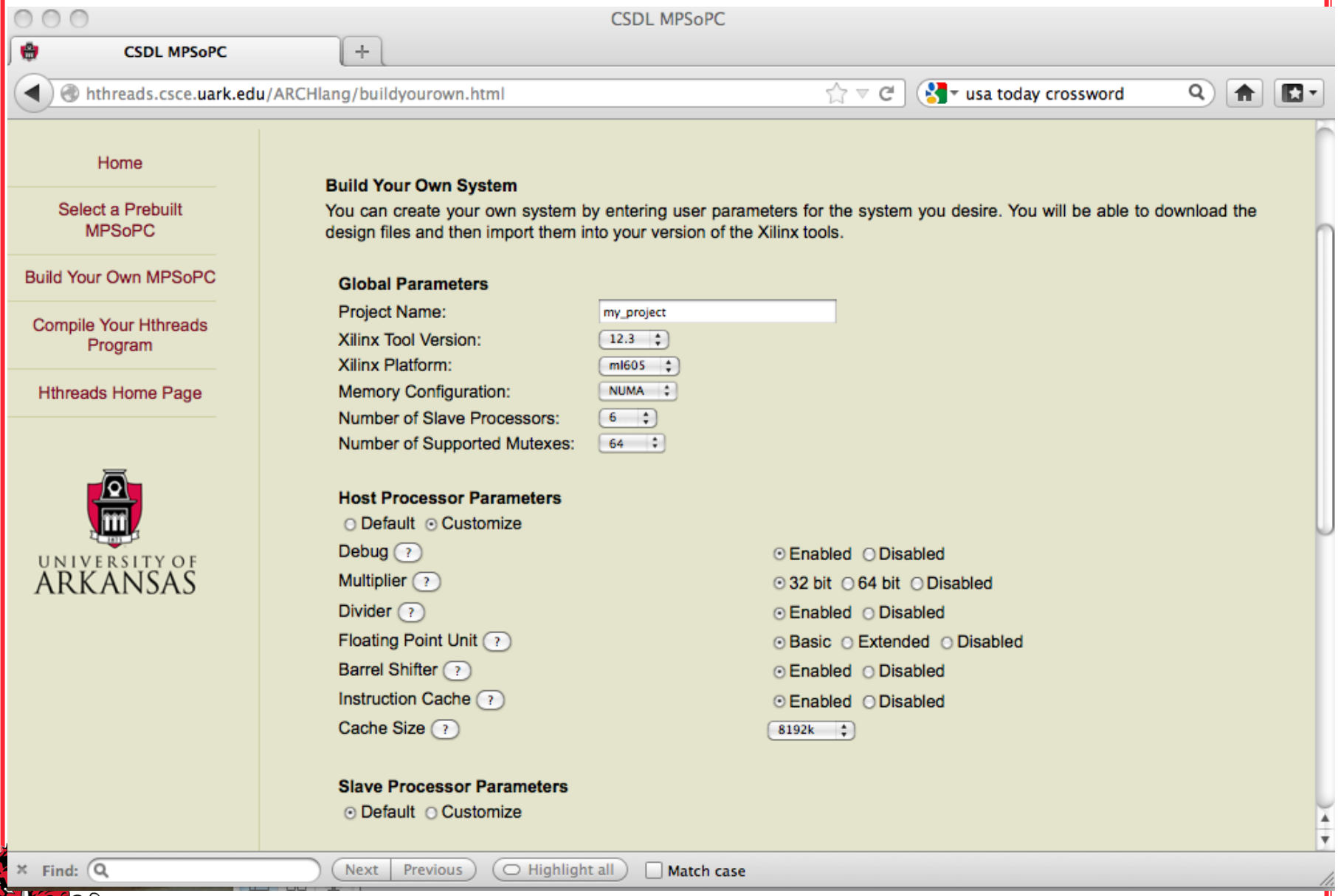
Previous
Highlight all
Match case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usa today crossword
Home
Select a Prebuilt MPSoPC
Build Your Own MPSoPC
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Multiplier ? 32 bit 64 bit Disabled
Divider ? Enabled Disabled
Floating Point Unit ? Basic Extended Disabled
Barrel Shifter ? Enabled Disabled
Instruction Cache ? Enabled Disabled
Cache Size ? 8192k
Slave Processor Parameters
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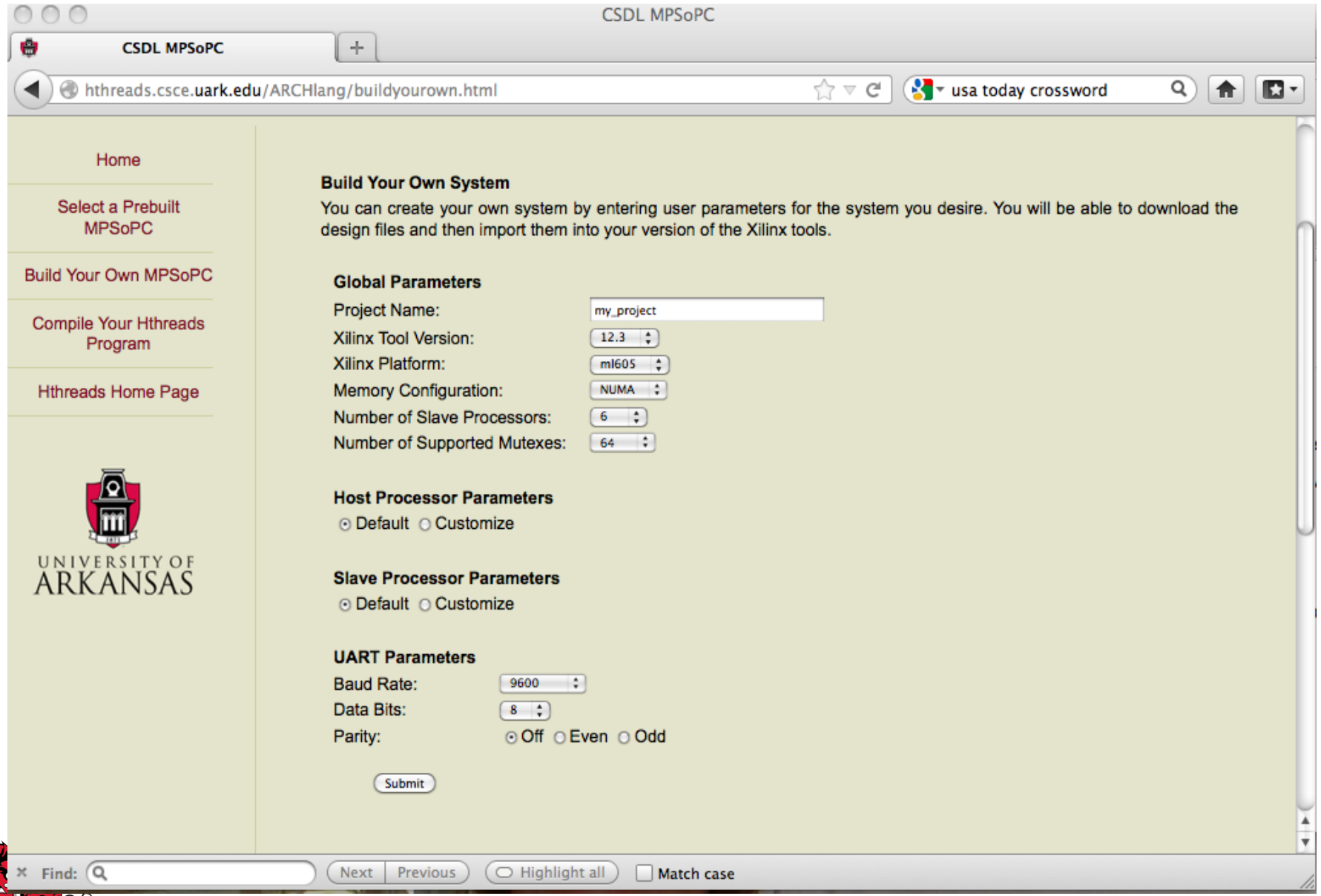
Find: Next Previous Highlight all Match case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usa today crossword

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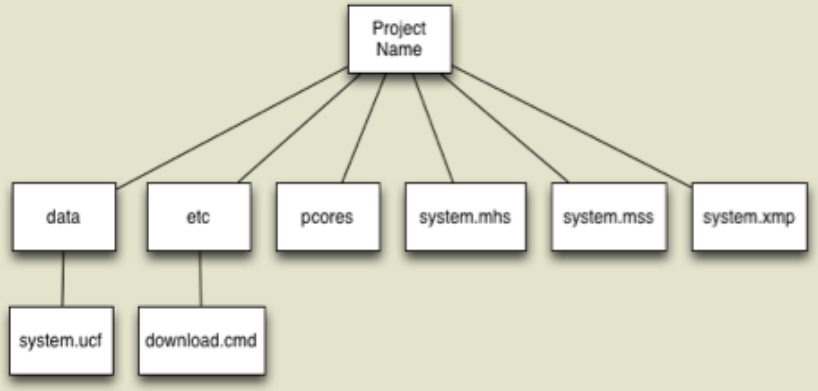
- Home
- Select a Prebuilt MPSoPC
- Build Your Own MPSoPC
- Compile Your Hthreads Program
- Hthreads Home Page

UNIVERSITY OF ARKANSAS

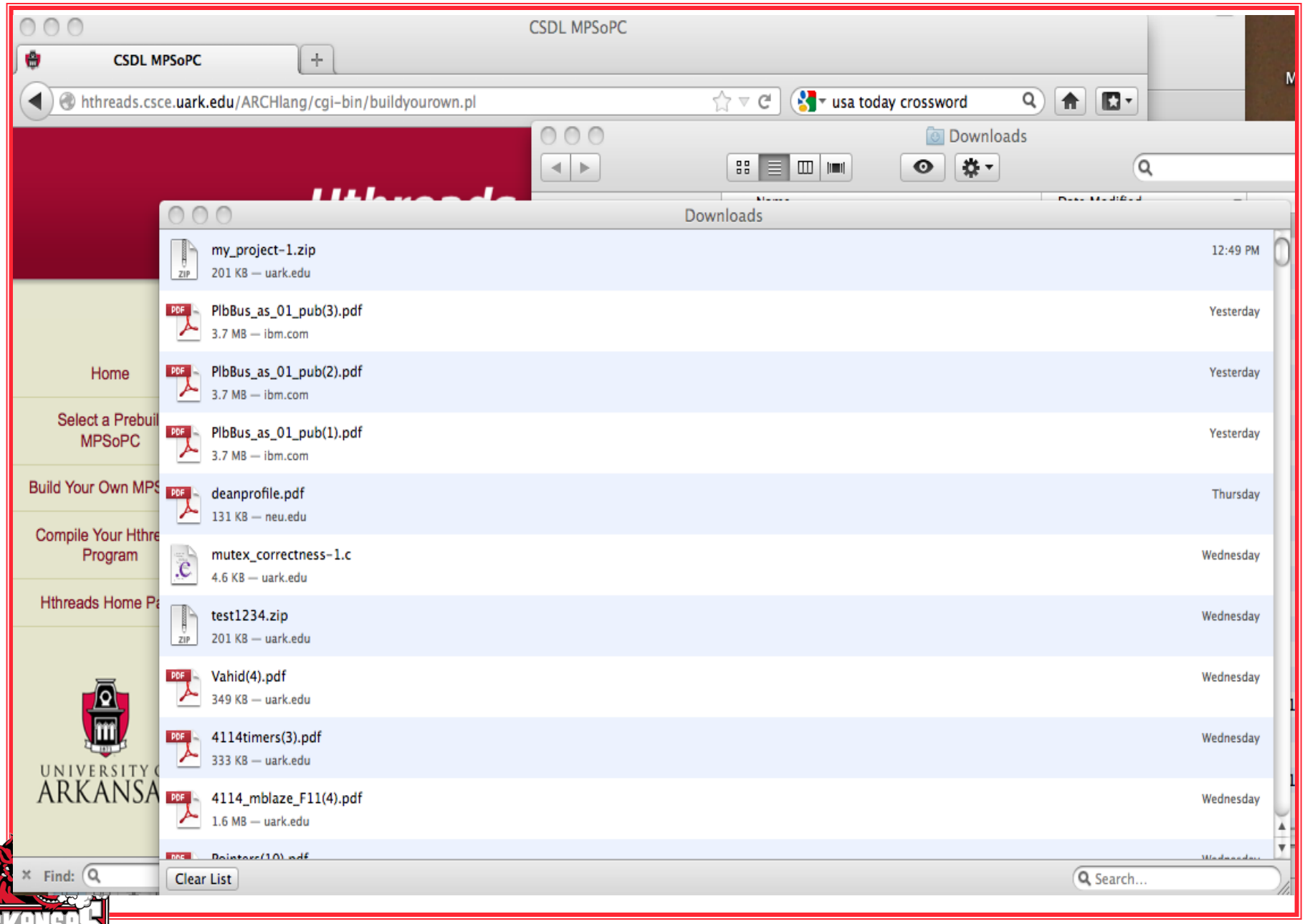
The structure below shows the hierarchy of the zip file given. Simply click the link below to download and extract the file. To open Xilinx XMP files, first start XPS, then open the XMP file, sythesize and download your bitstream onto your Xilinx platform board!



Click the link below to download your design files.

Design Files

Find: Next Previous Highlight all Match case


CSDL MPSoPC
CSDL MPSoPC
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Wednesday
Home
Select a Prebuil
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Find:
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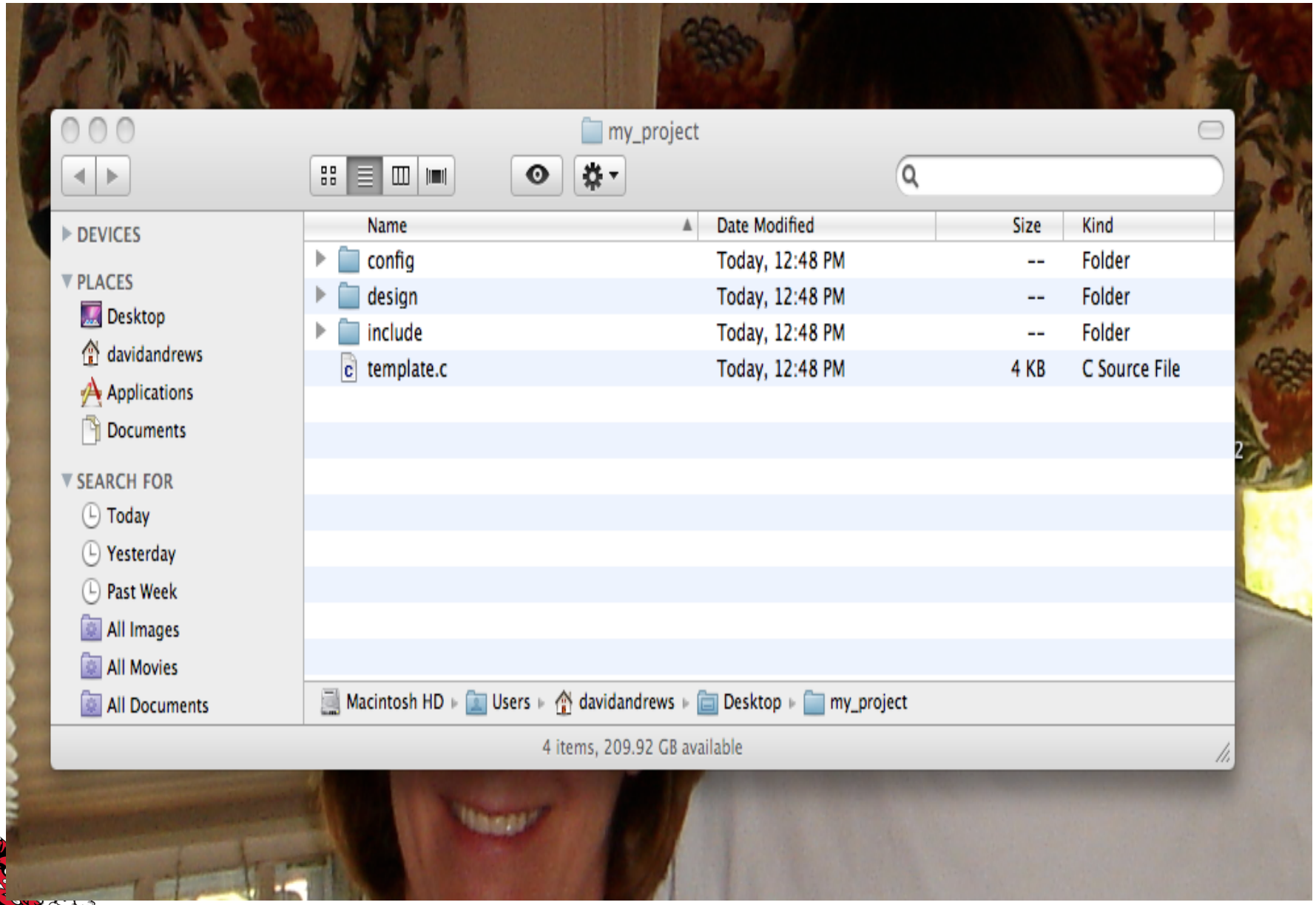
my_project
DEVICES
PLACES
Desktop
davidandrews
Applications
Documents
SEARCH FOR
Today
Yesterday
Past Week
All Images
All Movies
All Documents
Name
Date Modified
Size
Kind
config
Today, 12:48 PM
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Folder
design
Today, 12:48 PM
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Folder
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template.c
Today, 12:48 PM
4 KB
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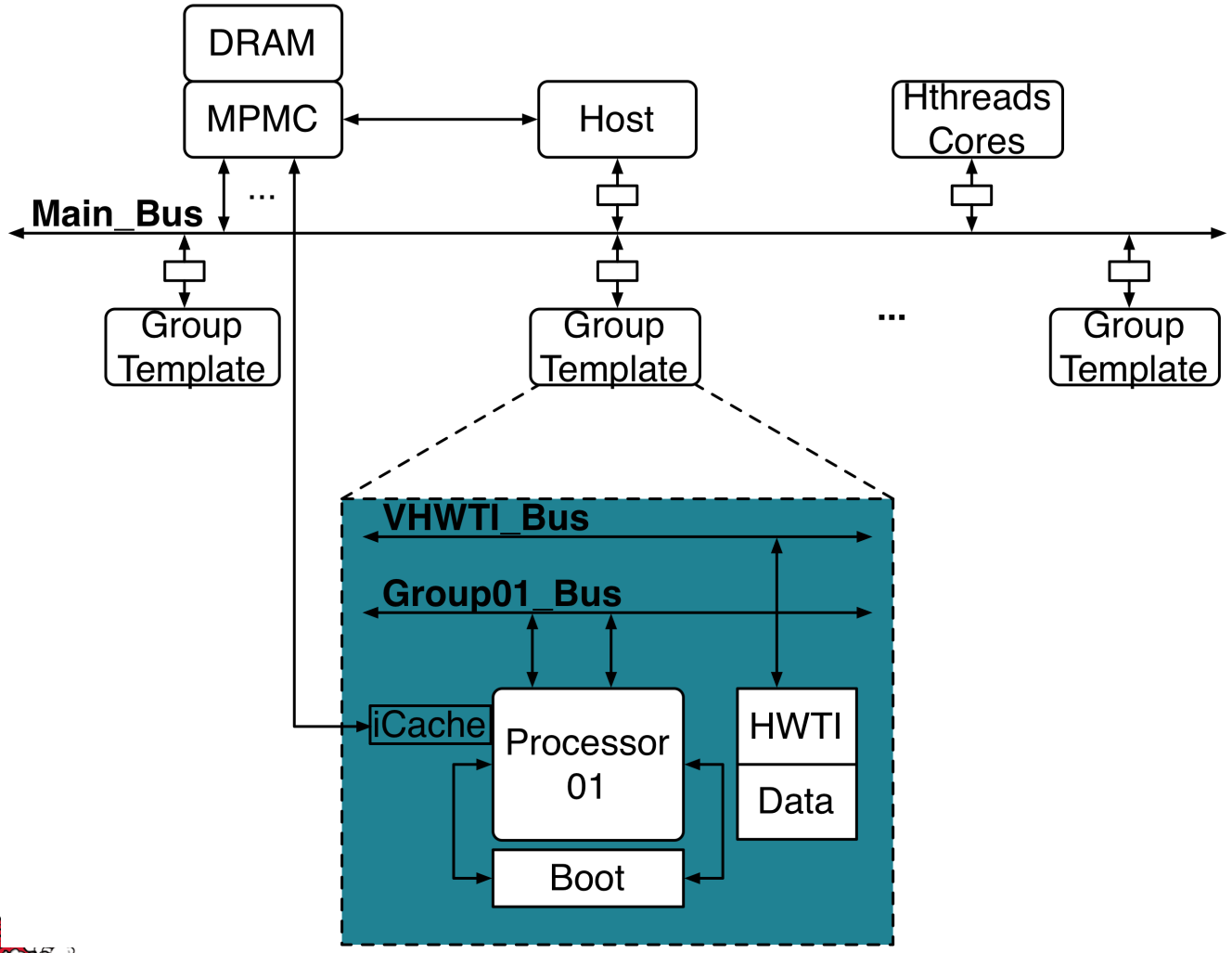
Users
davidandrews
Desktop
my_project
4 items, 209.92 GB available

Peeking at SMP Architectures….



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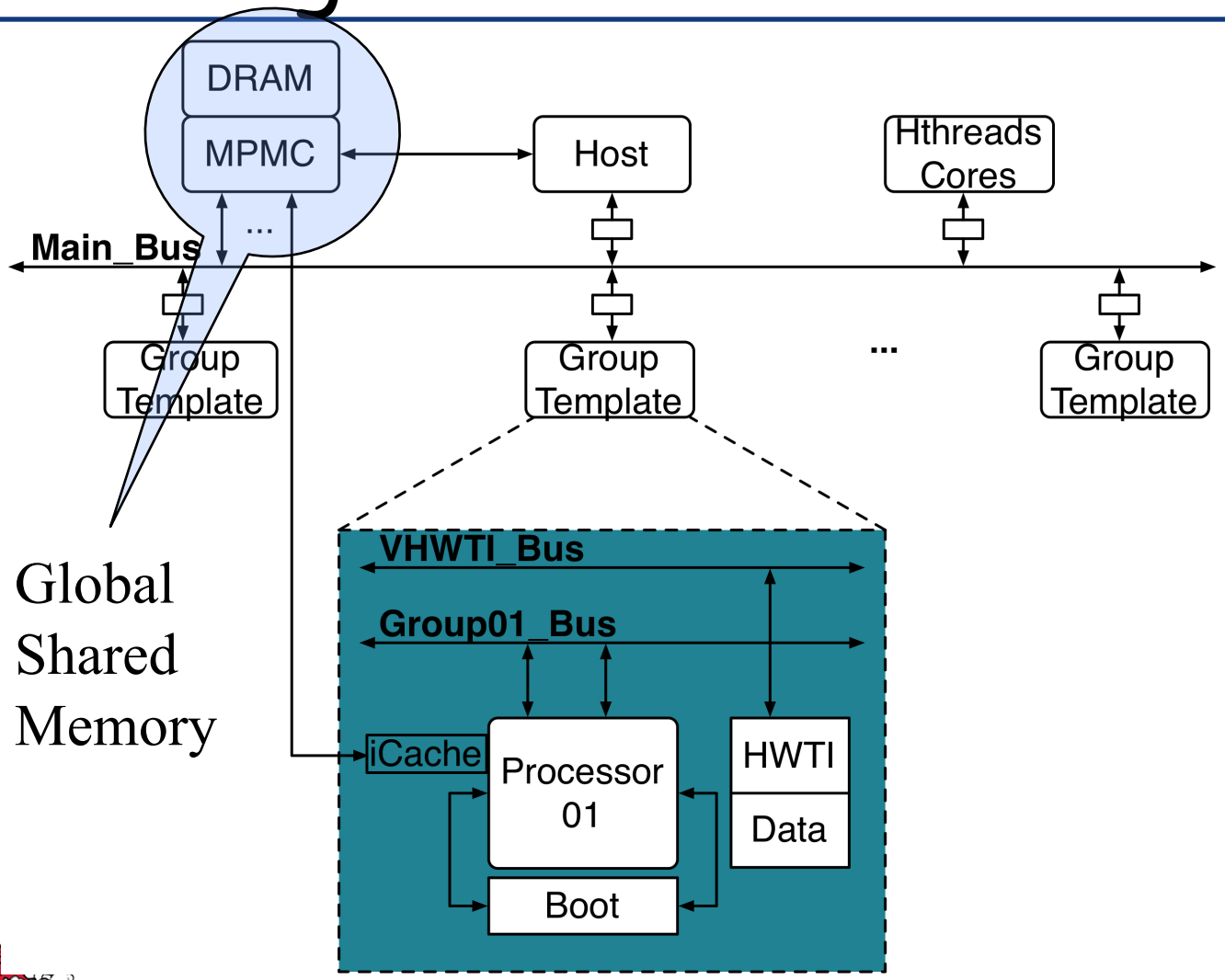
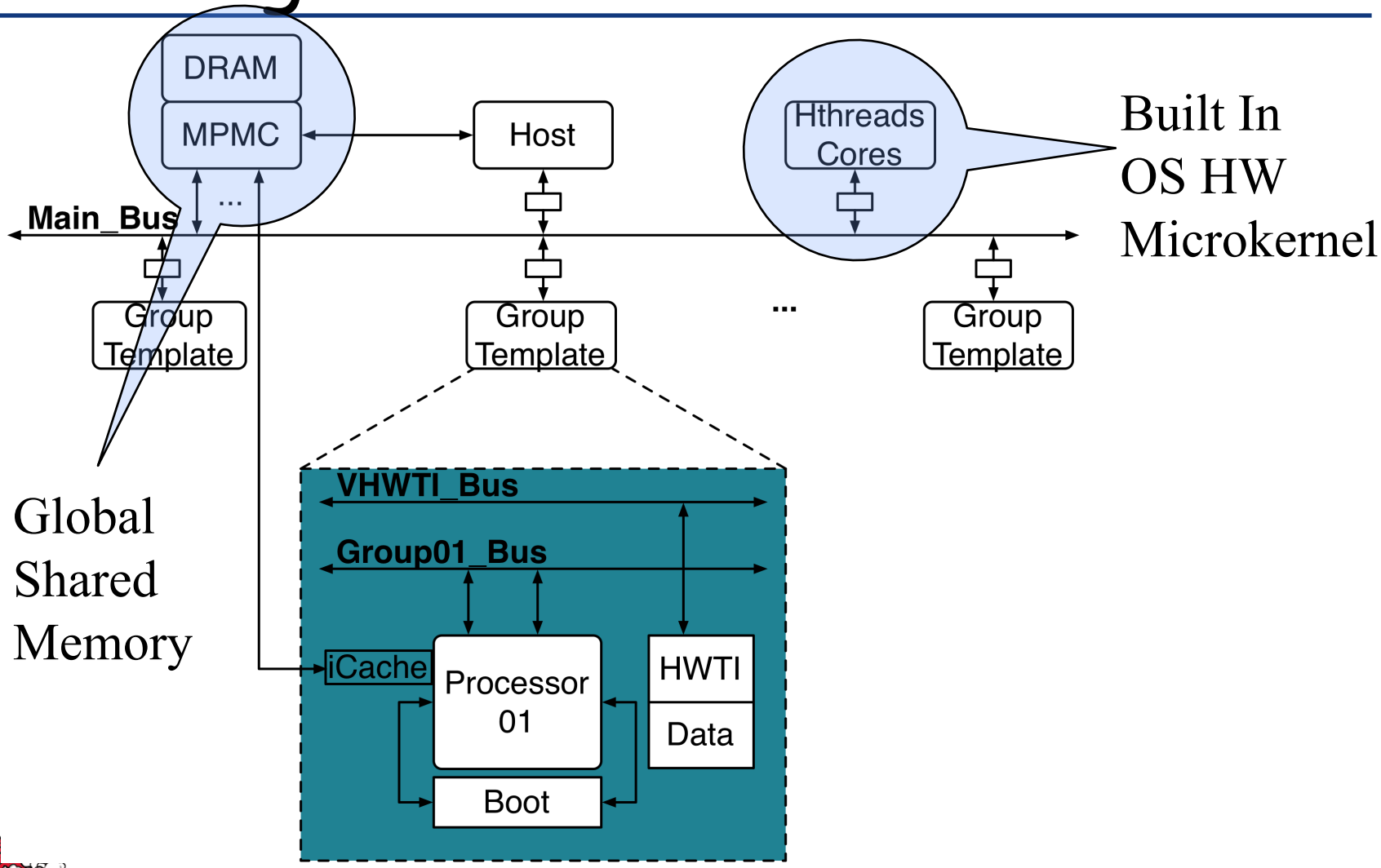


Peeking at SMP Architectures….



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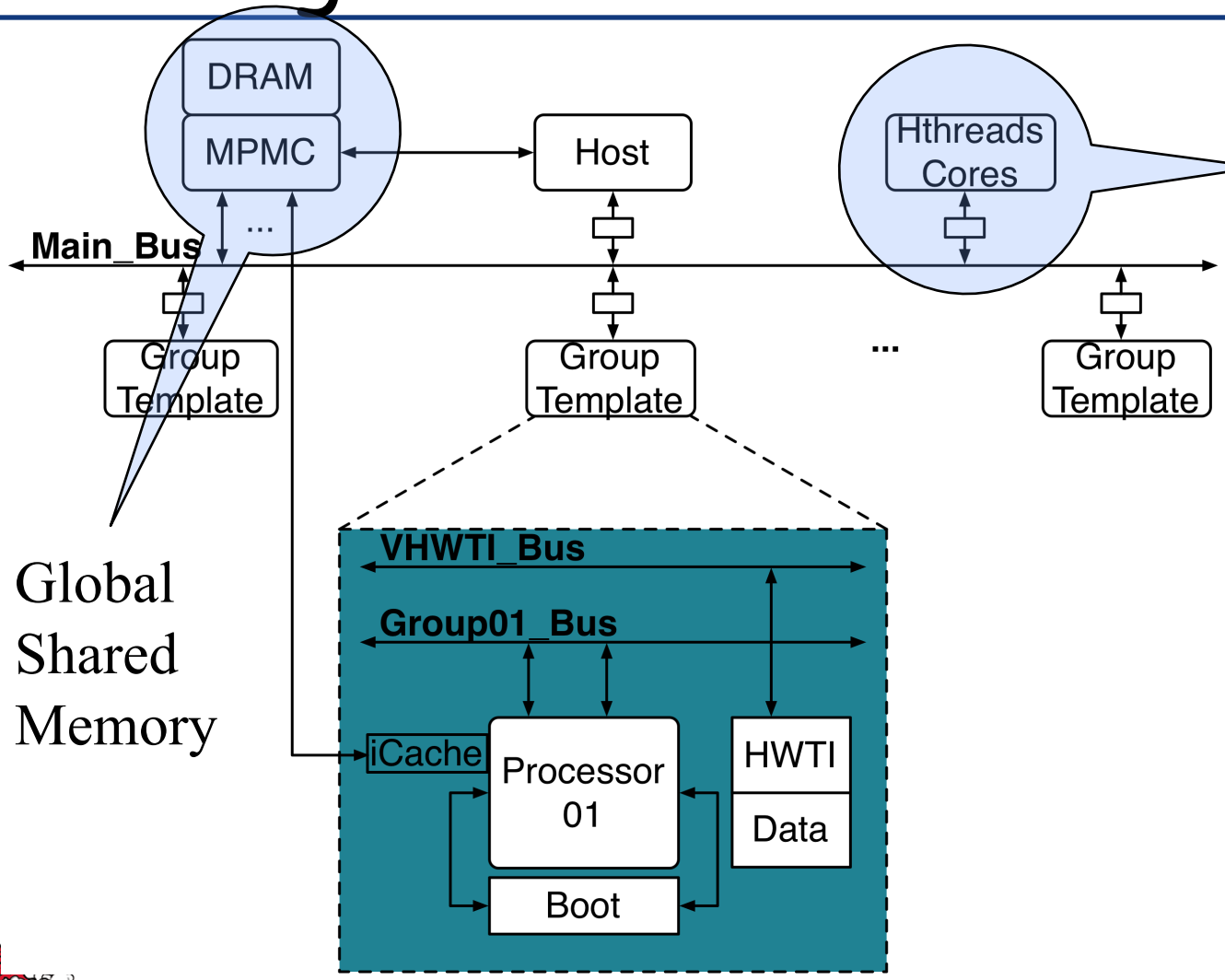
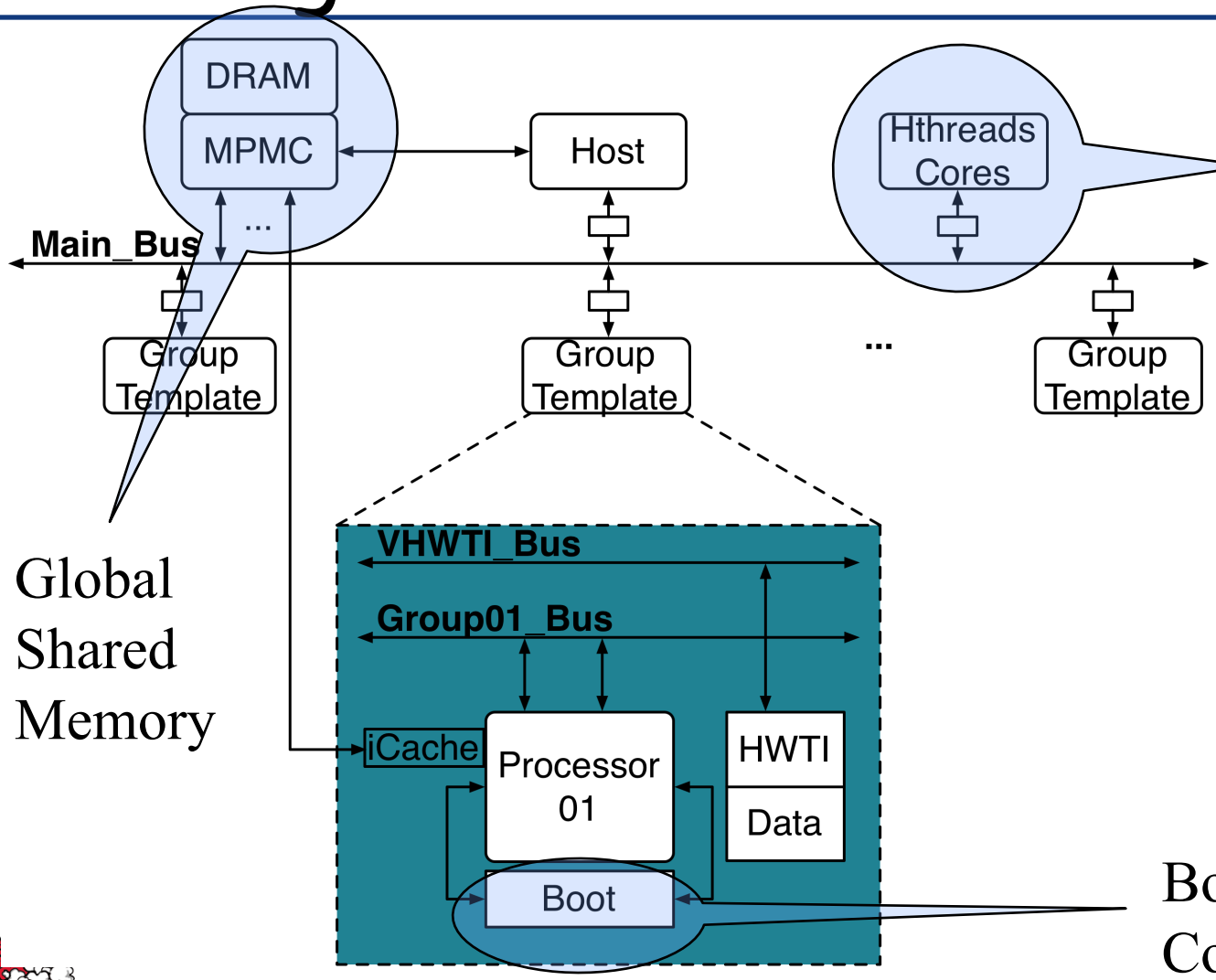


Global Shared Memory

Built In OS HW Microkernel

No Need For You To Port O S (Linux)

Peeking at SMP Architectures….



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No Need For You To Port O S (Linux)

Boot + (HAL) OS Code

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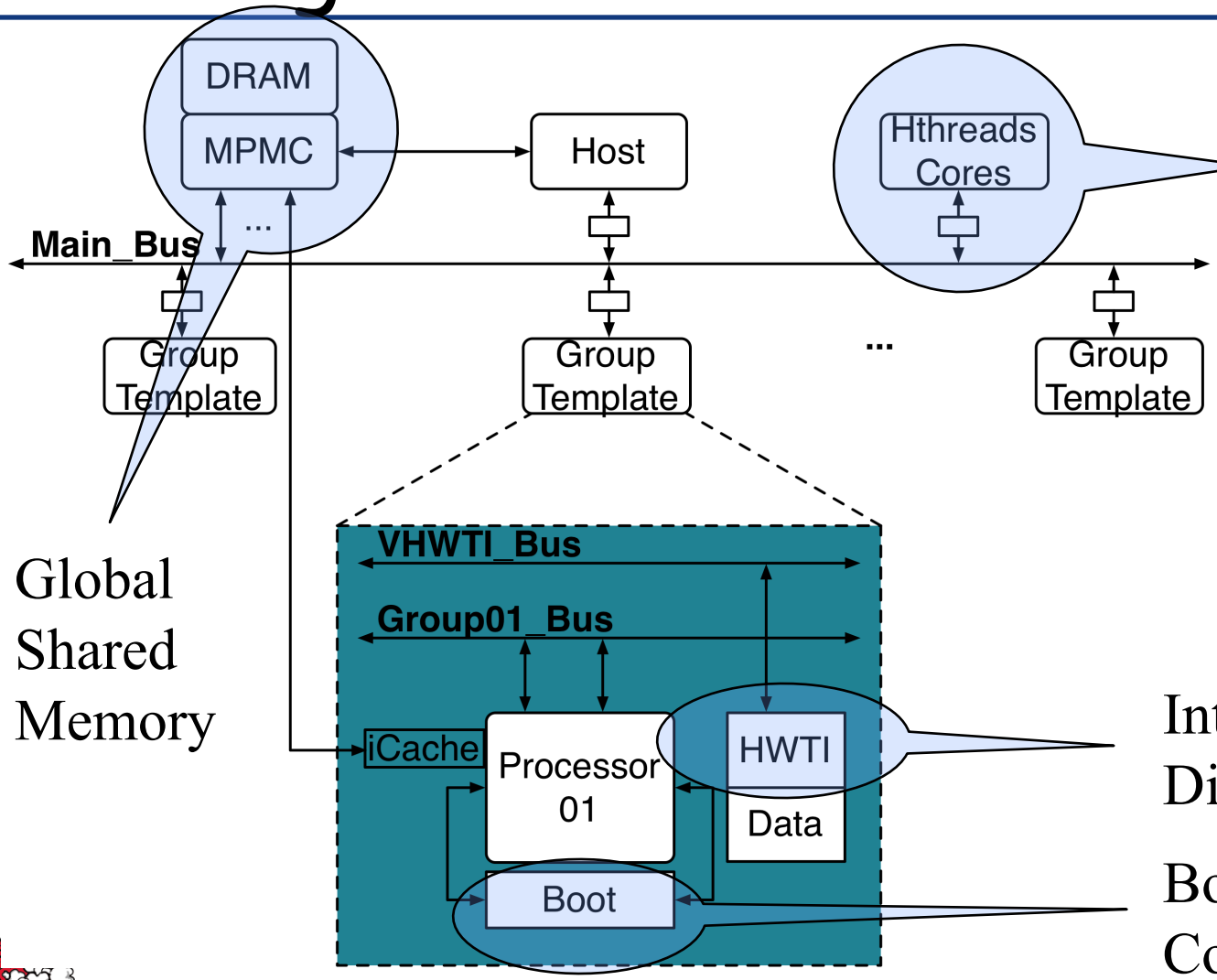


Global Shared Memory

Built In OS HW Microkernel

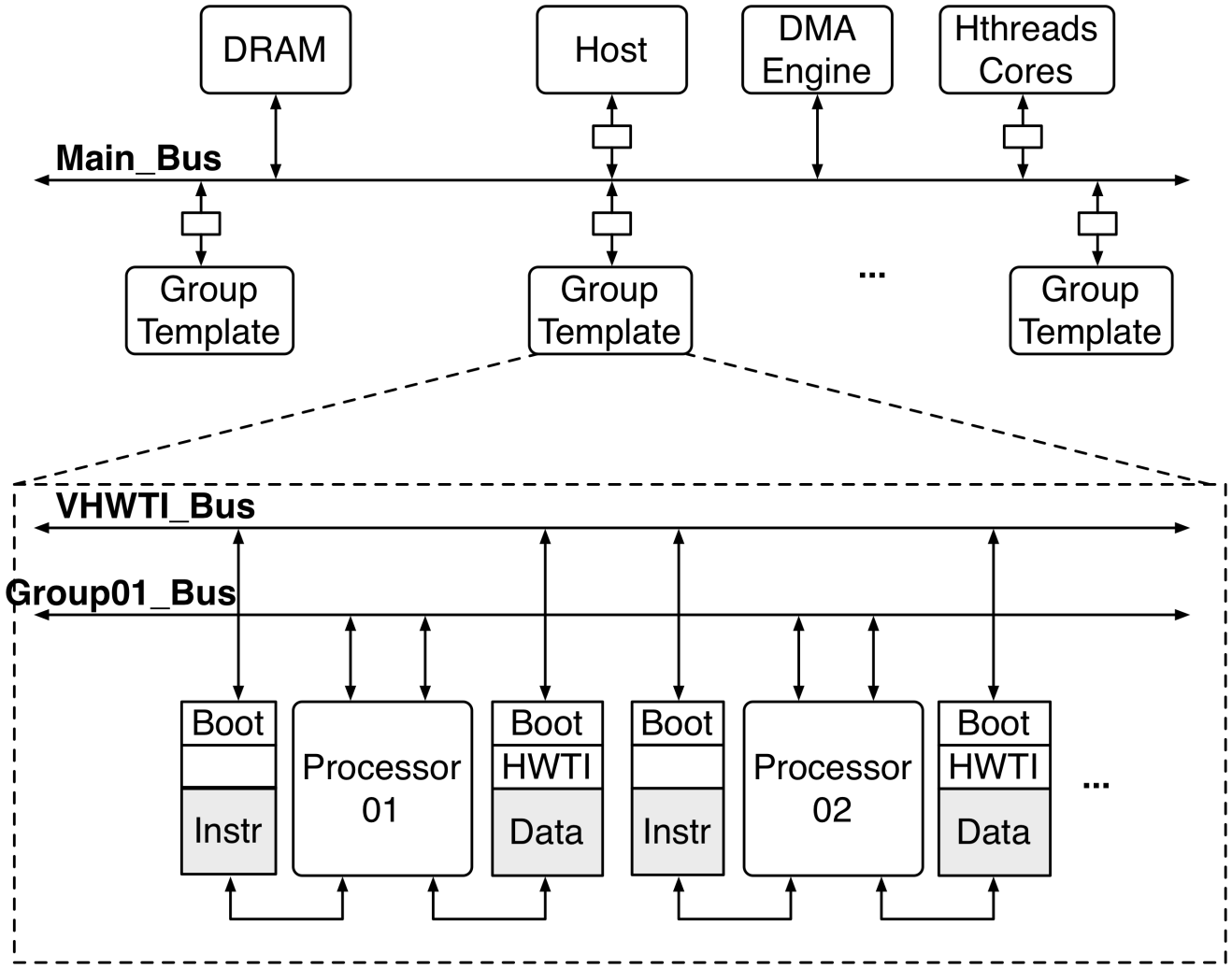
No Need For You To Port O S (Linux)

Interface for O S Distributed

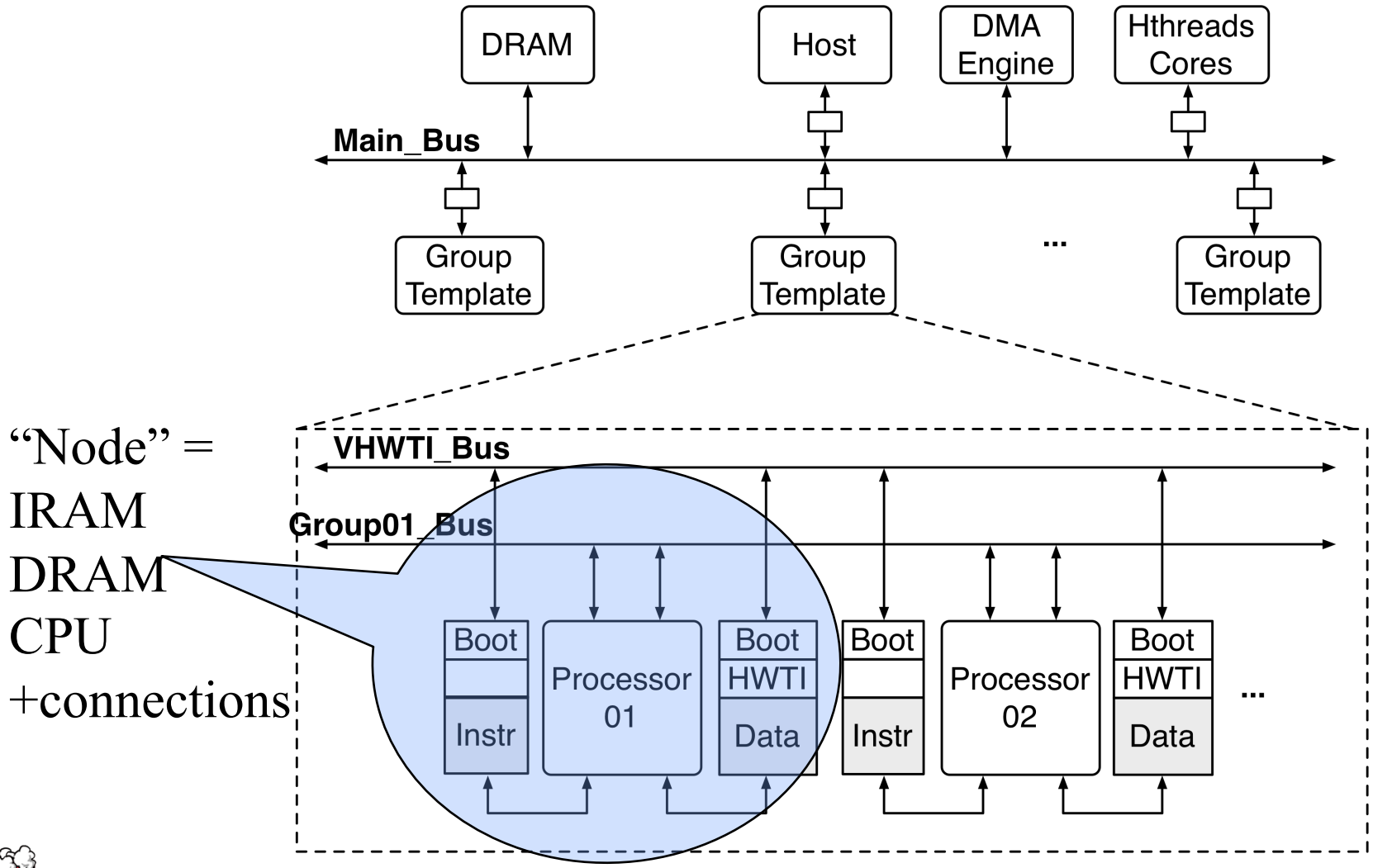
Boot + (HAL) OS Code

Peeking at SMP Architectures….

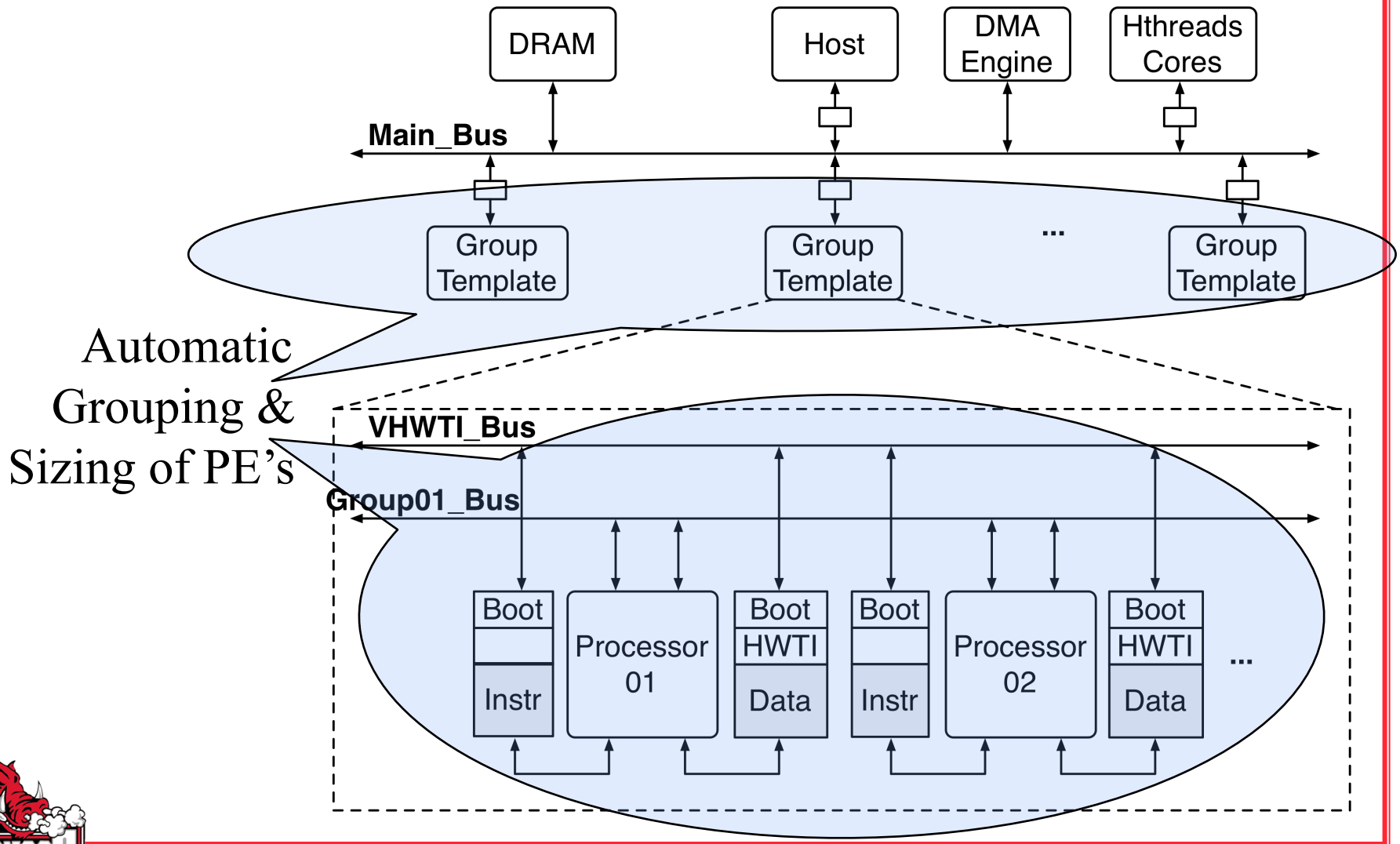
Peeking at NUMA Architectures



Peeking at NUMA Architectures

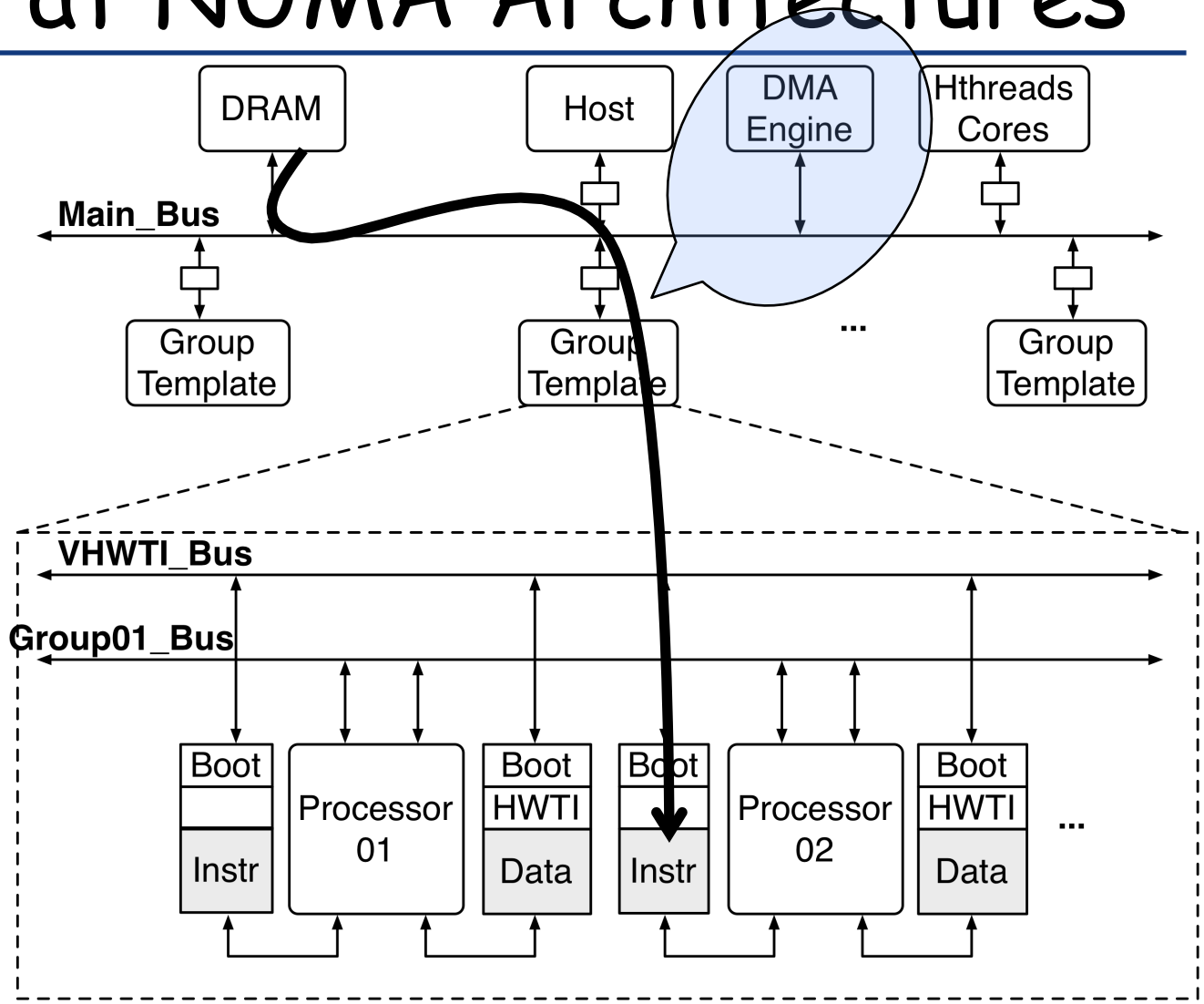


Peeking at NUMA Architectures



Peeking at NUMA Architectures

Implicit xfer in thread_create()



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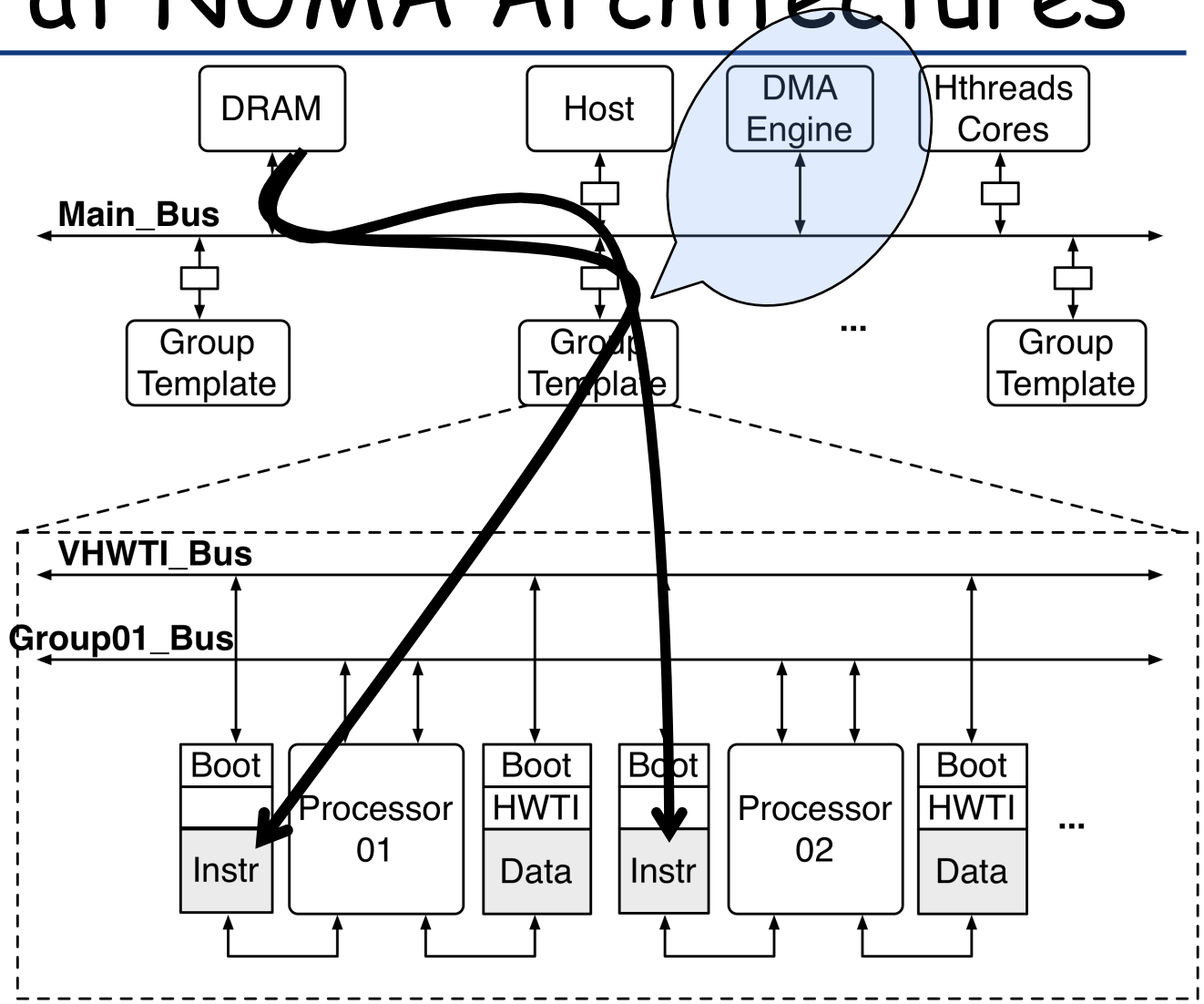


But Wait: Reality Check…….

"Hardware" Design Small Subset of Overall System Implementation Effort

But Wait: Reality Check…….

"Hardware" Design Small Subset of Overall System Implementation Effort

- Software Development Effort Generally O(10x) Greater than Hardware Development

But Wait: Reality Check…….

"Hardware" Design Small Subset of Overall System Implementation Effort

- Software Development Effort Generally O(10x) Greater than Hardware Development

- Do You Want to Build Software Infrastructure ?
  - "Scalable" Programming Model (HLL + Middleware)
  - Run Time System (Operating System + Debug Support)
    - Cross Compiler + Linker + Run Time System

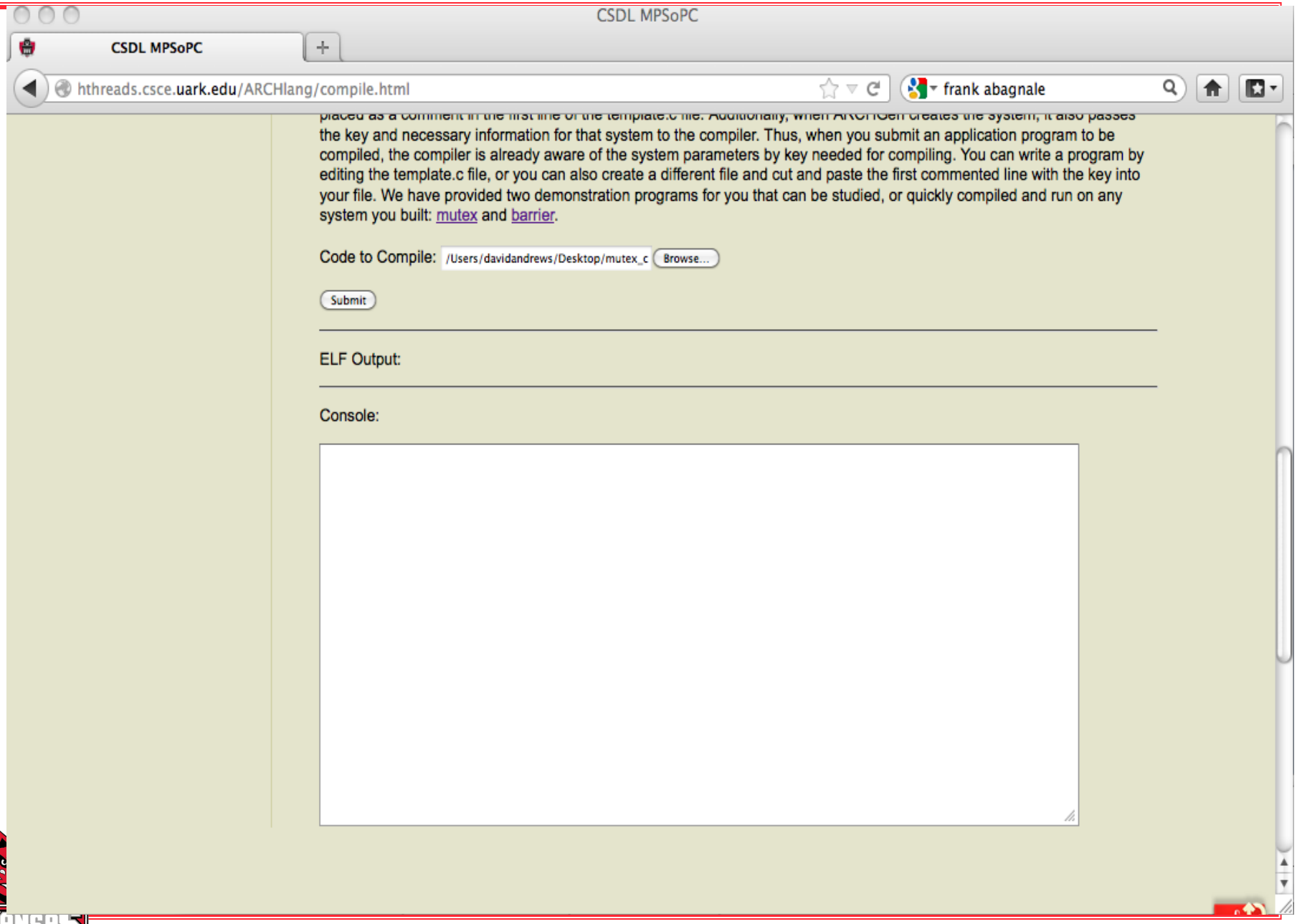
Pthreads Compliant System

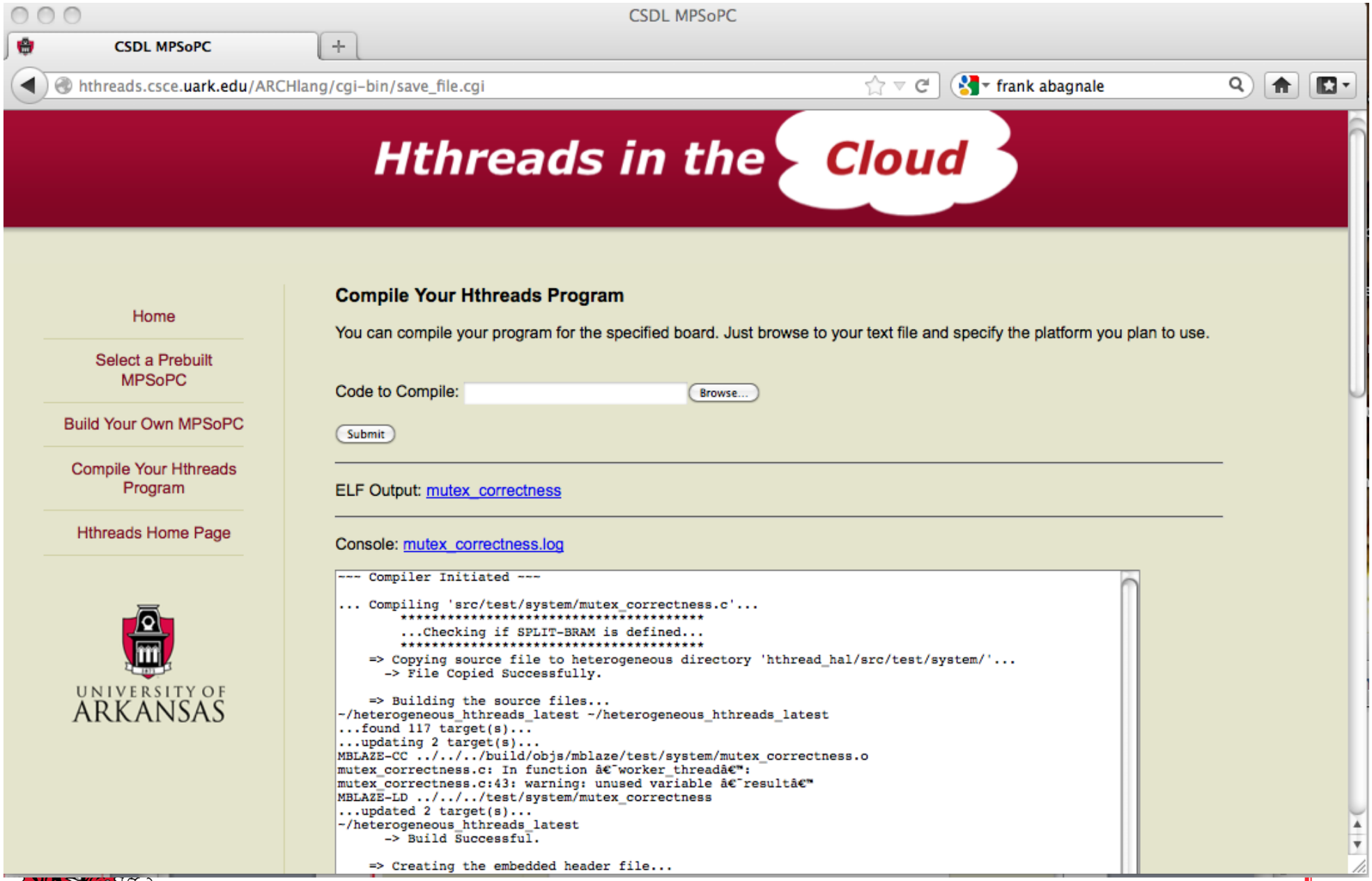
- User Submits Pthreads Compliant Code
  - Compilation + Linking Scripts Invoked on Local Server
- User Gets Executable For a Particular System
  - First Line in Program is comment line with compilation-linking key
    - Needed for linking correct libraries

File= mutex_correctness.c

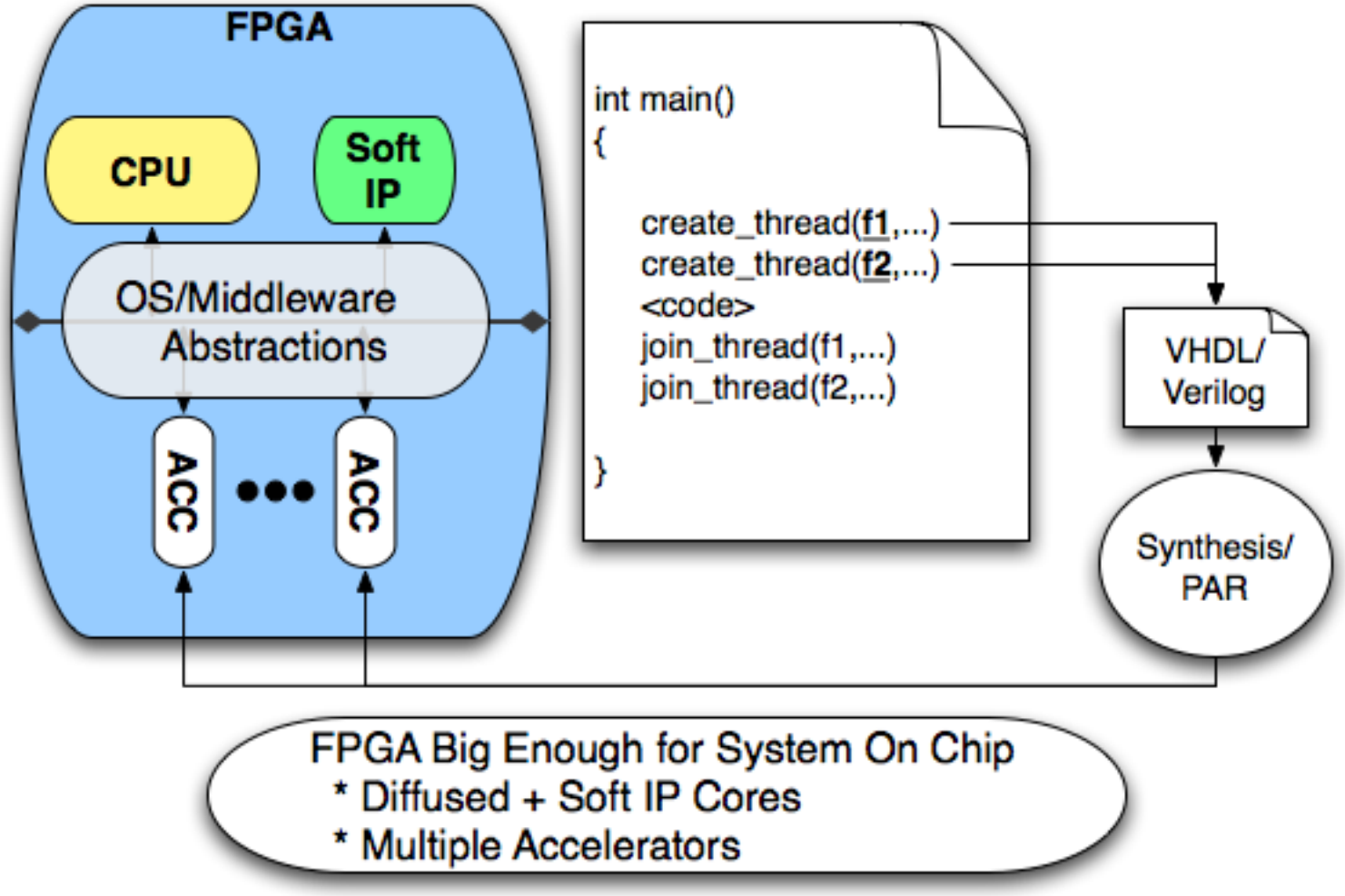
```
// Compilation Key: 00111111101111800 6 64 8192 9600 FPL_Demo_SMP_06
#include <hthread.h>
#include "hetero_time_lib.h"
#include <util/rops.h>
#include <mutex/commands.h>
#include <mutex/hardware.h>

// Data logging
#define NUM_THREADS     (8)
#define NUM_ITERATIONS  (2)
#define NUM_LOOPS     (100)
#define WORK_DELAY    (10000)
#define TIMER_BASE_ADDR (0x840B2000)
```

Complete file can be seen as example on web page

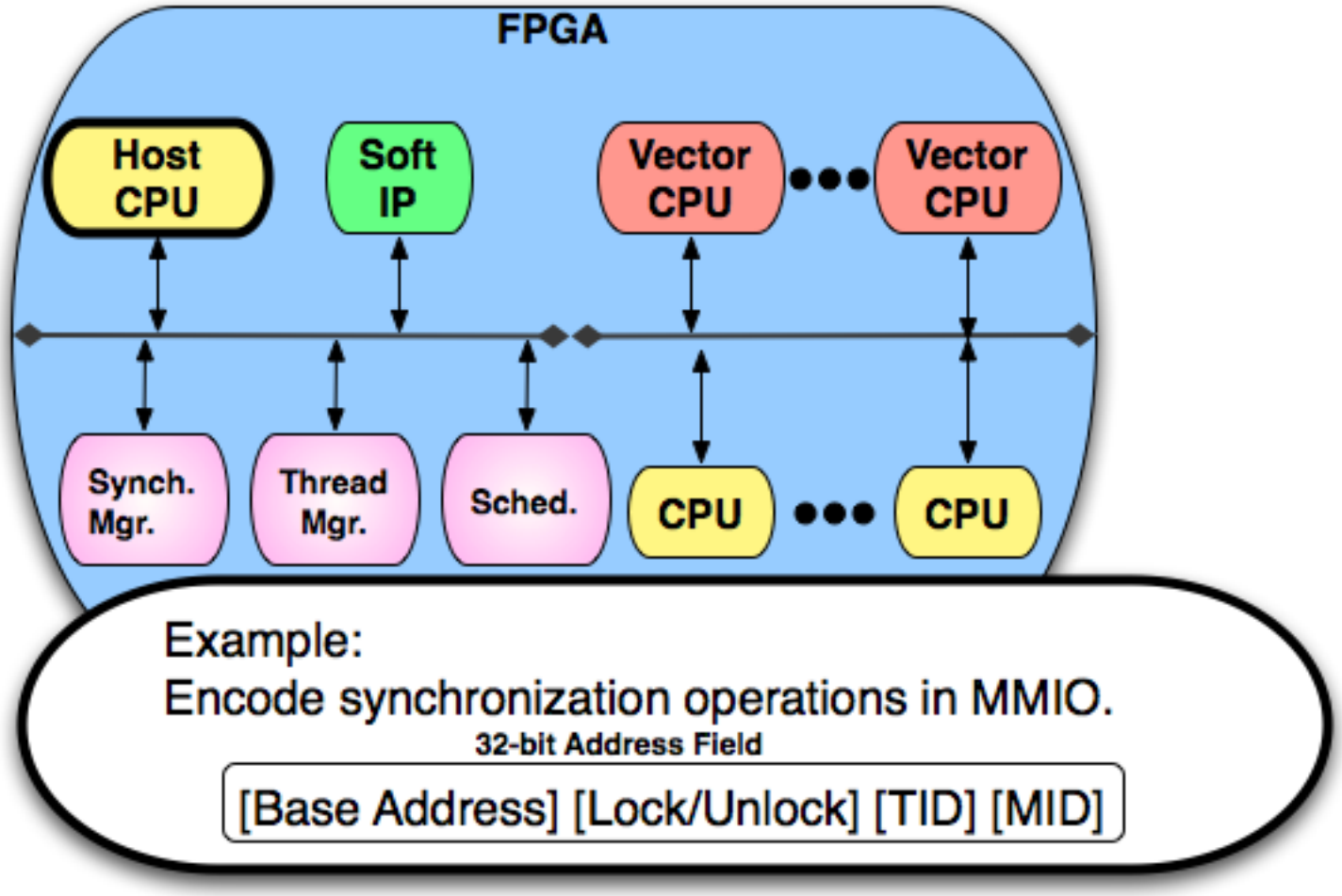

CSDL MPSoPC
CSDL MPSoPC
hthreads.csce.uark.edu/ARCHlang/compile.html
frank abagnale
the key and necessary information for that system to the compiler. Thus, when you submit an application program to be compiled, the compiler is already aware of the system parameters by key needed for compiling. You can write a program by editing the template.c file, or you can also create a different file and cut and paste the first commented line with the key into your file. We have provided two demonstration programs for you that can be studied, or quickly compiled and run on any system you built: mutex and barrier.
Code to Compile: /Users/davidandrews/Desktop/mutex_c
Browse...
Submit
ELF Output:
Console:


CSDL MPSoPC
CSDL MPSoPC
hthreads.csce.uark.edu/ARCHlang/cgi-bin/save_file.cgi
frank abagnale
Hthreads in the Cloud
Home
Select a Prebuilt MPSoPC
Build Your Own MPSoPC
Compile Your Hthreads Program
Hthreads Home Page
UNIVERSITY OF ARKANSAS
Compile Your Hthreads Program
You can compile your program for the specified board. Just browse to your text file and specify the platform you plan to use.
Code to Compile:
Browse...
Submit
ELF Output: mutex_correctness
Console: mutex_correctness.log
--- Compiler Initiated ---
... Compiling 'src/test/system/mutex_correctness.c'...
****
...Checking if SPLIT-BRAM is defined...
****
=> Copying source file to heterogeneous directory 'hthread_hal/src/test/system/'...
-> File Copied Successfully.
=> Building the source files...
~/heterogeneous_hthreads_latest ~/heterogeneous_hthreads_latest
...found 117 target(s)...
...updating 2 target(s)...
MBLAZE-CC ../../../build/objs/mblaze/test/system/mutex_correctness.o
mutex_correctness.c: In function â€˜worker_threadâ€™:
mutex_correctness.c:43: warning: unused variable â€˜resultâ€™
MBLAZE-LD ../../../test/system/mutex_correctness
...updated 2 target(s)...
~/heterogeneous_hthreads_latest
-> Build Successful.
=> Creating the embedded header file...

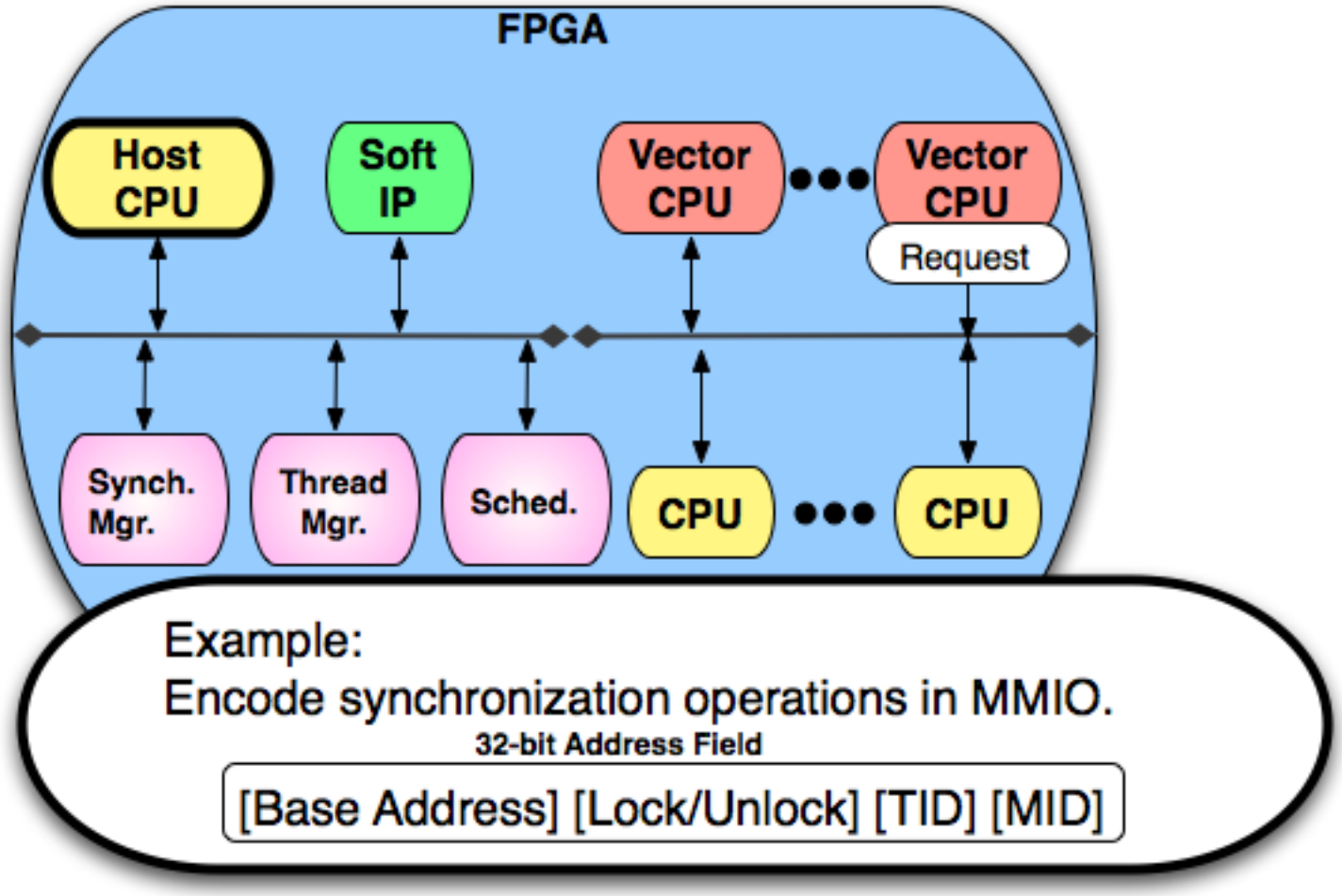
A little on hthreads



hthreads OS Framework



hthreads OS Framework



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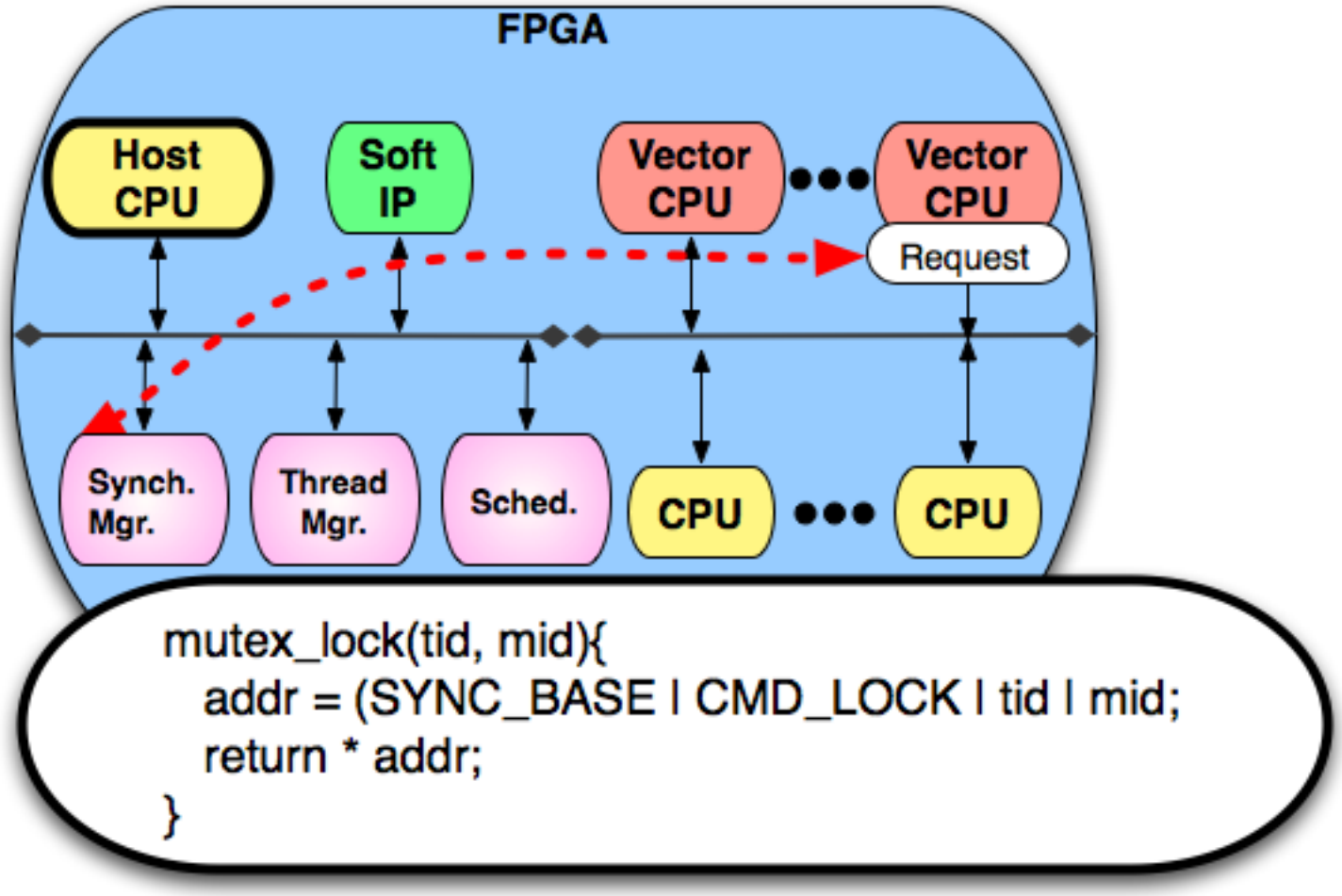
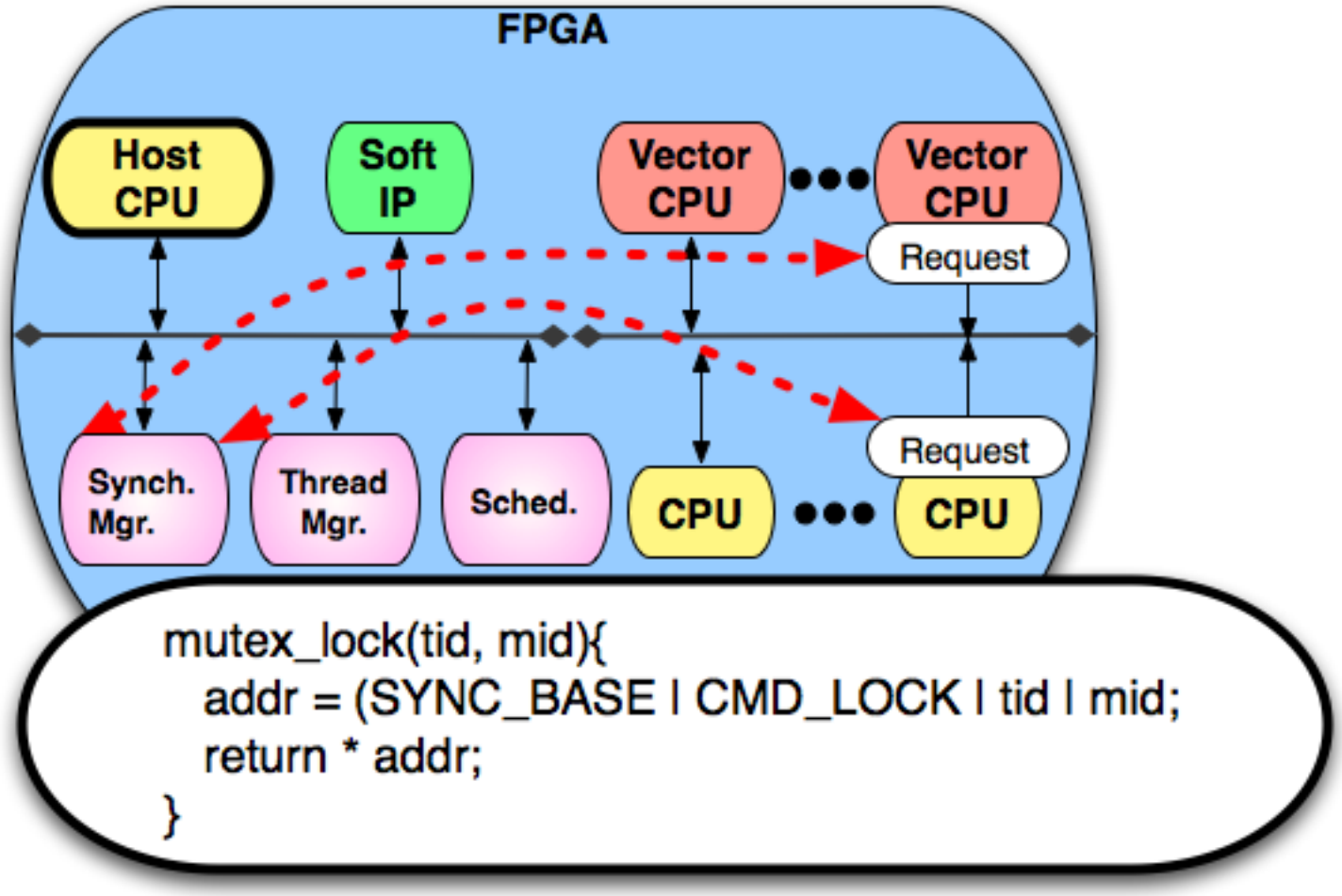
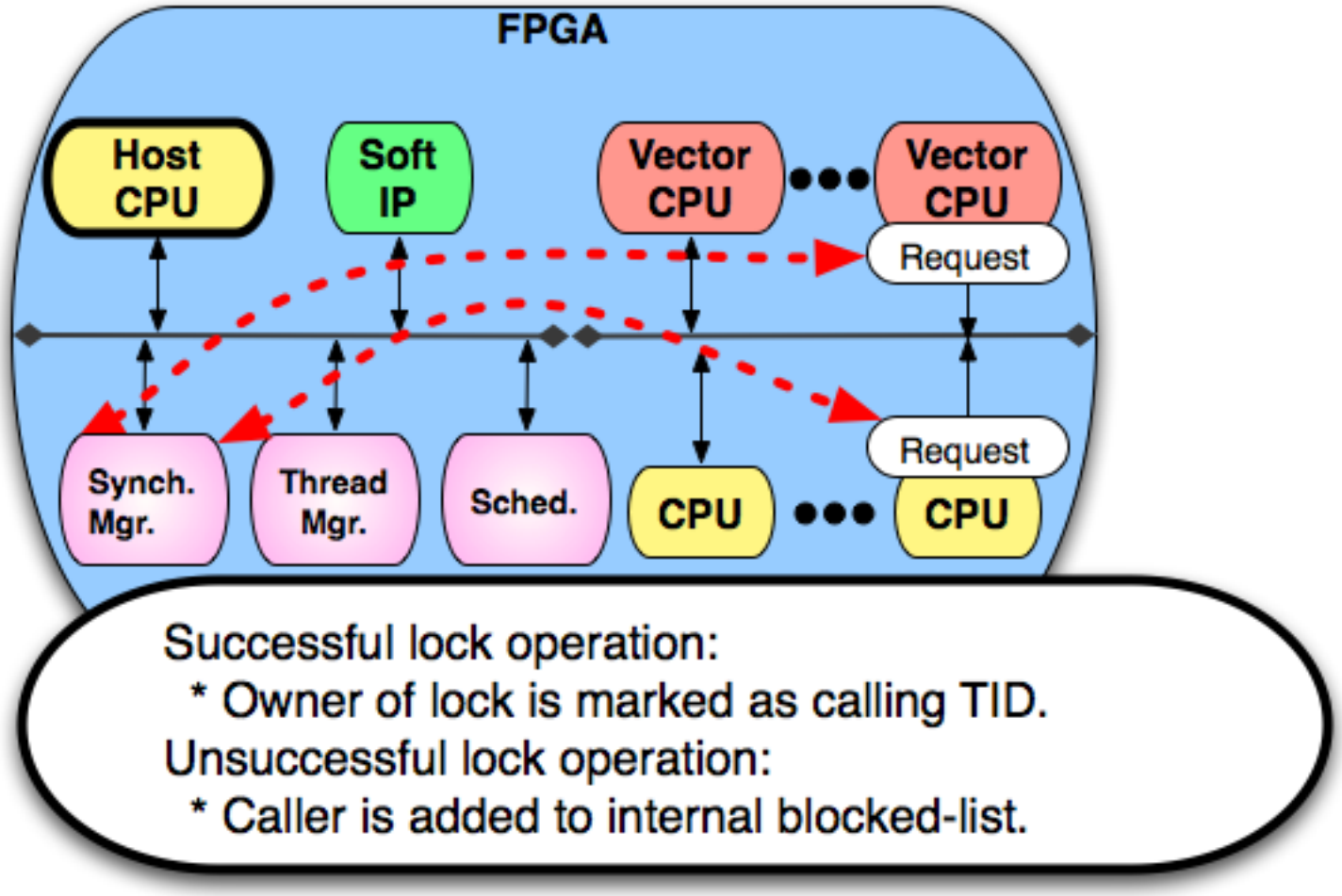


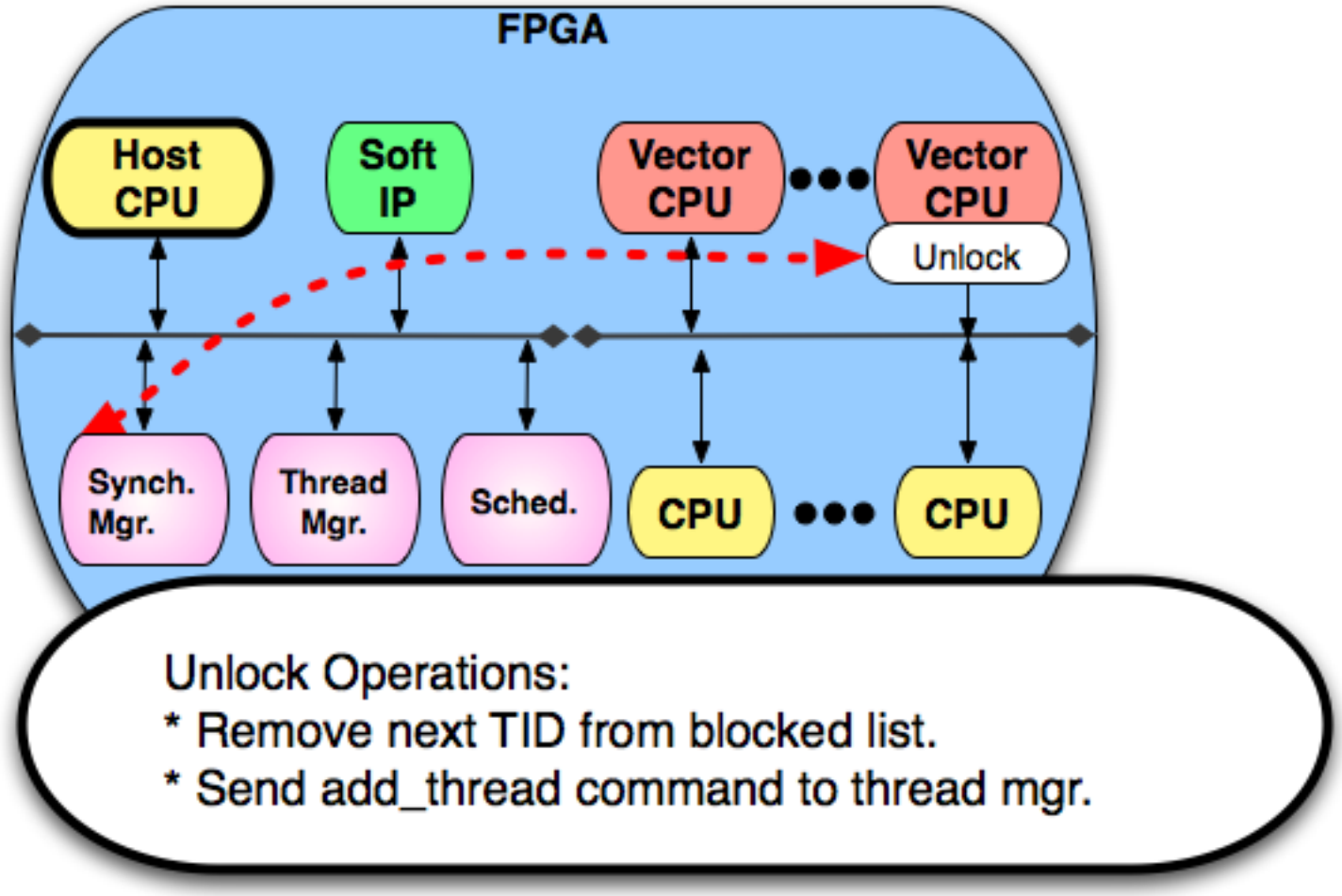
hthreads OS Framework



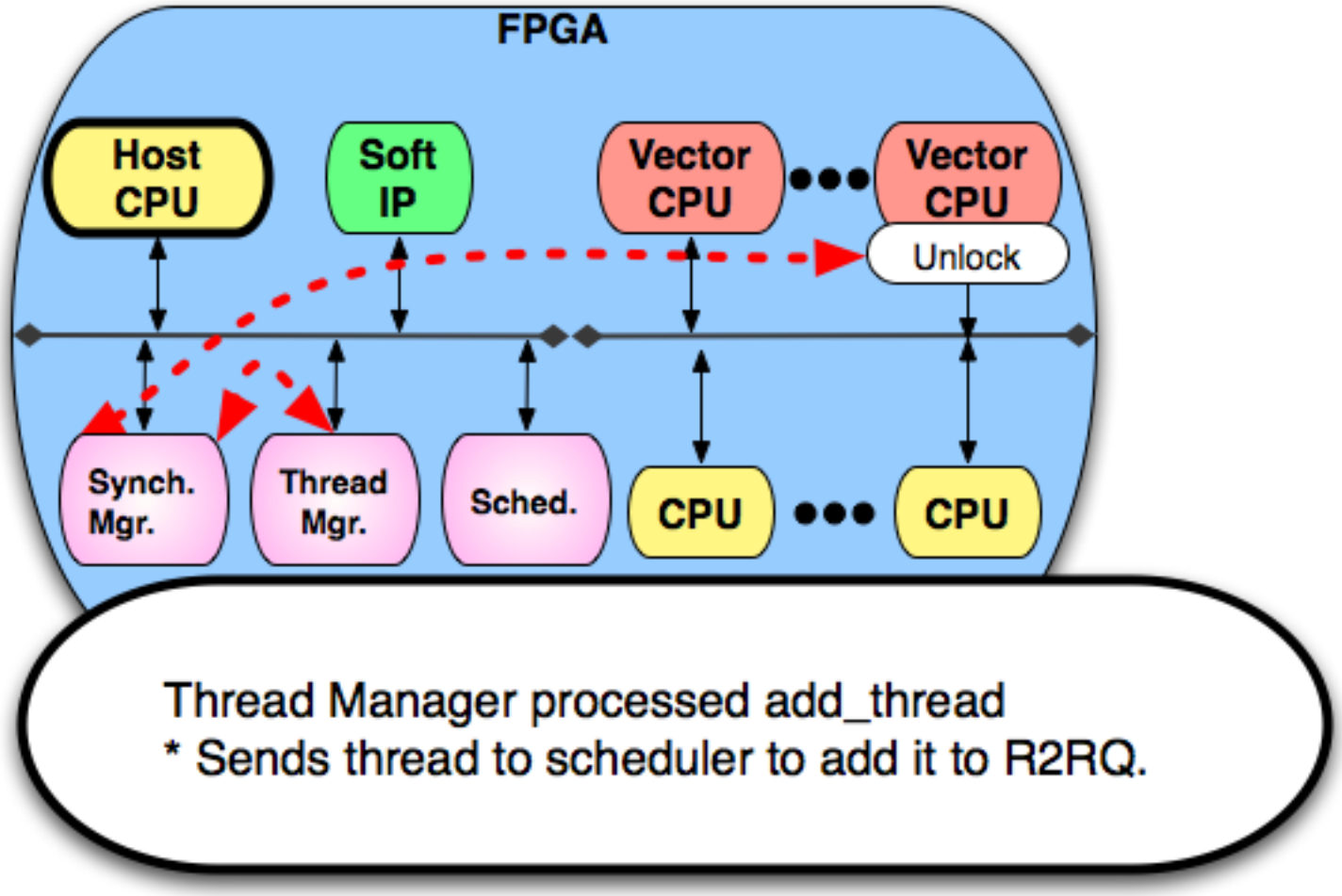
hthreads OS Framework



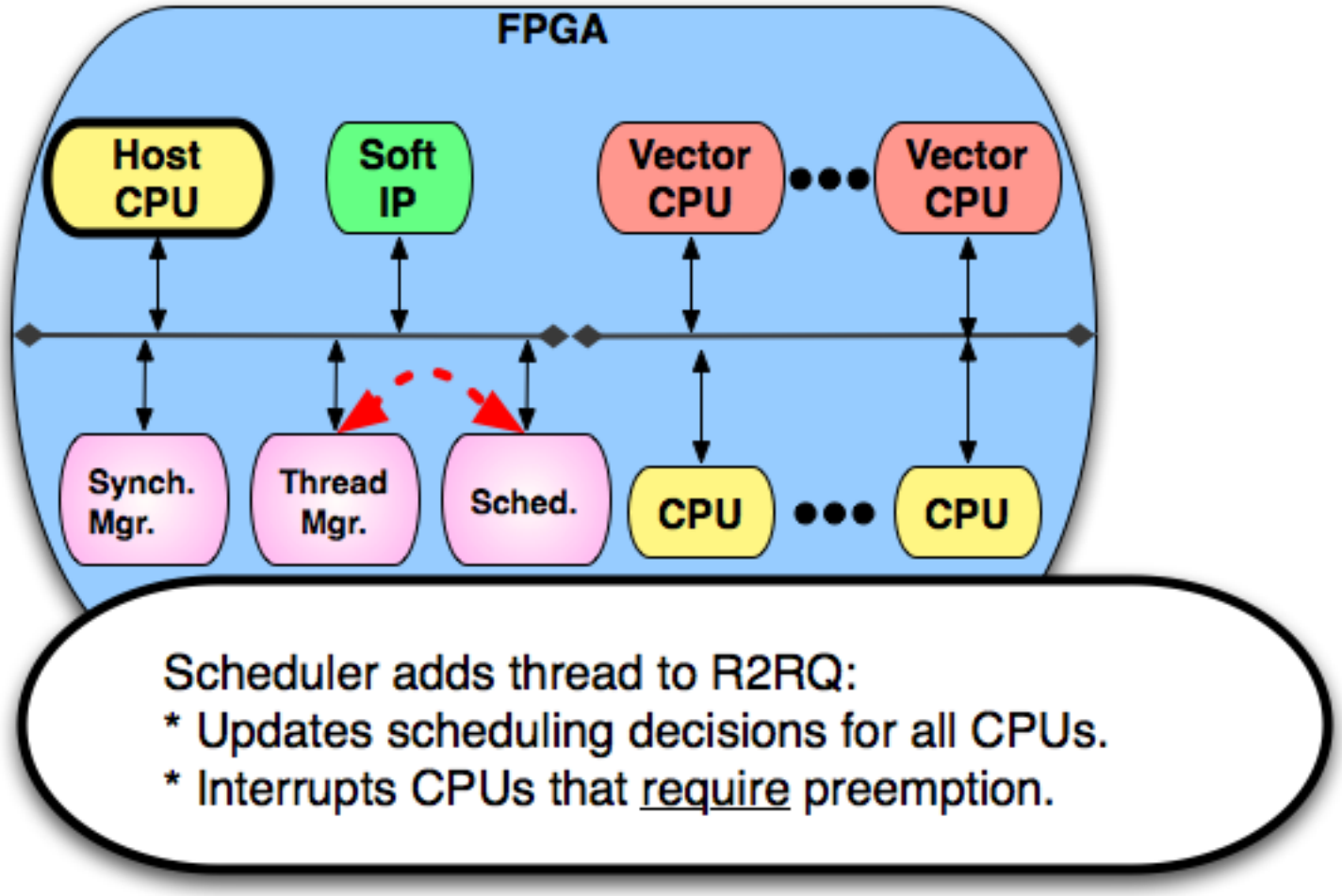
hthreads OS Framework



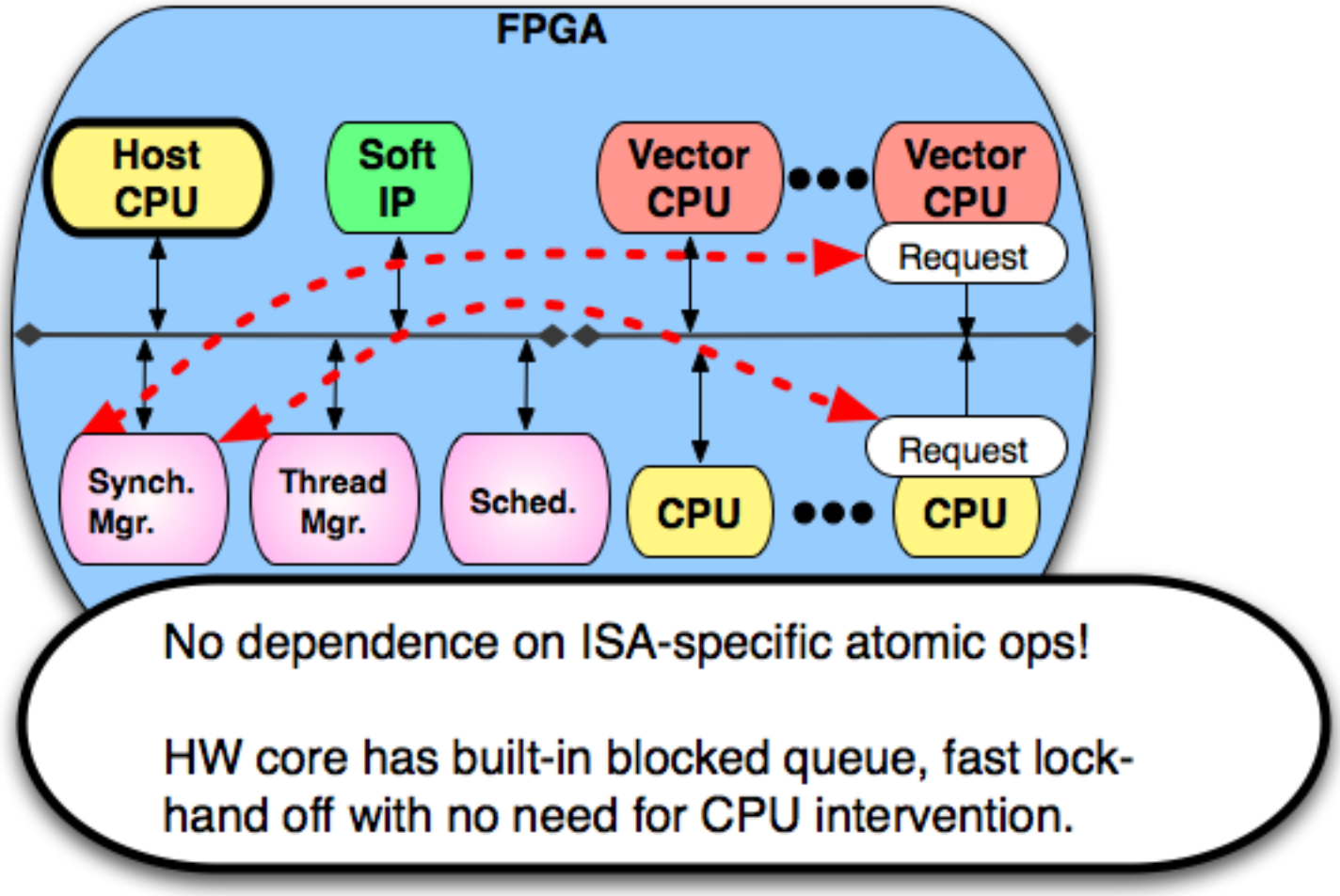
hthreads OS Framework



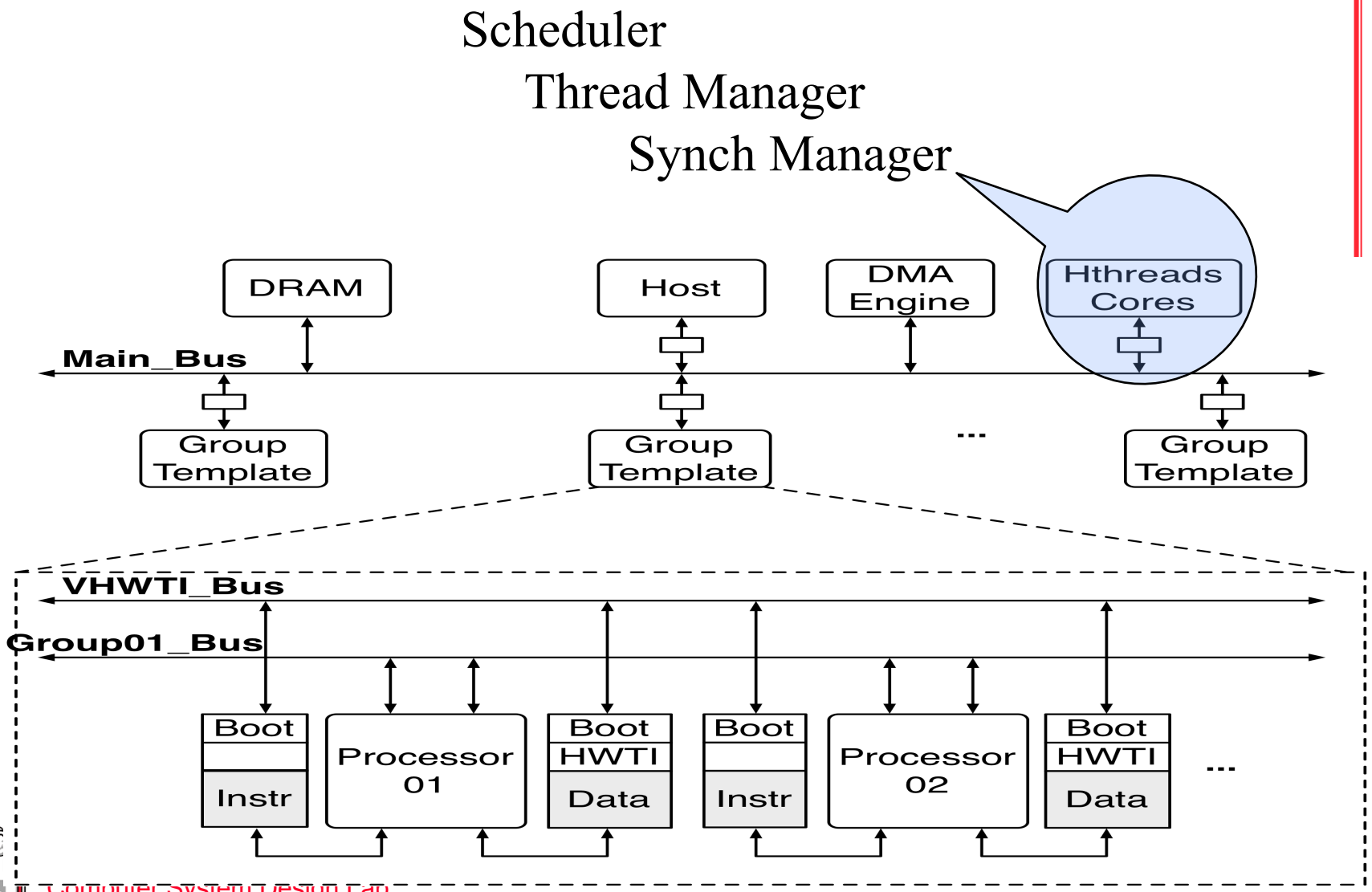
hthreads OS Framework

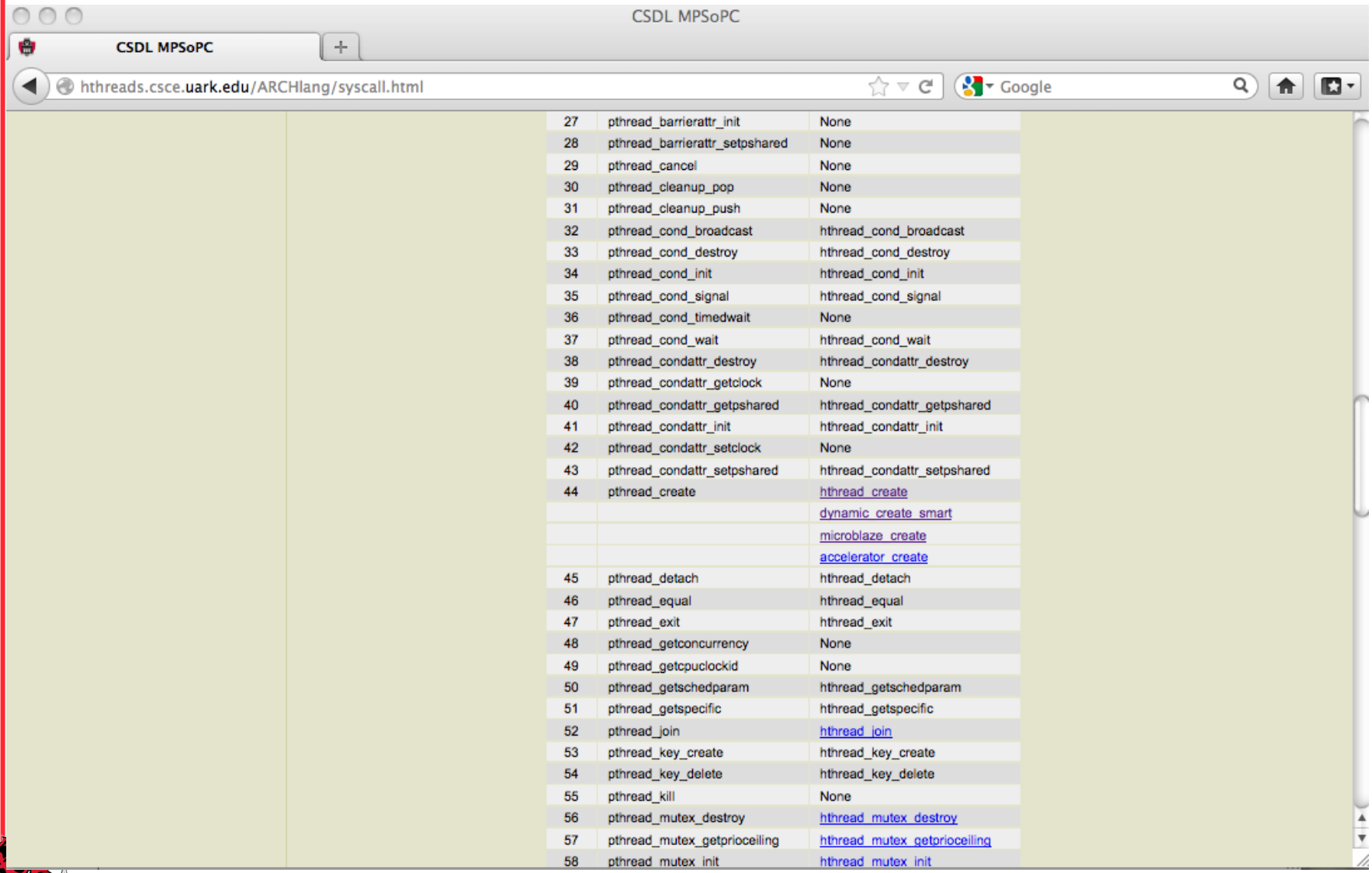


hthreads OS Framework



Pthreads Compliant Plus…….





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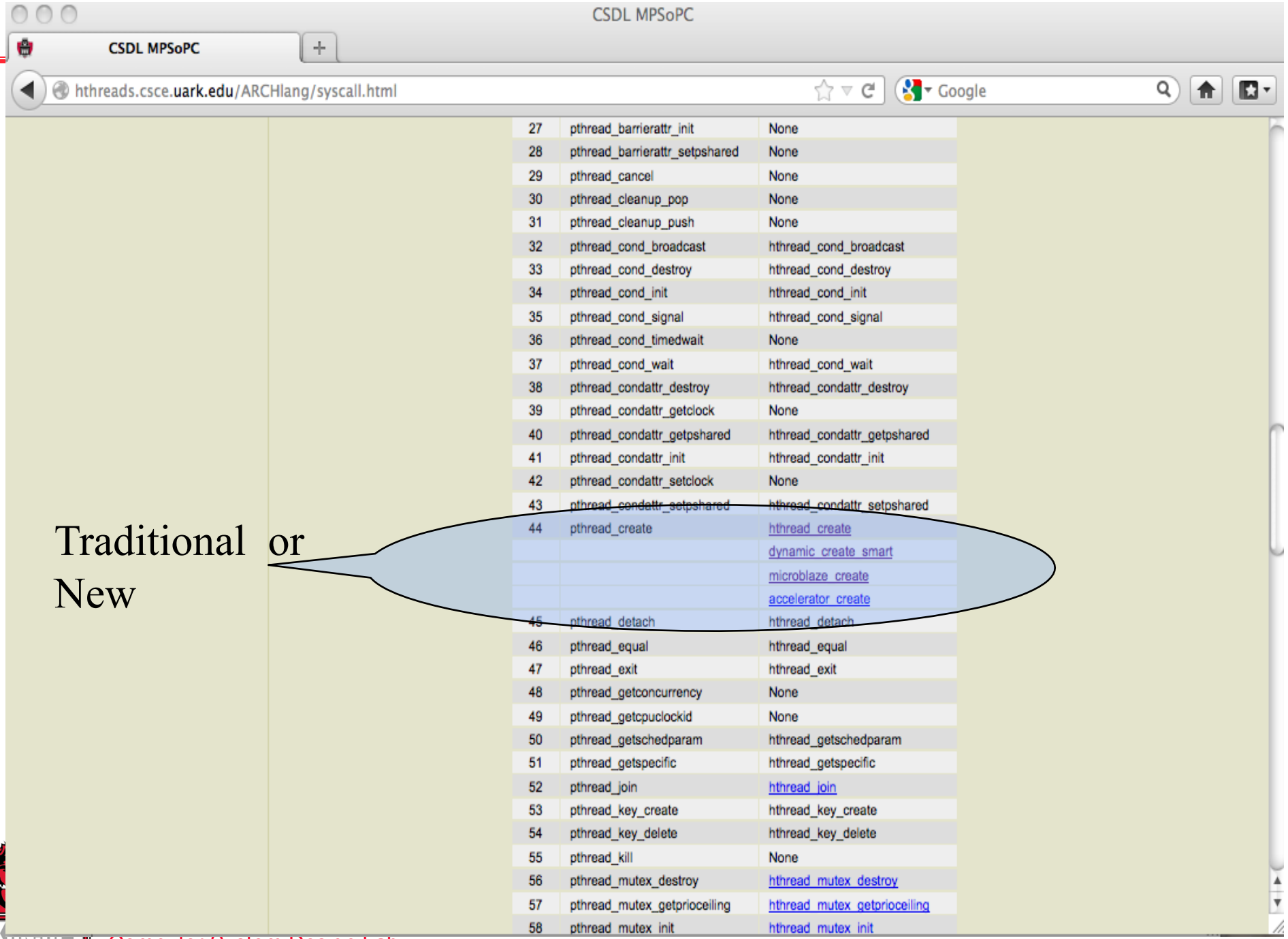
28	pthread_barrierattr_setpshared	None
29	pthread_cancel	None
30	pthread_cleanup_pop	None
31	pthread_cleanup_push	None
32	pthread_cond_broadcast	hthread_cond_broadcast
33	pthread_cond_destroy	hthread_cond_destroy
34	pthread_cond_init	hthread_cond_init
35	pthread_cond_signal	hthread_cond_signal
36	pthread_cond_timedwait	None
37	pthread_cond_wait	hthread_cond_wait
38	pthread_condattr_destroy	hthread_condattr_destroy
39	pthread_condattr_getclock	None
40	pthread_condattr_getpshared	hthread_condattr_getpshared
41	pthread_condattr_init	hthread_condattr_init
42	pthread_condattr_setclock	None
43	pthread_condattr_setpshared	hthread_condattr_setpshared
44	pthread_create	hthread_create
		dynamic_create_smart
		microblaze_create
		accelerator_create
45	pthread_detach	hthread_detach
46	pthread_equal	hthread_equal
47	pthread_exit	hthread_exit
48	pthread_getconcurrency	None
49	pthread_getcpuclockid	None
50	pthread_getschedparam	hthread_getschedparam
51	pthread_getspecific	hthread_getspecific
52	pthread_join	hthread_join
53	pthread_key_create	hthread_key_create
54	pthread_key_delete	hthread_key_delete
55	pthread_kill	None
56	pthread_mutex_destroy	hthread_mutex_destroy
57	pthread_mutex_getprioceiling	hthread_mutex_getprioceiling
58	pthread_mutex_init	hthread_mutex_init



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28	pthread_barrierattr_setpshared	None
29	pthread_cancel	None
30	pthread_cleanup_pop	None
31	pthread_cleanup_push	None
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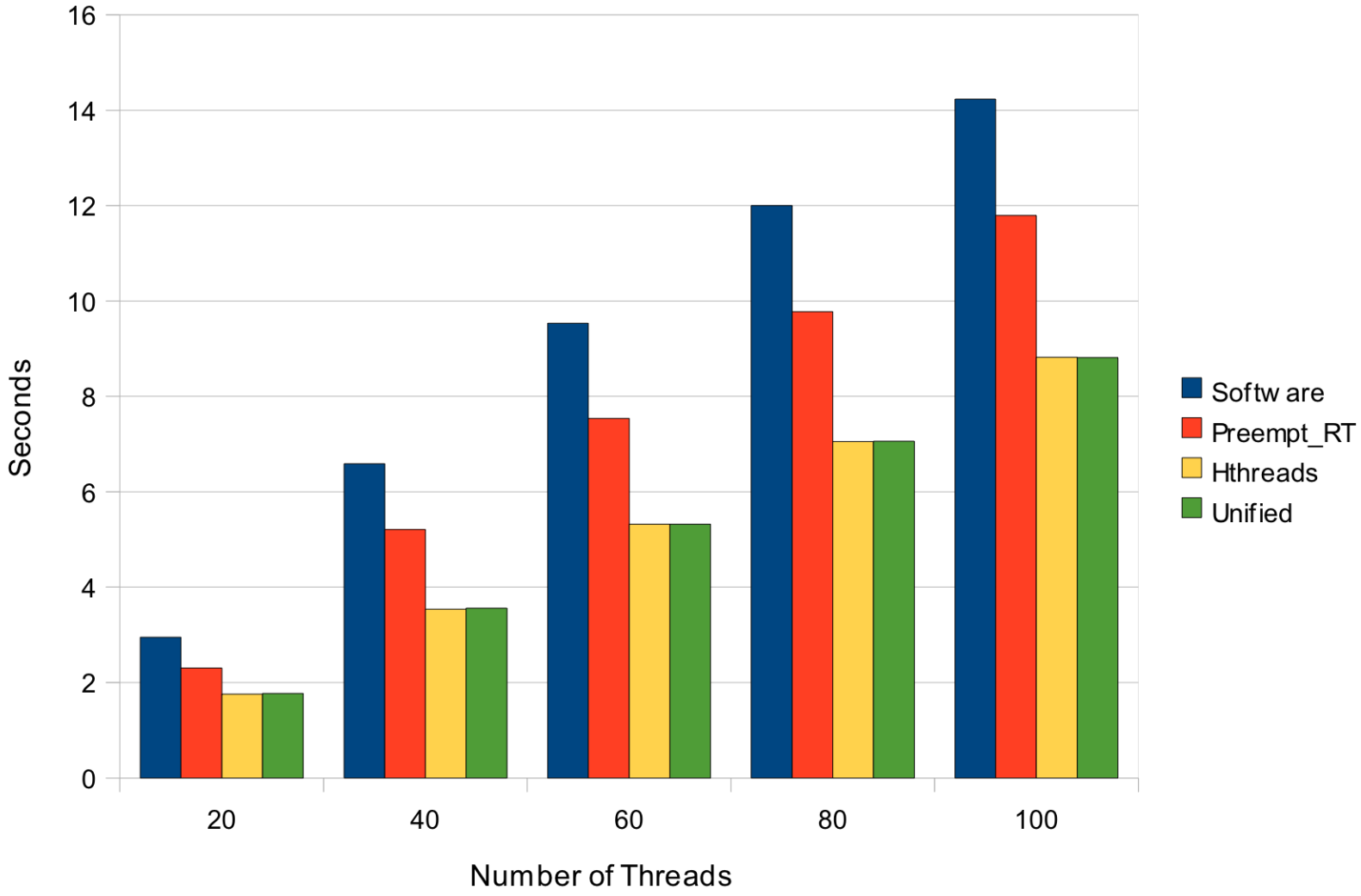
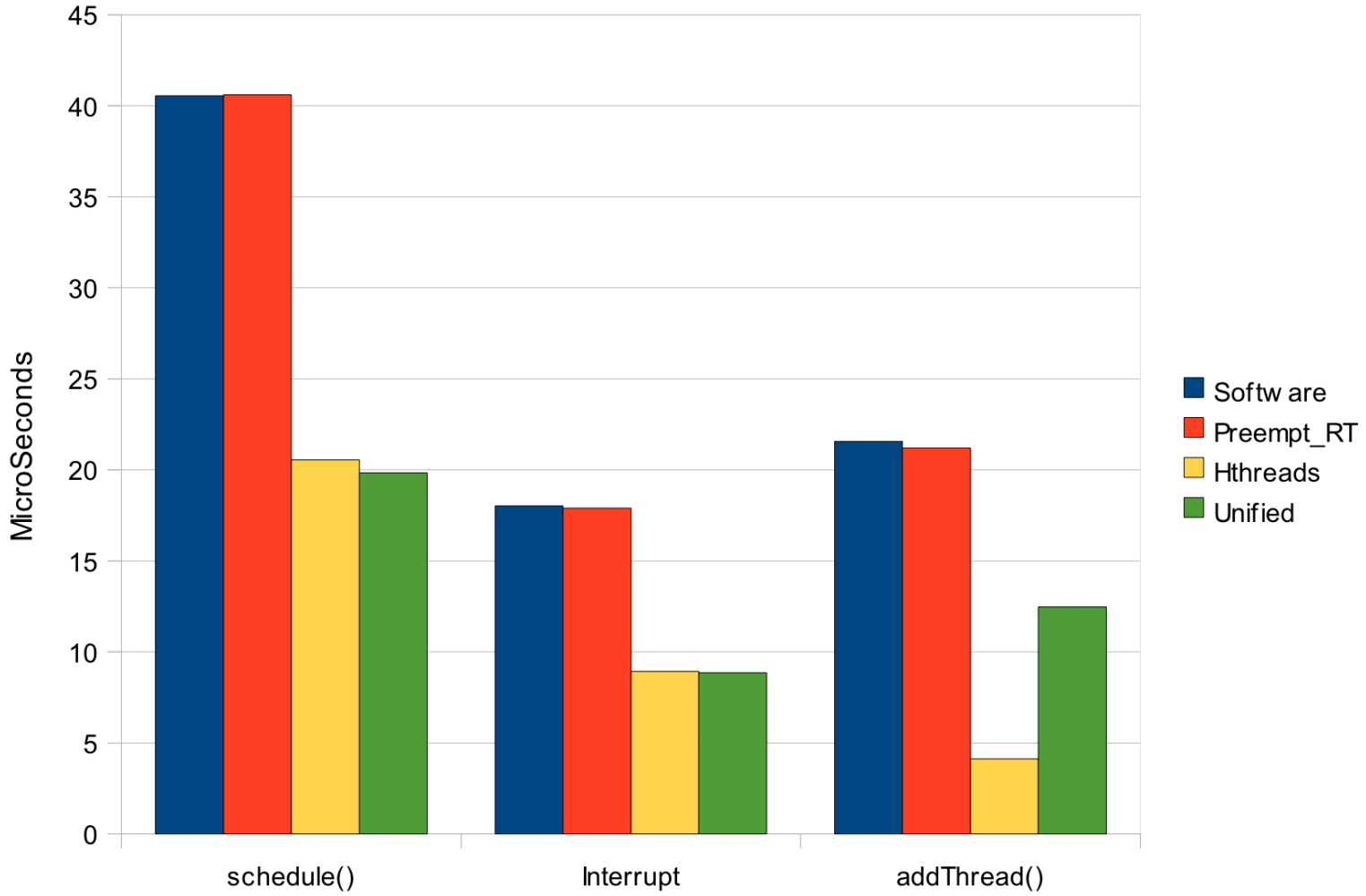
35	pthread_cond_signal	hthread_cond_signal
36	pthread_cond_timedwait	None
37	pthread_cond_wait	hthread_cond_wait
38	pthread_condattr_destroy	hthread_condattr_destroy
39	pthread_condattr_getclock	None
40	pthread_condattr_getpshared	hthread_condattr_getpshared
41	pthread_condattr_init	hthread_condattr_init
42	pthread_condattr_setclock	None
43	pthread_condattr_setpshared	hthread_condattr_setpshared
44	pthread_create	hthread_create
		dynamic_create_smart
		microblaze_create
		accelerator_create
45	pthread_detach	hthread_detach
46	pthread_equal	hthread_equal
47	pthread_exit	hthread_exit
48	pthread_getconcurrency	None
49	pthread_getcpuclockid	None
50	pthread_getschedparam	hthread_getschedparam
51	pthread_getspecific	hthread_getspecific
52	pthread_join	hthread_join
53	pthread_key_create	hthread_key_create
54	pthread_key_delete	hthread_key_delete
55	pthread_kill	None
56	pthread_mutex_destroy	hthread_mutex_destroy
57	pthread_mutex_getprioceiling	hthread_mutex_getprioceiling
58	pthread_mutex_init	hthread_mutex_init

Traditional or New

Performance with Linux



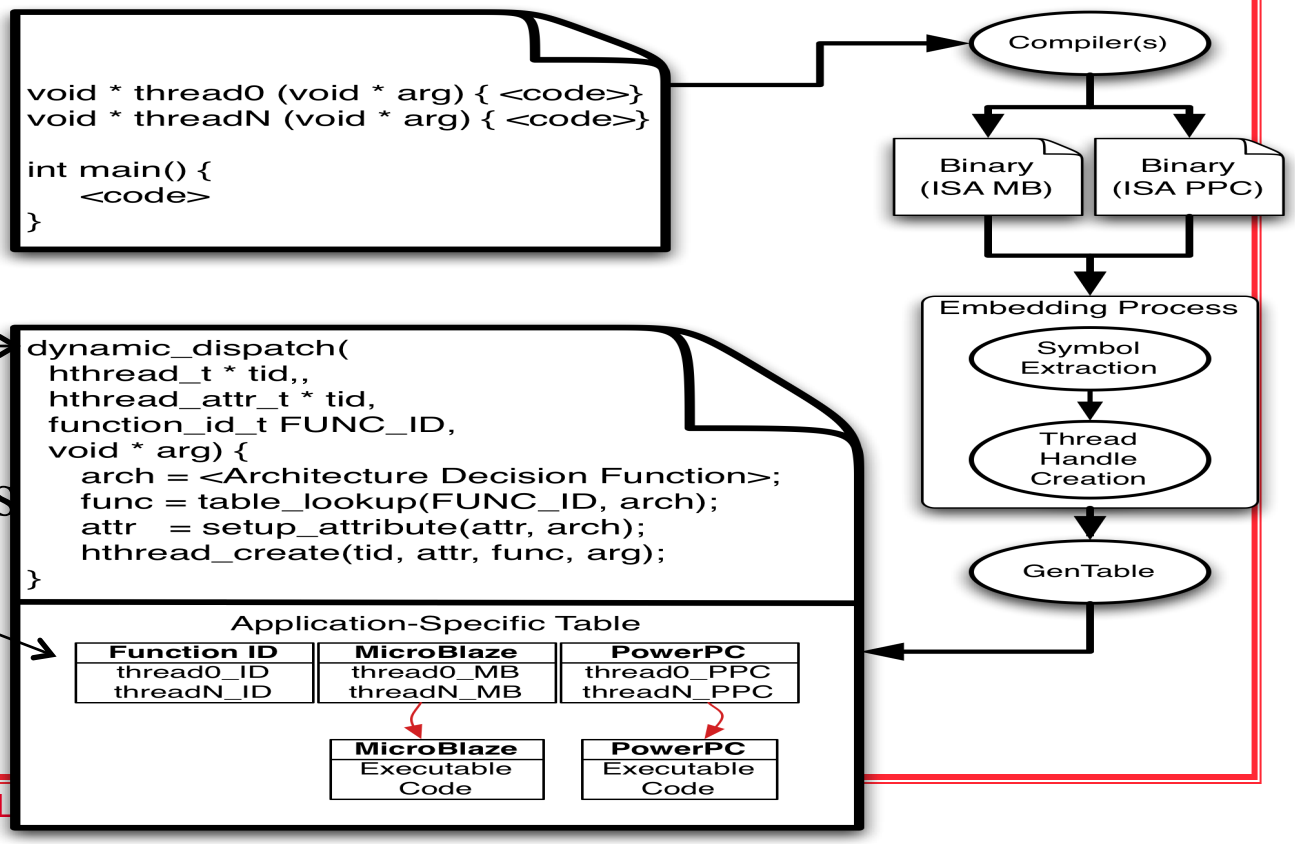
Performance with Linux



Pthreads Compliant Plus…….

```
int main(int argc, char *argv[]){
  for (i = 0; i < NUM_THREADS; i++){
        dynamic_create_smart( &hwThread[i], &hwAttr[i], (void*)
                                worker_thread_FUNC_ID, &arg[i] );
  }
}
```

sys_call
Schedules over all
Processor Resources



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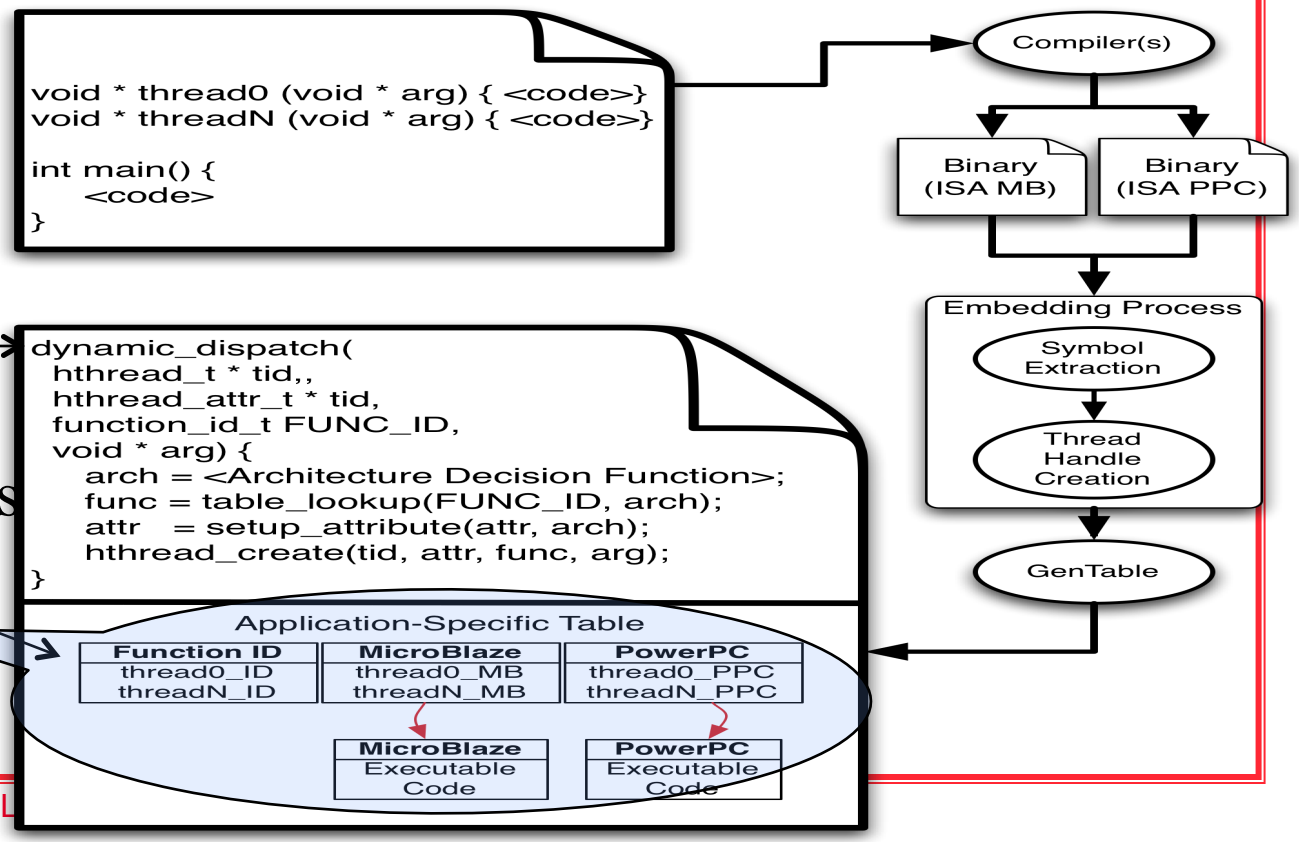
  }
}
```

sys_call
Schedules over all
Processor Resources

.exe's for each
Processor/accel



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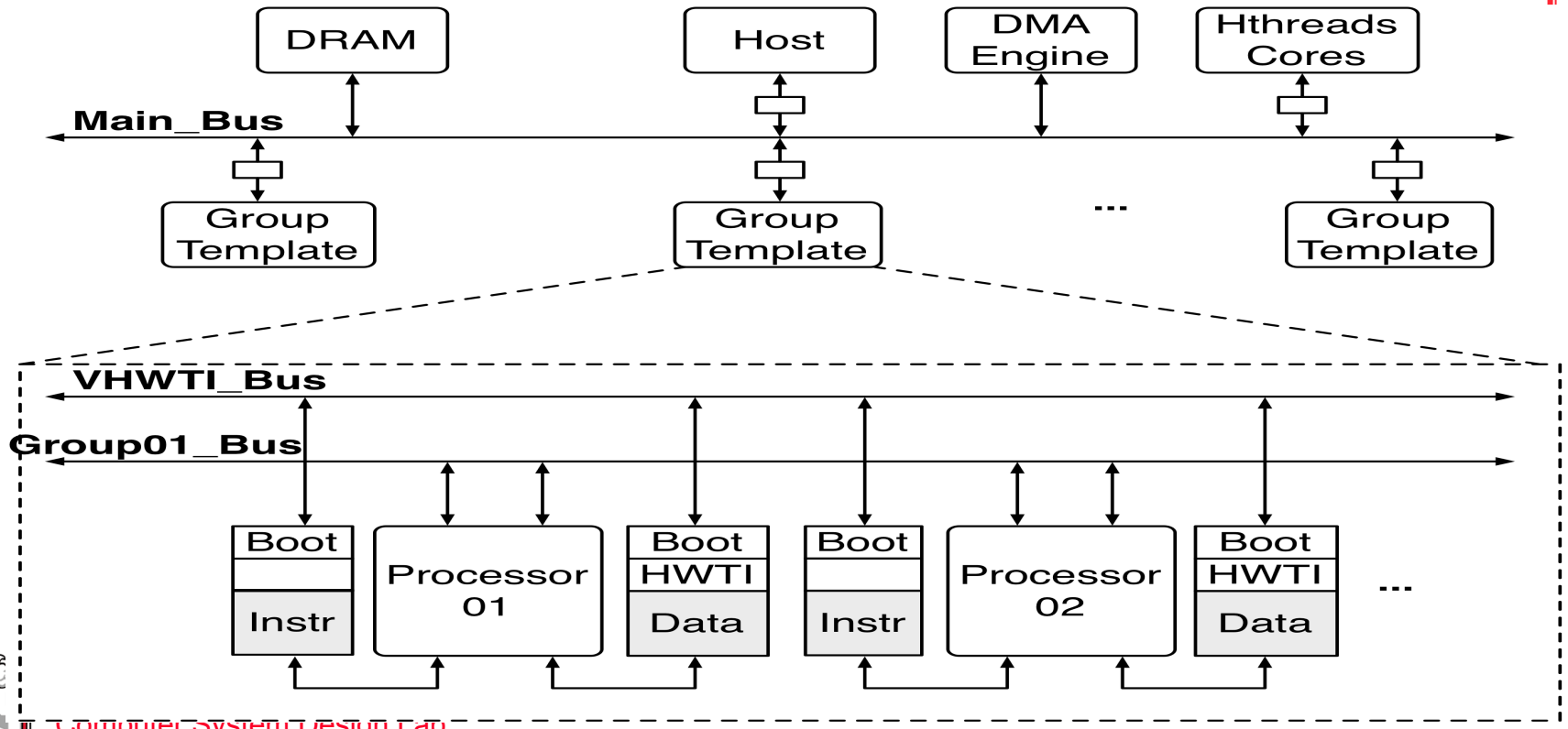

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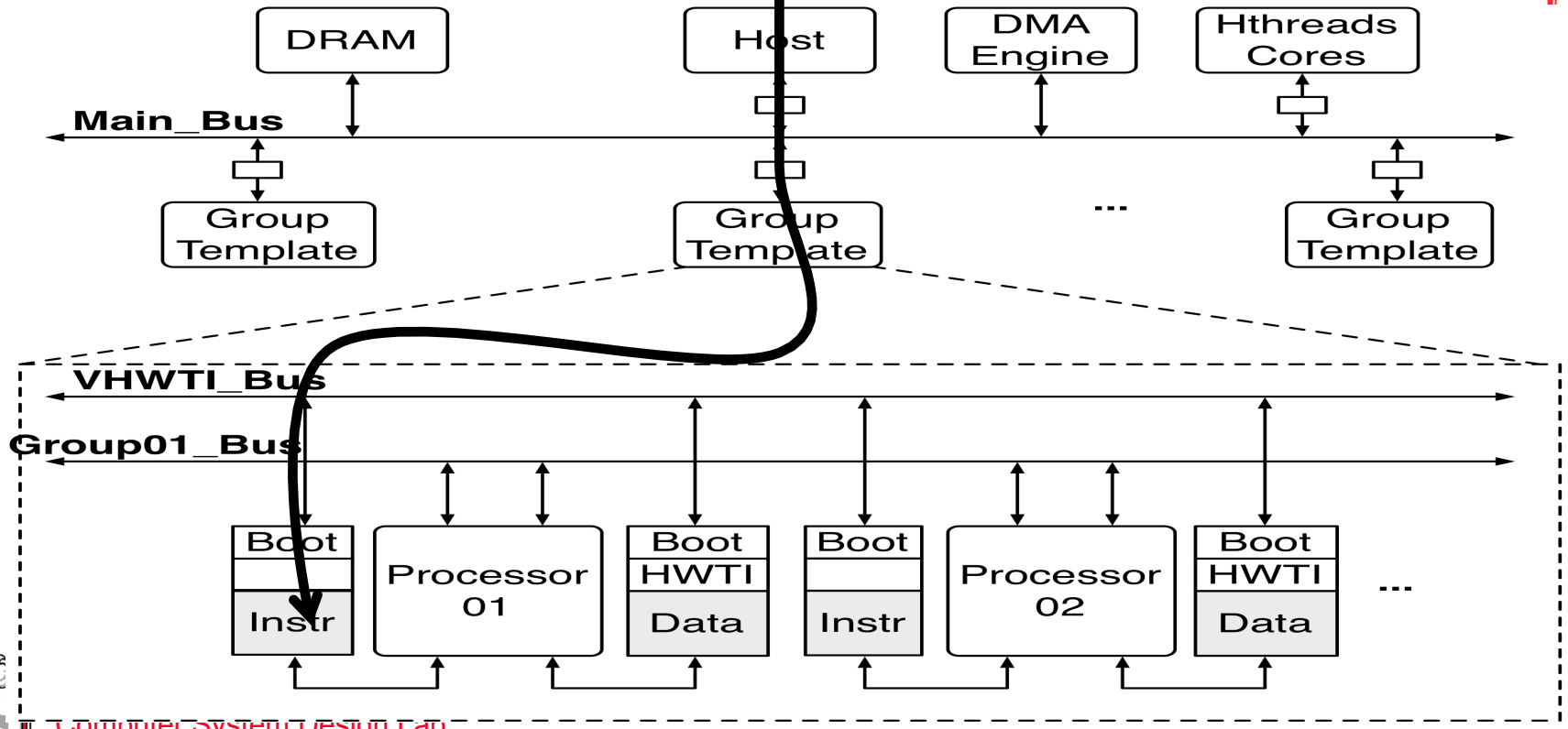

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}
```

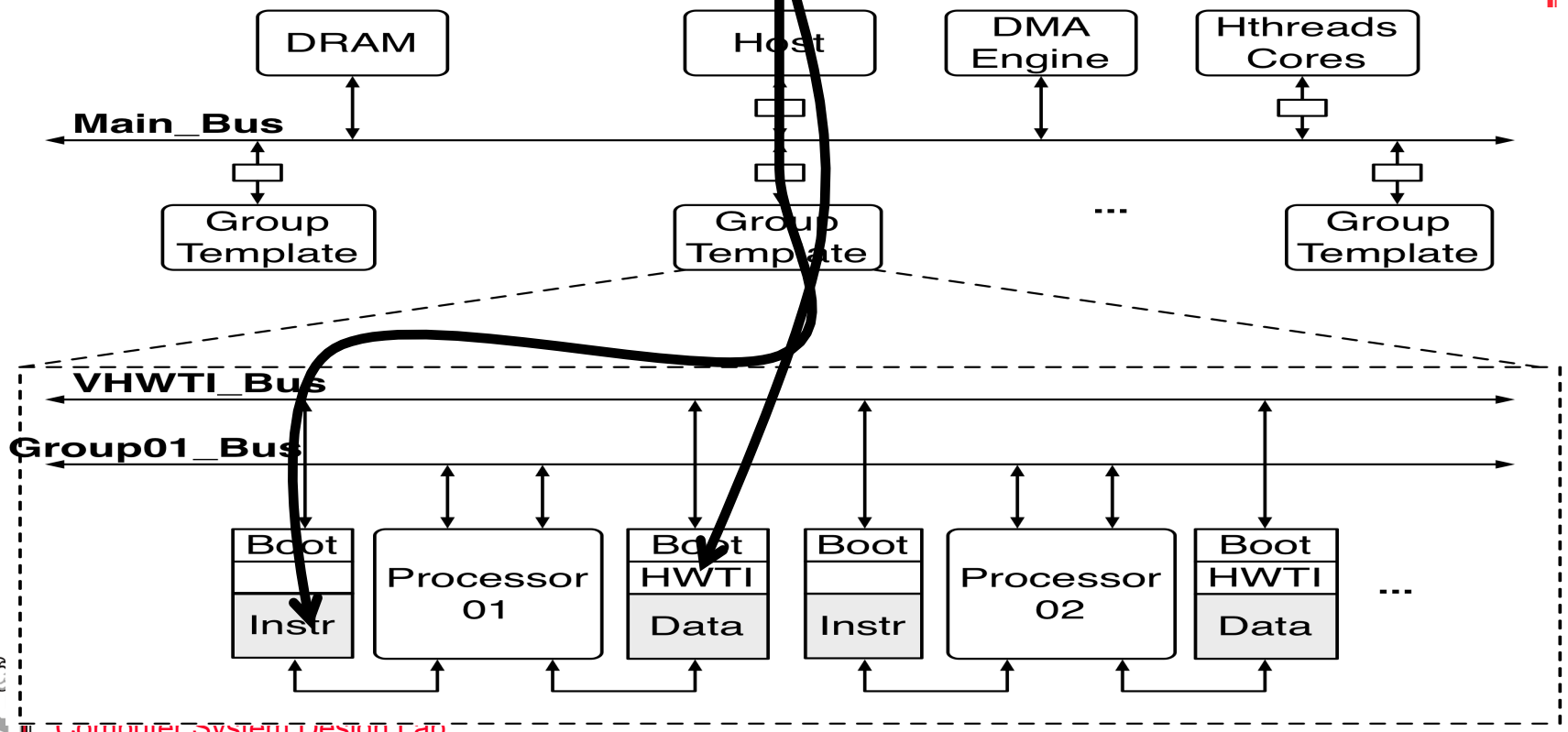

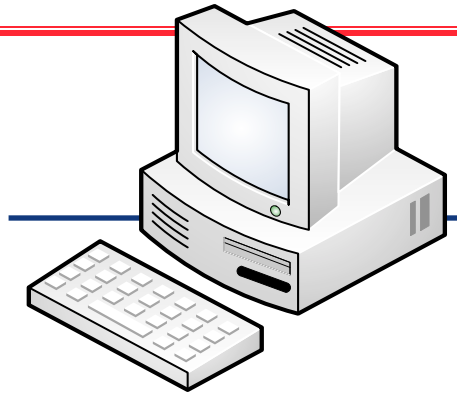

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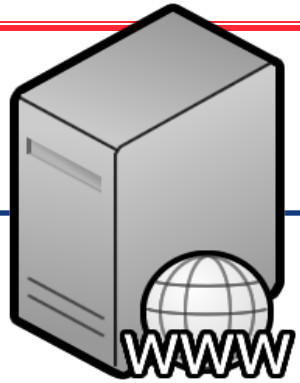
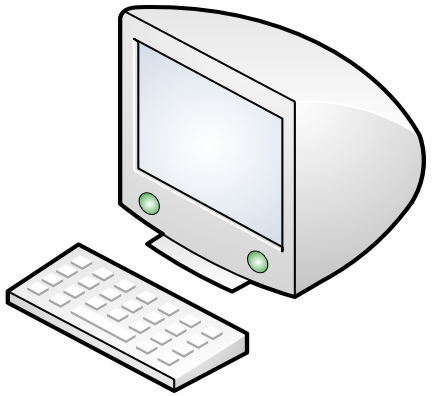


Hthreads System Build Serve



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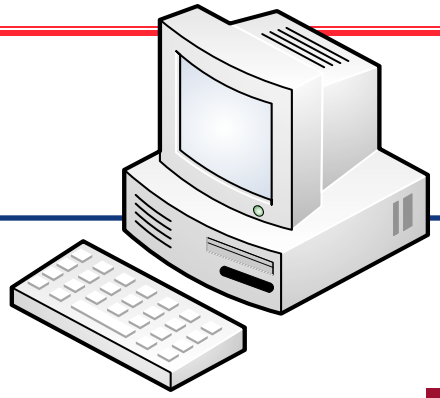

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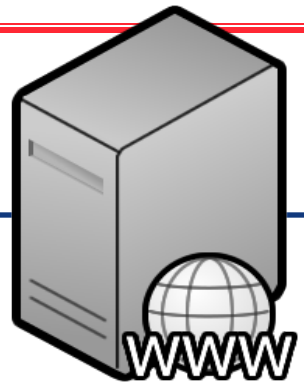
Hthreads System Build Page



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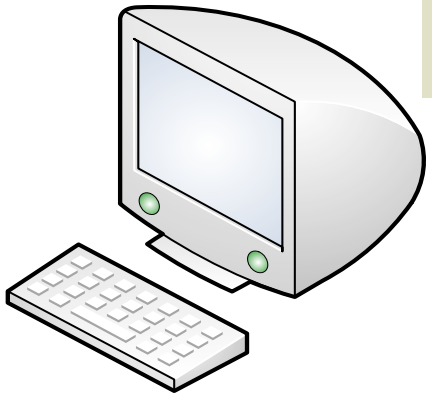

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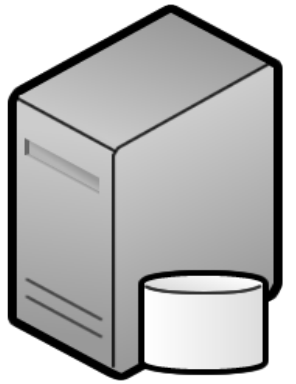

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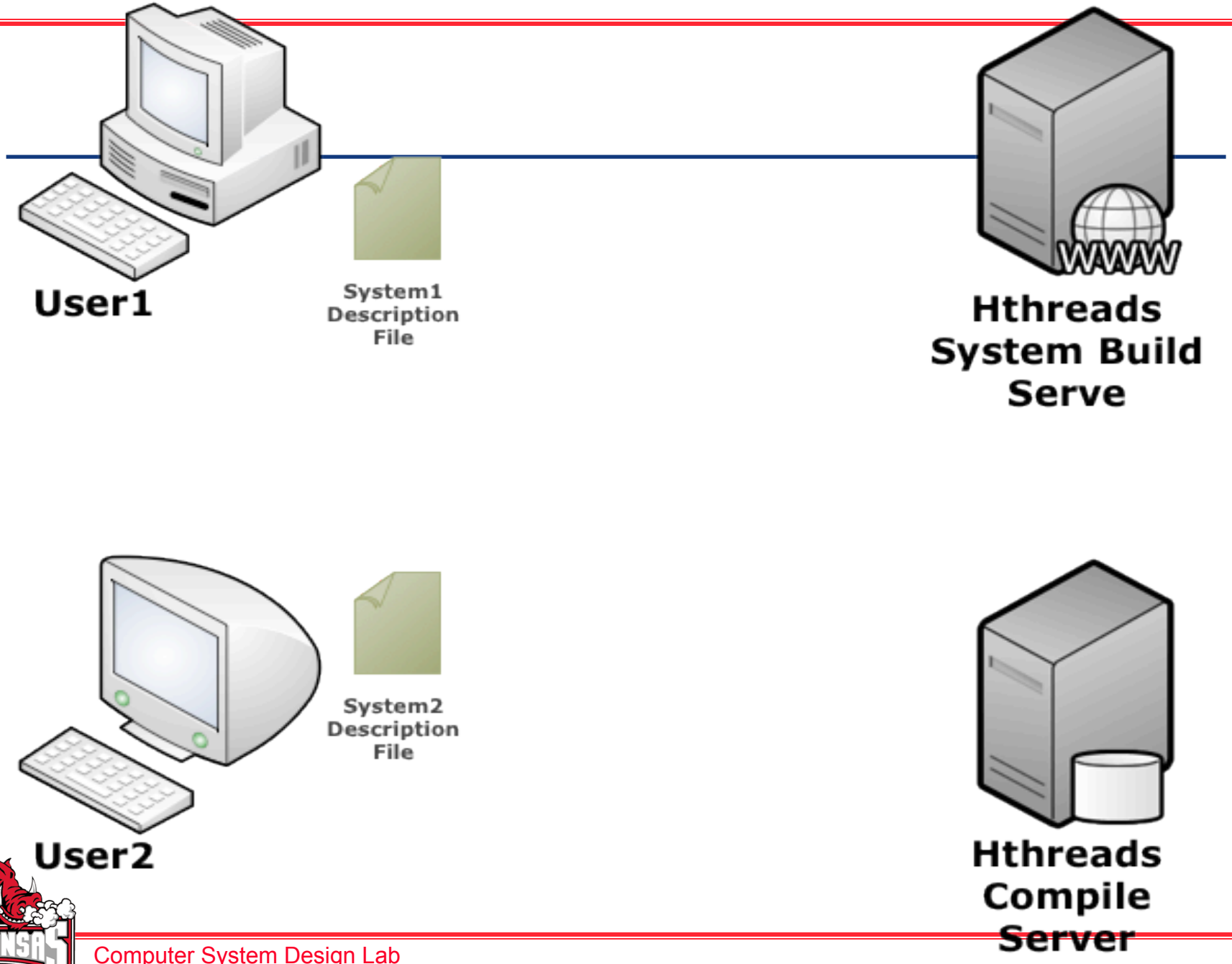
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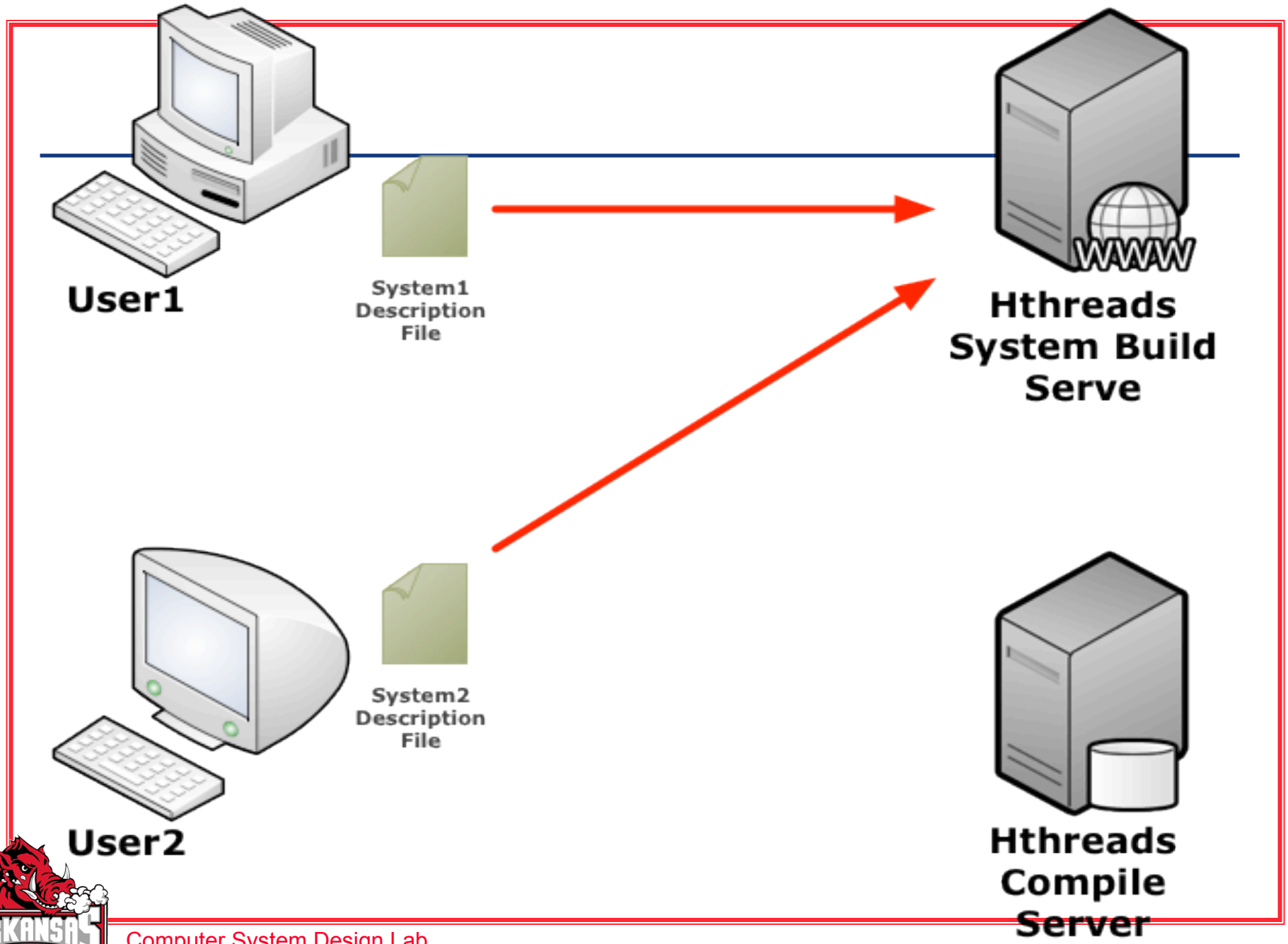
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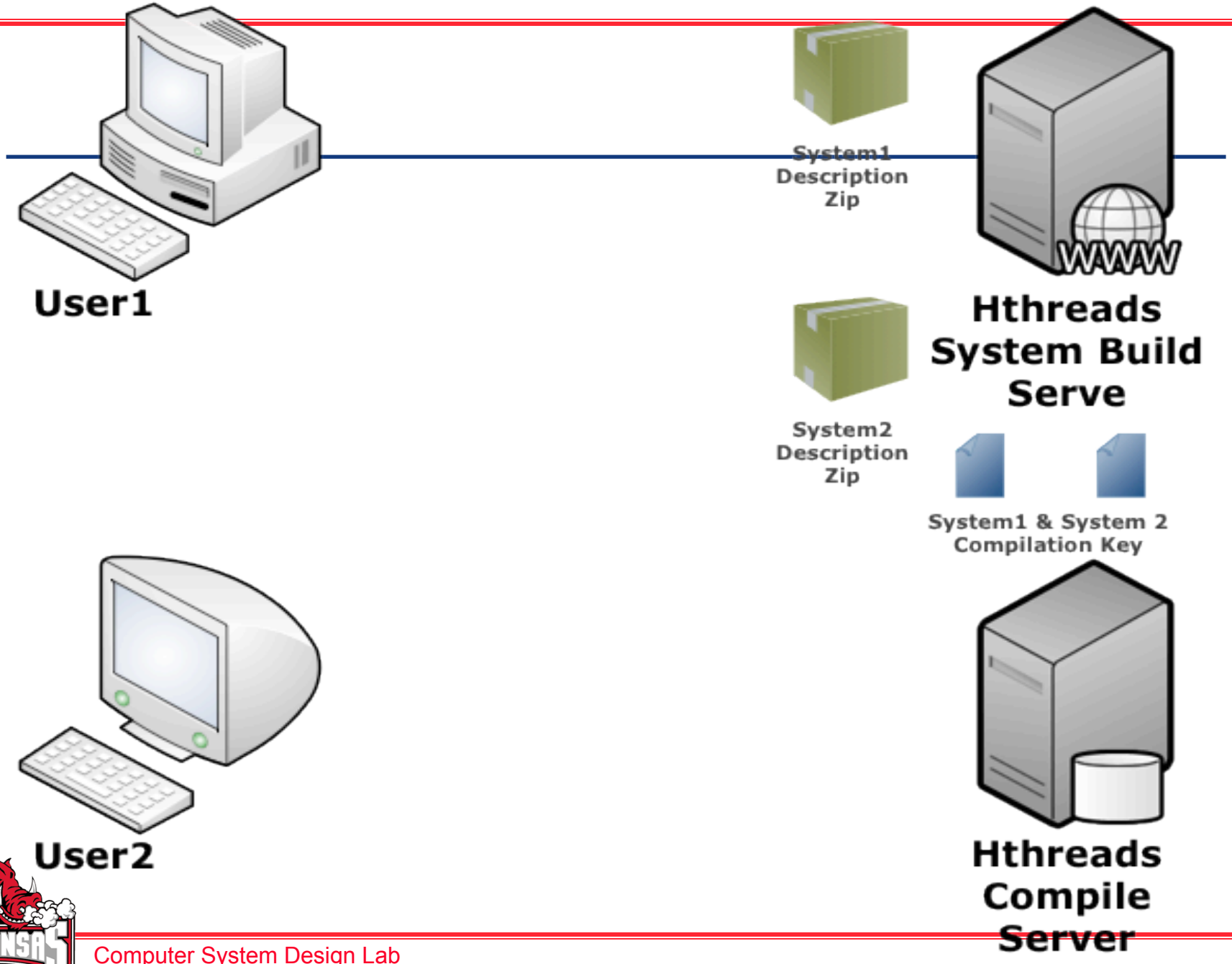
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Compilation Key
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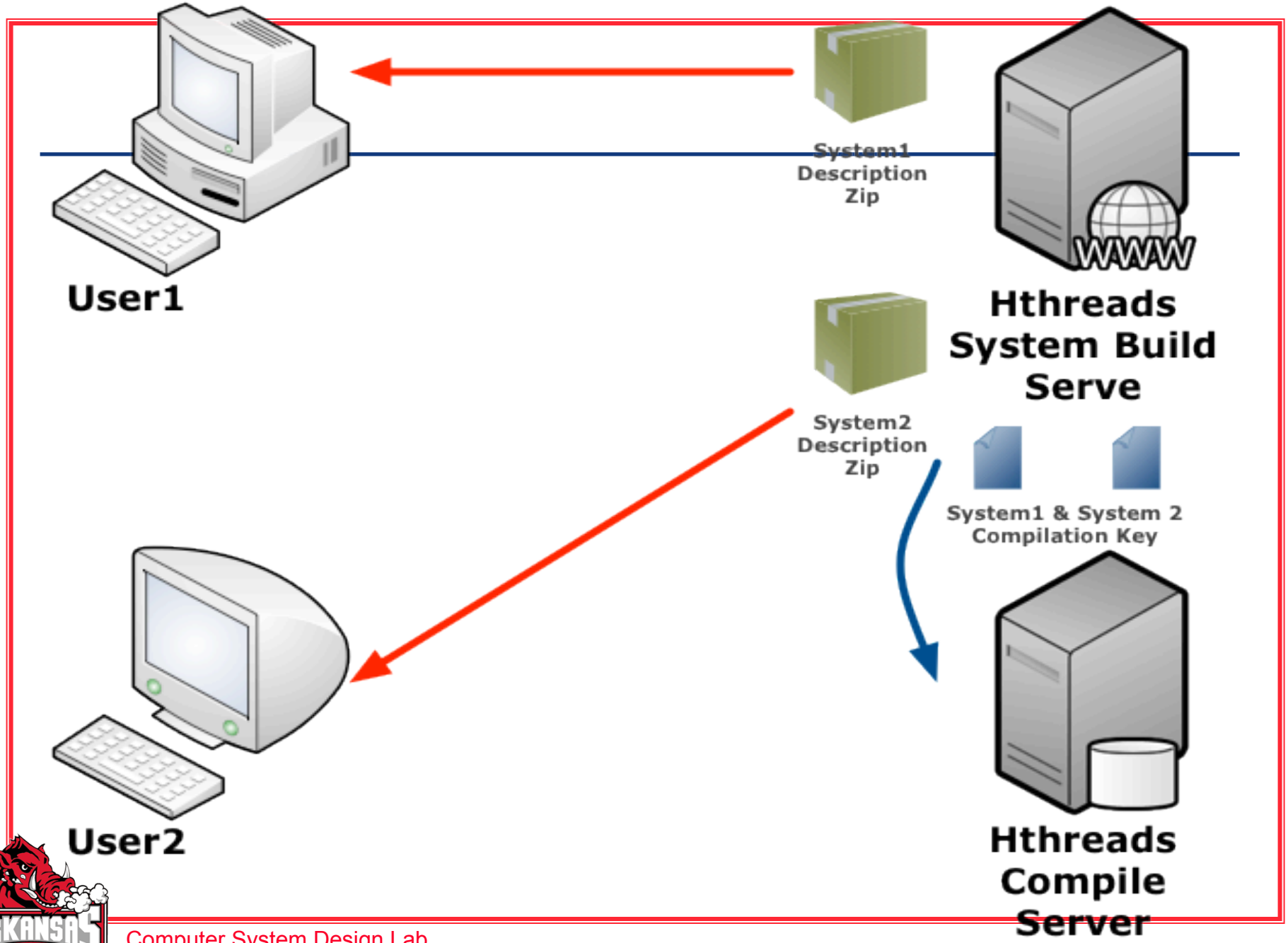
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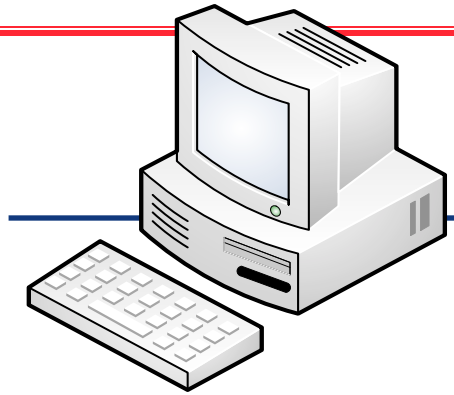

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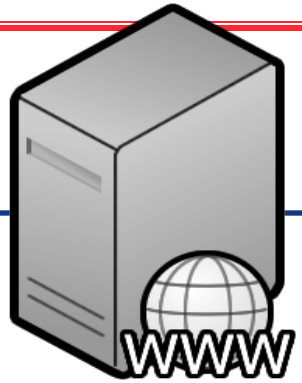
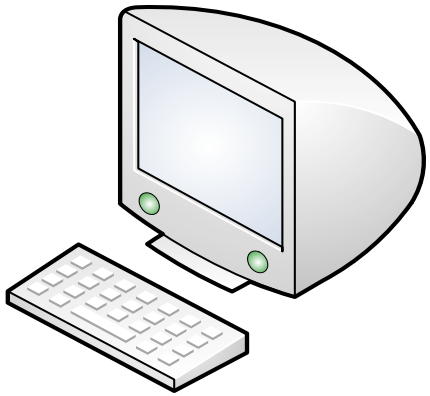


Hthreads System Build Serve



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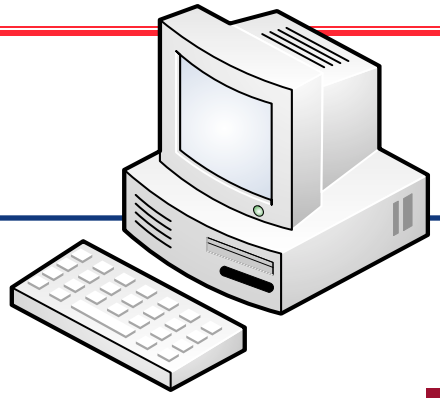
Hthreads Compile Server

Hthreads System Compilation Page



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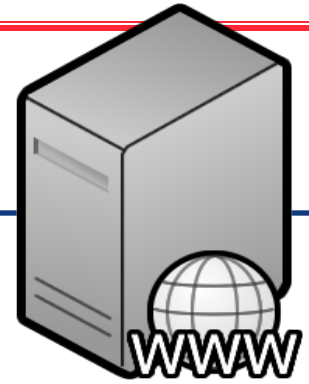

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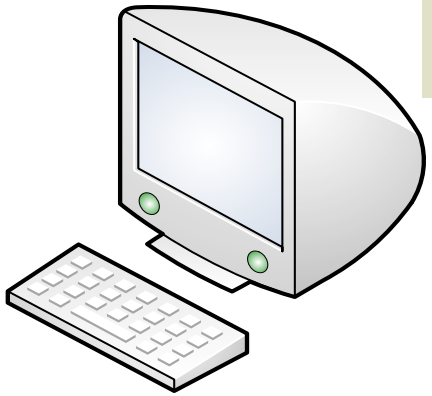

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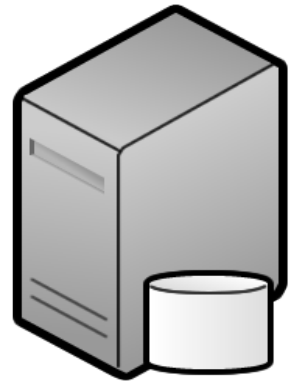

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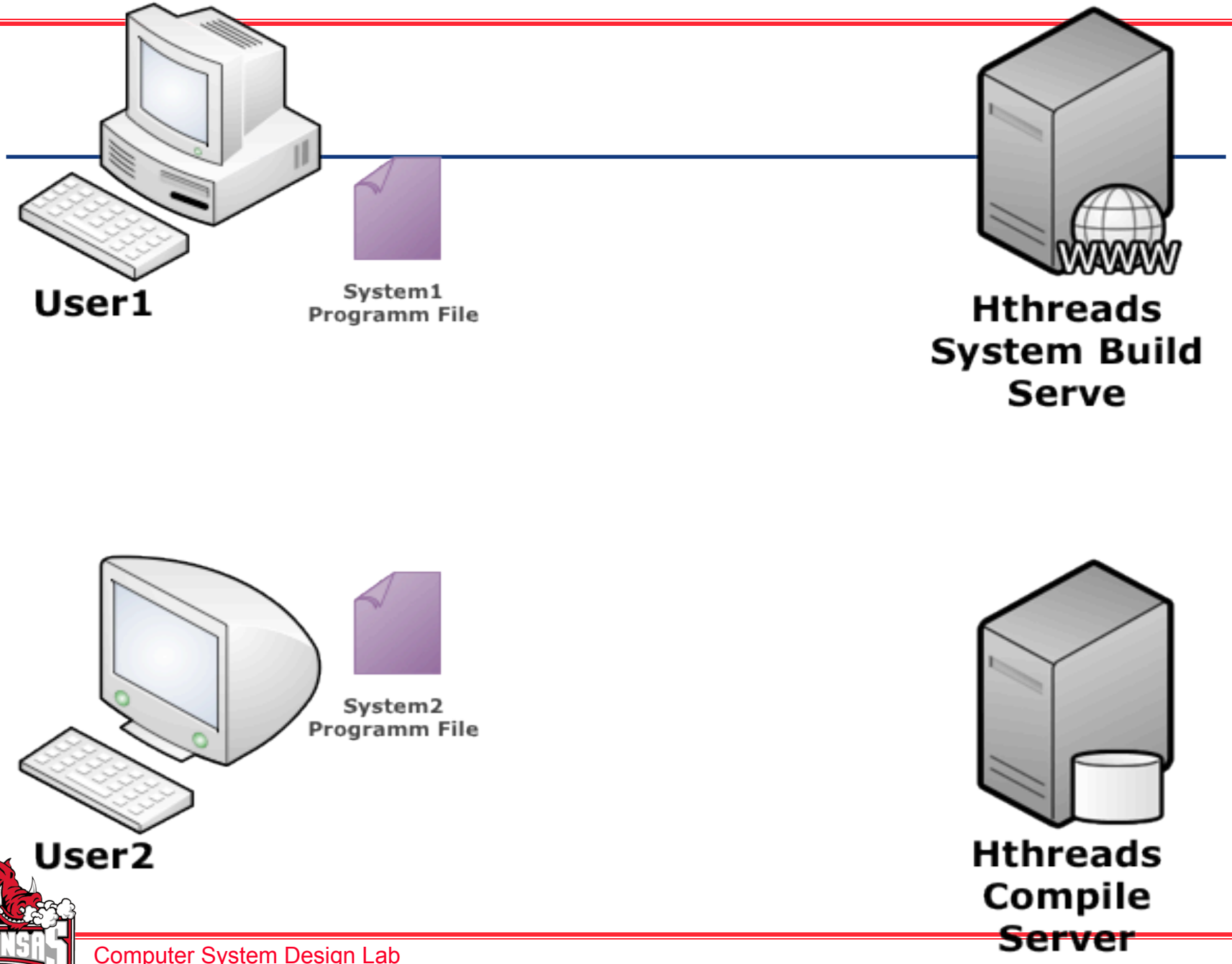
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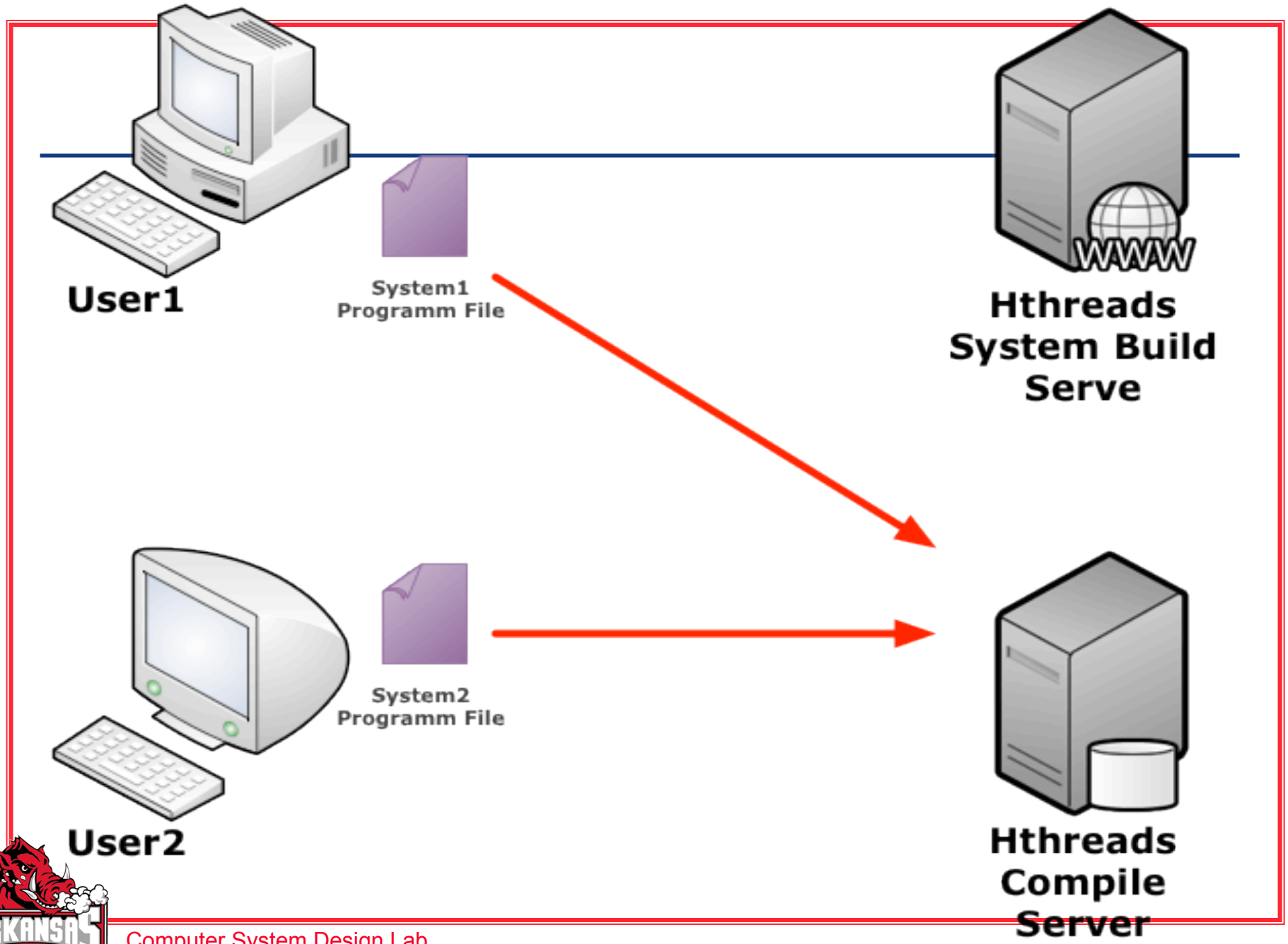
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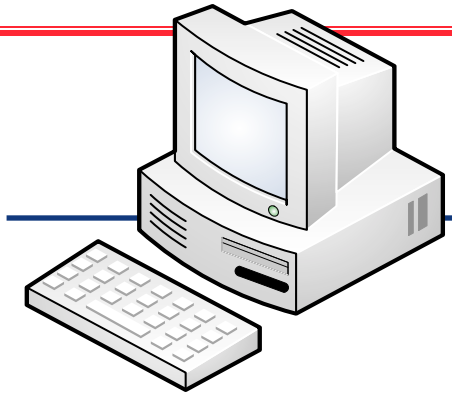

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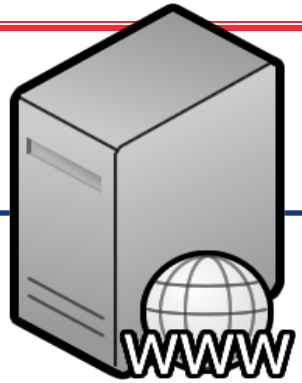

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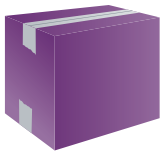

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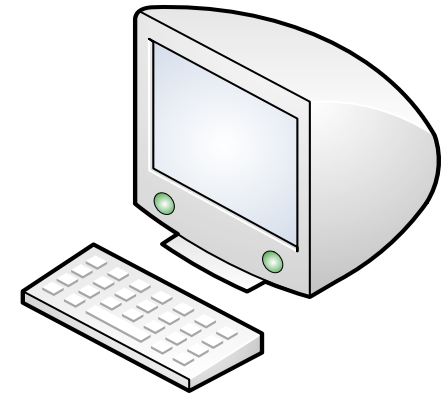

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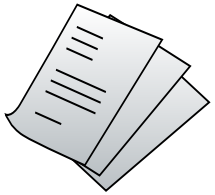
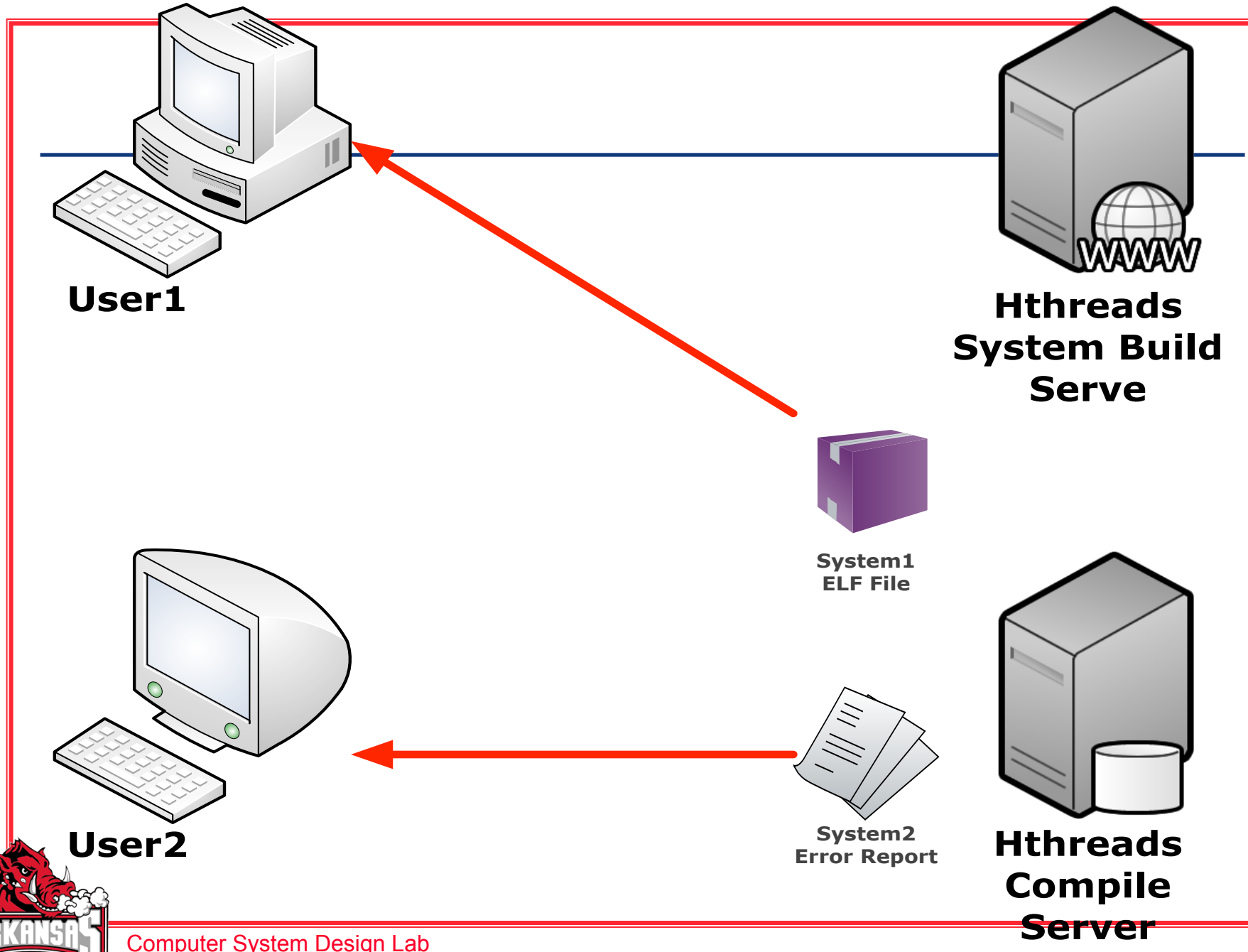


System2 Error Report

Hthreads Compile Server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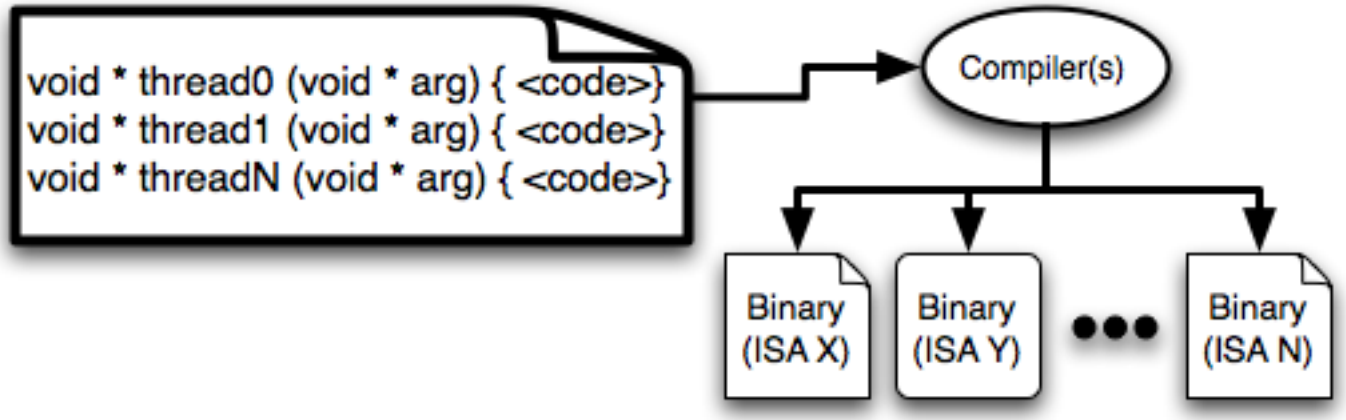
ELF File
User2
System2
Error Report
Hthreads
Compile
Server

Heterogeneous Compilation



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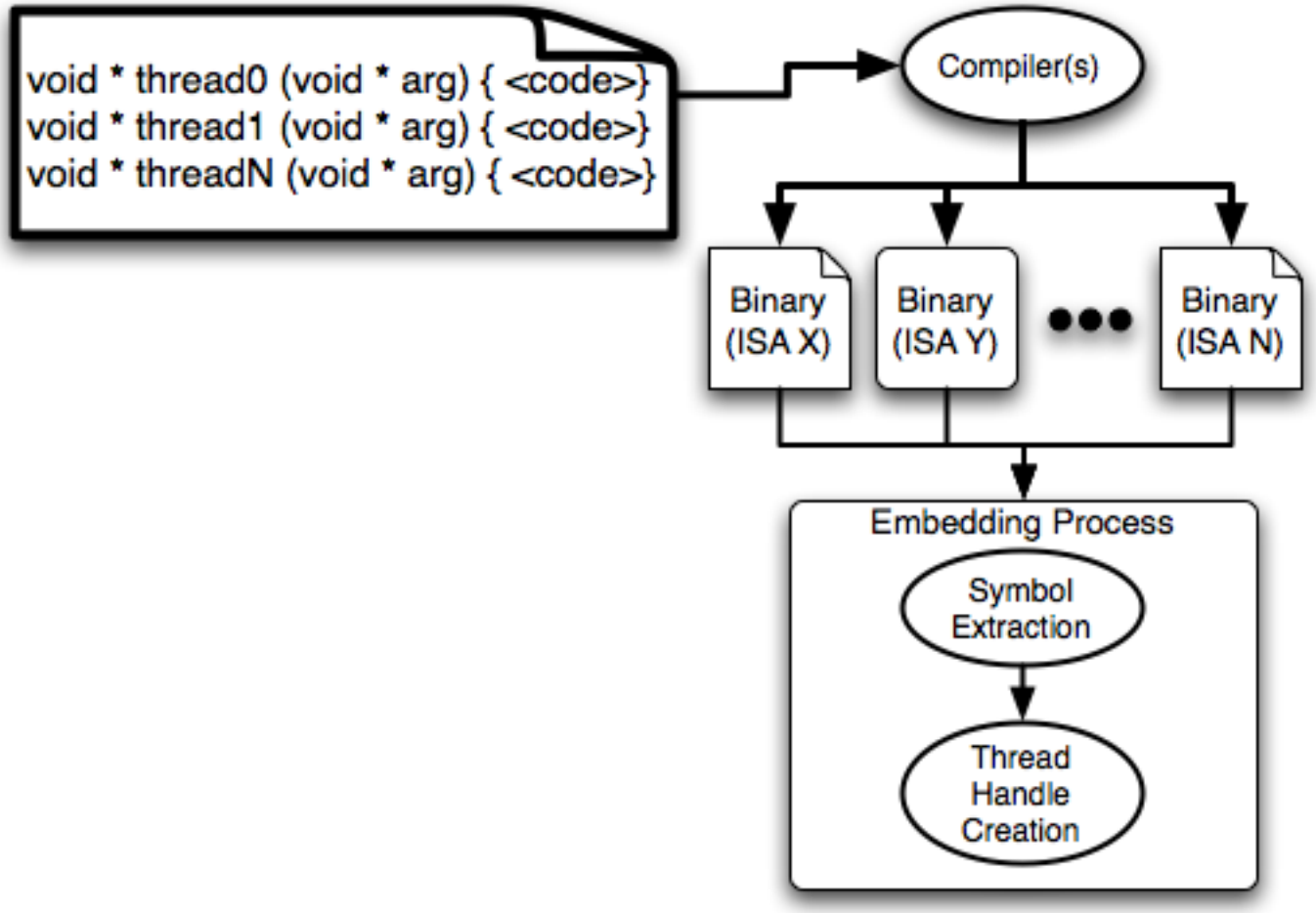

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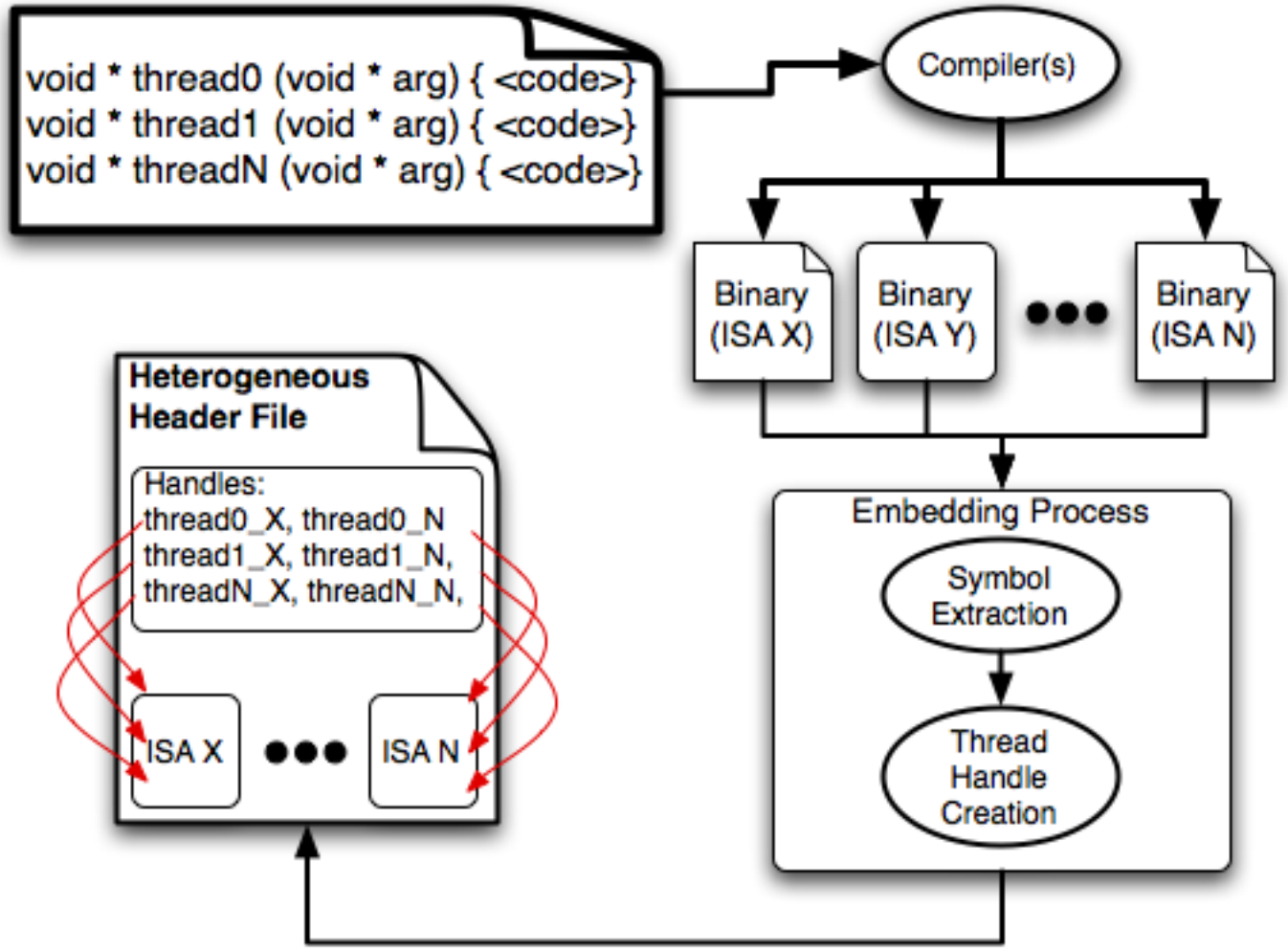
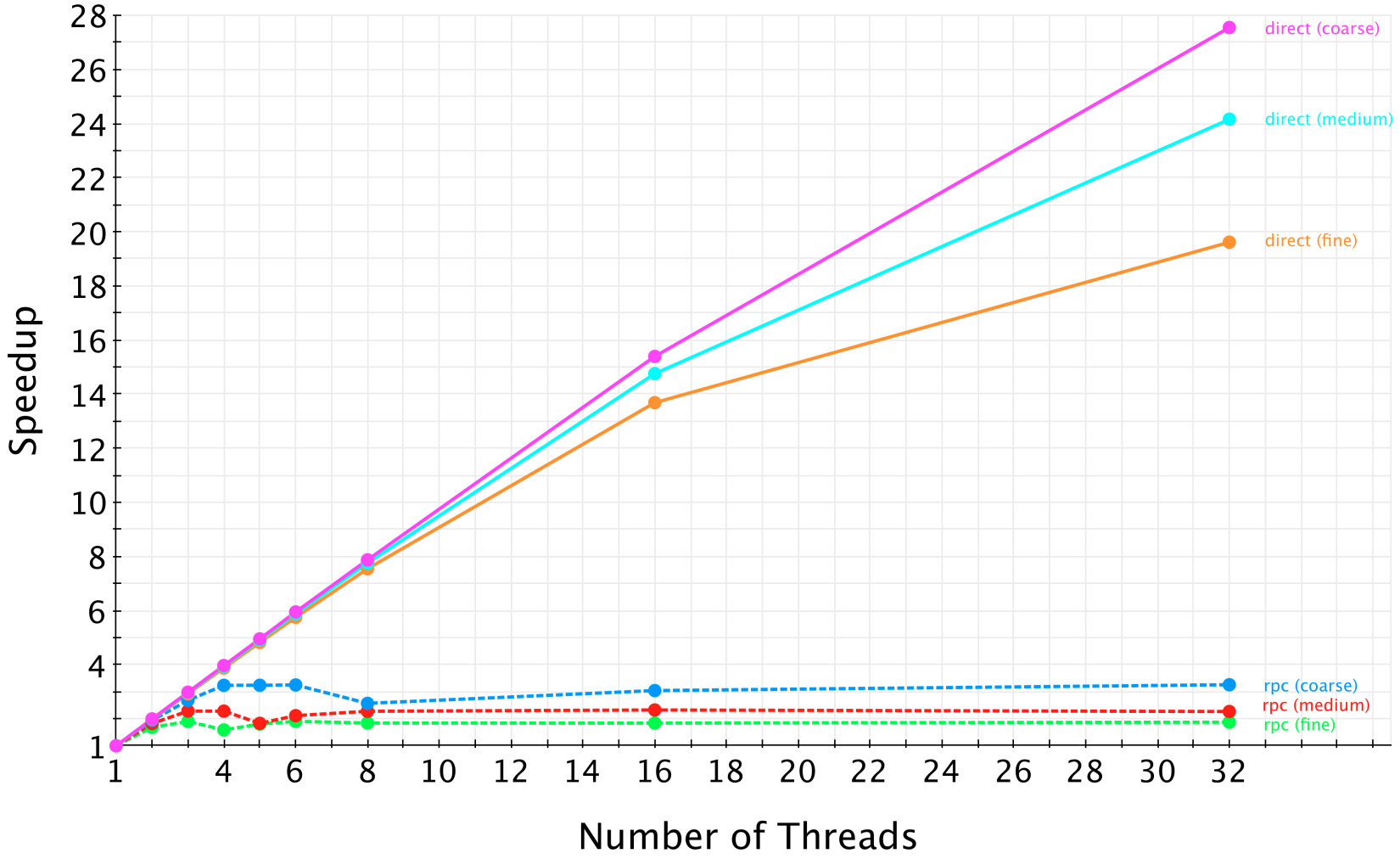


Utility: Overhead of RPC Calls



Utility: SMP/NUMA Comparisons

Table 1. SMP vs. NUMA (Six slave processors).

	Memory Hierarchy	Resource Requirement		Execution Time (μs)	Sp
		LUTs	BRAMs		
MM	Shared	34,051(22.6%)	286(68.8%)	12,711,517	
	Distr.	33,555(22.3%)	100(24.0%)	263,677	48
2D FFT	Shared	34,051(22.6%)	286(68.8%)	1,431,076	
	Distr.	34,051(22.6%)	92(22.1%)	35,685	40
Canny Detection	Shared	26,015(17.3%)	192(46.2%)	300,491,488	
	Distr.	26,633(17.1%)	116(27.9%)	11,136,755	26

Status

Philosophy: Get it working, Then Optimize

- ✓ Creation of SMP/NUMA Overlays
- ✓ Compiler/Linker

Existing Capabilities Ready to Use but "Primitive"

Status

Now, What To Optimize…..

Cross Platform Independence:

- Show same design mapping to different Vendor Formats

Platform Customization/Optimizations:

- Component Allocations/Partitionings
  - Interconnects,Memory
- Application Customization
  - Extensible Processors, Accelerators


CSDL MPSoPC
CSDL MPSoPC
hthreads.csce.uark.edu/ARCHlang/acc_compile.html
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Home
Select a Prebuilt MPSoPC
Build Your Own MPSoPC
Compile Your Hthreads Program
Hthreads Home Page
UNIVERSITY OF ARKANSAS
Compiling Hthreads Programs on Customized Accelerator
Customized Accelerator Overview
Code to Compile:
/Users/davidandrews/Desktop/mutex_c
Browse...
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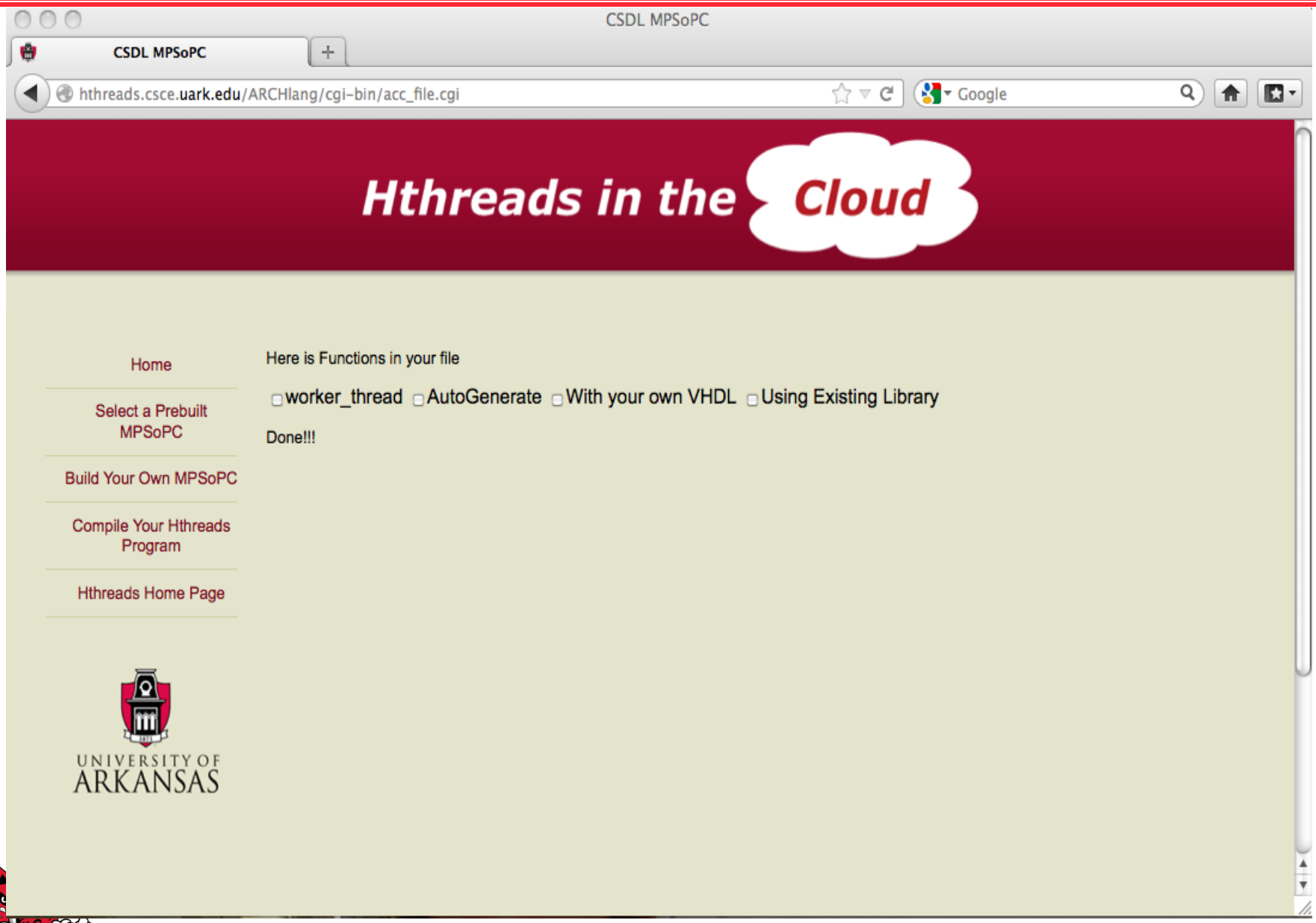
CSDL MPSoPC
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Build Your Own MPSoPC
Compile Your Hthreads Program
Hthreads Home Page
UNIVERSITY OF ARKANSAS
Here is Functions in your file
worker_thread
AutoGenerate
With your own VHDL
Using Existing Library
Done!!!

Integrate Vector CPUs (+Protocol Stack)