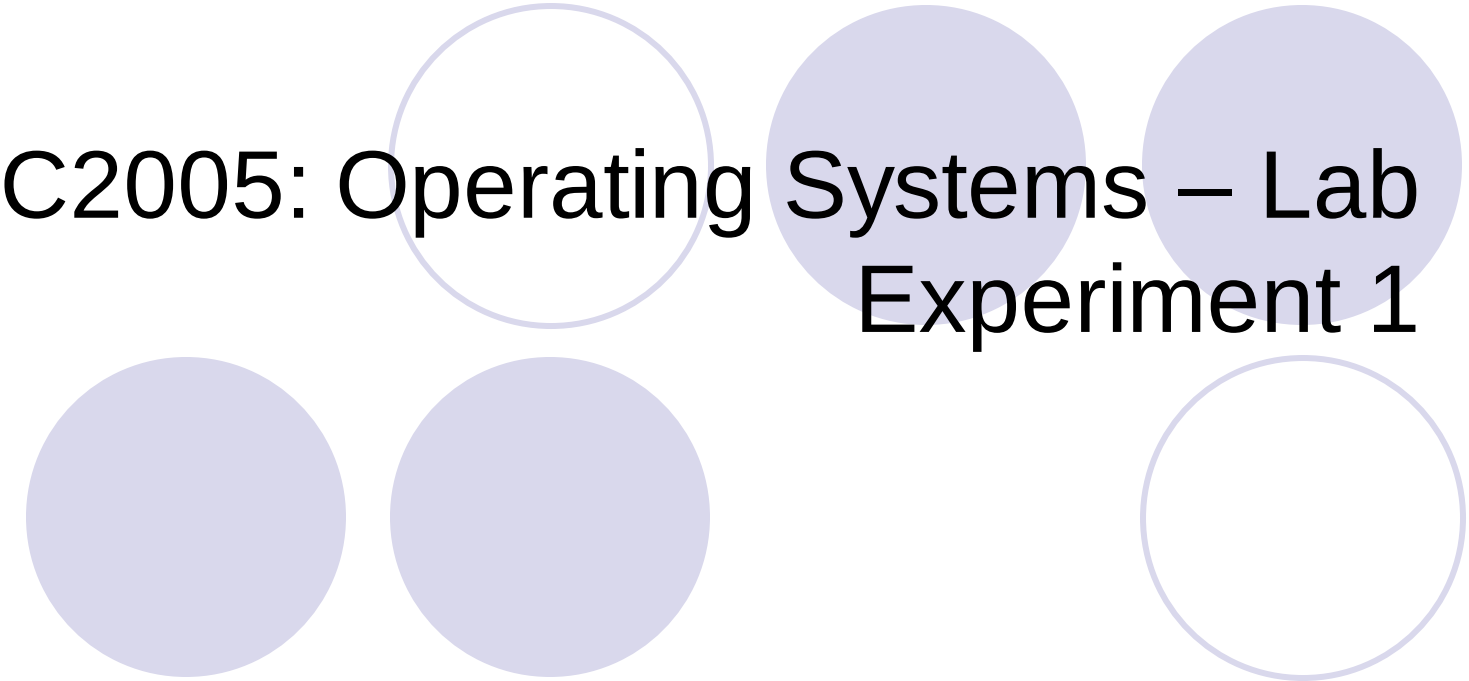
SC2005: Operating Systems – Lab Experiment 1



Outline

- Overview of NachOS
- Thread Management and Scheduling in NachOS
- Discussion of Experiment 1

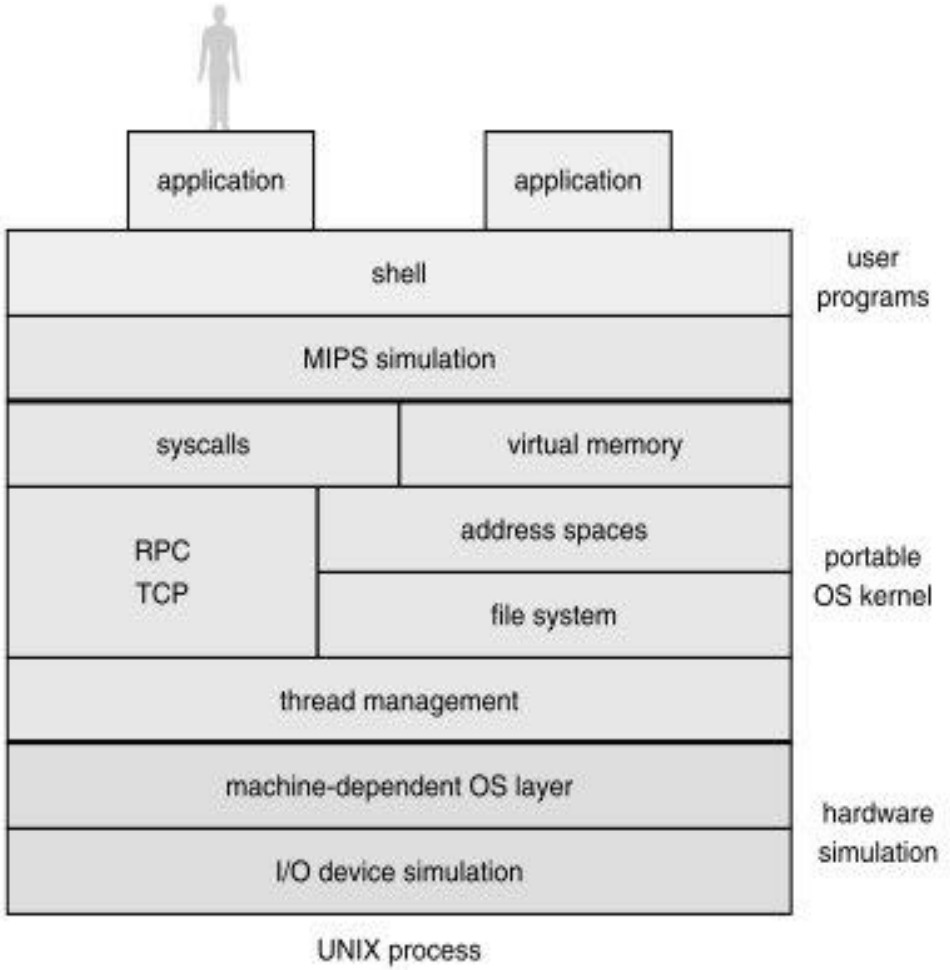
Overview of NachOS

NachOS – Background

- Real operating systems are very complex
  - Difficult to see how OS concepts are realized
  - Too time intensive to be part of an OS course
  - Therefore not so suitable for educational purposes
- NachOS is an educational operating system
  - Developed at UC Berkeley in C++
  - Freely available: http://www.cs.washington.edu/homes/tom/nachos
  - Idea: use the simplest possible implementation for each subsystem
  - Simple but complete
- Advantages of NachOS
  - Easier to read and understand the code
  - Easier to understand OS concepts
  - Easier to make changes and experiment
  - “Hands on” learning

NachOS – Architecture

- Approach in NachOS
  - Applications, kernel, and hardware simulator run in one UNIX process
  - NachOS uses a hardware simulation (virtual machine)

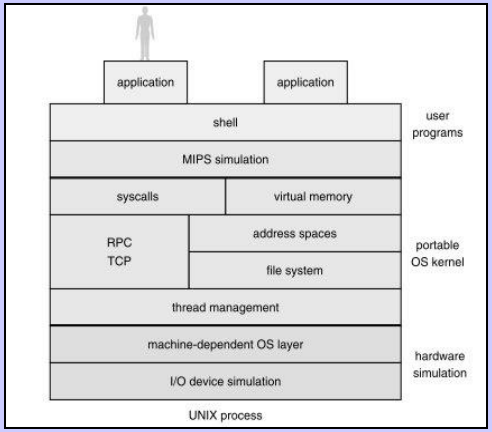


Advantages:

- System behavior is repeatable
- Easier to debug
- Shorter edit-compile-debug cycles

NachOS – Architecture

User Application

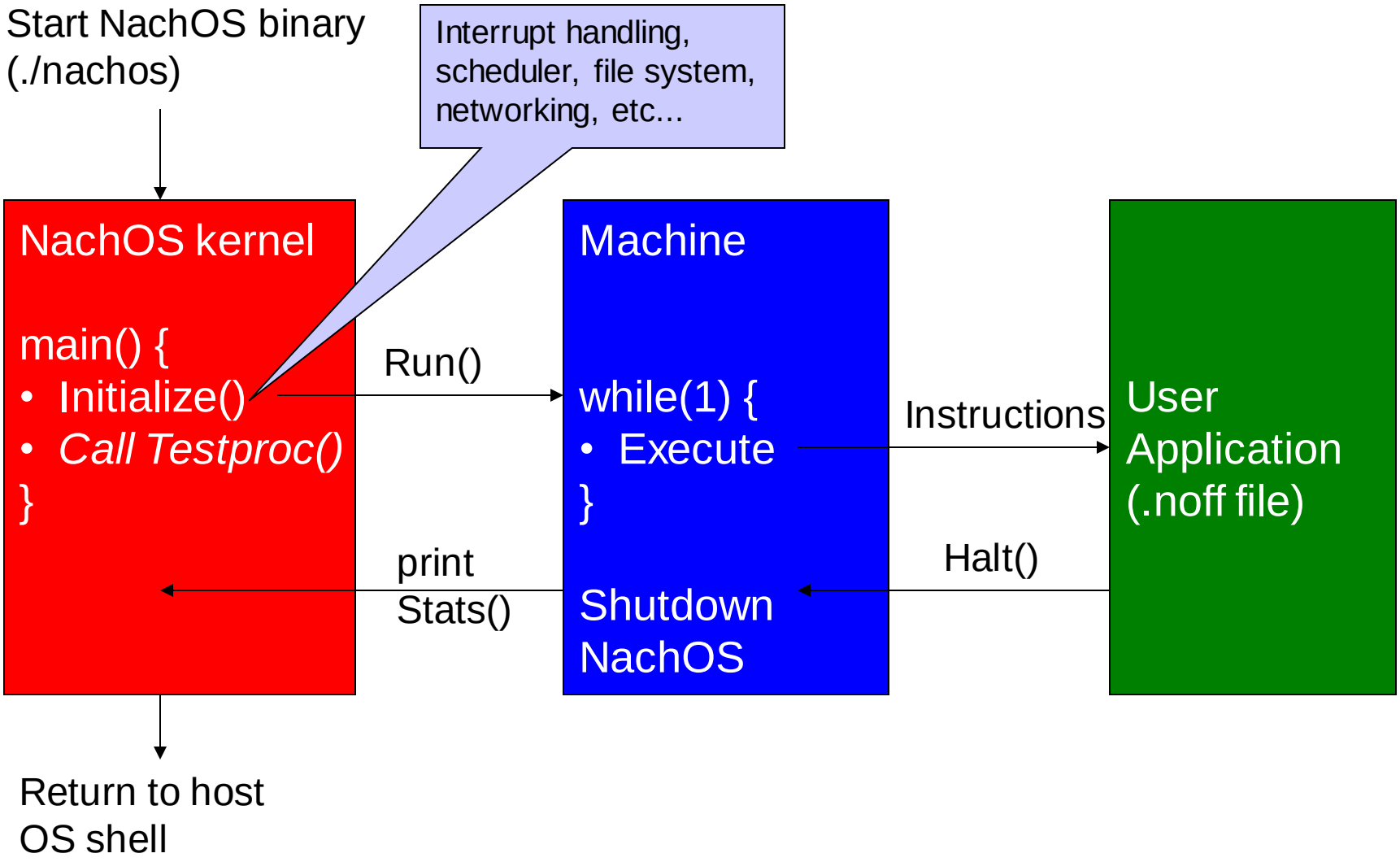


NachOS Process

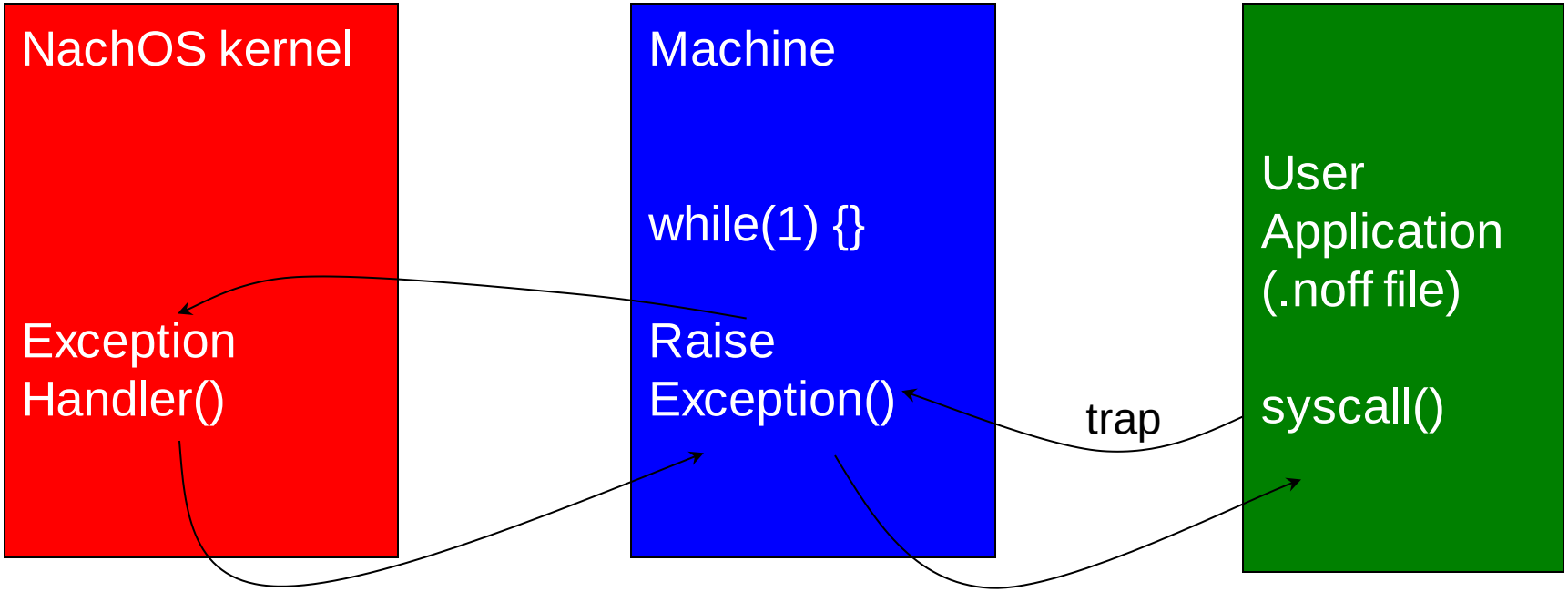
Host Operating System (e.g., Linux)

Hardware

NachOS – How does it work?



NachOS – How does it work?



Thread Management and Scheduling in NachOS

NachOS – Thread Management

- Thread management is explicit
  - It is possible to trace statement for statement
  - See and understand what happens during a context switch
- Two things are important to understand how NachOS performs thread management
  - Scheduler
  - Threads

NachOS – Scheduler

- Maintains a list of threads that are ready to run: *ready list (ready queue)*
- The scheduler is invoked whenever the current thread gives up the CPU (non-preemptive)
- Simple scheduling policy is used
  - Assume equal priority for all threads
  - Select threads in FCFS fashion
  - Append at the end and remove from the front
- The scheduler code can be found in `threads/scheduler.cc`
  - ReadyToRun()
  - FindNextToRun()
  - Run()

NachOS – Scheduler

- ReadyToRun(thread)
  - Makes a thread ready to run (set state to READY)
  - Adds it to the ready list
  - *Does not start the thread yet!*
- FindNextToRun() : thread
  - Simply returns the thread at the front of the ready list
- Run(thread)
  - Switches from one thread to another:
    1. Check whether the current thread overflowed its stack
    2. Change the state of the new thread to RUNNING
    3. Perform the actual context switch (by calling Switch())
    4. Terminate previous thread (if applicable)

NachOS –Thread

- A thread can be in either of these states
  - READY: eligible to run
  - RUNNING: only one thread can be in this state
  - BLOCKED: waiting for some external event
  - JUST_CREATED: temporary state used during creation

- Implementation can be found in `threads/thread.cc`
  - Fork()
  - Yield()
  - Sleep()
  - Finish()

You will use them in Experiments 1& 2

NachOS –Thread

- Fork(function, arg, flag)
  - Turns a thread into one that can be executed
  - Calls readyToRun()
- Yield()
  - Finds the next thread to run using findNextToRun()
  - If another thread has been found
    - Call readyToRun() for the old thread
    - Run the new thread using Run()
- Sleep()
  - Set status to BLOCKED
  - Find another thread to run using findNextToRun()
  - If another thread has been found
    - Run the new thread using Run()
- Finish()
  - Called at the end of execution
  - Marks a thread for termination

Discussion of Experiment 1

Experiment 1 – Overview

- Objective
  - Understand how context switches work
  - Trace the execution flow of a thread
- Tasks
  - Make a complete copy of NachOS
  - Build it & Run it
  - Analyze the output and the source code
  - Figure out what is happening and why

Directory Structure

bin	For generating NachOS format files, DO NOT CHANGE!
filesys	NachOS kernel related to file system, DO NOT CHANGE!
exp1	Experiment 1, nachos threads.
exp2	Experiment 2, CPU scheduling.
machine	MIPS H/W simulation, DO NOT CHANGE unless asked.
Makefile.common Makefile.dep	For compilation of NachOS, DO NOT CHANGE!
network	NachOS kernel related to network, DO NOT CHANGE!
port	NachOS kernel related to port, DO NOT CHANGE!
readme	Short description of OS labs and assessments
test	NachOS format files for testing virtual memory, DO NOT CHANGE!
threads	NachOS kernel related to thread management, DO NOT CHANGE!
userprog	NachOS kernel related to running user applications, DO NOT CHANGE!

Experiment 1 – User program

- User program for Experiment 1 can be found in `exp1/threadtest.cc`
  - SimpleThread()
  - ThreadTest() ← this is the test procedure called from within main()

Experiment 1 – ThreadTest()

```
void ThreadTest() {
    DEBUG('t', "Entering SimpleTest");
    Thread *t1 = new Thread("child1");
    t1->Fork(SimpleThread, 1, 0);
    Thread *t2 = new Thread("child2");
    t2->Fork(SimpleThread, 2, 0);
    SimpleThread(0);
}
```

Thread constructor does only minimal initialization

Turns a thread into one that can be scheduled and executed by the CPU

After starting two new threads, execute the SimpleThread function

- Fork(function, arg, join)
  - "function": the procedure to be executed concurrently
    - Here: SimpleThread
  - "arg": a single parameter which is passed to the procedure
    - Here: the id of the thread (0,1,2)
  - "join": a flag which indicates whether the thread can be joined
    - Not important for the lab

Experiment 1 – SimpleThread()

```
void SimpleThread(_int which) {
    int num;
    for (num = 0; num < 3; num++) {
         printf("*** thread %d looped %d times\n", (int) which, num);
         currentThread->Yield();
    }
}
```

Remember the only argument passed by fork? This is it. Here: 'which' tells you which thread

Causes the current thread to give up the CPU

- Each thread is executing this function
- The function does nothing but prints a status line three times
  - Check your program output

Experiment 1 – Task description

- 8.6 Fill in the following table in **Table.csv** (template is provided) whenever
  - the ready list is changed, or
  - the current thread is changed, or
  - a new message is printed in method SimpleTest()

Tick	Ready_list	Current thread	Printf message	Context switch
10	empty	main		
20	child1	main		
30	child1, child2	main	thread 0 looped 0 times	Main -> child1

- 8.7 List all context switches
  - For each switch: indicate from/to thread

Experiment 1 – Summary

- Objective:
  - Understand how thread management and scheduling works
- Assessment:
  - Assessment of your implementation. Please leave the file **output.txt** (containing output of execution) as well as **Table.csv** file in the **exp1** folder for TA/Supervisor to review. Deadline is 1 week after your lab session (e.g., if lab session is from 10AM-12PM on a Monday, then deadline is 9:59AM on the next Monday).
  - Lab Quiz 1, which is an online multiple-choice quiz, will be administered through NTULearn.
- Documents:
  - Can be found in NTULearn

Acknowledgement

- The slides are revised from the previous versions created by Dr. Heiko Aydt and Prof He Bingsheng.