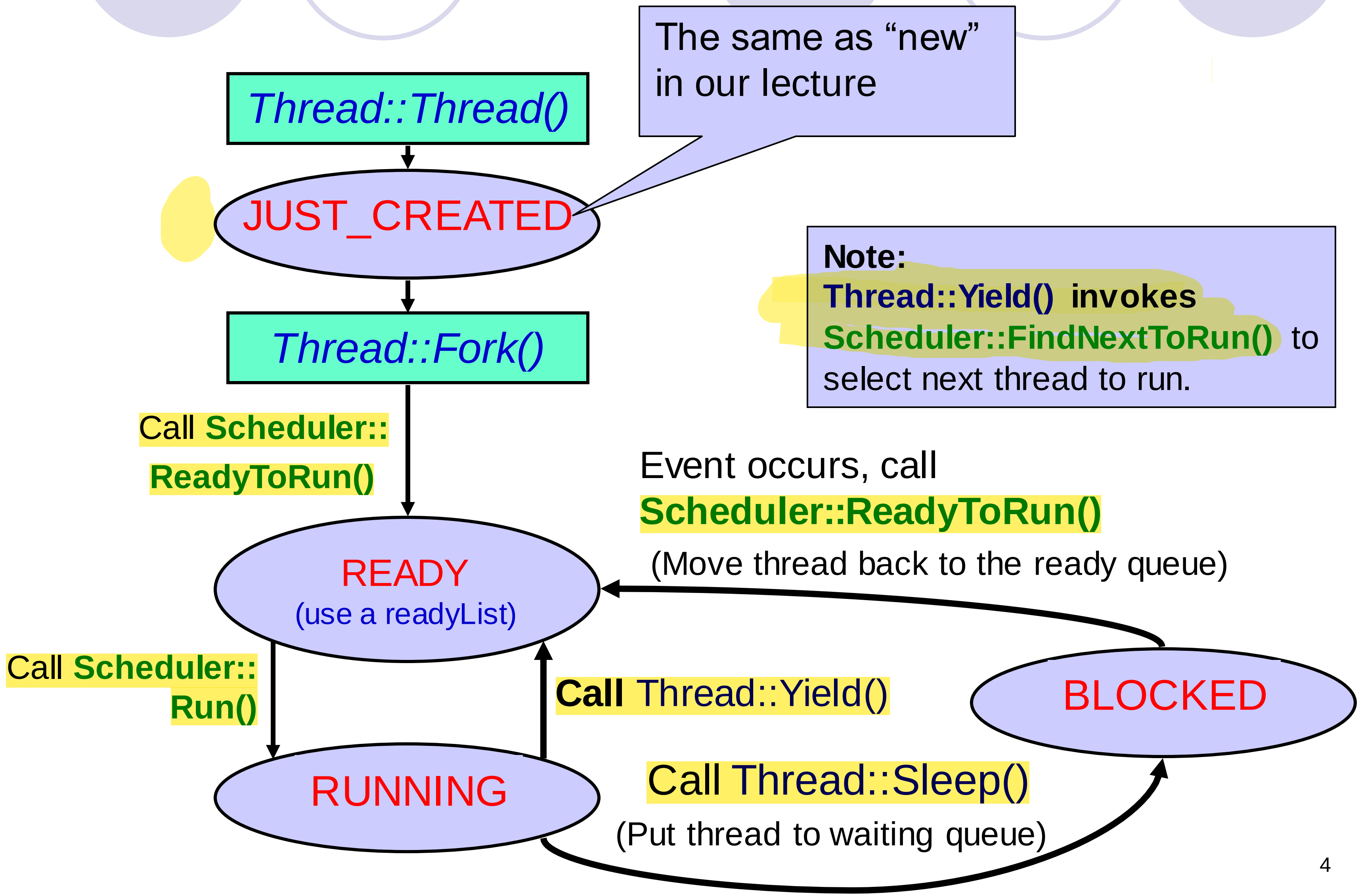
SC2005: Operating Systems – Lab Experiment 3

Outline

- Thread Operations
- Synchronization in NachOS
- Discussion of Experiment 3

Thread Operations of NachOS

Thread Life Cycle



Thread Object

- **Thread()**
  - Constructor: sets the thread as JUST_CREATED status
- **Fork()**
  - Allocate stack, initialize registers.
  - Call Scheduler::ReadyToRun() to put the thread into readyList, and set its status as READY.
- **Yield()**
  - Suspend the calling thread and put it into readyList.
  - Call Scheduler::FindNextToRun() to select another thread from readyList.
  - Execute selected thread by Scheduler::Run(), which sets its status as RUNNING and call SWITCH() (in code/threads/switch.s) to exchange the running thread.
- **Sleep()**
  - Suspend the current thread and find other thread to run
  - Change its state to BLOCKED.

Thread Object (Cont.)

- **Thread *Thread(char *debugName)**
  - The *Thread* constructor
    - Setting status to JUST_CREATED,
    - Initializing stack to NULL, and
    - Given the thread name for *debugging*.

Thread Object (Cont.)

- **Fork(VoidFunctionPtr func, int arg, int joinP);**
  - Thread creation
    - Allocating stack by invoking *StackAllocate()* function
    - Put this thread into ready queue by calling *Scheduler::ReadytoRun()*
  - Argument *func*
    - The address of a procedure where execution is to begin when the thread starts executing (***The thread's handler function***)
  - Argument *arg*
    - An integer argument that would be passed to thread handler function
  - Argument *joinP*
    - Indicate if a Join is going to happen. If joinP=1, a join is going to happen.

Thread Object (Cont.)

- **void Join (Thread *forked)**
  - The current thread ~~s~~waits for specified thread to finish before continuing.
  - Argument *forked*
    - Specify the thread to wait for;
    - The thread forked must be a joinable thread (Fork with *joinP=1*).

Synchronization in NachOS

Synchronization in NachOS

- There are three synchronization primitives in NachOS:
  1. Semaphores
  2. Locks
  3. Condition variables

- Source code and documentation can be found in
  - `threads/synch.h`
  - `threads/synch.cc`

Semaphores in NachOS

- A semaphore is a non-negative integer
- Initial value of semaphore depends on number of available resources
- Two operations
  - P() (down/wait) waits until semaphore value > 0 before decrementing it by 1
    - If value is zero, then calling thread is appended to a waiting queue and put to sleep
  - V() (up/signal) increments the semaphore value
    - First thread in waiting queue is put into the ready list

Locks in NachOS

- Locks are realized by using a binary semaphore
  - A lock can be either FREE or BUSY

- Two operations
  - Acquire()
    - Only one thread can acquire the lock
    - If a lock is busy, other threads have to wait
  - Release()
    - Once a thread releases a lock it will be free again
    - The lock can be acquired by the next thread

- Unlike semaphores, locks are owned by threads
  - Once acquired, a lock has exactly one owner
  - Only the owner can release the lock

Condition Variables in NachOS

- A condition variable requires a lock

- Three operations
  - Wait(lock)
    - Releases the lock
    - Relinquishes the CPU until signaled
      - Thread is appended to the waiting queue and put to sleep
    - Re-aquires the lock
  - Signal(lock) / notify
    - Wakes up the first thread in the waiting queue (if any)
  - Broadcast(lock) / notifyAll
    - Wakes up all threads in the waiting queue (if any)

Discussion of Experiment 3

Experiment 3 – Overview

- Objective
  - Understand how to synchronize processes/threads.
  - Understand interleavings and race conditions, and master some way of controlling them.
  - Know how to use locks/semaphores to solve a critical section problem.
- Tasks
  - Implement the race condition scenario for inconsistent output
  - Implement the process synchronization scheme for consistent output

Directory Structure

bin	For generating NachOS format files, DO NOT CHANGE!
filesys	NachOS kernel related to file system, DO NOT CHANGE!
exp3	Experiment 3, process synchronization.
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!
vm	**Experiment 4, coding virtual memory (TLB, page replacement)**

Experiment 3 – User program

- User program for Experiment 3 can be found in `exp3/threadtest.cc`
  - ThreadTest() ← this is the test procedure called from within main()
  - You will use it for specify the function to test.

```
//for exercise 1.
 TestValueOne();
 //TestValueMinusOne();
 //for exercise 2.
 //TestConsistency();
```

Experiment 3 – Task 1

- Arbitrary context switches cause different interleaving execution orders of two threads.
- Without proper process/thread synchronization, a shared variable may have inconsistent value for different interleaving execution orders.
- In this task, we consider a shared variable *value* (initially zero).
- You need to implement the following functions.

void Inc_v1(_int which)
void Dec_v1(_int which)
void TestValueOne()

After executing TestValueOne, *value=1*

void Inc_v2(_int which)
void Dec_v2(_int which)
void TestValueMinusOne()

After executing TestValueMinusOne, *value=-1*

Experiment 3 – Task 2

- With proper process/thread synchronization, shared variable can have consistent value for different interleaving execution orders and different folk orders.
- Continuing Task 1, we consider a shared variable *value* (initially zero).
- You need to implement the following functions, and demonstrate that the consistency is achieved for different interleaving execution orders and different folk orders.

```
void Inc_Consistent (_int which)
void Dec_Consistent (_int which)
void TestConsistency ()
```

After executing TestConsistency, *value* has a consistent value.

Experiment 3 – Summary

- Objective:
  - Understand how to synchronize processes/threads.
  - Understand interleavings and race conditions, and master some way of controlling them.
  - Know how to use locks/semaphores to solve a critical section problem.
- Assessment:
  - Assessment of your implementation. Please leave your code in the **exp3** 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 2, which is an online multiple-choice quiz, will be administered through NTULearn.
- Documents:
  - Can be found in NTULearn

Acknowledgement

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