Nachos

- Nachos is an instructional operating system developed at UC Berkeley
- Nachos consists of two main parts:
  - Operating system
    - This is the part of the code that you will study and modify
    - This code is in the **threads**, **userprog**, and **network** directories
    - We will not study user programs, so you can ignore files in the **userprog** directory
  - Machine emulator — simulates a (slightly old) MIPS CPU, registers, memory, timer (clock), console, disk drive, and network
    - You will study this code, but will not be allowed to modify it
    - This code is in the **machine** directory
- The OS and machine emulator run together as a single UNIX process

Preparing for the First Project

- Copy the files and compile Nachos
  - See "Getting Started" (online)
    - Threads version, then network version
- Start reading:
  - Read Nachos "Overview paper" (online)
  - Read Section 2 "Nachos Machine" and Section 3 "Nachos Threads" in Narten's "A Road Map Through Nachos" (online)
  - Read about threads, synchronization, interrupts, and networking in Kalra's "Salsa — An OS Tutorial" (online)
  - Start looking at the code in the **threads**, **machine** and **network** directories
  - Road Map plus printouts of all code are available in the MCS office for $4.50
- If you are not familiar with C++ or the gdb debugger, see the class web page

Preparing for the First Project (cont.)

- Compiling the code
  - Nachos source code is available in ~walker/pub
  - Read ~walker/pub/README
  - Decide where you want to work, so you can copy files from the appropriate directory into your account
    - ~walker/pub/nachos-3.4-hp
      - For HP workstations (aegis, intrepid)
      - Recommended
    - ~walker/pub/nachos-3.4-sparc
      - For Sun workstations (nimitz)
    - ~walker/pub/nachos-3.4-orig
      - The original, unmodified version
  - Read "Project 1 — Getting Started" on the class web page to find out how to copy the necessary files to your account, and compile an executable copy of Nachos into the **threads** directory

Nachos — The Emulated Machine

- Code is in the **machine** directory
- **machine.h**, **machine.cc** — emulates the part of the machine that executes user programs: main memory, processor registers, etc.
- **mipssim.cc** — emulates the integer instruction set of a MIPS R2/3000 CPU.
- **interrupt.h**, **interrupt.cc** — manages enabling and disabling interrupts as part of the machine emulation.
- **timer.h**, **timer.cc** — emulates a clock that periodically causes an interrupt to occur.
- **stats.h** — collects interesting statistics.

Nachos — The Operating System

- For now, we will mostly be concerned with code in the **threads** directory
- **main.cc**, **threadtest.cc** — a simple test of the thread routines.
- **system.h**, **system.cc** — Nachos startup/shutdown routines.
- **thread.h**, **thread.cc** — thread data structures and thread operations such as thread fork, thread sleep and thread finish.
- **scheduler.h**, **scheduler.cc** — manages the list of threads that are ready to run.
- **list.h**, **list.cc** — generic list management.
- **utility.h**, **utility.cc** — some useful definitions and debugging routines.

Nachos Threads

- As distributed, Nachos does not support multiple processes, only threads
  - All threads share / execute the same code (the Nachos source code)
  - All threads share the same global variables (have to worry about synch.)
- Threads can be in one of 4 states:
  - JUST_CREATED — exists, has not stack, not ready yet
  - READY — on the ready list, ready to run
  - RUNNING — currently running (variable currentThread points to currently running thread)
  - BLOCKED — waiting on some external even, probably should be on some event waiting queue

Scheduling in Nachos

- The Nachos scheduler is non-preemptive FCFS — chooses next process when:
  - Current thread calls Thread::Sleep( ) (to block (wait) on some event)
  - Current thread calls Thread::Yield( ) to explicitly yield the CPU
- main( ) (in threads/main.cc)
calls Initialize( ) (in threads/system.cc)
  - which starts scheduler, an instance of class Scheduler (defined in **threads/scheduler.h** and **scheduler.cc**)
- Interesting functions:
  - Mechanics of running a thread:
    - Scheduler::ReadyToRun( ) — puts a thread at the tail of the ready queue
    - Scheduler::FindNextToRun( ) — returns thread at the head of the ready queue
    - Scheduler::Run( ) — switches to thread

Scheduling in Nachos (cont.)

```
Scheduler::Scheduler ( )
{
    readyList = new List;
}

void
Scheduler::ReadyToRun (Thread *thread)
{
   DEBUG('t',
      "Putting thread %s on ready list.\n",
      thread->getName());
   thread->setStatus(READY);
   readyList->Append((void *)thread);
}

Thread *
Scheduler::FindNextToRun ( )
{
    return (Thread *)readyList->Remove();
}
```

Scheduling in Nachos (cont.)

```
void
Scheduler::Run (Thread *nextThread)
{
   Thread *oldThread = currentThread;

   oldThread->CheckOverflow();
   currentThread = nextThread;
   currentThread->setStatus(RUNNING);

   DEBUG('t', "Switching from thread \"%s\"
   to thread \"%s\"\n",oldThread->getName(),
      nextThread->getName());
   SWITCH(oldThread, nextThread);
   DEBUG('t', "Now in thread \"%s\"\n",
      currentThread->getName());

   if (threadToBeDestroyed != NULL) {
      delete threadToBeDestroyed;
      threadToBeDestroyed = NULL;
   }
}
```

Working with a Non-Preemptive Scheduler

- The Nachos scheduler is non-preemptive FCFS — chooses next process when:
  - Current thread calls Thread::Sleep( ) (to block (wait) on some event)
  - Current thread calls Thread::Yield( ) to explicitly yield the CPU
- Some interesting functions:
  - Thread::Fork( ) — create a new thread to run a specified function with a single argument, and put it on the ready queue
  - Thread::Yield( ) — if there are other threads waiting to run, suspend this thread and run another
  - Thread::Sleep( ) — this thread is waiting on some event, so suspend it, and hope someone else wakes it up later
  - Thread::Finish( ) — terminate the currently running thread

Manipulating Threads in Nachos

```
void
Thread::Fork(VoidFunctionPtr func, int arg)
{
   DEBUG('t',"Forking thread \"%s\" with
      func = 0x%x, arg = %d\n",
      name, (int) func, arg);

   StackAllocate(func, arg);

   IntStatus oldLevel = interrupt->
      SetLevel(IntOff);
   scheduler->ReadyToRun(this);
   (void) interrupt->SetLevel(oldLevel);
}
```

Manipulating Threads in Nachos (cont.)

```
void
Thread::Yield ()
{
   Thread *nextThread;

   IntStatus oldLevel = interrupt->
      SetLevel(IntOff);

   ASSERT(this == currentThread);
   DEBUG('t', "Yielding thread \"%s\"\n",
      getName());

   nextThread = scheduler->
      FindNextToRun();
   if (nextThread != NULL) {
      scheduler->ReadyToRun(this);
      scheduler->Run(nextThread);
   }
   (void) interrupt->SetLevel(oldLevel);
}
```

Manipulating Threads in Nachos (cont.)

```
void
Thread::Sleep ()
{
   Thread *nextThread;

   ASSERT(this == currentThread);
   ASSERT(interrupt->getLevel() == IntOff);
   DEBUG('t', "Sleeping thread \"%s\"\n",
      getName());

   status = BLOCKED;
   while ((nextThread = scheduler->
      FindNextToRun()) == NULL)
      interrupt->Idle();

   scheduler->Run(nextThread);
}
```

Semaphores in Nachos

- The class Semaphore is defined in **threads/synch.h** and **synch.cc**
  - The classes Lock and Condition are also defined , but their member functions are empty (implementation left as exercise)
- Interesting functions:
  - Semaphores:
    - Semaphore::Semaphore( ) — creates a semaphore with specified name & value
    - Semaphore::P( ) — semaphore wait
    - Semaphore::V( ) — semaphore signal
  - Locks:
    - Lock::Acquire( )
    - Lock::Release( )
  - Condition variables:
    - Condition::Wait( )
    - Condition::Signal( )

Networking in Nachos

- Low-level emulation of the physical network is defined in **machine/network.h** and **network.cc**
  - Provides ordered, unreliable, fixed-size packet delivery to other Nachos machines
  - Packets can be dropped (user-controllable), but are never corrupted
- High-level protocols for communication between multiple Nachos machines are defined in **network/post.h** and **post.cc**
  - An instance of class PostOffice manages a set of MailBoxes for each machine
    - PostOffice::Send( ) sends a message to a specific machine and mailbox
    - PostOffice::Receive( ) retrieves a message, or waits if none is available
  - Could provide reliable delivery of arbitrary-size messages, but currently does ***not*** (see Spring'97 AOS Project 1)