UNIT II

PROCESS SYNCHRONIZATION - THE CRITICAL-SECTION PROBLEM -SYNCHRONIZATION HARDWARE

Background

- Concurrent access to shared data may result in data inconsistency
- Maintaining data consistency requires mechanisms to ensure the orderly execution of cooperating processes
- Suppose that we wanted to provide a solution to the consumer-producer problem that fills all the buffers. We can do so by having an integer count that keeps track of the number of full buffers. Initially, count is set to 0. It is incremented by the producer after it produces a new buffer and is decremented by the consumer after it consumes a buffer.

Producer

```
while (true) {

     /*  produce an item and put in nextProduced  */
    while (count == BUFFER_SIZE)
          ; // do nothing
        buffer [in] = nextProduced;
        in = (in + 1) % BUFFER_SIZE;
        count++;
}
```

Consumer

```
while (true)  {
        while (count == 0)
                ; // do nothing
                nextConsumed =  buffer[out];
                 out = (out + 1) % BUFFER_SIZE;
                 count--;

                   /*  consume the item in nextConsumed
}
```

Race Condition

- count++ could be implemented as

  register1 = count

  register1 = register1 + 1

  count = register1

- count-- could be implemented as

  register2 = count

  register2 = register2 - 1

  count = register2

Race Condition

- Consider this execution interleaving with “count = 5” initially:

S0: producer execute register1 = count {register1 = 5}

S1: producer execute register1 = register1 + 1 {register1 = 6}

S2: consumer execute register2 = count {register2 = 5}

S3: consumer execute register2 = register2 - 1 {register2 = 4}

S4: producer execute count = register1 {count = 6 }

S5: consumer execute count = register2 {count = 4}

Solution to Critical-Section Problem

1. **Mutual Exclusion** - If process P_i is executing in its critical section, then no other processes can be executing in their critical sections

2. **Progress** - If no process is executing in its critical section and there exist some processes that wish to enter their critical section, then the selection of the processes that will enter the critical section next cannot be postponed indefinitely

3. **Bounded Waiting** - A bound must exist on the number of times that other processes are allowed to enter their critical sections after a process has made a request to enter its critical section and before that request is granted

Peterson's Solution

- Two process solution
- Assume that the LOAD and STORE instructions are atomic; that is, cannot be interrupted.
- The two processes share two variables:
  - int turn;
  - Boolean flag[2]
- The variable turn indicates whose turn it is to enter the critical section.
- The flag array is used to indicate if a process is ready to enter the critical section.

  flag[i] = true implies that process P_i is ready!

Algorithm for Process P_i

```
do {
        flag[i] = TRUE;
        turn = j;
        while (flag[j] && turn == j);
                critical section
        flag[i] = FALSE;
                remainder section
} while (TRUE);
```

Synchronization Hardware

- Many systems provide hardware support for critical section code
- **Uniprocessors** – could disable interrupts
  - Currently running code would execute without preemption
  - Generally too inefficient on multiprocessor systems
    - Operating systems using this not broadly scalable
- Modern machines provide special atomic hardware instructions
    - Atomic = non-interruptable
  - Either test memory word and set value or swap contents of two memory words

Solution to Critical-section Problem Using Locks

```
do {
    acquire lock
        critical section
    release lock
        remainder section
} while (TRUE);
```

TestAndSet Instruction

- Definition:

```
boolean TestAndSet (boolean *target)
{
    boolean rv = *target;
    *target = TRUE;
    return rv:
}
```

Solution using TestAndSet

- Shared boolean variable lock, initialized to false.
- Solution:

```
do {
        while ( TestAndSet (&lock ))
                ;   // do nothing
                    //    critical section
        lock = FALSE;
                //      remainder section

} while (TRUE);
```

Swap Instruction

- Definition:

```
void Swap (boolean *a, boolean *b)
{
        boolean temp = *a;
        *a = *b;
        *b = temp:
}
```

Solution using Swap

- Shared Boolean variable lock initialized to FALSE; Each process has a local Boolean variable key
- Solution:

```
do {
        key = TRUE;
        while ( key == TRUE)
              Swap (&lock, &key );
                    //    critical section

         lock = FALSE;

                    //      remainder section

 } while (TRUE);
```

Bounded-waiting Mutual Exclusion with TestandSet( )

```
do {
        waiting[i] = TRUE;
        key = TRUE;
        while (waiting[i] && key)
                key = TestAndSet(&lock);
        waiting[i] = FALSE;
                // critical section
        j = (i + 1) % n;
        while ((j != i) && !waiting[j])
                j = (j + 1) % n;
        if (j == i)
                lock = FALSE;
        else
                waiting[j] = FALSE;
                // remainder section
} while (TRUE);
```