CENG 2034 - Operating Systems

Week 10: Synchronization Examples

Burak Ekici

May 26, 2023

Outline

Classical Problems of Synchronization

Classical problems used to test newly-proposed synchronization schemes

Classical Problems of Synchronization

Classical problems used to test newly-proposed synchronization schemes

- Bounded-Buffer Problem

Classical Problems of Synchronization

Classical problems used to test newly-proposed synchronization schemes

- Bounded-Buffer Problem
- Readers and Writers Problem

Classical Problems of Synchronization

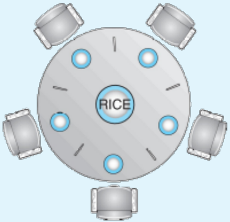
Classical problems used to test newly-proposed synchronization schemes

- Bounded-Buffer Problem
- Readers and Writers Problem
- Dining-Philosophers Problem

Outline

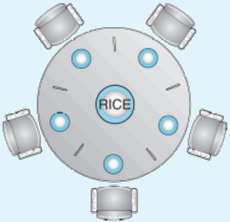
Dining-Philosophers Problem

- *N* philosophers' sit at a round table with a bowel of rice in the middle.



Dining-Philosophers Problem

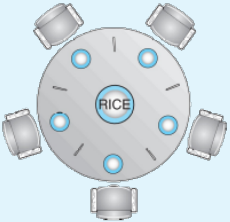
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.

Dining-Philosophers Problem

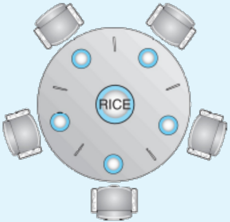
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.

Dining-Philosophers Problem

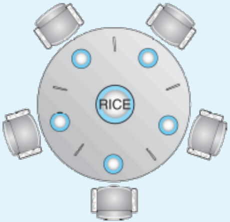
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl

Dining-Philosophers Problem

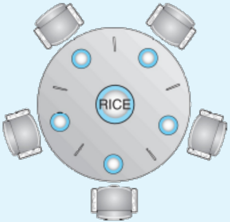
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
  - Need both to eat, then release both when done

Dining-Philosophers Problem

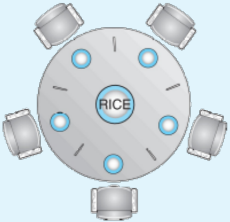
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
  - Need both to eat, then release both when done
- In the case of 5 philosophers, the shared data

Dining-Philosophers Problem

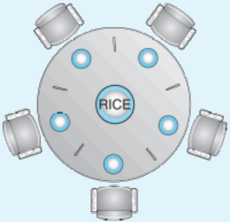
- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
  - Need both to eat, then release both when done
- In the case of 5 philosophers, the shared data
  - Bowl of rice (data set)

Dining-Philosophers Problem

- *N* philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
  - Need both to eat, then release both when done
- In the case of 5 philosophers, the shared data
  - Bowl of rice (data set)
  - Semaphore chopstick [5] initialized to 1

Dining-Philosophers Problem Algorithm

- Semaphore Solution

Dining-Philosophers Problem Algorithm

- Semaphore Solution
- The structure of Philosopher *i*:

```
while (true){
  wait (chopstick[i] );
  wait (chopStick[(i + 1) % 5] );

  /* eat for awhile */

   signal (chopstick[i] );
   signal (chopstick[(i + 1) % 5] );

   /* think for awhile */
}
```

Dining-Philosophers Problem Algorithm

- Semaphore Solution
- The structure of Philosopher *i*:

```
while (true){
  wait (chopstick[i] );
  wait (chopStick[(i + 1) % 5] );

  /* eat for awhile */

   signal (chopstick[i] );
   signal (chopstick[(i + 1) % 5] );

   /* think for awhile */
}
```

- What is the problem with this algorithm?

Monitor Solution to Dining Philosophers

The structure of Philosopher *i*:

```
monitor DiningPhilosophers
{
  enum {THINKING; HUNGRY, EATING} state [5];
  condition self [5];

  void pickup (int i) {
      state[i] = HUNGRY;
      test(i);
      if (state[i] != EATING) self[i].wait;
  }

  void putdown (int i) {
      state[i] = THINKING;
      // test left and right neighbors
      test((i + 4) % 5);
      test((i + 1) % 5);
  }

  void test (int i) {
      if ((state[(i + 4) % 5] != EATING) &&
      (state[i] == HUNGRY) &&
      (state[(i + 1) % 5] != EATING) ) {
          state[i] = EATING ;
          self[i].signal () ;
      }
  }

  initialization_code() {
      for (int i = 0; i < 5; i++)
        state[i] = THINKING;
  }
}
```

Solution to Dining Philosophers

- Each philosopher "i" invokes the operations `pickup()` and `putdown()` in the following sequence:

```
DiningPhilosophers.pickup(i);
    /** EAT **/
DiningPhilosophers.putdown(i);
```

Solution to Dining Philosophers

- Each philosopher "i" invokes the operations `pickup()` and `putdown()` in the following sequence:

```
DiningPhilosophers.pickup(i);
    /** EAT **/
DiningPhilosophers.putdown(i);
```

- No deadlock, but starvation is possible

Outline

Bounded-Buffer Problem

- n buffers, each can hold one item

Bounded-Buffer Problem

- n buffers, each can hold one item
- Semaphore `mutex` initialized to the value 1

Bounded-Buffer Problem

- *n* buffers, each can hold one item
- Semaphore `mutex` initialized to the value 1
- Semaphore `full` initialized to the value 0

Bounded-Buffer Problem

- *n* buffers, each can hold one item
- Semaphore `mutex` initialized to the value 1
- Semaphore `full` initialized to the value 0
- Semaphore `empty` initialized to the value n

Bounded-Buffer Problem

The structure of the producer process

```
while (true)
{
  ...
  /* produce an item in next_produced */
  ...
  wait(empty);
  wait(mutex);
  ...
  /* add next produced to the buffer */
    ...
  signal(mutex);
  signal(full);
}
```

Bounded-Buffer Problem

The structure of the consumer process

```
while (true)
{
  wait(full);
  wait(mutex);
  ...
  /* remove an item from buffer to next_consumed */
  ...
  signal(mutex);
  signal(empty);
  ...
  /* consume the item in next consumed */
  ...
}
```

Outline

1. Classical Synchronization Problem
2. Dining-Philosophers Problem
3. Bounded Buffer
4. Readers-Writers Problem

Readers-Writers Problem

- A data set is shared among a number of concurrent processes

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
  - Readers – only read the data set; they do not perform any updates

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
    - Readers – only read the data set; they do not perform any updates
    - Writers – can both read and write

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
  - Readers – only read the data set; they do not perform any updates
  - Writers – can both read and write
- Problem – allow multiple readers to read at the same time

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
  - Readers – only read the data set; they do not perform any updates
  - Writers – can both read and write
- Problem – allow multiple readers to read at the same time
  - Only one single writer can access the shared data at the same time

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
  - Readers – only read the data set; they do not perform any updates
  - Writers – can both read and write
- Problem – allow multiple readers to read at the same time
  - Only one single writer can access the shared data at the same time
- Several variations of how readers and writers are considered – all involve some form of priorities

Readers-Writers Problem (cont'd)

Shared Data

Readers-Writers Problem (cont'd)

Shared Data

- Data set

Readers-Writers Problem (cont'd)

Shared Data

- Data set
- Semaphore `rw_mutex` initialized to 1

Readers-Writers Problem (cont'd)

Shared Data

- Data set
- Semaphore `rw_mutex` initialized to 1
- Semaphore `mutex` initialized to 1

Readers-Writers Problem (cont'd)

Shared Data

- Data set
- Semaphore `rw_mutex` initialized to 1
- Semaphore `mutex` initialized to 1
- Integer `read_count` initialized to 0

Readers-Writers Problem (cont'd)

```
while (true)
{
  wait(rw_mutex);

  ...

  /* writing is performed */

  ...

  signal(rw_mutex);
}
```

Readers-Writers Problem (cont'd)

The structure of a reader process

Readers-Writers Problem (cont'd)

The structure of a reader process

```
while (true)
{
  wait(mutex);
  read_count++;
  if (read_count == 1) /* first reader */
    wait(rw_mutex);
  signal(mutex);

  ...

  /* reading is performed */

  ...

  wait(mutex);
  read_count--;
  if (read_count == 0) /* last reader */
    signal(rw_mutex);
  signal(mutex);
}
```

Readers-Writers Problem

- The solution in previous slide can result in a situation where a writer process never writes. It is referred to as the “First reader-writer” problem.

Readers-Writers Problem

- The solution in previous slide can result in a situation where a writer process never writes. It is referred to as the “First reader-writer” problem.
- The “Second reader-writer” problem is a variation the first reader-writer problem that state:

Readers-Writers Problem

- The solution in previous slide can result in a situation where a writer process never writes. It is referred to as the “First reader-writer” problem.
- The “Second reader-writer” problem is a variation the first reader-writer problem that state:
  - Once a writer is ready to write, no “newly arrived reader” is allowed to read.

Readers-Writers Problem

- The solution in previous slide can result in a situation where a writer process never writes. It is referred to as the "First reader-writer" problem.
- The "Second reader-writer" problem is a variation the first reader-writer problem that state:
  - Once a writer is ready to write, no "newly arrived reader" is allowed to read.
- Both the first and second may result in starvation. leading to even more variations

Readers-Writers Problem

- The solution in previous slide can result in a situation where a writer process never writes. It is referred to as the “First reader-writer” problem.
- The “Second reader-writer” problem is a variation the first reader-writer problem that state:
  - Once a writer is ready to write, no “newly arrived reader” is allowed to read.
- Both the first and second may result in starvation. leading to even more variations
- Problem is solved on some systems by kernel providing reader-writer locks

Thanks! & Questions?