Lecture 07: Task Scheduling Paradigms

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Last Lecture

```
#include <runtime-API.h>
main() {
  init_runtime();
  start_finish();
    async (S1);
    S2;
  end_finish();
  finalize_runtime();
}
```

```
volatile boolean shutdown = false;
void init_runtime() {
  int size = thread_pool_size();
  for(int i=1; i<size; i++) {
    pthread_create(worker_routine);
  }
}
```

```
volatile int finish_counter = 0;
void start_finish() {
  finish_counter = 0; //reset
}
```

```
void async(task) {
  lock_finish();
  finish_counter++;//concurrent access
  unlock_finish();
  // copy task on heap
  void* p = malloc(task_size);
  memcpy(p, task, task_size);
  //thread-safe push_task_to_runtime
  push_task_to_runtime(&p);
  return;
}
```

```
void end_finish() {
  while(finish_counter != 0) {
    find_and_execute_task();
  }
}
```

```
void worker_routine() {
  while( !shutdown ) {
     find_and_execute_task();
  }
}
```

```
void find_and_execute_task() {
   //pop_from_runtime is thread-safe
   task = pop_task_from_runtime();
   if(task != NULL) {
      execute_task(task);
      free(task);
      lock_finish();
      finish_counter--;
      unlock_finish();
   }
}
```

```
void finalize_runtime() {
   //all spinning workers
   //will exit worker_routine
   shutdown = true;
   int size = thread_pool_size();
   // master waits for helpers to join
   for(int i=1; i<size; i++) {
     pthread_join(thread[i]);
   }
}
```

Today's Lecture

- Task scheduling paradigms
  - **Work-sharing scheduling**
  - Work-stealing scheduling

How to Push/Pull Tasks in Runtime ?

- push_task_to_runtime()
- pop_task_from_runtime()

We saw the use of these two runtime APIs in Lecture 06

Data-structures for storing tasks in a thread pool based runtime plays a very important role in determining the scalability and performance of the runtime

How to Push/Pull Tasks in Runtime ?

- push_task_to_runtime()
- pop_task_from_runtime()

- Two widely used task scheduling techniques
  - Work-sharing
    - OpenMP parallel for loops
  - Work-stealing
    - OpenMP tasking pragmas, Cilk, X10, HClib, Habanero-Java

Work–Sharing

Store Keeper

Store Keeper

Shelf of Files

```
volatile boolean shutdown = false;
void init_runtime() {
  int size = thread_pool_size();
  for(int i=1; i<size; i++) {
    pthread_create(worker_routine);
  }
}
```

Office Clerk_0

Office Clerk_1

Office Clerk_2

Office Clerk_3

Work–Sharing

Store Keeper

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```
void worker_routine() {
  while( !shutdown ) {
     find_and_execute_task();
  }
}
```

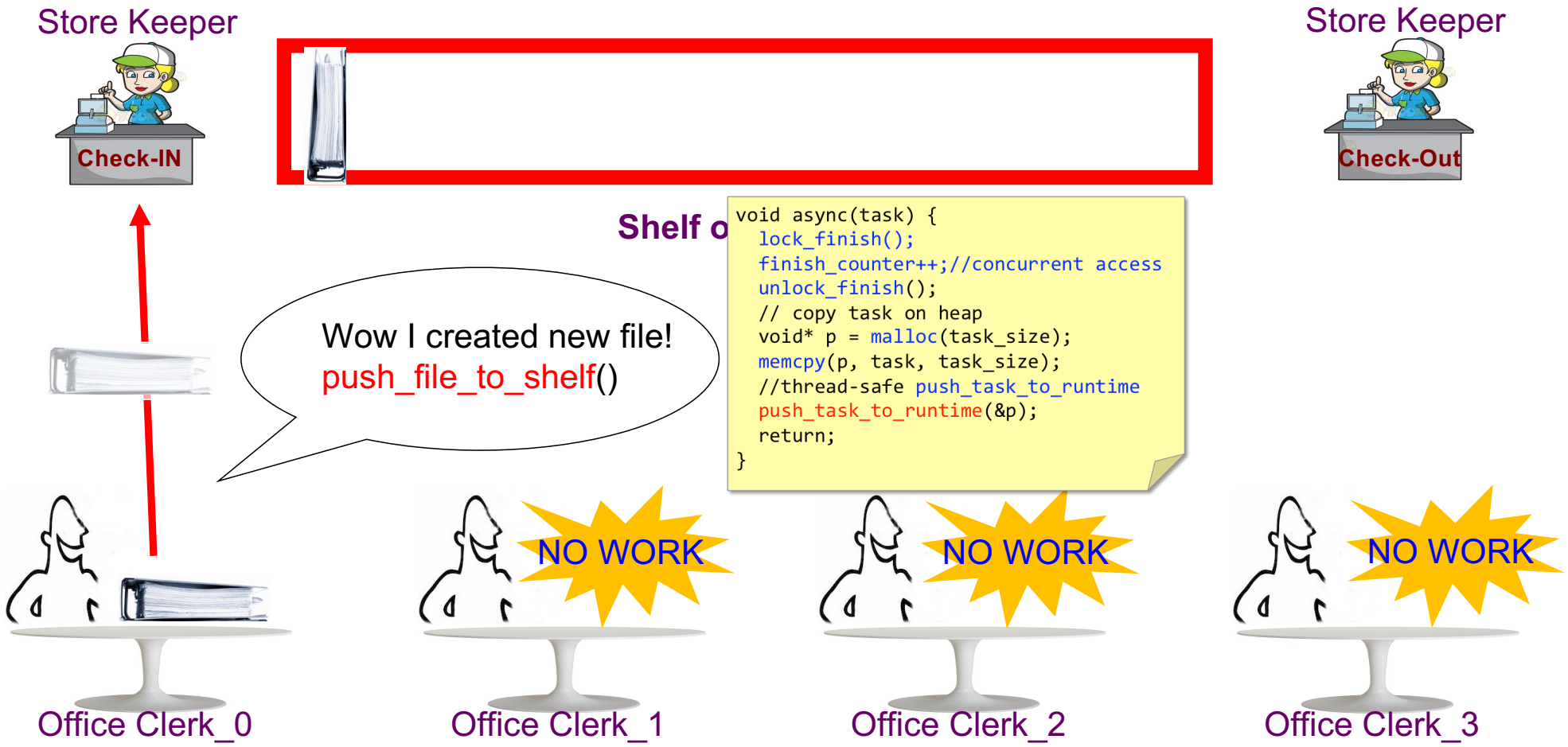
Office Clerk_0

Office Clerk_1

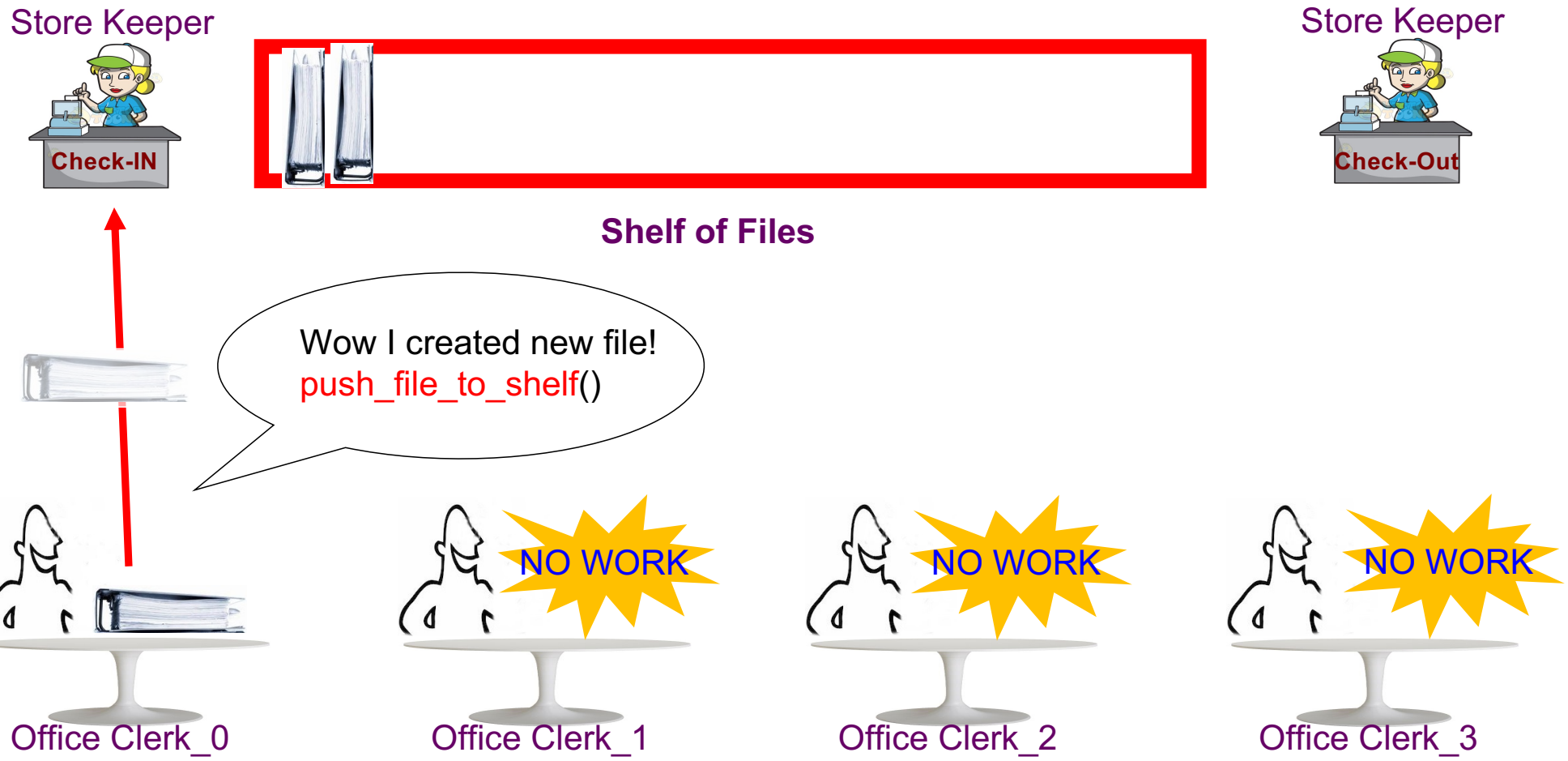
Office Clerk_2

Office Clerk_3

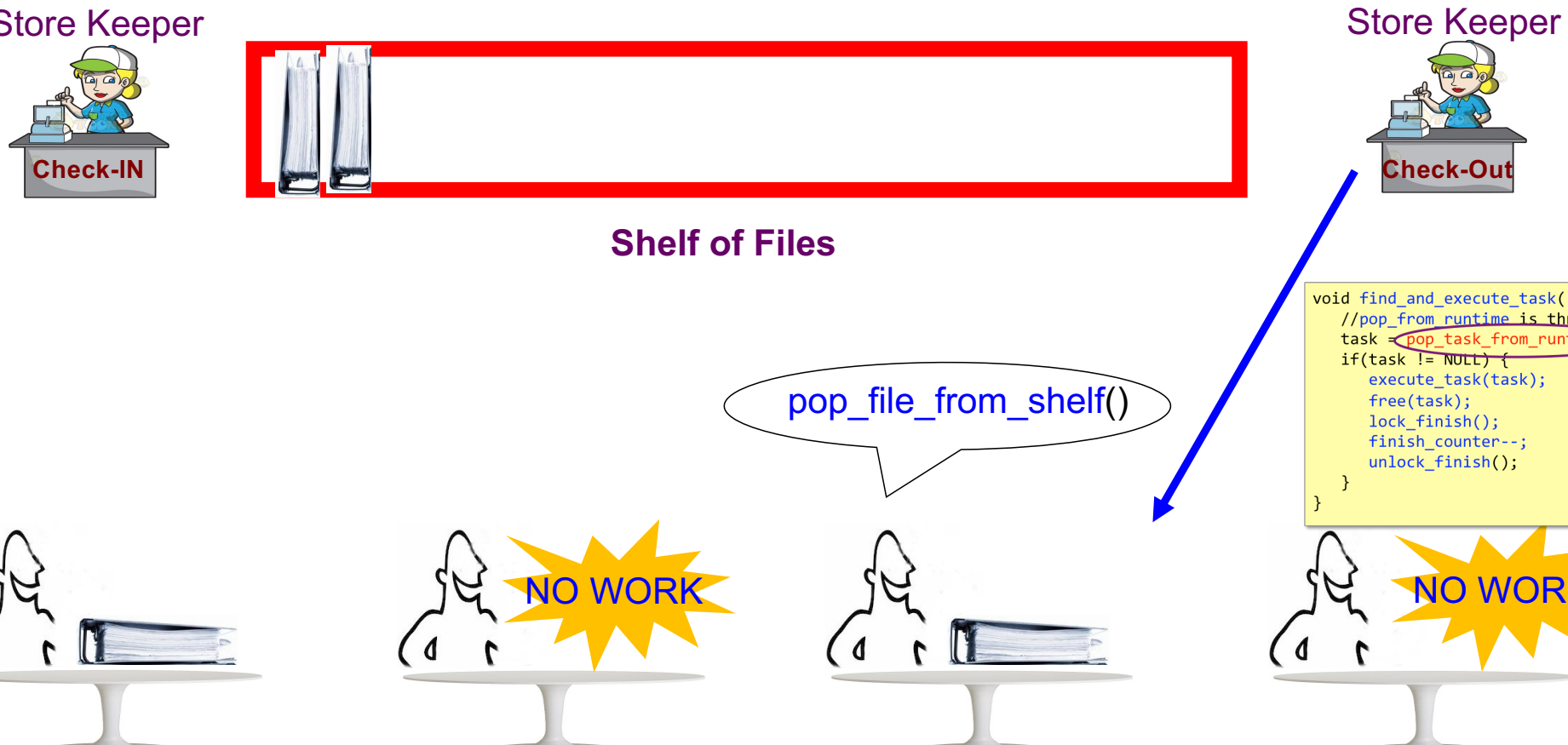
Work–Sharing



Work–Sharing



Work–Sharing



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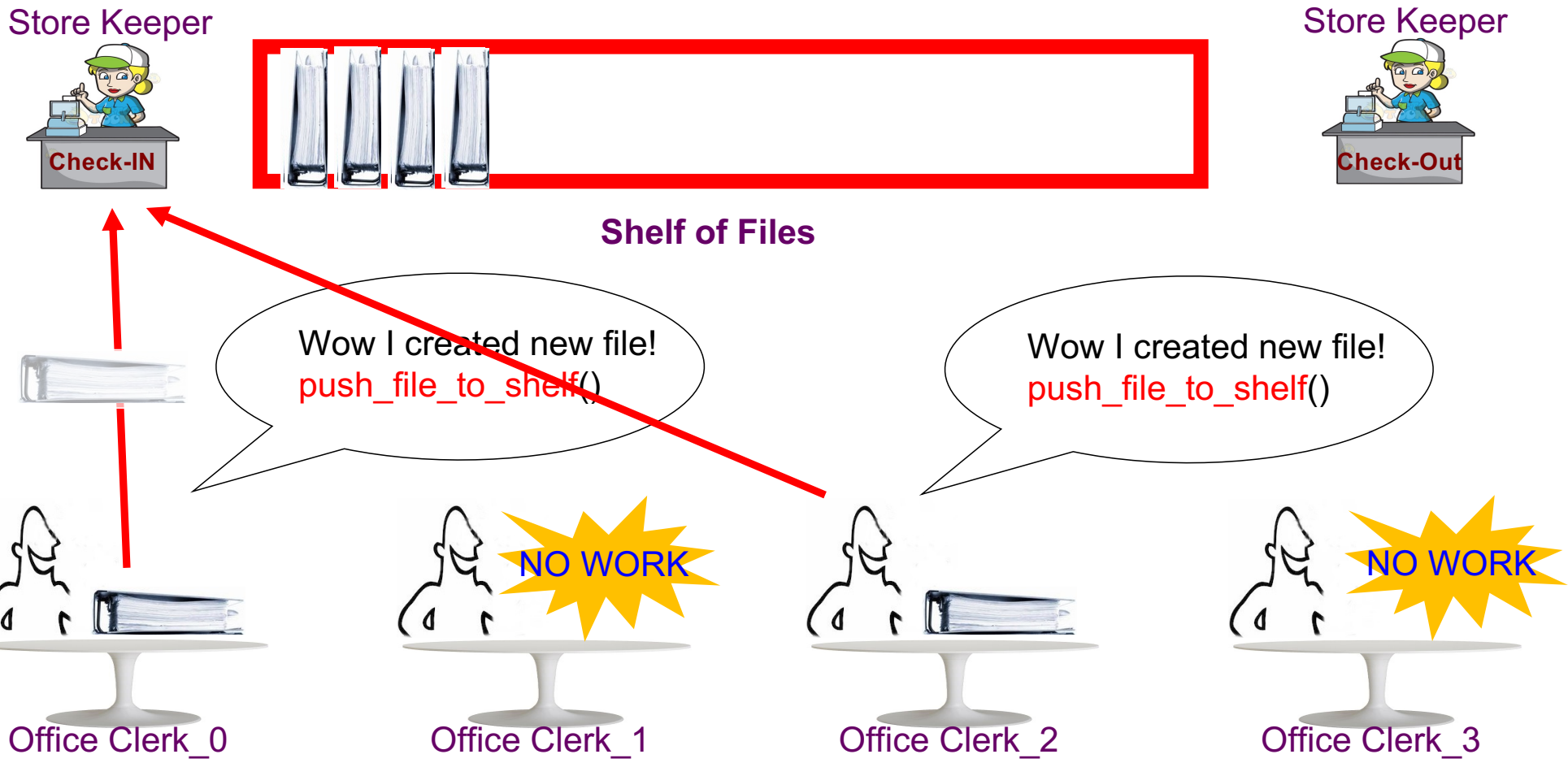
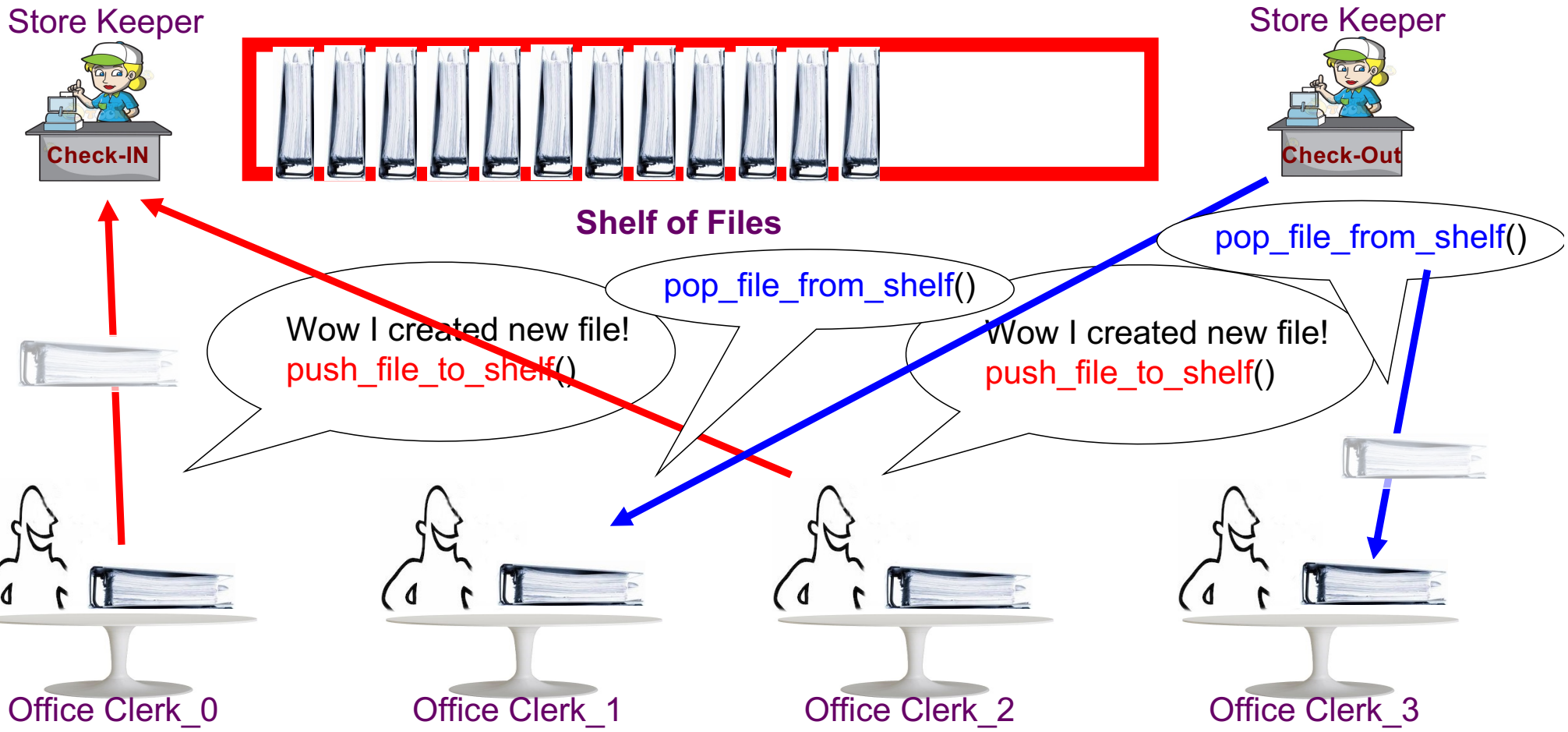


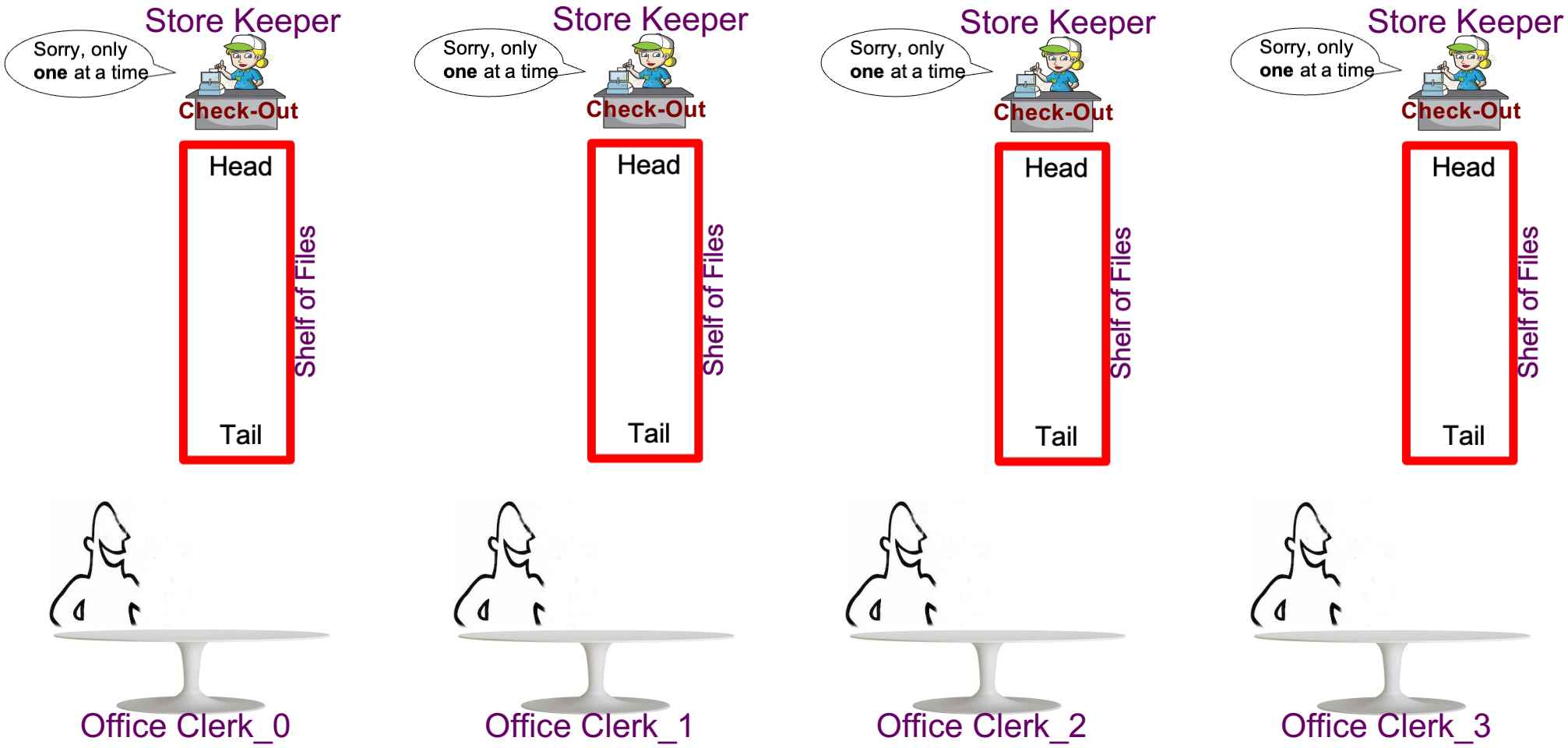
Work–Sharing



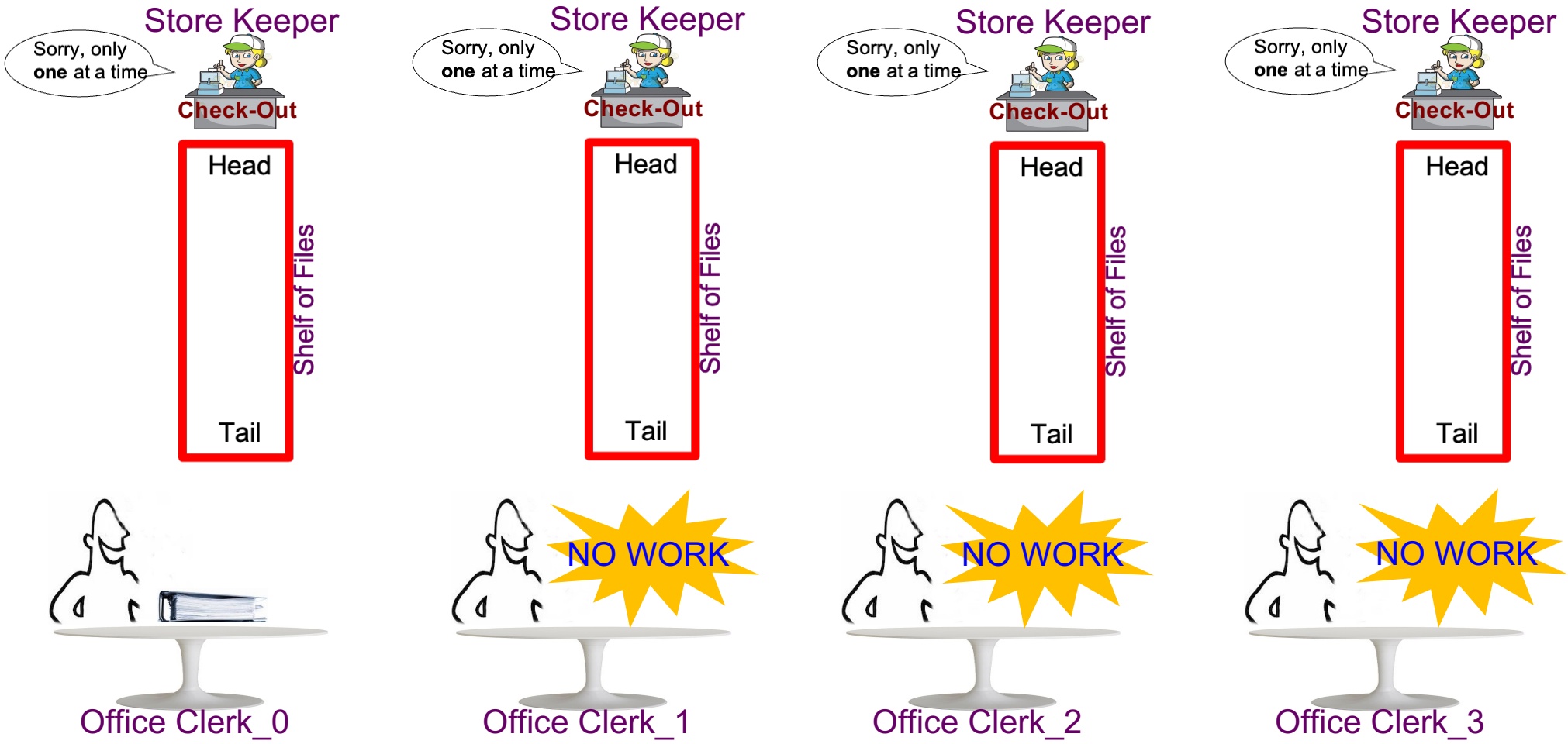
Today's Lecture

- Task scheduling paradigms
  - Work-sharing scheduling
  - **Work-stealing scheduling**

Work–Stealing



Work–Stealing



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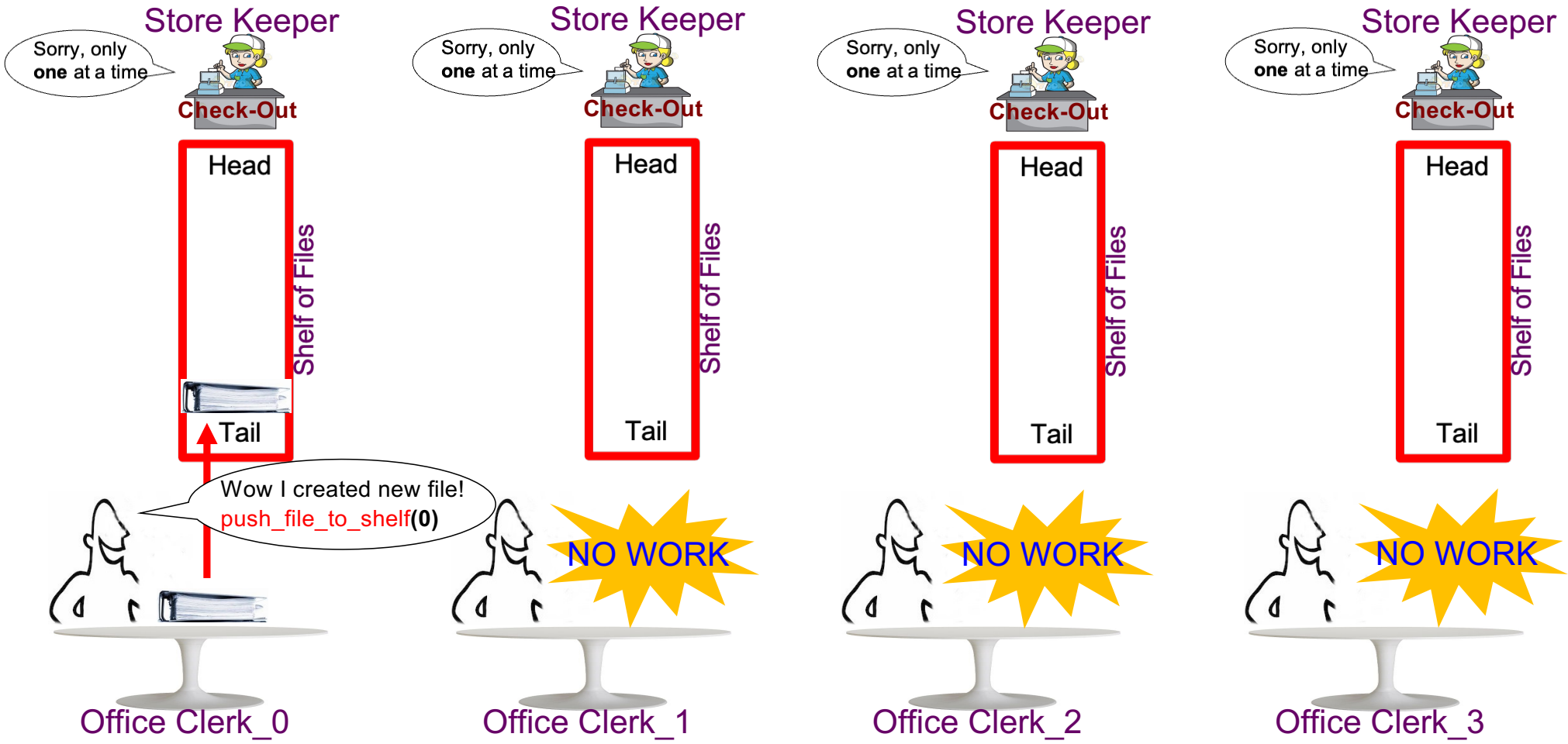

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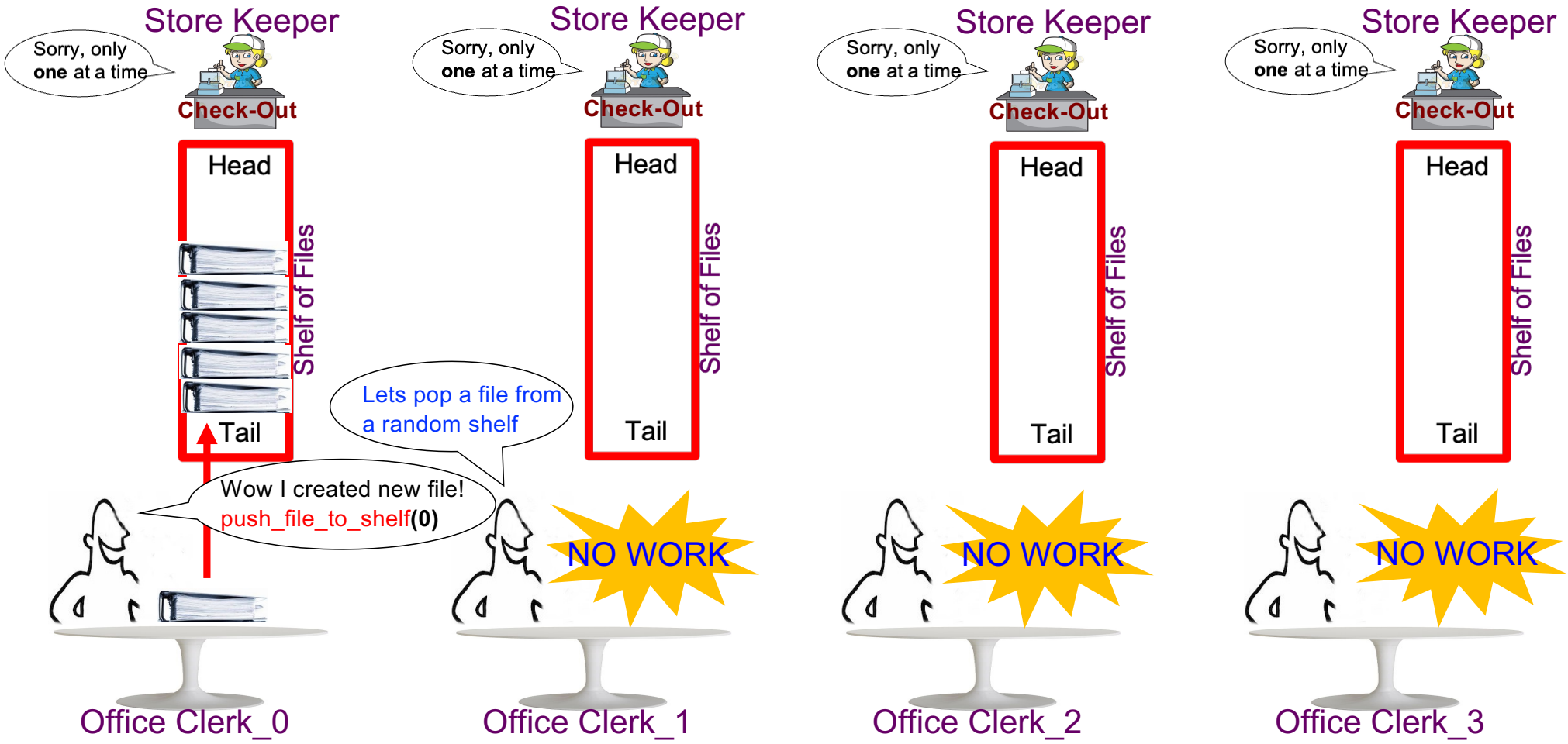

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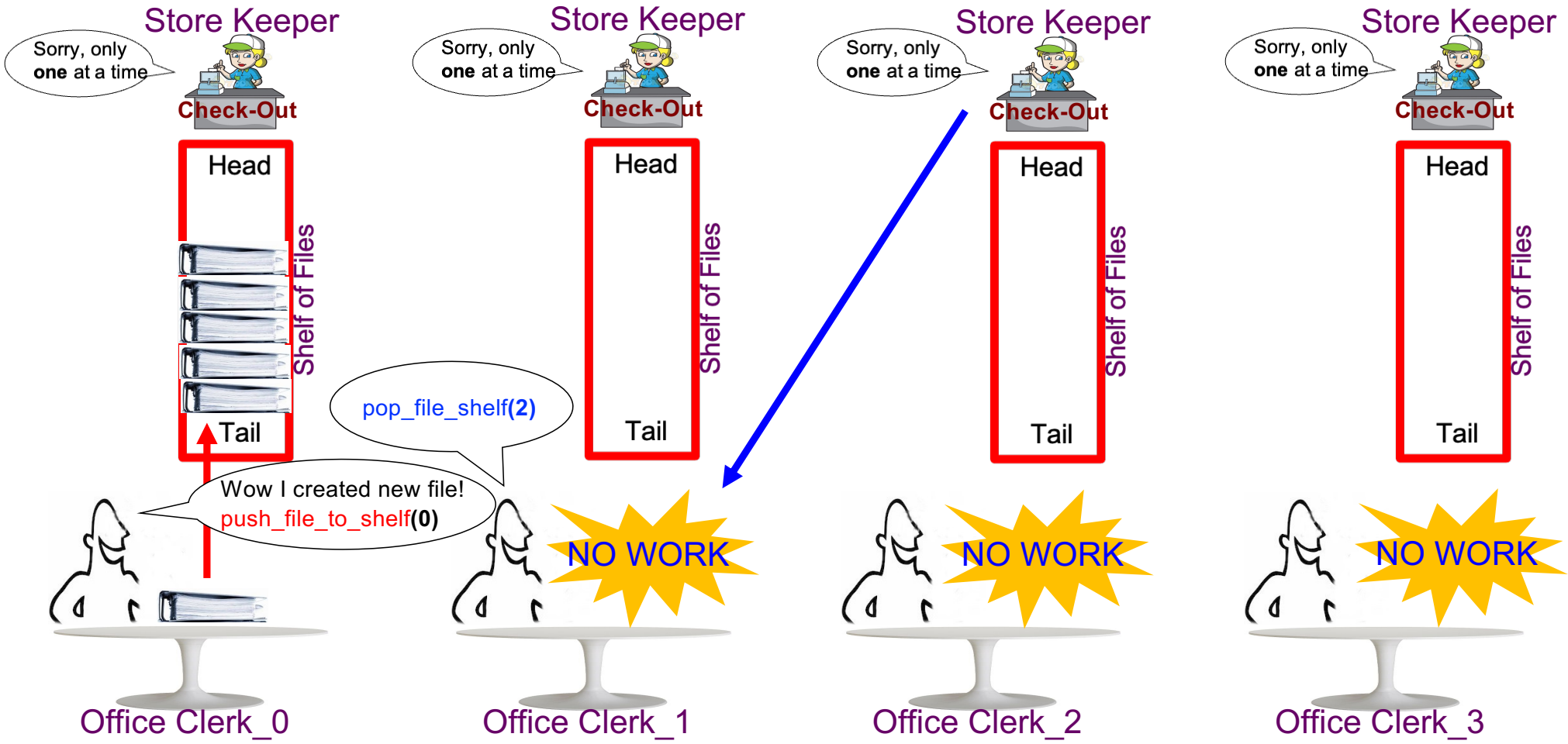

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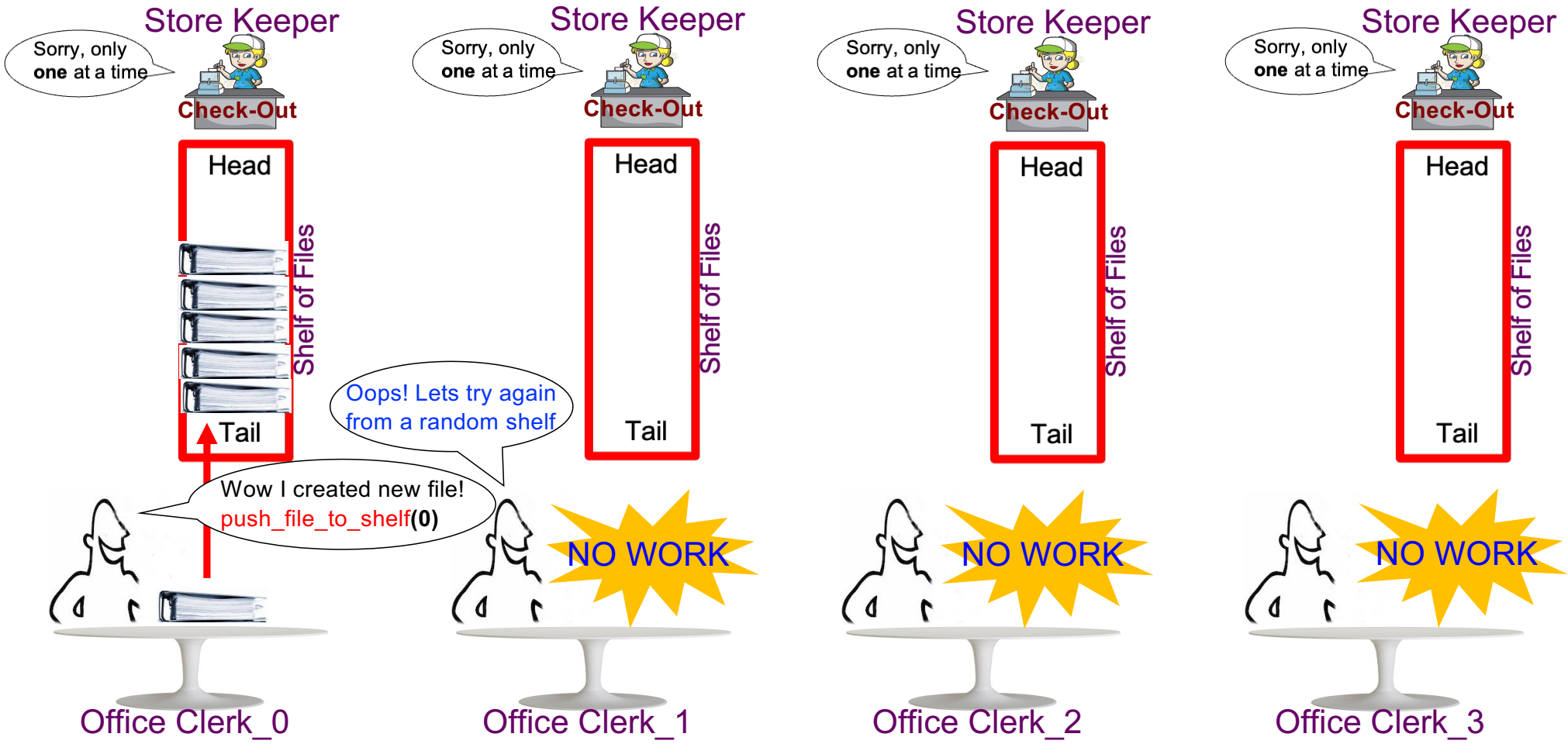

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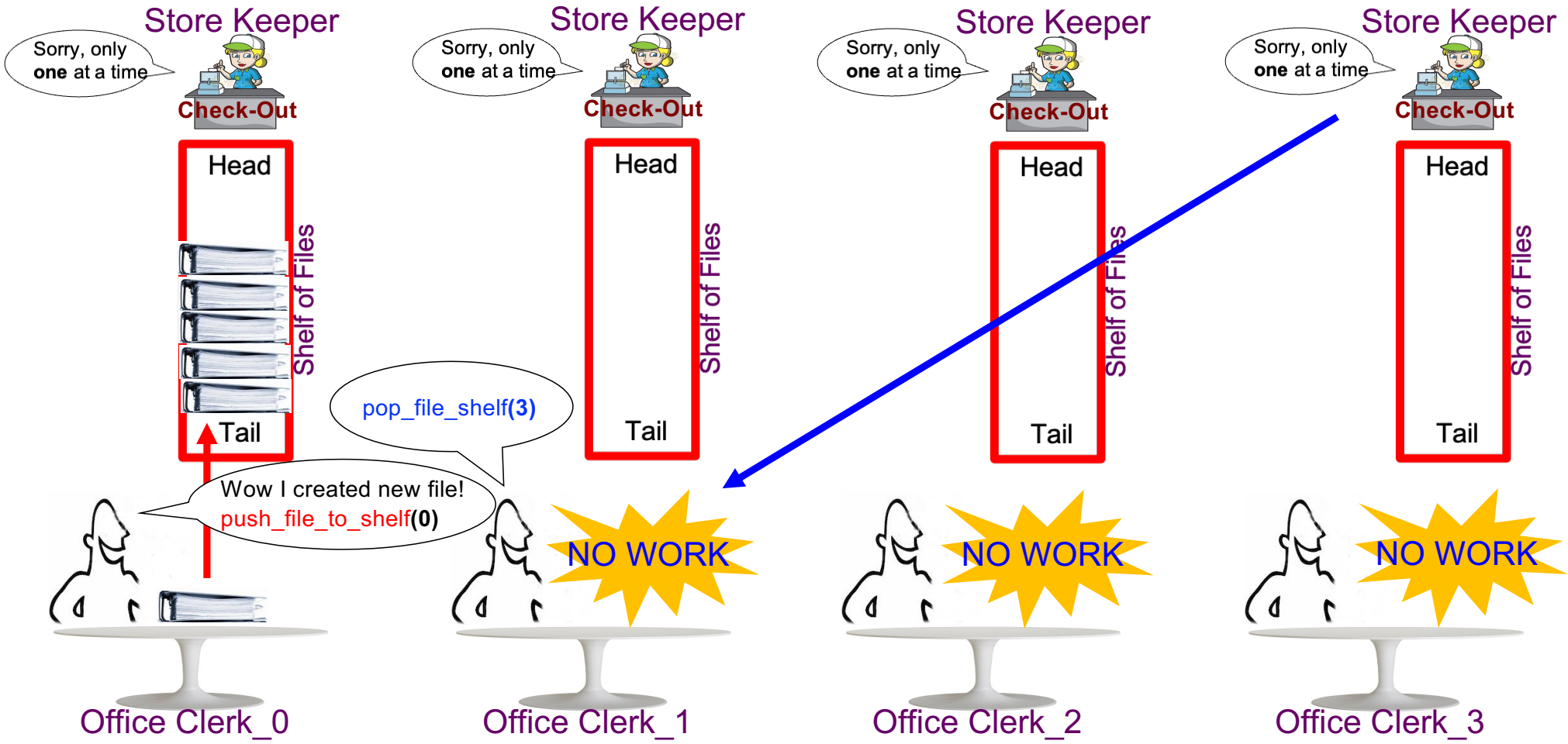

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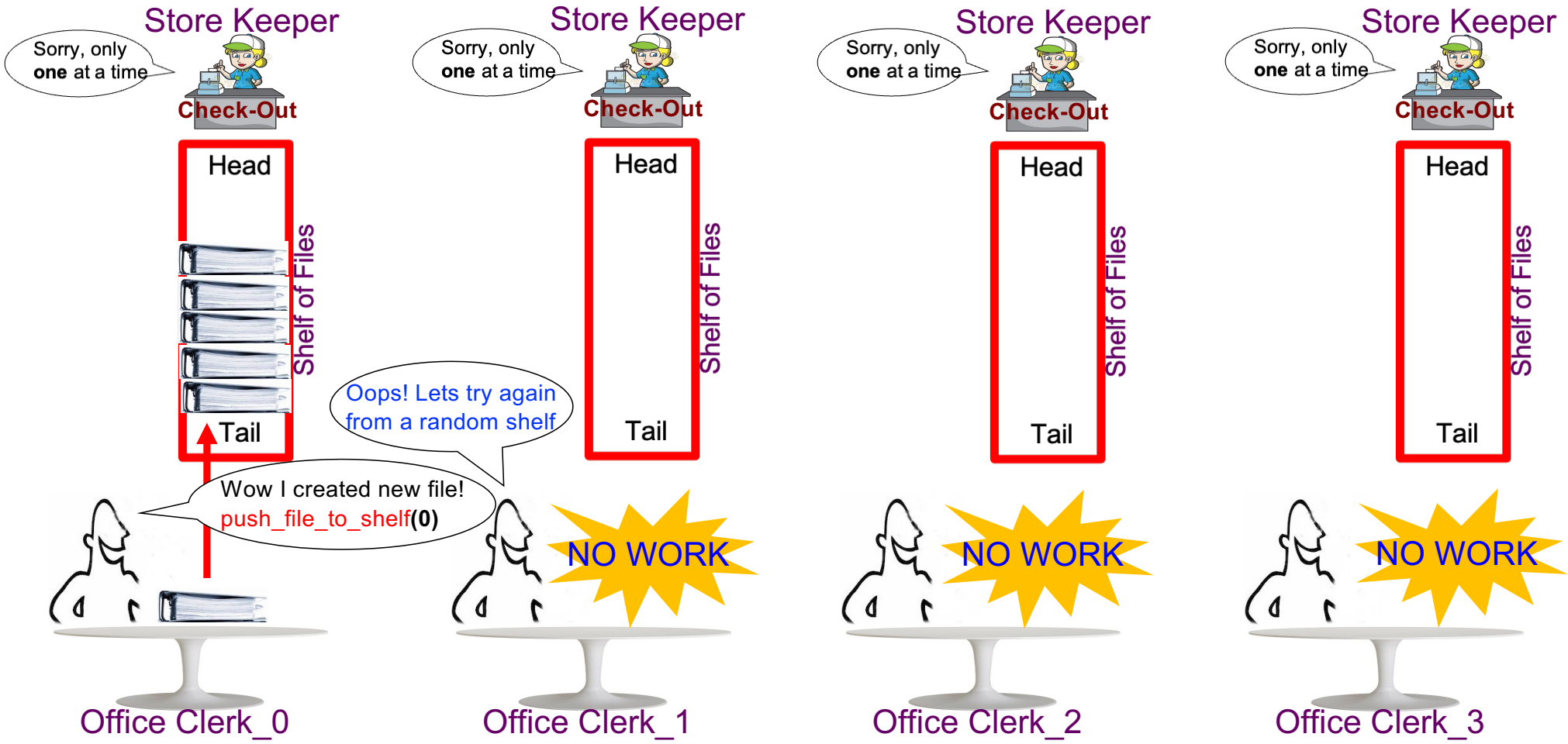

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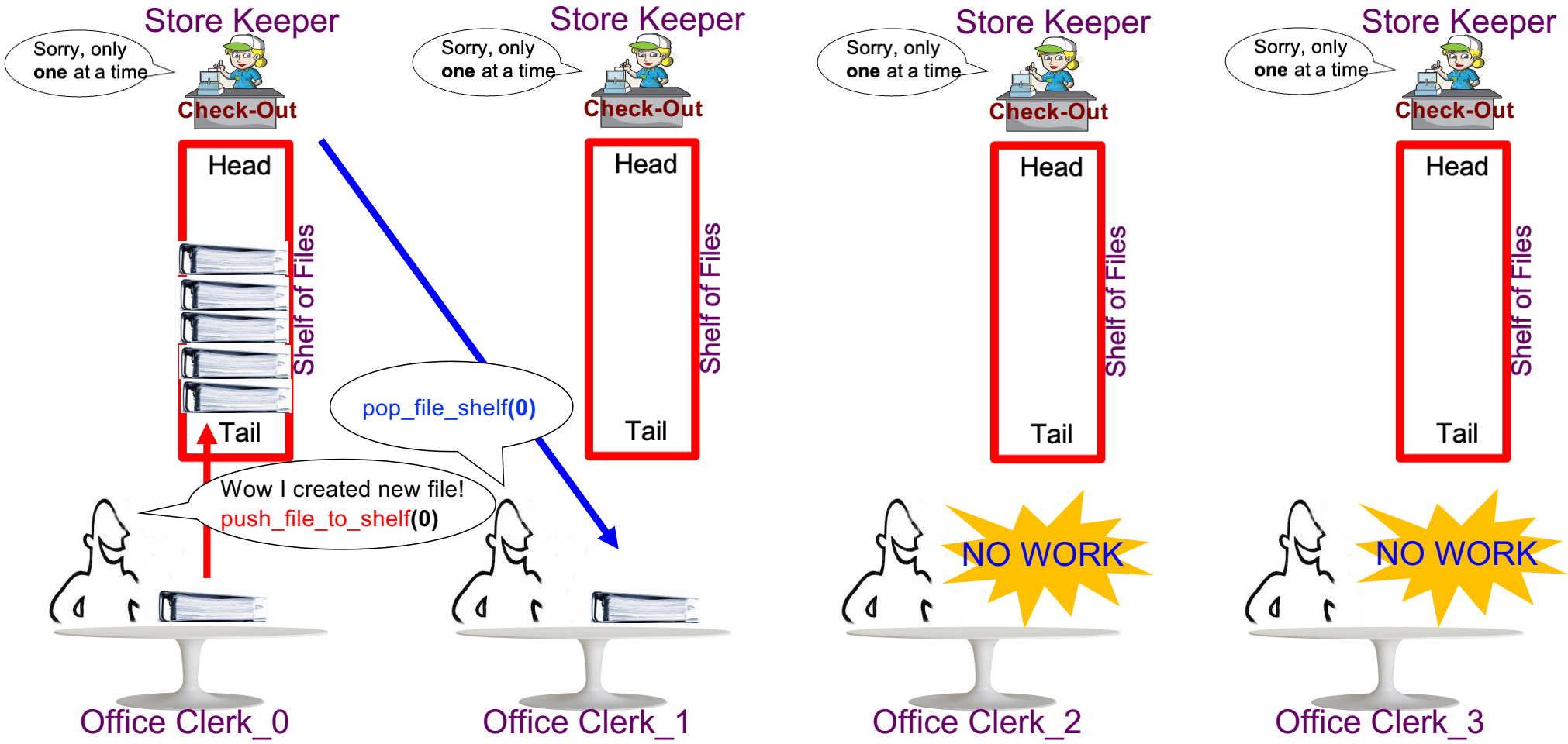

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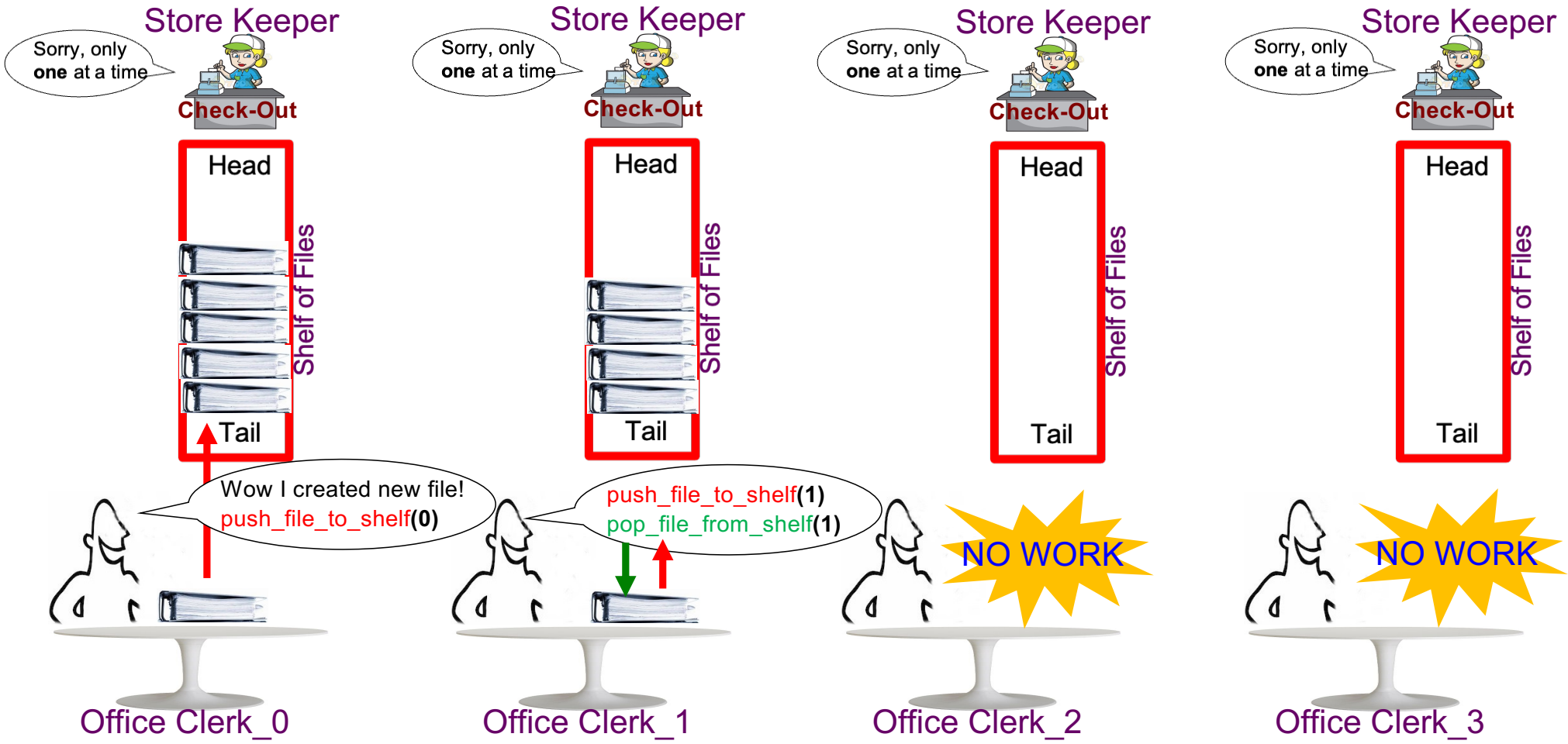

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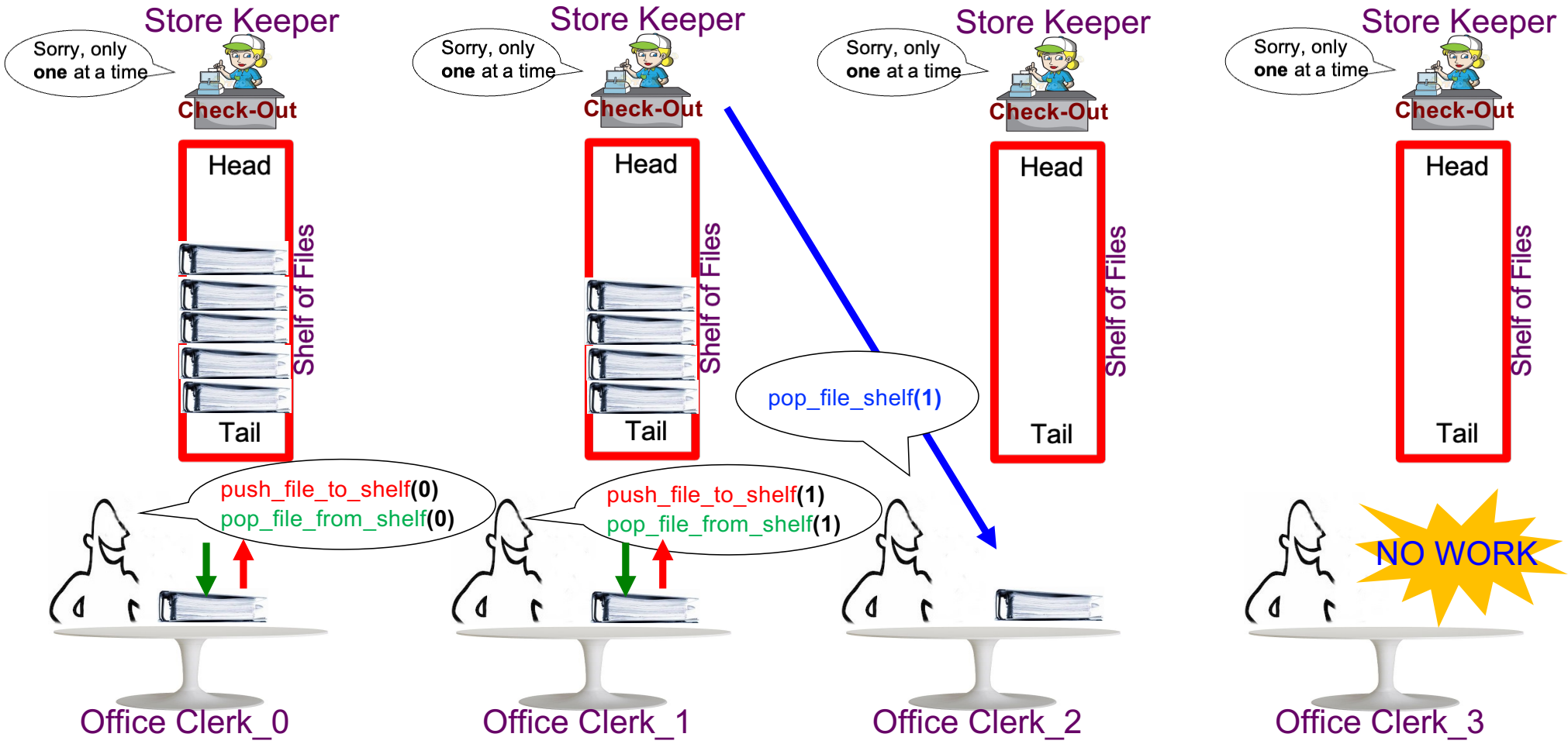

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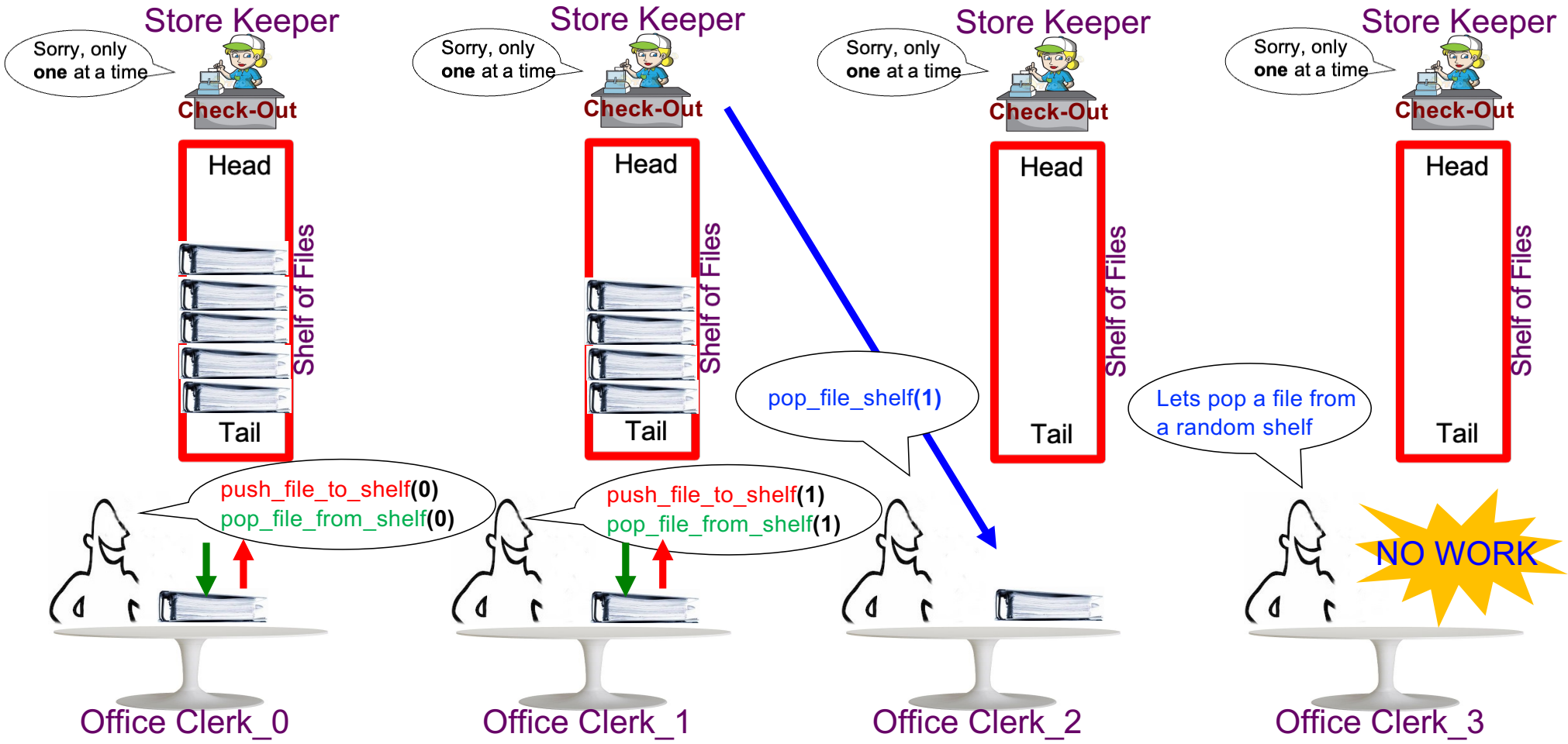
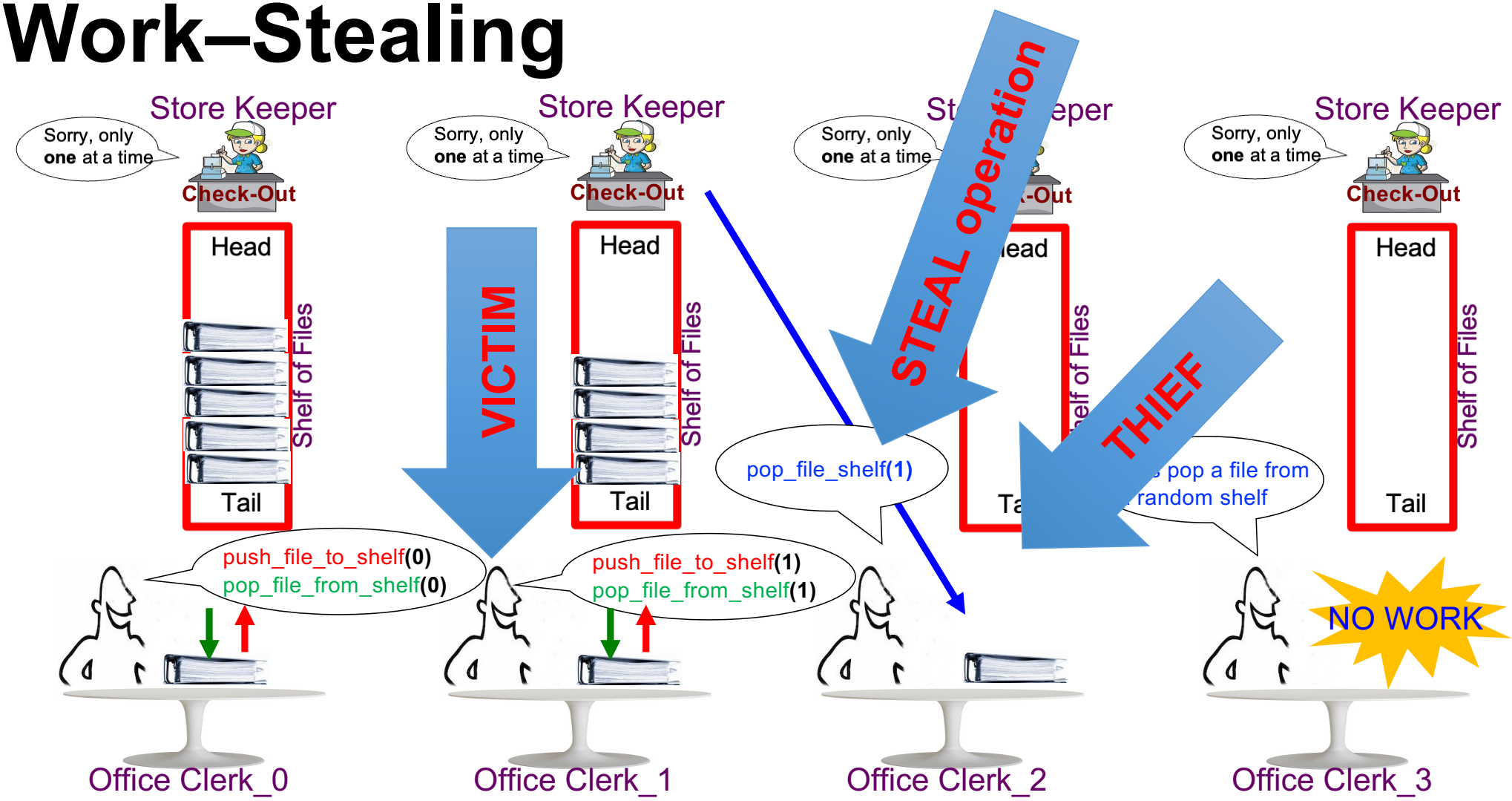


Work–Stealing



Task Scheduling Analogy With an Office

Store Keeper

Lock (usually implemented through compare-and-swap atomic operations, e.g., gcc built-in atomics)

Office File

Task

Office Clerk

Worker Thread (e.g., Pthread)

Shelf of Files in Work-sharing

Global FIFO queue

Shelf of Files in Work-stealing

Per worker LIFO queue ("**deque**"), where the **victim push** and **pop** tasks from the **tail** and **thief steals** task from the **head**. **Pop** and **steal** are serialized on a deque only in case there is **one** task remaining

Work-Sharing v/s Work-Stealing

- Work-sharing
  - Busy worker re-distributes the task eagerly
  - Easy implementation through global task pool
  - Access to the global pool needs to be synchronized: scalability bottleneck
- Work-stealing
  - Busy worker pays little overhead to enable stealing
    - A lock is required for pop and steal only in case single task remaining on deque (only feasible by using atomic operations)
    - Idle worker steals the tasks from busy workers
  - Distributed task pools
  - Better scalability

Reading Materials

- A Java Fork/Join framework, Doug Lea, ACM, 2000
  - http://gee.cs.oswego.edu/dl/papers/fj.pdf

Next Lecture

- Loop level parallelism