Parallel Programming
in C with MPI and OpenMP

Michael J. Quinn

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Chapter 9
Document Classification

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Chapter Objectives

- Complete introduction of MPI functions
- Show how to implement manager-worker programs

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Outline

- Introduce problem
- Parallel algorithm design
- Creating communicators
- Non-blocking communications
- Implementation
- Pipelining

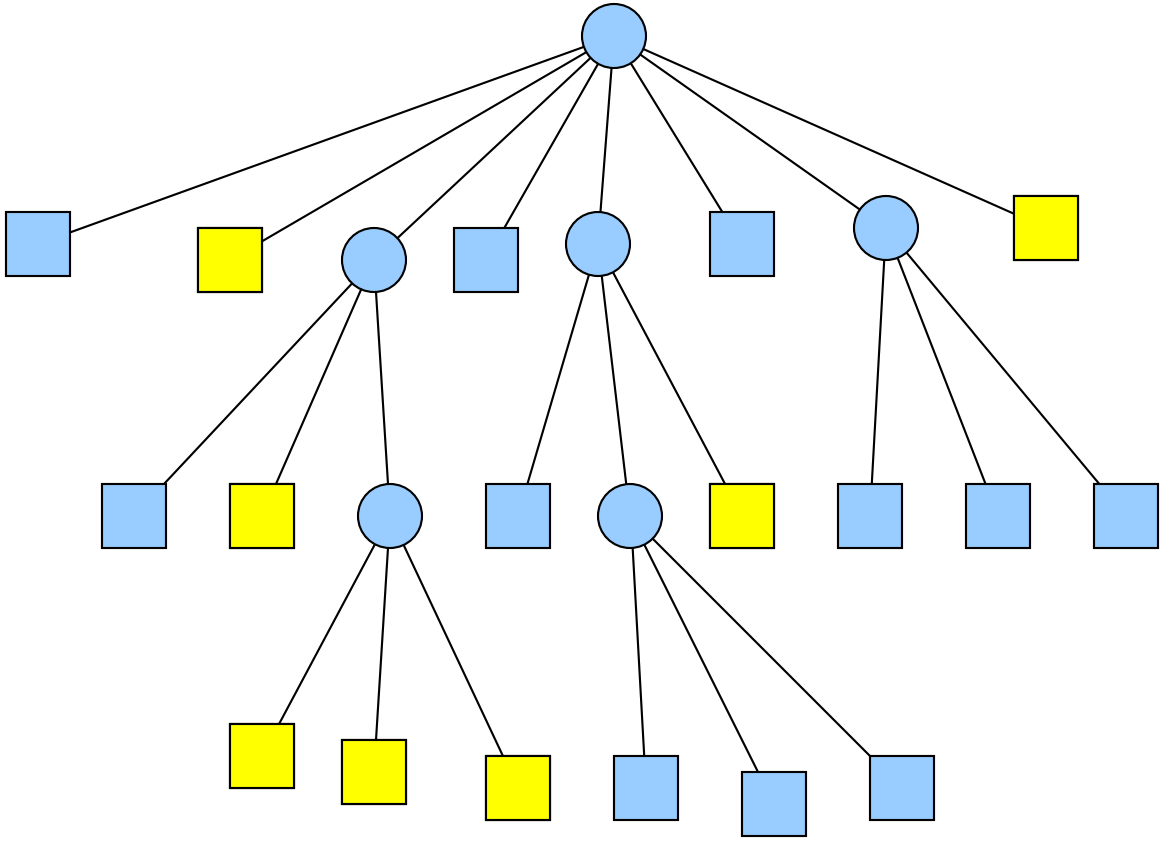
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Document Classification Problem

- Search directories, subdirectories for documents (look for .html, .txt, .tex, etc.)
- Using a dictionary of key words, create a profile vector for each document
- Store profile vectors

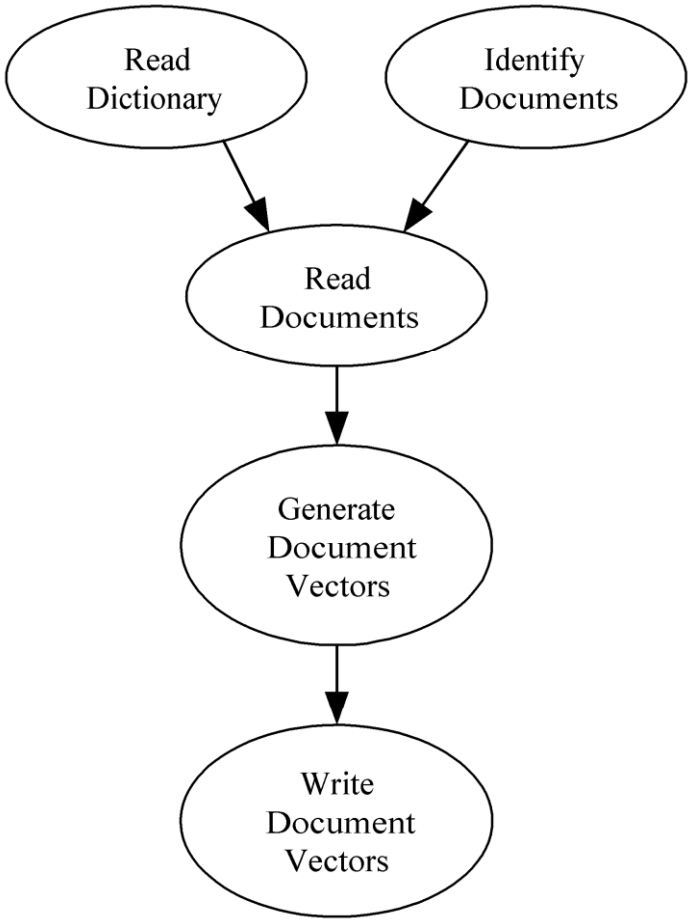
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Document Classification Problem



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Data Dependence Graph (1)



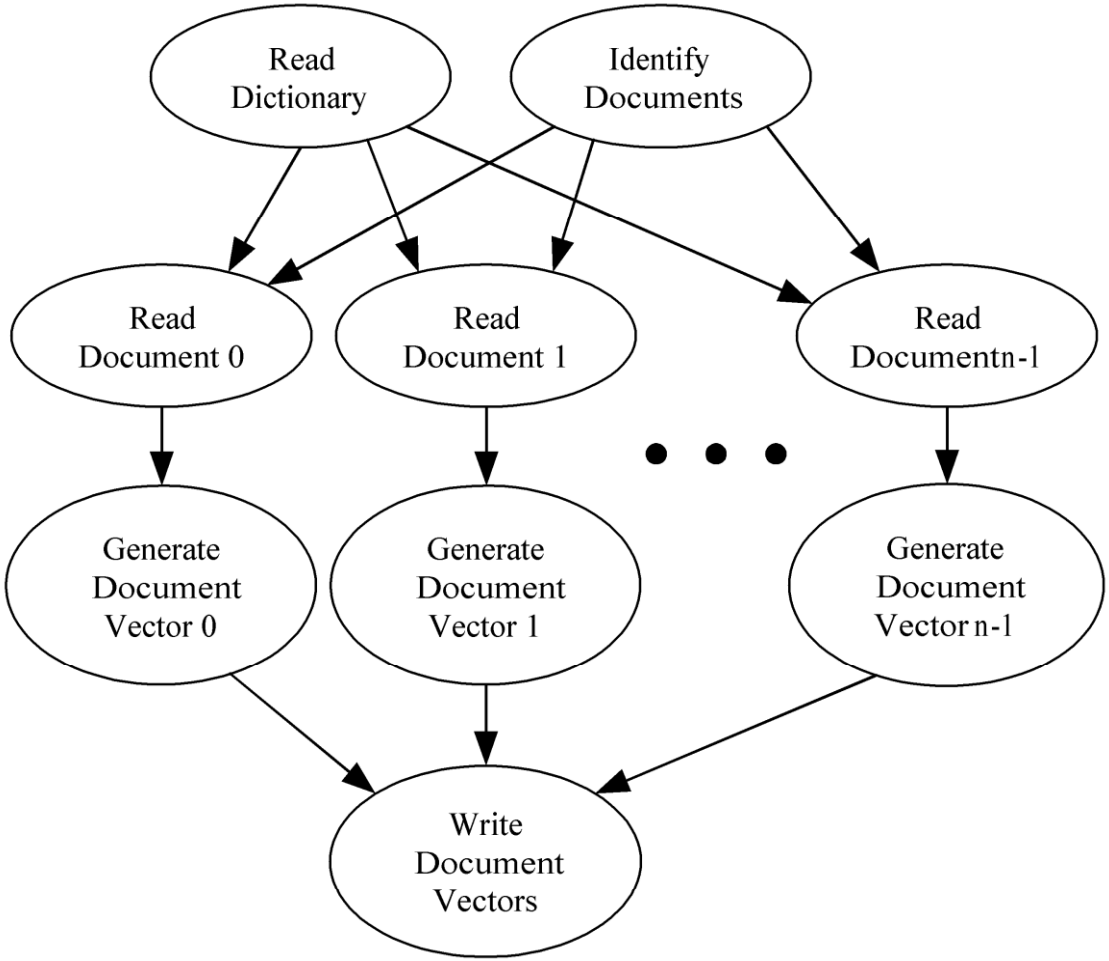
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Partitioning and Communication

- Most time spent reading documents and generating profile vectors
- Create two primitive tasks for each document

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Data Dependence Graph (2)



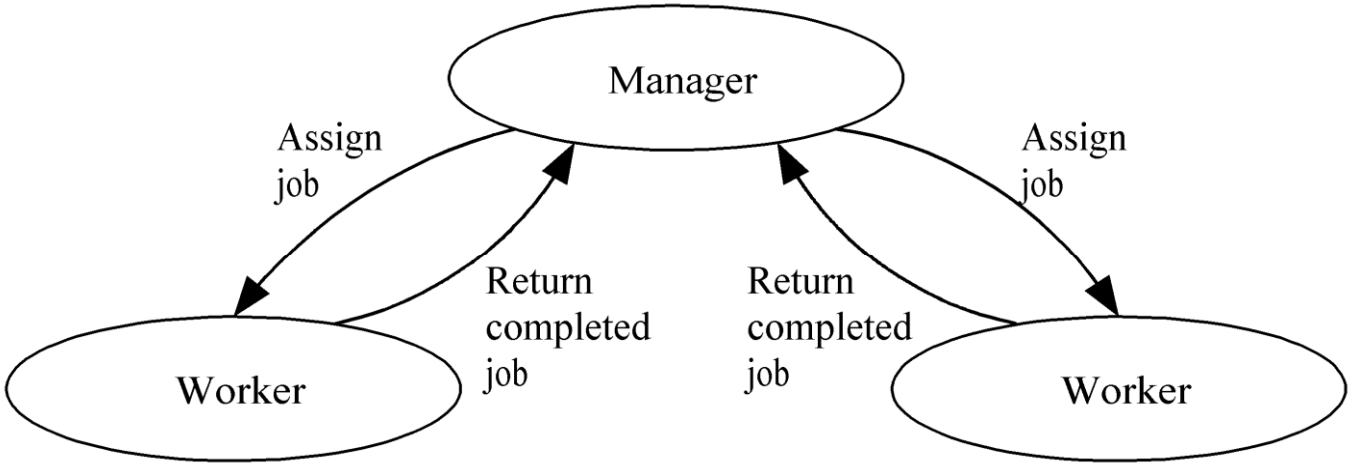
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Agglomeration and Mapping

- Number of tasks not known at compile time
- Tasks do not communicate with each other
- Time needed to perform tasks varies widely
- Strategy: map tasks to processes at run time

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Manager/worker-style Algorithm



Can also be viewed as domain partitioning with run-time allocation of data to tasks

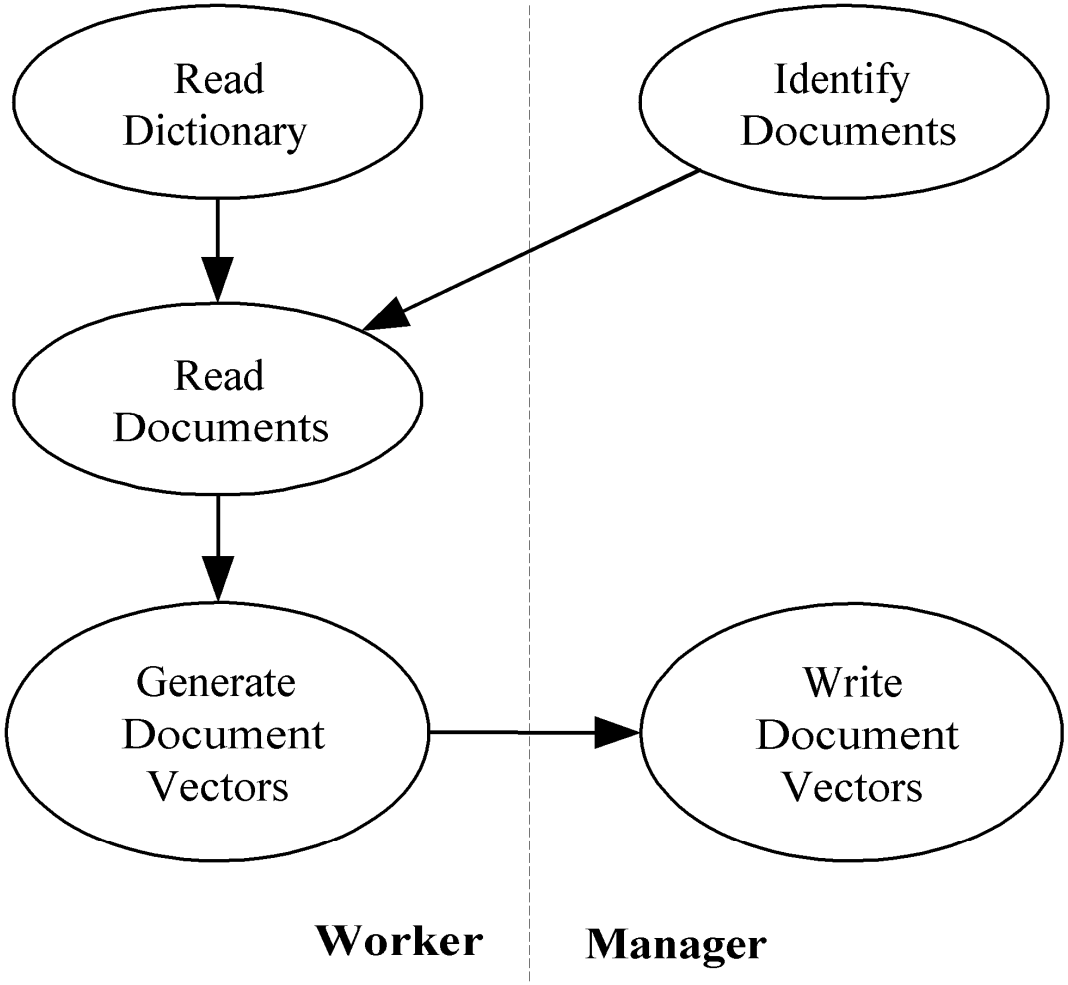
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Manager/Worker vs. SPMD

- SPMD (single program multiple data)
  - Every process executes same functions
  - Our prior programs fit this mold
- Manager/worker
  - Manager process has different responsibilities than worker processes
  - An MPI manager/worker program has an early control flow split (manager process one way, worker processes the other way)

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Roles of Manager and Workers



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Manager Pseudocode

```
Identify documents
Receive dictionary size from worker 0
Allocate matrix to store document vectors
repeat
    Receive message from worker
    if message contains document vector
            Store document vector
    endif
    if documents remain then Send worker file name
    else Send worker termination message
    endif
until all workers terminated
Write document vectors to file
```

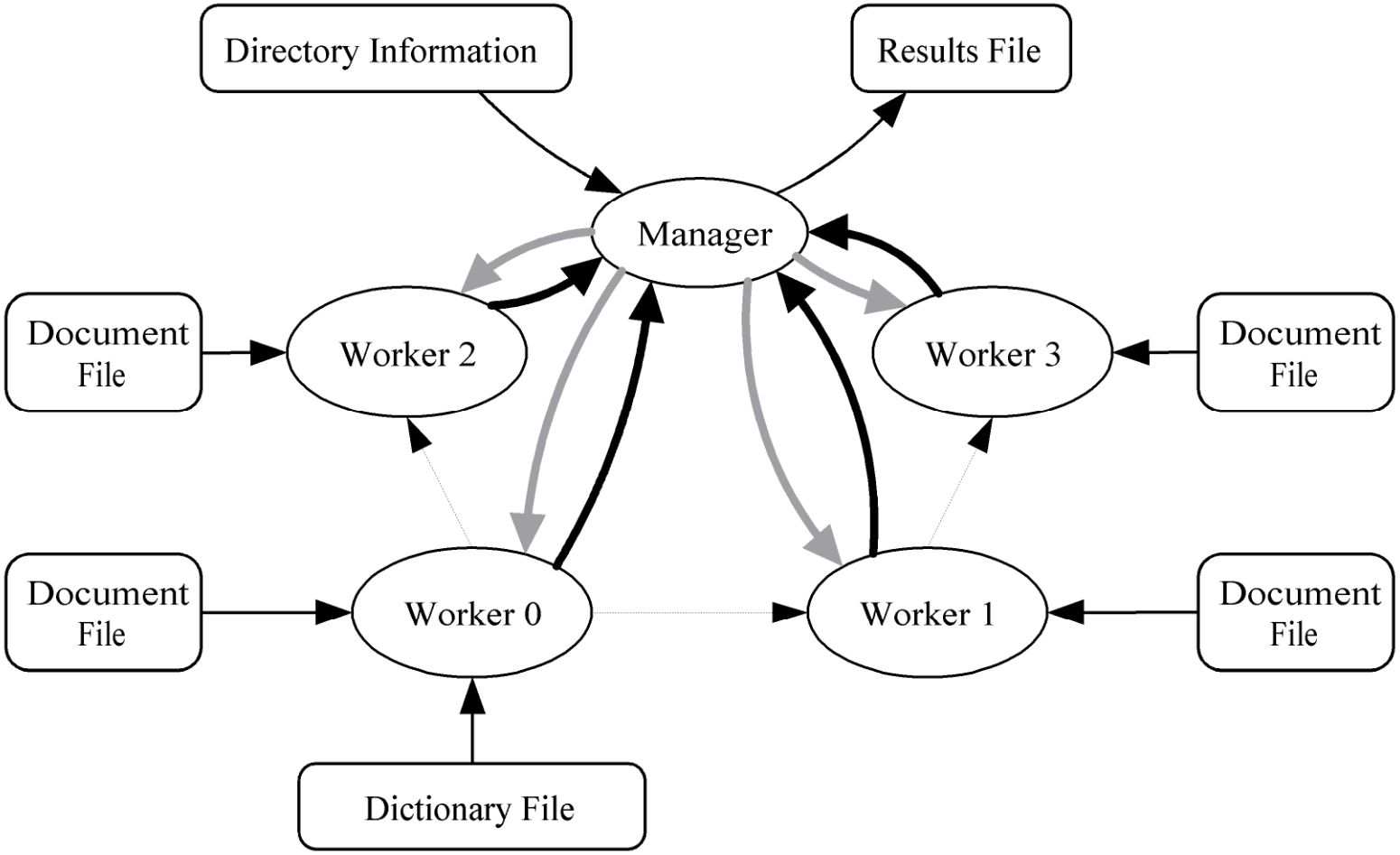

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Worker Pseudocode

```
Send first request for work to manager
if worker 0 then
    Read dictionary from file
endif
Broadcast dictionary among workers
Build hash table from dictionary
if worker 0 then
    Send dictionary size to manager
endif
repeat
    Receive file name from manager
    if file name is NULL then terminate endif
    Read document, generate document vector
    Send document vector to manager
forever
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Task/Channel Graph



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

MPI_Abort

- A “quick and dirty” way for one process to terminate all processes in a specified communicator
- Example use: If manager cannot allocate memory needed to store document profile vectors

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Header for MPI_Abort

```
int MPI_Abort (

   MPI_Comm comm, /* Communicator */

   int error_code /* Value returned to
                     calling environment */

)
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Creating a Workers-only Communicator

- Dictionary is broadcast among workers
- To support workers-only broadcast, need workers-only communicator
- Can use MPI_Comm_split
- Manager passes MPI_UNDEFINED as the value of split_key, meaning it will not be part of any new communicator

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Workers-only Communicator

```
int        id;
MPI_Comm worker_comm;

...

if (!id) /* Manager */
   MPI_Comm_split (MPI_COMM_WORLD,
      MPI_UNDEFINED, id, &worker_comm);

else /* Worker */
   MPI_Comm_split (MPI_COMM_WORLD, 0,
      id, &worker_comm);
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Nonblocking Send / Receive

- MPI_Isend, MPI_Irecv initiate operation
- MPI_Wait blocks until operation complete
- Calls can be made early
  - MPI_Isend as soon as value(s) assigned
  - MPI_Irecv as soon as buffer available
- Can eliminate a message copying step
- Allows communication / computation overlap

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Irecv

```
int MPI_Irecv (
      void           *buffer,
      int             cnt,
      MPI_Datatype    dtype,
      int             src,
      int             tag,
      MPI_Comm        comm,
      MPI_Request    *handle
)
```

Pointer to object that identifies communication operation

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Wait

```
int MPI_Wait (

      MPI_Request *handle,

      MPI_Status *status

)
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Isend

```
int MPI_Isend (
      void           *buffer,
      int             cnt,
      MPI_Datatype    dtype,
      int             dest,
      int             tag,
      MPI_Comm        comm,
      MPI_Request    *handle
)
```

Pointer to object that identifies communication operation

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Receiving Path Name

- Worker does not know length of longest path name it will receive
- Alternatives
  - Allocate huge buffer
  - Check length of incoming message, then allocate buffer
- We'll take the second alternative

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Probe

```
int MPI_Probe (
        int             src,
        int             tag,
        MPI_Comm        comm,
        MPI_Status *status
)
```

Blocks until message is available to be received

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Get_count

```
int MPI_Get_count (
      MPI_Status *status,
      MPI_Datatype dtype,
      int *cnt
)
```

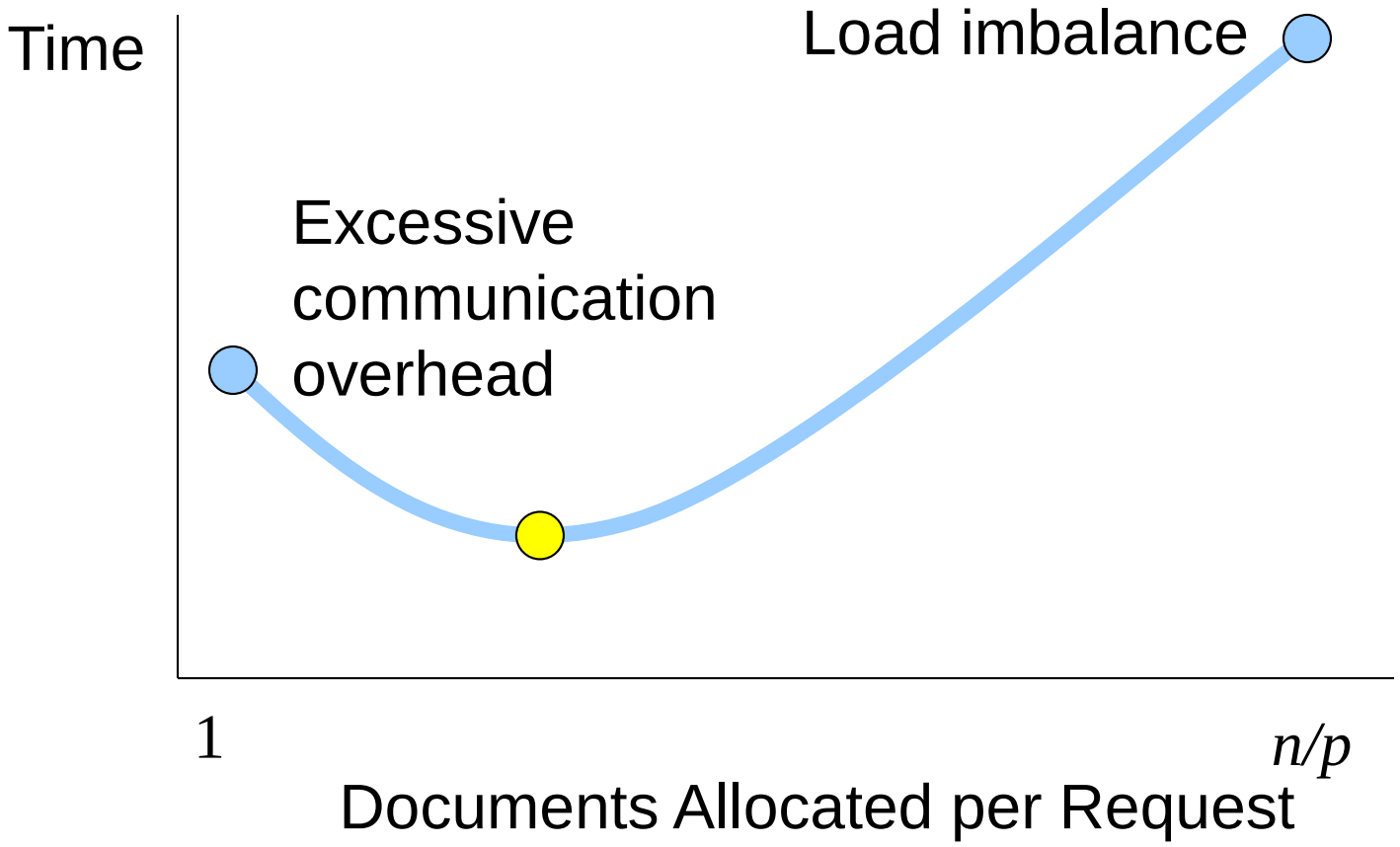

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Enhancements

- Middle ground between pre-allocation and one-at-a-time allocation
- Pipelining of document processing

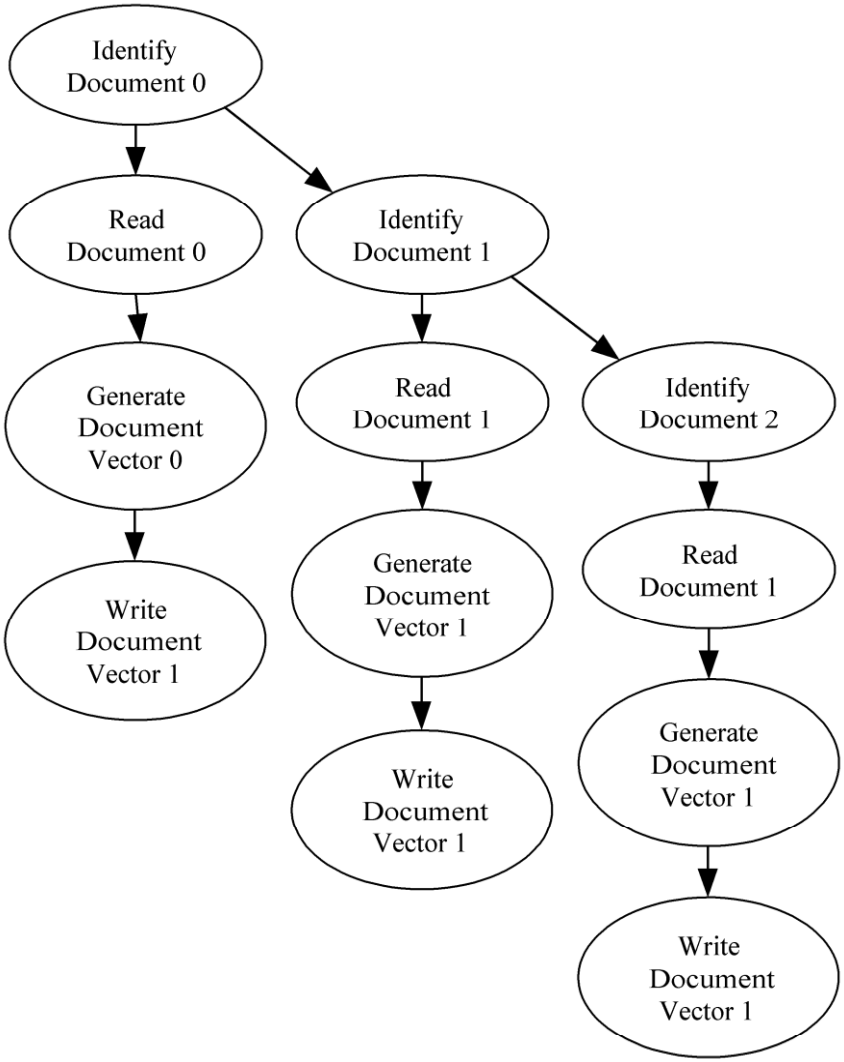
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Allocation Alternatives



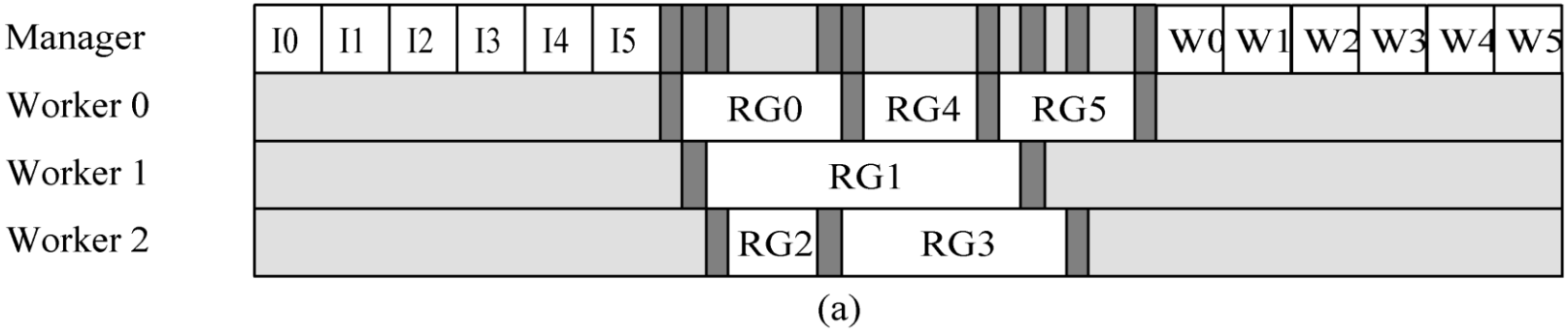
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Pipelining

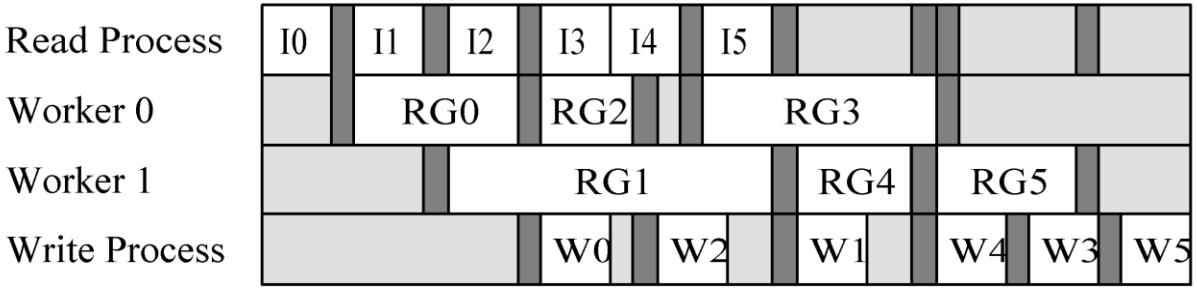


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Time Savings through Pipelining



(a)



(b)

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Pipelined Manager Pseudocode

```
a ← 0   {assigned jobs}
j ← 0   {available jobs}
w ← 0   {workers waiting for assignment}
repeat
    if (j > 0) and (w > 0) then
            assign job to worker
            j ← j – 1; w ← w – 1; a ← a + 1
    elseif (j > 0) then
            handle an incoming message from workers
            increment w
    else
            get another job
            increment j
    endif
until (a = n) and (w = p)
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Function MPI_Testsome

```
int MPI_Testsome (
   int in_cnt,
    /* IN - Number of nonblocking receives to check */

   MPI_Request *handlearray,
    /* IN - Handles of pending receives */

   int *out_cnt,
    /* OUT - Number of completed communications */

   int *index_array,
    /* OUT - Indices of completed communications */

   MPI_Status *status_array
    /* OUT - Status records for completed comms */
)
```


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Summary

- Manager/worker paradigm
  - Dynamic number of tasks
  - Variable task lengths
  - No communications between tasks
- New tools for “kit”
  - Create manager/worker program
  - Create workers-only communicator
  - Non-blocking send/receive
  - Testing for completed communications

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.