Four Variations of Matrix Multiplication

About 30 minutes – by Mike

Matrix Multiplication Challenge

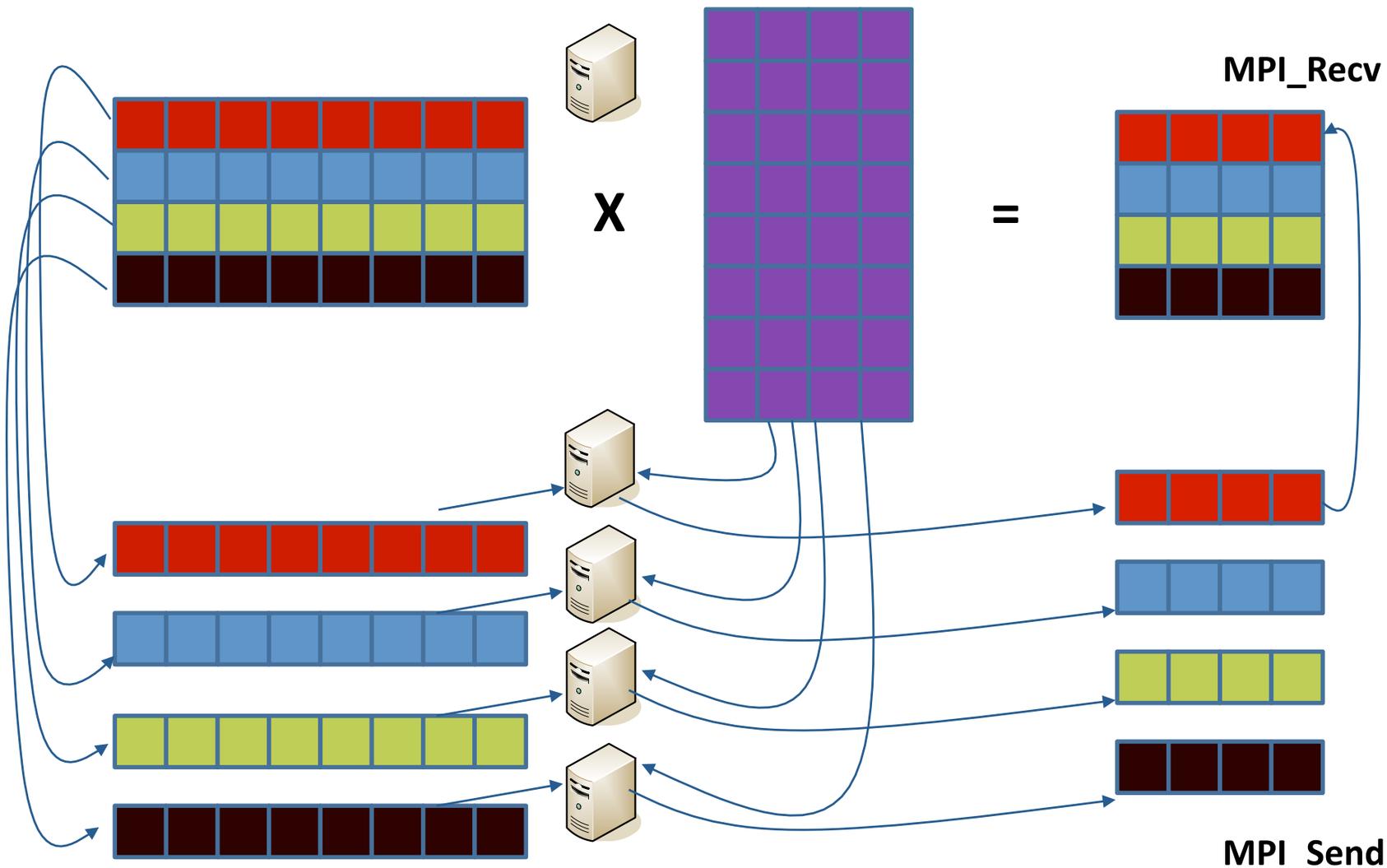
- See
  - http://www.cs.utah.edu/formal_verification
  - Look under Concurrency Education
  - Look at MPI teaching resources
    - Many of these resources are due to Simone Atzeni
    - Many are due to Geof Sawaya
      - All the examples from Pacheco's MPI book!
      - This will soon be available as projects within our ISP Eclipse GUI!
- Matrix Challenge is due to Steve Siegel
  - See http://www.cs.utah.edu/ec2
  - Steve's challenge stems from an MPI book It is based on an example from the book

    Using MPI: Portable Parallel Programming with the Message-Passing Interface by William Gropp, Ewing Lusk, and Anthony Skjellum.

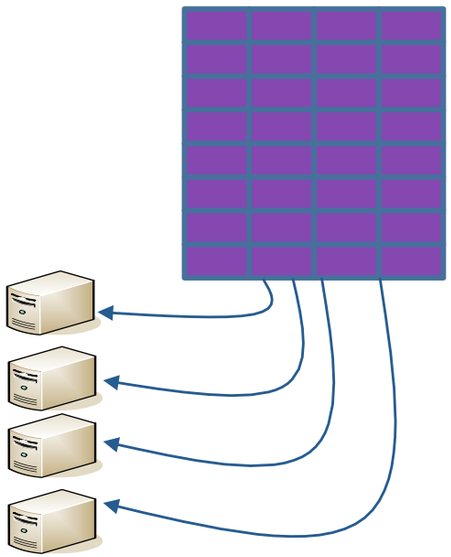
Matrix Multiplication Illustration

- For this tutorial, we include four variants
- These try various versions of mat-mult
- Includes one buggy version
- Also reveals one definite future work item
  - Detect symmetries in MPI programs
  - Avoid redundant searches
  - Very apparent when you run our fourth version

Example of MPI Code (Mat Mat Mult)

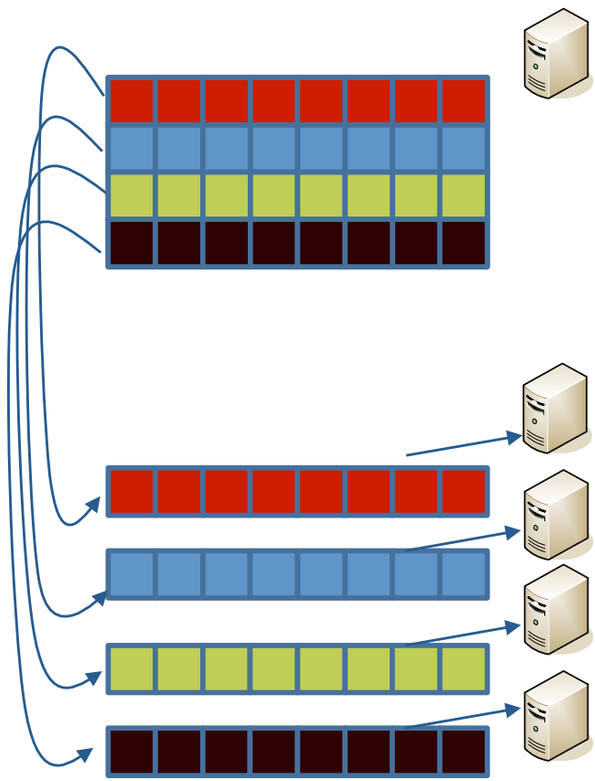


Salient Code Features



```
if (myid == master) {
  ...
  MPI_Bcast(b, brows*bcols, MPI_FLOAT, master, …);
  ...
 }
 else { // All Slaves do this
  ...
  MPI_Bcast(b, brows*bcols, MPI_FLOAT, master, …);
  ...
 }
```

Salient Code Features



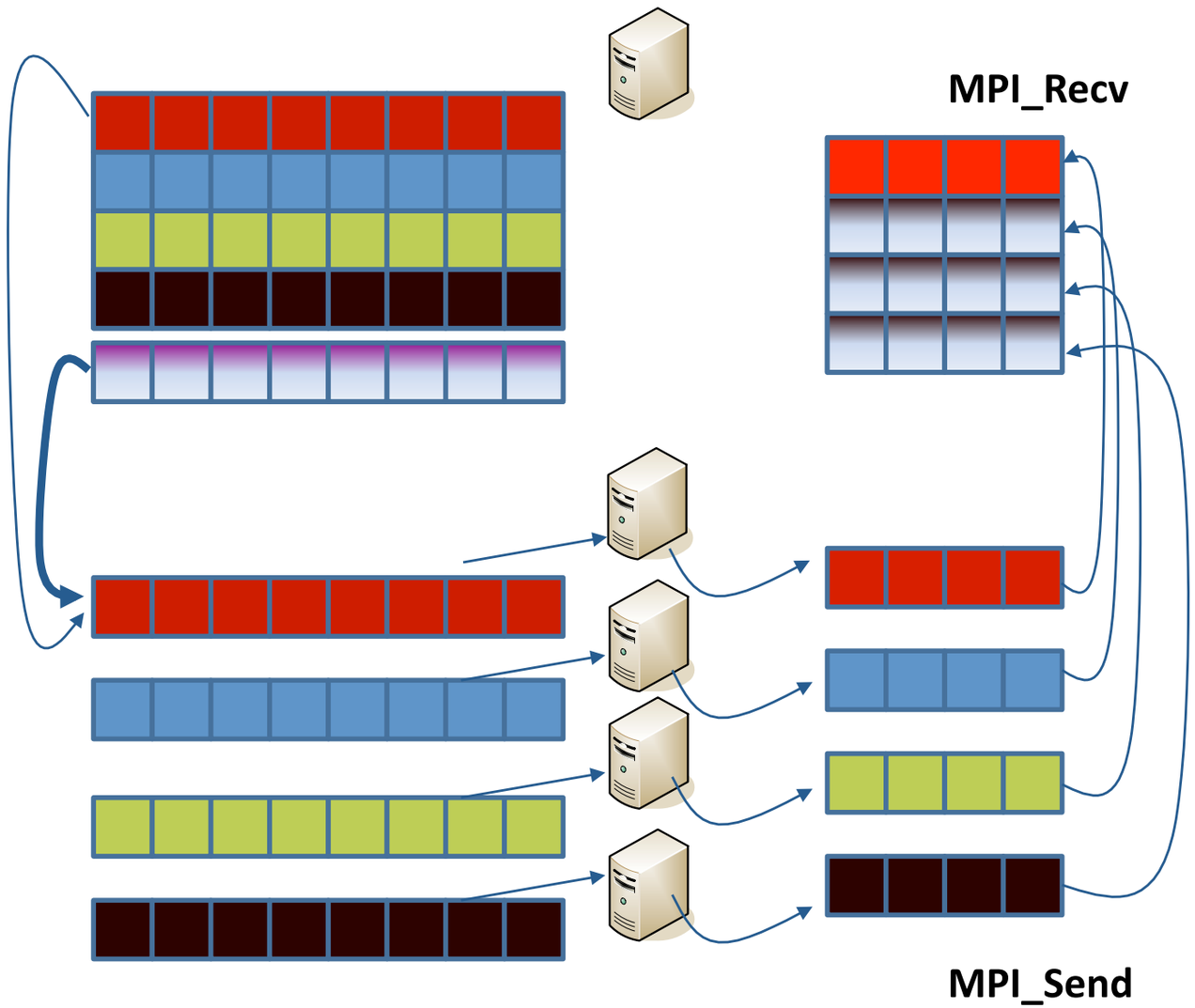
```
if (myid == master) {
 ...
 for (i = 0; i < numprocs-1; i++) {
  for (j = 0; j < acols; j++) {
   buffer[j] = a[i*acols+j];
  }
  MPI_Send(buffer, acols, MPI_FLOAT, i+1, …);
  numsent++;
 }
}
```

Block till buffer is copied into System Buffer

System Buffer

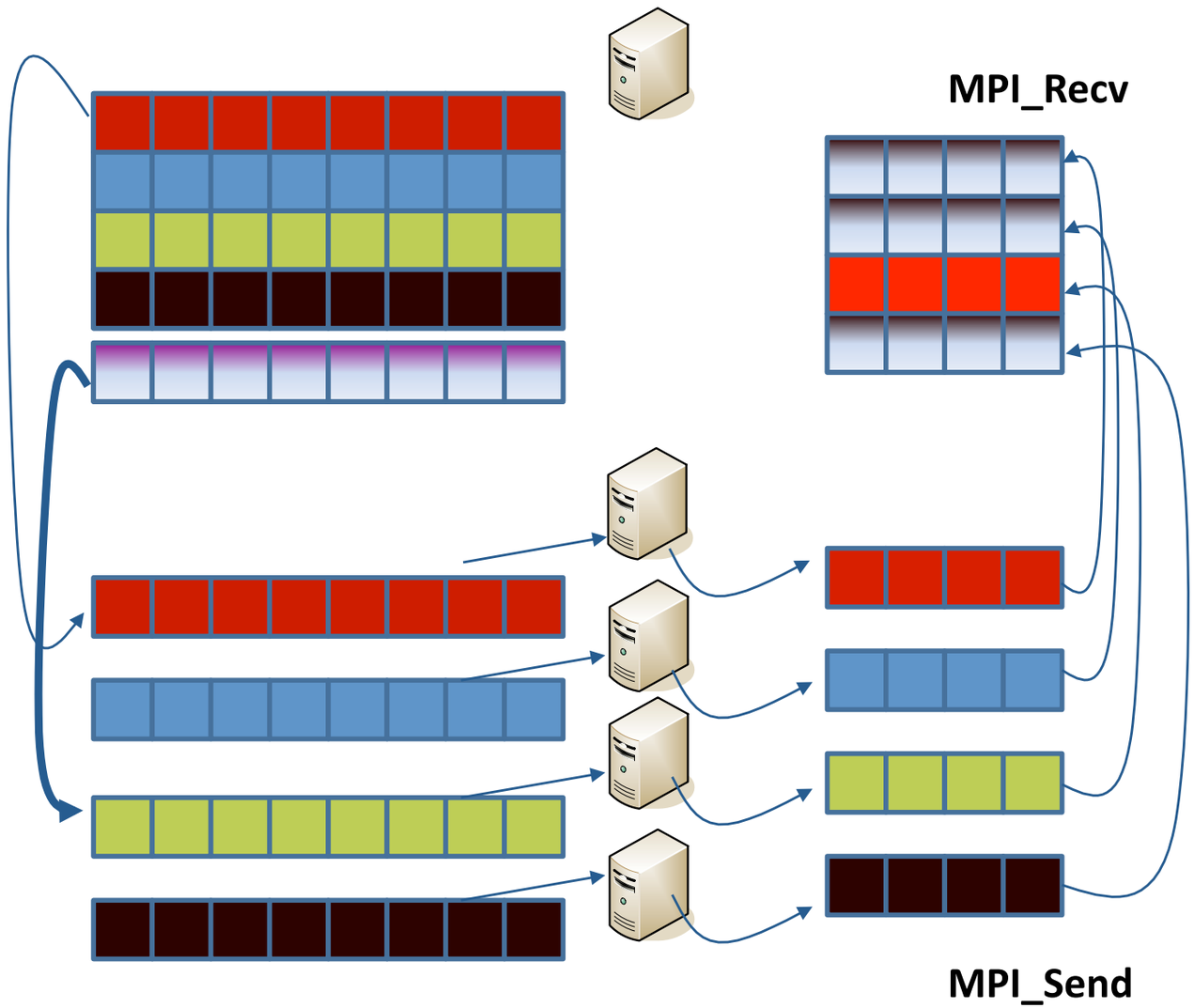
```
else { // slaves
  ...
  while (1) {
   ...
   MPI_Recv(buffer, acols, MPI_FLOAT, master, …);
   ...
  }
 }
```

Handling Rows >> Processors …



Send Next Row to
First Slave which
By now must be free

Handling Rows >> Processors …



OR

Send Next Row to First Slave that returns the answer!

Optimization

```
if (myid == master) {
  ...
  for (i = 0; i < crows; i++) {
    MPI_Recv(ans, ccols, MPI_FLOAT, FROM  ANYBODY, ...);
    ...
    if (numsent < arows) {
      for (j = 0; j < acols; j++) {
          buffer[j] = a[numsent*acols+j];
      }
    MPI_Send(buffer, acols, MPI_FLOAT, BACK TO  THAT BODY, ...);
     numsent++;
     ...
    }
  }
```

Optimization

```
if (myid == master) {
  ...
  for (i = 0; i < crows; i++) {
    MPI_Recv(ans, ccols, MPI_FLOAT, FROM  ANYBODY, ...);
    ...
    if (numsent < arows) {
      for (j = 0; j < acols; j++) {
          buffer[j] = a[numsent*acols+j];
      }
    MPI_Send(buffer, acols, MPI_FLOAT, BACK TO  THAT BODY, ...);
     numsent++;
     ...
    }
  }
```

Shows that wildcard receives can arise quite naturally …

Further Optimization

```
if (myid == master) {
  ...
  for (i = 0; i < crows; i++) {
   MPI_Recv(ans, ccols, MPI_FLOAT, FROM  ANYBODY, ...);
   ...
   if (numsent < arows) {
    for (j = 0; j < acols; j++) {
        buffer[j] = a[numsent*acols+j];
    }
    ... here, WAIT for previous Isend  to finish
        (software pipelining)  ...

    MPI_Isend(buffer, acols, MPI_FLOAT, BACK TO  THAT BODY, ...);

    numsent++;
    ...
   }
  }
```

Summary of Some MPI Commands

- MPI_Irecv(source, msg_bug, req_struct, ..)
- This is a non-blocking receive call
- MPI_Wait(req_struct) awaits completion
- Source could be
  - "wildcard" or * or ANY_SOURCE
- Receive from any eligible (matching) sender

End of E