Dynamic Processes: Spawn

Dynamic Processes

- Adding processes to a running job
  - As part of the algorithm i.e. branch and bound
  - When additional resources become available
  - Some master-slave codes where the master is started first and asks the environment how many processes it can create
- Joining separately started applications
  - Client-server or peer-to-peer
- Handling faults/failures

MPI-1 Processes

- All process groups are derived from the membership of the MPI_COMM_WORLD
  - No external processes
- Process membership static (vs. PVM)
  - Simplified consistency reasoning
  - Fast communication (fixed addressing) even across complex topologies
  - Interfaces well to many parallel run-time systems
Static MPI-1 Job

- MPI_COMM_WORLD
- Contains 16 processes

Static MPI-1 Job

- MPI_COMM_WORLD
- Contains 16 processes
- Can only subset the original MPI_COMM_WORLD
  - No external processes

Disadvantages of Static Model

- Cannot add processes
- Cannot remove processes
  - If a process fails or otherwise disappears, all communicators it belongs to become invalid

⇒ Fault tolerance undefined
MPI-2

- Added support for dynamic processes
  - Creation of new processes on the fly
  - Connecting previously existing processes
- Does not standardize inter-implementation communication
  - Interoperable MPI (IMPI) created for this

Open Questions

How do you add more processes to an already-running MPI-1 job?
- How would you handle a process failure?
- How could you establish MPI communication between two independently initiated, simultaneously running MPI jobs?

MPI-2 Process Management

- MPI-2 provides "spawn" functionality
  - Launches a child MPI job from a parent MPI job
- Some MPI implementations support this
  - Open MPI
  - LAM/MPI
  - NEC MPI
  - Sun MPI
- High complexity: how to start the new MPI applications?
MPI-2 Spawn Functions

• MPI_COMM_SPAWN
  – Starts a set of new processes with the same command line
  – Single Process Multiple Data
• MPI_COMM_SPAWN_MULTIPLE
  – Starts a set of new processes with potentially different command lines
  – Different executables and/or different arguments
  – Multiple Processes Multiple Data

Spawn Semantics

• Group of parents collectively call spawn
  – Launches a new set of children processes
  – Children processes become an MPI job
  – An intercommunicator is created between parents and children
• Parents and children can then use MPI functions to pass messages
• MPI_UNIVERSE_SIZE

Spawn Example
Spawn Example

Parents call MPI_COMM_SPAWN

Spawn Example

Two processes are launched

Spawn Example

Children processes call MPI_INIT

Parents call MPI_COMM_SPAWN

Two processes are launched

Children processes call MPI_INIT
Children create their own MPI_COMM_WORLD

An intercommunicator is formed between parents and children

Intercommunicator is returned from MPI_COMM_SPAWN
Spawn Example

Intercommunicator

Children call MPI_COMM_GET_PARENT to get intercommunicator

Master / Slave Demonstration

- Simple ‘PVM’ style example
  - User starts singleton master process
  - Master process spawns slaves
  - Master and slaves exchange data, do work
  - Master gathers results
  - Master displays results
  - All processed shut down

Master / Slave Demonstration

Master program

```c
MPI_Init(...)
MPI_Spawn(..., slave, ...);
for (i=0; i < size; i++)
  MPI_Send(work, ..., i, ...);
for (i=0; i < size; i++)
  MPI_Recv(presults, ...);
calc_and_display_result(...);
MPI_Finalize();
```

Slave program

```c
MPI_Init(...)
MPI_Comm_get_parent(&intercomm);
MPI_Recv(work, ..., intercomm);
result = do_something(work);
MPI_Send(result, ..., intercomm);
MPI_Finalize();
```
MPI “Connected”

• “Two processes are connected if there is a communication path directly or indirectly between them.”
  – E.g., belong to the same communicator
  – Parents and children from SPAWN are connected
• Connectivity is transitive
  – If A is connected to B, and B is connected to C
  – A is connected to C

MPI “Connected”

• Why does “connected” matter?
  – MPI_FINALIZE is collective over set of connected processes
  – MPI_ABORT may abort all connected processes
• How to disconnect?
  – …stay tuned

Multi-Stage Spawning

• What about multiple spawns?
  – Can sibling children jobs communicate directly?
  – Or do they have to communicate through a common parent?
  ➔ Is all MPI dynamic process communication hierarchical in nature?
Do we have to do this?
Multi-Stage Spawning

Dynamic Processes: Connect / Accept

Establishing Communications

• MPI-2 has a TCP socket style abstraction
  – Process can accept and connect connections from other processes
  – Client-server interface
• MPI_COMM_CONNECT
• MPI_COMM_ACCEPT
Establishing Communications

- How does the client find the server?
  - With TCP sockets, use IP address and port
  - What to use with MPI?
- Use the MPI name service
  - Server opens an MPI “port”
  - Server assigns a public “name” to that port
  - Client looks up the public name
  - Client gets port from the public name
  - Client connects to the port

Server Side

- Open and close a port
  - MPI_OPEN_PORT(info, port_name)
  - MPI_CLOSE_PORT(port_name)
- Publish the port name
  - MPI_PUBLISH_NAME(service_name, info, port_name)
  - MPI_UNPUBLISH_NAME(service_name, info, port_name)

Server Side

- Accept an incoming connection
  - MPI_COMM_ACCEPT(port_name, info, root, comm, newcomm)
  - comm is a intracommunicator; local group
  - newcomm is an intercommunicator; both groups
Client Side

- Lookup port name
  - MPI_LOOKUP_NAME(service_name, info, port_name)
- Connect to the port
  - MPI_COMM_CONNECT(port_name, info, root, comm, newcomm)
  - comm is a \textit{intra}communicator; local group
  - newcomm is an \textit{inter}communicator; both groups

Connect / Accept Example

Server calls MPI\_OPEN\_PORT
Server calls `MPI_PUBLISH_NAME("ocean", info, port_name)`

Server blocks in `MPI_COMM_ACCEPT("Port A", ...)`

Client calls `MPI_LOOKUP_NAME("ocean", ...), gets "Port A"`
Client calls MPI_COMM_CONNECT("Port A", ...)

Connect / Accept Example

Intercommunicator formed; returned to both sides

Server calls MPI_UNPUBLISH_NAME("ocean", ...)

Connect / Accept Example
Connect / Accept Example

Both sides call MPI_COMM_DISCONNECT

Summary

- Server opens a port
- Server publishes public “name”
- Client looks up public name
- Client connects to port
- Server unpublishes name
- Server closes port
- Both sides disconnect

Similar to TCP sockets / DNS lookups
MPI_COMM_JOIN

• A third way to connect MPI processes
  – User provides a socket between two MPI processes
  – MPI creates an intercommunicator between the two processes

➤ Will not be covered in detail here

Disconnecting

• Once communication is no longer required
  – MPI_COMM_DISCONNECT
  – Waits for all pending communication to complete
  – Then formally disconnects groups of processes -- no longer "connected"
• Cannot disconnect MPI_COMM_WORLD