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A Comparison of MPI and CPA Networking Communication Performance

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Breakdown

- Background
  - CPA Networking
- MPI and CPA Networking
- Experiments
- Future Work
  - New Network Layer
- Conclusions

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Motivation

- MPI is a standardised method of inter “process” communication in parallel computing applications
- Highly popular approach to developing parallel computing applications
- How well does CPA Networking compare to MPI for communication?
- I have been asked for a comparison for a couple of years now

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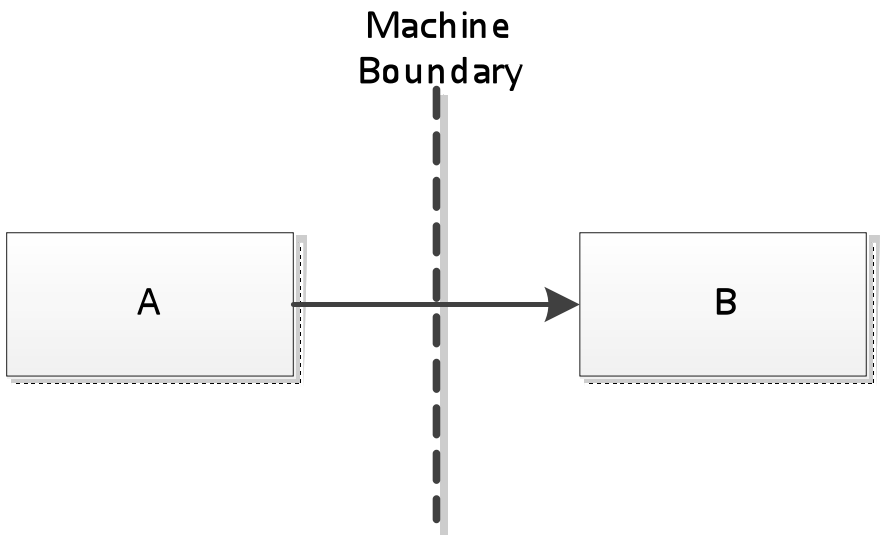
Goal of CPA Networking

- Provide *inter-process communication* across a communication medium *in a transparent manner*
- No notion of high performance
  - Distributed channel enabling framework



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Goal of MPI

- Provide a *high performance*, *scalable*, and *portable* inter-process communication mechanism for parallel computing applications

- Provides both point-to-point and collective communication mechanisms

- Commonly used for Single Program, Multiple Data applications

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Comparison

- Both CPA Networking and MPI aim at *inter-process communication*
- MPI aims at HPC type applications
- CPA Networking aims at …?
  - Good question
  - Has been previous work in HPC applications
  - Essentially an enabling technology

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CPA NETWORKING

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History of CPA Networking

- T9000 and Virtual Channel Processor
- JCSP.net
  - T9000 inspired
  - Highly integrated with Java and JCSP
- CPA Networking
  - Development of protocol
  - Lightly integrated with Java and JCSP
    - But still too much
  - Resource reduction

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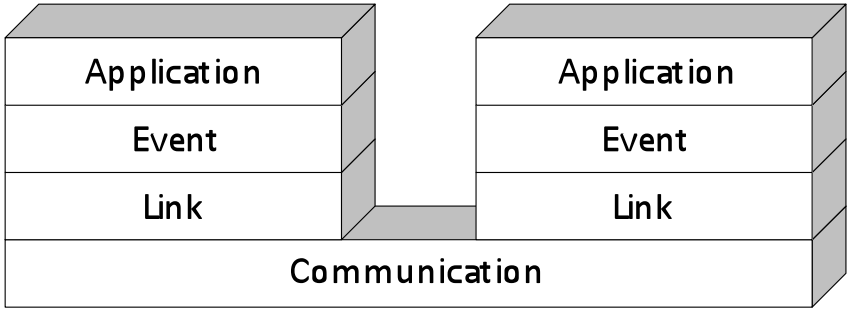
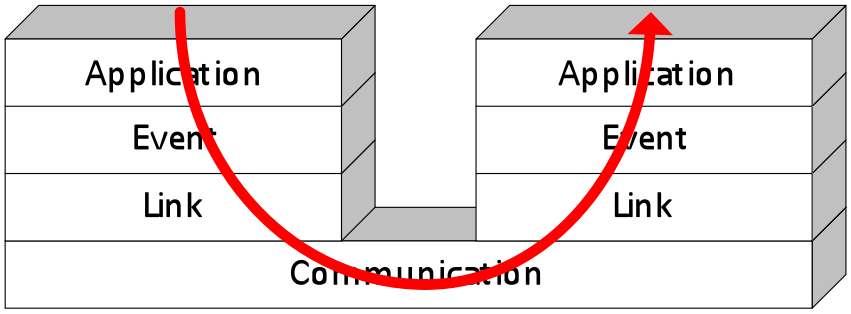
CPA Networking Functionality





Virtual Channel

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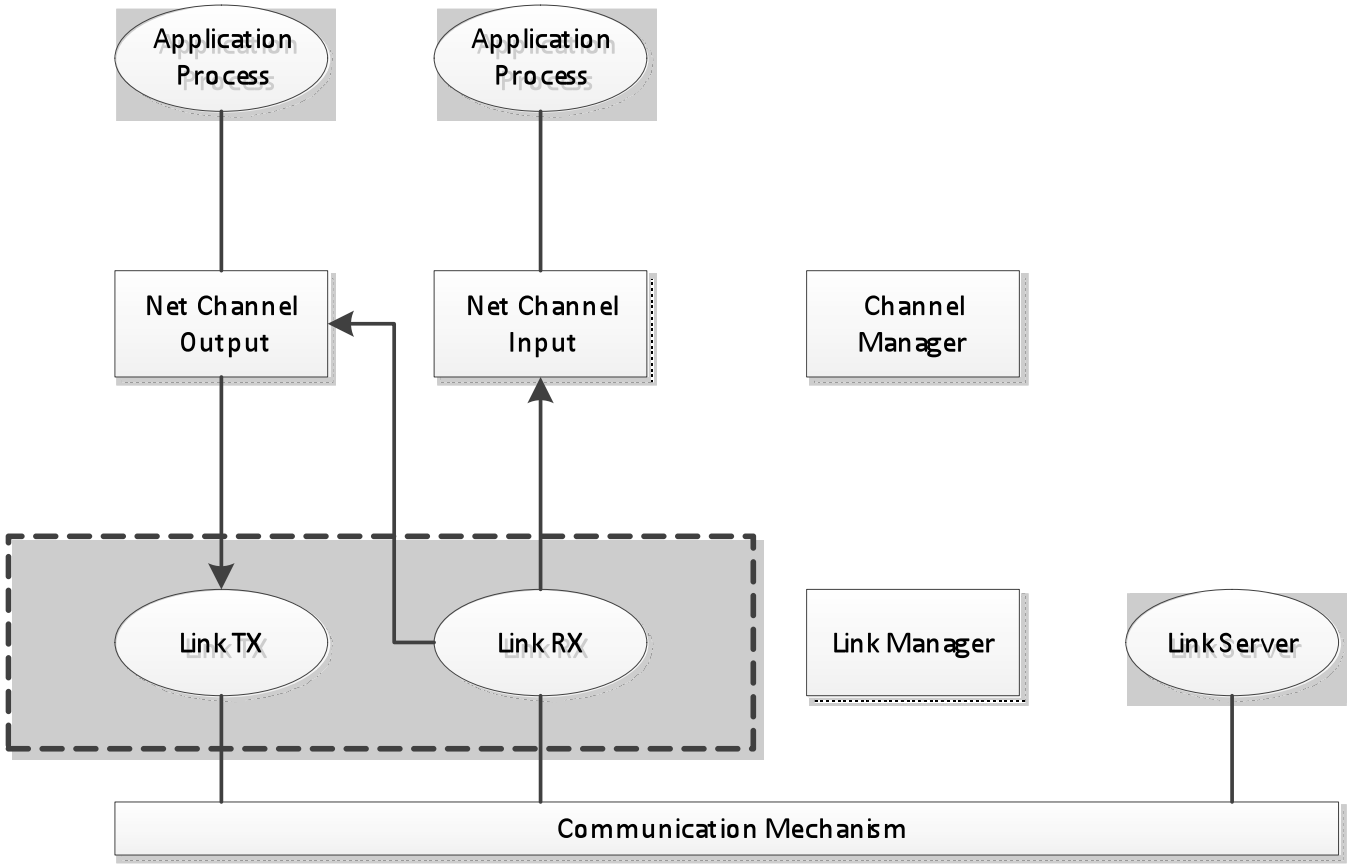
CPA Networking Architecture



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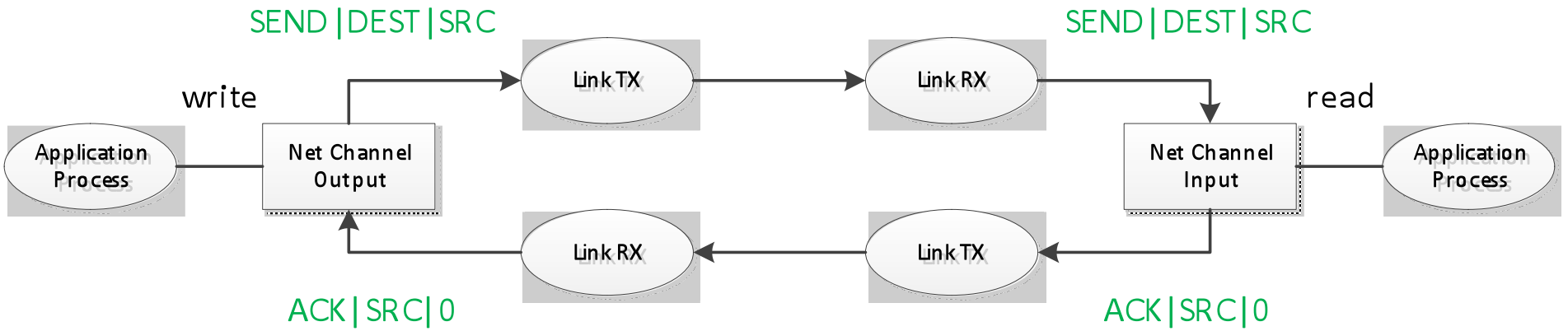
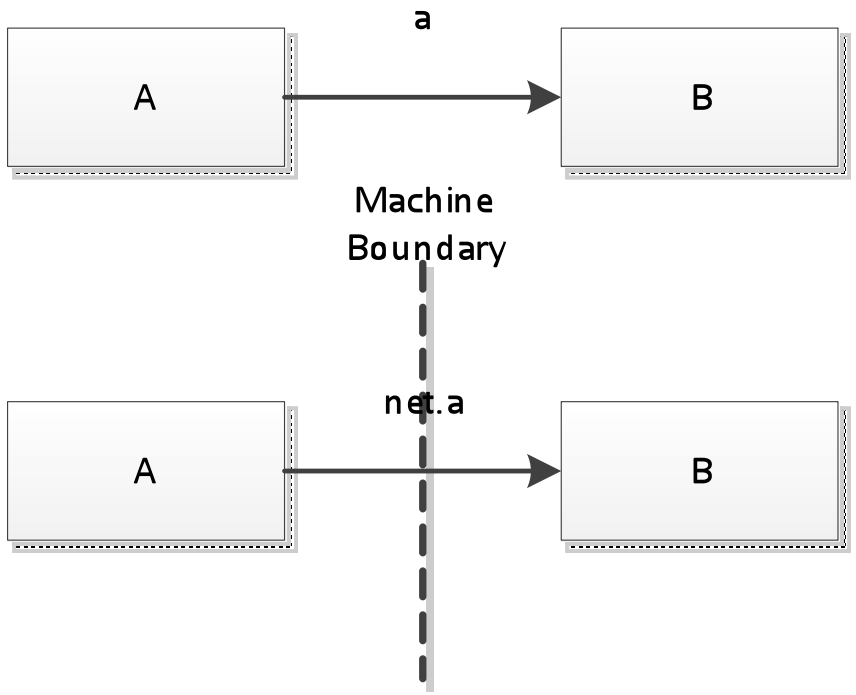
Channel Operation



- Protocol defines all messages as triples
  - TYPE | ATTR1 | ATTR2
  - Some messages have a data load
- Links process messages based on type and state of event primitive

Transparency of Distribution

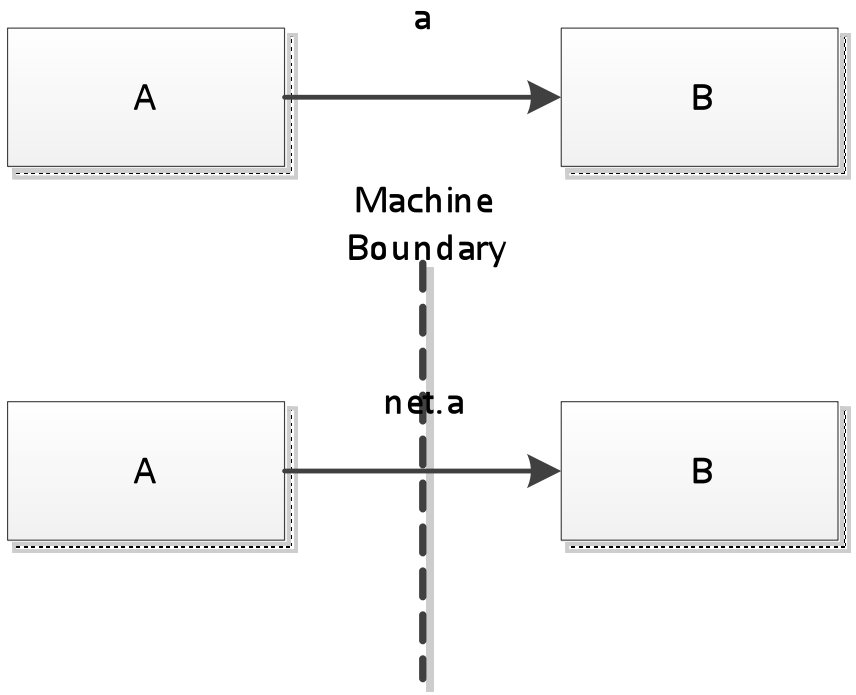
- Networked channels provide the *same interface and behaviour as standard channels*
  - A does not need to know if a is locally connected or remote connected
  - Couple of minor gotchas



Transparency of Distribution

- Powerful abstraction for distribution

- Most other approaches to distribution require you to know that you are distributed
  - For example, object-orientation aliasing is broken



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Synchronous and Asynchronous in CPA Networking

- CPA Networking channels have asynchronous capabilities
  - Allow simpler client-server interactions
- An asynchronous communication means no ACK is sent
  - The sender completes once networked output communicates with the Link
- Networked channels are supported by infinite buffering to ensure deadlock freedom
  - Possible memory issues

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MPI

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MPI Functionality

- MPI operates using a communicator mechanism
- Each process interacting with a communicator is assigned a rank
- Direct communication with a process can be achieved using the relevant rank

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MPI Functionality

- Initially, each process belongs to the WORLD communicator
- Sub-groups of processes can create specific communicators
- Although communicators can be used to communicate with local threads, MPI is usually considered an inter-process communication mechanism
  - It is designed to cross the machine boundary

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MPI Operations

- Some similar to CPA Networking
  - Send
  - Receive

- Some implementable in CPA Networking
  - Broadcast
  - Scatter
  - Gather

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MPI AND CPA NETWORKING OPERATIONS

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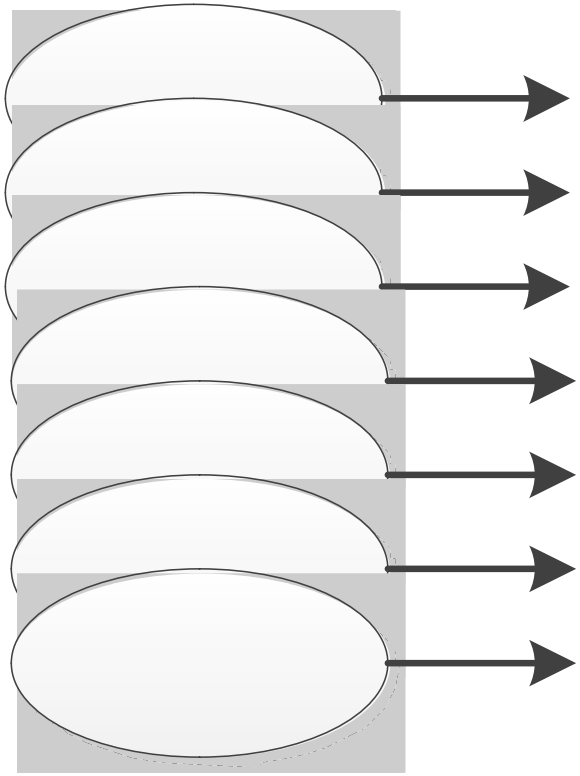
MPI in CPA Networking

- Broadcast in MPI allows one process to send a message to all others in a communicator
- Easily simulated using a standard parallel write in CPA Networking



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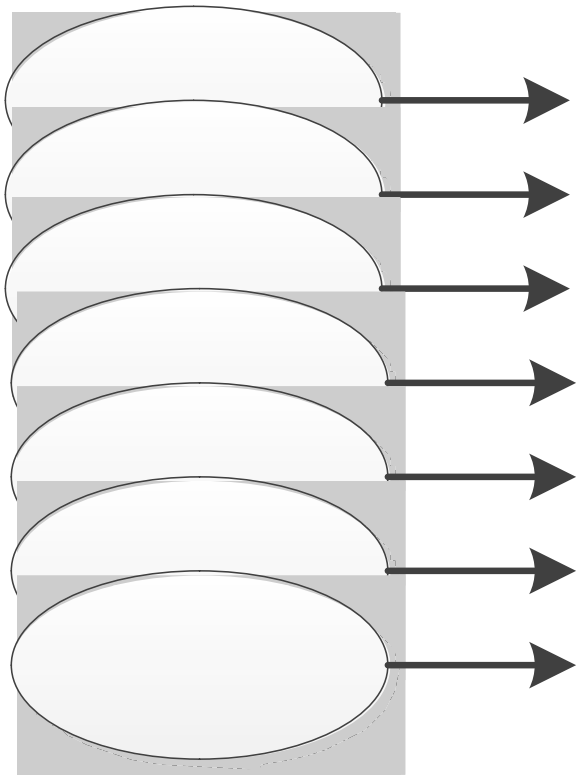
MPI in CPA Networking

- Problem is, we create many processes to achieve this
  - In JCSP and CSP for .NET this is bad
- Would have to add a barrier communication to ensure group synchronisation



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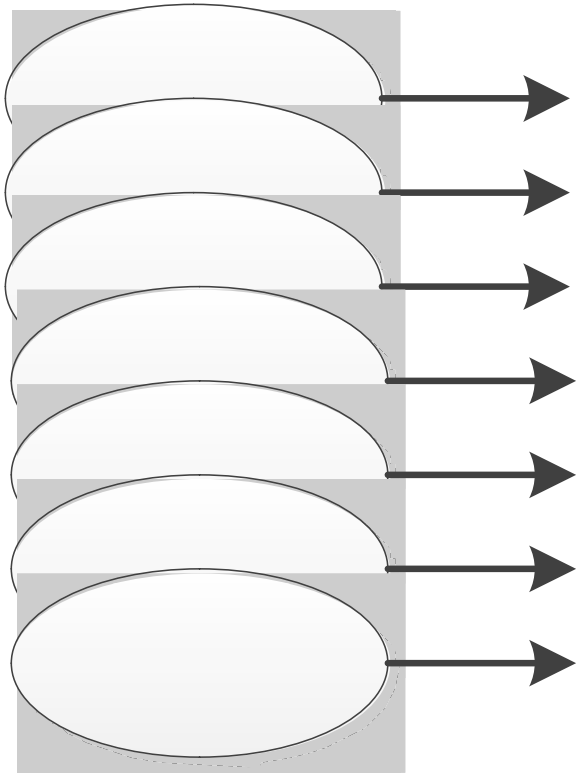
MPI in CPA Networking

- Scatter-Gather allows a single process to send an array of messages to other processes in the group, and wait for the reply



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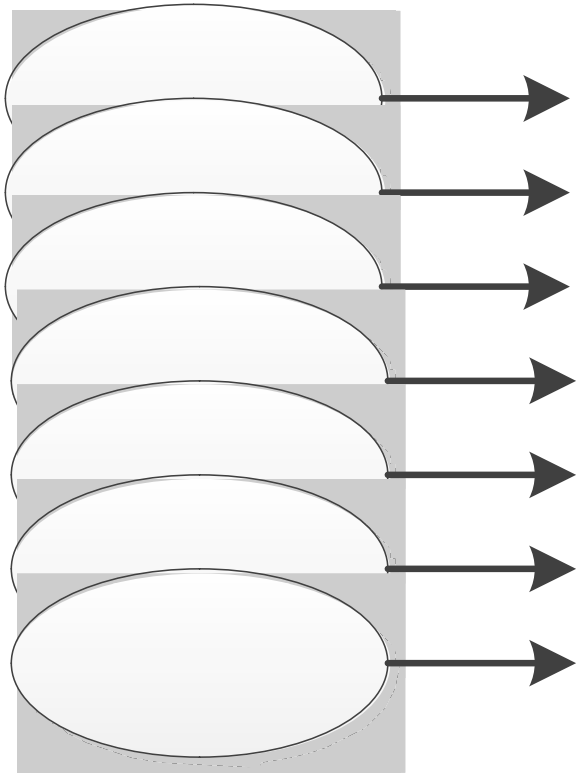
MPI in CPA Networking

- Scattering can be achieved using standard parallel writes
- Gathering can be achieved using parallel reads
  - Again an extra overhead



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Choice

- CPA Networking allows input channels to be used as guards

- They operate in the same manner as standard channel input guards

```
Alt a = new Alt(inputs);
int index = alt.Select();
data = inputs[index].Read();
```

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Choice

- MPI does not provide the same choice mechanism
  - Cannot mix timers, input, skip, etc.

- Selection of input from a group of processes can be achieved using the probe command

```
Status status = comm.Probe(Communicator.anySource, 1);
data = comm.Receive<Data>(status.Source, 1);
```

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CPA Networking and MPI Operations

- MPI and CPA Networking share the same general communication mechanisms
  - Send, Receive
- MPI provides collective communication mechanisms implementable in CPA Networking
  - Broadcast, Scatter-gather
- CPA Networking provides choice, and this is possible in MPI using the probe command

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EXPERIMENTAL RESULTS

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Approach

- Two different areas evaluated

- Base network performance
  - Latency and throughput
  - Broadcast

- Communication stress
  - Scatter-gather, request-response

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Monte-Carlo Pi

- Monte-Carlo Pi was used as the work packet for stress
  - Allows work size to be scaled
  - Small communication size
  - Not looking for parallel speedup

```
IN: NUM_ITERATIONS
COUNT := 0
FOR i in 0 to NUM_ITERATIONS - 1
    X := random 0.0 to 1.0
    Y := random 0.0 to 1.0
    DIST := √(X * X + Y * Y)
    IF DIST <= 1.0
        COUNT := COUNT + 1
OUT: 4.0 * (COUNT / NUM_ITERATIONS)
```

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Platform

- Simple set up
  - Intel Core Due E8400 3.0 GHz (no HT)
  - 2 GB RAM
  - CSP for .NET versus MPI .NET
- Small Ethernet network, 100 Mbit/s
- Microsoft MPI via HPC SDK

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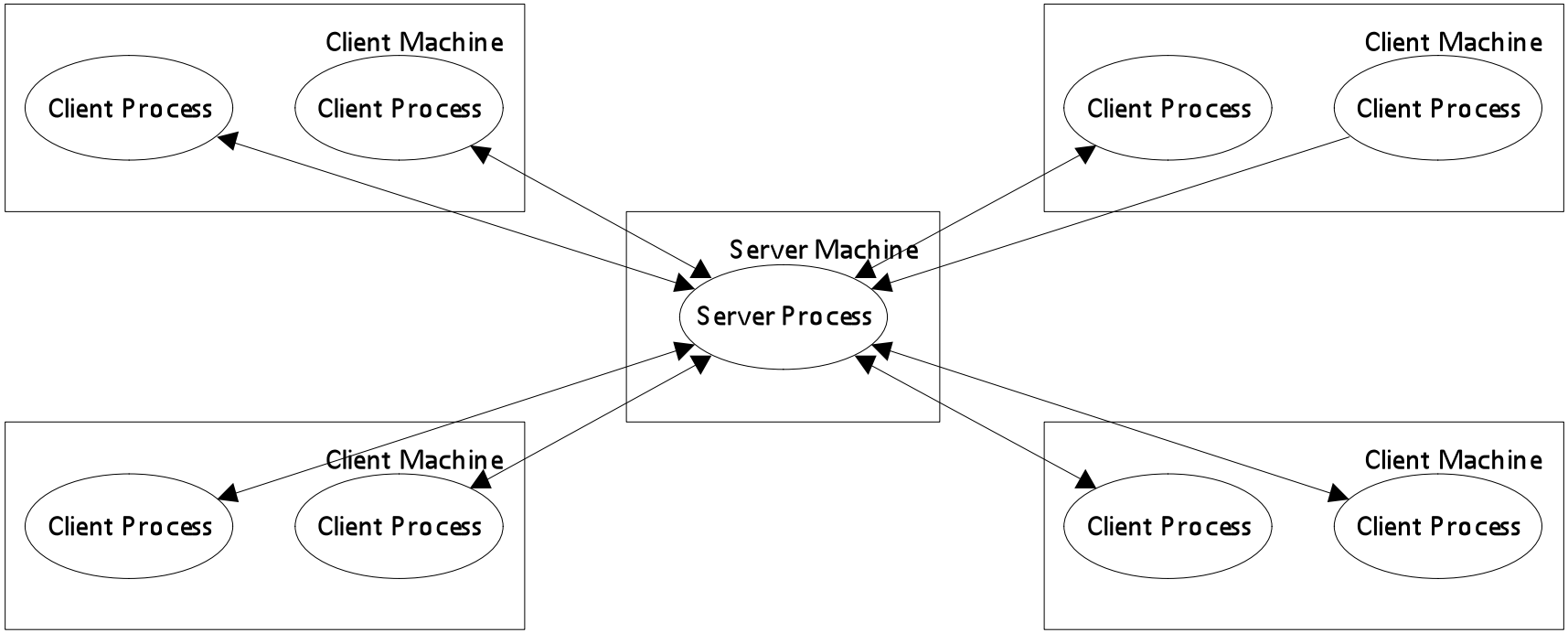
Machine Organisation



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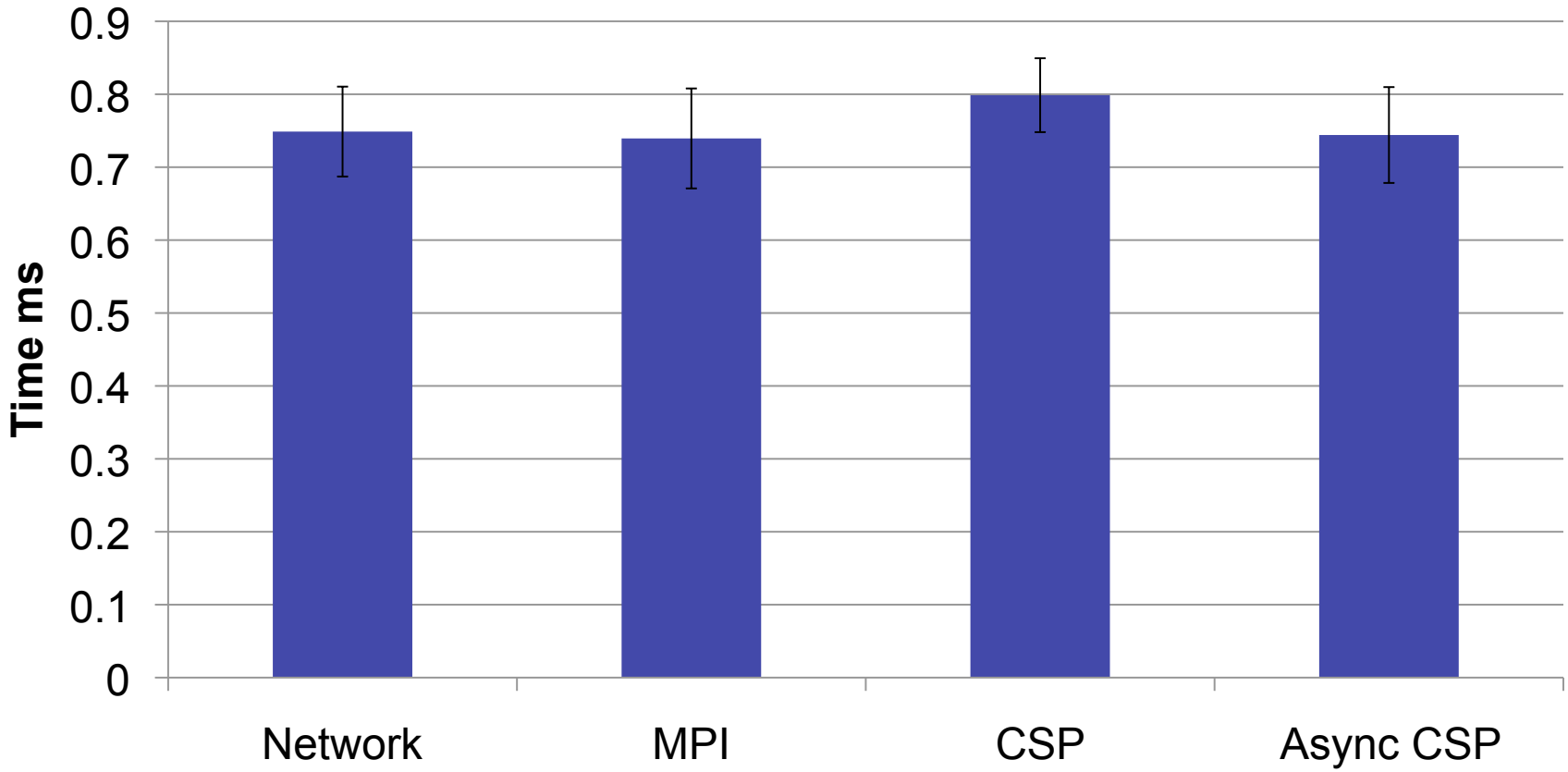
Ping-Pong Time



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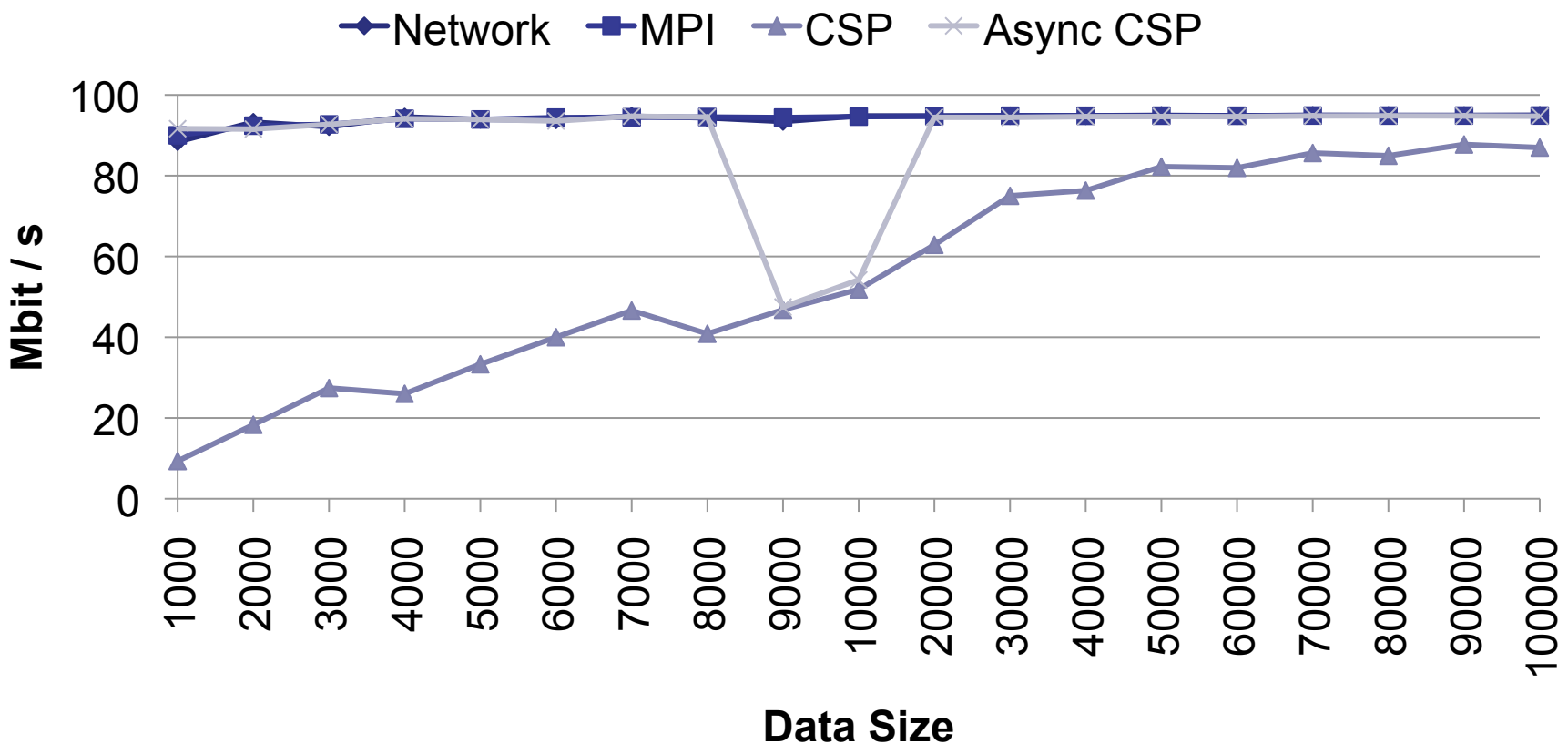
Throughput Point-to-Point



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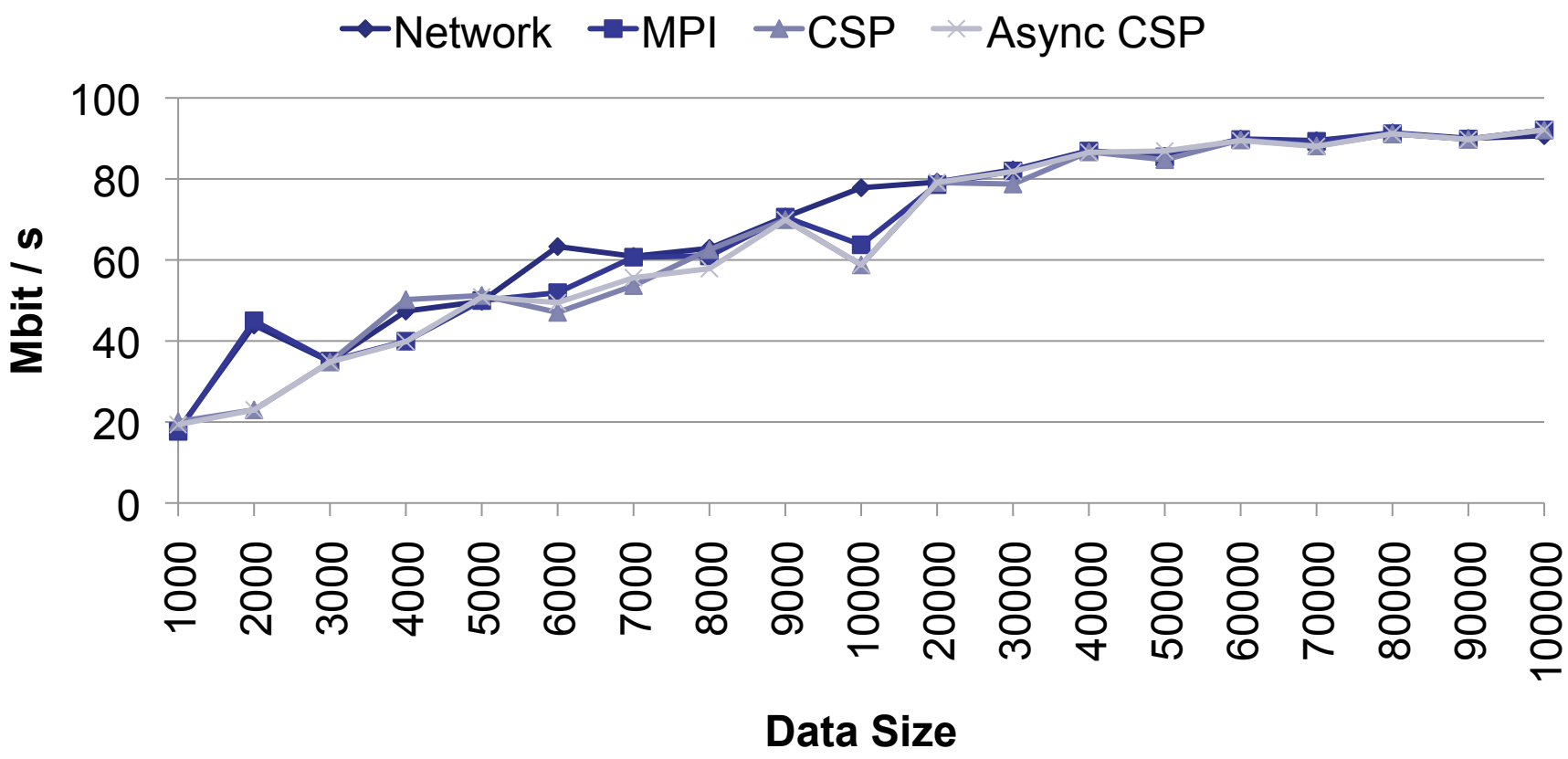
Throughput Ping-Pong



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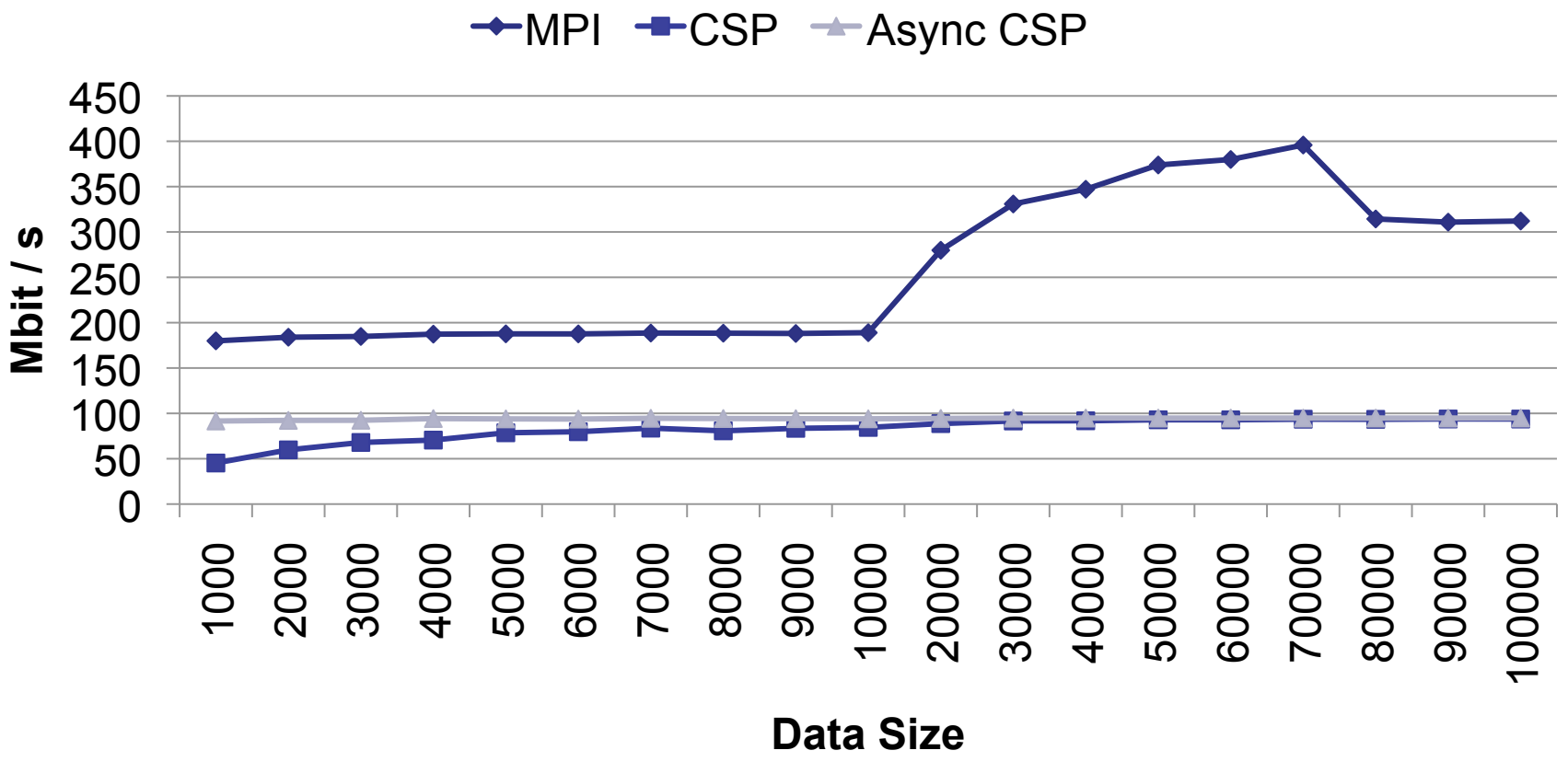
Throughput Broadcast



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Stressed Communication

- Optimal Time

$$\frac{computation\ time + communication\ time}{number\ of\ processes}$$

- Sub-Optimal

$$\frac{computation\ time}{number\ of\ processes} + communication\ time$$

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Stressed Communication

- Communication time
  - Each communication mechanism had an approximate 0.75ms ping-pong time

$$0.75ms \times number\ of\ packets$$

- Computation time
  - Machine can perform ~4.85 million Monte Carlo Pi iterations per second
  - Perform 1×10^9 iterations

$$computation\ time = \frac{\left(\frac{1 \times 10^9}{4.85 \times 10^6}s\right)}{8} = 25773ms$$

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Approximate Optimal and Sub-Optimal Times

Iterations Per Packet	Num Packets	Comm Time	Comp Time	Optimal	Sub-Optimal
1×10^3	1×10^6	750000	25773	119523	775773
1×10^4	1×10^5	75000	25773	35148	100773
1×10^5	1×10^4	7500	25773	26711	33273
1×10^6	1×10^3	750	25773	25867	26523
1×10^7	1×10^2	75	25773	25782	25848

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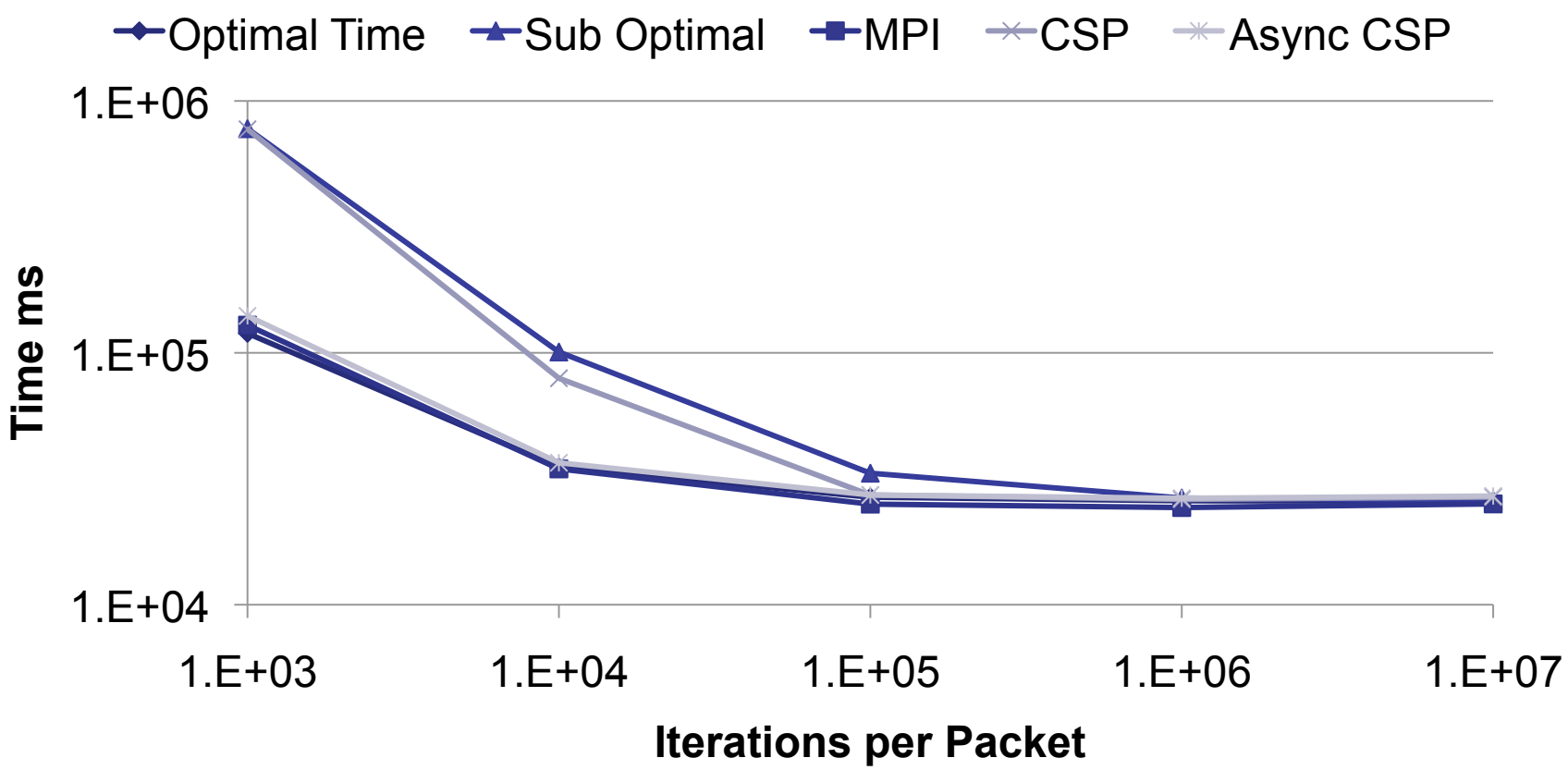
Monte-Carlo Pi Request-Respond



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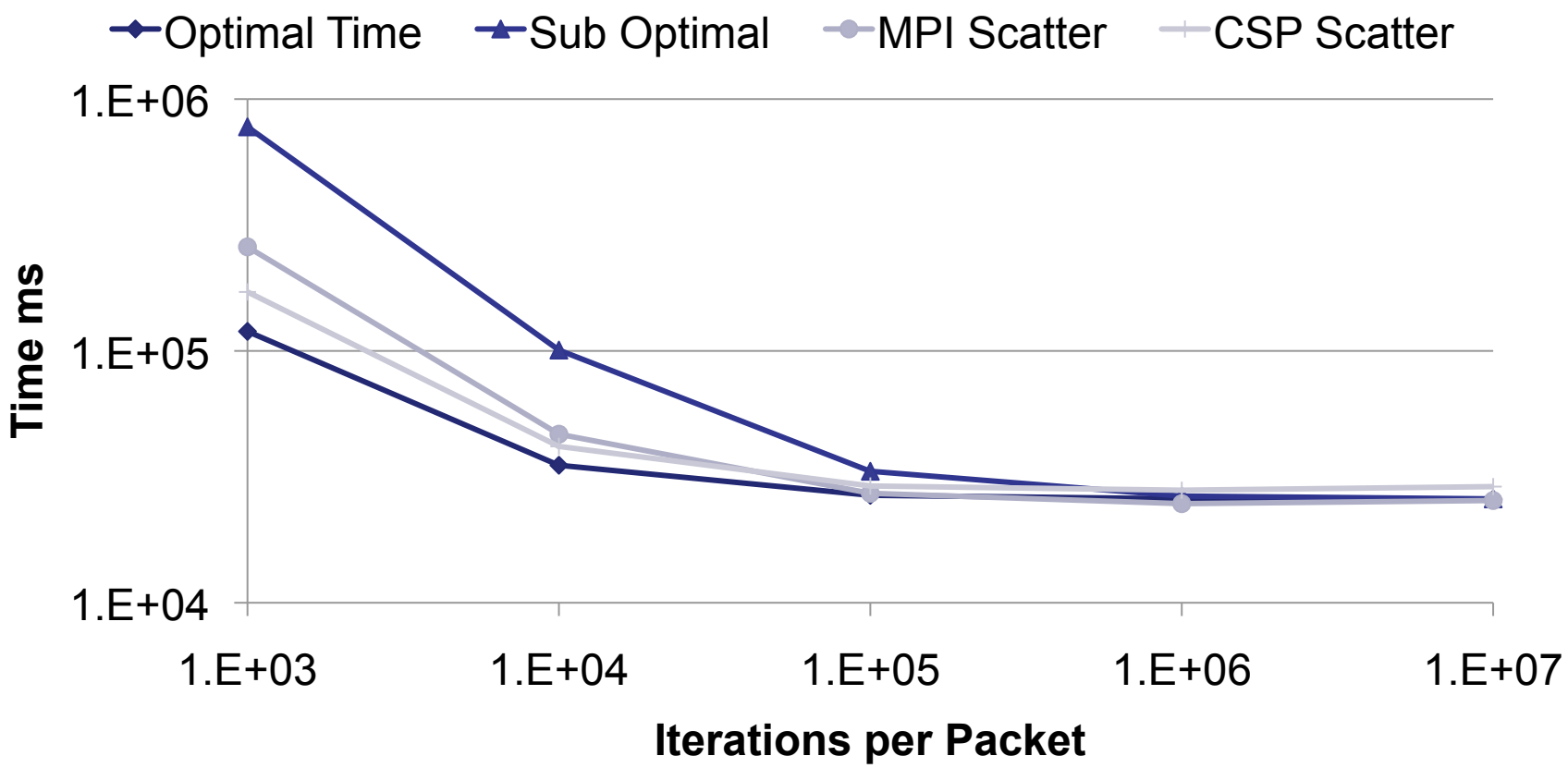
Monte-Carlo Pi Scatter-Gather



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CONCLUSIONS AND FUTURE WORK

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Quick Summary

- So MPI and CPA Networking provide no great difference in communication performance
  - You could probably optimise to a particular scenario
  - Different scenarios might favour one over the other

- So why do we have CPA Networking? Why don't we just use MPI and be done with it?
  - This had me thinking a bit

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Advantages of CPA Networking

- It provides distributed channel semantics, transparently to the application programmer
  - And hopefully in a cross-platform manner
- …
- We have mobility?
  - But I could never work out a good purpose, or a reasonable approach to achieve channel mobility

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Limitations of CPA Networking

- It is still limited in the platforms it supports
  - Actually only JCSP and CSP for .NET
  - Tried others – will discuss next
- It has a protocol definition that was developed to support JCSP style concurrency
- It is still closely coupled with the network layer
  - Expects stream connections internally

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Integration of CPA Networking into a Library

- CPA Networking is still tightly coupled within a library
  - JCSP, CSP for .NET
- It relies on extending functionality of an existing framework
- This has led to problems in implementation on other platforms / frameworks
  - Tried occam-π
  - Tried C++CSP

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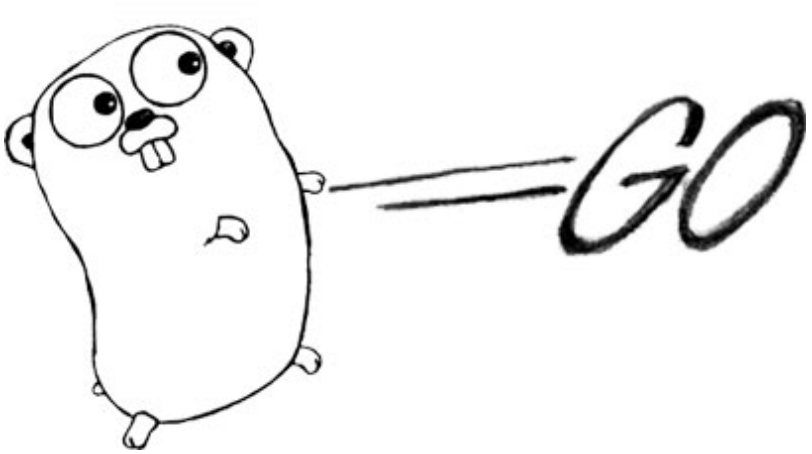
Integration of CPA Networking into a Library

- What about other languages that support a CPA style?
  - Google Go
  - Erlang
  - etc.



ERLANG

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New Network Layer

- We need a new network layer
- We need a better network layer
- We need a network layer that is decoupled from the library / language that wishes to use it
- We have a protocol and existing verified architecture, we just need to adapt it for general purpose

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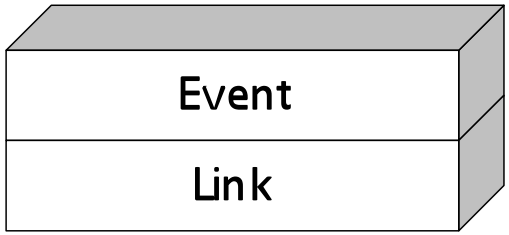
New Network Layer

No concept of sharing

Management

Simple commands



Management

Simple commands

Write your own
communication wrapper

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New Network Layer

- Write it in something low level
- Don't rely on channels internally?
  - All we really have is unbounded queues – there is no requirement of choice in the architecture
- Can hook in existing communication layers
  - TCP/IP
  - MPI

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Networked Mobile Channels

- Considering using MPI as a base layer has made me decide on a model to support channel mobility

- Use mailboxes to store messages, the receiver requests the next message when it is ready
  - It can only be ready when it is not mobile

- All communicating applications will belong to the same group, thus allowing simple access to the mailbox

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Mobile Processes

- We have been able to write distributed mobile processes for a long time in JCSP
  - About 2005

- Still the only framework that can do this (as far as I know)
  - Code mobility system
  - I know a bit too much about Java class loading than is probably healthy

Component Model for Mobility

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Traditional Model

- Code
  - Code that describes the mobile component
- State
  - Active state – program counter, etc.
  - Passive state – data attributes of the component

CPA Model

- Type
  - Name of the type
  - Code (if required for strong mobility)
- State
  - Connection state (required for strong mobility)
  - Data – attributes of the component
  - Behaviour – active state of the component (required for strong mobility)

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Transparency of Mobility

- Really, we want to have transparency of mobility
  - Send a channel across a network or local channel
  - Send a process across a network or local channel

- We do have most of the requirements met in the current version of JCSP
  - Local to distributed channel mobility is the hard part
  - Protocol driven on the network layer

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Mobile Agent Framework in CPA Networking and MPI

- We actually have the technology to develop a robust mobile agent framework that can
  - Either allow known components to migrate between frameworks, maintaining connection state
  - Or strong mobility with dynamic code loading on a single framework
- Using MPI as a base communication layer would make this fairly trivial to use, once the pieces are in place
- The question is, does anyone want such a system?

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Conclusions

- MPI and CPA Networking, although aimed at different audiences, provide similar performance for communication
- We can simulate many of the different operations in either approach
  - Although performance may be an issue
- A revaluation of CPA Networking is probably required to allow more general usage