Extensions to the Concurrent Communications Library

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CPA 2016 - Copenhagen

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Background

Overview

A CSP inspired library in/for C# (and other CIL languages)

- Utilizes await/async
- Builds FSMs from sequential code
- Low memory overhead pr. process
- Fewer context switches

```
while(true)
    out.Write(
      in.Read());
```

```
while(true)
    await out.WriteAsync(
      await in.ReadAsync());
```

Features

Only one channel type, generics for type-safety

Named and anonymous channels

Alternation with priority, random, and fair select

Sequence guarantee through request lists

Two-phase commit used to guarantee atomic selection external to the channel

Alternation with input or output and timeouts

Skip guards supported through immediate timeouts

Minimalistic channel core, features outside

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atomic selection external to the channel

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Minimalistic channel core, features outside

Productivity enhancements

Mixing read and write requests

Overflowing a channel

```
var warn = ChannelManager.GetChannel<int>("warn");
var report = ChannelManager.GetChannel<int>("report");

while(true) {
  var current = ReadHardwareSensor ();
  if (current > 10)
    warn.Write(current);
  report.Write(current);
}

var warn = ChannelManager.GetChannel<int>("warn");
var report = ChannelManager.GetChannel<int>("report",
  new BoundedChannelOptions(1)
  {
    FullMode = BoundedChannelFullMode.DropOldest
  });

while(true) {
  var current = ReadHardwareSensor ();
  if (current > 10)
    warn.Write(current);
  report.WriteAsync(current);
}
```

- Enables Actor-like paradigms
- The WriteAsync() method returns a value that can be checked for failure

Channel scopes

```
var external = ChannelManager.GetChannel<int>("out");
using(new IsolatedScope())
    await Task.WhenAll(
        Task.Run(async () => { // Process 1
            var internal =
                ChannelManager.GetChannel<int>("out");

            while(true)
                await internal.WriteAsync(42);
        }),

        Task.Run(async () => { // Process 2
            var internal =
                ChannelManager.GetChannel<int>("out");

            while(true)
                await external.WriteAsync(
                    await internal.ReadAsync()
                );
        })
    );
```

Wiring channels automatically

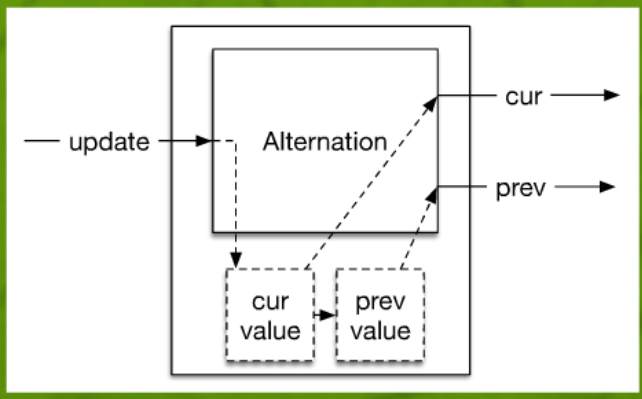
Leave and Join

Mixing read and write requests

```
var cur = 0, prev = 0;
var updatechan = ChannelManager.GetChannel <string >("update");
var curchan = ChannelManager.GetChannel<int>("cur");
var prevchan = ChannelManager.GetChannel<int>("prev");

while(true) {
  var res = await MultiChannelAccess.ReadOrWriteAnyAsync(
    MultisetRequest.Read(updatechan),
    MultisetRequest.Write(cur, curchan),
    MultisetRequest.Write(prev, prevchan),
  );

  if (res.IsRead) {
    prev = cur;
    cur = int.Parse((string)res.Value);
  }
}
```



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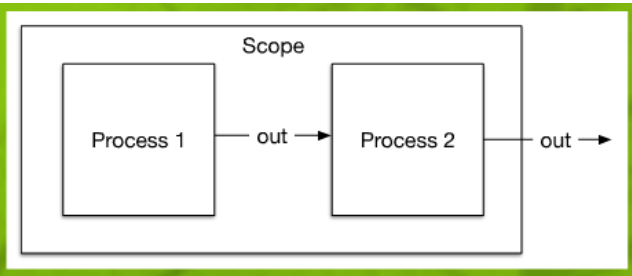
while(true) {
  var current = ReadHardwareSensor ();
  if (current > 10)
    warn.Write(current);
  report.Write(current);
}
```

```
var warn = ChannelManager.GetChannel<int>("warn");
var report = ChannelManager.GetChannel<int>("report",
    maxPendingWriters: 1,
    pendingWritersOverflowStrategy:
        QueueOverflowStrategy.FIFO
);

while(true) {
  var current = ReadHardwareSensor ();
  if (current > 10)
    warn.Write(current);
  report.WriteNoWait(current);
}
```

- Enables Actor-like paradigme
- The WriteAsync() method returns a value that can be checked for failure

Channel scopes

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                    await internal.ReadAsync()
                );
        })
    );
```

Wiring channels automatically

Prototein Network in PyCSP

```
feeder = One2AnyChannel()
collector = Any2OneChannel()
done = Any2OneChannel()

Parallel(
    Process(producer, protein, map, place, feeder.write),
    Process(worker, feeder.read, collector.write, done.write),
    Process(worker, feeder.read, collector.write, done.write),
    Process(worker, feeder.read, collector.write, done.write),
    Process(worker, feeder.read, collector.write, done.write),
    Process(worker, feeder.read, collector.write, done.write),
    Process(barrier, 5, done.read, collector.write),
    Process(consumer , collector.read))
```

Prototein Network in CoCoL

```
var feeder = ChannelManager.GetChannel<int>();
var collector = ChannelManager.GetChannel<int>();
var done = ChannelManager.GetChannel<bool>();

Task.WhenAll(
    Producer(protein, map, place, feeder.AsWrite()),
    Worker(feeder.AsRead(), collector.AsWrite(), done.AsWrite()),
    Worker(feeder.AsRead(), collector.AsWrite(), done.AsWrite()),
    Worker(feeder.AsRead(), collector.AsWrite(), done.AsWrite()),
    Worker(feeder.AsRead(), collector.AsWrite(), done.AsWrite()),
    Worker(feeder.AsRead(), collector.AsWrite(), done.AsWrite()),
    Barrier(5, done.AsRead(), collector.AsWrite(), done.AsWrite()),
    Consumer(collector.AsRead()));
```

Prototein Network with Wiring

```
public class Worker : ProcessHelper {
    [ChannelName("feeder")]
    private IReadChannel<int> feeder;

    [ChannelName("collector")]
    private IWriteChannel<int> collector;

    [ChannelName("done")]
    private IWriteChannel<bool> done;

    ... code omitted ...
}

Task.WhenAll(
    new Producer(protein, map, place),
    new Worker(), new Worker(), new Worker(),
    new Worker(), new Worker(),
    new Barrier(5),
    new Consumer());
```

Prototein Network in PyCSP

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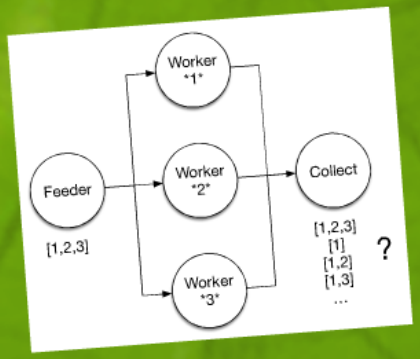
```

Leave and Join



Solution:

- Readers and writers "join" the channel
- Keep a counter for number of readers and number of writers
- When poisoned, "leave" the channel
- When either counter reaches zero poison the channel

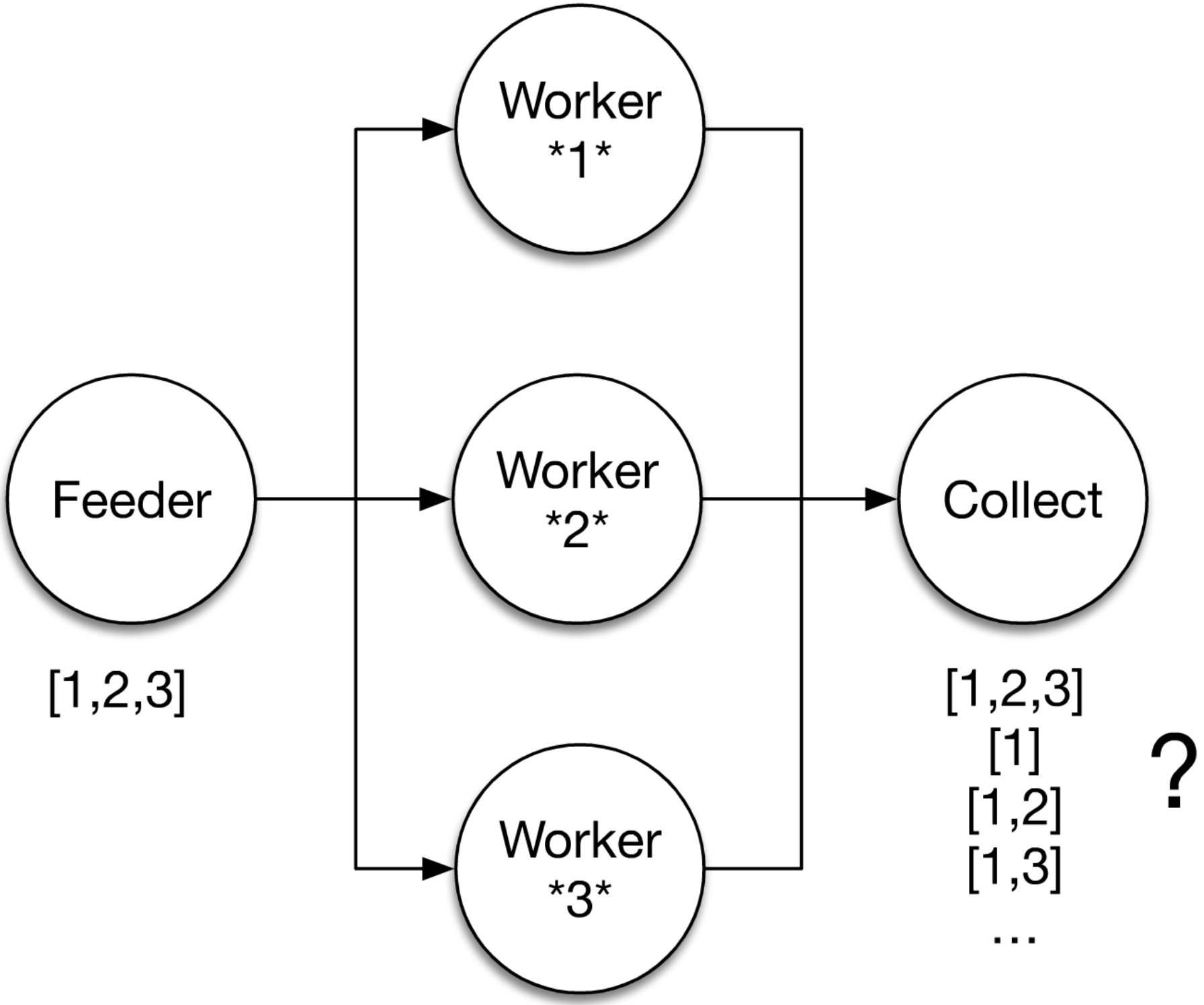
*Same as in PyCSP Revisited, but differs in handling poison/retire

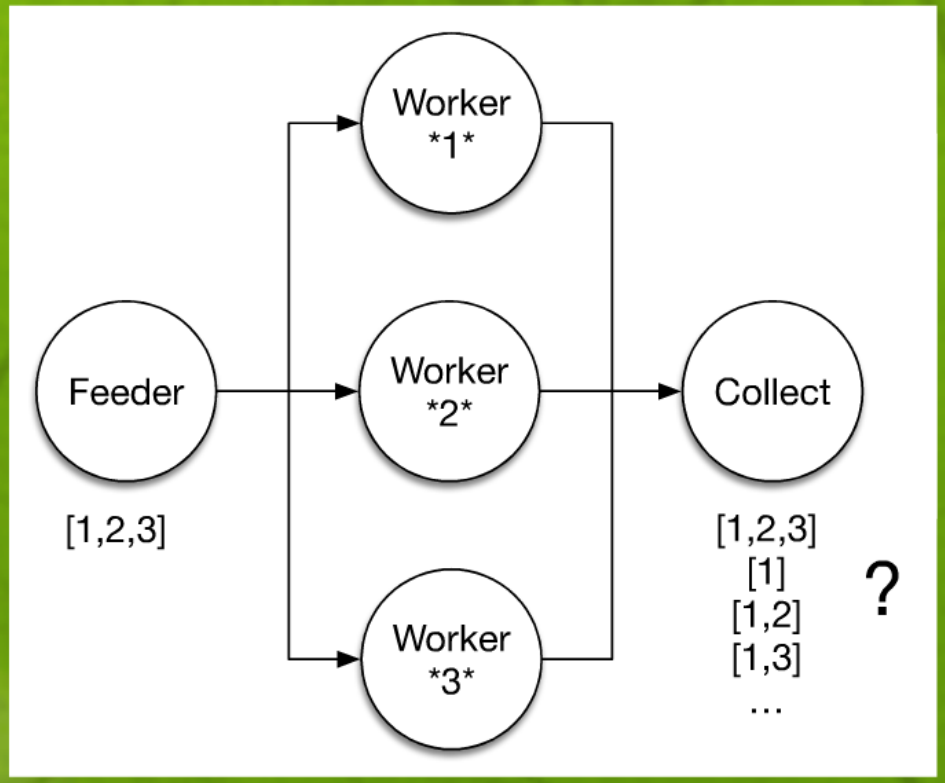
Adding Lambda Closures

```
private static Task Worker () {
    return AutomationExtensions.RunTask(
        new {
            feed = ChannelMarker.ForRead<int>("feeder"),
            coll = ChannelMarker.ForWrite<int>("collector")
        },

        async (self) => {
            while (true) {
                var data = await self.feed.ReadAsync();
                ... code omitted ...
                await self.coll.WriteAsync(result);
            }
        }
    );
}

Task.WhenAll(
    Producer(protein, map, place),
    Worker(), Worker(), Worker(), Worker(), Worker(),
    Consumer());
```


Worker
1
Feeder
Worker
2
Collect
[1,2,3]
Worker
3
[1,2,3]
[1]
[1,2]
[1,3]
...
?



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            while (true) {
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        }
    );
}

Task.WhenAll(
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```
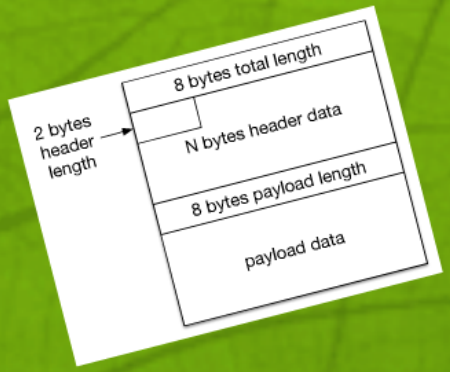
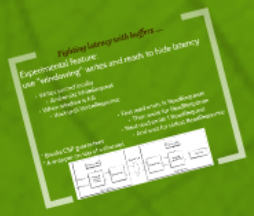

Network support





Design ideas

Drop-in replacement channel,
user should not take special care

3-tier setup:

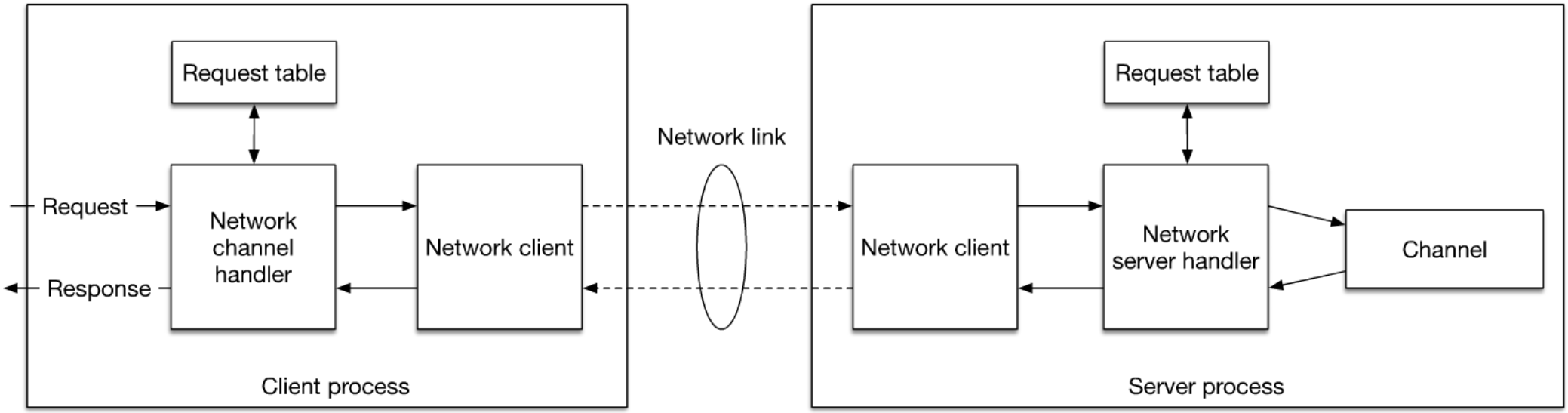
- Name-/discovery-servers
- Channel hosting servers
- Clients

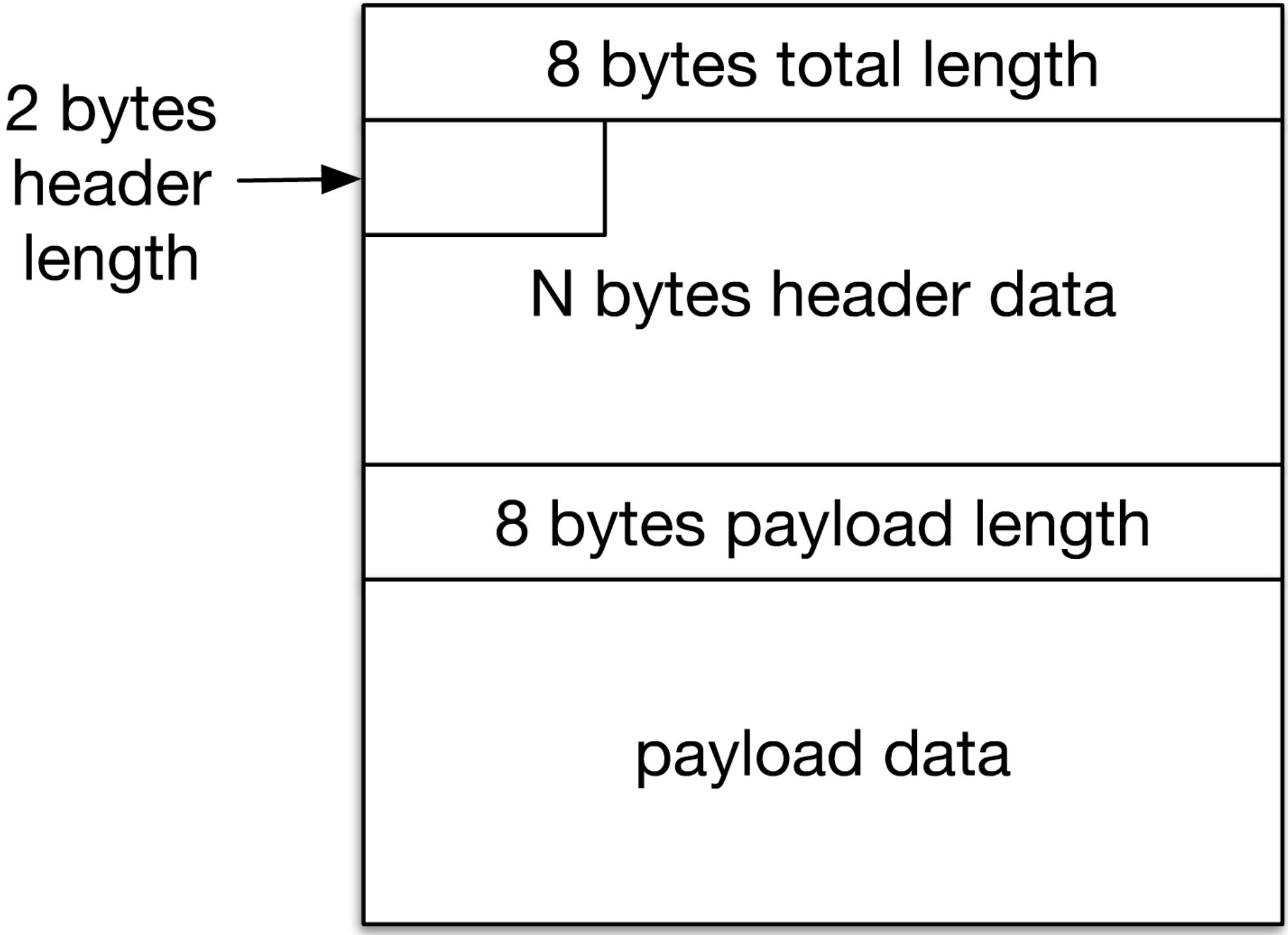
* Currently has name+hosting in one

Channel hosting server should only relay to/from
network to a normal hosted channel:
no special logic for a network channel

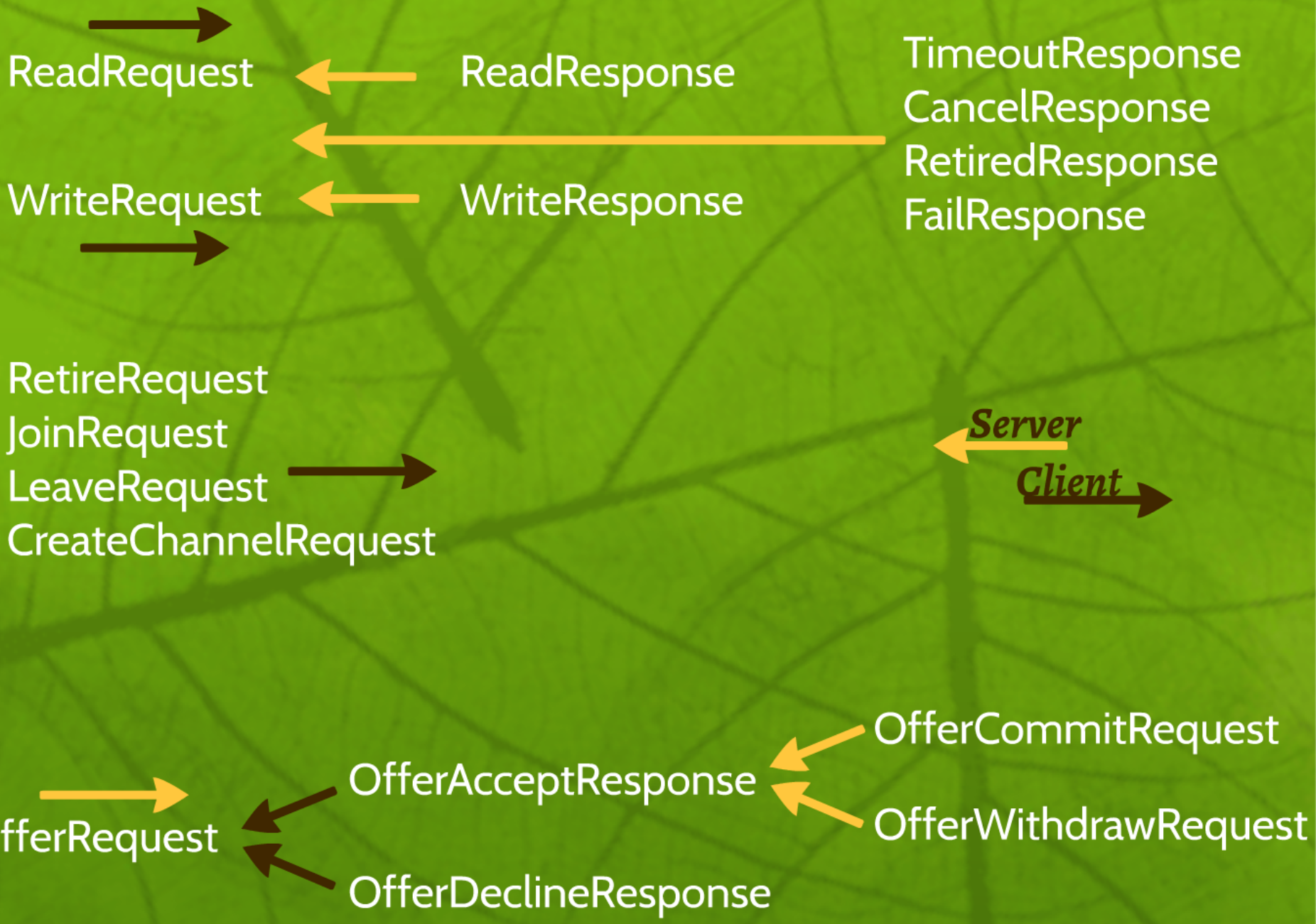
Timeout handled on hosting server

Two-phase commit support,
enables ALT'ing with any type channel-mix


Request table
Request
Response
Network channel handler
Network client
Network link
Request table
Network client
Network server handler
Channel
Client process
Server process


8 bytes total length
2 bytes
header
length
N bytes header data
8 bytes payload length
payload data

Message types



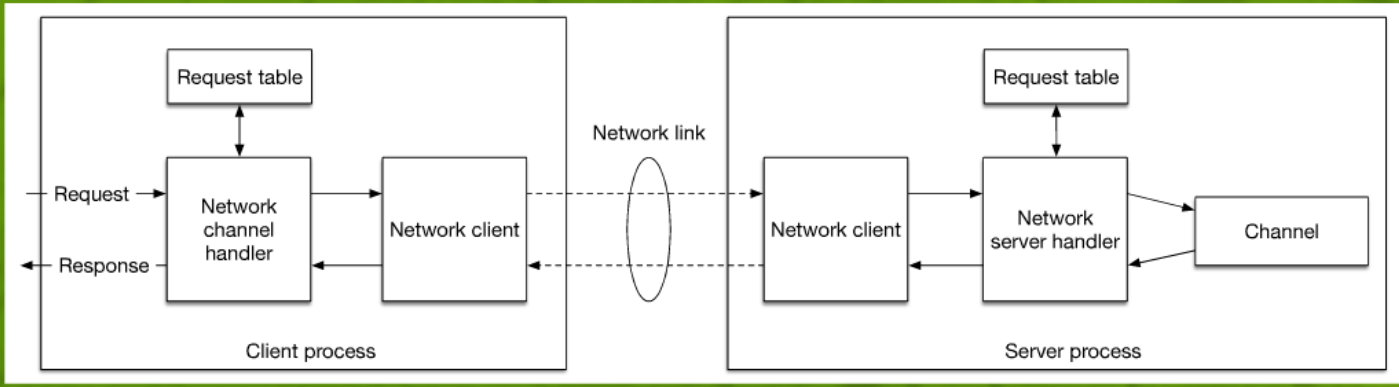
Fighting latency with buffers ....

Experimental feature:
use "windowing" writes and reads to hide latency

- Writes succed locally
  - And emits WriteRequest
- When window is full
  - Wait until WriteResponse

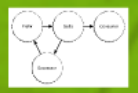
- First read emits N ReadRequests
  - Then waits for ReadResponse
- Next read emits 1 ReadRequest
  - And wait for oldest ReadResponse

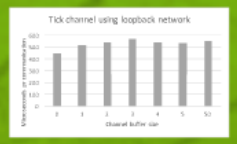
* Breaks CSP guarantees
* A wrapper on top of a channel

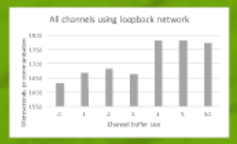


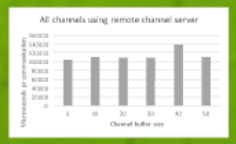
Experiments

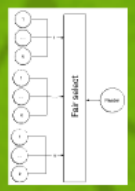
CommsTime



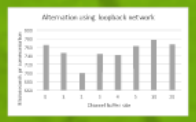


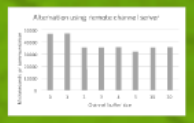




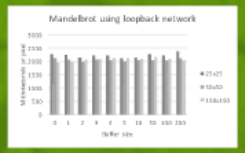


StressedAlt

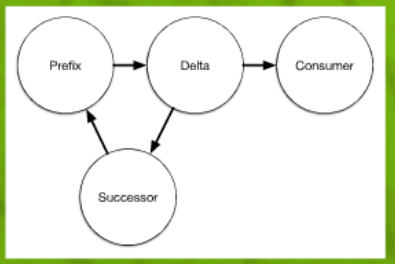


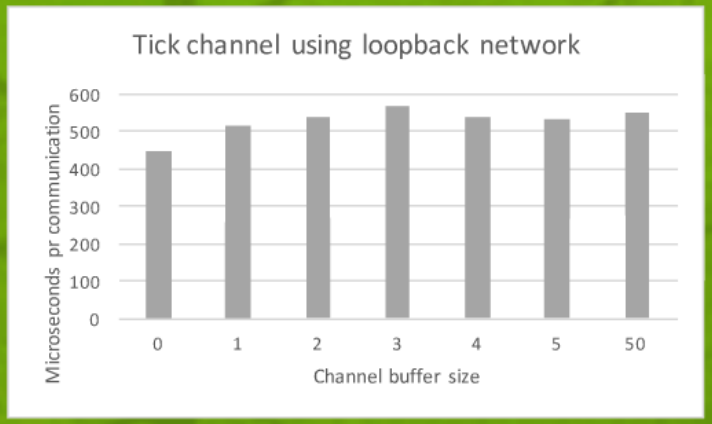


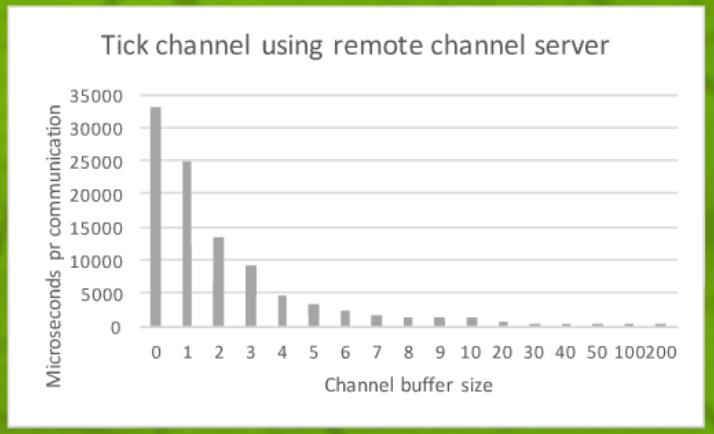
Mandelbrot

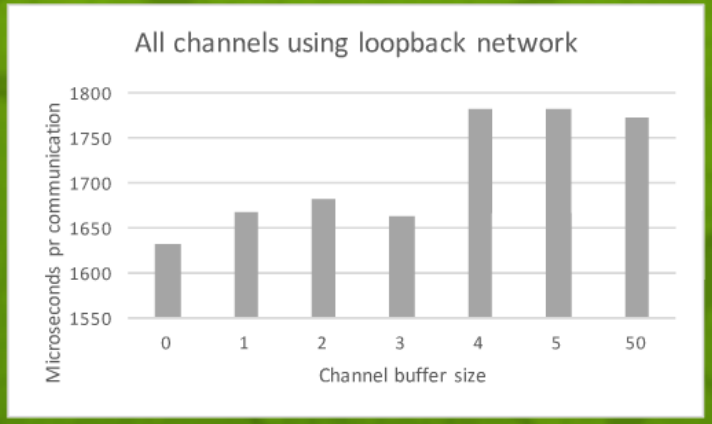


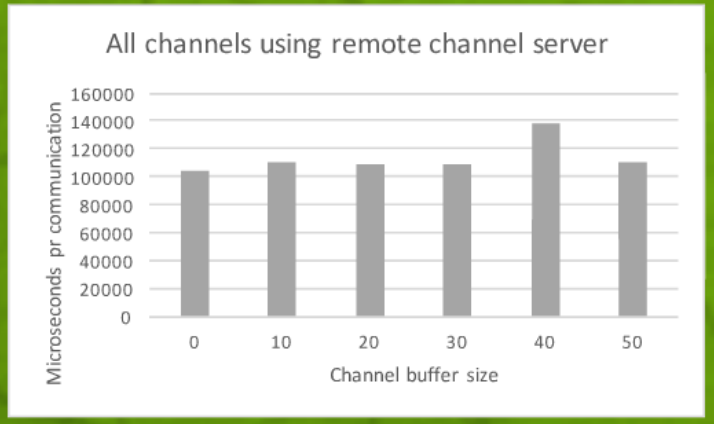
CommsTime


Prefix
Delta
Consumer
Successor

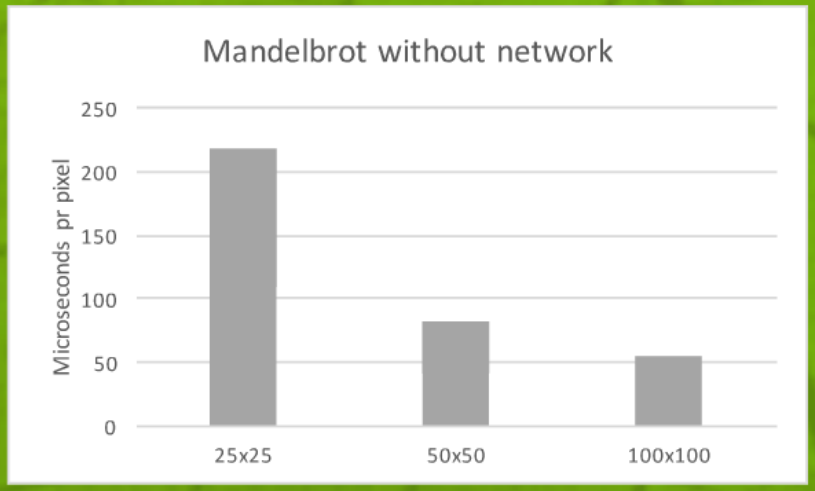

Tick channel using loopback network
Microseconds pr communication
600
500
400
300
200
100
0
0
1
2
3
4
5
50
Channel buffer size

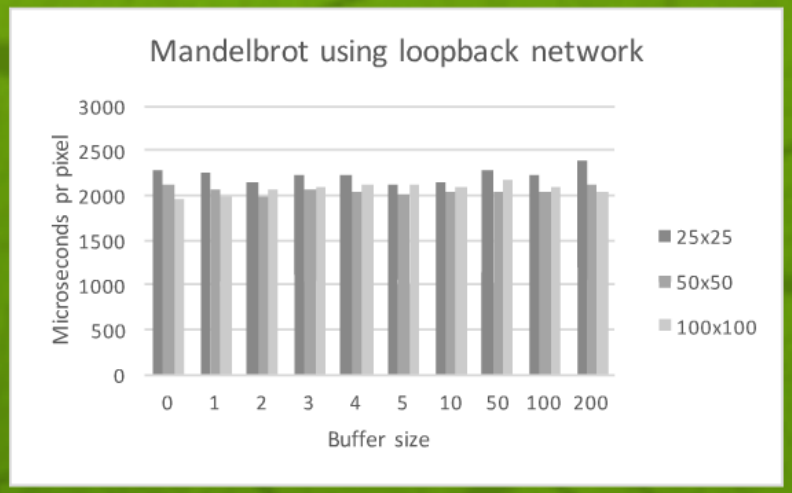

Tick channel using remote channel server
Microseconds pr communication
35000
30000
25000
20000
15000
10000
5000
0
0 1 2 3 4 5 6 7 8 9 10 20 30 40 50 100200
Channel buffer size

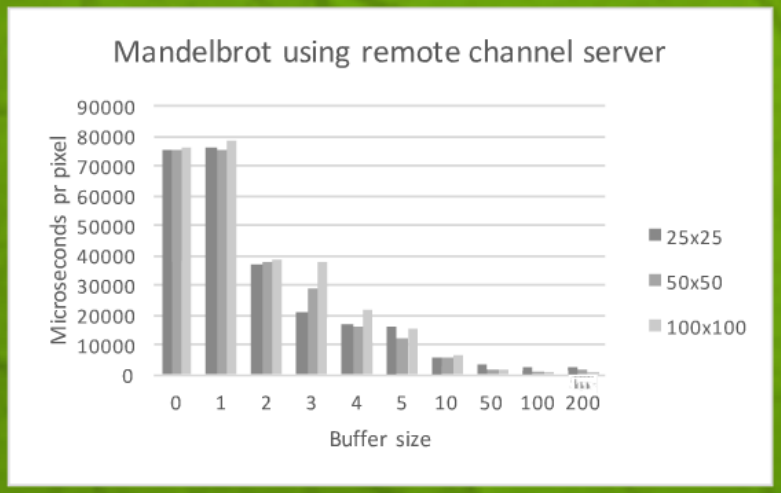

All channels using loopback network
Microseconds pr communication
1800
1750
1700
1650
1600
1550
0
1
2
3
4
5
50
Channel buffer size

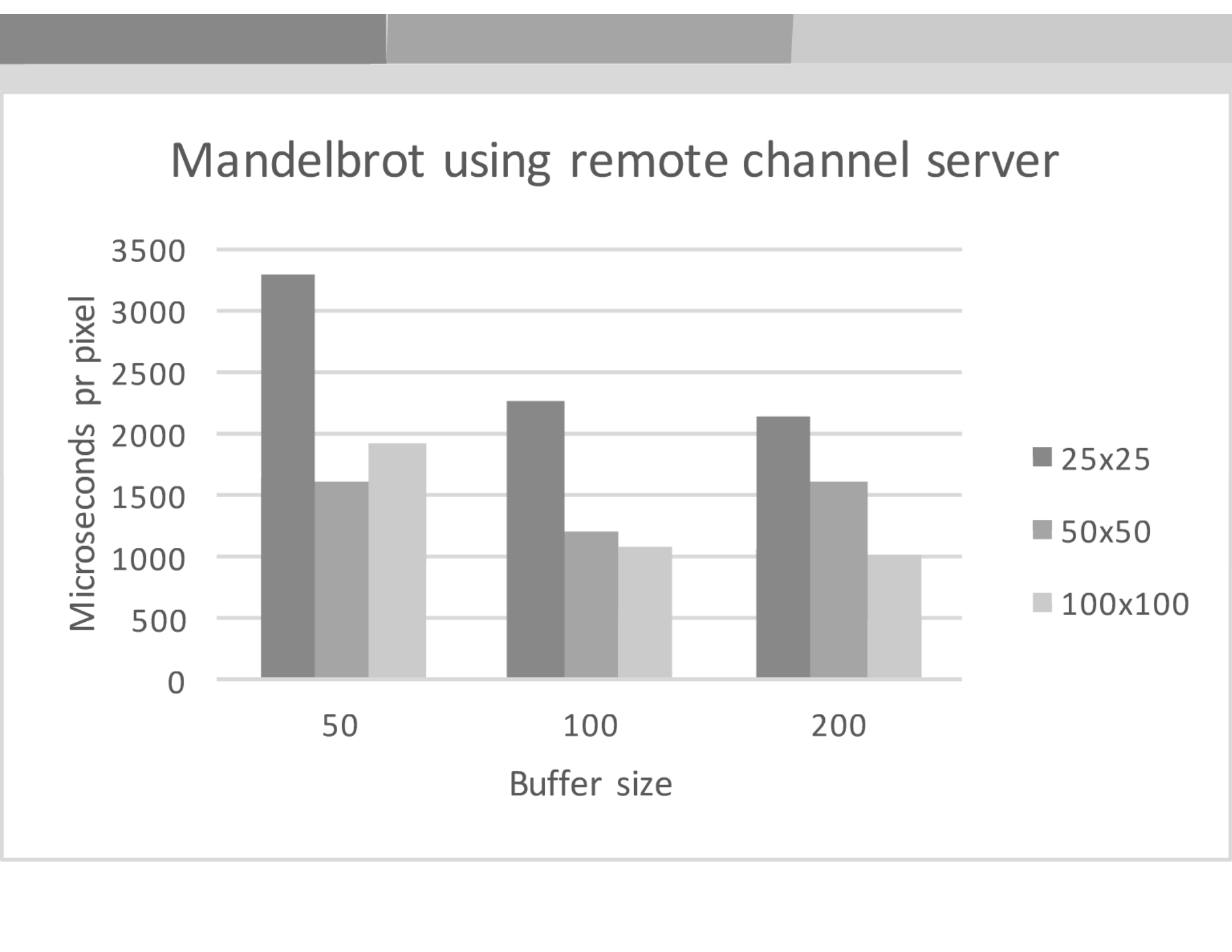

All channels using remote channel server
Microseconds pr communication
160000
140000
120000
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
Channel buffer size

Mandelbrot


Mandelbrot without network
Microseconds pr pixel
250
200
150
100
50
0
25x25
50x50
100x100


Mandelbrot using loopback network
Microseconds pr pixel
3000
2500
2000
1500
1000
500
0
0 1 2 3 4 5 10 50 100 200
Buffer size
25x25
50x50
100x100


Mandelbrot using remote channel server
Microseconds pr pixel
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0 1 2 3 4 5 10 50 100 200
Buffer size
25x25
50x50
100x100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0
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100
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Buffer size
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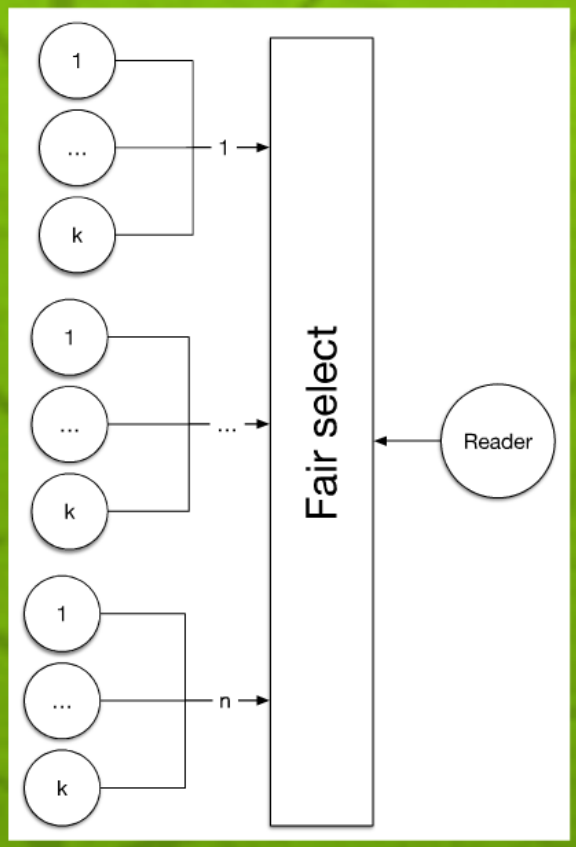
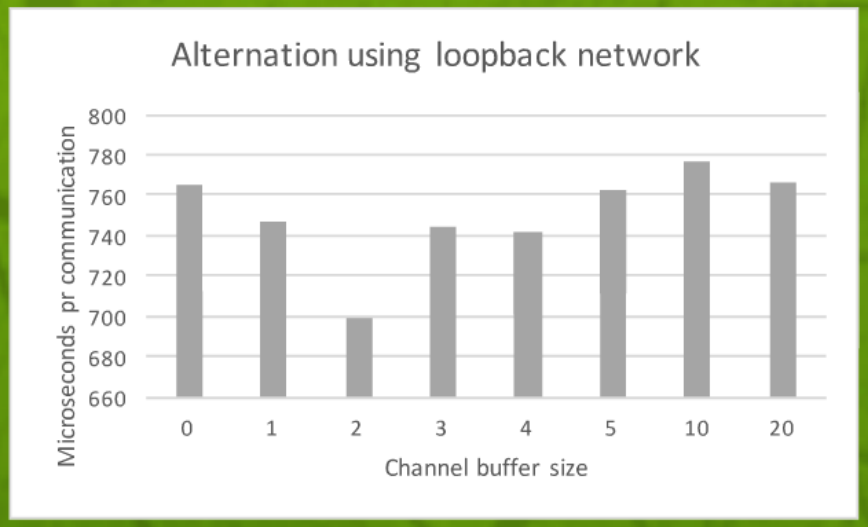
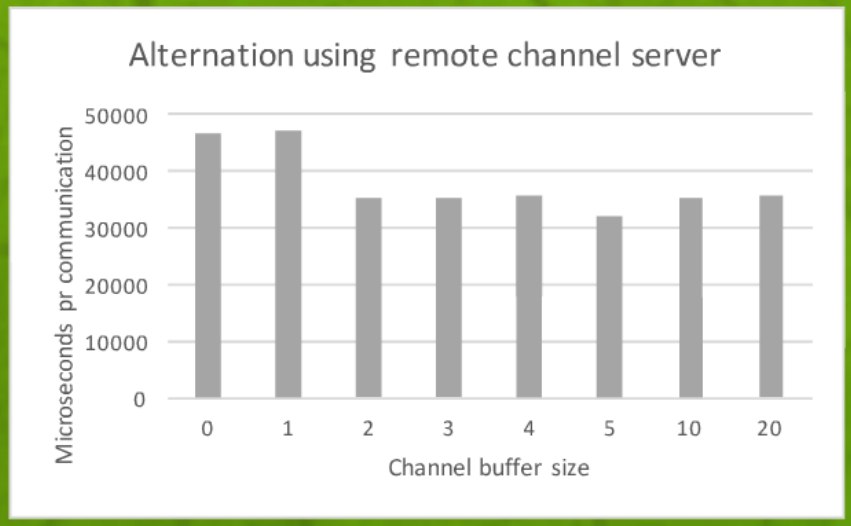
50x50
100x100

StressedAlt







Future work

Error handling,
transaction logs

Skeleton methods

Channel mobility

Thanks!

Source code with benchmarks and examples on GitHub:
https://github.com/kenkendk/cocol

Extensions to the Concurrent Communications Library

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CPA 2016 - Copenhagen