CoCoL

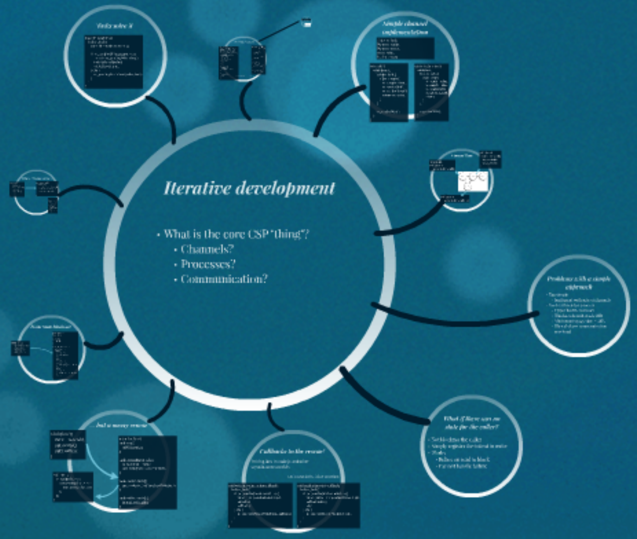
Concurrent Communication Library

Motivation

CIL (aka .Net aka CLR aka Mono) does not have a CSP library*

The CSP.Net library featured on CPA in 2008 went commercial, then extinct

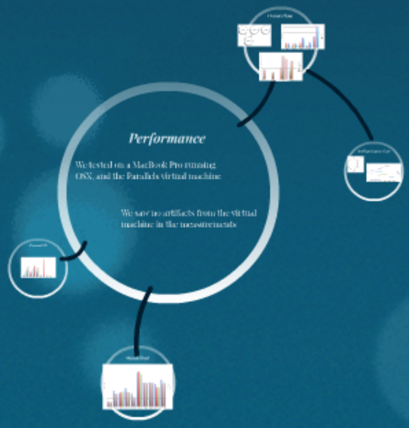
*) number of implementations existed, but none appear active



Iterative development

- What is the core CSP "thing"?
  - Channels?
  - Processes?
  - Communication?

Simple channel implementation
Problems with a simple approach
What if there was no state for the caller?
Callbacks to the rescue!
... but a messy rescue



Performance

We tested on a MacBook Pro running OSX, and the Parallels virtual machine

We saw no artifacts from the virtual machine in the measurements

CPA 2015-08-25
Kenneth Skovhede
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University of Copenhagen

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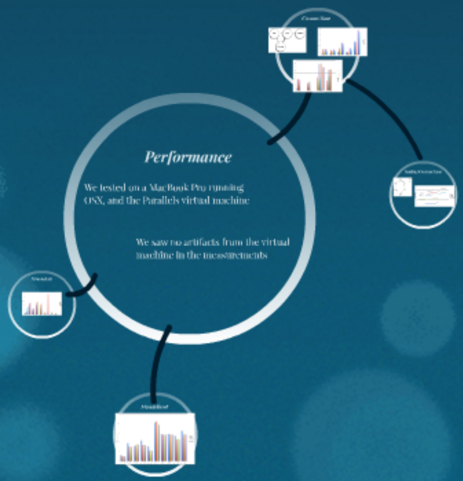

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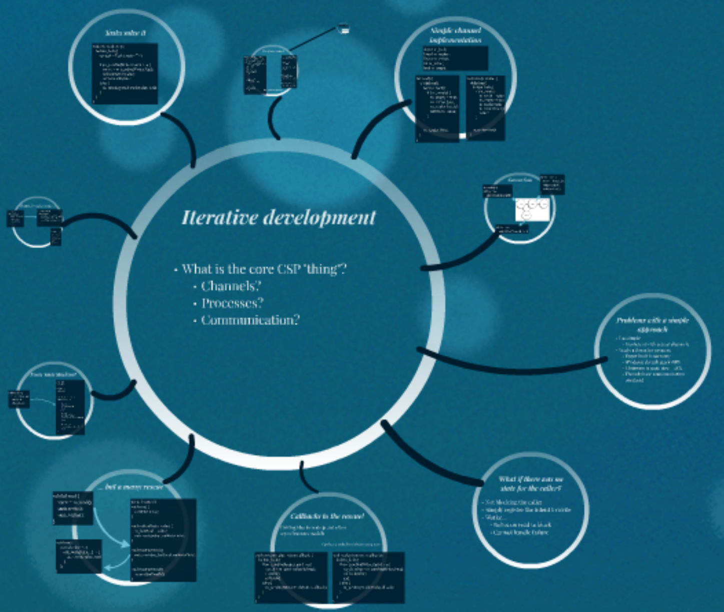

Iterative development

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Tasks solve it
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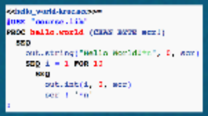
KRoC



```
<<hello_world-kroc.occ>>
#USE "course.lib"
PROC hello.world (CHAN BYTE scr!)
  SEQ
    out.string("Hello World!*n", 0, scr!)
    SEQ i = 1 FOR 10
      SEQ
        out.int(i, 0, scr!)
        scr ! '*n'
:
```

Design goals for a new CSP Library

- Fully contained in C#
    - No additional compilers or tools
    - No extra language constructs
- Simple codebase
- Fit into existing terminology & code
- Scalable
- Efficient execution

JCSP, C++CSP, PyCSP

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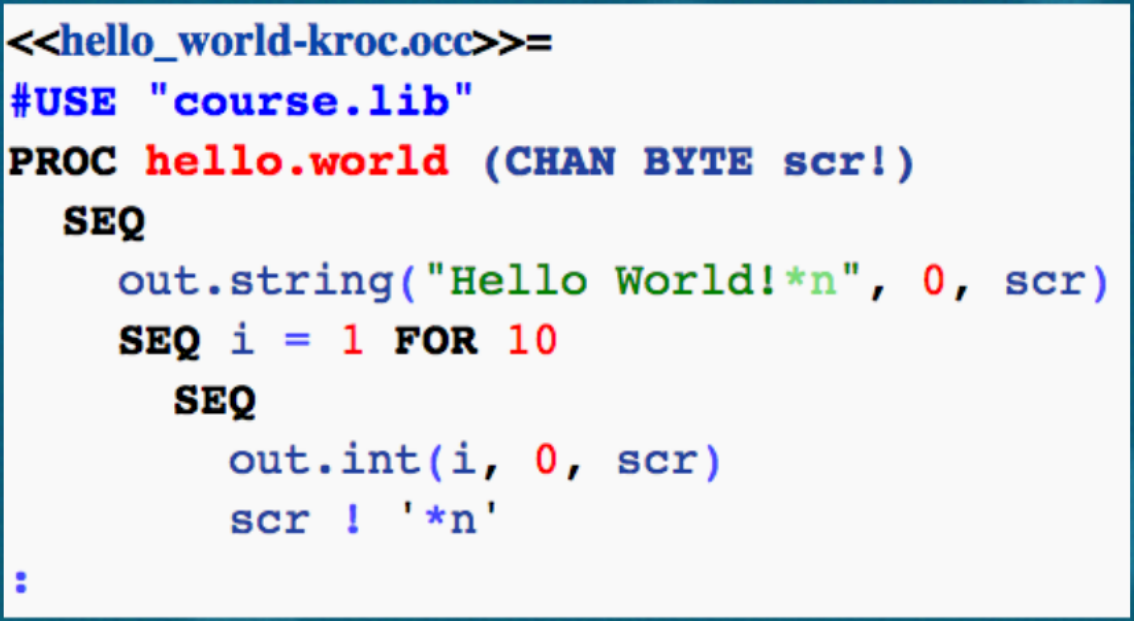

```
<<hello_world-kroc.occ>>=
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:
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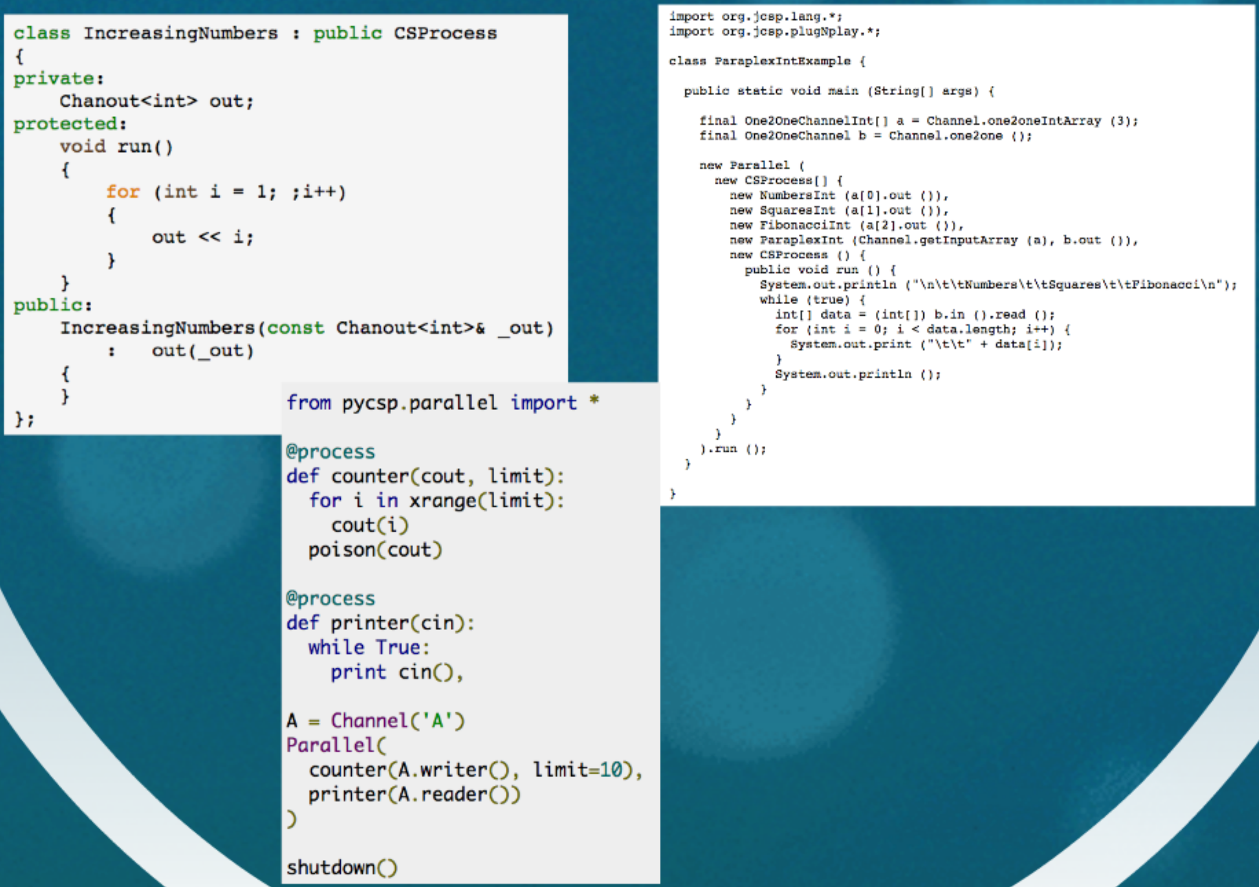
JCSP, C++CSP, PyCSP



```cpp
class IncreasingNumbers : public CSProcess
{
private:
    Chanout<int> out;
protected:
    void run()
    {
        for (int i = 1; ;i++)
        {
            out << i;
        }
    }
public:
    IncreasingNumbers(const Chanout<int>& _out)
        :   out(_out)
    {
    }
};
```

```python
from pycsp.parallel import *

@process
def counter(cout, limit):
  for i in xrange(limit):
    cout(i)
  poison(cout)

@process
def printer(cin):
  while True:
    print cin(),

A = Channel('A')
Parallel(
  counter(A.writer(), limit=10),
  printer(A.reader())
)

shutdown()
```

```java
import org.jcsp.lang.*;
import org.jcsp.plugNplay.*;

class ParaplexIntExample {

  public static void main (String[] args) {

    final One2OneChannelInt[] a = Channel.one2oneIntArray (3);
    final One2OneChannel b = Channel.one2one ();

    new Parallel (
      new CSProcess[] {
        new NumbersInt (a[0].out ()),
        new SquaresInt (a[1].out ()),
        new FibonacciInt (a[2].out ()),
        new ParaplexInt (Channel.getInputArray (a), b.out ()),
        new CSProcess () {
          public void run () {
            System.out.println ("\n\t\tNumbers\t\tSquares\t\tFibonacci\n");
            while (true) {
              int[] data = (int[]) b.in ().read ();
              for (int i = 0; i < data.length; i++) {
                System.out.print ("\t\t" + data[i]);
              }
              System.out.println ();
            }
          }
        }
      }
    ).run ();
  }

}
```

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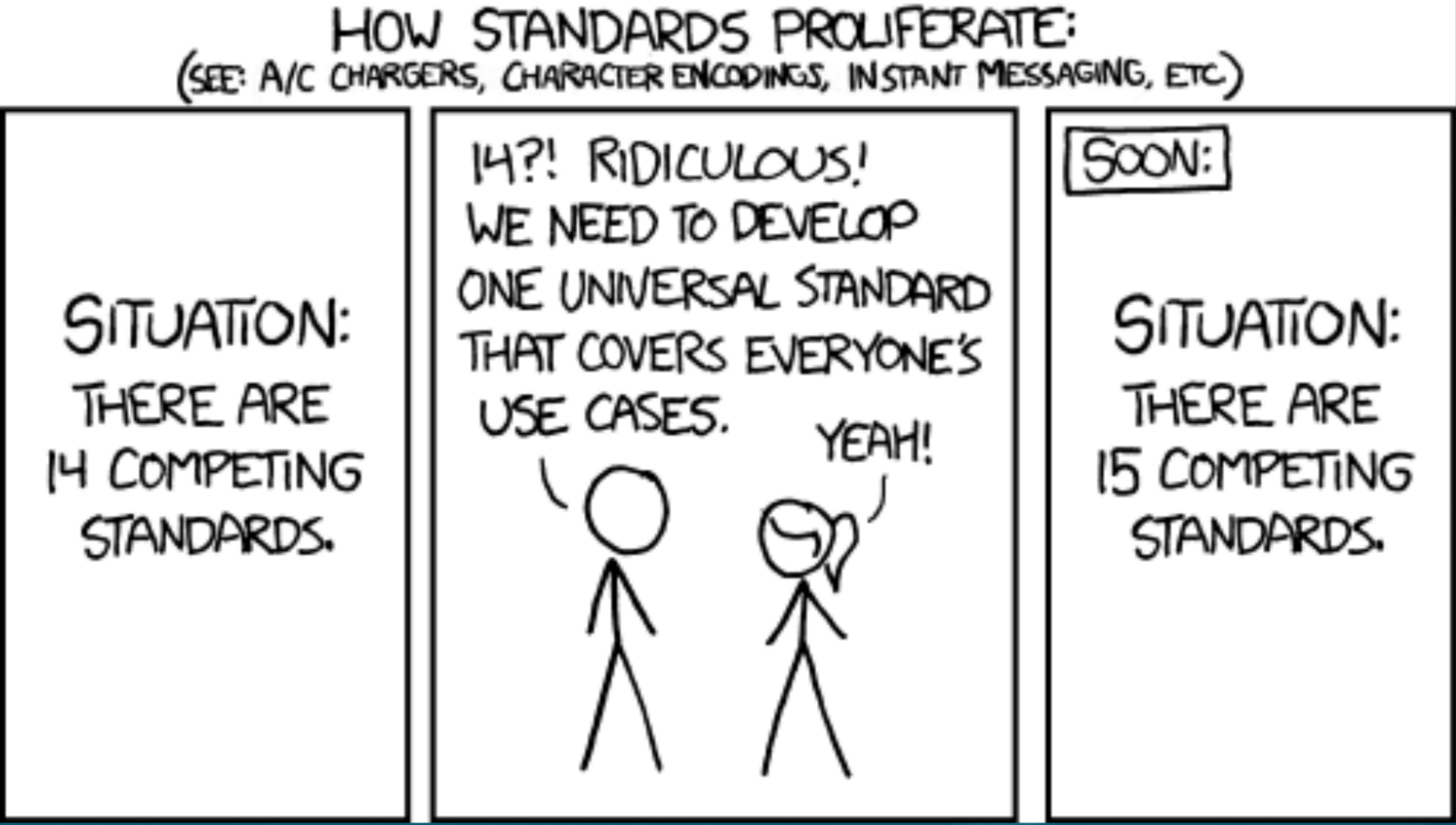
HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.

Iterative development

- What is the core CSP "thing"?
    - Channels?
    - Processes?
    - Communication?

Tasks solve it

```
Task<T> read<T>() {
   lock(m_lock) {
      var task = Task.Create<T>();

      if (m_pendingWrites.Count > 0) {
         var wt = m_pendingWrites.Pop();
         task.SetResult(value);
         wt.SetResult(true);
      } else {
         m_pendingReads.Push(value, task);
      }
   }
}
```

Two-phase commit?

```
[illegible]
```

Simple channel implementation

```
object m_lock;
Event m_reader;
Event m_writer;
int m_value;
bool m_empty
```

```
int read() {
   while(true) {
      lock(m_lock) {
         if (!m_empty) {
            m_empty = true;
            m_writer.Set();
            m_reader.Reset();
            return m_value;
         }
      }

      m_reader.Wait();
   }
}
```

```
void write(int value) {
   while(true) {
      lock(m_lock) {
         if (m_empty) {
            m_result = value;
            m_empty = false;
            m_reader.Set();
            m_writer.Reset();
            return;
         }
      }

      m_writer.Wait();
   }
}
```

CommsTime

```
in.write(0);
while(true)
   out.write(in.read());
```

```
while(true) {
   var v = in.read();
   out1.write(v);
   out2.write(v);
}
```

```
while(true)
   out.write(in.read() + 1);
```

Problems with a simple approach

- Too simple
    - Inefficient with sets of channels
- Needs a thread pr process
    - Upper limit is memory
    - Windows default stack 1MB
    - Minimum is page size = 4KB
    - Threads have communication overhead

What if there was no state for the caller?

- Not blocking the caller
- Simply register the intent to write
- Works....
    - Relies on read to block
    - Cannot handle failure

Callbacks to the rescue!

Driving idea in node.js and other asynchronous models

Can be extended to deliver exceptions

```
void write(int value, Action callback) {
   lock(m_lock) {
      if (m_pendingReads.Count > 0) {
         var cb = m_pendingReads.Pop();
         cb(value);
         callback();
      } else {
         m_pendingWrites.Push(value, callback);
      }
   }
}
```

```
void read(Action<int> callback) {
   lock(m_lock) {
      if (m_pendingWrites.Count > 0) {
         var cb, value = m_pendingWrites.Pop();
         callback(value);
         cb();
      } else {
         m_pendingReads.Push(callback);
      }
   }
}
```

... but a messy rescue

```
while(true) {
   var v = in.read();
   out1.write();
   out2.write();
}
```

```
int m_lastRead;
void run() {
   onWriteOut2();
}

void onReadIn(int value) {
   m_lastRead = value;
   out1.write(value, onWriteOut1);
}

void onWriteOut1() {
   out2.write(m_lastRead, onWriteOut2);
}

void onWriteOut2() {
   in.read(onReadIn);
}
```

```
void run() {
   in.read(value => {
      out1.write(value, () => {
         out2.write(value, run)
      })
   });
}
```

Finite State Machine?

```
while(true) {
   var v = in.read();
   out1.write();
   out2.write();
}
```

```
[illegible]
```

Future, Promise, async ...

```
[illegible]
```

Iterative development

- What is the core CSP "thing"?
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  - Communication?

in.write(0);
while(true)
  out.write(in.rea

while(tru
  out.wr

te Machine?

```
int m_state = 0;
int m_value;

void run() {
  callback();
}

void callback(int? value) {
  switch(m_state) {
    case 0:
      m_state = 1;
      in.read(callback);
      break;
    case 1:
      m_state = 2;
      m_value = value;
      out1.write(m_value, callback);
      break;
    case 2:
      m_state = 0;
      out2.write(m_value, callback);
      break;
  }
}
```

Simple channel implementation

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object m_lock;
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      }

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```

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         }
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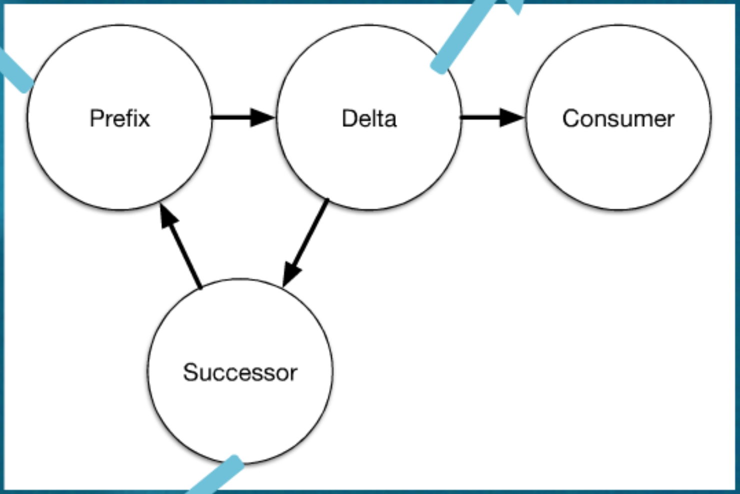

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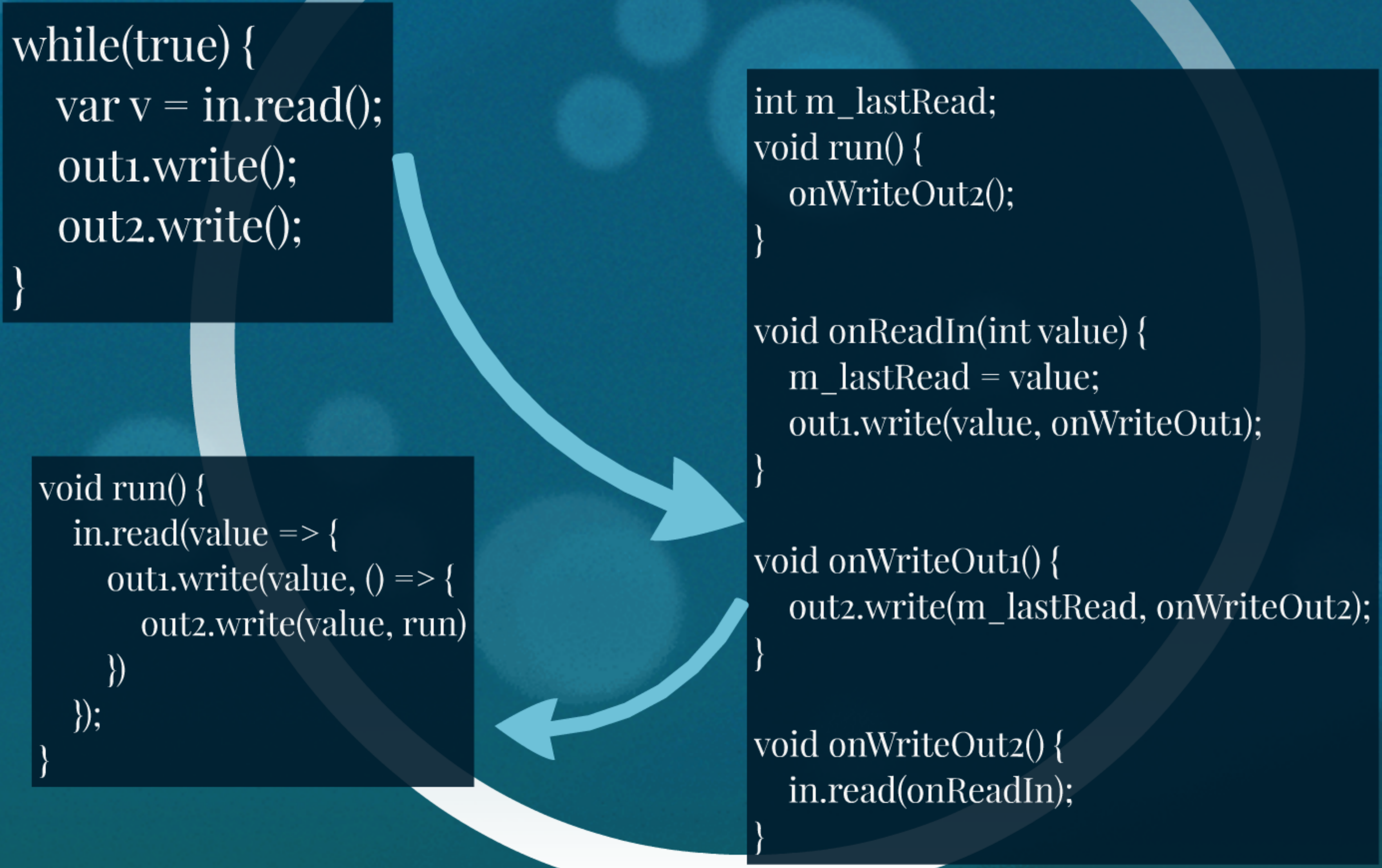

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void onWriteOut1() {
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}

void onWriteOut2() {
   in.read(onReadIn);
}
```

```
void run() {
   in.read(value => {
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      })
   });
}
```

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         break;
      case 2:
         m_state = 0;
         out2.write(m_value, callback);
         break;
   }
}
```

Future, Promise, async …

```
void run() {
   while(true) {
      var v = in.read();
      out1.write();
      out2.write();
   }
}
```

```
void async run() {
   while(true) {
      var value = await in.read();
      await out1.write(value);
      await out2.write(value);
   }
}
```

```
int m_state = 0;
int m_value;

void callback(int? value) {
   switch (m_state) {
      case 0:
         m_state = 1;
         in.read(callback);
         break;
      case 1:
         m_state = 2;
         m_value = value;
         out1.write(m_value, callback);
         break;
      case 2:
         m_state = 0;
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}
```

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      task.SetResult(value);
      wt.SetResult(true);
    } else {
      m_pendingReads.Push(value, task);
    }
  }
}
```

Two-phase commit

```
while (m_pendingWrites.Count > 0) {
   var wt = m_pendingWrites.Peek();
   var writerAccepts = wt.Offer();
   var readerAccepts = task.Offer();
   if (writerAccepts && readerAccepts) {
      m_pendingWrites.Pop();
      wt.Commit();
      task.Commit();
      task.SetResult(value);
      wt.SetResult(true);
      return;
   }

   if (writerAccepts) {
      wt.WithDraw();
      m_pendingWrites.Pop();
   }

   if (readerAccepts) {
      task.WithDraw();
      return;
   }
}
```

```
bool Offer(object caller) {
   Monitor.Enter(m_lock);

   if (!m_taken)
      return true;

   Monitor.Exit(m_lock);
   return false;
}

void Commit() {
   m_taken = true;
   Monitor.Exit(m_lock);
}

void WithDraw() {
   Monitor.Exit(m_lock);
}
```

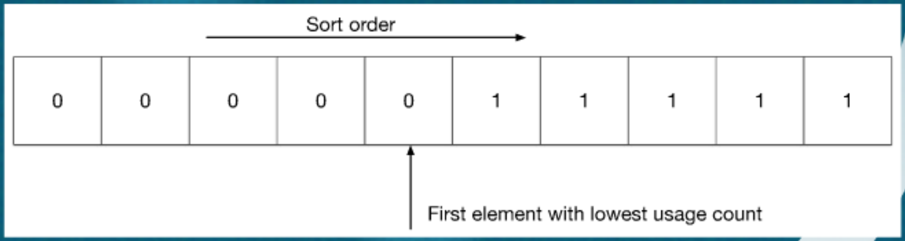
Many optimizations implemented ...

External choice

```
Task<T> readFromAny(IEnumerable<Channel<T>> channels) {
   var twophase = new TwoPhaseCommit();
   return Task.WhenAny(from c in channels select c.read(twophase));
}
```

Timeouts are handled with a shared timer, skip is done with timeout=0

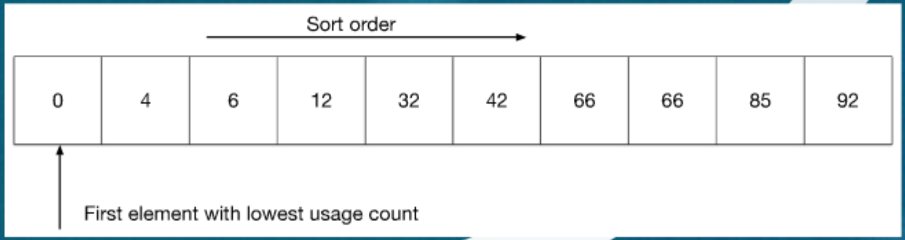
Fair select relies on a "usage counter"



Sort order

0	0	0	0	0	1	1	1	1	1

First element with lowest usage count



Sort order

0	4	6	12	32	42	66	66	85	92

First element with lowest usage count

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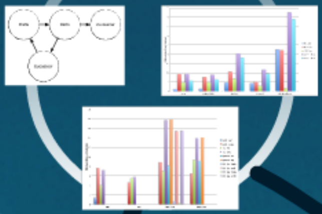
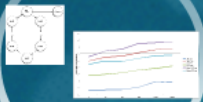


CommsTime



Scaling CommsTime

StressedAlt

Mandelbrot

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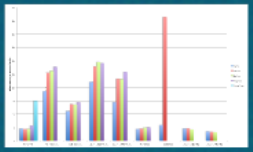
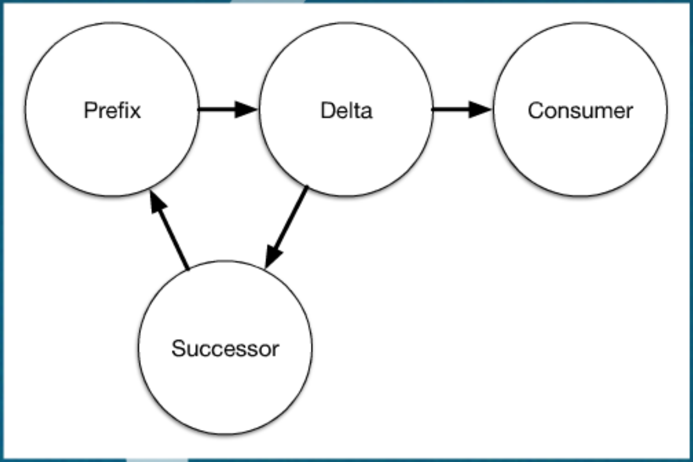
StressedAlt



CommsTime


Prefix
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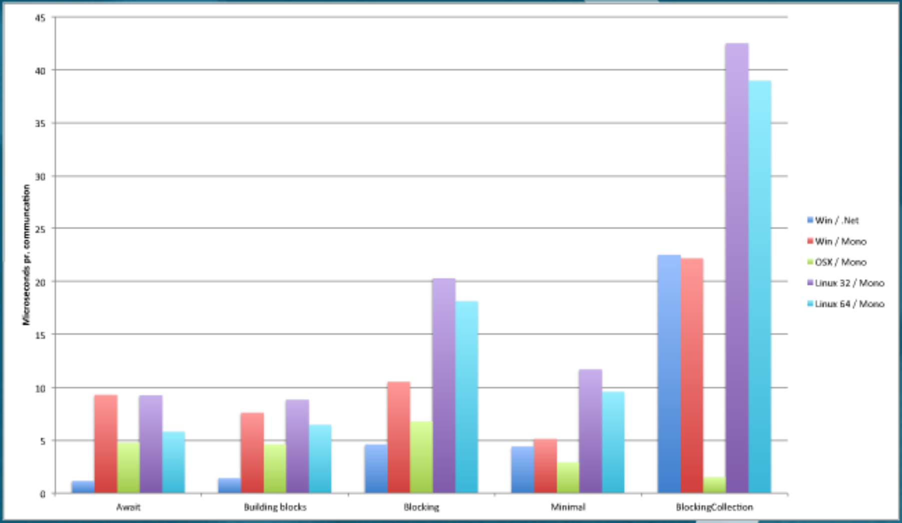
Consumer
Successor


45
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25
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15
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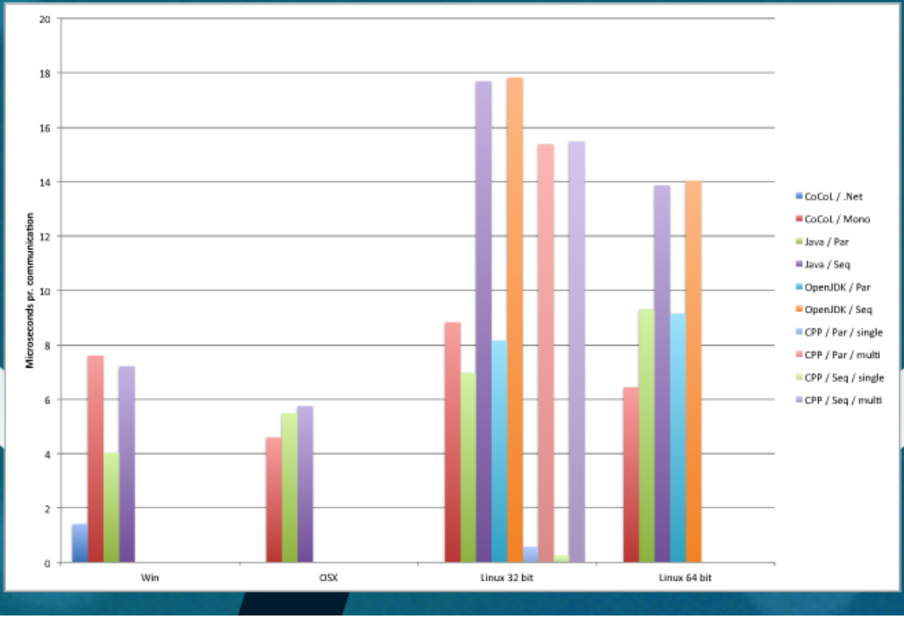
0
Microseconds pr. communcation
Await
Building blocks
Blocking
Minimal
BlockingCollection
Win / .Net
Win / Mono
OSX / Mono
Linux 32 / Mono
Linux 64 / Mono


20
18
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14
12
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6
4
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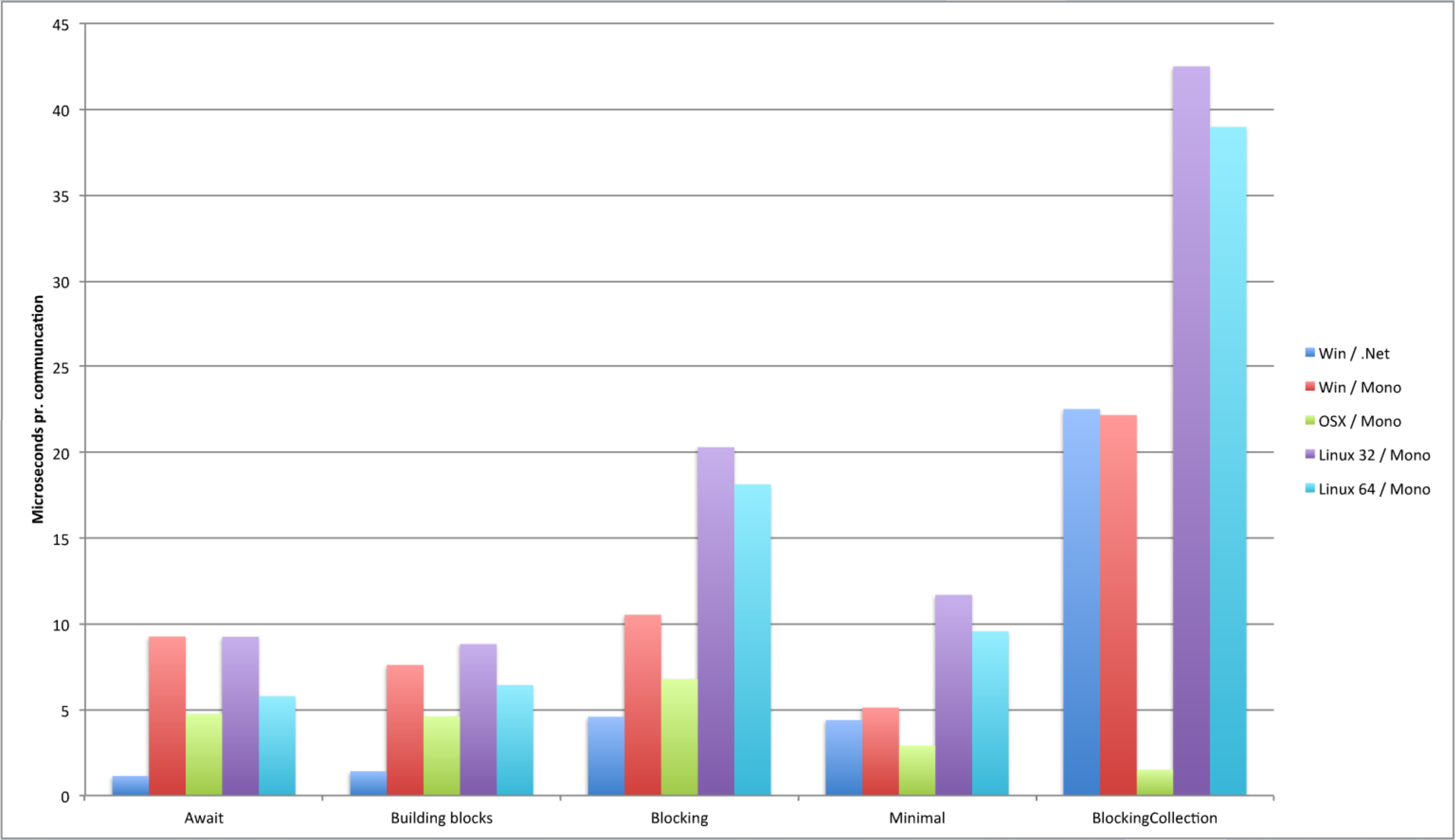
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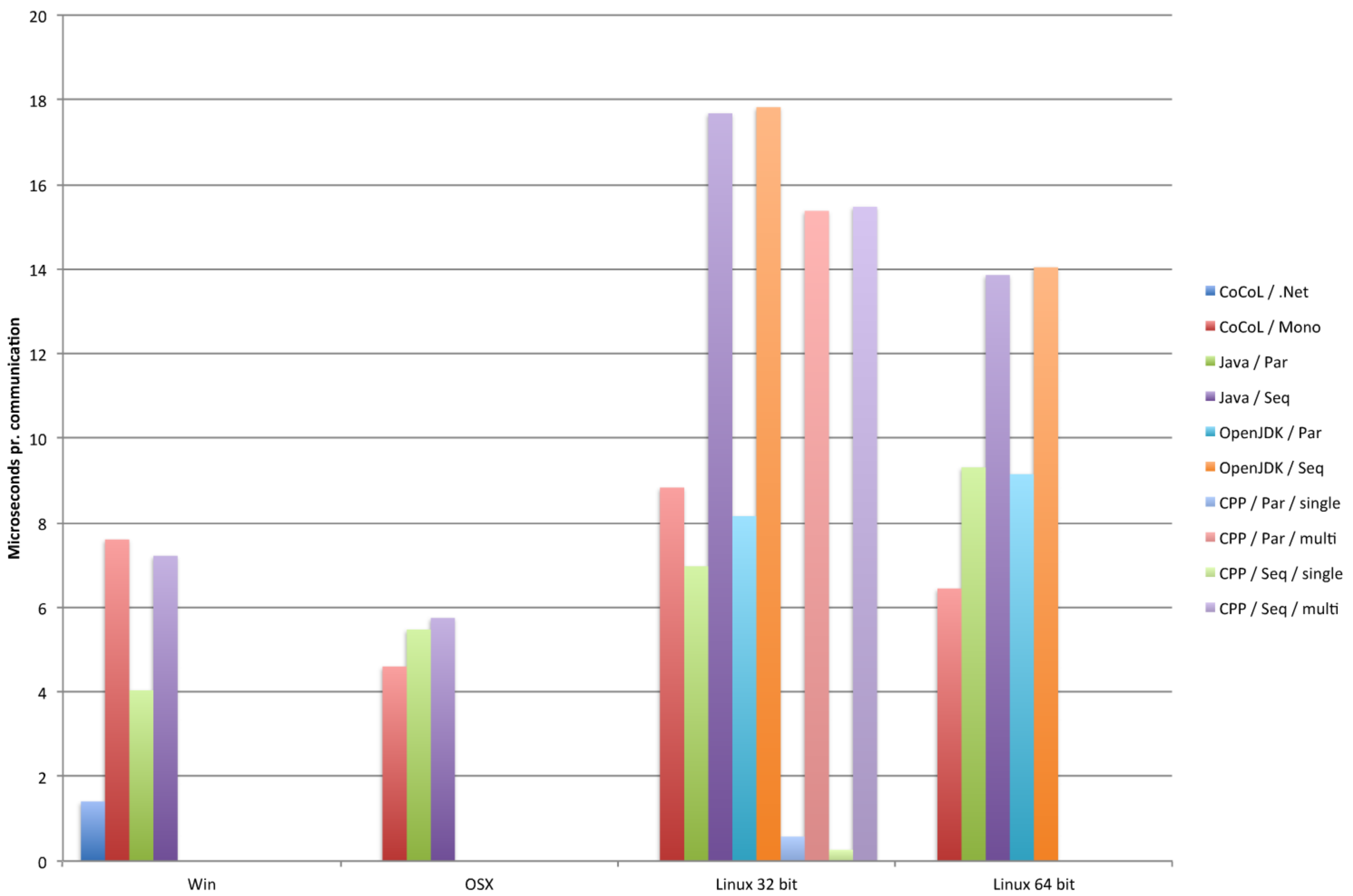

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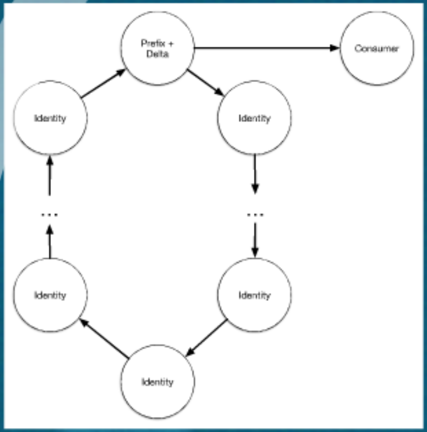
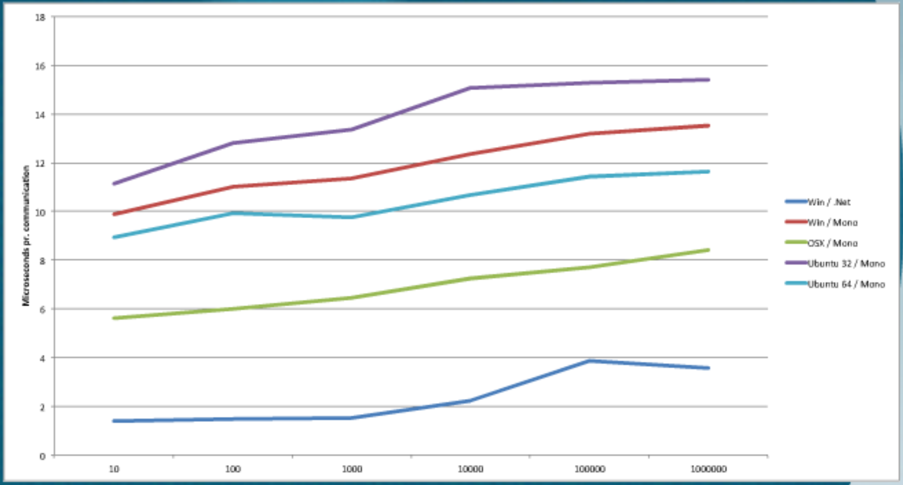
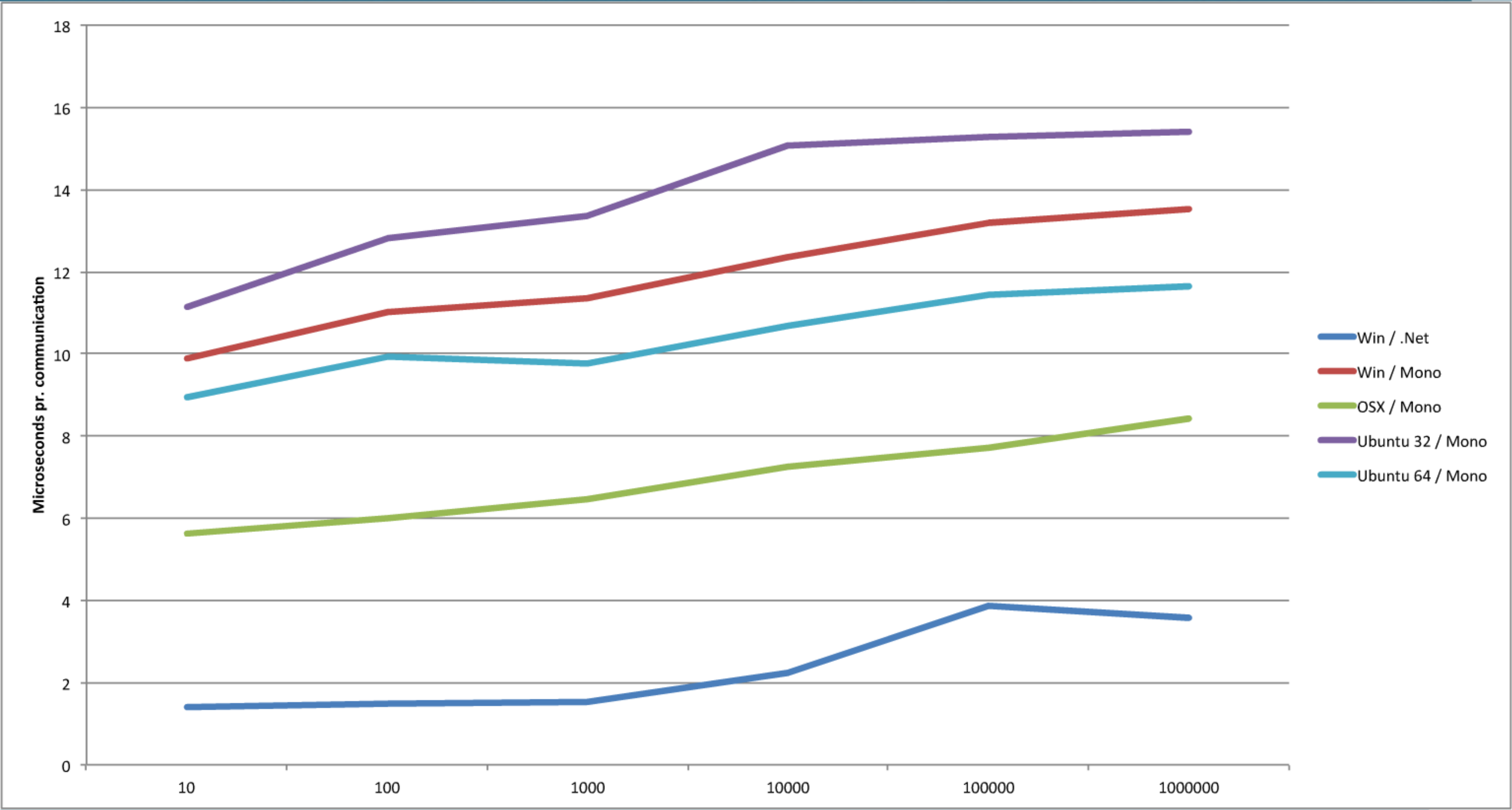
Scaling CommsTime







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1000
10000
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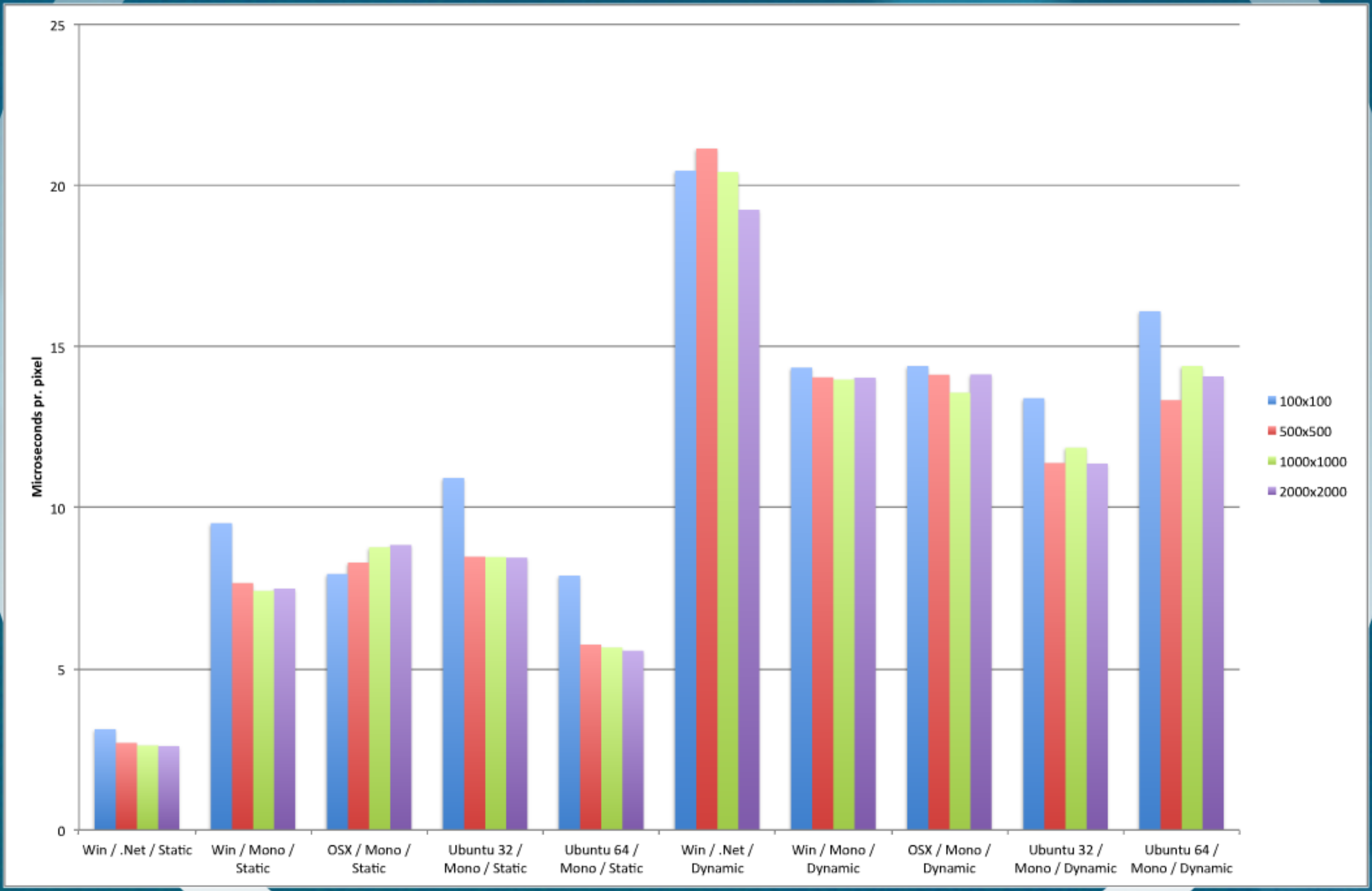
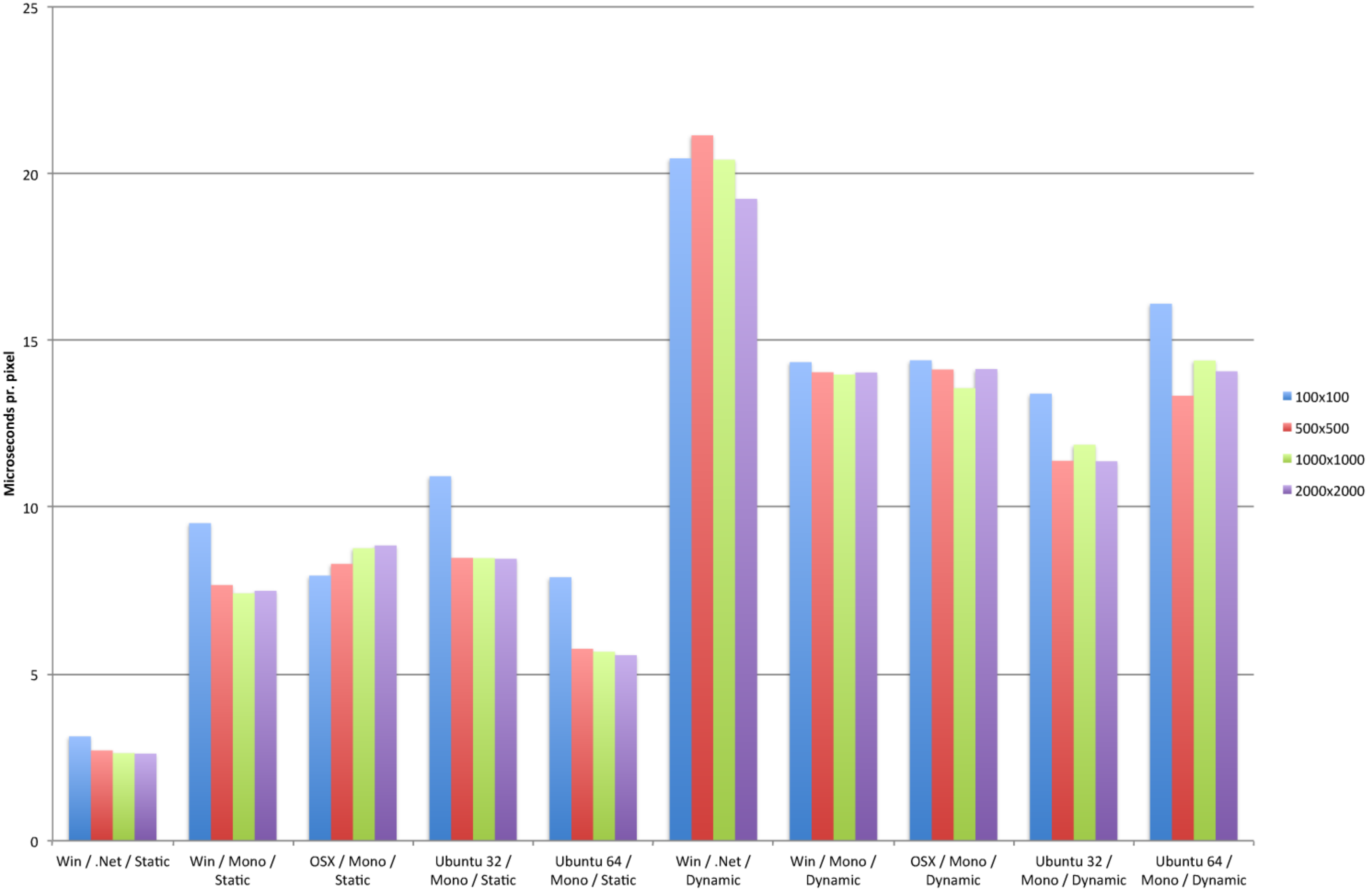
Win / Mono
OSX / Mono
Ubuntu 32 / Mono
Ubuntu 64 / Mono

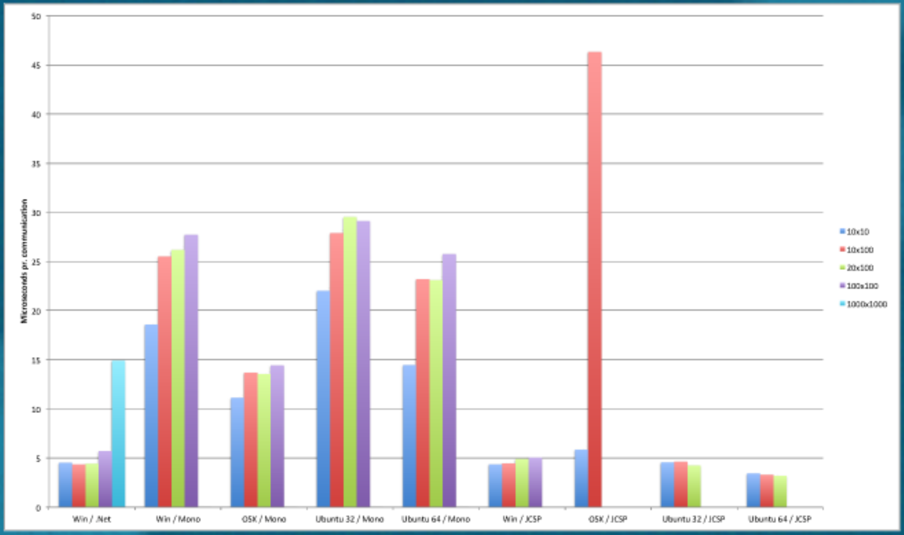
Mandelbrot

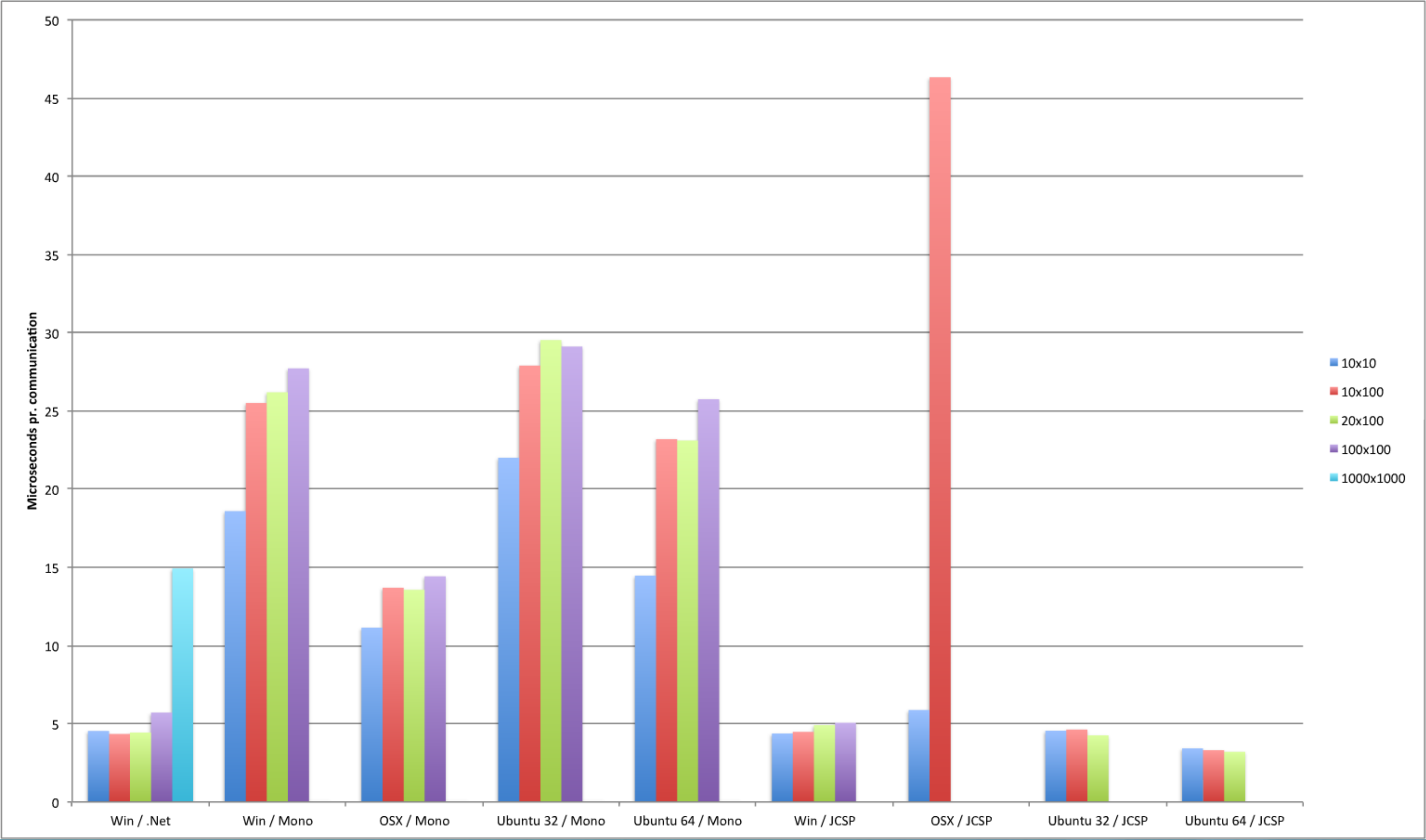

Microseconds pr. pixel
0
5
10
15
20
25
Win / .Net / Static
Win / Mono / Static
OSX / Mono / Static
Ubuntu 32 / Mono / Static
Ubuntu 64 / Mono / Static
Win / .Net / Dynamic
Win / Mono / Dynamic
OSX / Mono / Dynamic
Ubuntu 32 / Mono / Dynamic
Ubuntu 64 / Mono / Dynamic
100x100
500x500
1000x1000
2000x2000



Microseconds pr. pixel
25
20
15
10
5
0
Win / .Net / Static
Win / Mono / Static
OSX / Mono / Static
Ubuntu 32 / Mono / Static
Ubuntu 64 / Mono / Static
Win / .Net / Dynamic
Win / Mono / Dynamic
OSX / Mono / Dynamic
Ubuntu 32 / Mono / Dynamic
Ubuntu 64 / Mono / Dynamic
100x100
500x500
1000x1000
2000x2000

StressedAlt




50
45
40
35
30
25
20
15
10
5
0
Microseconds pr. communication
Win / .Net
Win / Mono
OSX / Mono
Ubuntu 32 / Mono
Ubuntu 64 / Mono
Win / JCSP
OSX / JCSP
Ubuntu 32 / JCSP
Ubuntu 64 / JCSP
10x10
10x100
20x100
100x100
1000x1000

All code, including examples / benchmarks:

https://github.com/kenkendk/cocol

Small code footprint:

Channel is appx 300 SLOC
Entire library is 1500 SLOC