Embracing the Global Interpreter Lock (GIL)

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Let's Love the GIL!

- After blowing up the GIL at PyCon'2010, I thought it needed a little more love
- Hence this talk!
- Let's begin

That is All

- Thanks for listening!
- Hope you learned something new
- Follow me! (@dabeaz)
- P.S. Use multiprocessing, futures

Embracing that the GIL Could be Better

David Beazley
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No, Seriously

- Let's talk about the GIL
- Apparently, it's an issue for *some* people
- Always comes up in discussions about Python's future whether warranted or not
- Godwin's law of Python?

My Interest

- Why am I so fixated on the GIL?

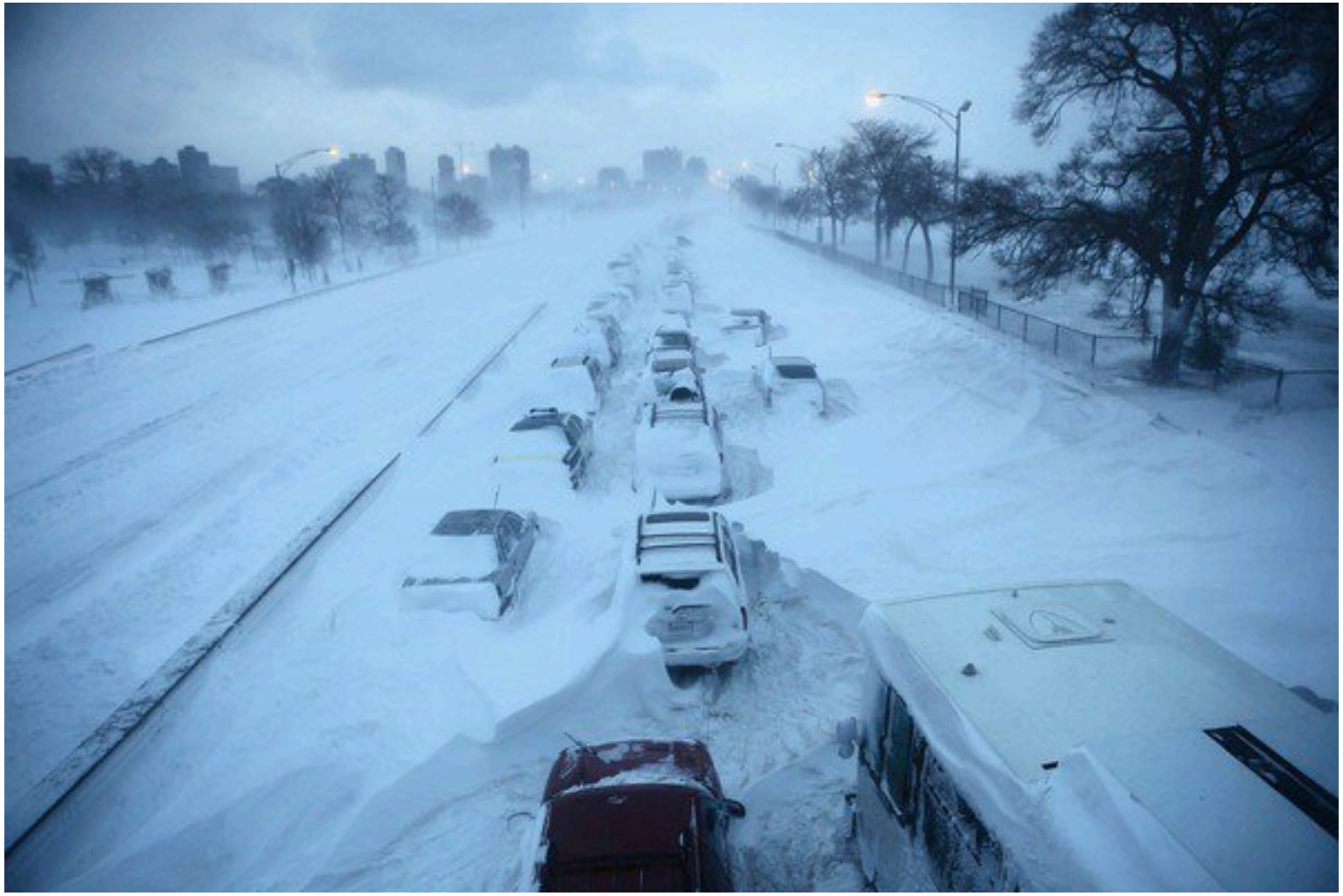
- Short answer: It's a fun hard systems problem
- Breaking GILs is my hobby

Premise

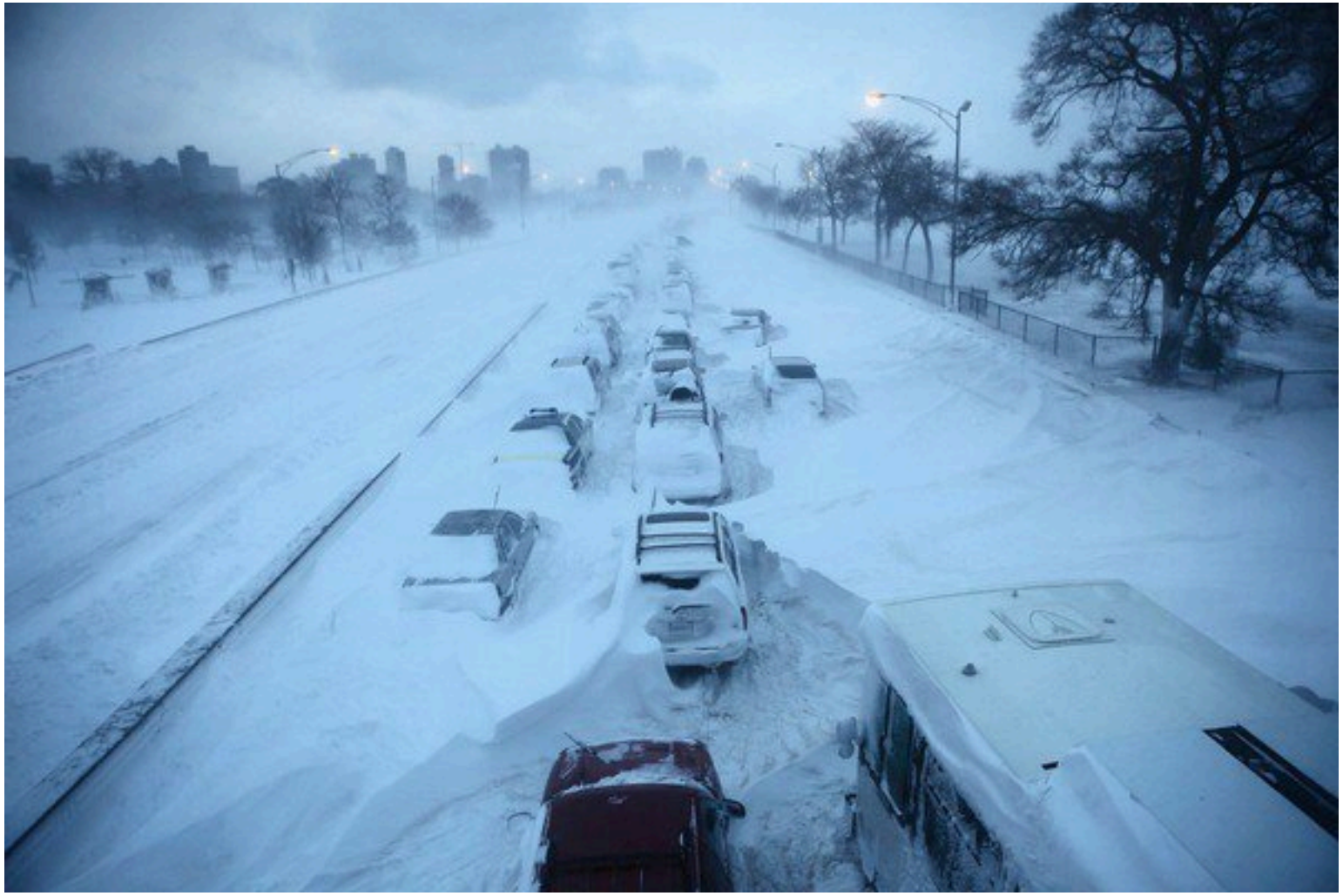
Threads are useful

- Yes, yes, lots of people love to hate on threads
- That's only because they're being used!
- Threads make all sorts of great stuff work
- Even if you don't see them directly

Solution: Threads



Solution: Threads



P.S. Come visit me in Chicago

The GIL in a Nutshell

- Python code is compiled into VM instructions

```
def countdown(n):
    while n > 0:
        print n
        n -= 1
```



```
>>> import dis
>>> dis.dis(countdown)
0 SETUP_LOOP              33 (to 36)
3 LOAD_FAST                0 (n)
6 LOAD_CONST               1 (0)
9 COMPARE_OP               4 (>)
12 JUMP_IF_FALSE           19 (to 34)
15 POP_TOP
16 LOAD_FAST                0 (n)
19 PRINT_ITEM
20 PRINT_NEWLINE
21 LOAD_FAST                0 (n)
24 LOAD_CONST               2 (1)
27 INPLACE_SUBTRACT
28 STORE_FAST               0 (n)
31 JUMP_ABSOLUTE            3
...
```

- In CPython, it is unsafe to execute instructions concurrently
- Hence: Locking

The GIL in a Nutshell

- Things that the GIL protects
  - Reference count updates
  - Mutable types (lists, dicts, sets, etc.)
  - Some internal bookkeeping
  - Thread safety of C extensions
- Keep in mind: It's all low-level (C)

Major GIL Issues

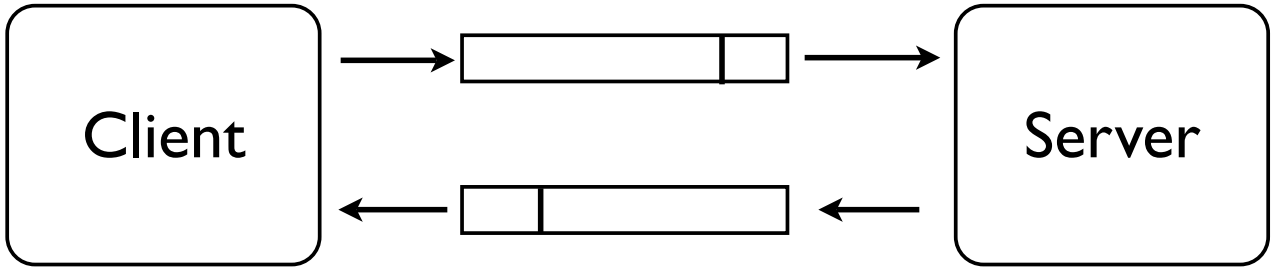
- Threads using multiple CPUs (for computation)
- Uninterruptible instructions
- Bad behavior of CPU-bound threads

The Challenge

- The GIL is unlikely to go away anytime soon
- However, can it be improved?
- Yes!
- Must embrace the idea that it's possible
- ... and agree that it's worthy goal
- There's been some progress in Python 3

An Experiment: Messaging

- A request/reply server for size-prefixed messages



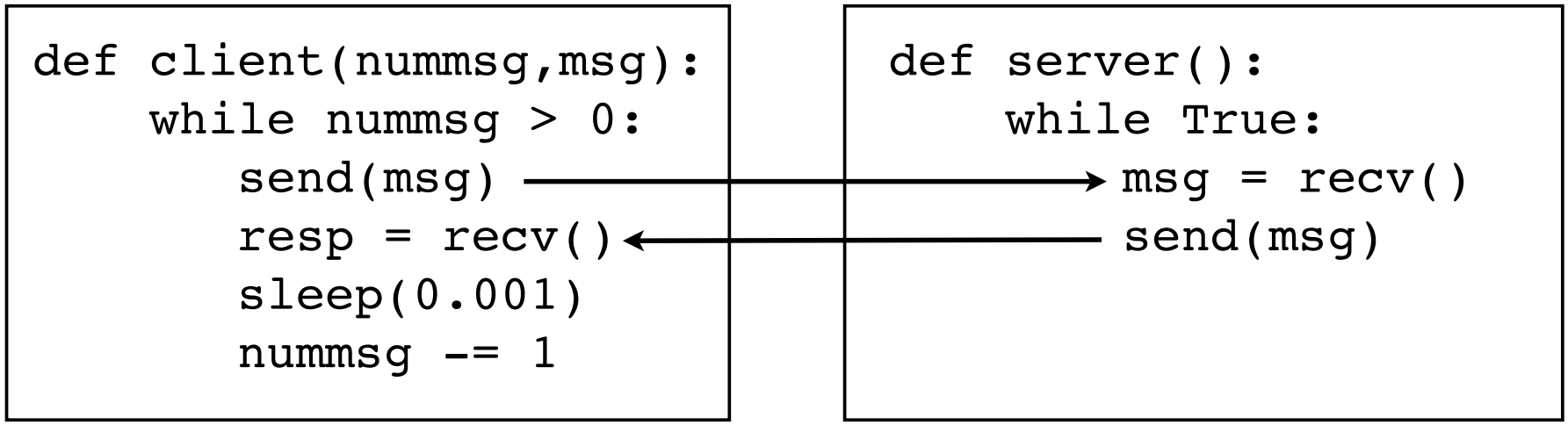
- Each message: a size header + payload

An Experiment: Messaging

- Why this experiment?
- Messaging comes up in a lot of contexts
- Involves I/O
- Foundation of various techniques for working around the GIL (cooperating processes + IPC)

An Experiment: Messaging

- A simple test - message echo (pseudocode)



An Experiment: Messaging

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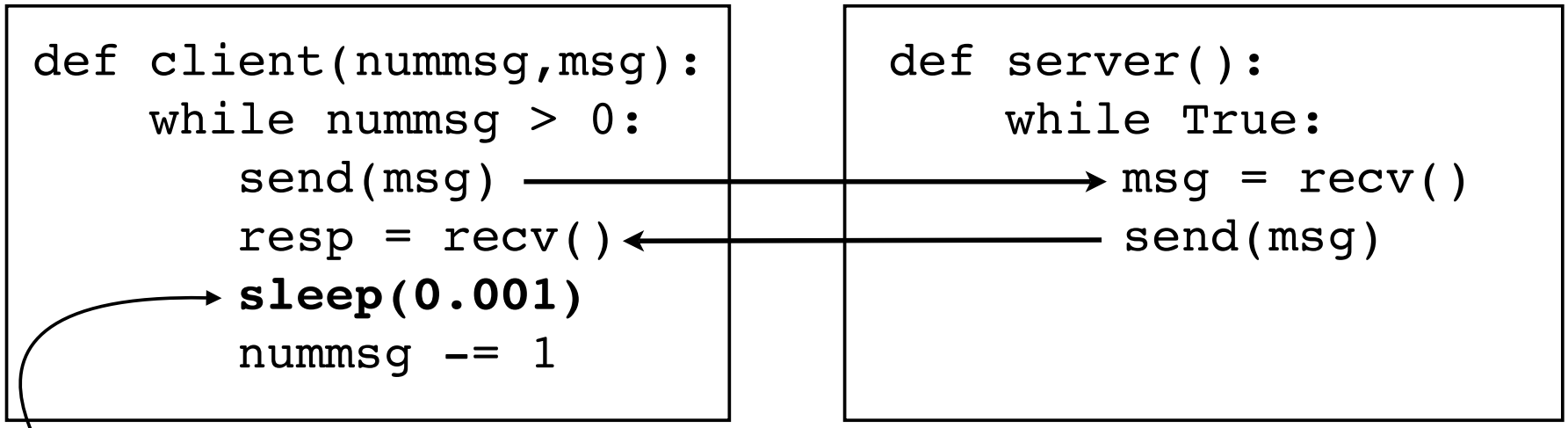


- To be less evil, it's throttled (<1000 msg/sec)
- Hardly a messaging stress test

An Experiment: Messaging

- Five server implementations
  - C with ZeroMQ (no Python)
  - Python with ZeroMQ (C extension)
  - Python with multiprocessing
  - Python with blocking sockets
  - Python with nonblocking sockets, coroutines
- Reminder: Not a messaging stress test

An Experiment: Messaging

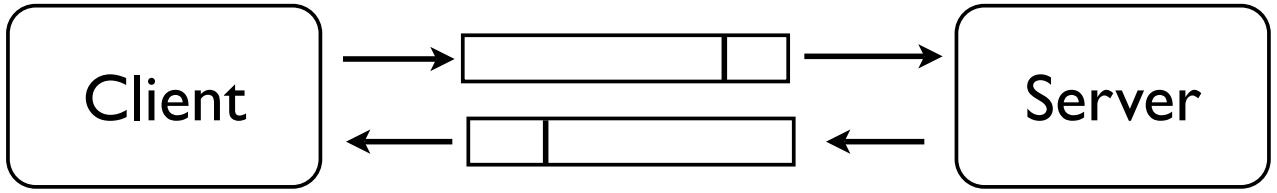
- Hardware setup
- 8-CPU Amazon EC2 (c1.xlarge) instance
    - Linux
    - 64 bit
    - 7 GB RAM
    - High I/O performance
- In other words, not my laptop

An Experiment: Messaging

- The test
  - Send/receive 10000 8K messages (echo)
  - 1ms delay after each message
- Emphasis: Not a messaging stress test

An Experiment: Messaging

- Scenario 1 : Unloaded server

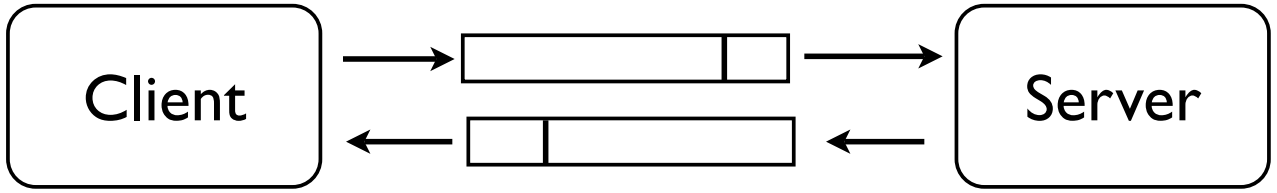


Time to send/receive 10000 8k messages (Py3.2)

- Question: What do you expect?
- 10000 messages w/ 1ms delay = ~10sec

An Experiment: Messaging

- Scenario 1 : Unloaded server



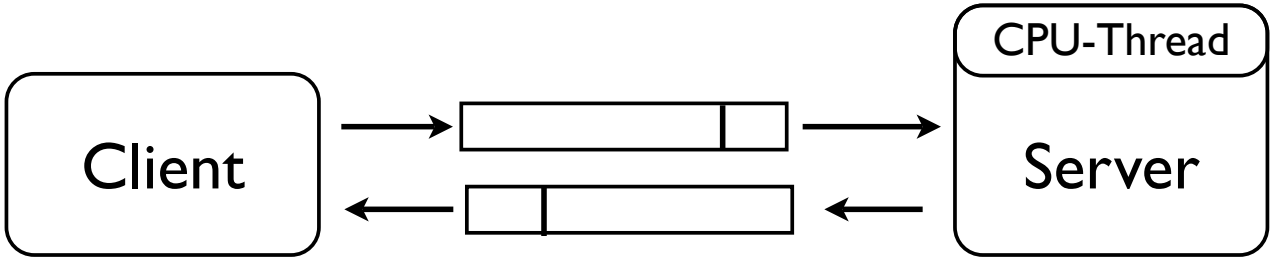
Time to send/receive 10000 8k messages (Py3.2)

C + ZeroMQ	12.8s
Python + ZeroMQ	13.0s
Python + multiprocessing	11.6s
Python + blocking sockets	11.8s
Python + nonblocking sockets	12.2s

- Runs at about 10-20% CPU load

An Experiment: Messaging

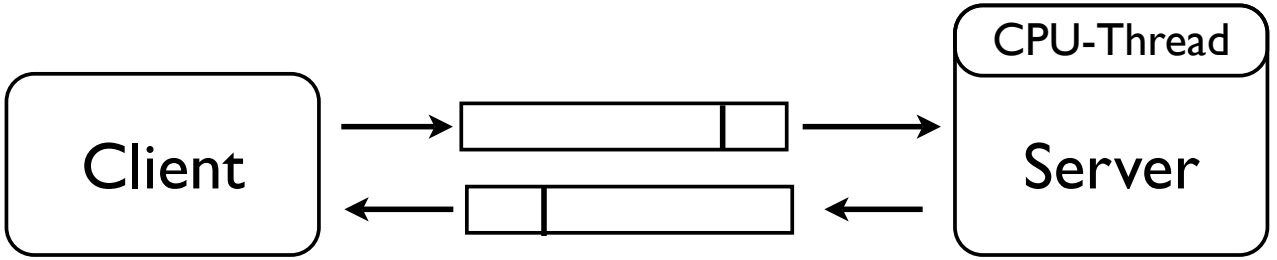
- Scenario 2 : Server competes with one CPU-thread



- Imagine it's computing something very important
- Like the 200th Fibonacci number via recursion

An Experiment: Messaging

- Scenario 2 : Server competes with one CPU-thread



Time to send/receive 10000 8k messages (Py3.2)

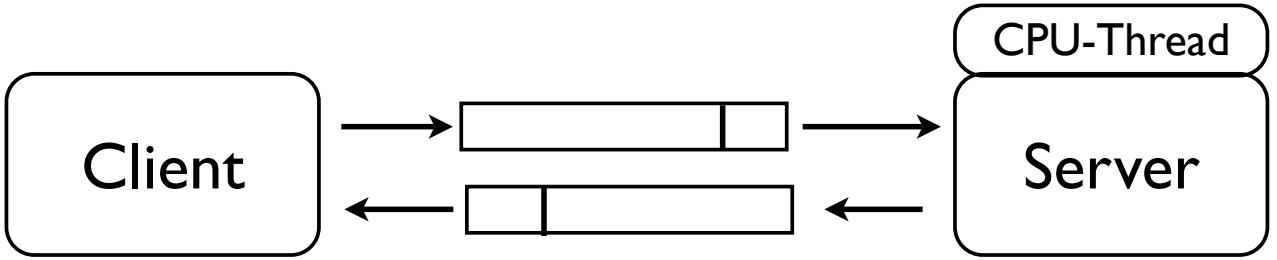
C + ZeroMQ	12.6s	(same)
Python + ZeroMQ	91.6s	(7.0x slower)
Python + multiprocessing	103.3s	(8.9x slower)
Python-Blocking	142.7s	(12.1x slower)
Python-Nonblocking	126.2s	(10.3x slower)

Commentary

- This aggression will not stand.
- Surely it can be better
- We're not talking about micro-optimization
- Reminder: Not a messaging stress test

Thought: Try PyPy

- Scenario 2 : Server competes with one CPU-thread

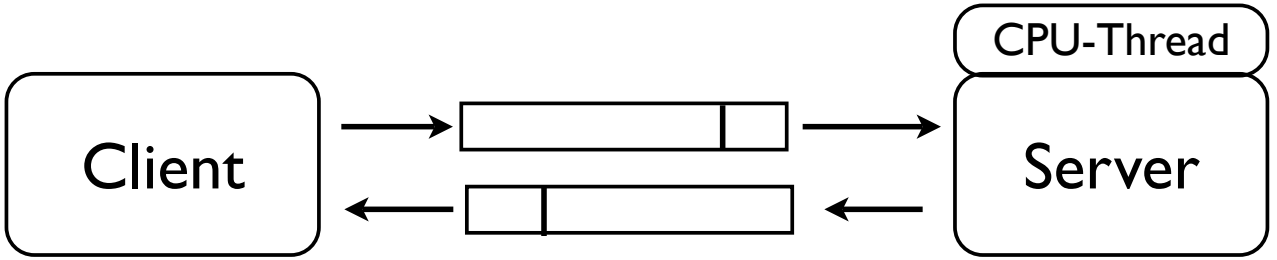


Time to send/receive 10000 8k messages (pypy-1.6)

.... wait for it (drumroll)

Thought: Try PyPy

- Scenario 2 : Server competes with one CPU-thread



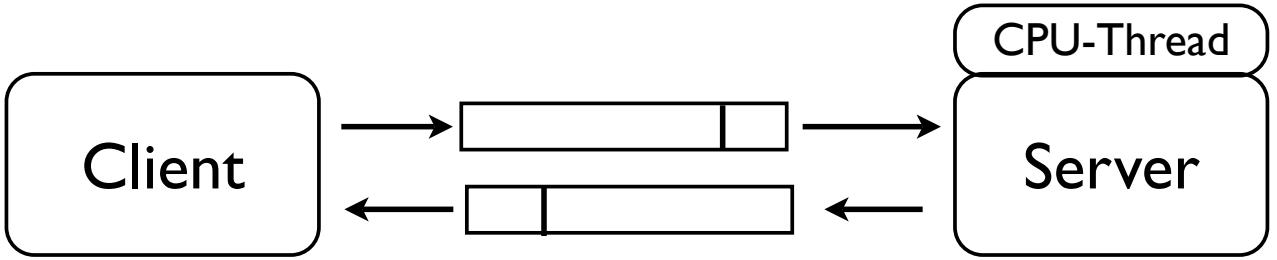
Time to send/receive 10000 8k messages (pypy-1.6)

Python-Blocking	6689.2s (567x slower)
Python-Nonblocking	4975.0s (408x slower)

- To be fair--there was a bug (already fixed)

Thought : Try Python2.7

- Scenario 2 : Server competes with one CPU-thread



Time to send/receive 10000 8k messages (Py2.7)

C + ZeroMQ	12.6s	(same)
Python + ZeroMQ	27.7s	(2.1x slower)
Python + multiprocessing	15.0s	(1.3x slower)
Python-Blocking	15.6s	(1.3x slower)
Python-Nonblocking	18.1s	(1.5x slower)

Try This At Home

- Not just networks : Try this GUI experiment

```
# badidle.py

import threading
def spin():
    while True:
        pass

t = threading.Thread(target=spin)
t.daemon=True
t.start()

import idlelib.idle
```

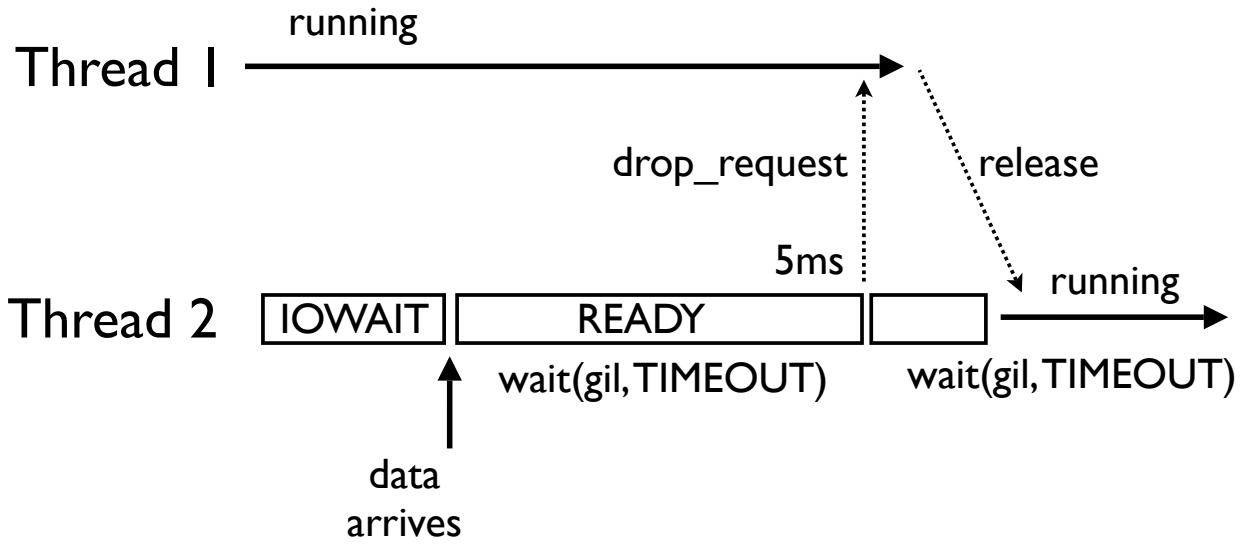
- GUI is completely unusable!

Thread Switching

- The performance problems are related to the mechanism used to switch threads
- In particular, the preemption mechanism and lack of thread priorities
- Py3.2 GIL severely penalizes response-time

GIL Acquisition Sequence

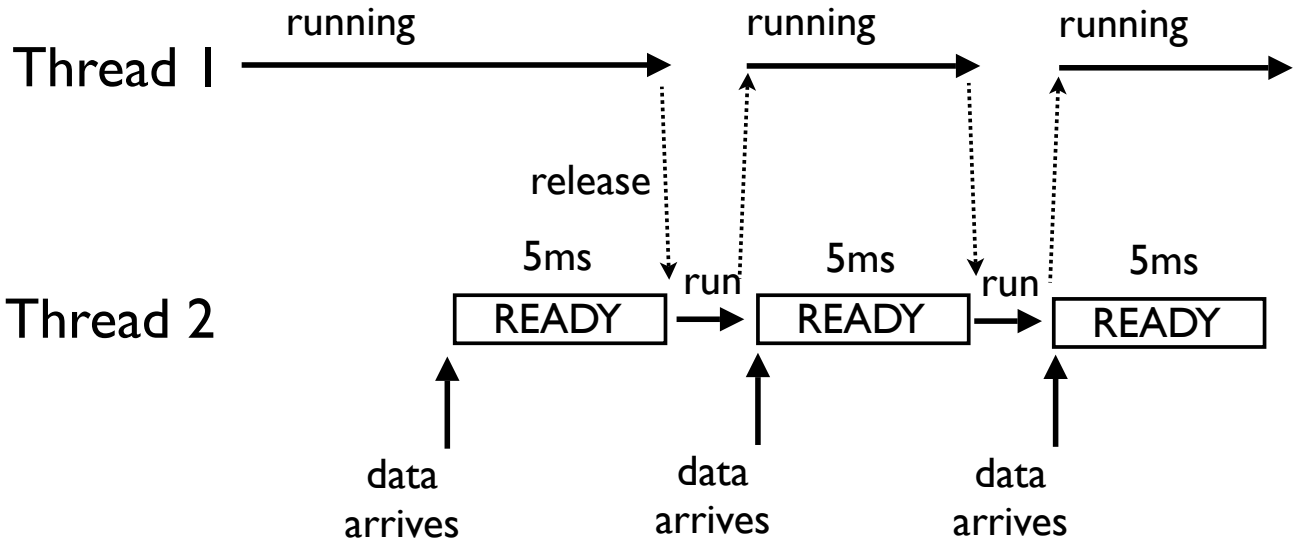
- GIL acquisition based on timeouts



- Any thread that wants the GIL must wait 5ms

Problem : GIL Release

- CPU-bound threads significantly degrade I/O



- Each I/O call drops the GIL and might restart the CPU bound thread
- If it happens, need 5ms to get the GIL back

Performance Explained

- Go back to the server

```
def server():
    while True:
        msg = recv()
        send(msg)
```

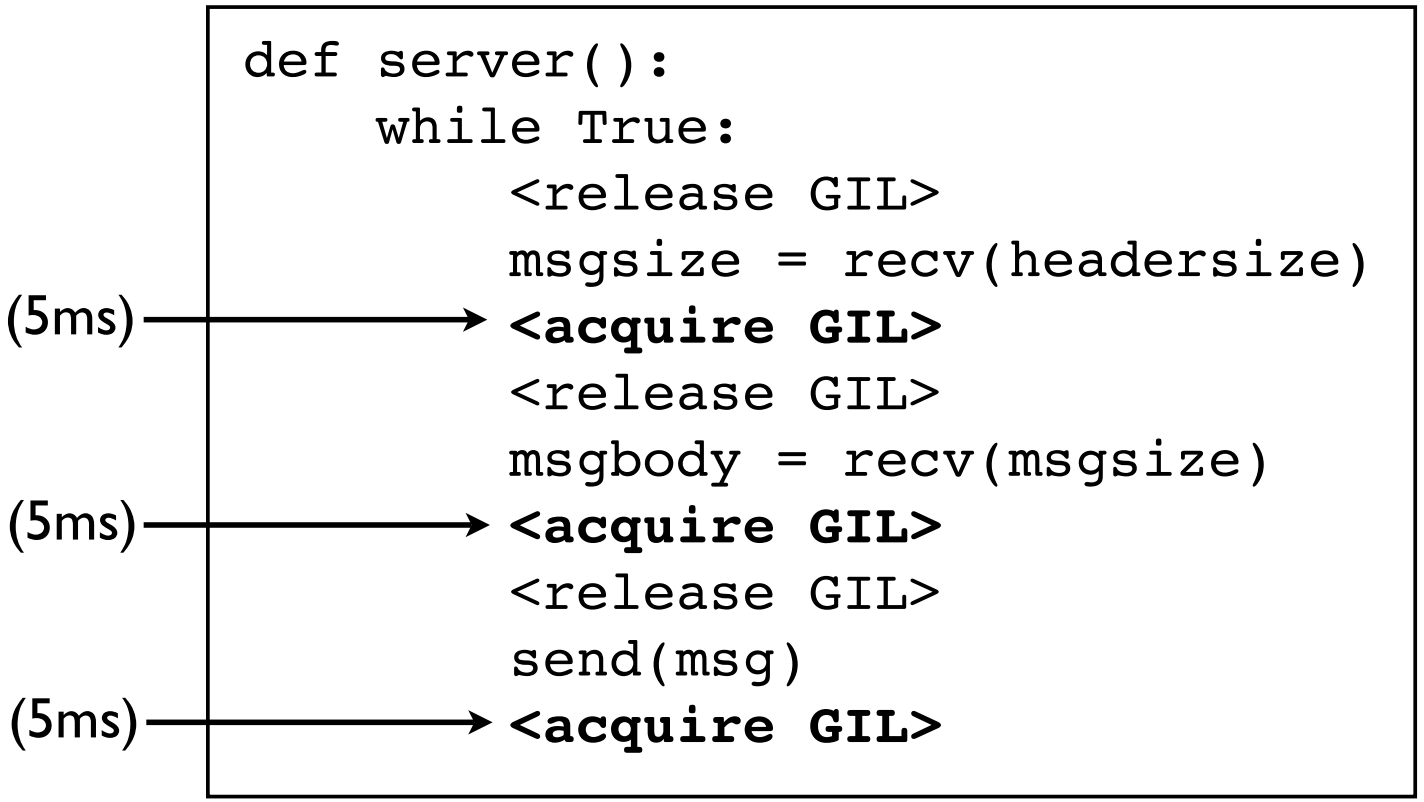
Performance Explained

- What's really happening

```
def server():
    while True:
        <release GIL>
        msg = recv()
        <acquire GIL>
        <release GIL>
        send(msg)
        <acquire GIL>
```

Performance Explained

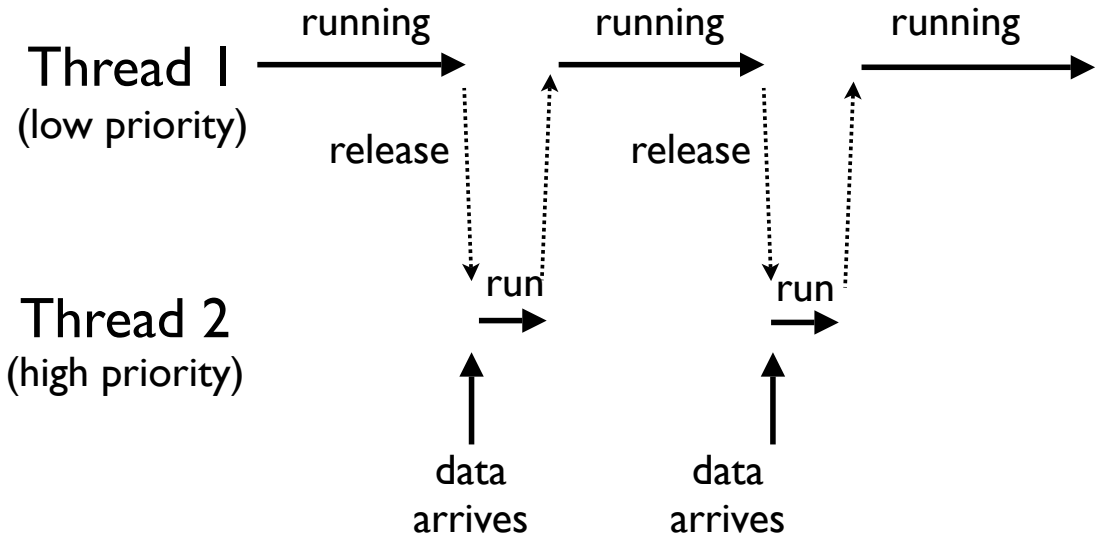
- Actually, it's just a bit worse...



- 10000 messages x15ms = 150s (worst case)

Thread Priorities

- To fix, you need priorities



- The original "New GIL" patch had priorities
- That should be revisited

An Experiment

- I have an experimental Python3.2 w/ priorities
- Extremely minimal
  - Manual priority adjustment (sys.setpriority)
  - Highest priority thread always runs
- Probably too minimal for real (just for research)

Example: Priorities

- Setting a thread's priority

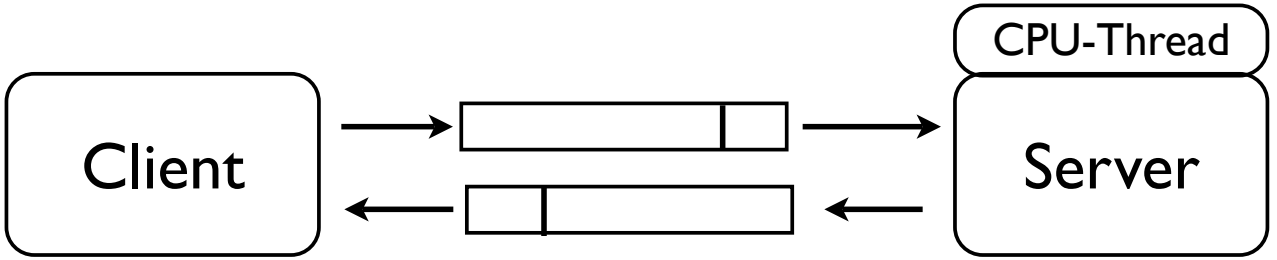
```
import sys
import threading

def cputhread():
    sys.setpriority(-1)   # Lower my priority
    ...

t = threading.Thread(target=cputhread)
t.start()
```

Messaging + Priorities

- Scenario 2 : Server competes with one CPU-thread



Send/receive 10000 8k messages (Py3.2+priorities)

C + ZeroMQ	12.6s (same)
Python + ZeroMQ	17.6s (1.3x slower)
Python + multiprocessing	14.2s (1.2x slower)
Python-Blocking	13.0s (1.1x slower)
Python-Nonblocking	14.0s (1.1x slower)

GUI Revisited

- Try this variant with priorities

```
# badidle.py

import sys
import threading
def spin():
    sys.setpriority(-1)
    while True:
        pass

t = threading.Thread(target=spin)
t.daemon=True
t.start()
import idlelib.idle
```

- GUI is completely usable (barely notice)

Some Thoughts

- A huge boost in performance with very few modifications to Python (only a few files)
- Is this the only possible GIL improvement?
- Answer: No
- Example: Should the GIL be released on non-blocking I/O operations? (think about it)

Wrapping Up

- I think all Python programmers should be interested in having a better GIL
- Improving it doesn't necessarily mean huge patches to the Python core
- You (probably) don't have to write an OS
- Incremental improvements can be made

Final Words

- Code and resources

  http://www.dabeaz.com/talks/EmbraceGIL/

- All code available under version control
- Hope you enjoyed the talk!
- Follow me on Twitter (@dabeaz)