Axum

Getting the Genie Back into the Lamp

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Once upon a time…

My parallel programs looked something like:

```
ls -l | awk ‘ { print “%6d %s\n” NR $0 } | sed 7q
```

People who really knew what they were doing used…

- … more complex IPC
- … co-routines
- … languages with support for pre-emptive multi-tasking

Then…

… C/C++ thread libraries used by experts…

… clock-cycle glass ceiling → no more automatic speedups of sequential code…

… multi-core…

… everyone has to leverage parallelism…

… but no one wants to learn a new language…

… a model for experts used by the masses…

Trouble

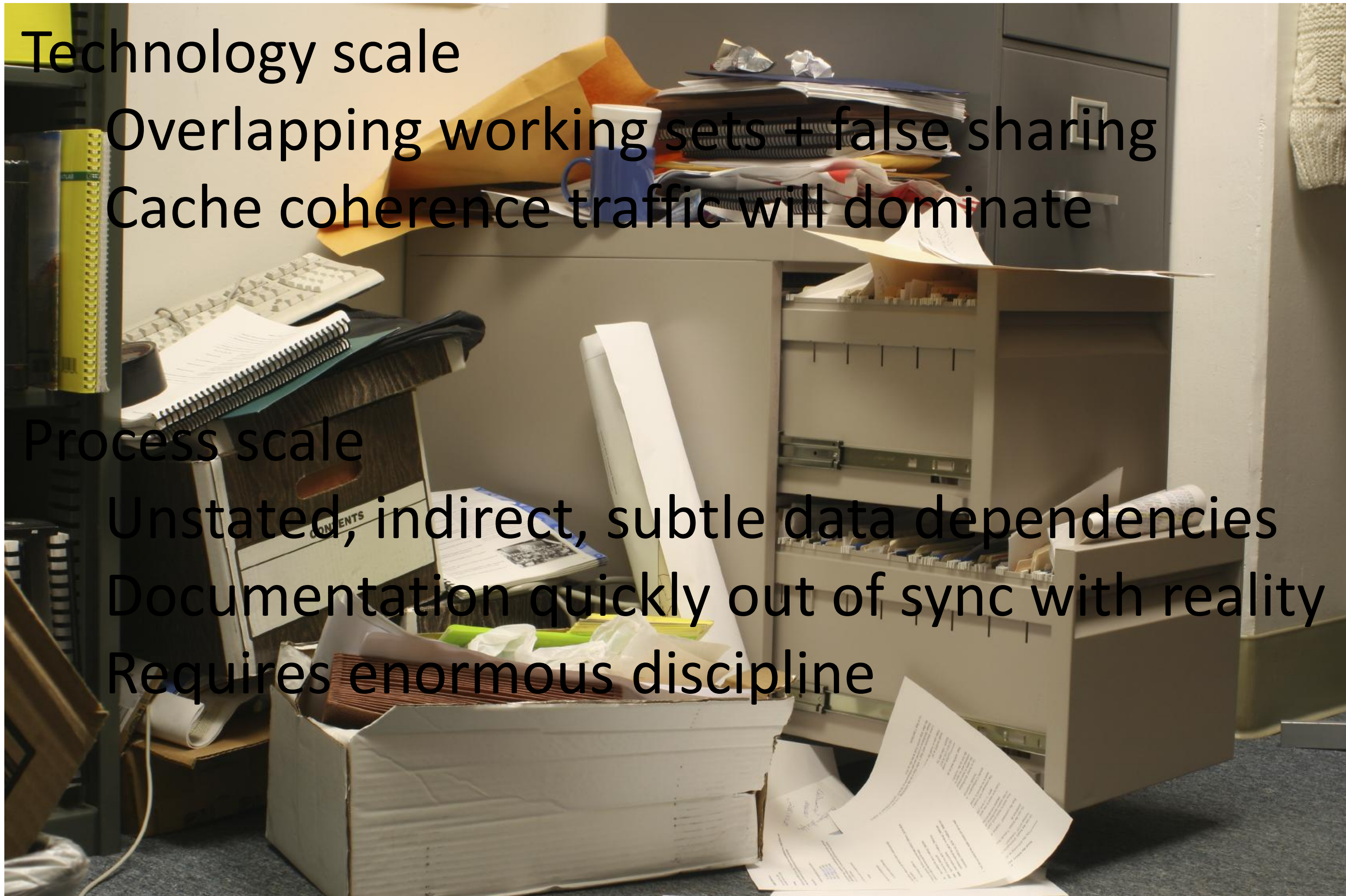
Shared Memory Parallelism

In theory…

Shared Memory Parallelism

… and practice

Un-partitioned Shared Memory State



- Technology scale
  - Overlapping working sets + false sharing
  - Cache coherence traffic will dominate
- Process scale
  - Unstated, indirect, subtle data dependencies
  - Documentation quickly out of sync with reality
  - Requires enormous discipline

The Web

Loosely coupled

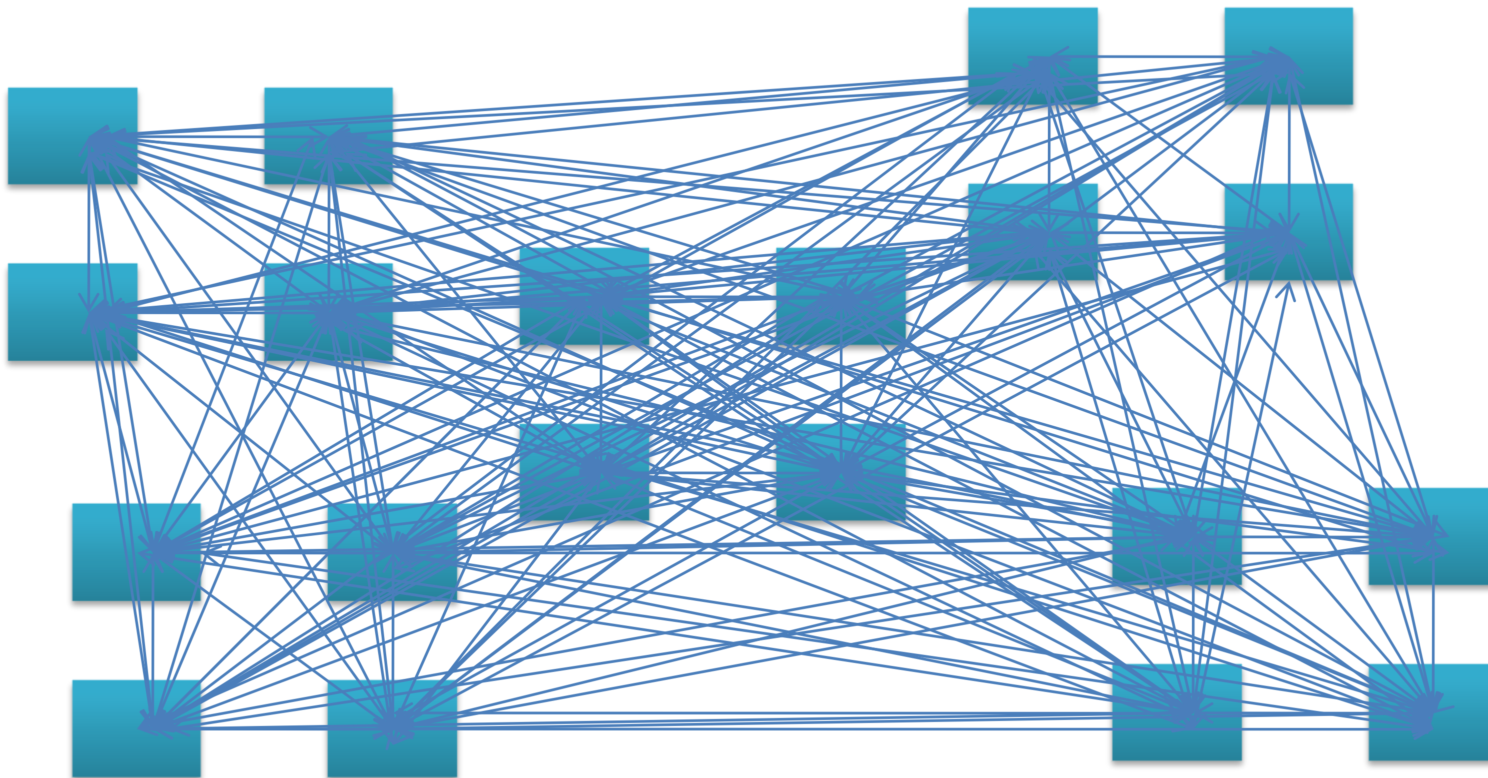
Low trust between "components"

Partitioned state

Message-passing (HTTP Get/Put)

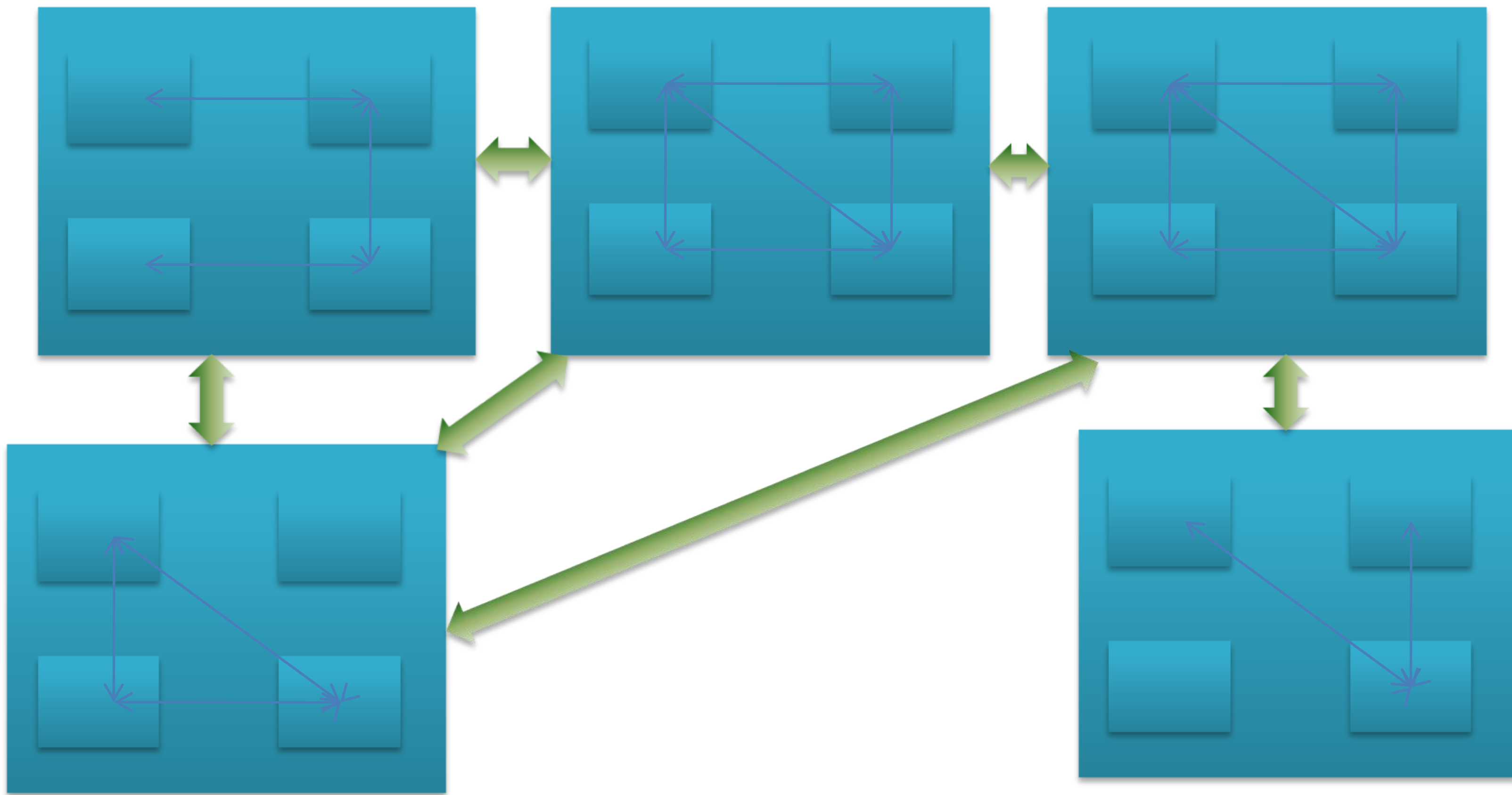
Un-partitioned State

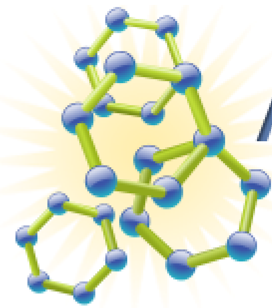
Instead of this…



Partitioned State

… we want this:





Axum

Special-purpose language in incubation

Partition data into domains

Agents use shared state within domains

Agents use message-passing between domains

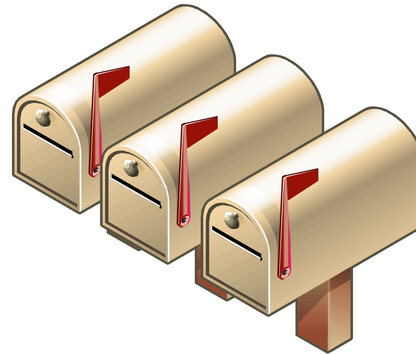
Support for asynchrony and data-flow

Axum Concepts

Domain

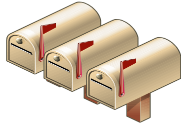
Agent

Channel



Schema

Channels



Conduit for messages between two agents

- Support for in-process and distributed messaging

Define ports as communication vocabulary

```
channel PingPong
{
    input  bool   Ping;
    output Signal Pong;
}
```

Input port ‘Ping,’ sending data from a client to an agent

Output port ‘Pong,’ sending data from an agent to its client

Agents

Active components, similar to threads but has limited access to shared <u>mutable</u> state

Send and receive messages via channels

```
agent PingAgent : channel PingPong
{
    public PingAgent ()
    {
        while (receive(Ping))
        {
            Pong <-- Signal.Value;
        }
        Pong <-- Signal.Value;
    }
}
```

Connecting to an Agent

Connections are made in one of two ways:

```
var tble = provider.Connect<TableAccess>("http://localhost/foo");
```

A factory for channels

A channel type

An agent address

```
var tble = Table.TableAgent.CreateInNewDomain();
```

An agent type

A factory method for in-process agents

Ping Pong

```
channel PingPong
{
    input bool Ping;
    output Signal Pong;
}

agent PingAgent : channel PingPong
{
    public PingAgent()
    {
        while (receive(Ping))
        {
            Pong <-- Signal.Value;
        }
        Pong <-- Signal.Value;
    }
}
```

```
agent MainAgent : channel
    Microsoft.Axum.Application
{
    public MainAgent()
    {
        var pp =
          PingAgent.CreateInNewDomain();

        for (int i = 0; i < 100; i++)
        {
            pp::Ping <-- true;
            receive(pp::Pong);
        }

        pp::Ping <-- false;
        receive(pp::Pong);

        Done <-- Signal.Value;
    }
}
```

Domains

Define state shared by several agent instances

- Isolate agents in different domains from each other
- Foundation for seamless distribution of agents

Agents are “hosted” within domains

```
domain Table
{
    Dictionary<string, string> dict = new Dictionary<string,string>();

    public Table()
    {
        Host<TableAgent>(“TableAgentAddress");
    }

    public agent TableAgent : channel TableAccess ...
}
```

Domains + Agents = Balanced SM/MP

Agents declared as

- Writer – allowed to modify state
- Reader – allowed to read mutable state
- N/A – no access to mutable state

Agent code is scheduled in parallel based on classification

- Agents in different domains run in parallel
- “One writer, many readers” within each domain
- No-access agents run completely in parallel

Schema

Payload definition

- Guaranteed to serialize
- Efficient in-process copying

```
schema TableEntry
{
    required String Key;
    required String Value;

    rules { require !String.IsNullOrEmpty(Key);
            require !String.IsNullOrEmpty(Value); }
}
```

Protocols

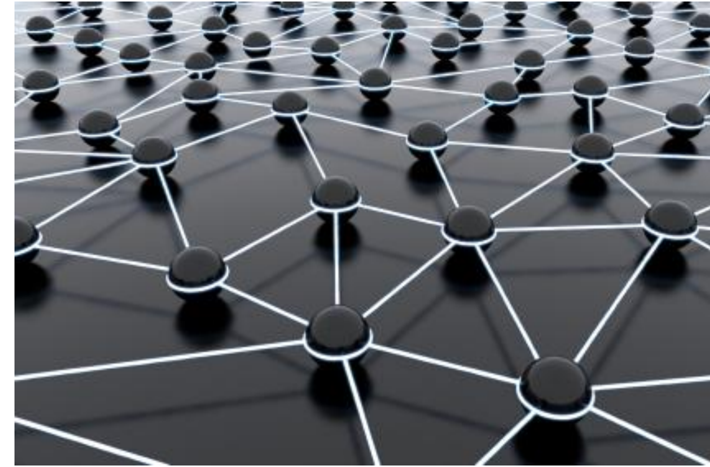
Define legal order of messages

Place constraints on payload values

```
channel TableAccess
{
    input KeyValuePair <String,String> Put;
    input String Get : String;
    input Signal Done;

    Start: { Put $ (!String.IsNullOrEmpty(value.Key)) -> Start;
             Get $ (!String.IsNullOrEmpty(value)) -> Start;
             Done -> End; }
}
```

Dataflow Networks



Propagate data between

- Computations (methods)
- Buffers
- Channel ports

Operators

- forward, forward once, broadcast, alternate, multiplex, join

Operands

- buffer, single-assignment, transforms, sinks

```
chan::Request ==> TranformString ==> chan::Reply;

buffer -<< { TransformString ==> sink, PrintString };
```

Ping Pong

```
agent PingAgent : channel PingPong
{
    public PingAgent()
    {
        Ping ==> (b => Signal.Value) ==> Pong;
    }
}
```

Summary

- Un-partitioned shared memory state leads to complexity
- Runtime-isolated memory has high overheads
- Static isolation has lower overheads, but still too high
- A mix of static isolation / MP and shared memory balances complexity and performance
- Domain-based isolation provides most of what we need from the programming model to get “transparent” distribution
- Asynchronous interactions become commonplace