D Adoption Case Study

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Outline

- Quick Adoption History
- Business overview
- Software requirement
- Where D addresses these
- Event Sourcing Description
- Architecture

D Adoption History

Business Overview

- Group within a Fund management firm
  - Accountable at Group, Firm, & Regulatory Authority
- Technology function to support business
  - Market Data Recording
  - Trading Frameworks
    - Interact directly with brokers
  - Introduce new data sources
  - Simulation / Analysis tools
- Competitive / Time pressure environment

Requirements ...

- Correctness
- Testability
- Reliability
- Modifiable
- Productive
- Performant

What makes D a good citizen

- Fast development iterations (DMD)
- Built-in unit-tests
- C-like Syntax
- Posix Availability
- Good Standard Library
- Easy to modify
- (So far) no nasty language surprises

Phobos Goodness

- Time savers
  - Commandline option parsing
  - JSON Parsing
  - DateTime module
  - Atomics
  - Bitop
  - CSV. Inescapable in finance!

Event Sourcing

Event Sourcing

- Represent Everything as stream of events
  - Ordered
  - Persisted
- Examples of Events
  - Orders
  - Executions
  - User actions
    - Button Press
    - Numeric Field change
  - Heartbeats

System is a pure State Function

$$(S_{n+1}, O_{n+1}) = f(S_n, I_n)$$

- Inputs (State,Input Event) 2-tuple
- Outputs (State,Output Event) 2-tuple

System is a 'fold-left' over events

$$S_1 = f(S_0, E_0)$$
$$S_2 = f(S_1, E_1)$$
$$S_3 = f(S_2, E_2)$$

$$S_3 = f(f(S_1, E_1), E_2)$$
$$S_3 = f(f(f(S_0, E_0), E_1), E_2)$$

i.e. a pure function of initial +input events

$$S_n = f_2(S_0, E_0, E_1, E_2 \ldots E_{n-1}, E_n)$$

Purity?

If we are 'pure' we get …

- Determinism
  - Same result every time. Repeatable behaviour
  - Regression testing
  - Post-Trade analysis
  - Auditable
- Resilience
  - Copy events off to another box for standby system
- Parallelizable

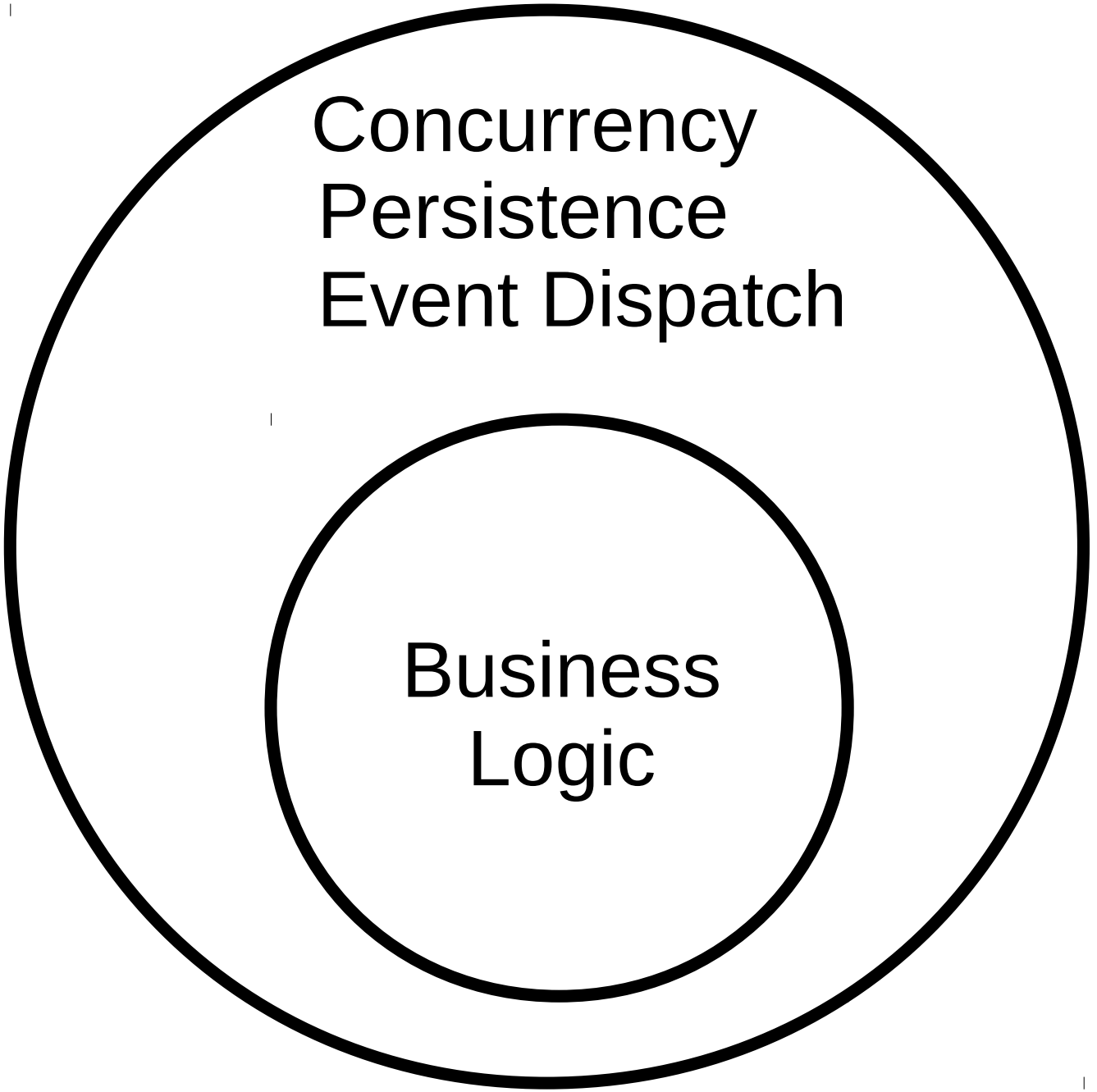
But ...

But ... lied a bit :-(

- Pure functional version performs badly
  - Allocate new state for every event
  - Even with persistent structures not good enough
- Imperative code with state mutation much faster
  - That's what we **ACTUALLY** have
- However ...
  - Same input still produces same outputs
  - Mutation still okay
  - c.f. Clojure 'transients'
  - Lose ability to cache intermediate state objects

Architecture

Layered Separation of Concerns



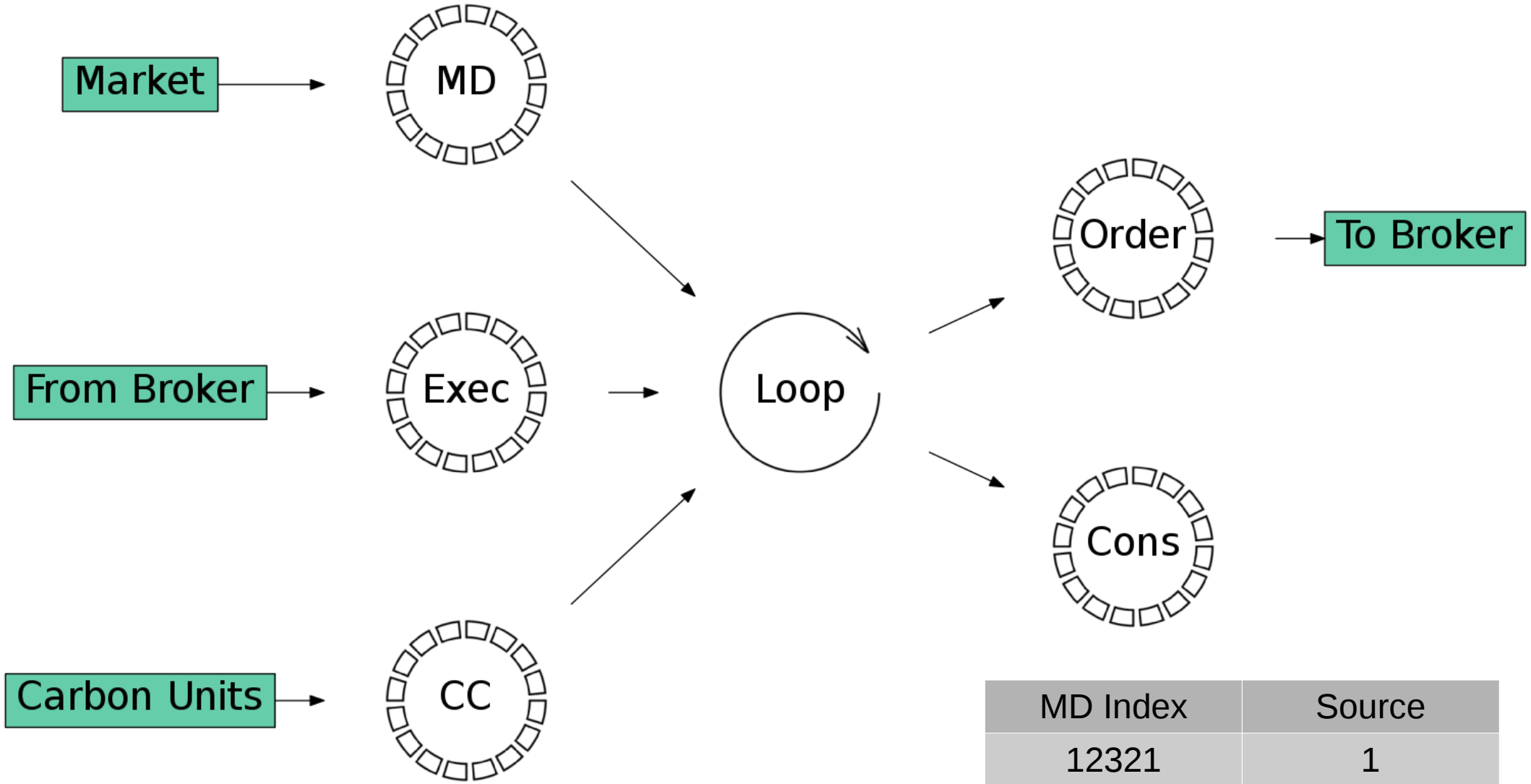
Inner layer – Business Logic

- Simple vanilla callback code
- Handles
  - Order Logic
  - Stats calculations
  - Profit/Loss calculations
- Single threaded
  - Cache friendly
- Gets time from the outer layer

Outer Layer (the D parts!)

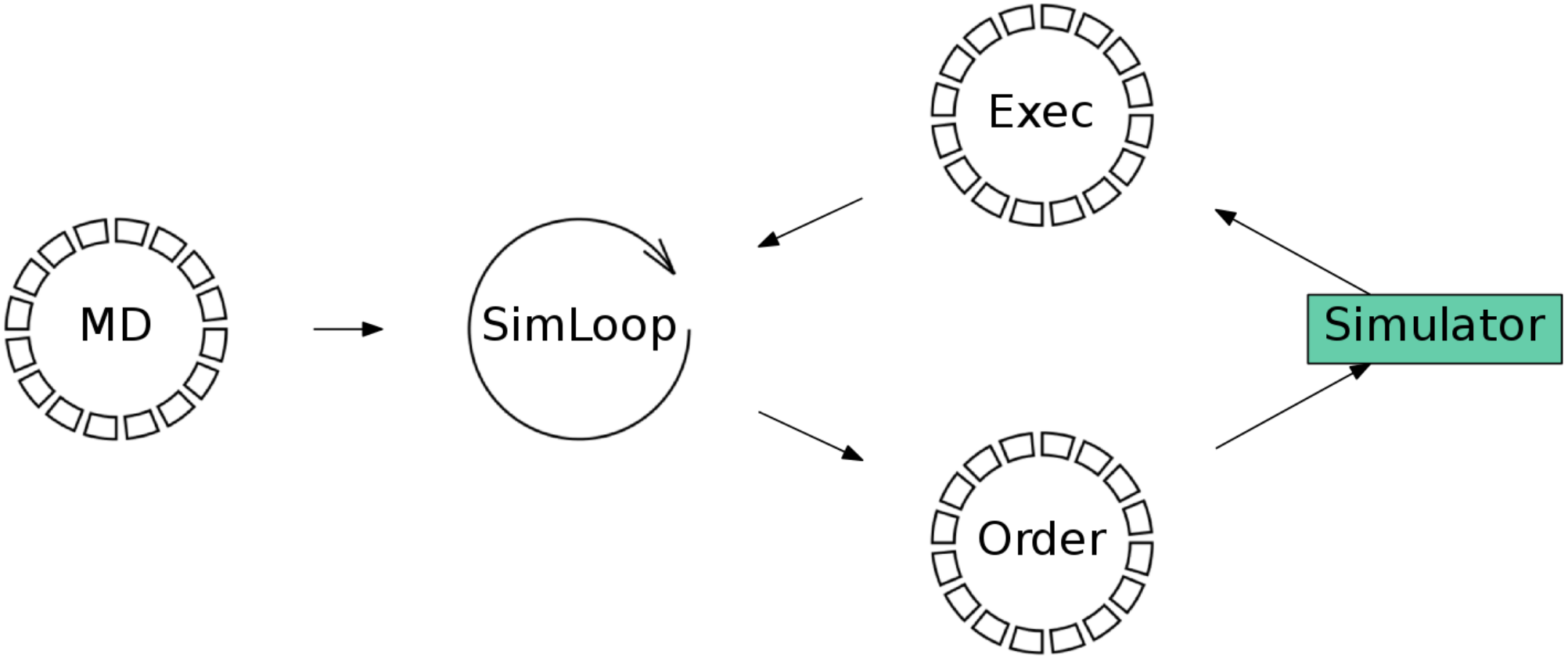
- Handles
  - Concurrency
  - Persistence
  - Event Delivery
- Implemented in terms of
  - Stream consumers
  - Event Loop (Live or Simulation)
    - Decides (and persists) event firing order

Live Event Sources



MD Index	Source
12321	1
12432	1
12543	2

Simulation



Where is D used?

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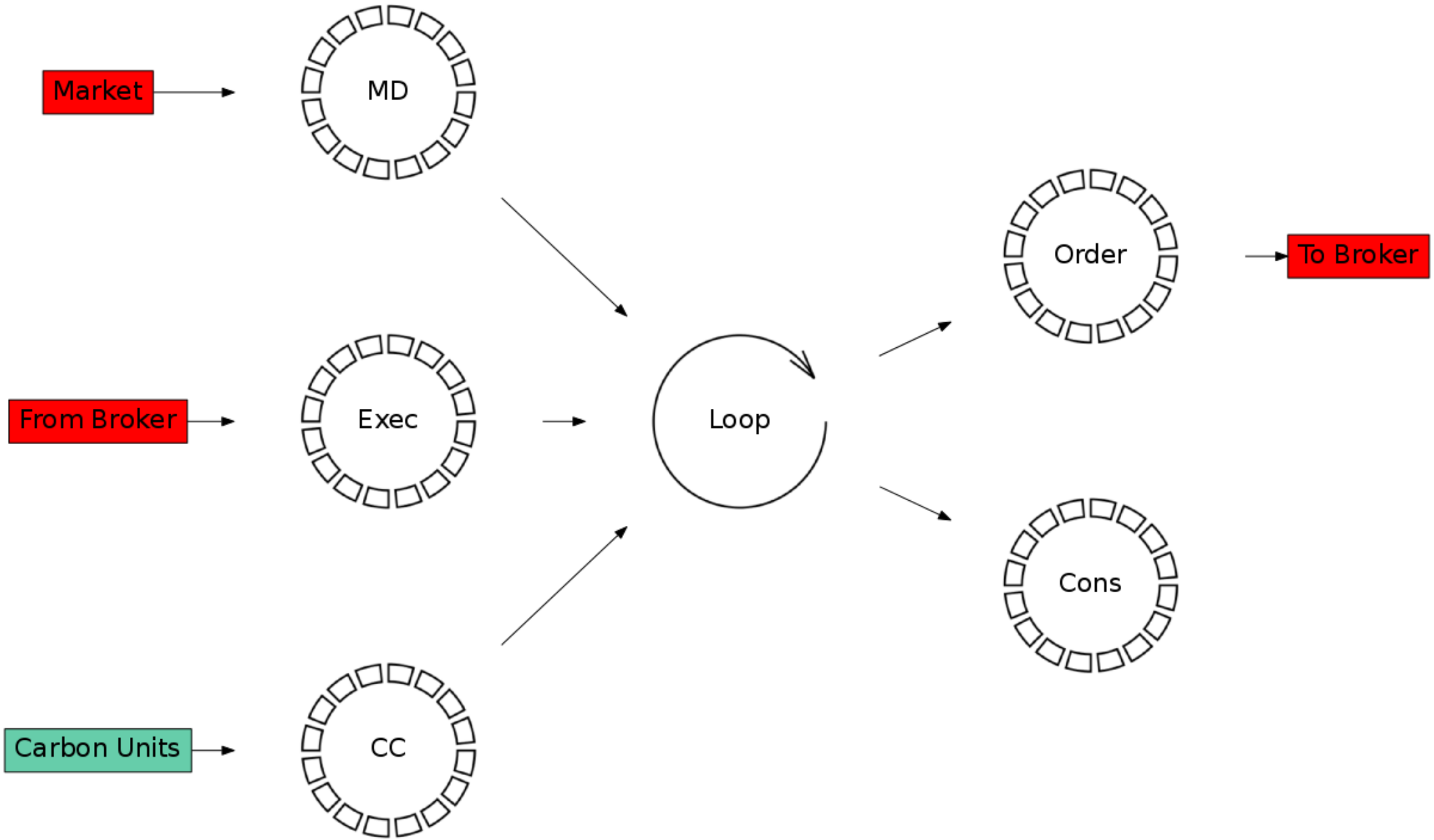


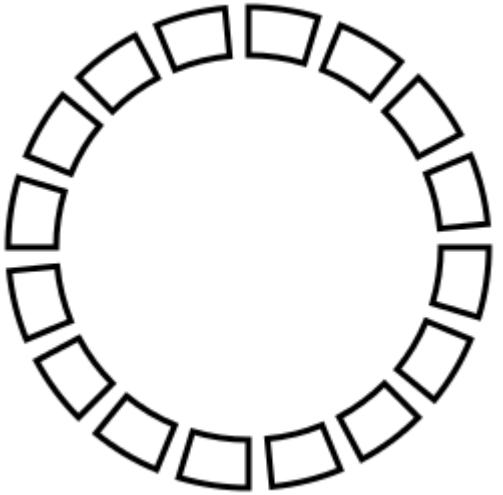
Why there?

- Require C-linkage for optimal API usage
- Alternatives?
  - JNI (homegrown)
  - JNI (vendor)
  - JNA (maybe)
  - C / C++
- D with C-linkage + SHM kills two birds with one stone
- Intention was to rewrite in C/C++ (probably C++11)
  - But stuck with D

Stream == ???

Stream Candidates
(Contiguous vs Circular Array)

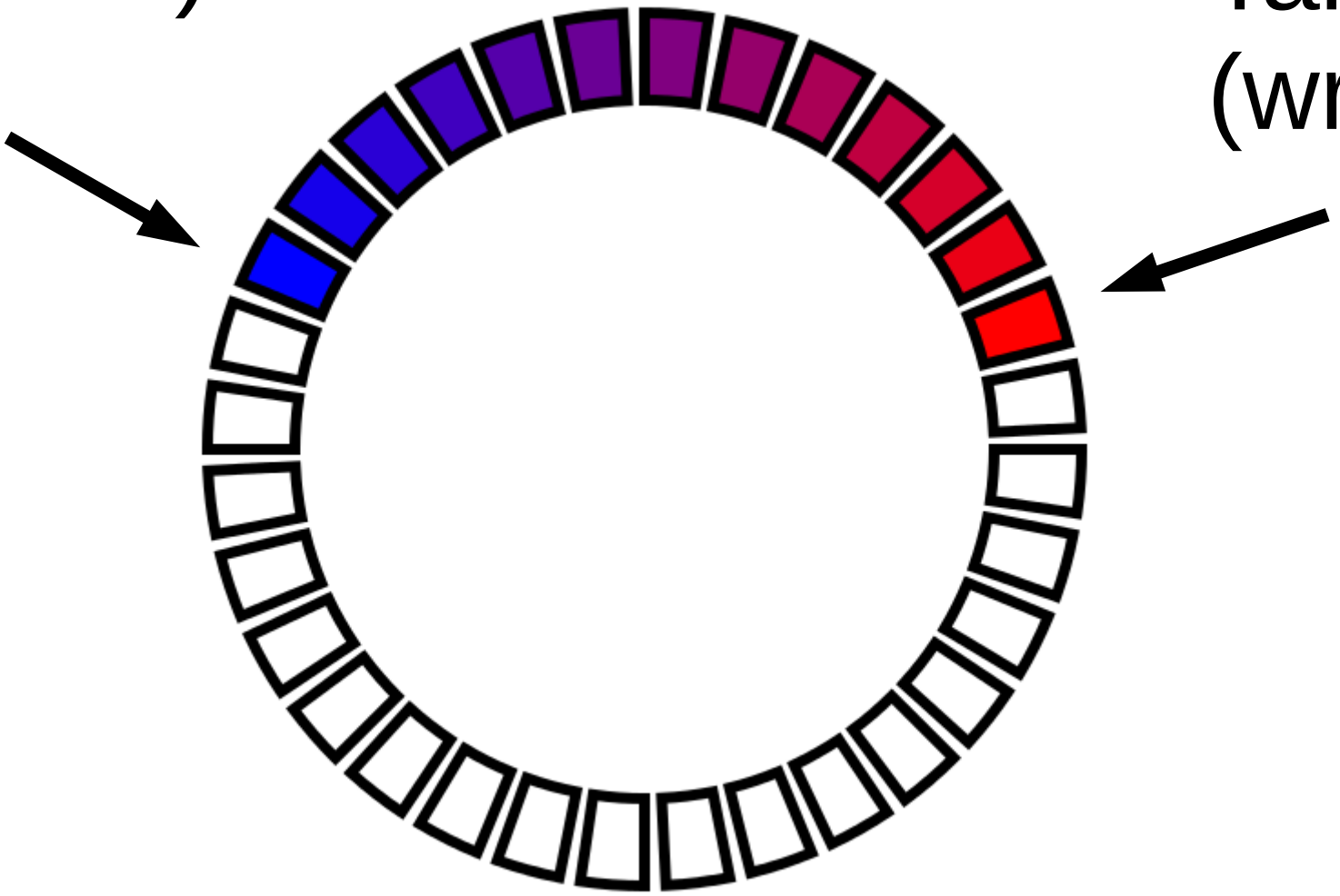
- Credit
  - Martin Thompson
  - Peter Lawrey
- Contiguous
  - Simple, mmap required memory segment
  - Not so simple in Java-land mmap takes integer :
  - Numpy friendly
  - Page Faults
  - Bounded, can run out!!
- Circular Array
  - Less simple
  - Cache friendly
  - Need journal of retired entries



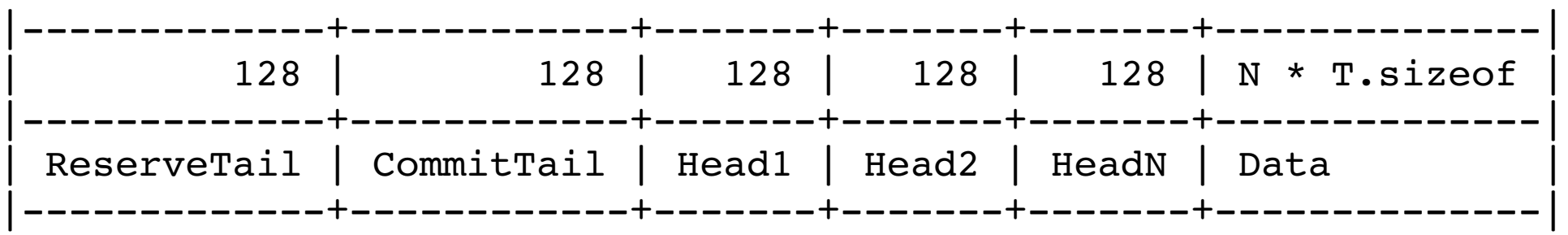
Stream Implementation with circular array

Head (readers)

Tail (writers)



MMFile Layout



Atomic 'incrementAndGet'
(courtesy of mnovak)

- We need 'LOCK XADD' ASM instruction on X86_64 for wait free operation in a MPMC queue
- AKA 'UNSAFE.incrementAndGet' in Java 7+ land
- Unavailable in Phobos (as of writing), but not a problem...

```
version (X86_64)
{
  T atomicOp(string s : "+=", T)(ref shared T val, T mod) pure nothrow @nogc
     if (__traits(isIntegral, T))
        {
        T oval = void;
        static if (T.sizeof == 8)
          {
            asm pure nothrow @nogc
              {
                mov RAX, mod;
                mov RDX, val;
                lock;
                xadd[RDX], RAX;
                mov oval, RAX;
              }
          }
        return oval + mod;
        }
}
```

MPMC Writer

```
struct ManyToManyWriter( T, int Consumers, int Capacity ) if (isPow2(Capacity)) {
  mixin ManyToManyCommon!(T, Consumers, Capacity);

  long cacheTail;
  long cacheHead;

  bool reserved = false;
  long reservedPos = long.max;

  T* reserve() {
     enforce(!reserved);
     reservedPos = atomicOp!"+="(header.reserveTail.value, 1) - 1;
     while ( reservedPos - cacheHead == Capacity ) {
        cacheHead = getHead();
     };
     reserved = true;
     return &data[indexOf(reservedPos)];
  };

  void commit() {
     enforce(reserved);
     while ( !cas( &header.commitTail.value, reservedPos, reservedPos + 1 ) ) {};
     cacheTail = reservedPos + 1;
     reserved = false;
     reservedPos = long.max;
  };
};
```

Multiple Heads

```
mixin template MultipleHeads() {
  long getHead() {
     long getMinHead( uint X )( long prev ) {
        static if ( X == 0 ) {
          return prev;
        } else {
          return getMinHead!(X-1)( min( prev, nthHead!X) );
        };
     };

     long nthHead(uint X)() if (X>=1 && X<=Consumers) {
        return atomicLoad!(MemoryOrder.acq)( header.heads[X-1].value );
     }
    return getMinHead!(Consumers-1)( nthHead!Consumers );
  };
}
```

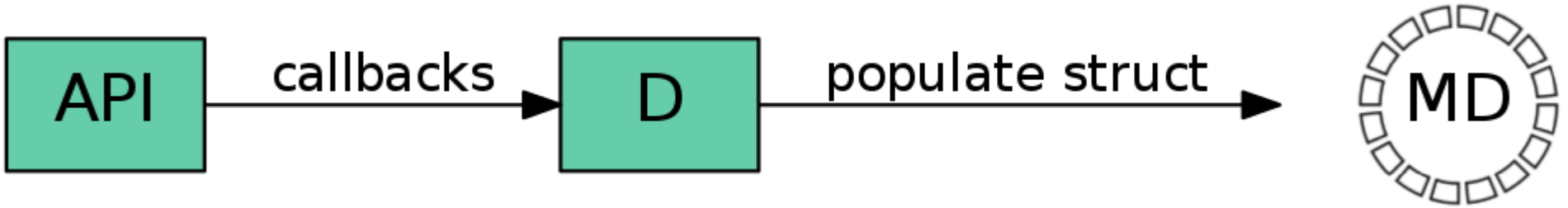
A D solution to false sharing

```
template Padded(T) {
  const postAmbleLength = 128 - 4 * long.sizeof - T.sizeof;
  struct Padded {
     private long[4] preamble;
     T value;
     private byte[postAmbleLength] postAmble;

     alias value this;
  };
};
```

- Java alternatives not very attractive

Market Data Consumption



D Market Data Message

```
align(1) struct BidAskChange {
   int     messageType;
   int     securityId;
   long    timeStamp;
   long    bidQty;
   double  bidPrice;
   long    askQty;
   double  askPrice;
};

pragma(msg, "Size is ", BidAskChange.sizeof);
static assert (BidAskChange.sizeof == 48);
```

Reading Structs in Java

```
import sun.misc.Unsafe;

public class BidAskChange {
    long address;

    Unsafe unsafe;

    private static final int MESSAGE_ID_OFFSET   = 0;
    private static final int SECURITY_ID_OFFSET  = MESSAGE_ID_OFFSET + INT_SIZE;
    private static final int TIMESTAMP_OFFSET    = SECURITY_ID_OFFSET + INT_SIZE;
    private static final int BID_VOLUME_OFFSET   = TIMESTAMP_OFFSET + LONG_SIZE;
    private static final int BID_PRICE_OFFSET    = TIMESTAMP_OFFSET + LONG_SIZE;

    public int getSecurityId() {
        return unsafe.getInt( null, address + SECURITY_ID_OFFSET);
    }

    public long getTimeStamp() {
        return unsafe.getLong( null, address + TIMESTAMP_OFFSET);
    }

    public double getBidPrice() {
        return unsafe.getDouble( null, address + BID_PRICE_OFFSET);
    }

}
```

Compile time introspection

```
void dumpType(T, string member)() {
  auto val = T.init;
  auto sizeOf  = __traits(getMember, val, member).sizeof;
  auto alignOf = __traits(getMember, val, member).alignof;
  auto offsetOf = __traits(getMember, val, member).offsetof;
  auto stringof = typeof(__traits(getMember, val, member)).stringof;
  writefln("%20s %4s align=%s stringof=%20s offset=%s",
           member, sizeOf, alignOf, stringof, offsetOf);
};

void dumpInfo(T)()  {
  foreach(member ; __traits(derivedMembers, T)) {
    dumpType!( T, member);
  }
};

void main() {

  dumpInfo!BidAskChange;
};
```

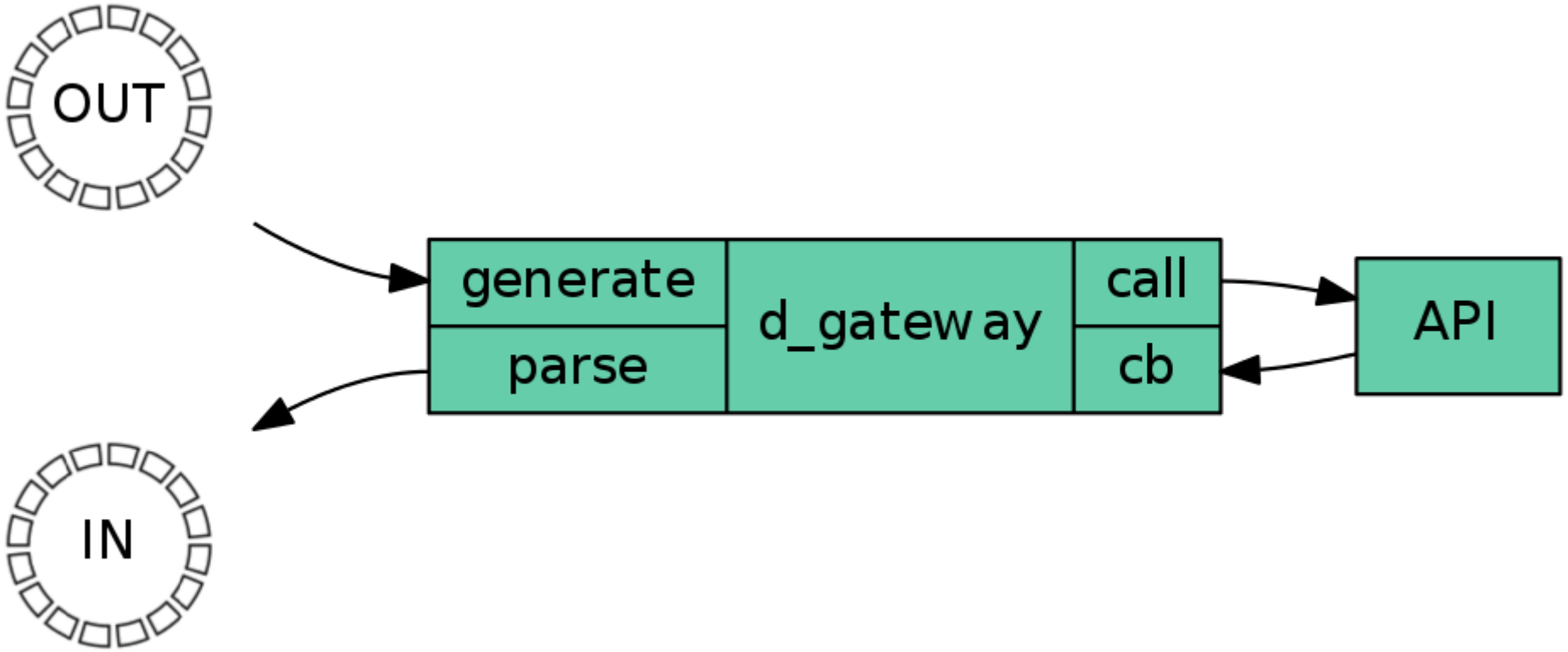
Output...

```
Size is 48LU
Size is 48LU
    messageType    4 align=4 stringof=     int offset=0
     securityId    4 align=4 stringof=     int offset=4
      timeStamp    8 align=8 stringof=    long offset=8
         bidQty    8 align=8 stringof=    long offset=16
       bidPrice    8 align=8 stringof=  double offset=24
         askQty    8 align=8 stringof=    long offset=32
       askPrice    8 align=8 stringof=  double offset=40
```

- Enough info to generate the java reader code at compile time

Electronic Trading

Trading



Trading API

- Relatively straightforward
- Process performs two tasks
  - Convert outbound structs to strings (main thread)
  - Convert inbound strings to structs (cb thread)
- One thread dedicated to each task
  - No contention/locking

FIX ...

FIX Protocol

- 'Human Readable ?'

```
8=FIX.4.29=17835=849=PHLX56=PERS52=20071123-
05:30:00.00011=ATOMNOCCC999090020=3150=E39=E55=MSFT167=CS54=1
38=1540=244=1558=PHLX EQUITY

TESTING59=047=C32=031=0151=1514=06=010=128
```

- Warty Protocol
  - Conflates OSI session + application layers in ugly ways
  - Compare with
    - MIDI
    - Military Protocols
    - Native exchange
- Parsing / Generation done with old school C-style string processing

Conclusion

- D is very useful addition to toolbox
- Adoption was worth it
- Project completed faster than could have with C / C++
- Has a definite niche in finance

Q?