

Fabio Galuppo, M.Sc.

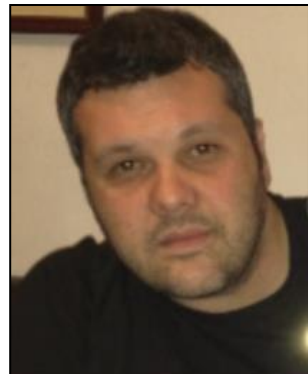
<http://fabiogaluppo.com> e <http://simplycpp.com/>

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Microsoft MVP Visual Studio and Development Technologies

<https://mvp.microsoft.com/en-us/PublicProfile/9529>



Award Categories

Visual Studio and Development
Technologies

First year awarded:

2002

Number of MVP Awards:

13

O que é ZeroMQ?

- *Intelligent socket library for messaging*
 - Variedade nos padrões de comunicação
 - Request-Reply, Publisher-Subscriber, Push-Pull, Dealer-Router, ...
 - Suporta: *inproc, IPC, TCP, TIPC, multicast*
- Modelo de concorrência baseado em atores (*Erlang-style*)
- *Open Source*
- Multiplas plataformas
- Diversas linguagens (mais de 30)
 - C, C++, Java, C#, Python, ...
- *Deploy* simples (uma *library*)
- Alta performance
 - <http://zeromq.org/results/multicore-tests>
 - ~6 milhões de mensagens por segundo



Destaque

Who is Using ZeroMQ?

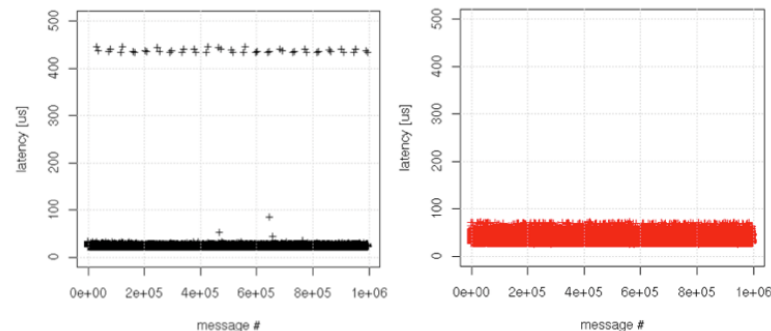
Since ZeroMQ is free software we don't track who uses it. However, some organizations that we know use it are: AT&T, Cisco, EA, Los Alamos Labs, NASA, Weta Digital, Zynga, Spotify, Samsung Electronics, Microsoft, and CERN.

- Cisco: The Avalanche Project: When High Frequency Trading Meets Traffic Classification
- CERN: MIDDLEWARE TRENDS AND MARKET LEADERS 2011

<http://accelconf.web.cern.ch/AccelConf/icalepcs2011/papers/frbhmult05.pdf>

CHOOSING A ROBUST MESSAGING SYSTEM

The foundation of our architecture relies on choosing the right messaging library. This will be a key factor to determine how well our data processing pipeline will perform. I will save you from all the details of a descriptive comparison between all the technology, but ZeroMQ is one of the best messaging middleware available, and it is very well known in the finance world. It also provides an amazing paradigm to build a distributed system with different message passing patterns. During my analysis, some important metrics caught my attention :



Source: <http://zeromq.org/results:rt-tests-v031>

<https://umbrella.cisco.com/blog/2015/11/05/the-avalanche-project-when-high-frequency-trading-meets-traffic-classification/>

	patterns	QoS	resources	performance	user friendly	community	score
CORBA	✗	✓	✗	✓	✗	✗	2
Ice	✓	✓	✗	✓	✓	✓	5
Thrift	✗	✗	✓	✓	✗	✗	2
ZeroMQ	✓	✓	✓	✓	✓	✓	6
YAMI4	✓	✓	✓	✗	✓	✗	4
RTI	✗	✓	✗	✓	✗	✓	3
Qpid	✗	✓	✗	✗	✓	✓	3

Figure 3: Summary of evaluated middleware products.

ZeroMQ: APIs essenciais

- <http://api.zeromq.org/>
 - [zmq_ctx_new](#) - create new 0MQ context
 - [zmq_term](#) - terminate 0MQ context
 - [zmq_socket](#) - create 0MQ socket
 - [zmq_close](#) - close 0MQ socket
 - [zmq_bind](#) - accept incoming connections on a socket
 - [zmq_connect](#) - create outgoing connection from socket
 - [zmq_send](#) - send a message part on a socket
 - `zmq_send`, `zmq_sendmsg`, `zmq_send_const`
 - [zmq_recv](#) - receive a message part from a socket
 - `zmq_recv`, `zmq_recvmsg`
 - [zmq_setsockopt](#) - set 0MQ socket options
 - [zmq_getsockopt](#) - get 0MQ socket options



ZeroMQ API

ØMQ/4.2.2 API Reference

[v4.2 master](#) | [v4.2 stable](#) | [v4.1 stable](#) | [v4.0 stable](#) | [v3.2 legacy](#)

- `zmq` - 0MQ lightweight messaging kernel
- `zmq_atomic_counter_dec` - decrement an atomic counter
- `zmq_atomic_counter_destroy` - destroy an atomic counter
- `zmq_atomic_counter_inc` - increment an atomic counter
- `zmq_atomic_counter_new` - create a new atomic counter
- `zmq_atomic_counter_set` - set atomic counter to new value
- `zmq_atomic_counter_value` - return value of atomic counter
- `zmq_bind` - accept incoming connections on a socket
- `zmq_close` - close 0MQ socket
- `zmq_connect` - create outgoing connection from socket
- `zmq_ctx_destroy` - terminate a 0MQ context
- `zmq_ctx_get` - get context options
- `zmq_ctx_new` - create new 0MQ context
- `zmq_ctx_set` - set context options
- `zmq_ctx_shutdown` - shutdown a 0MQ context
- `zmq_ctx_term` - terminate a 0MQ context
- `zmq_curve_keypair` - generate a new CURVE keypair
- `zmq_curve_public` - derive the public key from a private key
- `zmq_curve` - secure authentication and confidentiality
- `zmq_disconnect` - Disconnect a socket
- `zmq_errno` - retrieve value of errno for the calling thread
- `zmq_getsockopt` - get 0MQ socket options
- `zmq_gssapi` - secure authentication and confidentiality
- `zmq_has` - check a ZMQ capability
- `zmq_init` - initialise 0MQ context
- `zmq_inproc` - 0MQ local in-process (inter-thread) communication transport
- `zmq_ipc` - 0MQ local inter-process communication transport
- `zmq_msg_close` - release 0MQ message
- `zmq_msg_copy` - copy content of a message to another message
- `zmq_msg_data` - retrieve pointer to message content
- `zmq_msg_gets` - get message metadata property
- `zmq_msg_get` - get message property
- `zmq_msg_init_data` - initialise 0MQ message from a supplied buffer
- `zmq_msg_init_size` - initialise 0MQ message of a specified size
- `zmq_msg_init` - initialise empty 0MQ message

Request-Reply Pattern

```
void* zmq_context = zmq_ctx_new();
void* request_socket = zmq_socket(zmq_context, ZMQ_REQ);
zmq_connect(request_socket, "tcp://localhost:60000");

char* msg = "Hello, World!";
if (argc > 1)
    msg = argv[1];

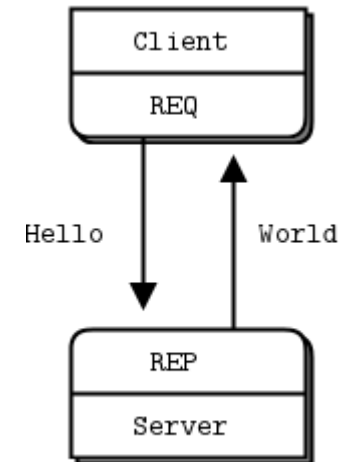
zmq_send(request_socket, msg, strlen(msg), 0);

char buffer[64];
zmq_recv(request_socket, buffer, sizeof(buffer), 0);
printf("%s\n", buffer);

zmq_close(request_socket);
zmq_ctx_term(zmq_context);
```

```
void* zmq_context = zmq_ctx_new();
void* reply_socket = zmq_socket(zmq_context, ZMQ_REP);
if (0 == zmq_bind(reply_socket, "tcp://*:60000")) {
    char buffer[64];
    zmq_recv(reply_socket, buffer, sizeof(buffer), 0);
    printf("%s\n", buffer);
    size_t N = strlen(buffer);
    for (size_t i = 0; i < N; ++i)
        buffer[i] = toupper(buffer[i]);
    zmq_send(reply_socket, buffer, N, 0);
}
else {
    printf("%s\n", strerror(errno));
}

zmq_close(reply_socket);
zmq_ctx_term(zmq_context);
```



```
sample-1 — bash — 80x24
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ clang -I../include -lzmq req.c
n/req.exe
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ ./bin/req.exe
ZMQ version = 4.2.3
HELLO, WORLD!
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ ./bin/req.exe "Testing 1, 2, 3"
ZMQ version = 4.2.3
TESTING 1, 2, 3
Fabios-MacBook-Pro:sample-1 fabiogaluppo$
```

```
sample-1 — bash — 80x24
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ clang -I../incl
n/rep.exe
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ ./bin/rep.exe
ZMQ version = 4.2.3
Hello, World!
Fabios-MacBook-Pro:sample-1 fabiogaluppo$ ./bin/rep.exe
ZMQ version = 4.2.3
Testing 1, 2, 3
Fabios-MacBook-Pro:sample-1 fabiogaluppo$
```

Publisher-Subscriber Pattern

```
zmq::context_t zmq_context(1);
zmq::socket_t publisher_socket(zmq_context, ZMQ_PUB);

publisher_socket.bind("tcp://*:60001");
publisher_socket.bind("ipc://pub.ipc");

std::cout << "Publishing...\n";
std::cout << "[CTRL + C] to finish...\n";

std::string data;
while (std::getline(std::cin, data)) {
    std::transform(data.begin(), data.end(), data.begin(),
        [](int ch){ return std::toupper(ch); });
    publisher_socket.send(zmq::message_t(data.begin(), data.end()), 0);
}

publisher_socket.close();
zmq_context.close();
```

Publisher - C++ Binding (cppzmq) – 2 endpoints (tcp, ipc)

```
zmq::context_t zmq_context(1);
zmq::socket_t subscriber_socket(zmq_context, ZMQ_SUB);

subscriber_socket.connect("tcp://localhost:60001");

std::cout << "Listening...\n";
std::cout << "[CTRL + C] to finish...\n";

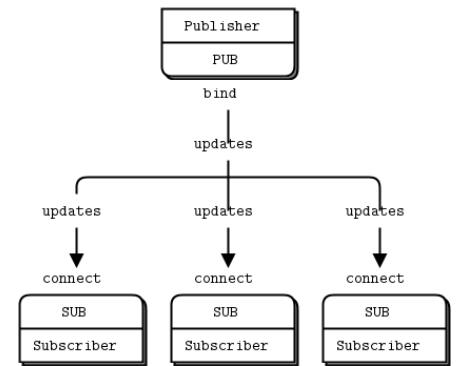
for (int i = 2; i < argc; ++i) {
    const char* filter = argv[i];
    subscriber_socket.setsockopt(ZMQ_SUBSCRIBE, filter, std::strlen(filter));
}

for (long i = 0; i < N; ++i) {
    zmq::message_t msg;
    subscriber_socket.recv(&msg, 0);

    std::cout << to_string(msg) << "\n";
}

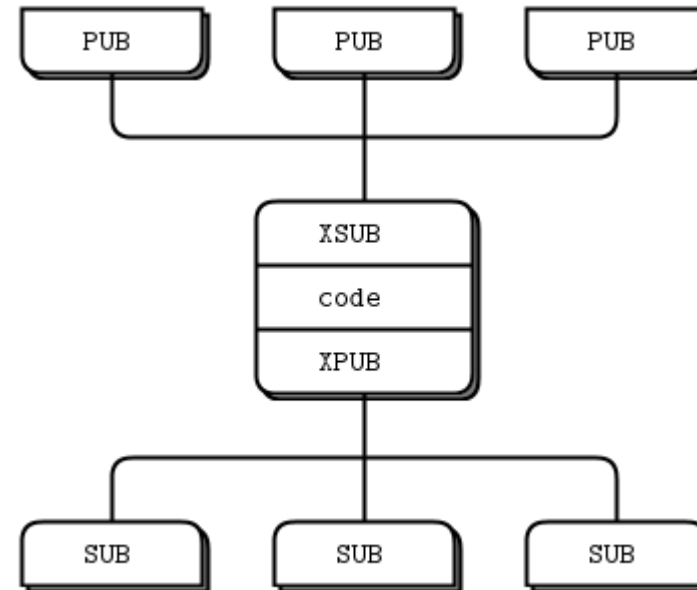
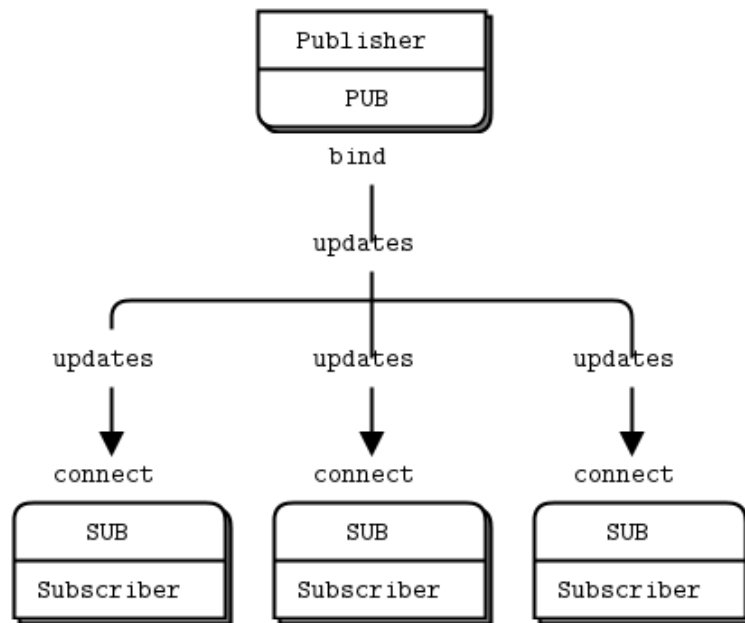
subscriber_socket.close();
zmq_context.close();
```

Subscriber – C++ Binding (cppzmq)



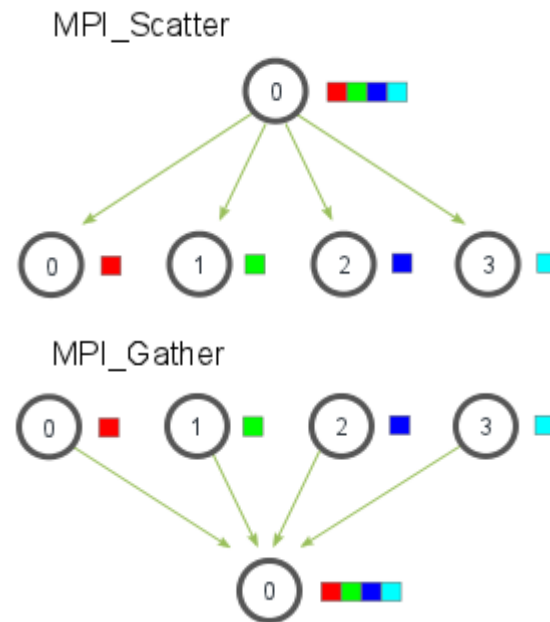
Publisher-Subscriber Pattern

- PUB-SUB versus XPUB-XSUB

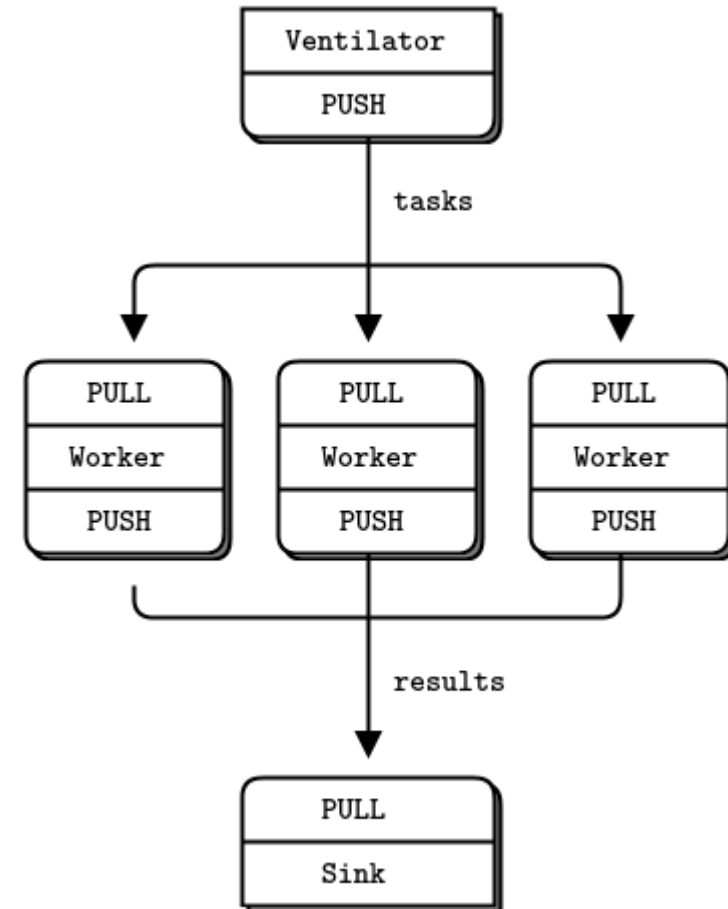


Parallel Pipeline Pattern

- Divide and Conquer
 - Fork-Join
 - Map-Reduce
 - MPI_Scatter-MPI_Gather



<http://mpitutorial.com/tutorials/mpi-scatter-gather-and-allgather/>



Parallel Pipeline Pattern

```
zmq::context_t zmq_context(2);
zmq::socket_t source_socket(zmq_context, ZMQ_PUSH);
zmq::socket_t sink_socket(zmq_context, ZMQ_PUSH);

zmq_utils::set_affinity(source_socket, 1);
zmq_utils::set_affinity(sink_socket, 2);

source_socket.bind("tcp://*:60002");
sink_socket.connect("tcp://localhost:60003");

//notify # of messages to sink
std::string SM = std::to_string(M);
sink_socket.send(zmq::message_t(SM.begin(), SM.end()), 0);

std::cout << "Waiting for workers...\n";
std::cout << "Press [ENTER] when workers are ready...\n";
std::getchar();
std::cout << "Publishing...\n";

seed_rand();
for (long i = 0; i < M; ++i) {
    int coin = rand_int(1, 2);
    if (coin == 1) {
        source_socket.send(command_msg(COMMAND_1), ZMQ_SNDMORE);
        source_socket.send(command_1_args(i + 1, i + 1), 0);
    }
    else {
        source_socket.send(command_msg(COMMAND_2), ZMQ_SNDMORE);
        char a = rand_int<short>(97, 122);
        bool b = rand_int(1, 2) == 1;
        char c = rand_int<short>(97, 122);
        source_socket.send(command_2_args(a, b, c), 0);
    }
}

for (long i = 0; i < N; ++i) {
    source_socket.send(command_msg(POISON_PILL), 0);
}
```

```
zmq::context_t zmq_context(2);
zmq::socket_t worker_socket(zmq_context, ZMQ_PULL);
zmq::socket_t sink_socket(zmq_context, ZMQ_PUSH);

zmq_utils::set_affinity(worker_socket, 1);
zmq_utils::set_affinity(sink_socket, 2);

worker_socket.connect("tcp://localhost:60002");
sink_socket.connect("tcp://localhost:60003");

while (true) {
    std::cout << "Waiting message...\n";

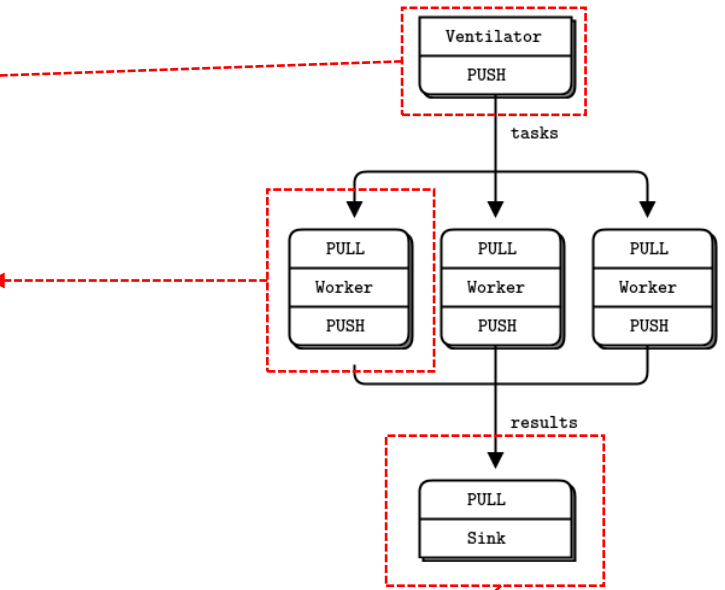
    zmq::message_t msg;
    worker_socket.recv(&msg, 0);
    auto scmd = zmq_utils::to_string(msg);
    if (is_command(scmd, POISON_PILL))
        break;

    std::cout << "Processing message...\n";

    worker_socket.recv(&msg, 0);
    auto result = process(scmd, msg);

    std::cout << "Sending result...\n";
    sink_socket.send(result, 0);

    std::cout << "-----\n";
}
```



```
zmq::context_t zmq_context(1);
zmq::socket_t sink_socket(zmq_context, ZMQ_PULL);

sink_socket.bind("tcp://*:60003");

std::cout << "Waiting for start...\n";

zmq::message_t msg;
sink_socket.recv(&msg, 0);
int M = std::stoi(zmq_utils::to_string(msg));
std::cout << "Waiting " << M << " messages...\n";
for (int i = 0; i < M; ++i) {
    sink_socket.recv(&msg, 0);
    std::cout << "Result #" << (i + 1) << ": " << zmq_ut
}
```

Multipart-Messages e Variadic Templates

- <http://zguide.zeromq.org/page:all#Multipart-Messages>

```
zmq_msg_send (&message, socket, ZMQ_SNDMORE);  
...  
zmq_msg_send (&message, socket, ZMQ_SNDMORE);  
...  
zmq_msg_send (&message, socket, 0);
```

Frame 1

3	ABC
---	-----

Identity of connection

Frame 2

0	
---	--

Empty delimiter frame

Frame 3

5	Hello
---	-------

Data frame

```
template <typename... Ts>  
inline result_type bulk_send(zmq::socket_t& sender_socket, Ts&... args) {  
    size_t total_bytes_sent = 0;  
    bool success = true;  
    internal::variadic::bulk_sender<Ts...>::send(sender_socket, total_bytes_sent, success, args...);  
    return std::make_tuple(success, total_bytes_sent);  
}
```

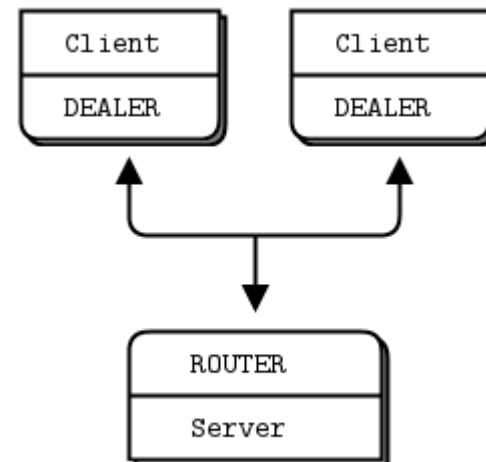
```
zmq::message_t data_1_msg { data1.begin(), data1.end() };  
zmq::message_t data_2_msg { data2.begin(), data2.end() };  
  
bulk_send(dealer, data_1_msg, data_2_msg);
```

Dealer-Router Pattern

Now we can switch out both REQ and REP with DEALER and ROUTER to get the **most powerful socket combination**, which is DEALER talking to ROUTER. It gives us asynchronous clients talking to asynchronous servers, where both sides have full control over the message formats.

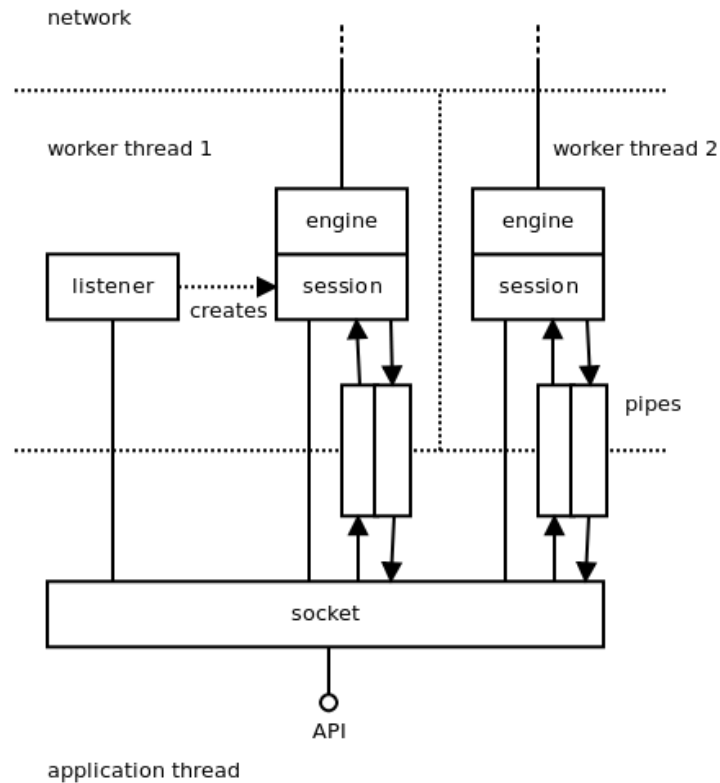
Because both DEALER and ROUTER can work with arbitrary message formats, if you hope to use these safely, you have to become a little bit of a protocol designer. At the very least you must decide whether you wish to emulate the REQ/REP reply envelope. It depends on whether you actually need to send replies or not.

<http://zguide.zeromq.org/page:all#The-DEALER-to-ROUTER-Combination>



<http://zguide.zeromq.org/page:all#The-Asynchronous-Client-Server-Pattern>

Arquitetura, Mensagem e *Batching*

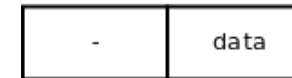


<https://github.com/zeromq/libzmq/blob/master/src/pipe.hpp>
<https://github.com/zeromq/libzmq/blob/master/src/pipe.cpp>
https://github.com/zeromq/libzmq/blob/master/src/session_base.hpp
https://github.com/zeromq/libzmq/blob/master/src/session_base.cpp
https://github.com/zeromq/libzmq/blob/master/src/i_engine.hpp
https://github.com/zeromq/libzmq/blob/master/src/tcp_listener.hpp
https://github.com/zeromq/libzmq/blob/master/src/tcp_listener.cpp

<http://aosabook.org/en/zeromq.html>

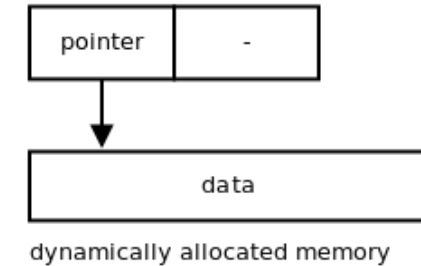
Small Message

handle

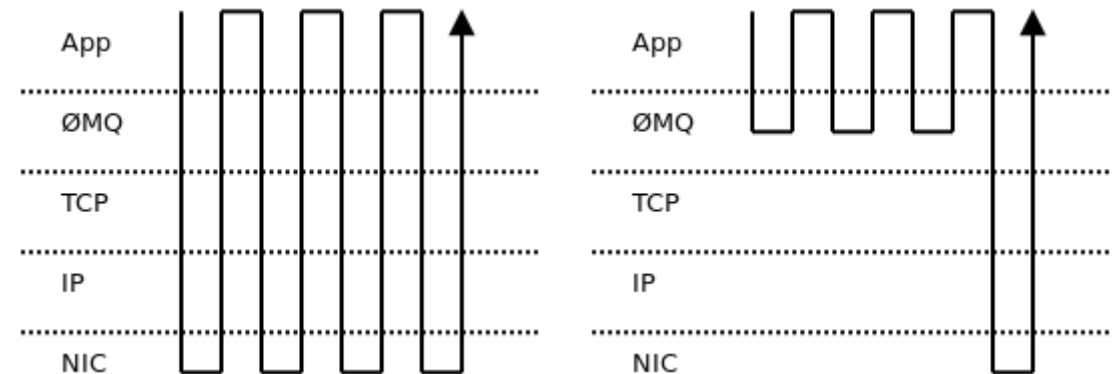


Large Message

handle

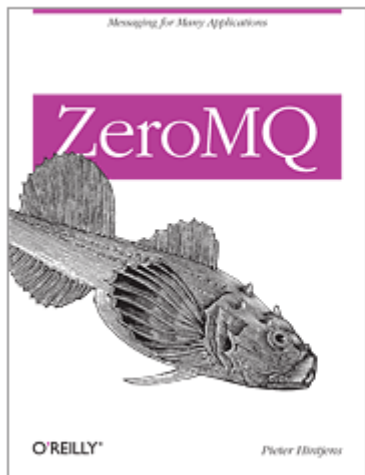


<https://github.com/zeromq/libzmq/blob/master/src/msg.hpp>
<https://github.com/zeromq/libzmq/blob/master/src/msg.cpp>



Referências

- <http://zeromq.org>
- ZeroMQ
 - <http://shop.oreilly.com/product/0636920026136.do>
 - <http://zguide.zeromq.org/>



ZeroMQ

Messaging for Many Applications

By Pieter Hintjens

Publisher: O'Reilly Media

Final Release Date: March 2013

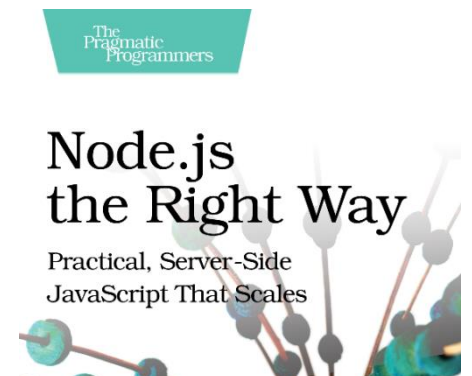
Pages: 516

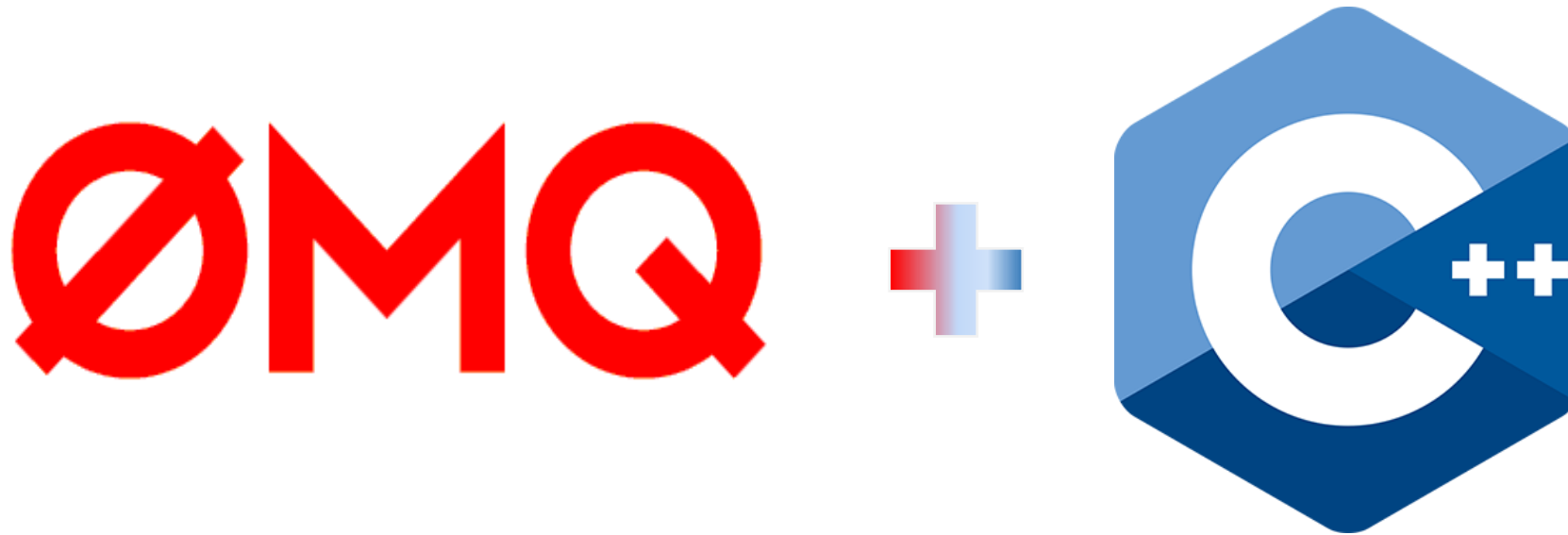


[Read 6 Reviews](#) | [Write a Review](#)

- Node.js the Right Way

- <https://pragprog.com/book/jwnode/node-js-the-right-way>
- Um capítulo dedicado a ZeroMQ
 - Robust Messaging Services
 - Advantages of ØMQ
 - Importing External Modules with npm
 - Message-Publishing and -Subscribing
 - Responding to Requests
 - Routing and Dealing Messages
 - Clustering Node.js Processes
 - Pushing and Pulling Messages
 - Wrapping Up





Fabio Galuppo, M.Sc.

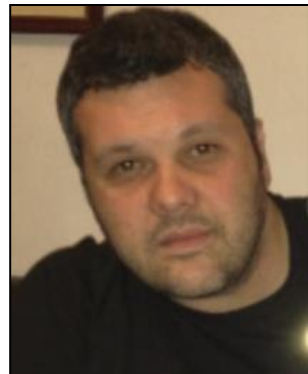
<http://fabiogaluppo.com> e <http://simplycpp.com/>

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Microsoft MVP Visual Studio and Development Technologies

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