

Get Rich Quick!

Using Boost.Beast WebSockets and Networking TS

Vinnie Falco
Author of Boost.Beast

CppCon 2018
Sep 23-29





visit cpp.al

Boost.Beast

- HTTP and WebSocket protocols
- Using Boost.Asio
- Header-only C++11
- Part of Boost 1.66.0 and later
- Goal: Standardization

<https://github.com/boostorg/beast>

Boost C++ Libraries

- Best permissive license
- Review process breeds excellence
- Establish existing practice
- Become part of C++

`boost::shared_ptr`

`boost::optional`

`boost::bind`

`boost::mutex`

`boost::chrono`

`BOOST_FOREACH`

`boost::asio`

`boost::filesystem`

`boost::thread`

`boost::shared_mutex`

`boost::function`

`BOOST_STATIC_ASSERT`

Repository

<https://github.com/vinniefalco/CppCon2018>

This repository

Search

Pull requests Issues Marketplace Explore

vinniefalco / CppCon2018

Watch 1 Star 0 Fork 0

Code Issues 0 Pull requests 0 Projects 0 Wiki Insights Settings

CppCon 2018 Presentation materials

Add topics

Edit

2 commits 1 branch 0 releases 1 contributor BSL-1.0

Branch: master New pull request

Create new file Upload files Find file Clone or download

vinniefalco Add websocket-chat-server Latest commit b112869 11 days ago

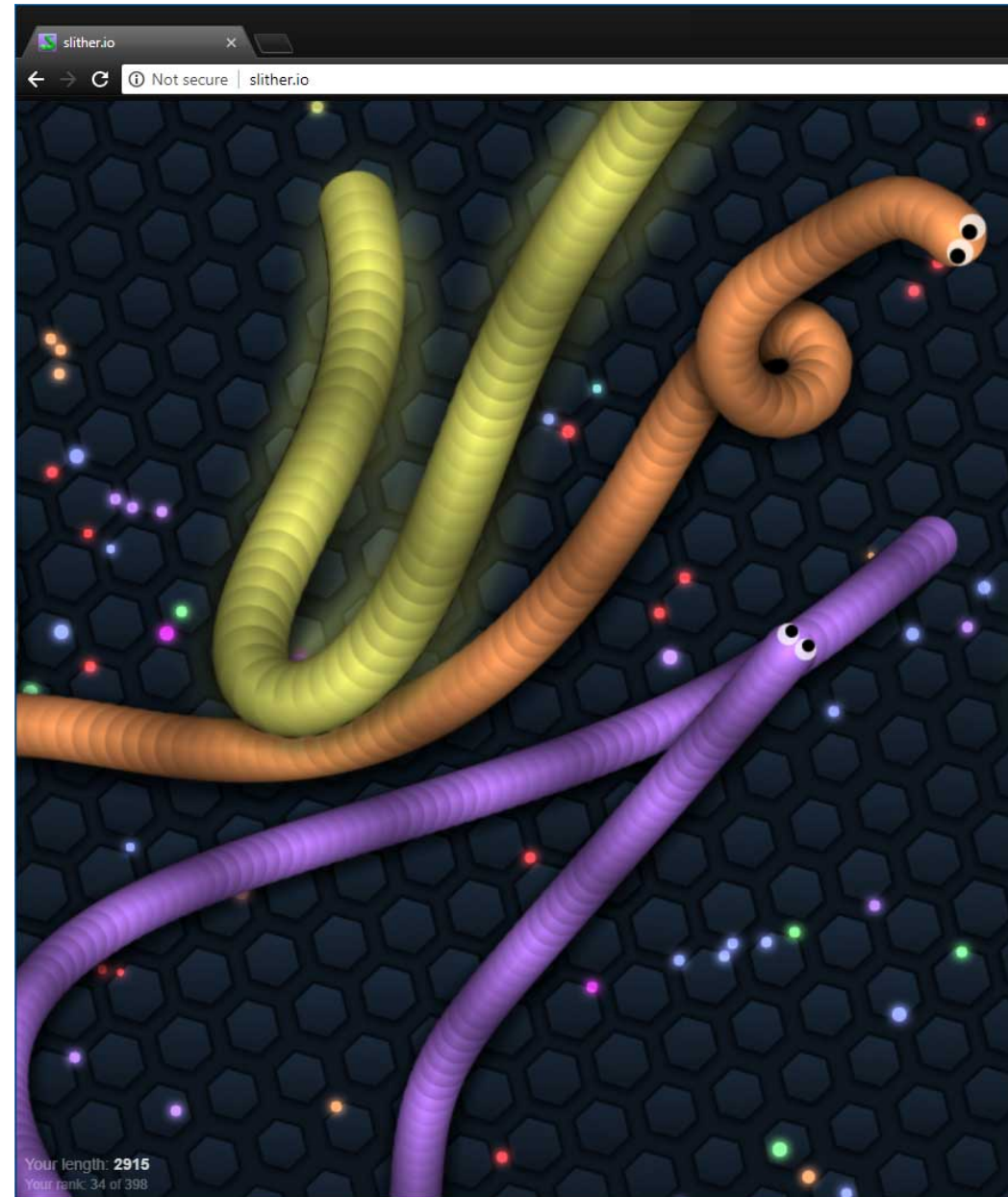
.gitignore	Add websocket-chat-server	10 days ago
.travis.yml	Add websocket-chat-server	10 days ago
Beast.WebSockets - Vinnie Falco - CppCon 2018.odp	Add websocket-chat-server	10 days ago
CMakeLists.txt	Add websocket-chat-server	10 days ago
LICENSE_1_0.txt	Add websocket-chat-server	10 days ago
README.md	Add websocket-chat-server	10 days ago
asio.hpp	Add websocket-chat-server	10 days ago
beast.hpp	Add websocket-chat-server	10 days ago
chat_client.html	Add websocket-chat-server	10 days ago
http_session.cpp	Add websocket-chat-server	10 days ago
http_session.hpp	Add websocket-chat-server	10 days ago
listener.cpp	Add websocket-chat-server	10 days ago
listener.hpp	Add websocket-chat-server	10 days ago
main.cpp	Add websocket-chat-server	10 days ago
shared_state.cpp	Add websocket-chat-server	10 days ago
shared_state.hpp	Add websocket-chat-server	10 days ago



<http://agar.io>



<http://slither.io>



<http://agar.io>

- Written by Matheus Valdares
- Released in 2015 on 4chan
- Free to play, runs in browser
- Multiplayer online battle arena
- 500 players per instance
- Peak \$100,000 daily ad income
- Number 1 mobile game

App Store Preview

This app is only available on the App Store for iOS devices.



Agar.io 9+

Play the online phenomenon!

Miniclip.com

#21 in Strategy

★★★★☆ 4.5, 1.4K Ratings

Free · Offers In-App Purchases

<http://slither.io>

- Written by Steven Howse
- Self-published in 2016
- Free to play, runs in browser
- Multiplayer online battle arena
- 600 players per instance
- Peak \$100,000 daily ad income
- HTML5 graphics



WSJ



SUBSCRIBE NOW

SIGN IN



Investors Step Back
From Social-Media
Highfliers



FULL DISCLOSURE
Facebook's Hard
Shows the Pitfall
Big Data



TECH

As 'Slither.io' Goes Viral, Game's Creator Scrambles to Keep Up

The multiuser app checks the boxes for an addictive game: free, easy to pick up, seemingly endless

Recipe

- C++ WebSocket Server
- Browser WebSocket Client



Contents

- Protocols
- Networking TS
- Chat Server
- Chat Client
- Epilogue

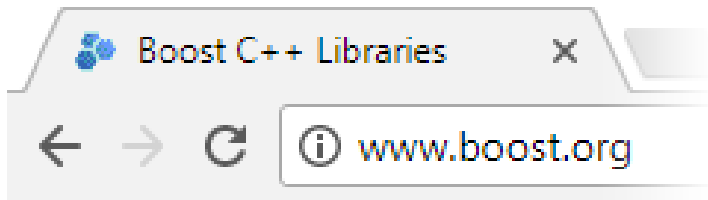
Protocols

HTTP

“Hypertext Transfer Protocol”

Client

Server



DNS

192.168.17.42

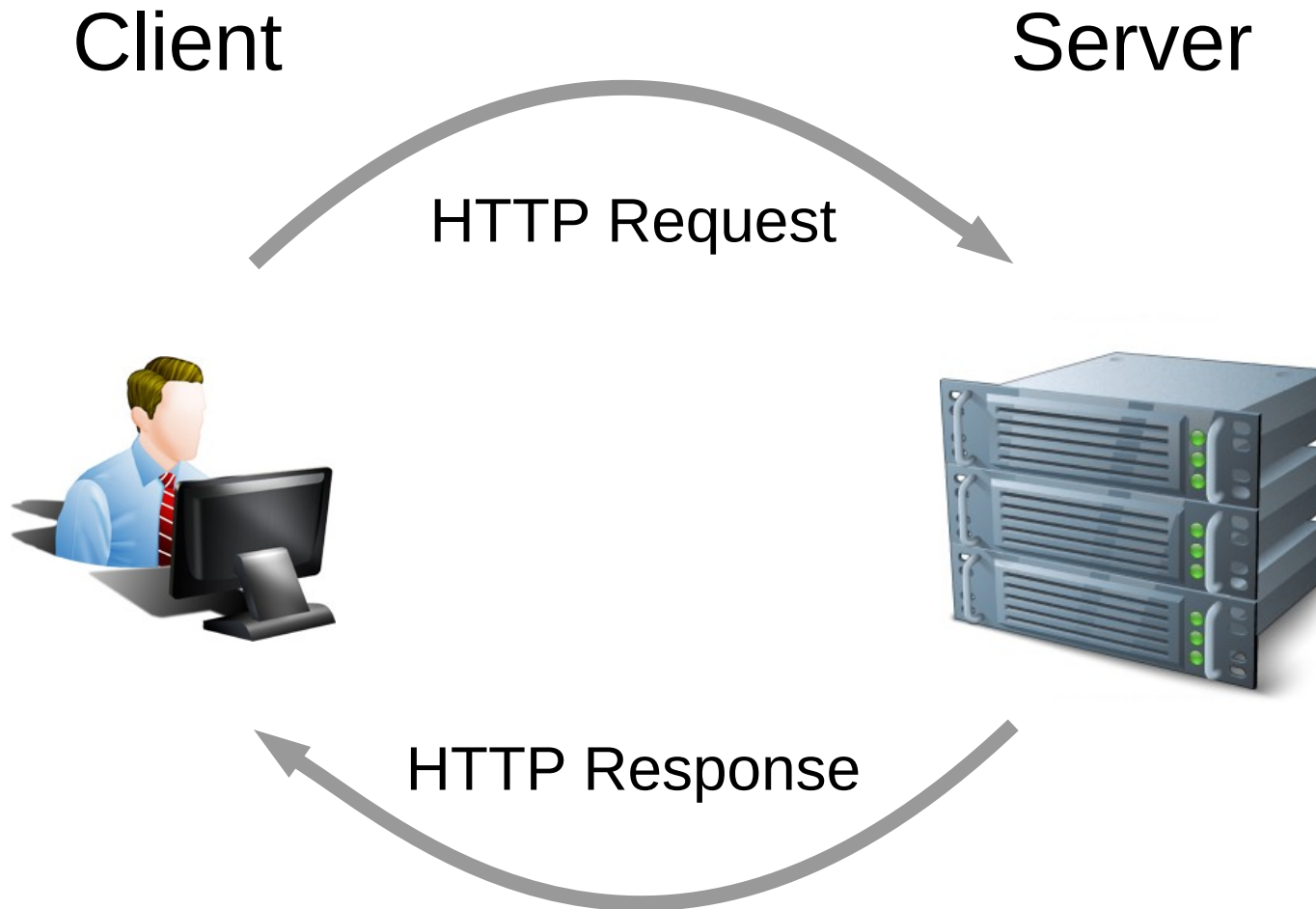


TCP/IP



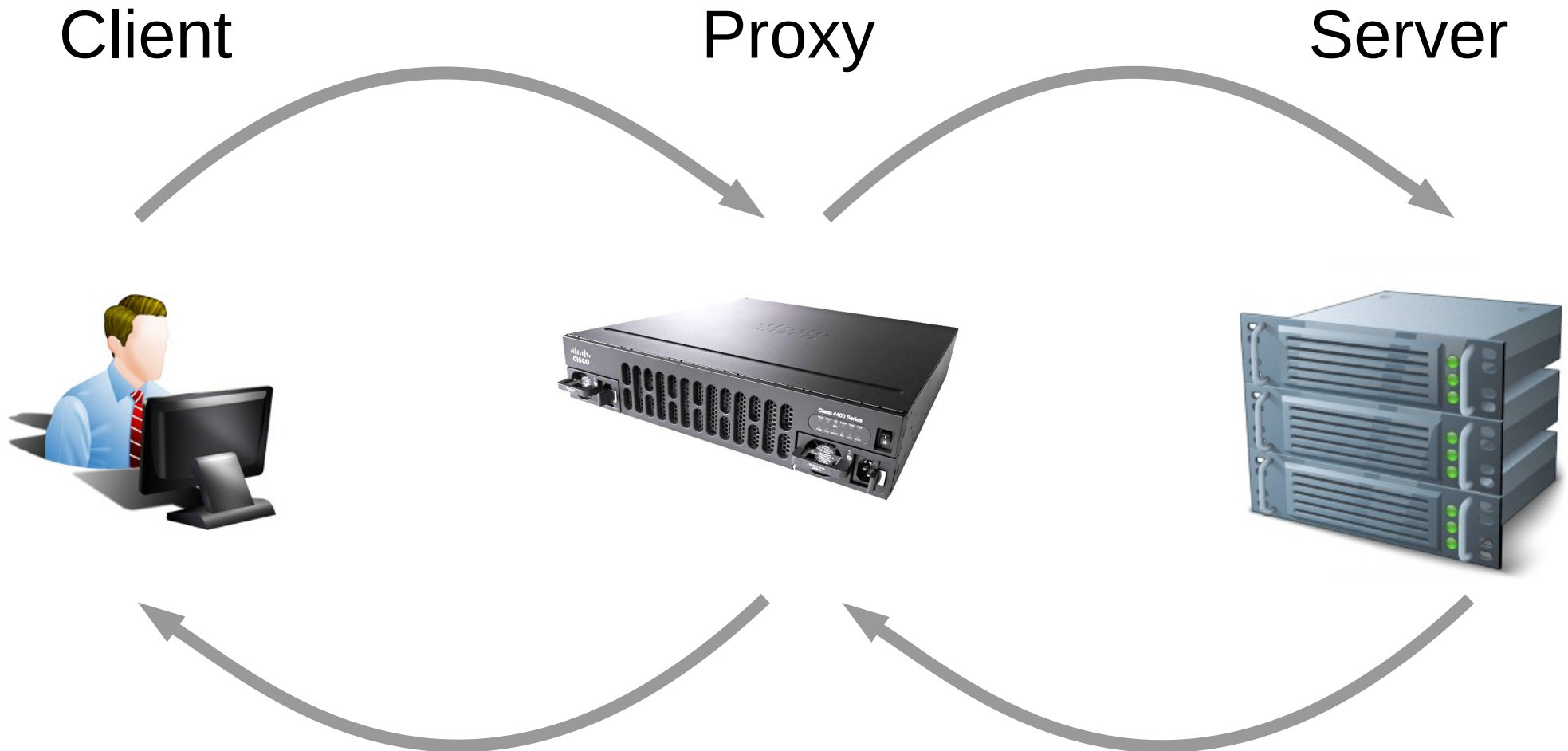
HTTP

- Half-Duplex



HTTP

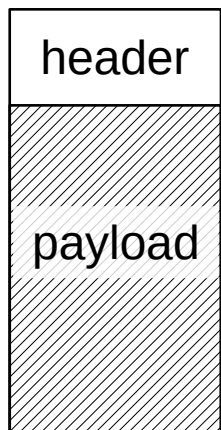
- Transportable by proxies and firewalls



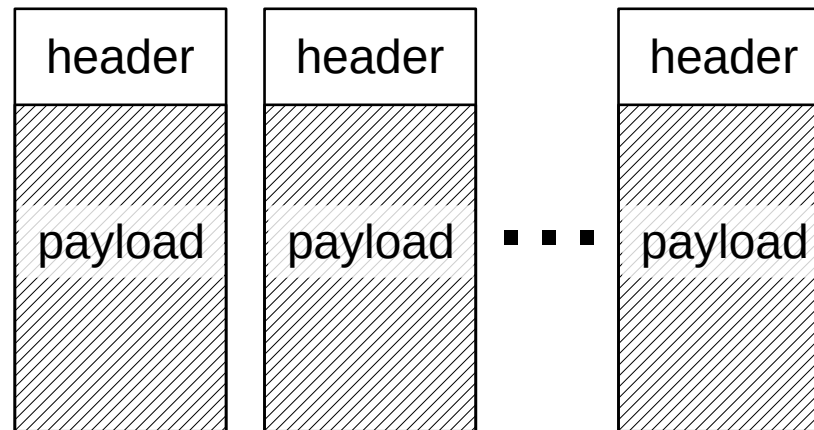
WebSocket

- RFC6455 (hybi-17)
- Symmetric, full-duplex
- Transportable by proxies and firewalls
- Message oriented, length-prefixed frames

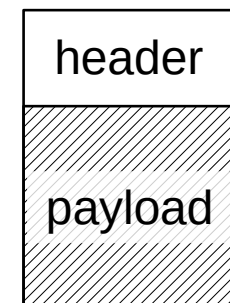
Single-frame message



Multi-frame message



Control frame:
close, ping, pong



127 byte max

WebSocket

Client

Server

HTTP Upgrade Request



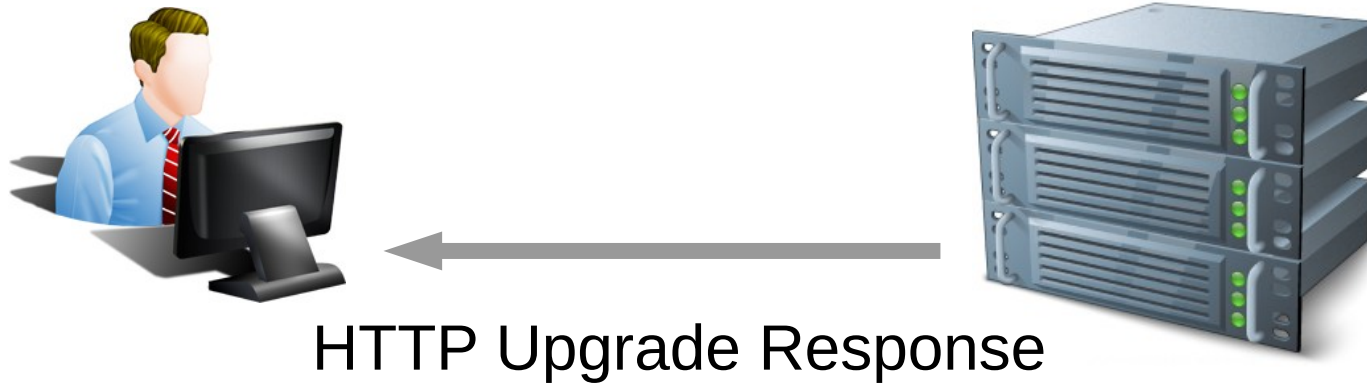
TARGET

```
GET /chat.cgi HTTP/1.1
Host: www.example.org
Upgrade: websocket
Connection: upgrade
Sec-WebSocket-Key: 2pGeTR08MA==
Sec-WebSocket-Version: 13
User-Agent: Beast
```


WebSocket

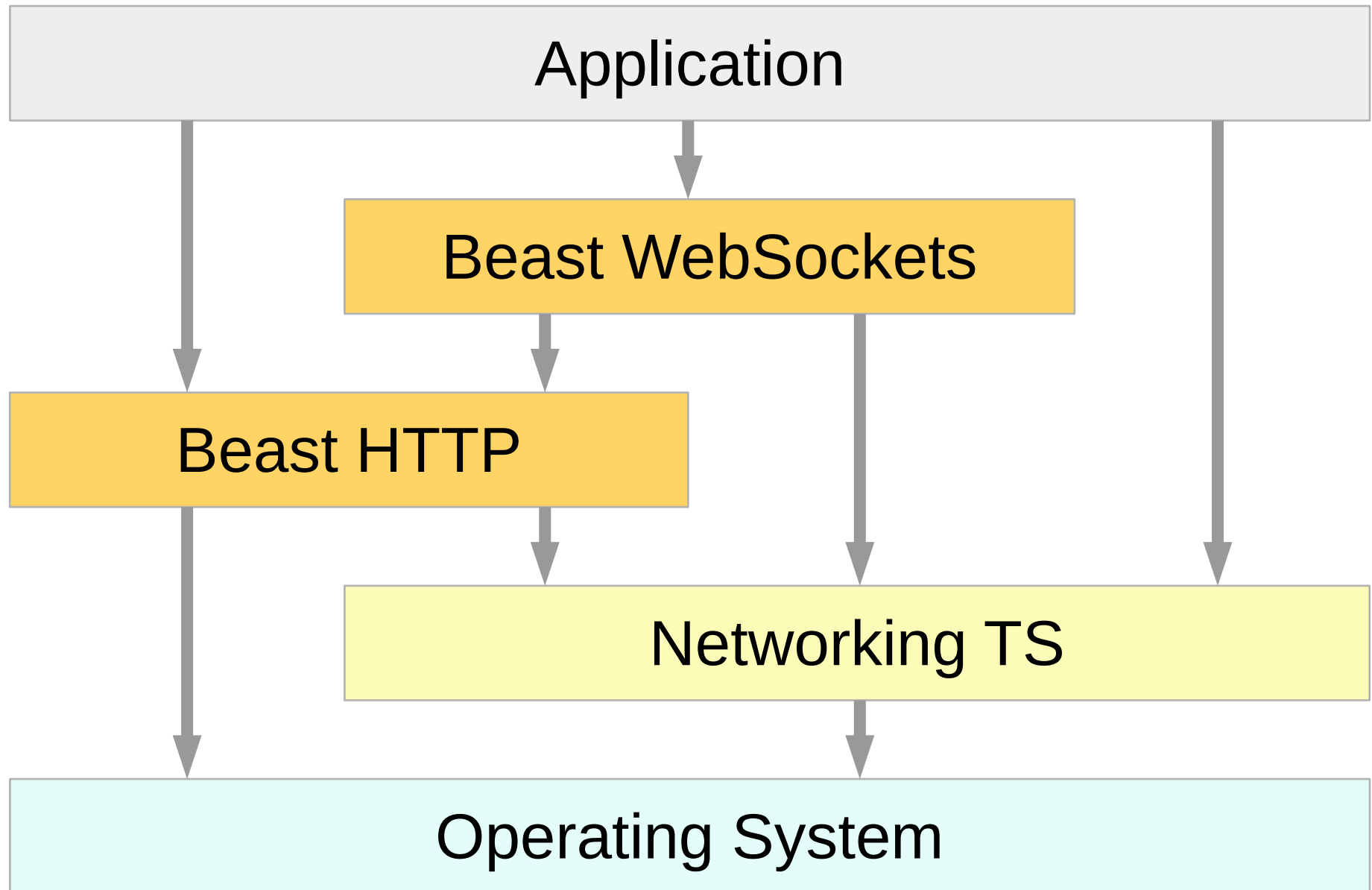
Client

Server



```
HTTP/1.1 101 Switching Protocols  
Upgrade: websocket  
Connection: upgrade  
Sec-WebSocket-Accept: shZRK+x0o=  
Server: Beast
```

API Layers



Networking TS

Flavors

Library	Header file location and namespace
Networking TS	<code><experimental/io_context></code> <code>std::experimental::net::io_context</code>
Boost.Asio	<code><boost/asio/io_context.hpp></code> <code>boost::asio::io_context</code>
Asio	<code><asio/io_context.hpp></code> <code>asio::io_context</code>

Basics

```
// Required for ALL I/O activities  
net::io_context ioc;
```

```
// Declare a TCP/IP socket  
net::ip::tcp::socket sock(ioc);
```

```
...
```

```
// Write some data  
auto bytes_transferred = sock.write_some(b);
```

Basics

```
// Required for ALL I/O activities  
net::io_context ioc;
```

```
// Declare a TCP/IP socket  
net::ip::tcp::socket sock(ioc);
```

```
...
```

```
// Write some data  
auto bytes_transferred = net::write(sock, b);
```

Basics

```
// Required for ALL I/O activities  
net::io_context ioc;
```

```
// Declare a TCP/IP socket  
net::ip::tcp::socket sock(ioc);
```

```
...
```

```
// Write some data  
auto bytes_transferred = net::write(sock, b);
```

Basics

```
// Required for ALL I/O activities  
net::io_context ioc;
```

```
// Declare a TCP/IP socket  
net::ip::tcp::socket sock(ioc);
```

```
...
```

```
// Write some data  
auto bytes_transferred = net::write(sock, (b));
```



Buffers

```
class mutable_buffer
{
    ...
public:
    mutable_buffer();

    mutable_buffer(
        void*, size_t);

    size_t size();

    void* data();
};
```

```
class const_buffer
{
    ...
public:
    const_buffer();

    const_buffer(
        void const*, size_t);

    const_buffer(
        mutable_buffer);

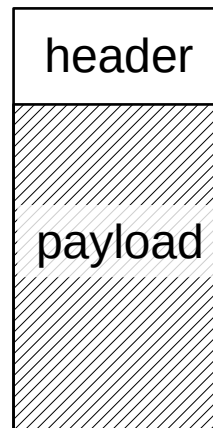
    size_t size();

    void const* data();
};
```

Buffers

```
// Send a payload prefixed with a header  
template<class SyncWriteStream>  
void  
send_message(  
    SyncWriteStream& stream,  
    net::const_buffer payload);
```

message:



Buffers

```
// Send a payload prefixed with a header
template<class SyncWriteStream>
void
send_message(
    SyncWriteStream& stream,
    net::const_buffer payload)
{
    net::write(stream, make_header(payload));
    net::write(stream, payload);
}
```

Buffers

```
// Send a payload prefixed with a header
template<class SyncWriteStream>
void
send_message(
    SyncWriteStream& stream,
    net::const_buffer payload)
{
    net::write(stream, make_header(payload));
    net::write(stream, payload);
}
```



System I/O calls, such as socket reads and writes, are usually incredibly expensive.

Buffers

```
// Send a payload prefixed with a header
template<class SyncWriteStream>
void
send_message(
    SyncWriteStream& stream,
    net::const_buffer payload)
{
    auto header = make_header(payload)

    // Create a non-owning, 2-element buffer range
    std::array<2,
        net::const_buffer> b{header, payload};
    net::write(stream, b);
}
```


Buffer Sequence

```
// Write a buffer sequence to a stream
// Returns: The number of bytes written
template<
    class SyncWriteStream,
    class ConstBufferSequence>
size_t
write(
    SyncWriteStream& stream,
    ConstBufferSequence const& b);
```

Buffer Sequence

- Bidirectional range of contiguous memory regions
- Reference semantics (no ownership)
- Length is fixed and cannot be resized
- Lightweight and copyable (don't use **vector**!)
- Networking TS concept, user-defined types possible
- Beast provides several buffer sequence types

ConstBufferSequence

A *ConstBufferSequence* is a non-owning range of read-only memory regions.

In this table:

- **X** is a type meeting the requirements of *ConstBufferSequence*
- **a** is a value of type **X**

Expression	Type	Description
<code>X::value_type</code>	<code>T</code>	<code>T</code> is convertible to <code>const_buffer</code> .
<code>X::const_iterator</code>	<code>U</code>	<code>U</code> is a bidirectional iterator whose reference type is convertible to <code>const_buffer</code> .
<code>X(a)</code>	<code>X</code>	<code>X</code> is <i>CopyConstructible</i> . The copy will reference the same memory regions as the original sequence.
<code>a.begin();</code> <code>a.end();</code>	<code>const_iterator</code> or convertible to <code>const_iterator</code>	
<code>const_buffer</code> <code>mutable_buffer</code>		Also a <i>ConstBufferSequence</i> .

MutableBufferSequence

A *MutableBufferSequence* is a non-owning range of mutable memory regions.

In this table:

- **X** is a type meeting the requirements of *MutableBufferSequence*
- **a** is a value of type **X**

Expression	Type	Description
<code>X::value_type</code>	T	T is convertible to <code>mutable_buffer</code> .
<code>X::const_iterator</code>	U	U is a bidirectional iterator whose reference type is convertible to <code>mutable_buffer</code> .
<code>X(a)</code>	X	X is <i>CopyConstructible</i> . The copy will reference the same memory regions as the original sequence.
<code>a.begin();</code> <code>a.end();</code>	<code>const_iterator</code> or convertible to <code>const_iterator</code>	
<code>mutable_buffer</code>		Also a <i>MutableBufferSequence</i> .

Buffers

```
string s = "Hello, world!";  
  
net::write(sock,  
            net::const_buffer(s.data(), s.size()));  
  
// Better  
net::write(sock, net::buffer(s));
```


Buffers

```
string s = "Hello, world!";  
  
net::write(sock,  
            net::const_buffer(s.data(), s.size()));  
  
// Better  
net::write(sock, net::buffer(s));
```

Buffers

```
template<typename PodType, size_t N>  
mutable_buffer buffer(array<PodType, N>& data);
```

```
template<typename PodType, size_t N>  
const_buffer buffer(array<PodType, N> const& data);
```

```
template<typename PodType, typename Allocator>  
mutable_buffer buffer(vector<PodType, Allocator>& data);
```

```
template<typename PodType, typename Allocator>  
const_buffer buffer(vector<PodType, Allocator> const& data);
```

```
template<typename Elem, typename Traits, typename Allocator>  
mutable_buffer buffer(basic_string<Elem, Traits, Allocator>& data);
```

```
template<typename Elem, typename Traits, typename Allocator>  
const_buffer buffer(basic_string<Elem, Traits, Allocator> const&  
data);
```

```
// ...26 more overloads
```

Buffers

```
// Read data into a buffer until  
// it contains a specified string  
auto matching_bytes =  
    net::read_until(sock, b, "\r\n\r\n");
```

Buffers

```
// Read data into a buffer until  
// it contains a specified string  
auto matching_bytes =  
    net::read_until(sock, b, "\r\n\r\n");
```



Buffers

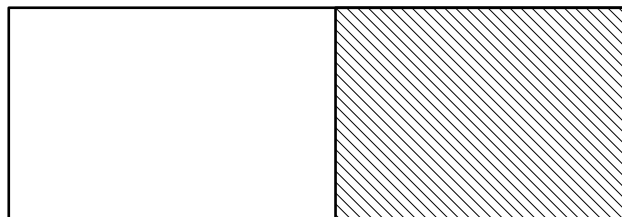
```
// Read data into a buffer until
// it contains a specified string
auto matching_bytes =
    net::read_until(sock, b, "\r\n\r\n");

template<
    class SyncReadStream,
    class DynamicBuffer>
size_t
read_until(
    SyncReadStream& s,
    DynamicBuffer&& buffer,
    string_view match);
```


DynamicBuffer

- A resizable buffer sequence with a *read area* and a *write area*
- Useful when the expected input size is unknown
- Networking TS concept, user-defined types possible
- Beast provides several dynamic buffer types

read area
ConstBufferSequence

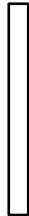


write area
MutableBufferSequence

DynamicBuffer

```
// X is a type meeting the requirements of DynamicBuffer  
X a;
```

read area
0 bytes



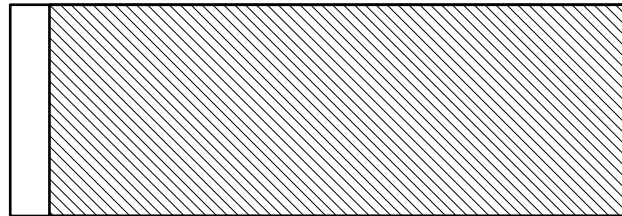
write area
0 bytes

DynamicBuffer

```
X a;
```

```
// Resize the write area and read into it  
auto bytes_transferred = sock.read_some(a.prepare(128));
```

read area
0 bytes

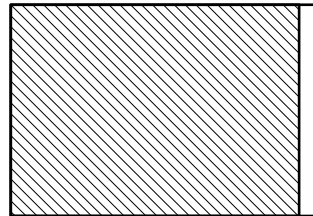


write area
128 bytes

DynamicBuffer

```
X a;  
auto bytes_transferred = sock.read_some(a.prepare(128));  
  
// Move bytes from the write area to the read area  
a.commit(bytes_transferred);
```

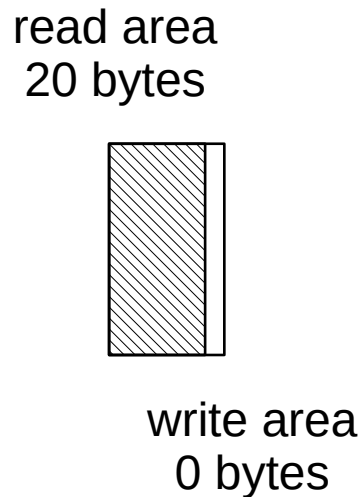
read area
60 bytes



write area
0 bytes

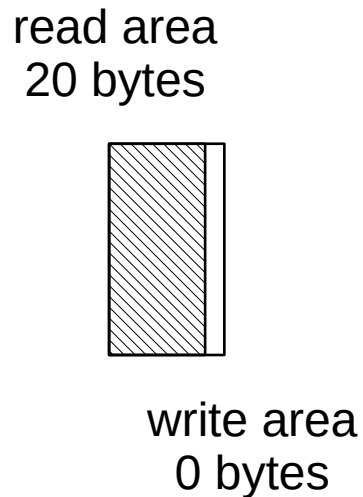
DynamicBuffer

```
X a;  
auto bytes_transferred = sock.read_some(a.prepare(128));  
a.commit(bytes_transferred);  
  
// Process data in the read area  
auto bytes_used = process(a.data());
```



DynamicBuffer

```
X a;  
auto bytes_transferred = sock.read_some(a.prepare(128));  
a.commit(bytes_transferred);  
auto bytes_used = process(a.data());  
  
// Remove bytes from the read area  
a.consume(bytes_used);
```



DynamicBuffer

```
class DynamicBuffer
{
public:
    using const_buffers_type = ...;    // The type representing the read area
    using mutable_buffers_type = ...;  // The type representing the write area

    size_t size() const;               // Returns the size of the read area
    size_t max_size() const;           // Returns maximum sum of read and write area sizes
    size_t capacity() const;           // Returns maximum sum of sizes without reallocating

    // Returns the read area as a ConstBufferSequence
    const_buffers_type data() const;

    // Resize the write area and return it as a MutableBufferSequence
    mutable_buffers_type prepare(size_t size);

    // Move bytes from beginning of write area to end of read area
    void commit(size_t size);

    // Remove bytes from beginning of read area
    void consume(size_t size);
};
```

Asynchronous I/O

```
// Perform a blocking read
auto bytes_transferred = sock.read_some(b);

// Start a non-blocking read
// this call returns immediately
sock.async_read_some(buffers, handler);
```

Asynchronous I/O

```
// Perform a blocking read
auto bytes_transferred = sock.read_some(b);

// Start a non-blocking read
// this call returns immediately
sock.async_read_some(buffers, handler);
```

Asynchronous I/O

```
// Perform a blocking read
auto bytes_transferred = sock.read_some(b);

// Start a non-blocking read
// this call returns immediately
sock.async_read_some(buffers, handler);
```



Asynchronous I/O

```
// Perform a blocking read
auto bytes_transferred = sock.read_some(b);

// Start a non-blocking read,
// this call returns immediately
sock.async_read_some(buffers,
    [&](error_code ec,
        size_t bytes_transferred)
    {
        // Called later when the read is complete
        ...
    });
```

Completion Handler

- An invocable function object with the right signature
- Requires *MoveConstructible*
- Networking TS concept for user-defined types

```
// Lambda expression  
[](error_code, size_t){}
```

```
// User-defined function object  
struct my_handler  
{  
    void operator()(error_code, size_t);  
};
```

```
// A call wrapper  
bind(&connection::on_read, this, _1, _2); // gasp!
```

Asynchronous I/O

```
// Start a non-blocking read,  
// this call returns immediately  
sock.async_read_some(buf, buffers,  
    [&](error_code ec,  
        size_t bytes_transferred)  
    {  
        // Called when the read is complete  
        ...  
    });  
  
// Execution continues here while the  
// read operation is "outstanding" (a TS term).
```

Asynchronous I/O

```
// Start a non-blocking read,  
// this call returns immediately  
sock.async_read_some(buffers,  
    [&](error_code ec,  
        size_t bytes_transferred)  
    {  
        // Called when the read is complete  
        ...  
    });
```



Asynchronous I/O

```
// Start a non-blocking read,  
// this call returns immediately  
sock.async_read_some(buffers,  
    [&](error_code ec,  
        size_t bytes_transferred)  
    {  
        // Called when the read is complete  
        ...  
    });
```



Asynchronous I/O

- Basic guarantee



Completion handlers will only be called from threads that are currently calling `io_context::run()`.

io_context::run

```
// I/O context uses the current thread  
ioc.run();
```

```
// I/O context uses a newly created thread  
thread([&ioc]{ ioc.run(); });
```

io_context::run

```
// I/O context uses the current thread  
ioc.run();
```

```
// I/O context uses a newly created thread  
thread([&ioc]{ ioc.run(); });
```

io_context::run

```
// I/O context uses the current thread  
ioc.run();
```

```
// I/O context uses a newly created thread  
thread([&ioc]{ ioc.run(); }).detach();
```



io_context::run

```
// I/O context uses the current thread
ioc.run();

// I/O context uses a newly created thread
thread([&ioc]{ ioc.run(); }).detach();

// I/O context uses a group of N threads
assert(N > 0);
vector<thread> v;
v.reserve(N - 1);
while(N--)
    v.emplace_back([&ioc]{ ioc.run(); });
ioc.run();
```

io_context::run

```
// I/O context uses the current thread
ioc.run();

// I/O context uses a newly created thread
thread([&ioc]{ ioc.run(); }).detach();

// I/O context uses a group of N threads
assert(N > 0);
vector<thread> v;
v.reserve(N - 1);
while(N--)
    v.emplace_back([&ioc]{ ioc.run(); });
ioc.run(); // ...including the current thread!
```



io_context::run

- User determines synchronization:
 - Single-threaded
 - Multi-threaded
 - Stranded
- User-controlled
 - Catch exceptions
 - Do thread-specific init (e.g. CoInitializeEx)
- Thread-agnostic
 - `std::thread`
 - `boost::thread`
 - Platforms with no threads

Multi-threading

- An executor embodies a set of rules about where, when and how to run a function object.
- Networking TS can use an executor to run a completion handler
- A *strand* provides an additional execution guarantee:
 - Completion handlers invoked through a given strand's executor will never run concurrently
- Single-threaded `io_context` is an “implicit strand”:
 - Completion handlers can never run concurrently
- Multi-threaded programs are hard to write, hard to reason about, and hard to maintain.

Threading Models

Type	Features	Notes
single threaded, single io_context	<ul style="list-style-type: none">• Fastest• Limited capacity• Implicit strand	Easiest to write
multi-threaded, single io_context	<ul style="list-style-type: none">• Highest capacity• Explicit strand	More capacity, but more overhead
multi-threaded, io_context per thread	<ul style="list-style-type: none">• Fastest• Highest capacity• Implicit strand• Needs balancing	Most complex



Chat Server

Chat Server

```
// Boost/Asio
```

```
namespace net = boost::asio;
```

```
using tcp = net::ip::tcp;
```

```
using error_code = boost::system::error_code;
```

```
// Beast
```

```
namespace beast = boost::beast;
```

```
namespace http = boost::beast::http;
```

```
namespace websocket = boost::beast::websocket;
```

Chat Server

```
// Creates and runs the server
int main(int argc, char* argv[]);

// Holds the server data
class shared_state;

// Accepts incoming connections
class listener;

// Handles HTTP requests on a connection
class http_session;

// Maintains an active WebSocket session
class websocket_session;
```

Chat Server

```
class shared_state
{
    std::string doc_root_;
    std::unordered_set<websocket_session*> sessions_;

public:
    explicit
    shared_state(std::string doc_root);

    std::string const&
    doc_root() const noexcept { return doc_root_; }

    void join (websocket_session& session);
    void leave (websocket_session& session);
    void send (std::string message);
};
```

Chat Server

```
void shared_state::join(websocket_session& session)
{
    sessions_.insert(&session);
}
```

```
void shared_state::leave(websocket_session& session)
{
    sessions_.erase(&session);
}
```

```
void shared_state::send(std::string message)
{
    auto const ss = std::make_shared<
        std::string const>(std::move(message));

    for(auto session : sessions_)
        session->send(ss);
}
```

Chat Server

```
int main(int argc, char* argv[])
{
    // Usage:
    // websocket-chat-server <address> <port> <doc_root>

    auto address =
        net::ip::make_address(argv[1]);

    auto port =
        static_cast<unsigned short>(std::atoi(argv[2]));

    auto doc_root = argv[3];

    . . .
}
```


Chat Server

```
int main(int argc, char* argv[])
...

// The io_context is required for all I/O
net::io_context ioc;

// Create and launch a listening port
std::make_shared<listener>(
    ioc,
    tcp::endpoint{address, port},
    std::make_shared<shared_state>(doc_root)
)->run();

ioc.run();

return EXIT_SUCCESS;
}
```

Chat Server

```
class listener
    : public std::enable_shared_from_this<listener>
{
    tcp::acceptor acceptor_;
    tcp::socket socket_;
    std::shared_ptr<shared_state> state_;

    void fail(error_code ec, char const* what);
    void on_accept(error_code ec);

public:
    listener(
        net::io_context& ioc,
        tcp::endpoint endpoint,
        std::shared_ptr<shared_state> const& state);

    void run();
};
```

Chat Server

```
void listener::run()
{
    // Start accepting a connection.
    acceptor_.async_accept(
        socket_,
        [self = shared_from_this()](error_code ec)
        {
            self->on_accept(ec);
        });
}
```

Chat Server

```
void listener::on_accept(error_code ec)
{
    if(ec)
        fail(ec, "accept");
    else
        // Launch a new session for this connection
        std::make_shared<http_session>(
            std::move(socket_), state_)->run();

    // Accept another connection
    acceptor_.async_accept(
        socket_,
        [self = shared_from_this()](error_code ec)
        {
            self->on_accept(ec);
        });
}
```

Chat Server

```
void listener::fail(  
    error_code ec, char const* what)  
{  
    // Don't report on canceled operations  
    if(ec == net::error::operation_aborted)  
        return;  
  
    std::cerr <<  
        what << ": " <<  
        ec.message() << "\n";  
}
```

Chat Server

```
class http_session
    : public std::enable_shared_from_this<http_session>
{
    tcp::socket socket_;
    beast::flat_buffer buffer_;
    std::shared_ptr<shared_state> state_;
    http::request<http::string_body> req_;

    void fail(error_code ec, char const* what);
    void on_read(error_code ec, std::size_t);
    void on_write(error_code ec, std::size_t, bool close);

public:
    http_session(tcp::socket socket,
                 std::shared_ptr<shared_state> const& state);

    void run();
};
```

Chat Server

```
http_session::http_session(  
    tcp::socket socket,  
    std::shared_ptr<shared_state> const& state)  
    : socket_(std::move(socket))  
    , state_(state)  
{  
}  
  
void http_session::run()  
{  
    // Read a request  
    http::async_read(socket_, buffer_, req_,  
        [self = shared_from_this()]  
        (error_code ec, std::size_t bytes)  
        {  
            self->on_read(ec, bytes);  
        });  
}
```

Chat Server

```
void http_session::on_read(error_code ec, std::size_t)
{
    // This means they closed the connection
    if(ec == http::error::end_of_stream)
    {
        socket_.shutdown(tcp::socket::shutdown_send, ec);
        return;
    }

    if(ec)
        return fail(ec, "read");

    // Handle WebSocket Upgrade
    if(websocket::is_upgrade(req_))
    {
        // Create a WebSocket session by transferring the socket
        std::make_shared<websocket_session>(
            std::move(socket_), state_)->run(std::move(req_));
        return;
    }

    ...
}
```


Chat Server

```
void http_session::on_read(error_code ec, std::size_t)
...

handle_request(state_->doc_root(), std::move(req_),
    [this](auto&& response)
    {
        using response_type = typename
            std::decay<decltype(response)>::type;

        auto sp = std::make_shared<response_type>(
            std::move(response));

        http::async_write(this->socket_, *sp,
            [self = shared_from_this(), sp](
                error_code ec, std::size_t bytes)
            {
                self->on_write(ec, bytes, sp->need_eof());
            });
    });
}
```

Chat Server

```
void http_session::on_write(
    error_code ec, std::size_t, bool close)
{
    if(ec)
        return fail(ec, "write");

    if(close)
    {
        // This means we should close the connection,
        socket_.shutdown(tcp::socket::shutdown_send, ec);
        return;
    }

    // Clear contents of the request message,
    // otherwise the read behavior is undefined.
    req_ = {};

    // Read another request
    http::async_read(socket_, buffer_, req_,
        [self = shared_from_this()]
        (error_code ec, std::size_t bytes)
        {
            self->on_read(ec, bytes);
        });
}
```

Chat Server

```
class websocket_session
    : public std::enable_shared_from_this<websocket_session>
{
    beast::flat_buffer buffer_;
    websocket::stream<tcp::socket> ws_;
    std::shared_ptr<shared_state> state_;
    std::vector<std::shared_ptr<std::string const>> queue_;

    void fail(error_code ec, char const* what);
    void on_accept(error_code ec);
    void on_read(error_code ec, std::size_t);
    void on_write(error_code ec, std::size_t);

public:
    ~websocket_session();
    websocket_session(tcp::socket socket,
                     std::shared_ptr<shared_state> const& state);

    template<class Body, class Allocator>
    void run(http::request<Body, http::basic_fields<Allocator>> req);

    void send(std::shared_ptr<std::string const> const& ss);
};
```

Chat Server

```
template<class Body, class Allocator>
void websocket_session::
run(
    http::request<Body, http::basic_fields<Allocator>> req)
{
    // Accept the websocket handshake
    ws_.async_accept(req,
        [self = shared_from_this()](error_code ec)
        {
            self->on_accept(ec);
        });
}
```

Chat Server

```
void websocket_session::  
on_accept(error_code ec)  
{  
    if(ec)  
        return fail(ec, "accept");  
  
    // Add this session to the list  
    state_->join(*this);  
  
    // Read a message  
    ws_.async_read(  
        buffer_,  
        [sp = shared_from_this()](  
            error_code ec, std::size_t bytes)  
        {  
            sp->on_read(ec, bytes);  
        });  
}
```

Chat Server

```
void websocket_session::
on_read(error_code ec, std::size_t)
{
    if(ec)
        return fail(ec, "read");

    // Send to all connections
    state_->send(
        beast::buffers_to_string(buffer_.data()));

    // Clear the buffer
    buffer_.consume(buffer_.size());

    ws_.async_read(buffer_, [sp = shared_from_this()](
        error_code ec, std::size_t bytes)
        {
            sp->on_read(ec, bytes);
        });
}
```

Chat Server

```
void websocket_session::
send(std::shared_ptr<std::string const> const& ss)
{
    // Always add to queue
    queue_.push_back(ss);

    // Are we already writing?
    if(queue_.size() > 1)
        return;

    ws_.async_write(
        net::buffer(*queue_.front()),
        [sp = shared_from_this()](
            error_code ec, std::size_t bytes)
        {
            sp->on_write(ec, bytes);
        });
}
```

Chat Server

```
void websocket_session::  
on_write(error_code ec, std::size_t)  
{  
    if(ec)  
        return fail(ec, "write");  
  
    queue_.erase(queue_.begin());  
  
    if(! queue_.empty())  
        ws_.async_write(  
            net::buffer(*queue_.front()),  
            [sp = shared_from_this()](  
                error_code ec, std::size_t bytes)  
            {  
                sp->on_write(ec, bytes);  
            });  
}
```


Chat Server

```
void
websocket_session::
fail(error_code ec, char const* what)
{
    // Don't report these
    if(ec == net::error::operation_aborted ||
        ec == websocket::error::closed)
        return;

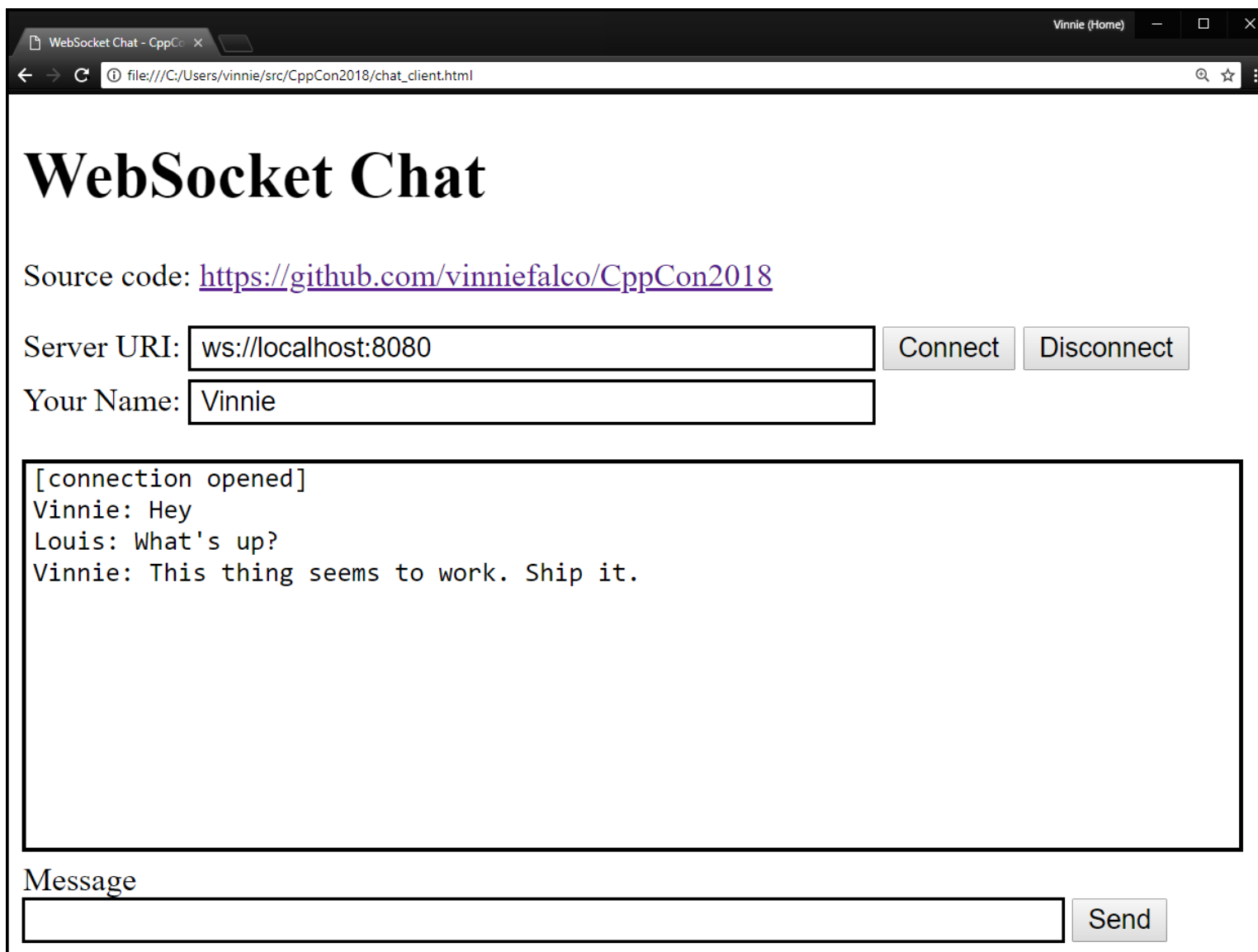
    std::cerr << what << ": " <<
        ec.message() << "\n";
}
```

Chat Server

```
websocket_session::  
~websocket_session()  
{  
    state_->leave(*this);  
}
```

Chat Client

Chat Client



The screenshot shows a web browser window with the title "WebSocket Chat - CppCon2018". The address bar displays the file path "file:///C:/Users/vinnie/src/CppCon2018/chat_client.html". The main content area has a heading "WebSocket Chat". Below the heading, it says "Source code: <https://github.com/vinniefalco/CppCon2018>". There are two input fields: "Server URI:" with the value "ws://localhost:8080" and "Your Name:" with the value "Vinnie". To the right of the "Server URI" field are two buttons: "Connect" and "Disconnect". Below the input fields is a large text area containing the chat log: "[connection opened]", "Vinnie: Hey", "Louis: What's up?", and "Vinnie: This thing seems to work. Ship it.". At the bottom, there is a "Message" label, an input field, and a "Send" button.

WebSocket Chat

Source code: <https://github.com/vinniefalco/CppCon2018>

Server URI:

Your Name:

[connection opened]
Vinnie: Hey
Louis: What's up?
Vinnie: This thing seems to work. Ship it.

Message

Chat Client

```
<html>
<head>
<title>WebSocket Chat - CppCon2018</title>
</head>
<body>
<h1>WebSocket Chat</h1>
<!-- UI and app -->
</body>
</html>
```

Chat Client

Server URI:

```
<input
  id="uri"
  size="47"
  class="draw-border"
  style="margin-bottom: 5px;"
  value="ws://localhost:8080">
```

Server URI:

Chat Client

```
<button  
  id="connect"  
  class="echo-button">  
Connect  
</button>
```

```
<button  
  id="disconnect"  
  class="echo-button">  
Disconnect  
</button>
```

Connect

Disconnect

Chat Client

Your Name:

```
<input  
  id="userName"  
  class="draw-border"  
  size=47>
```

Your Name:

Chat Client

```
<pre  
  id="messages"  
  style="border: solid 1px #cccccc;">  
</pre>
```

Chat Client

```
Message<br>
<input
  id="sendMessage"
  class="draw-border">
<button
  id="send"
  class="echo-button">Send</button>
```

Message



Dom PÉRIGNON • MILLESIMÉ
Altum Villare

Champagne
Dom Pérignon

Vintage 2004



Sparkling Wine

Brut

Vin Mousseux

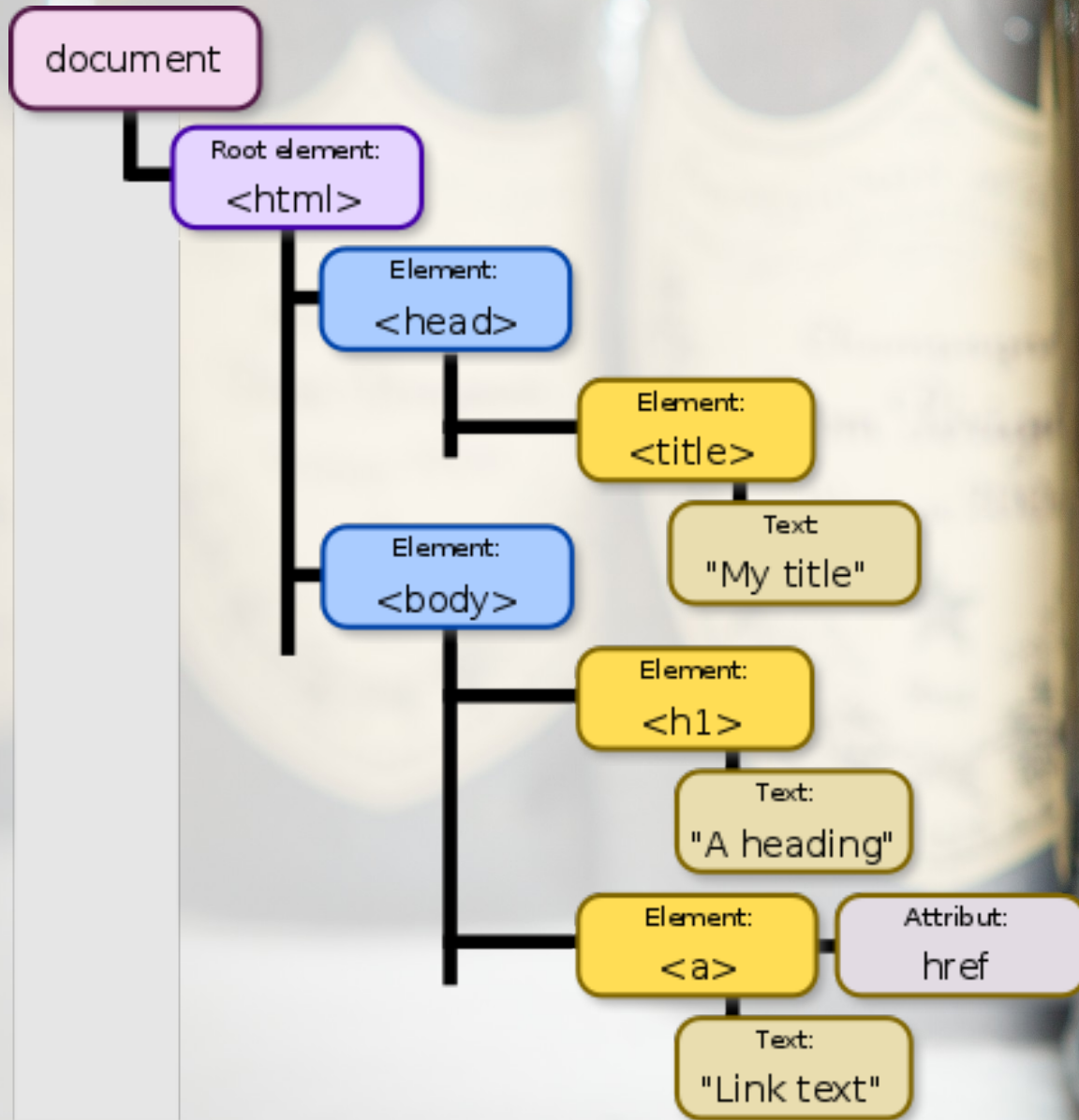
750ml

12.5% alc./vol. NM-549-002-MILLESIMÉ-PRODUCT

CHAMPAGNE DOM PÉRIGNON & CHANDON PERNAY - FRANCE

DOM

Document Object Model



DANGER!





DANGER!

JavaScript ahead!

Chat Client

```
<script>
  var ws = null;
  connect.onclick = function() {
    ws = new WebSocket(uri.value);

    ...

  };
</script>
```

Server URI:

Chat Client

```
connect.onclick = function() {  
    ...  
  
    ws.onopen = function(ev) {  
        messages.innerText +=  
            "[connection opened]\n";  
    };  
  
    ws.onclose = function(ev) {  
        messages.innerText +=  
            "[connection closed]\n";  
    };  
};
```


Chat Client

```
connect.onclick = function() {  
    ...  
  
    ws.onmessage = function(ev) {  
        messages.innerText += ev.data + "\n";  
    };  
  
    ws.onerror = function(ev) {  
        messages.innerText += "[error]\n";  
        console.log(ev);  
    };  
};
```

Chat Client

...

```
disconnect.onclick = function() {  
    ws.close();  
};
```

Server URI:

`id="disconnect"`

Chat Client

...

```
send.onclick = function() {  
    ws.send(userName.value +  
        ":" + sendMessage.value);  
    sendMessage.value = "";  
};
```

Message id="sendMessage" id="send"

Send

Chat Client

...

```
sendMessage.onkeyup = function(ev) {  
    ev.preventDefault();  
    if (event.keyCode === 13) {  
        send.click();  
    };  
};  
</script>
```

Message id="sendMessage" id="send"

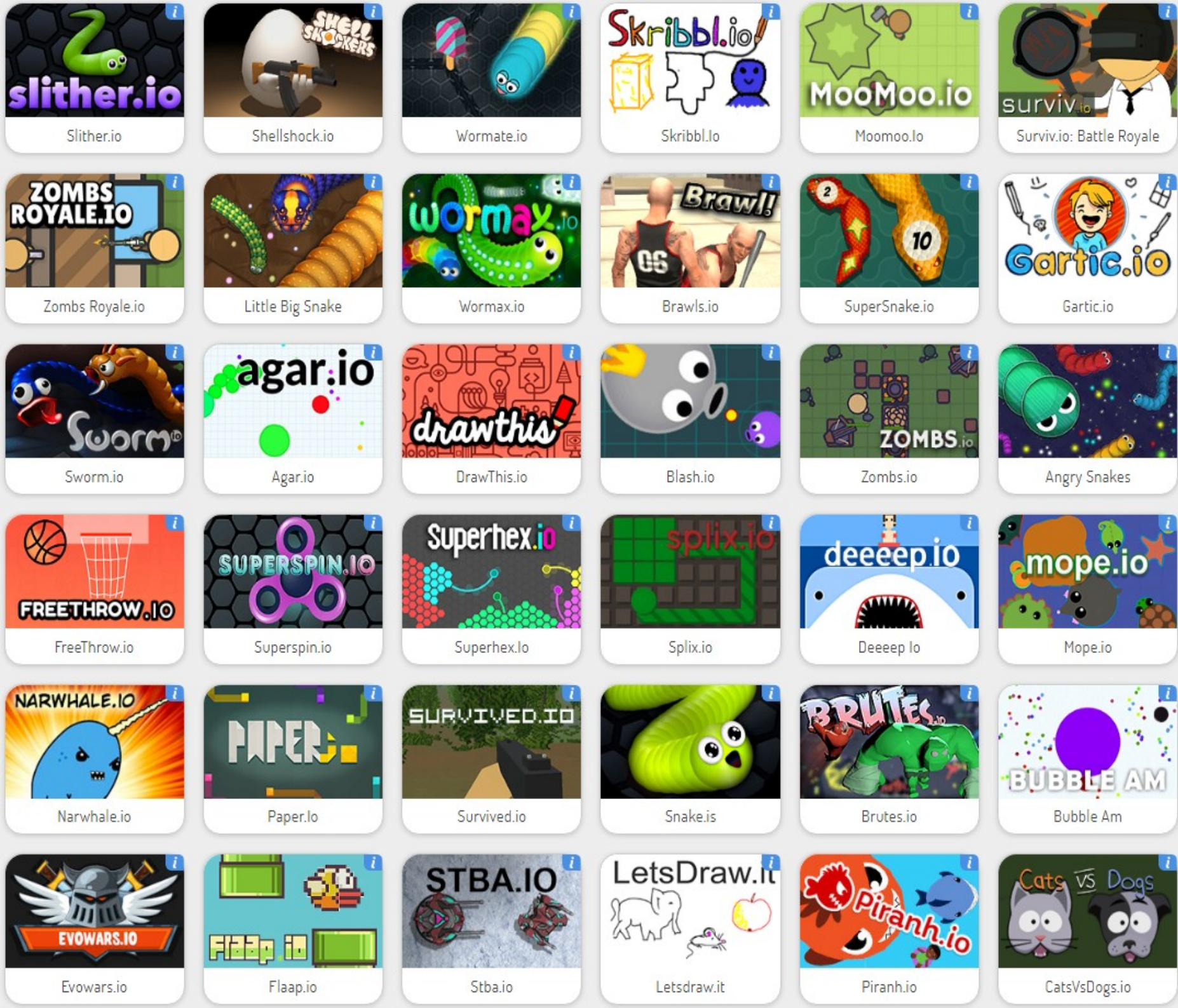
Send

Chat Client

```
<script>
  var ws = null;

  connect.onclick = function() {
    ws = new WebSocket(uri.value);
    ws.onopen = function(ev) {
      messages.innerHTML += "[connection opened]\n";
    };
    ws.onclose = function(ev) {
      messages.innerHTML += "[connection closed]\n";
    };
    ws.onmessage = function(ev) {
      messages.innerHTML += ev.data + "\n";
    };
    ws.onerror = function(ev) {
      messages.innerHTML += "[error]\n";
      console.log(ev);
    };
  };
  disconnect.onclick = function() {
    ws.close();
  };
  send.onclick = function() {
    ws.send(userName.value + ": " + sendMessage.value);
    sendMessage.value = "";
  };
  sendMessage.onkeyup = function(ev) {
    ev.preventDefault();
    if (event.keyCode === 13) {
      send.click();
    }
  }
}
</script>
```

Epilogue



Your App Title Here



You are standing in an open field west of a white house, with a boarded front door.

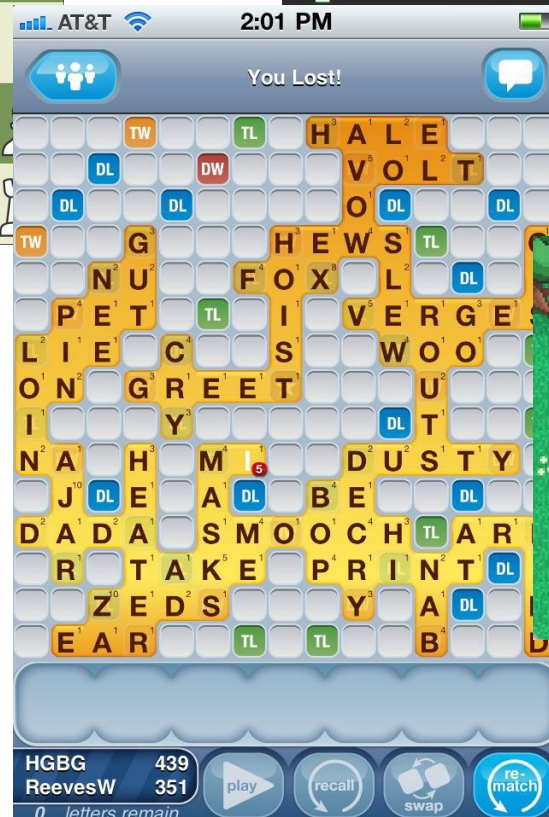
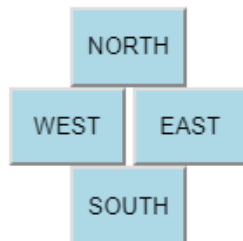
There is a small mailbox here.

>open mailbox

Opening the small mailbox reveals a leaflet.

>

Result JavaScript HTML CSS Edit in JSFiddle



Learning Networking

- Read the documentation
- Study the examples
- Write, write, write!
- Ask questions
 - Stack Overflow
 - Slack / IRC
- Find a mentor

Summary

// Code and slides from the talk

<https://github.com/vinniefalco/CppCon2018>

// Boost.Beast library

<https://github.com/boostorg/beast>

// Boost libraries, including Asio

<https://www.boost.org/doc/libs/>