Get Rich Quick!

Using Boost.Beast WebSockets and Networking TS

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Author of Boost.Beast

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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

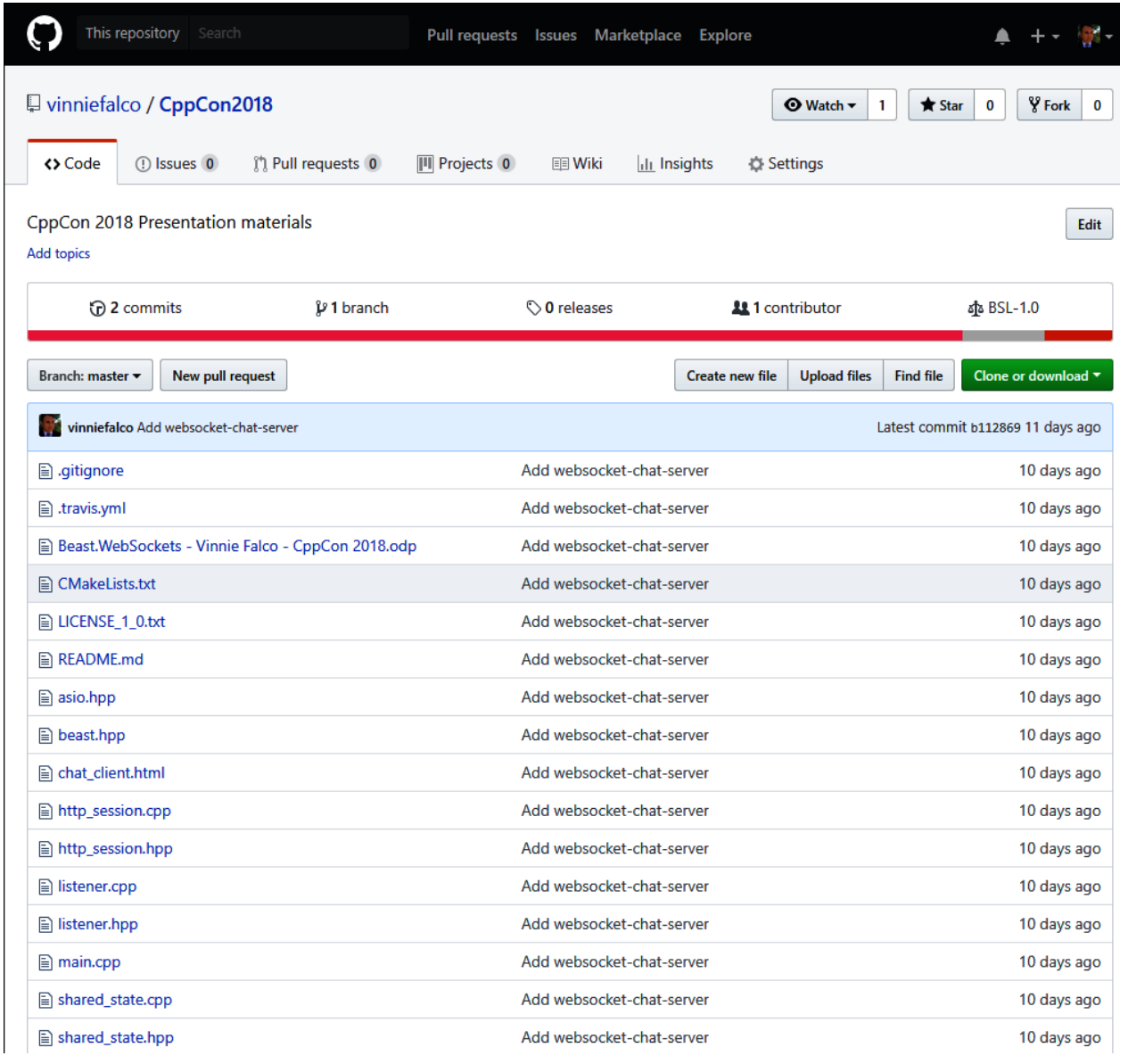
- Best permissive license
- Review process breeds excellence
- Establish existing practice
- Become part of C++

```
boost::shared_ptr
boost::optional
boost::bind
boost::mutex
boost::chrono
BOOST_FOR_EACH
```

```
boost::asio
boost::filesystem
boost::thread
boost::shared_mutex
boost::function
BOOST_STATIC_ASSERT
```

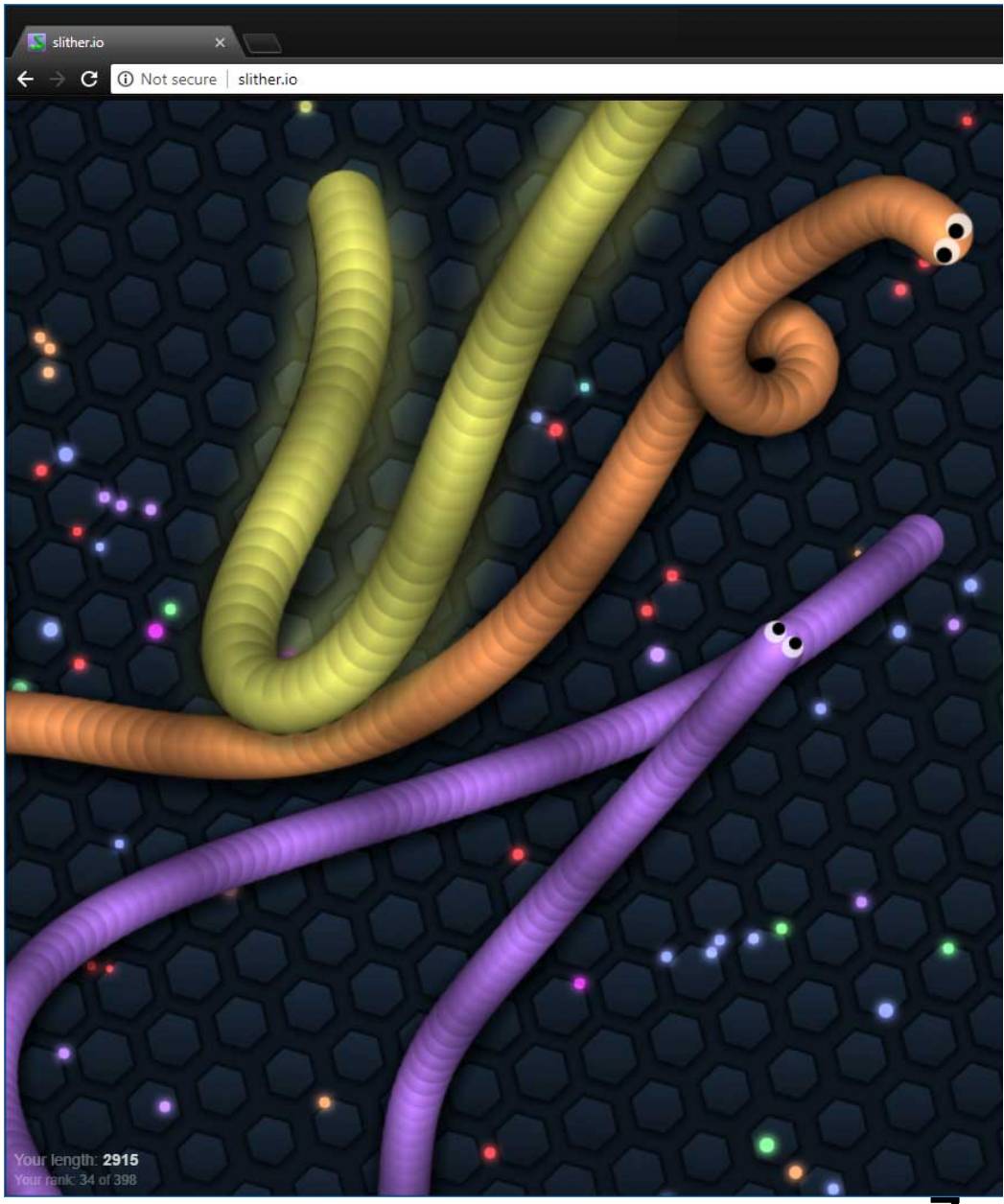
Repository

https://github.com/vinniefalco/CppCon2018



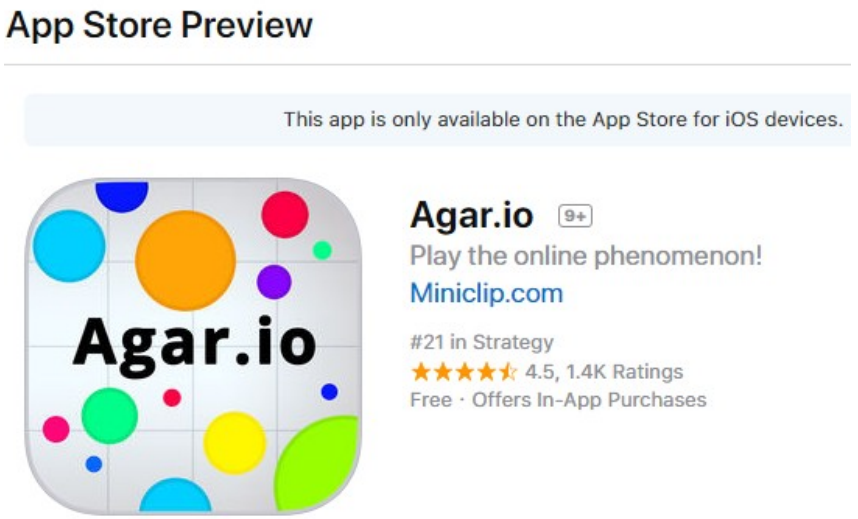
http://agar.io

http://slither.io



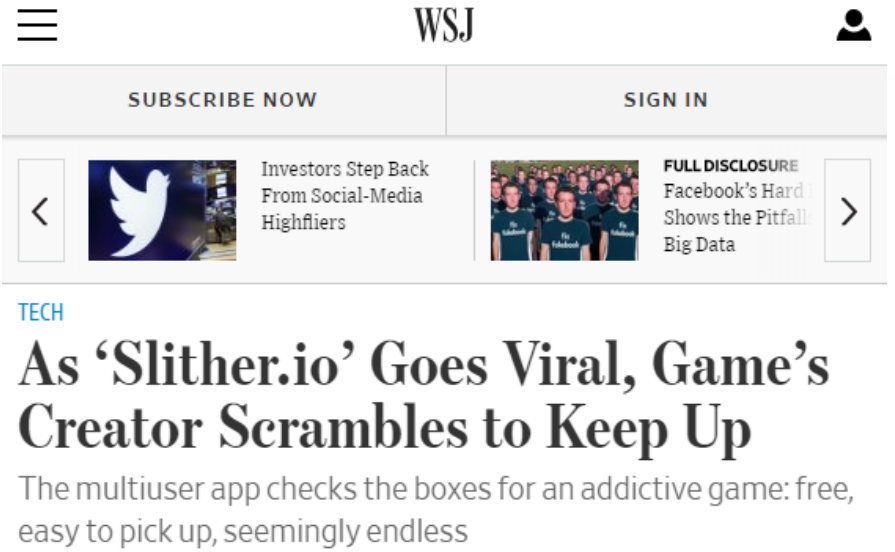
http://agar.io

- 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



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



Recipe

- C++ WebSocket Server
- Browser WebSocket Client

Contents

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

Protocols

HTTP

“Hypertext Transfer Protocol”

Client

Server

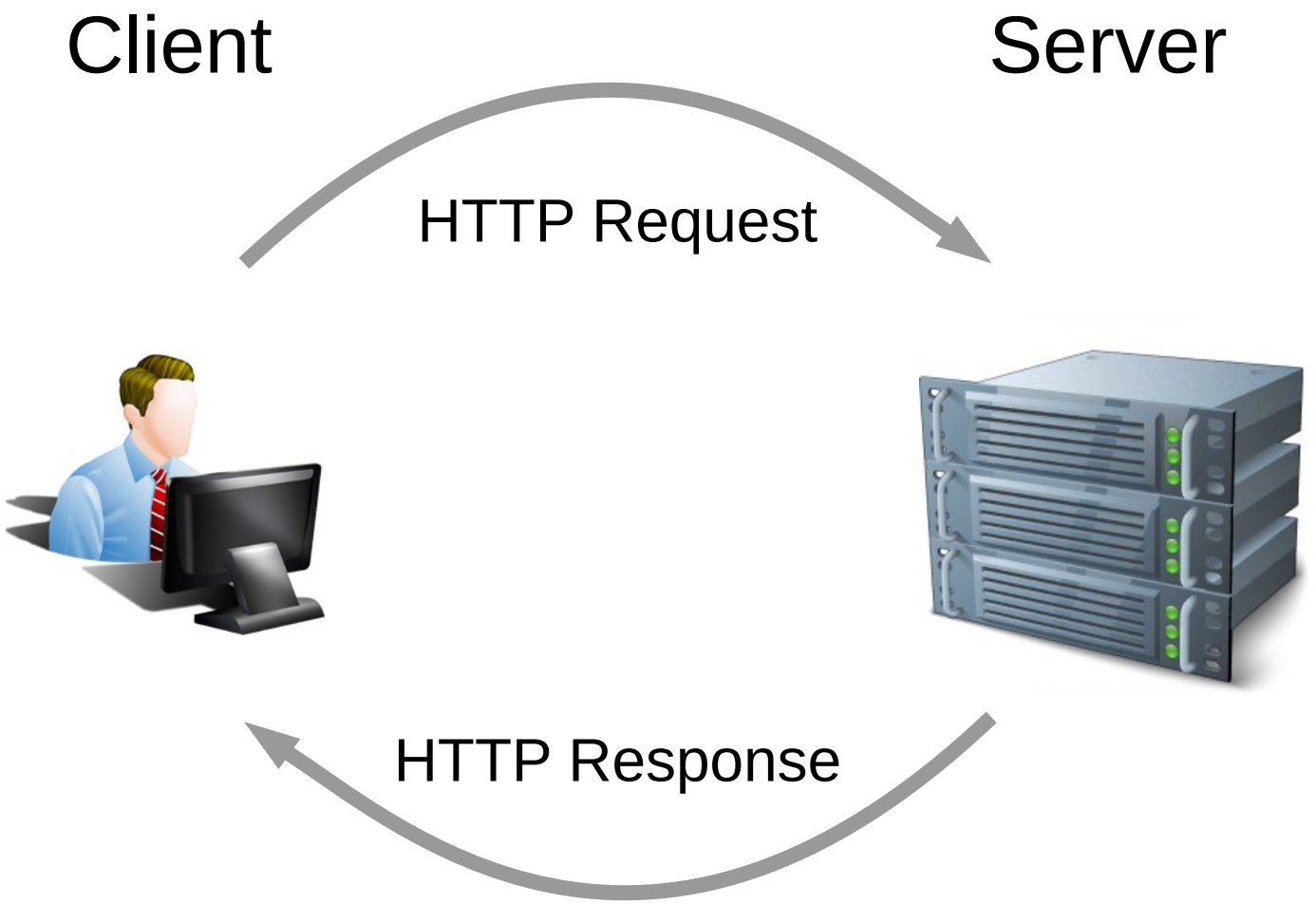
DNS

192.168.17.42

TCP/IP

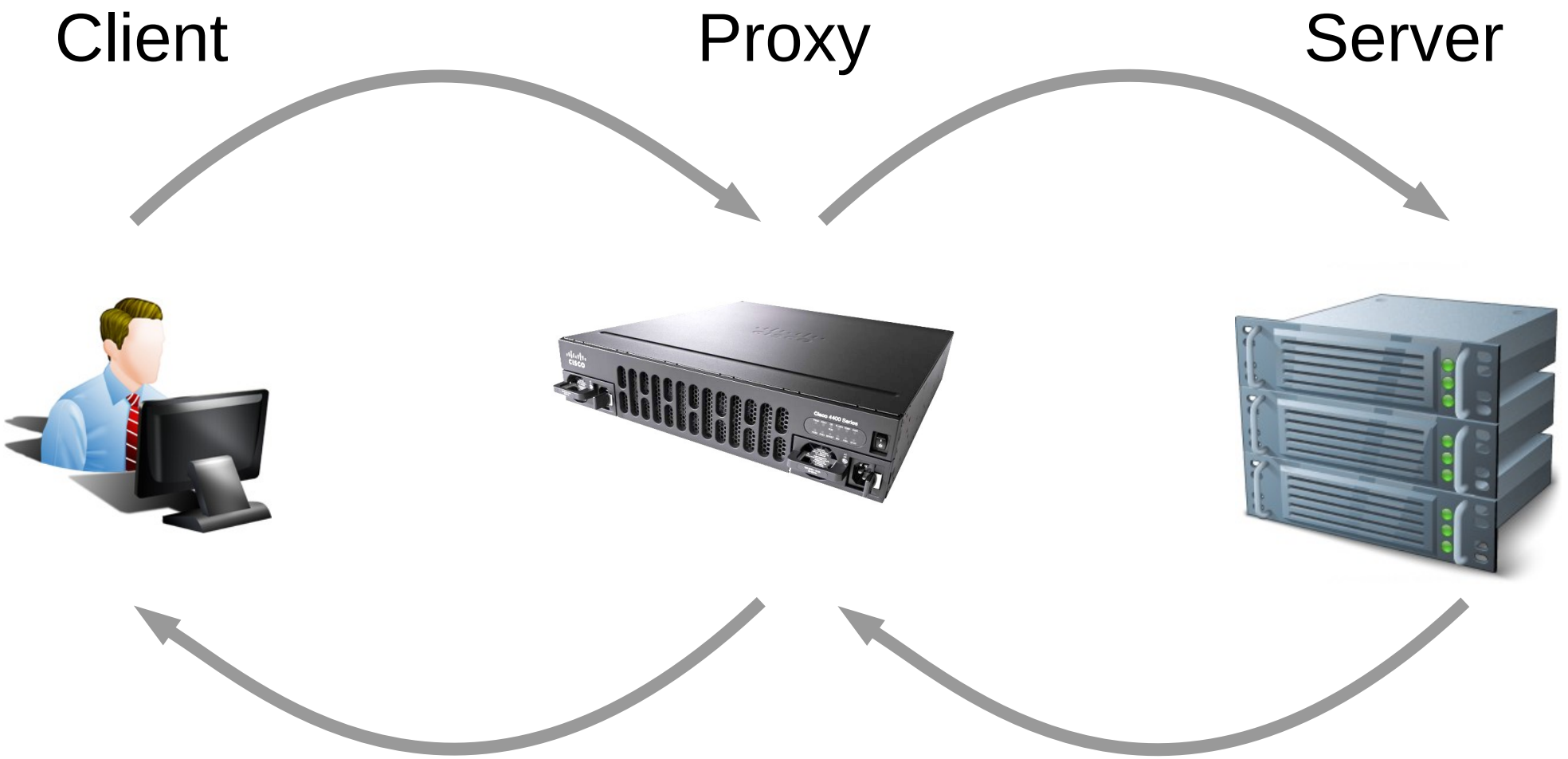
HTTP

- Half-Duplex



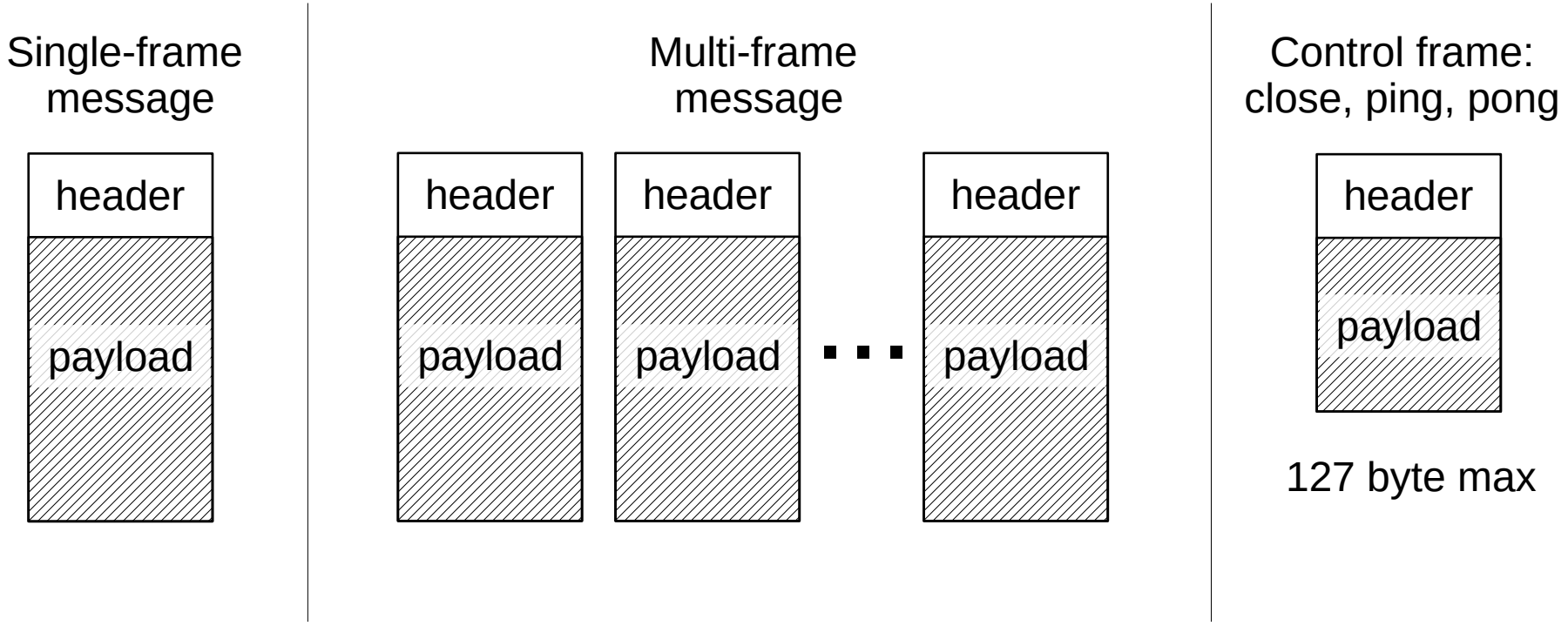
HTTP

- Transportable by proxies and firewalls



WebSocket

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



WebSocket

Client Server

HTTP Upgrade Request

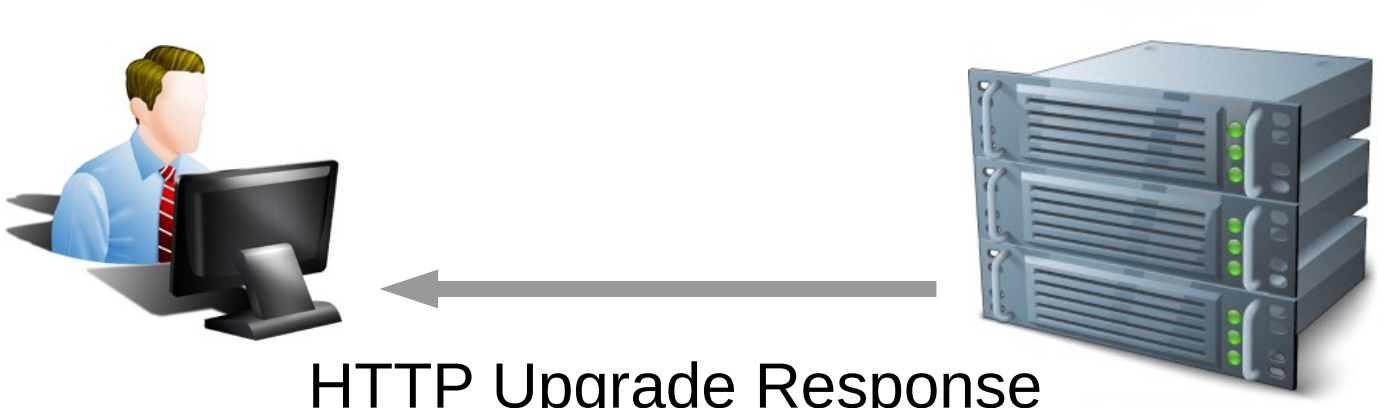
TARGET

```
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

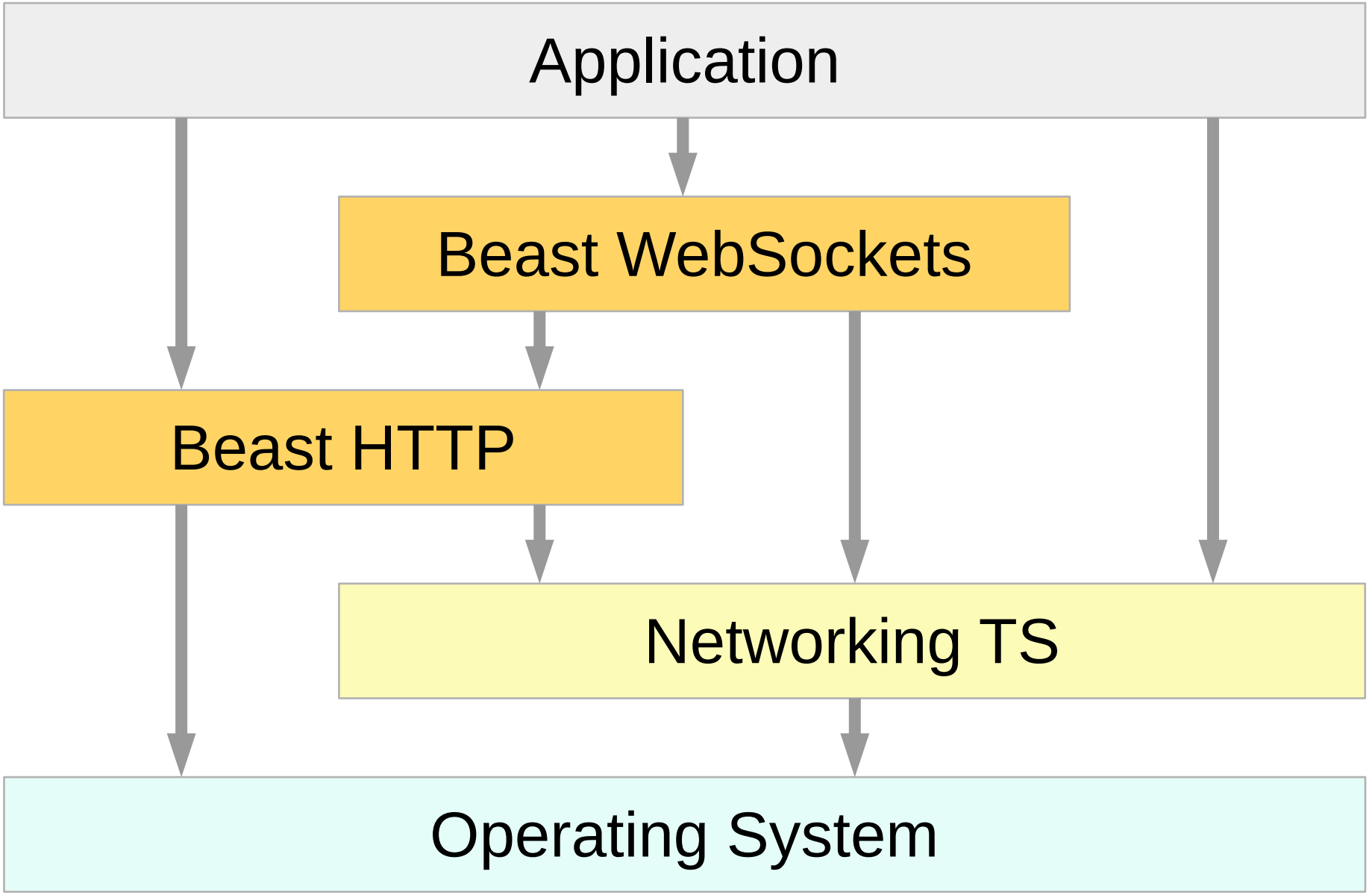
Server



HTTP Upgrade Response

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

API Layers


Application
Beast WebSockets
Beast HTTP
Networking TS
Operating System

Networking TS

Flavors

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

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

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// Declare a TCP/IP socket
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...

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

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

  const_buffer(
    void const*, size_t);

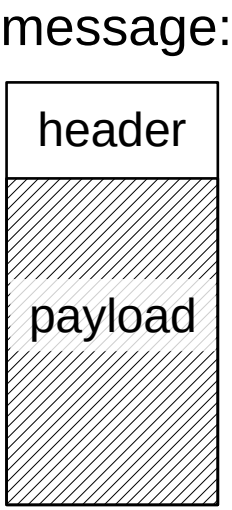
  const_buffer(
    mutable_buffer);

  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);
```



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
`X::value_type`	`T`	`T` is convertible to `const_buffer`.
`X::const_iterator`	`U`	`U` is a bidirectional iterator whose `reference` type is convertible to `const_buffer`.
`X(a)`	`X`	`X` is *CopyConstructible*. The copy will reference the same memory regions as the original sequence.
`a.begin();` `a.end();`	`const_iterator` or convertible to `const_iterator`	
`const_buffer` `mutable_buffer`		Also a *ConstBufferSequence*.

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
`X::value_type`	`T`	`T` is convertible to `mutable_buffer`.
`X::const_iterator`	`U`	`U` is a bidirectional iterator whose `reference` type is convertible to `mutable_buffer`.
`X(a)`	`X`	`X` is *CopyConstructible*. The copy will reference the same memory regions as the original sequence.
`a.begin();` `a.end();`	`const_iterator` or convertible to `const_iterator`	
`mutable_buffer`		Also a *MutableBufferSequence*.

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,
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// 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”);
```

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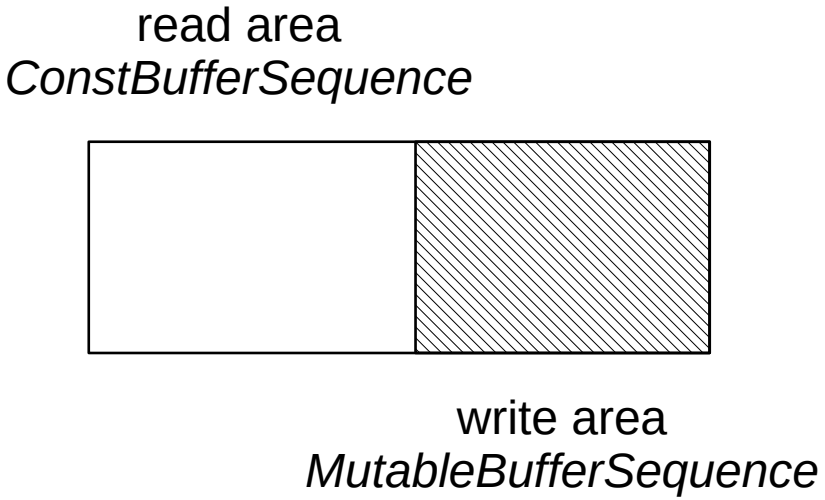
Buffers

```
// 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);
```

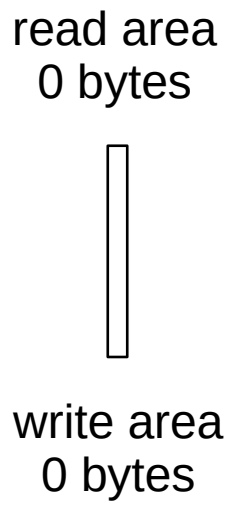
DynamicBuffer

- 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



DynamicBuffer

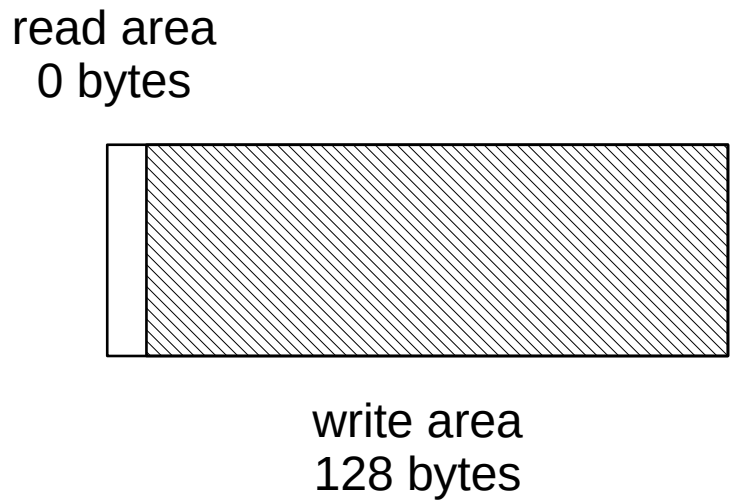
```
// X is a type meeting the requirements of DynamicBuffer
X a;
```



DynamicBuffer

```
X a;

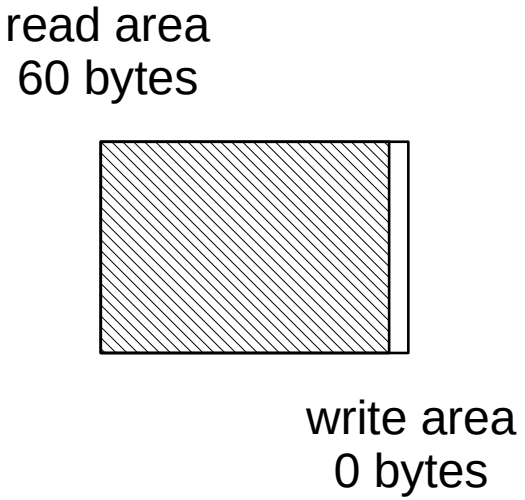
// Resize the write area and read into it
auto bytes_transferred = sock.read_some(a.prepare(128));
```



DynamicBuffer

```
X a;
auto bytes_transferred = sock.read_some(a.prepare(128));

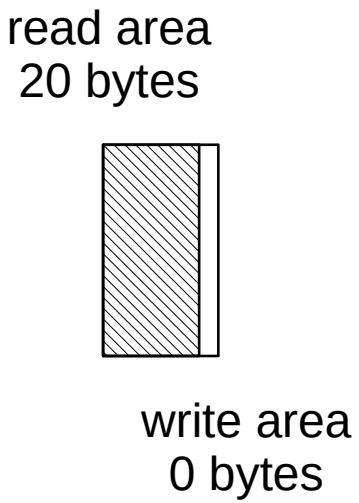
// Move bytes from the write area to the read area
a.commit(bytes_transferred);
```



DynamicBuffer

```
X a;
auto bytes_transferred = sock.read_some(a.prepare(128));
a.commit(bytes_transferred);

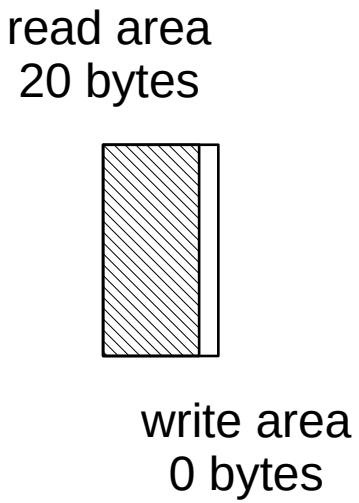
// Process data in the read area
auto bytes_used = process(a.data());
```



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

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```

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(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

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// 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(); });
```

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// 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`	• Fastest • Limited capacity • Implicit strand	Easiest to write
multi-threaded, single `io_context`	• Highest capacity • Explicit strand	More capacity, but more overhead
multi-threaded, `io_context` per thread	• 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

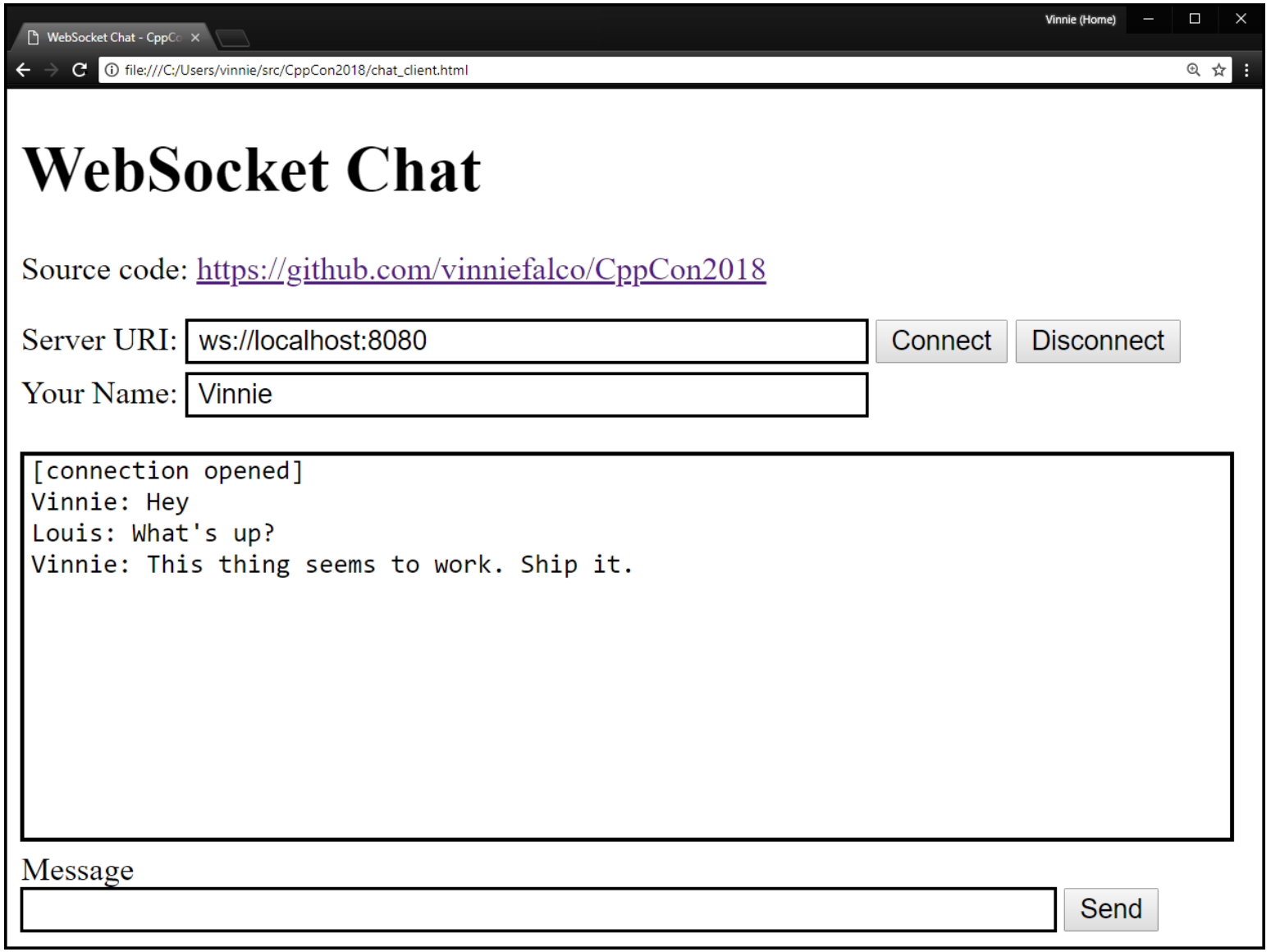
```
void
websocket_session::
fail(error_code ec, char const* what)
{
   // Don't report these
   if(ec == net::error::operation_aborted ||
       ec == websocket::error::closed)
      return;

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

Chat Server

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

Chat Client

Chat Client

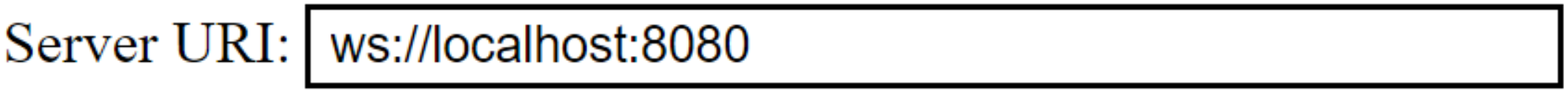

WebSocket Chat - CppCo
Vinnie (Home)
file:///C:/Users/vinnie/src/CppCon2018/chat_client.html
WebSocket Chat
Source code: https://github.com/vinniefalco/CppCon2018
Server URI: ws://localhost:8080
Connect
Disconnect
Your Name: Vinnie
[connection opened]
Vinnie: Hey
Louis: What's up?
Vinnie: This thing seems to work. Ship it.
Message
Send

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">
```



Chat Client

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

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

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>
```

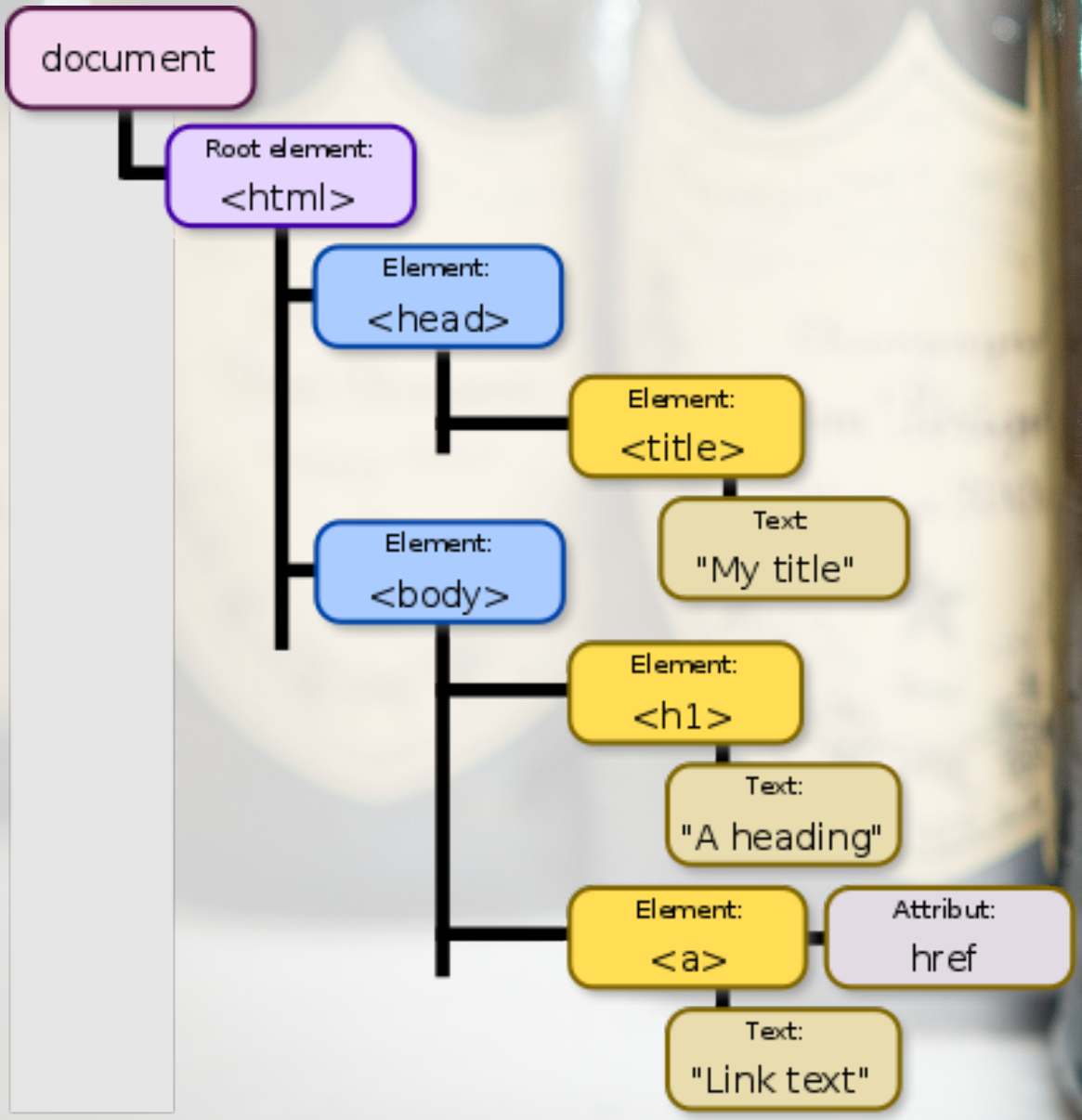
Message

Send


Dom PERIGNON · MILLÉSIME
Altum villare
Champagne
Dom Pérignon
Vintage 2004
Sparkling Wine
Vin Mousseux
Brut
750ml
12.5% alc./vol.

DOM

Document Object Model

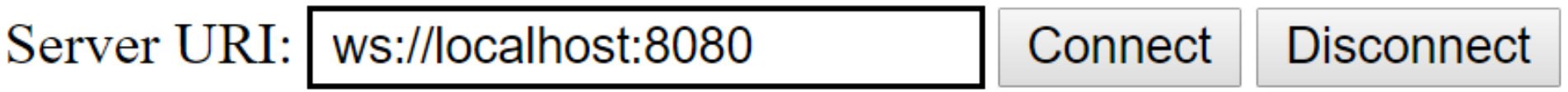



DANGER!


DANGER!
JavaScript ahead!

Chat Client

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

      ...

   };
</script>
```



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

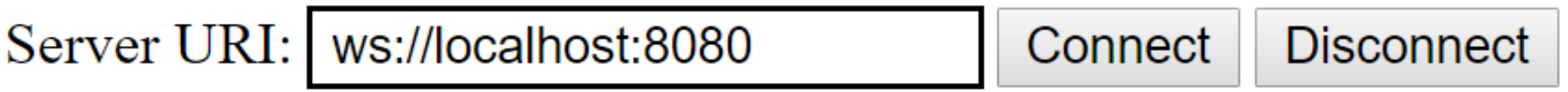
```
connect.onclick = function() {
   ...

   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();
};
```

---

id="disconnect"



Chat Client

```
...

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

Chat Client

```
    ...

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

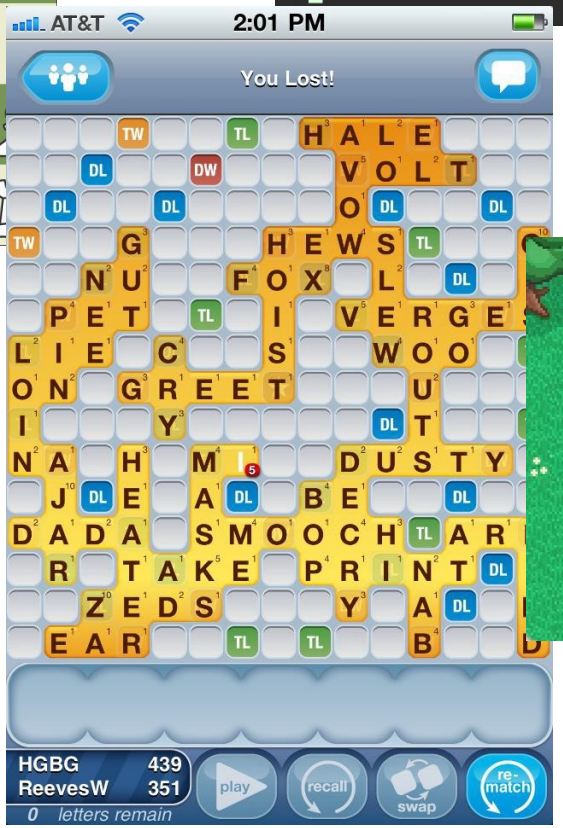
Chat Client

```
<script>
  var ws = null;

  connect.onclick = function() {
    ws = new WebSocket(uri.value);
    ws.onopen = function(ev) {
      messages.innerText += "[connection opened]\n";
    };
    ws.onclose = function(ev) {
      messages.innerText += "[connection closed]\n";
    };
    ws.onmessage = function(ev) {
      messages.innerText += ev.data + "\n";
    };
    ws.onerror = function(ev) {
      messages.innerText += "[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>
```

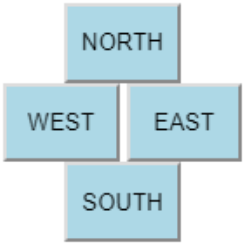
Epilogue

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 docmentation
- 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/
```