Solid C++ code by example

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Sometimes you see code that is perfectly OK according to the definition of the language, but which is flawed because it breaks too many established idioms and conventions. On the other hand, a solid piece of code is something that looks like it is written by an experienced person who cares about professionalism in programming.

This will be an interactive discussion about good vs bad C++ code. We will discuss simple C++ idioms and coding conventions, but we will also touch upon best practices when working with C++ in large codebases with lots of developers with mixed skills.

A 90 minute presentation at the ACCU conference
Oxford, April 13-16 2011

Disclaimer I: the is basically a rerun of the talk I did at ACCU 2010, 80-90% of the material is the same. However, the audience is not the same, so discussions might provide 80-90% new insight...

Disclaimer II: there are some issues that we do not address properly here (at least 3). They are left as an exercise for the reader. Email me if you find them, or if you want to know more!

~/myprog/foo.hpp

```
namespace bar {
  class Foo {
    int _value;
    int my_magic(int a, int b);
  public:
    Foo(int seed);
    int calc(int number = 7);
    int getValue() {
      return _value;
    }
    void print(char* prefix);
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}
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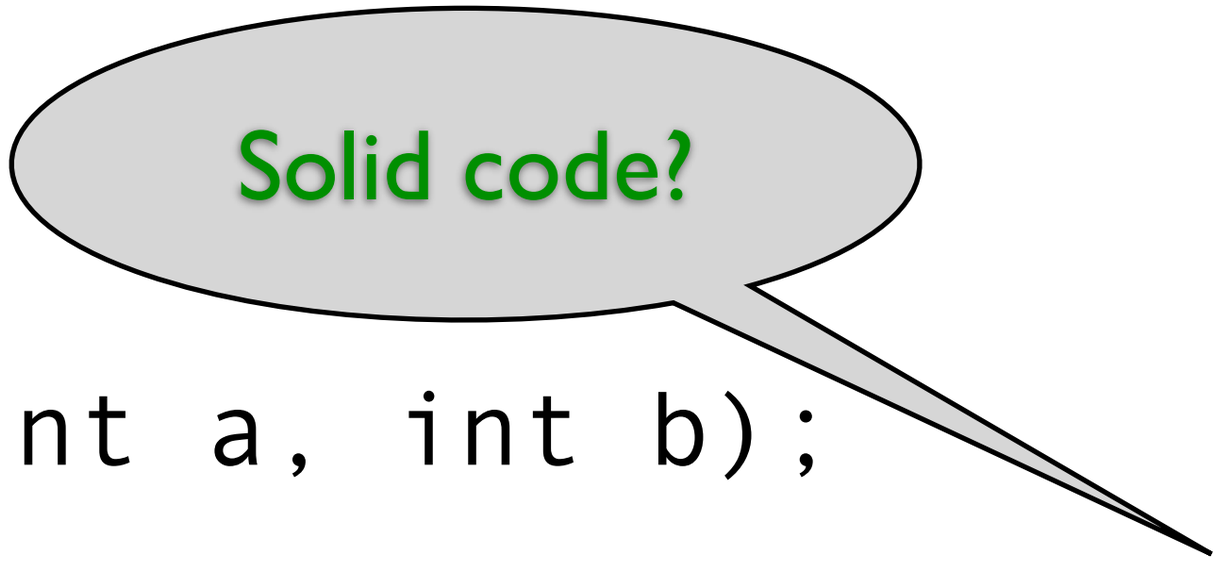

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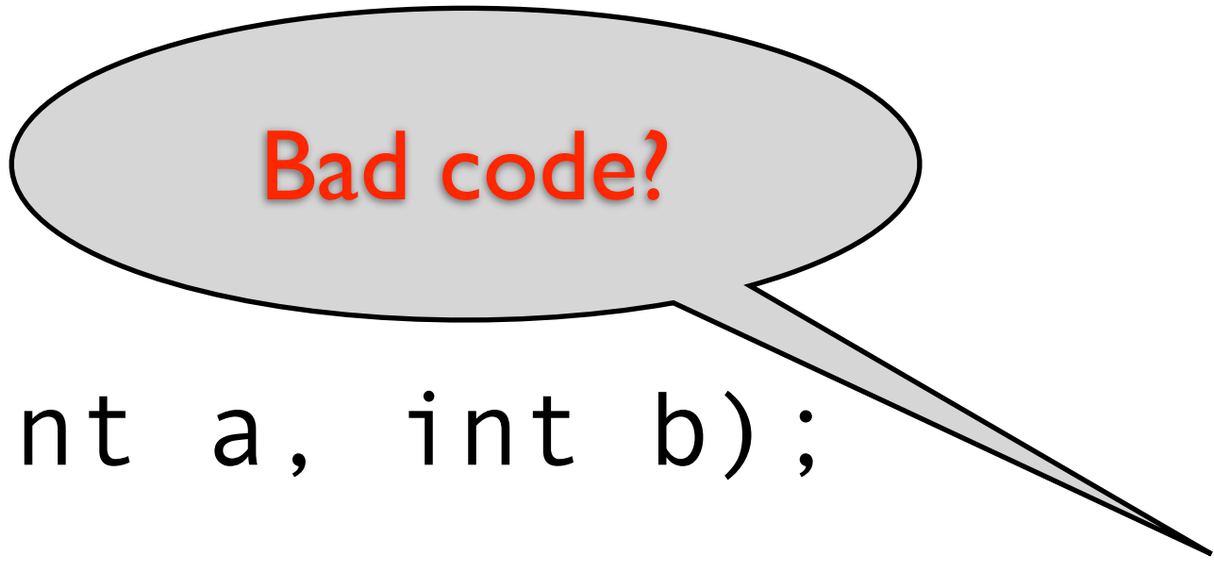

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}
```

PAL - a Primitive Authentication Library in C++ for educational purposes

http://github.com/olvemaudal/pal

(from the README file)

Here is the main "use story":

As a client, when prompted for ntlm authentication by the server, I want a tool/library that can help me to create the initial ntlm **request** (type 1 message) that I can send to the server to receive a **challenge** (type 2 message) that needs to be solved by applying my username and password to create an ntlm **response** that I can send to the server. (phew...)

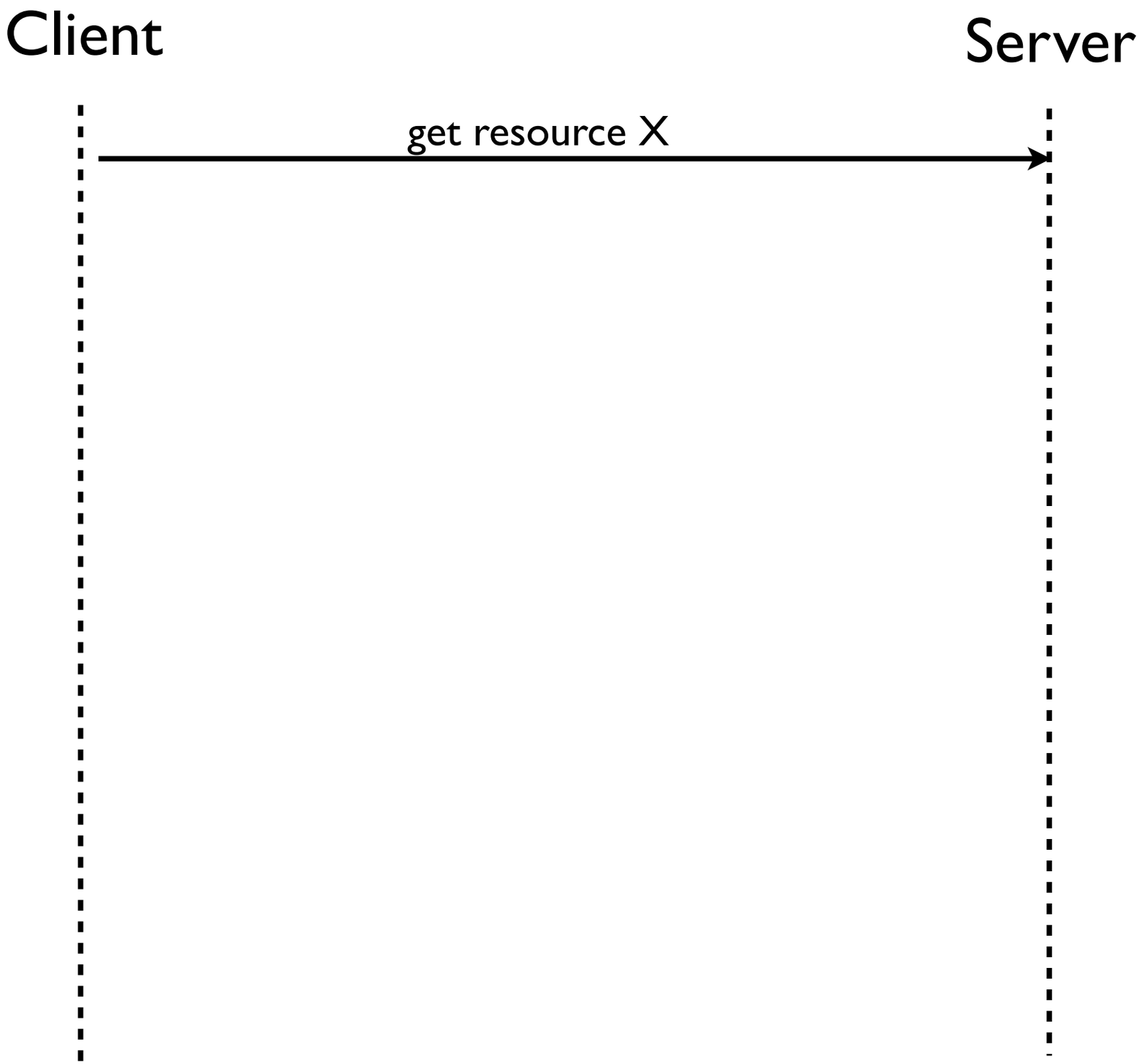
Here are some (imaginary) additional requirements:
- target typically an embedded system
- it should be possible and convenient to create a <100kb client using the PAL library
- must use C++ (due to PHB decision)
- due to compiler support, tr1 and boost can not be used
- initally the library will only be used to communicate HTTP with a Windows 2003 Server SP2, currently no need to support other servers

The NTLM Protocol (simplified)

Client

Server

The NTLM Protocol (simplified)



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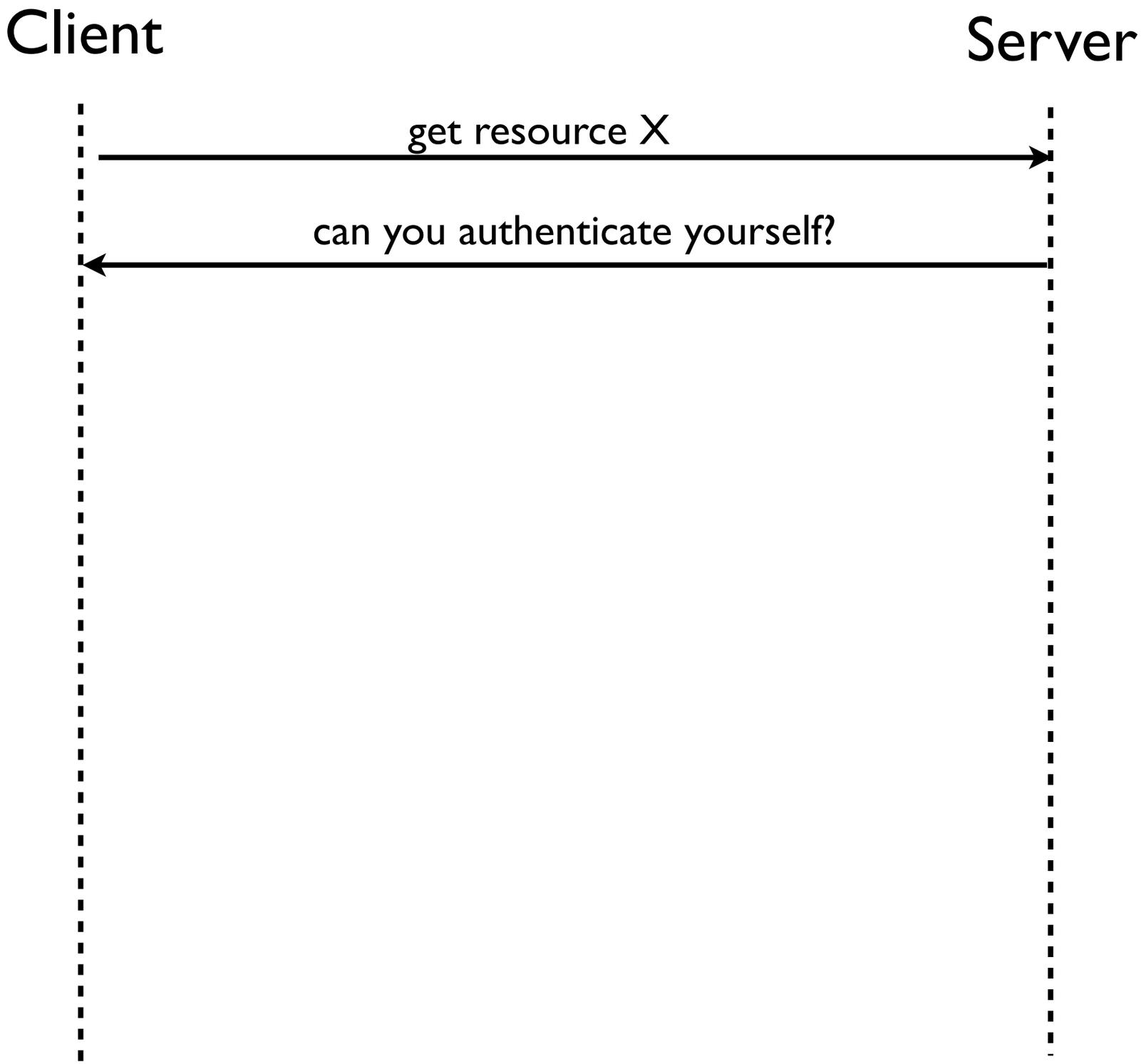

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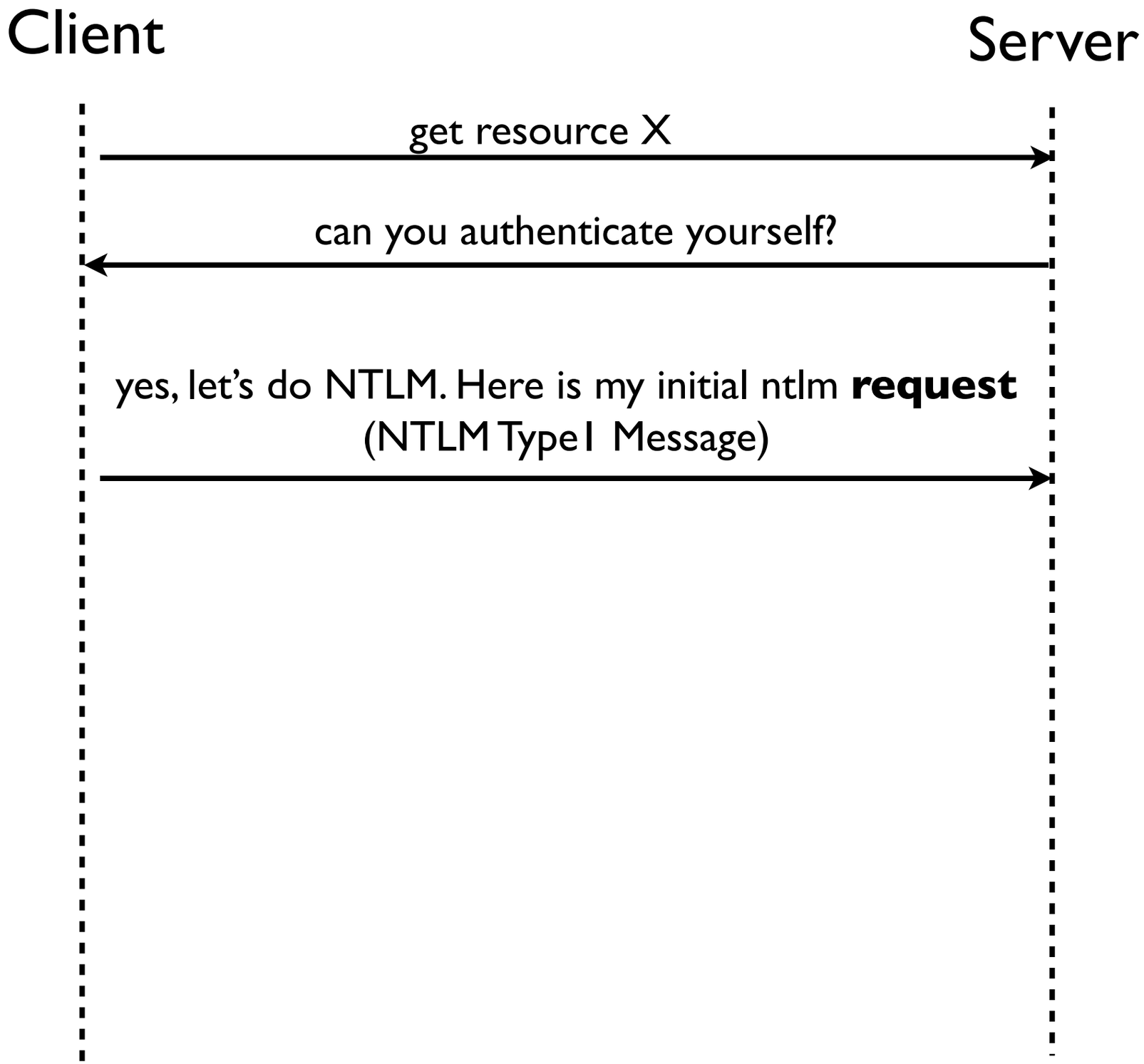

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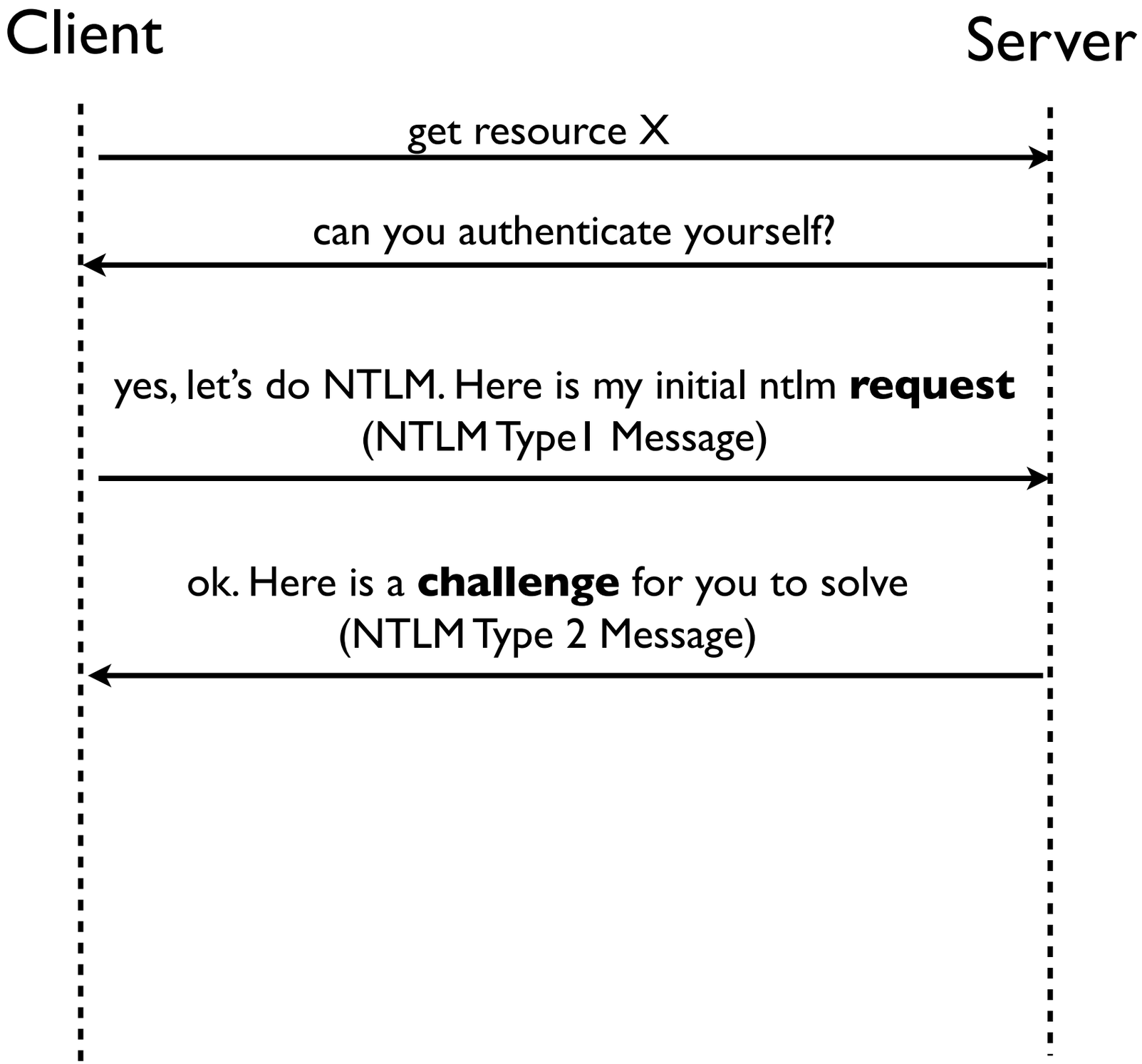

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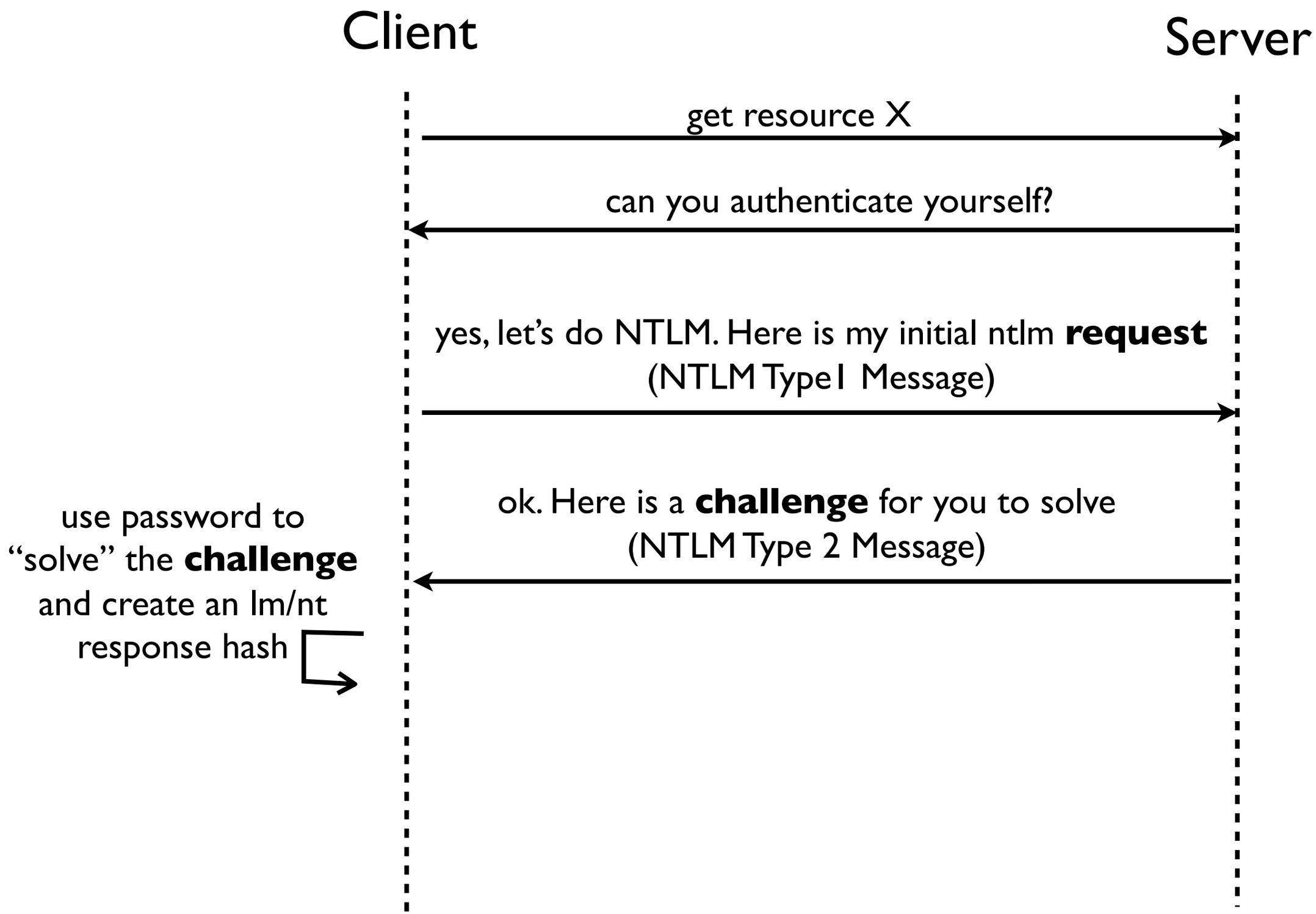

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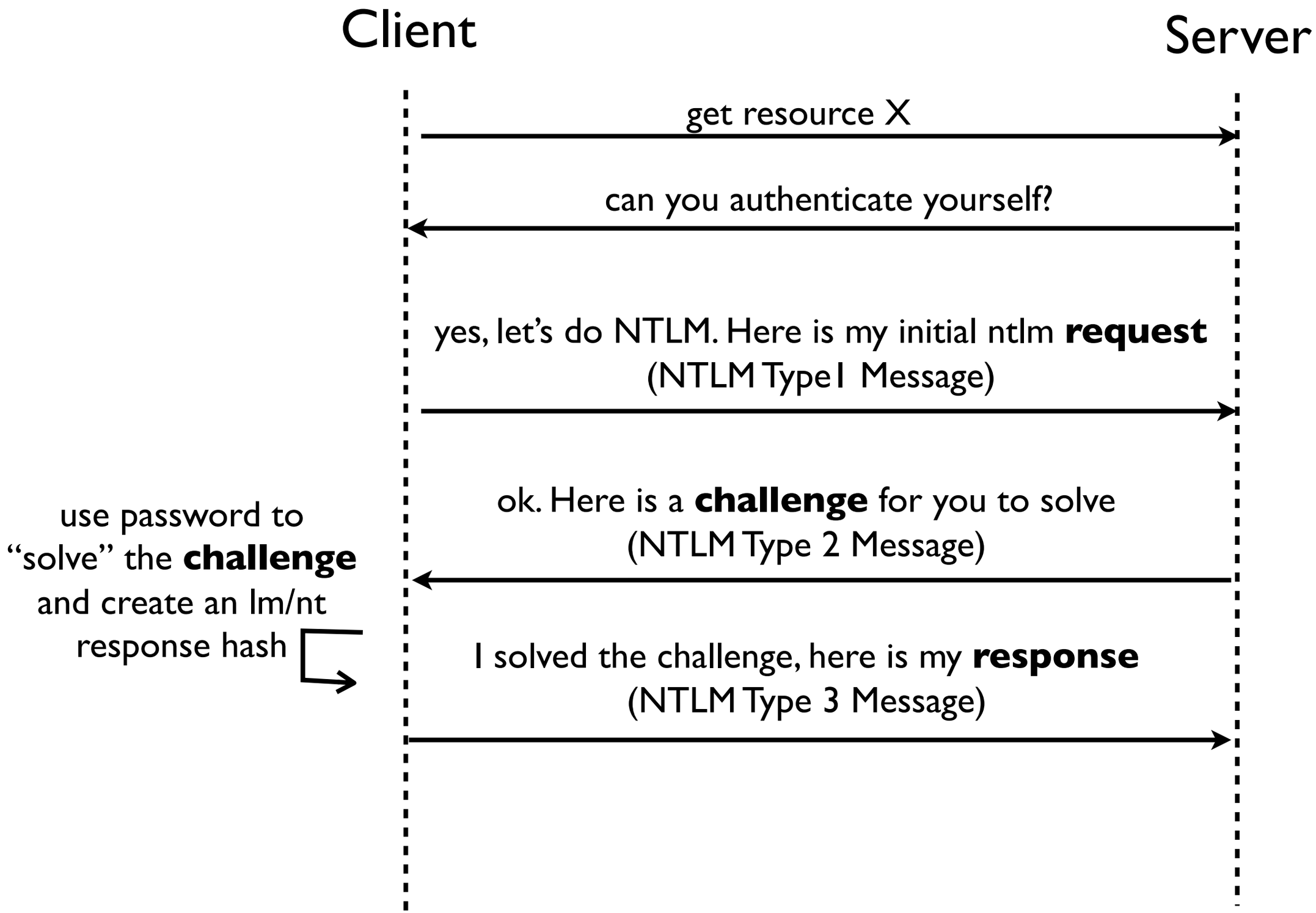

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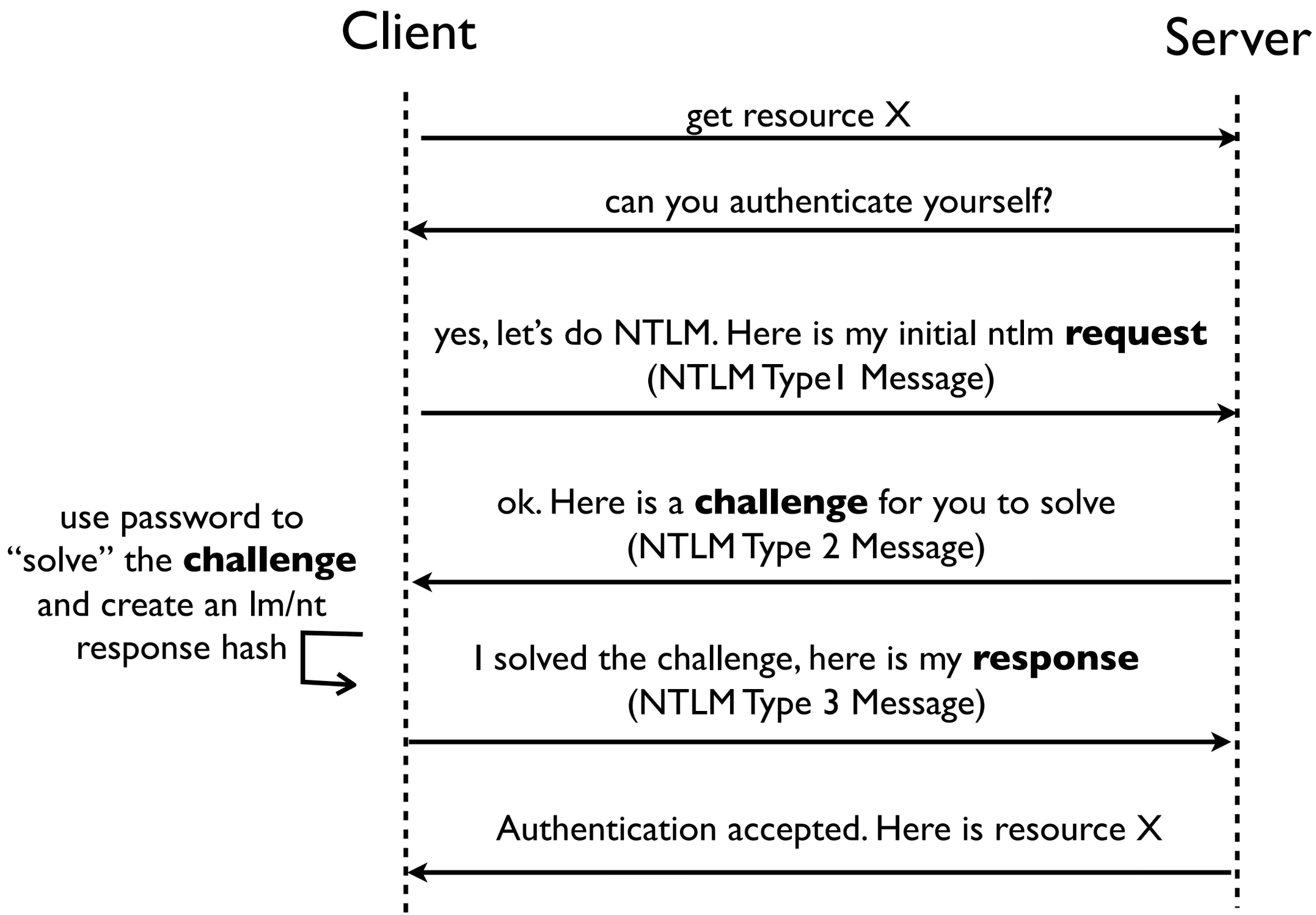
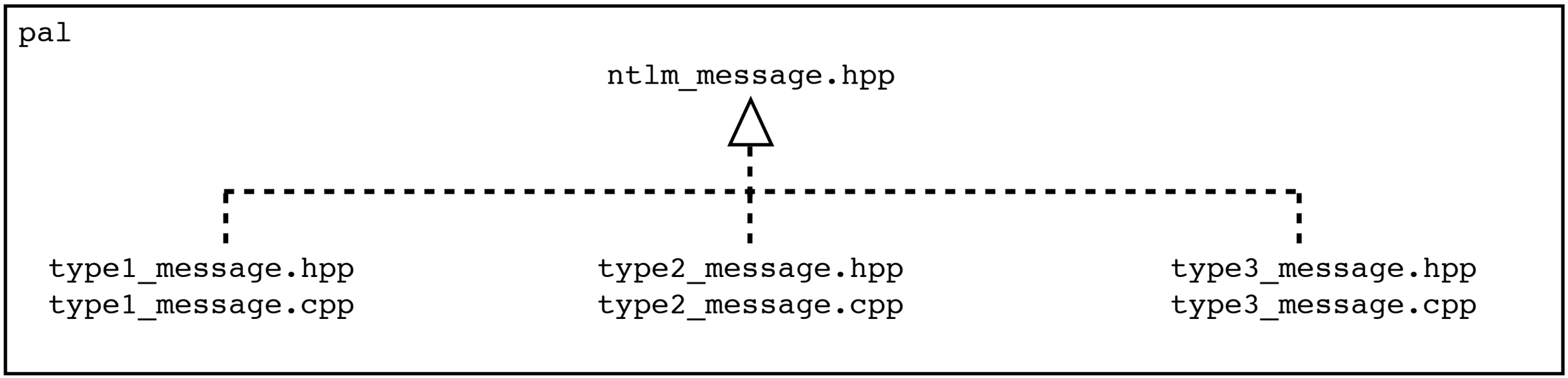


Code under discussion



***Note**: the code under discussion compiles just fine and does exactly what it is supposed to do... but can you suggest improvements?*

Study code....

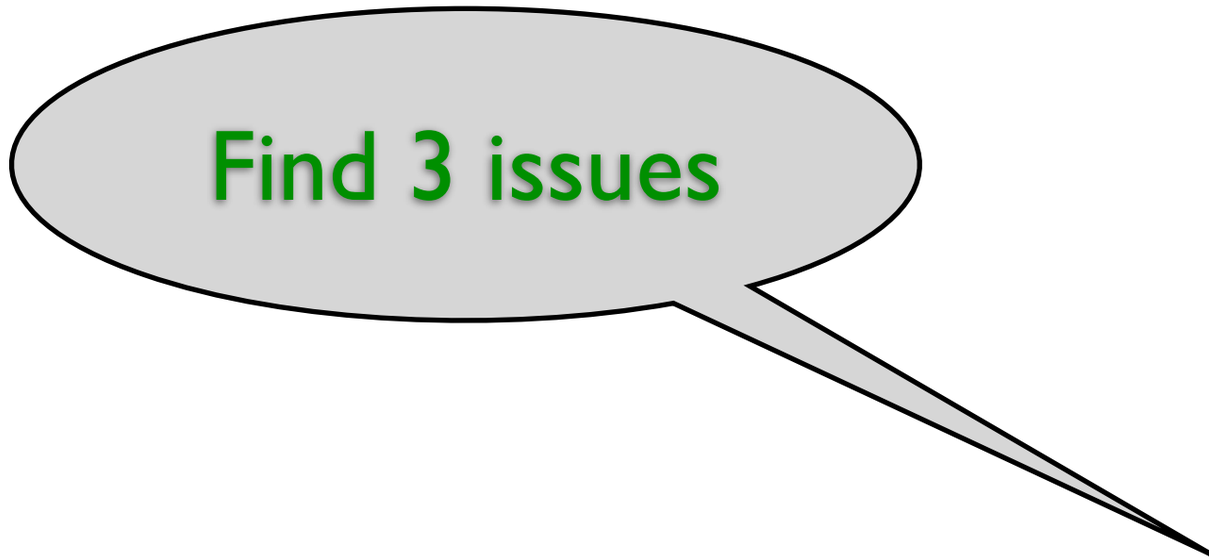
ntlm_message.hpp

```
#include <vector>

namespace pal {

    class ntlm_message {
    public:
        virtual std::vector<uint8_t> as_bytes() const = 0;
    };

}
```

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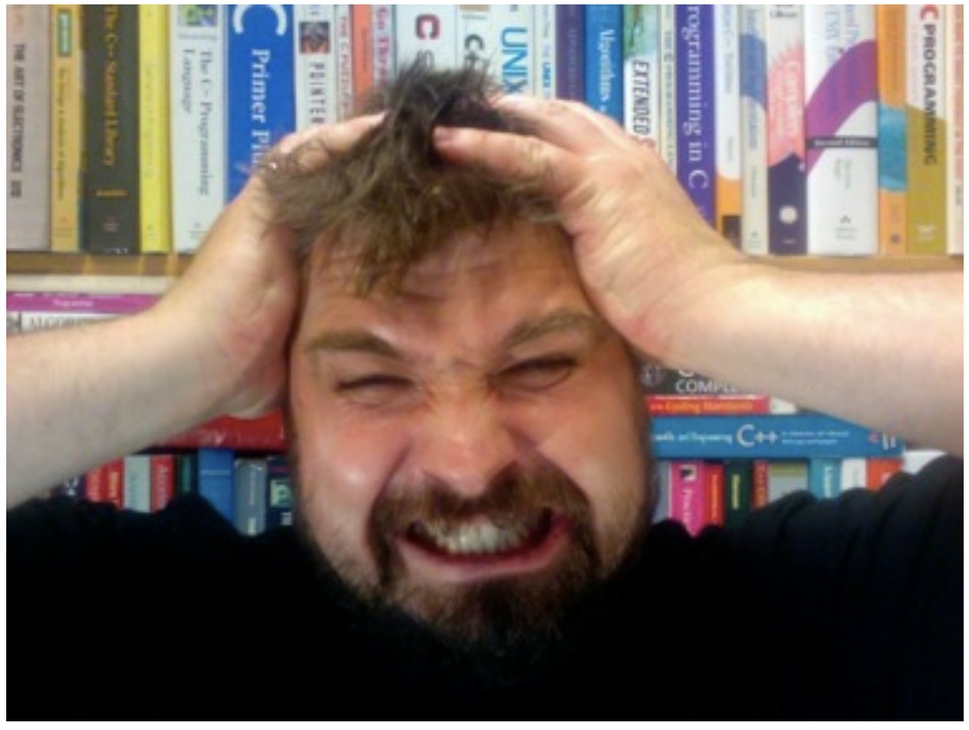

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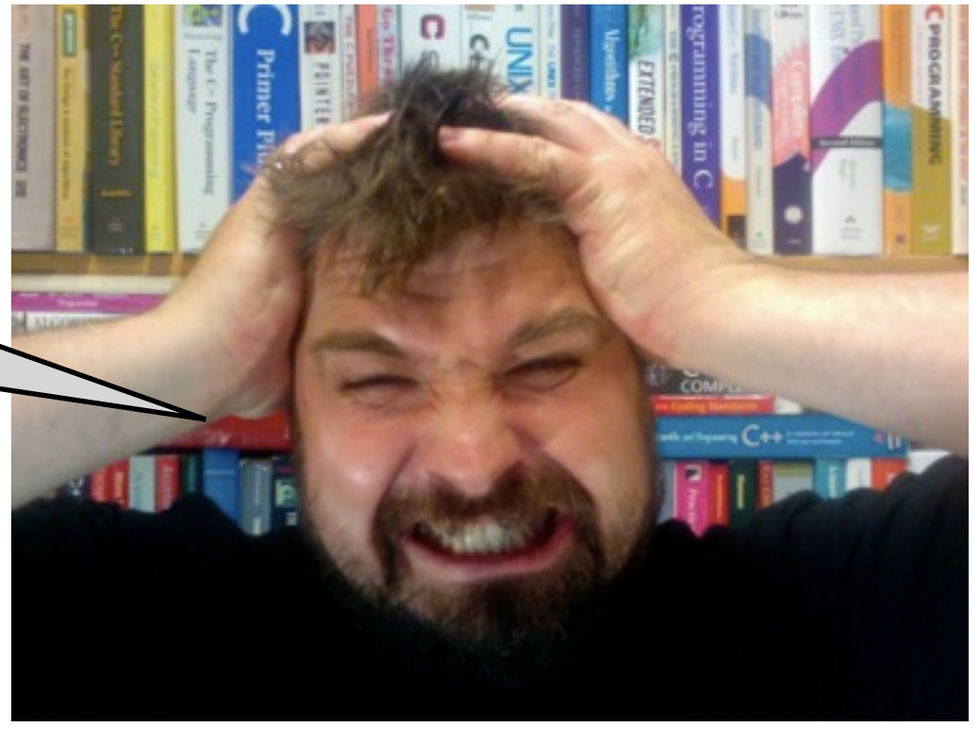
}
```

WTF? This class must have a virtual destructor!



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    class ntlm_message {
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    };

}
```

missing header guard

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namespace pal {

    class ntlm_message {
    public:
        virtual std::vector<uint8_t> as_bytes() const = 0;
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}
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namespace pal {

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    };

}
```

should include <stdint.h>

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namespace pal {

    class ntlm_message {
    public:
        virtual std::vector<uint8_t> as_bytes() const = 0;
    };

}
```

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#ifndef PAL_NTLM_MESSAGE_HPP_INCLUDED
#define PAL_NTLM_MESSAGE_HPP_INCLUDED

#include <vector>

namespace pal {

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#endif
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    public:
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}

#endif
```

This is Solid C++!

type1_message.hpp

```
#ifndef PAL_TYPE1_MESSAGE_HPP_INCLUDED
#define PAL_TYPE1_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <vector>

namespace pal {

    class type1_message : public ntlm_message {
        uint32_t ssp_flags_;
    public:
        type1_message(uint32_t ssp_flags);
        virtual std::vector<uint8_t> as_bytes() const;
    };

}

#endif
```

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#ifndef PAL_TYPE1_MESSAGE_HPP_INCLUDED
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namespace pal {

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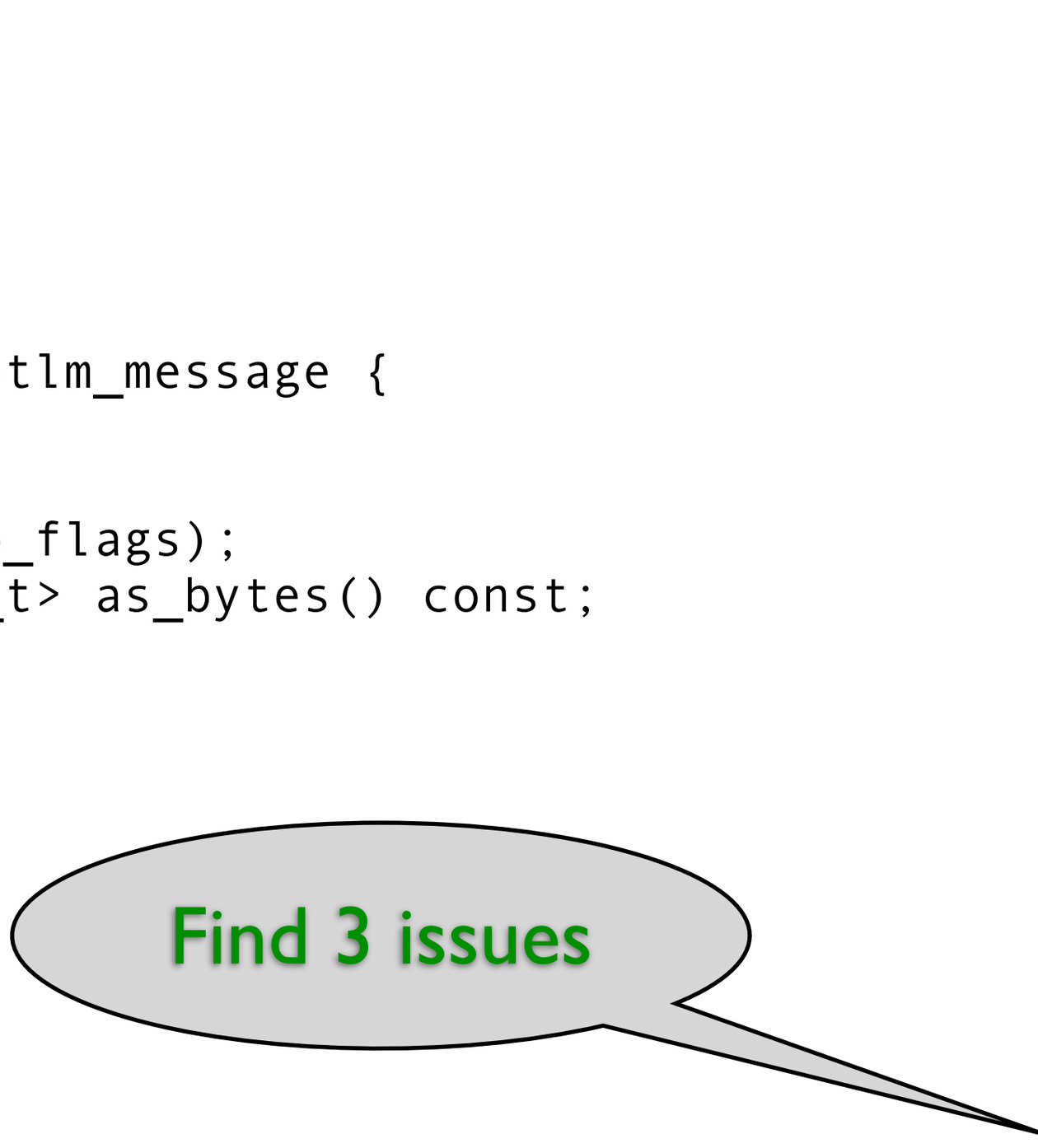

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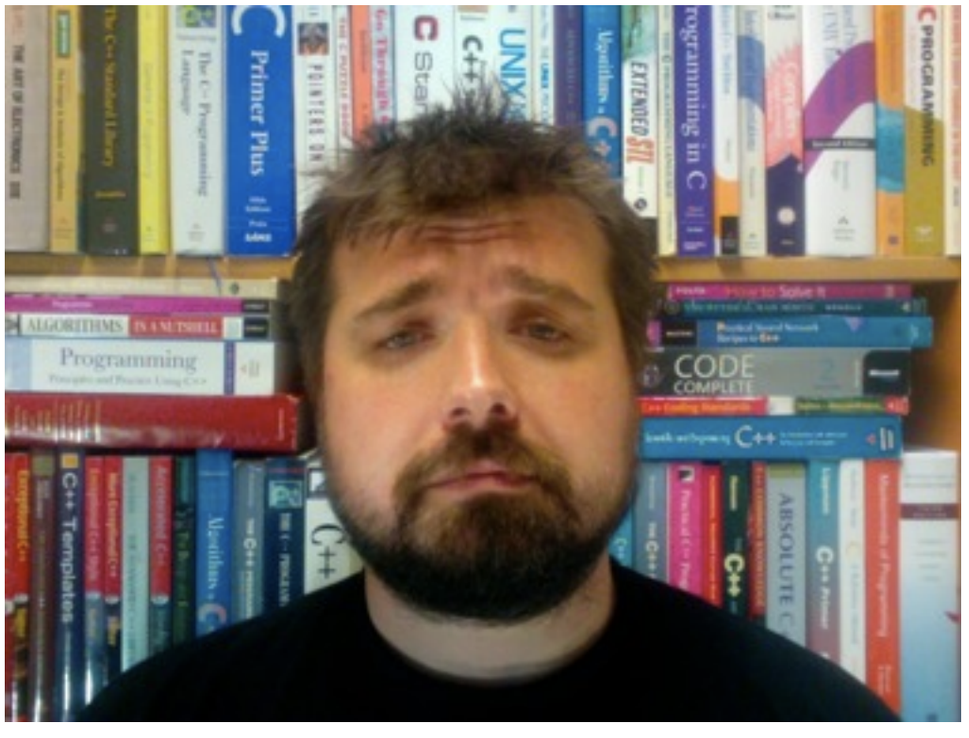

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single argument constructors should nearly always have the `explicit` specifier

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    public:
        explicit type1_message(uint32_t ssp_flags);
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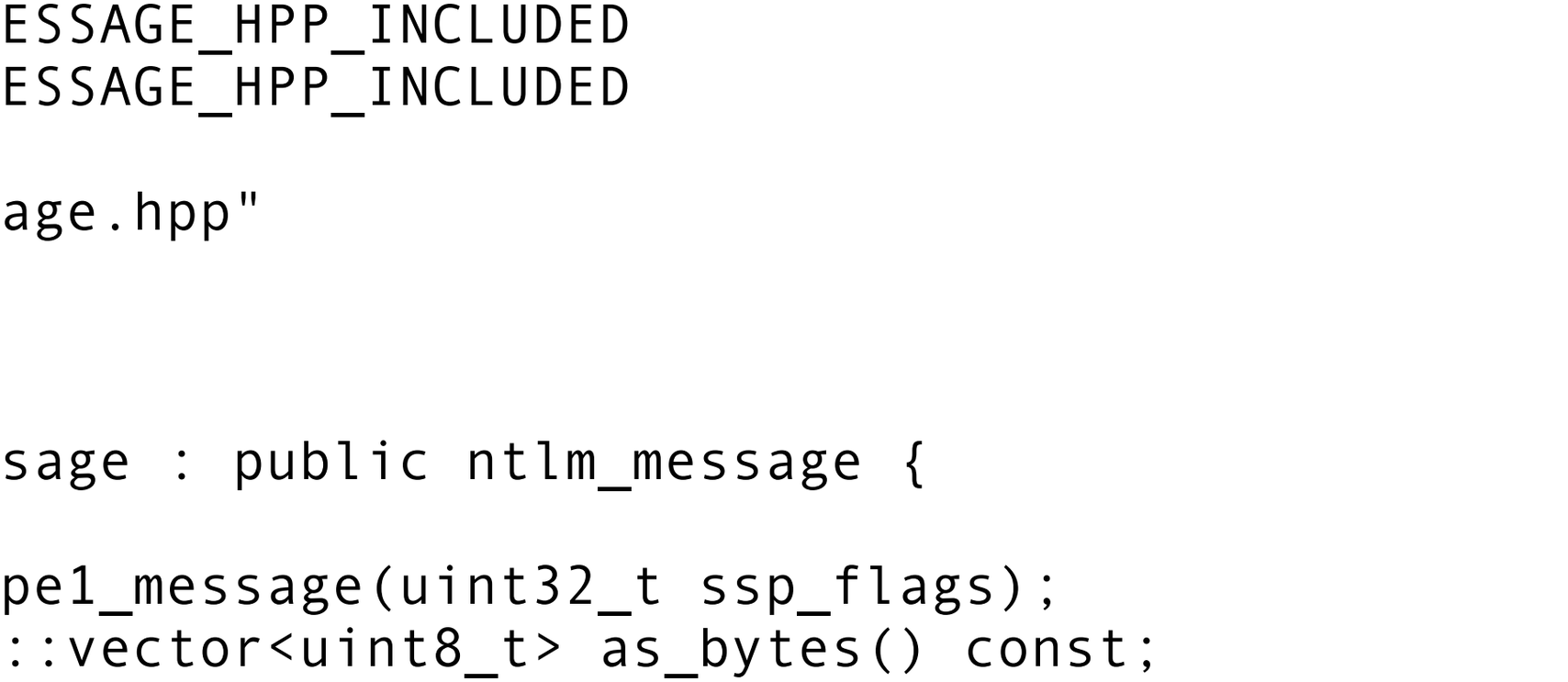

type1_message.cpp

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 *  (16) Supplied Domain (optional)        (security buffer)
 *  (24) Supplied Workstation (optional)   (security buffer)
 *  (32) (start of datablock) if required
 */

using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

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#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
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 */
```

Find at least 3 issues here

```
using namespace std;

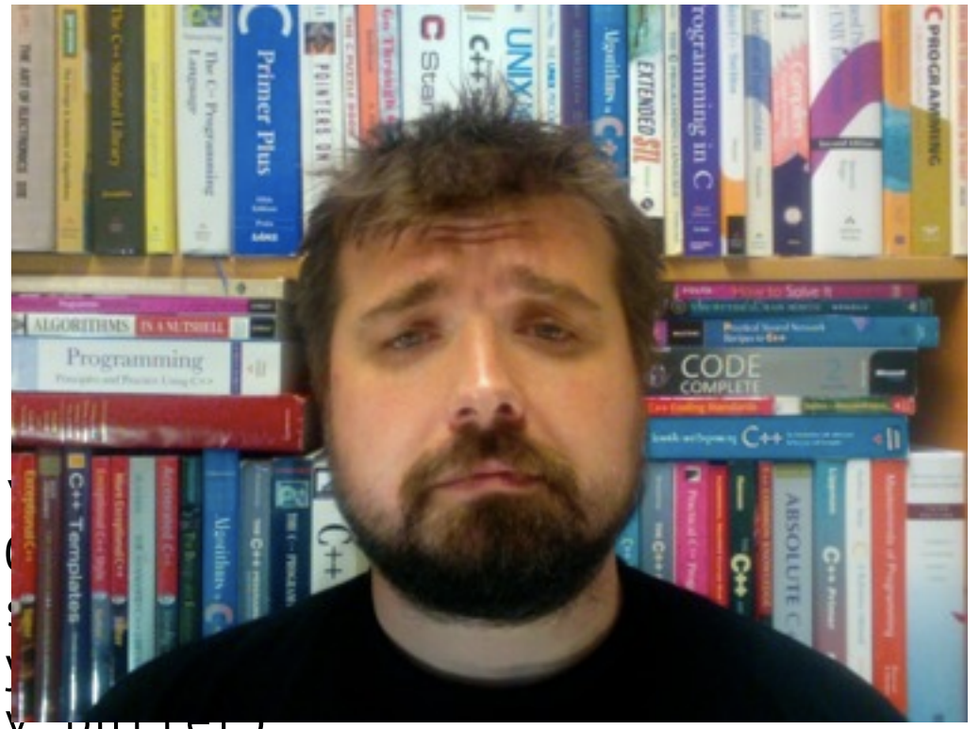
pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                          "NTLMSSP
 *    8  NTLM Message Type                          {0x01,0x
 *   12  Flags                                      uint32 a
 * (16) Supplied Domain (optional)                  (security
 * (24) Supplied Workstation (optional)             (security buffer)
 * (32) (start of datablock) if required
 */
```




```
using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
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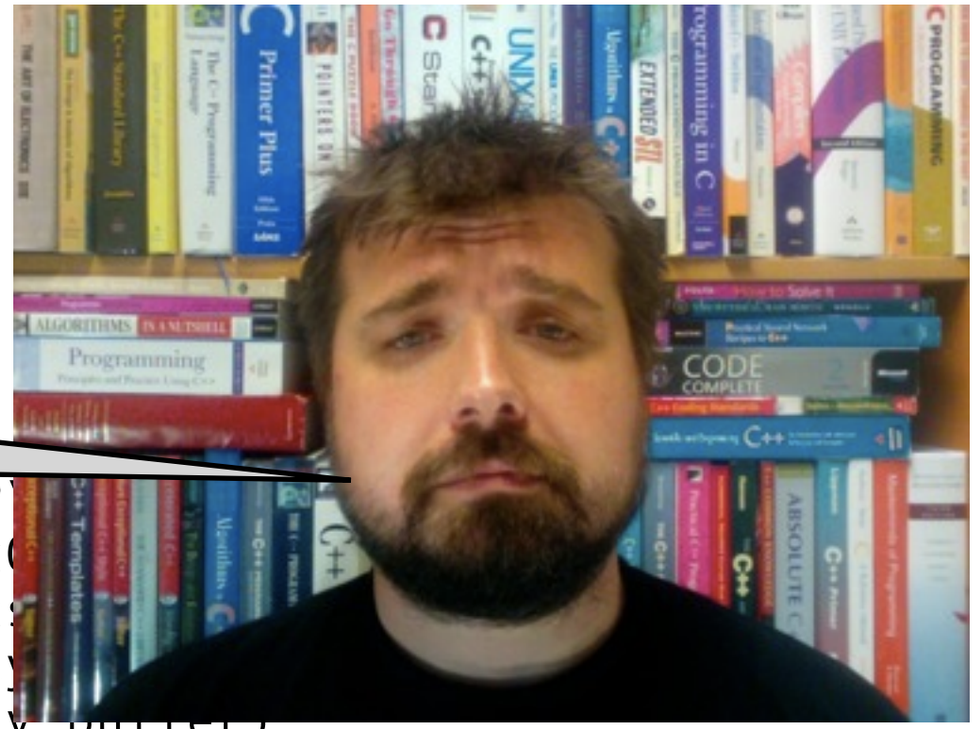
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"
```

focus on readability;
importing a namespace might save some keystrokes, but often it does not increase readability




```
m.html

NTLMSSP
0x01,0x0
uint32 a
(security
(security buffer)

 * (24) Supplied Workstation (optional)
 * (32) (start of datablock) if required
 */

using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
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vector<uint8_t> pal::type1_message::as_bytes() const
{
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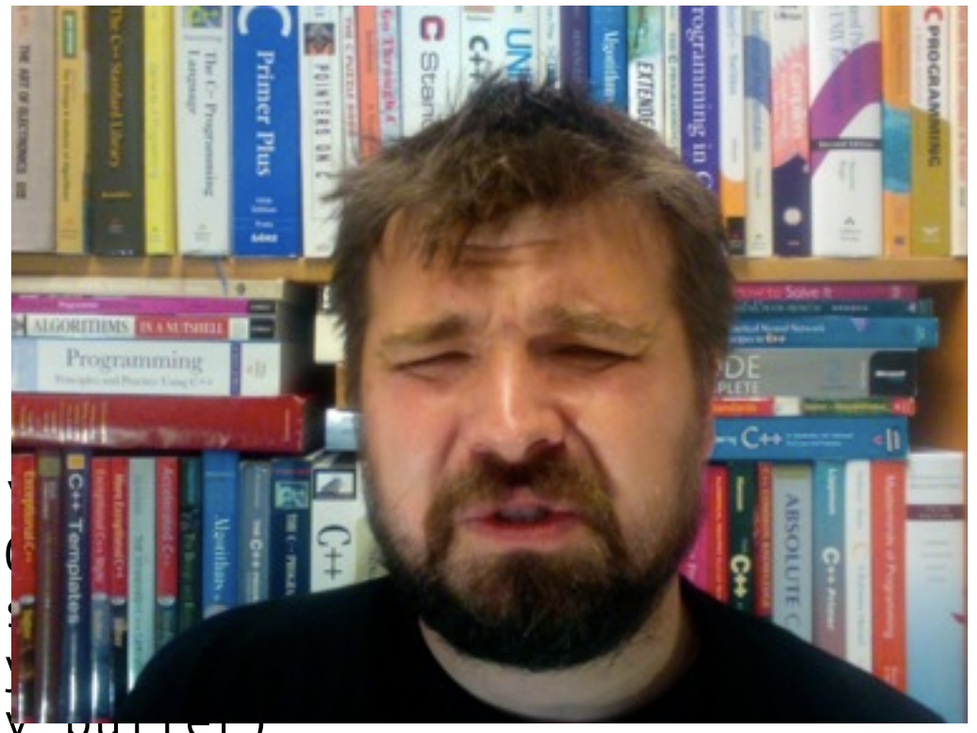
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                          "NTLMSSP
 *    8  NTLM Message Type                          {0x01,0x
 *   12  Flags                                      uint32 a
 * (16) Supplied Domain (optional)                  (security
 * (24) Supplied Workstation (optional)             (security buffer)
 * (32) (start of datablock) if required
 */
```




```
using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
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vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "to

/*
 * See http://davenport
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                "NTLMSSP
 *    8  NTLM Message Type                {0x01,0x0
 *   12  Flags                            uint32 as
 * (16) Supplied Domain (optional)        (security
 * (24) Supplied Workstation (optional)   (security buffer)
 * (32) (start of datablock) if required
 */
```

use the initializer list

```
using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
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        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                    "NTLMSSP
 *    8  NTLM Message Type                    {0x01,0x
 *   12  Flags                                uint32 a
 * (16) Supplied Domain (optional)            (security
 * (24) Supplied Workstation (optional)       (security buffer)
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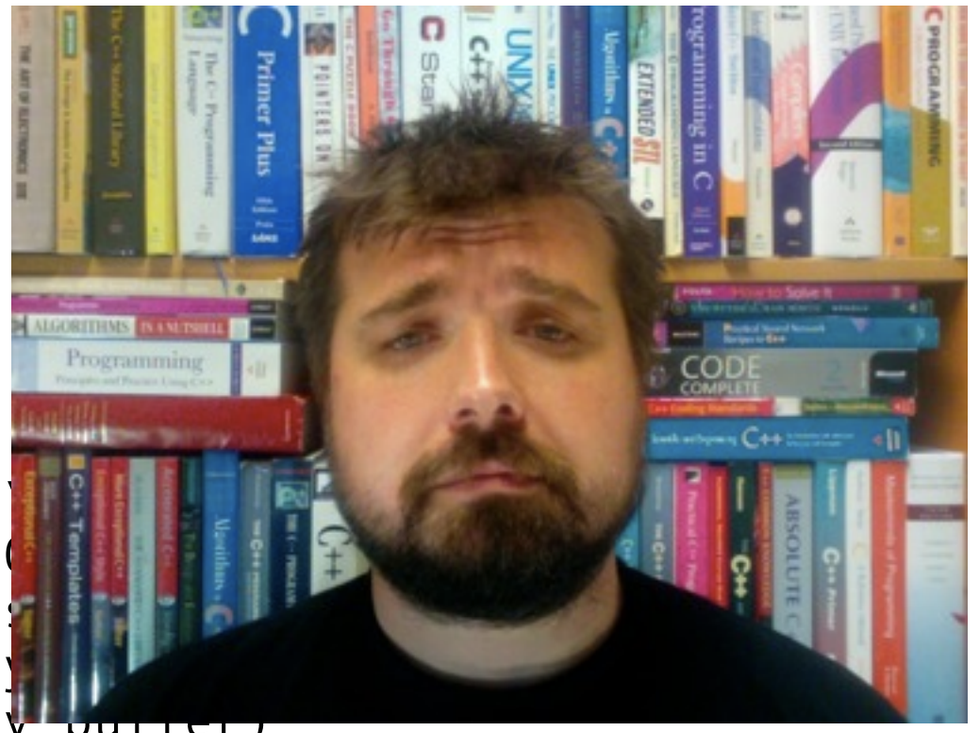
 */
```




```
using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
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vector<uint8_t> pal::type1_message::as_bytes() const
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    uint8_t message[16] = {
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        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tool

/*
 * See http://
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                "NTLMSSP
 *    8  NTLM Message Type                {0x01,0x0
 *   12  Flags                            uint32 as
 * (16) Supplied Domain (optional)        (security
 * (24) Supplied Workstation (optional)   (security buffer)
 * (32) (start of datablock) if required
 */
```

use std::size_t when appropriate

```
using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
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    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 *  (16) Supplied Domain (optional)        (security buffer)
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    return vector<uint8_t>(message, message + sizeof message);
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```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
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 * See http://davenport.sourceforge.net/ntlm.html
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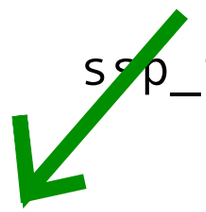

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```
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    };
    const std::size_t ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
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}
```

```
#include "type1_message.hpp"

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/*
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    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
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}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
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    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return std::vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 * (16) Supplied Domain (optional)        (security buffer)
 * (24) Supplied Workstation (optional)   (security buffer)
 * (32) (start of datablock) if required
 */


pal::type1_message::type1_message(uint32_t ssp_flags)
    : ssp_flags_(ssp_flags)
{
}

std::vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
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 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 *  (16) Supplied Domain (optional)        (security buffer)
 *  (24) Supplied Workstation (optional)   (security buffer)
 *  (32) (start of datablock) if required
 */


pal::type1_message::type1_message(uint32_t ssp_flags)
    : ssp_flags_(ssp_flags)
{
}

std::vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const std::size_t ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return std::vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 * (16) Supplied Domain (optional)        (security buffer)
 * (24) Supplied Workstation (optional)   (security buffer)
 * (32) (start of datablock) if required
 */

pal::type1_message::type1_message(uint32_t ssp_flags)
    : ssp_flags_(ssp_flags)
{
}

std::vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const std::size_t ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return std::vector<uint8_t>(message, message + sizeof message);
}
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 * Type 1 Message
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 */
```

```
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    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const std::size_t ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return std::vector<uint8_t>(message, message + sizeof message);
}
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenpo
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                    "NTLMSS
 *    8  NTLM Message Type                    {0x01,0x0
 *   12  Flags                                uint32 as
 * (16) Supplied Domain (optional)            (security
 * (24) Supplied Workstation (optional)       (security buffer)
 * (32) (start of datablock) if required
 */
```

```
pal::type1_message::type1_message(uint32_t ssp_flags)
    : ssp_flags_(ssp_flags)
{
}

std::vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const std::size_t ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return std::vector<uint8_t>(message, message + sizeof message);
}
```

type2_message.hpp

```
#ifndef PAL_TYPE2_MESSAGE_HPP_INCLUDED
#define PAL_TYPE2_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

using namespace std;

namespace pal {

    class type2_message : public ntlm_message {
    public:
        explicit type2_message(vector<uint8_t> buffer);
        virtual vector<uint8_t> as_bytes() const;
        uint32_t ssp_flags();
        uint64_t challenge();
    private:
        const vector<uint8_t> buffer_;
    };

}

#endif
```

Find 3 issues

```
#ifndef PAL_TYPE2_MESSAGE_HPP_INCLUDED
#define PAL_TYPE2_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

using namespace std;

namespace pal {

    class type2_message : public ntlm_message {
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#endif
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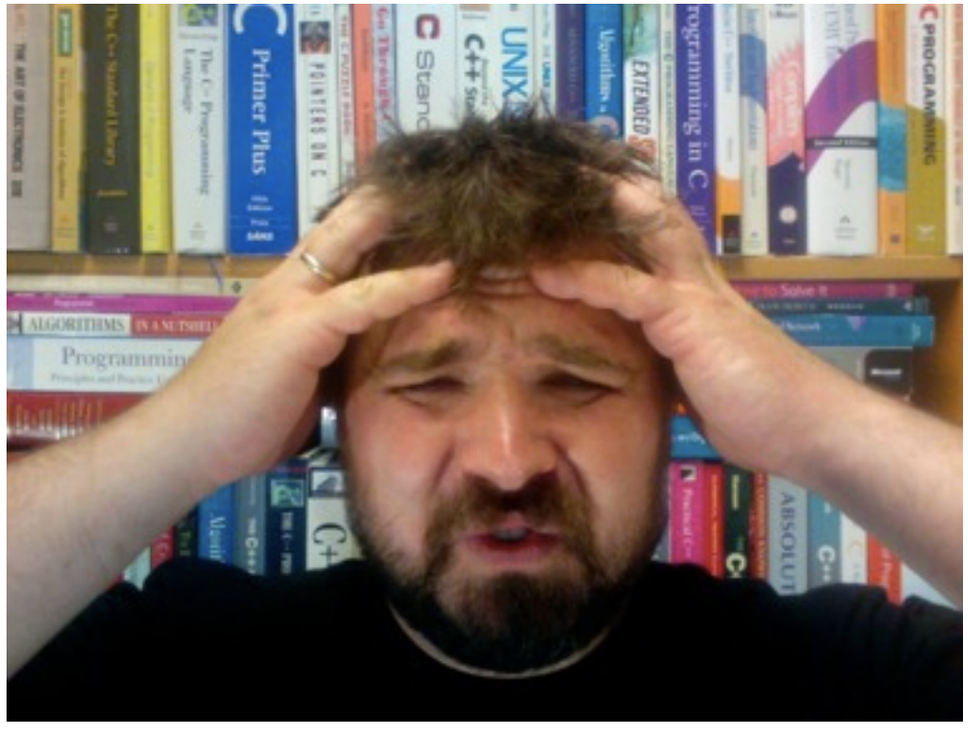
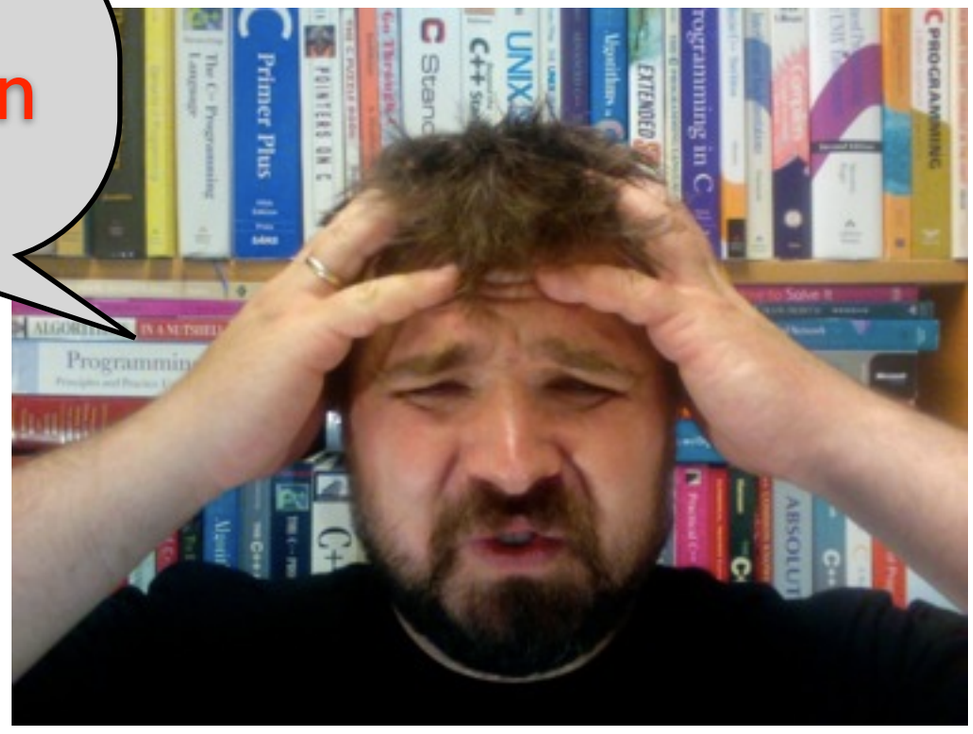
        uint64_t challenge();
    private:
        const vector<uint8_t> buffer_;
    };

}

#endif
```



Ouch, do not import namespaces in header files!



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        explicit type2_message(vector<uint8_t> buffer);
        virtual vector<uint8_t> as_bytes() const;
        uint32_t ssp_flags();
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        explicit type2_message(vector<uint8_t> buffer);
        virtual vector<uint8_t> as_bytes() const;
        uint32_t ssp_flags();
        uint64_t challenge();
    private:
        const vector<uint8_t> buffer_;
    };

}

#endif
```

pass this vector as const &

```
#ifndef PAL_TYPE2_MESSAGE_HPP_INCLUDED
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namespace pal {

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    public:
        explicit type2_message(vector<uint8_t> buffer);
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    private:
        const vector<uint8_t> buffer_;
    };

}

#endif
```

this looks like query methods, they should probably be const

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#ifndef PAL_TYPE2_MESSAGE_HPP_INCLUDED
#define PAL_TYPE2_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

using namespace std;

namespace pal {

    class type2_message : public ntlm_message {
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        explicit type2_message(vector<uint8_t> buffer);
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        virtual      vector<uint8_t> as_bytes() const;
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        explicit type2_message(std::vector<uint8_t> buffer);
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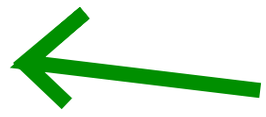
    private:
        const std::vector<uint8_t> buffer_;
    };

}

#endif
```



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        uint32_t ssp_flags() const;
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    private:
        const std::vector<uint8_t> buffer_;
    };

}

#endif
```

type2_message.cpp

... page 1 of 2

```
#include <cstddef>
#include <algorithm>
#include <stdexcept>

#include "tools.hpp"

#include "type2_message.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 2 Message
 *
 *   0  NTLMSSP Signature                {'N','T','L','M','S','S','P','\0'}
 *   8  NTLM Message Type                {0x02,0x00,0x00,0x00}
 *  12  Target Name                      (security buffer)
 *  20  Flags                            uint32 as little endian
 *  24  Challenge                        8 bytes / uint64 as little endian
 * (32) Context (optional)               8 bytes (2xlong)
 * (40) Target Information               (security buffer)
 * (48) (start of datablock)
 *      targetname
 *      targetinfo
 *          server (type=0x0100, len, data)
 *          domain (type=0x0200, len, data)
 *          dnsserver (type=0x0300, len, data)
 *          dnsdomain (type=0x0400, len, data)
 *          type5 (type=0x0500, len, data)   // unknown role
 *          <terminator> (type=0,len=0)
 */
```

...

... page 1 of 2

Find one issue

```
#include <cstddef>
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#include "tools.hpp"

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 * See http://davenport.sourceforge.net/ntlm.html
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 * Type 2 Message
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...

... page 1 of 2

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... page 1 of 2

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...

... page 1 of 2

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... page 1 of 2

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 *          domain (type=0x0200, len, data)
 *          dnsserver (type=0x0300, len, data)
 *          dnsdomain (type=0x0400, len, data)
 *          type5 (type=0x0500, len, data)   // unknown role
 *          <terminator> (type=0,len=0)
 */
```

...

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
}

uint64_t pal::type2_message::challenge() const
{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
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}

uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
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{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

Any issues here?

... page 2 of 2

```
pal::type2_message::type2_message(const std::vecto
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 m
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
}

uint64_t pal::type2_message::challenge() const
{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

... page 2 of 2

magic numbers

```
pal::type2_message::typ
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 m
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
}

uint64_t pal::type2_message::challenge() const
{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() cons
{
    return pal::read_uint32_from_little_endia
}

uint64_t pal::type2_message::challenge() cons
{
    return pal::read_uint64_from_little_endia
}

std::vector<uint8_t> pal::type2_message::as_b
{
    return (buffer_);
}
```

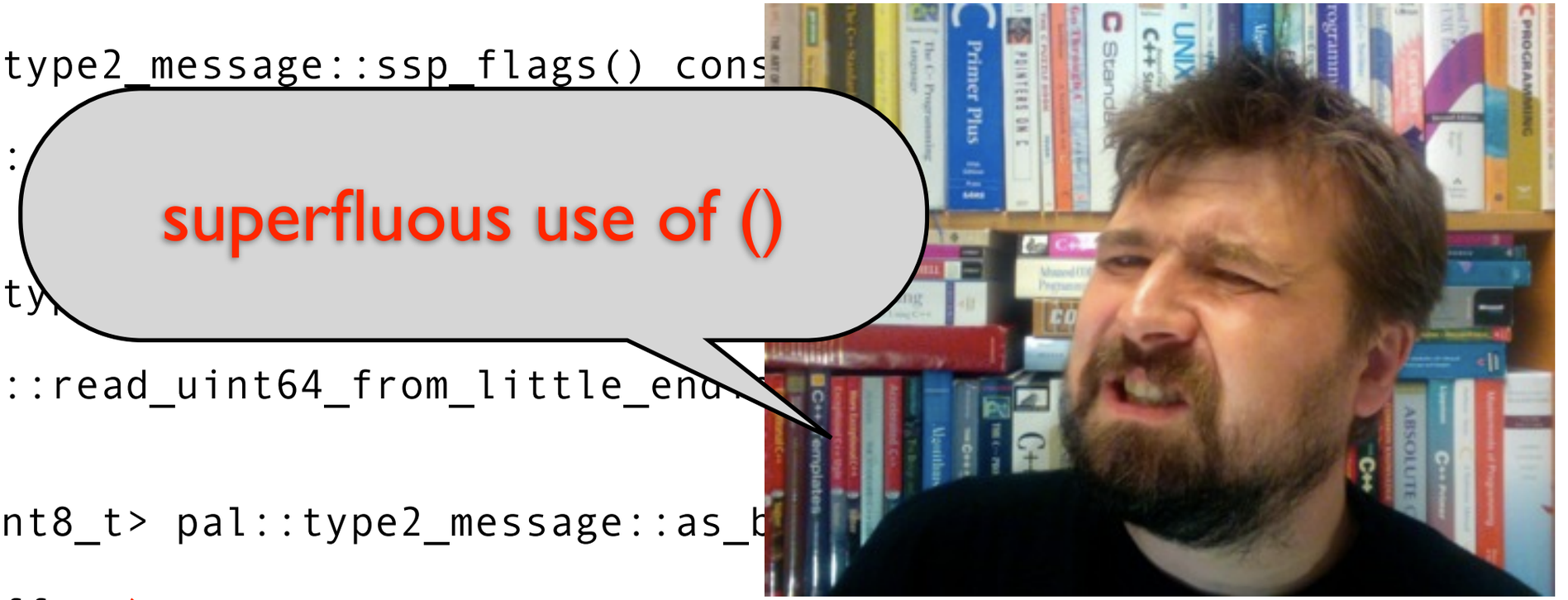
... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() cons
{
    return pal:
}

uint64_t pal::ty
{
    return pal::read_uint64_from_little_end
}

std::vector<uint8_t> pal::type2_message::as_b
{
    return (buffer_);
}
```



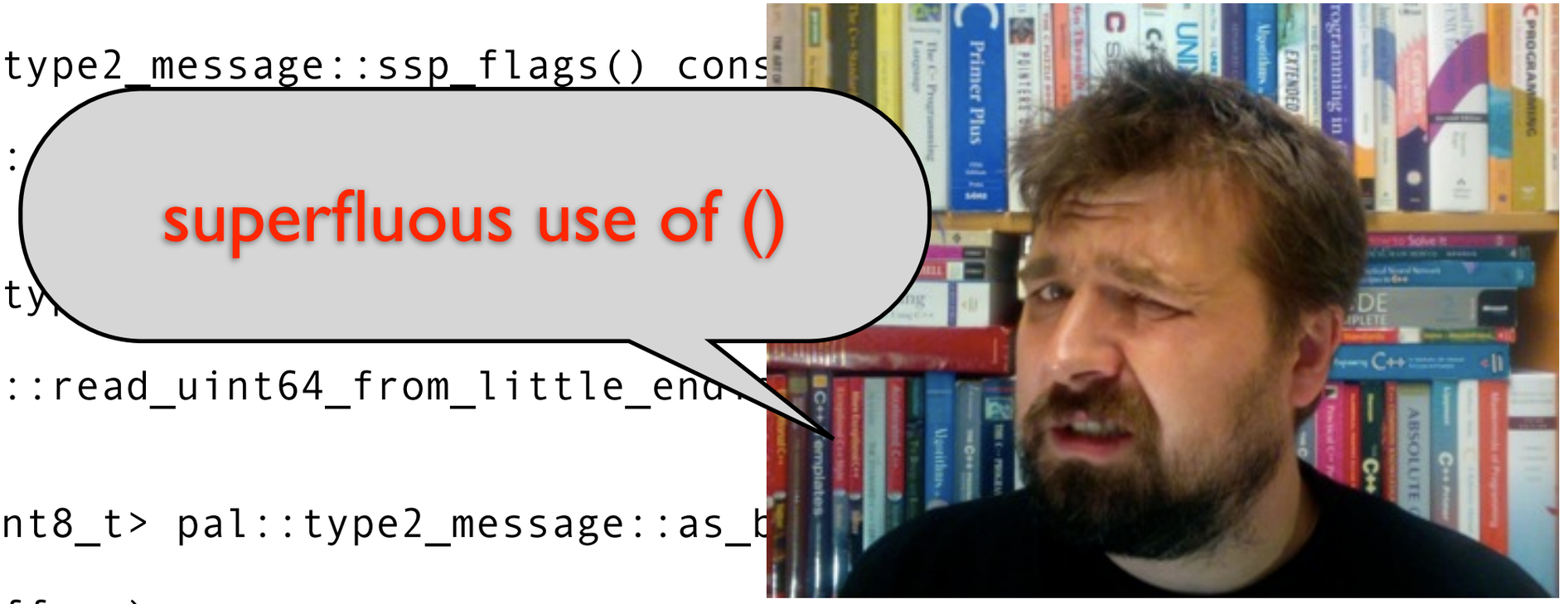
... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() cons
{
    return pal:
}

uint64_t pal::ty
{
    return pal::read_uint64_from_little_end
}

std::vector<uint8_t> pal::type2_message::as_b
{
    return (buffer_);
}
```



... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof((prefix)), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() cons
{
    return
}

uint64_t pa
{
    return pal::read_uint64_from_little_endia
}

std::vector<uint8_t> pal::type2_message::as_b
{
    return (((buffer_)));
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = (32);
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof((prefix)), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() cons
{
    return
}

uint64_t pa
{
    return pal::read_uint64_from_little_endia
}

std::vector<uint8_t> pal::type2_message::as_b
{
    return (((buffer_)));
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
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uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
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uint64_t pal::type2_message::challenge() const
{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
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{

    return pal::read_uint32_from_little_endian(&buffer_[20]);
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{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
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std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
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    return (buffer_);
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```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
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uint32_t pal::type2_message::ssp_flags() const
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}

uint64_t pal::type2_message::challenge() const
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    const std::size_t challenge_offset = 24;
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std::vector<uint8_t> pal::type2_message::as_bytes() const
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```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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uint32_t pal::type2_message::ssp_flags() const
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```

… page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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uint32_t pal::type2_message::ssp_flags() const
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```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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uint32_t pal::type2_message::ssp_flags() const
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... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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uint64_t pal::type2_message::challenge() const
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}

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{
    return (buffer_);
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
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    };
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uint64_t pal::type2_message::challenge() const
{
    const std::size_t challenge_offset = 24;
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}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return  buffer_ ;
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
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{
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uint64_t pal::type2_message::challenge() const
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}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return buffer_;
}
```

... page 2 of 2

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
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        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() const
{
    const std::size_t ssp_flags_offset = 20;
    return pal::read_uint32_from_little_endian(&buffer_[ssp_flags_offset]);
}

uint64_t pal::type2_message::challenge() const
{
    const std::size_t challenge_offset = 24;
    return pal::read_uint64_from_little_endian(&buffer_[challenge_offset]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return buffer_;
}
```

type3_message.hpp

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

Find 3 issues

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESS
#define PAL_TYPE3_MES

#include "ntlm_message

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

include <iosfwd> instead

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & domain,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESS
#define PAL_TYPE3_MES

#include "ntlm_message

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & domain,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

this default argument is probably not needed

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP
#define PAL_TYPE3_MESSAGE_HPP

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

useless explicit specifier

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iosfwd>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
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    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

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#include <string>
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namespace pal {

    class type3_message : public ntlm_message {
    public:
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            const std::vector<uint8_t> & lm_response,
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        void debug_print(std::ostream & out) const;
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        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
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    };

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#endif
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    public:
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            const std::vector<uint8_t> & lm_response,
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            const std::string & user,
            uint32_t ssp_flags = 0x202);
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#endif
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    public:
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            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags        );
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

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        const std::vector<uint8_t> lm_response_;
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        const uint32_t ssp_flags_;
    };

}

#endif
```

```
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    class type3_message : public ntlm_message {
    public:
        type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iosfwd>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

type3_message.cpp

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

Find 3 issues

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

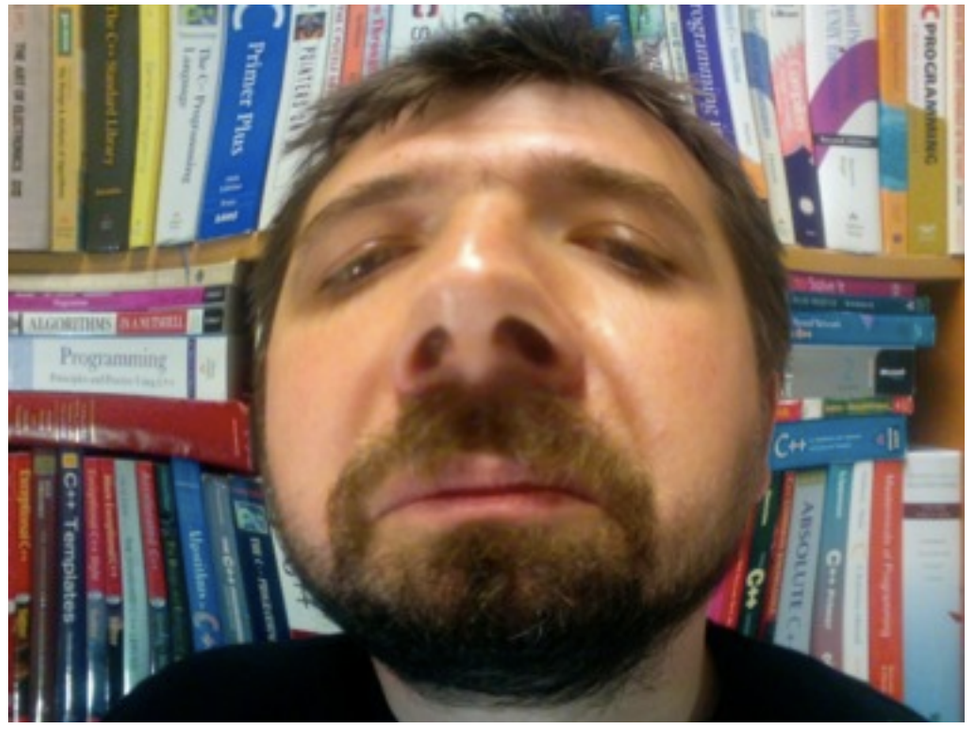
```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...



...

Does not match initialization order...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

... but this indicates a deeper problem, the user is not compiling with -Wall and -Wextra, or even worse... they do not care about warnings!

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

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pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
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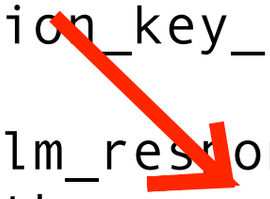
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```



...

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```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw     std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw     std::invalid_argument("invalid size of nt_response");
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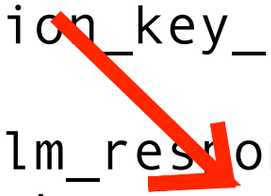

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    lm_response_(lm_response),
    nt_response_(nt_response),
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    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
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    if (lm_response_.size() != lm_response_size)
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    lm_response_(lm_response),
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    if (lm_response_.size() != lm_response_size)
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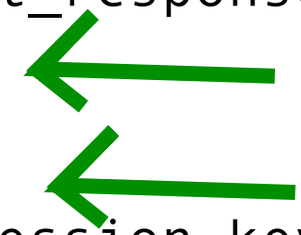

...

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    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    domain_(),
    user_(user),
    workstation_(),
    session_key_(session_key_size),
    ssp_flags_(ssp_flags)
{
    if (lm_response_.size() != lm_response_size)
        throw std::invalid_argument("invalid size of lm_response");
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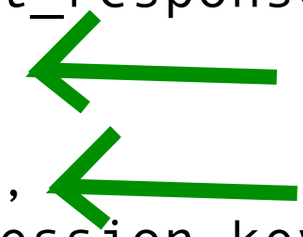

...

...

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    const std::vector<uint8_t> & lm_response,
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    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    domain_(),
    user_(user),
    workstation_(),
    session_key_(session_key_size),
    ssp_flags_(ssp_flags)
{
    if (lm_response_.size() != lm_response_size)
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    const std::vector<uint8_t> & lm_response,
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    :
    lm_response_(lm_response),
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    session_key_(session_key_size),
    ssp_flags_(ssp_flags)
{
    if (lm_response_.size() != lm_response_size)
        throw std::invalid_argument("invalid size of lm_response");
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        throw std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
void pal::type3_message::debug_print(std::ostream & out) const
{
    out << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
        << "lm_response = " << pal::as_hex_string(lm_response_)
        << "\nnt_response = " << pal::as_hex_string(nt_response_)
        << "\ndomain = " << domain_
        << "\nuser = " << user_
        << "\nworkstation = " << workstation_
        << "\nsession_key = " << pal::as_hex_string(session_key_)
        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
}
```

...

Any issues here?

...

```
void pal::type3_message::debug_print(std::ostream & out) const
{
    out << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
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        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
}
```

...

DO NOT MESS WITH BORROWED THINGS!

...

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{
    out << "### type3_message:" << '\n'
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        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
}
```

...

No easy way to fix this! Probably better to build into a local stringstream and return it.

```
...
void pal::type3_message::debug_print(std::ostream & out) const
{
    out << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
        << "lm_response = " << pal::as_hex_string(lm_response_)
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...
```

...

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void pal::type3_message::debug_print(std::ostream & out) const
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        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
}
```

...

...

```
std::string pal::type3_message::debug_print() const
{
    std::ostringstream buf;
    buf << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
        << "lm_response = " << pal::as_hex_string(lm_response_)
        << "\nnt_response = " << pal::as_hex_string(nt_response_)
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        << "\nsession_key = " << pal::as_hex_string(session_key_)
        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
    return buf.str();
}
```

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```
std::string pal::type3_message::debug_print() const
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    std::ostringstream buf;
    buf << "### type3_message:" << '\n'
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        << "lm_response = " << pal::as_hex_string(lm_response_)
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        << "\nssp_flags = " << ssp_flags_;
    return buf.str();
}
```

...

Big improvement!

...

```
std::string pal::type3_message::debug_print() const
{
    std::ostringstream buf;
    buf << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
        << "lm_response = " << pal::as_hex_string(lm_response_)
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    return buf.str();
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```

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19. consider explainability, don't do things that needs elaborate explainations

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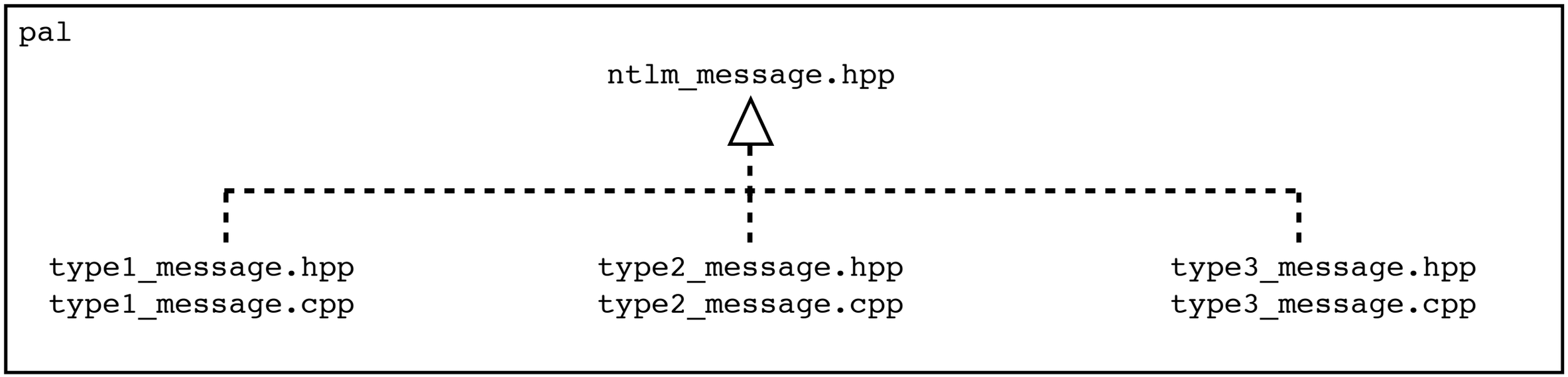
25. always consider the sideeffects of what you do

Handouts

Code under discussion



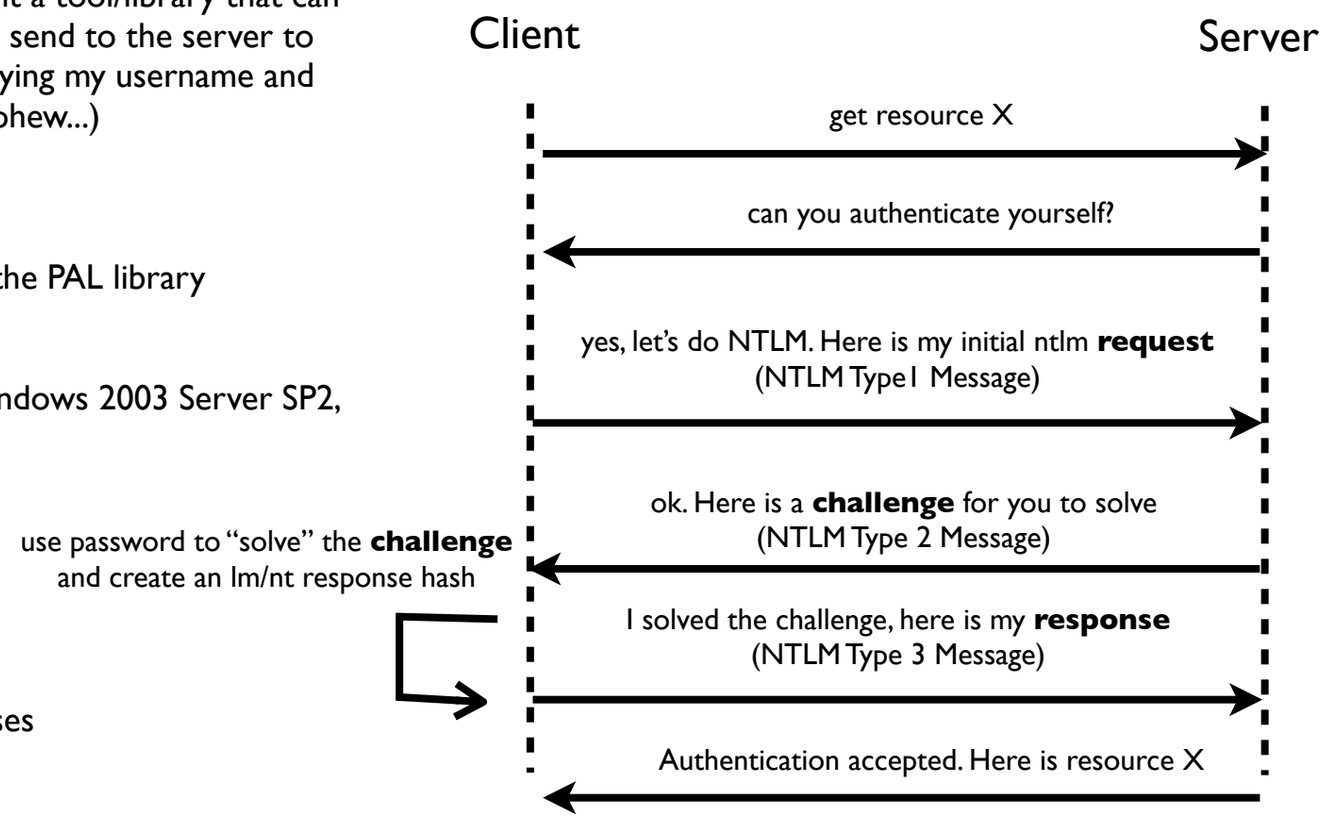
***Note**: the following code compiles just fine and does exactly what it is supposed to do... can you improve it?*

As a client, when prompted for ntlm authentication by the server, I want a tool/library that can help me to create the initial ntlm **request** (type 1 message) that I can send to the server to receive a **challenge** (type 2 message) that needs to be solved by applying my username and password to create an ntlm **response** that I can send to the server. (phew...)

Here are some (imaginary) additional requirements:
- target typically an embedded system
- it should be possible and convenient to create a <100kb client using the PAL library
- must use C++ (due to PHB decision)
- due to compiler support tr1 and boost can not be used
- initally the library will only be used to communicate HTTP with a Windows 2003 Server SP2, currently no need to support other servers

For more info:
PAL - a Primitive Authentication Library in C++ for educational purposes
http://github.com/olvemaudal/pal

The NTLM Protocol (simplified)



```
#include <vector>

namespace pal {

    class ntlm_message {
    public:
        virtual std::vector<uint8_t> as_bytes() const = 0;
    };

}
```

```
#ifndef PAL_TYPE1_MESSAGE_HPP_INCLUDED
#define PAL_TYPE1_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <vector>

namespace pal {

    class type1_message : public ntlm_message {
        uint32_t ssp_flags_;
    public:
        type1_message(uint32_t ssp_flags);
        virtual std::vector<uint8_t> as_bytes() const;
    };

}

#endif
```

```
#include "type1_message.hpp"

#include "tools.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 1 Message
 *
 *    0  NTLMSSP Signature                 "NTLMSSP\0"
 *    8  NTLM Message Type                 {0x01,0x00,0x00,0x00}
 *   12  Flags                             uint32 as little endian
 * (16) Supplied Domain (optional)        (security buffer)
 * (24) Supplied Workstation (optional)   (security buffer)
 * (32) (start of datablock) if required
 */

using namespace std;

pal::type1_message::type1_message(uint32_t ssp_flags)
{
    ssp_flags_ = ssp_flags;
}

vector<uint8_t> pal::type1_message::as_bytes() const
{
    uint8_t message[16] = {
        'N', 'T', 'L', 'M', 'S', 'S', 'P', '\0',
        0x01, 0x00, 0x00, 0x00, 0, 0, 0, 0
    };
    const int ssp_flags_offset = 12;
    pal::write_little_endian_from_uint32(&message[ssp_flags_offset], ssp_flags_);
    return vector<uint8_t>(message, message + sizeof message);
}
```

```
#ifndef PAL_TYPE2_MESSAGE_HPP_INCLUDED
#define PAL_TYPE2_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

using namespace std;

namespace pal {

    class type2_message : public ntlm_message {
    public:
        explicit type2_message(vector<uint8_t> buffer);
        virtual vector<uint8_t> as_bytes() const;
        uint32_t ssp_flags();
        uint64_t challenge();
    private:
        const vector<uint8_t> buffer_;
    };

}

#endif
```

```
#include <cstddef>
#include <algorithm>
#include <stdexcept>

#include "tools.hpp"

#include "type2_message.hpp"

/*
 * See http://davenport.sourceforge.net/ntlm.html
 *
 * Type 2 Message
 *
 *   0  NTLMSSP Signature                {'N','T','L','M','S','S','P','\0'}
 *   8  NTLM Message Type                {0x02,0x00,0x00,0x00}
 *  12  Target Name                      (security buffer)
 *  20  Flags                            uint32 as little endian
 *  24  Challenge                        8 bytes / uint64 as little endian
 * (32) Context (optional)               8 bytes (2xlong)
 * (40) Target Information               (security buffer)
 * (48) (start of datablock)
 *      targetname
 *      targetinfo
 *          server (type=0x0100, len, data)
 *          domain (type=0x0200, len, data)
 *          dnsserver (type=0x0300, len, data)
 *          dnsdomain (type=0x0400, len, data)
 *          type5 (type=0x0500, len, data)   // unknown role
 *          <terminator> (type=0,len=0)
 */
```

...

```
pal::type2_message::type2_message(const std::vector<uint8_t> & buffer)
    : buffer_(buffer)
{
    const std::size_t min_type2_buffer_size = 32;
    if (buffer.size() < min_type2_buffer_size)
        throw std::invalid_argument("not a type2 message, message too short");
    const uint8_t prefix[12] = {
        'N','T','L','M','S','S','P','\0',
        0x02,0x00,0x00,0x00
    };
    if (!std::equal(prefix, prefix + sizeof(prefix), buffer.begin()))
        throw std::invalid_argument("not a type2 message, invalid prefix");
}

uint32_t pal::type2_message::ssp_flags() const
{
    return pal::read_uint32_from_little_endian(&buffer_[20]);
}

uint64_t pal::type2_message::challenge() const
{
    return pal::read_uint64_from_little_endian(&buffer_[24]);
}

std::vector<uint8_t> pal::type2_message::as_bytes() const
{
    return (buffer_);
}
```

```
#ifndef PAL_TYPE3_MESSAGE_HPP_INCLUDED
#define PAL_TYPE3_MESSAGE_HPP_INCLUDED

#include "ntlm_message.hpp"

#include <string>
#include <iostream>

namespace pal {

    class type3_message : public ntlm_message {
    public:
        explicit type3_message(
            const std::vector<uint8_t> & lm_response,
            const std::vector<uint8_t> & nt_response,
            const std::string & user,
            uint32_t ssp_flags = 0x202);
        virtual std::vector<uint8_t> as_bytes() const;
        void debug_print(std::ostream & out) const;
    private:
        const std::vector<uint8_t> lm_response_;
        const std::vector<uint8_t> nt_response_;
        const std::string domain_;
        const std::string user_;
        const std::string workstation_;
        const std::vector<uint8_t> session_key_;
        const uint32_t ssp_flags_;
    };

}

#endif
```

...

```
pal::type3_message::type3_message(
    const std::vector<uint8_t> & lm_response,
    const std::vector<uint8_t> & nt_response,
    const std::string & user,
    uint32_t ssp_flags)
    :
    lm_response_(lm_response),
    nt_response_(nt_response),
    user_(user),
    ssp_flags_(ssp_flags),
    session_key_(session_key_size)
{
    if (lm_response_.size() != lm_response_size)
        throw new std::invalid_argument("invalid size of lm_response");
    if (nt_response_.size() != nt_response_size)
        throw new std::invalid_argument("invalid size of nt_response");
}
```

...

...

```
void pal::type3_message::debug_print(std::ostream & out) const
{
    out << "### type3_message:" << '\n'
        << pal::as_hex_dump(as_bytes())
        << "lm_response = " << pal::as_hex_string(lm_response_)
        << "\nnt_response = " << pal::as_hex_string(nt_response_)
        << "\ndomain = " << domain_
        << "\nuser = " << user_
        << "\nworkstation = " << workstation_
        << "\nsession_key = " << pal::as_hex_string(session_key_)
        << std::hex << std::setw(8) << std::setfill('0')
        << "\nssp_flags = " << ssp_flags_;
}
```

...