Programming in C

Lecture 9: Tooling

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Undefined and Unspecified Behaviour

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- Enormous number of possible sources of undefined behavior (See `https://blog.regehr.org/archives/1520`)

Undefined and Unspecified Behaviour

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- Programming errors can arbitrarily corrupt runtime data structures...
- ...leading to *undefined behaviour*
- Enormous number of possible sources of undefined behavior (See `https://blog.regehr.org/archives/1520`)
- What can we do about it?

Tooling and Instrumentation

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- Add instrumentation to detect unsafe behaviour!

Tooling and Instrumentation

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- ...leading to *undefined behaviour*
- There is a great deal of *undefined behaviour*
- Add instrumentation to detect unsafe behaviour!
- We will look at 3 tools: ASan, UBSan, and Valgrind

ASan: Address Sanitizer

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- Built into gcc and clang!

ASan Example #1

```
1  #include <stdlib.h>
2  #include <stdio.h>
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4  #define N 10
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6  int main(void) {
7    char s[N]  = "123456789";
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9      printf ("%c", s[i]);
10   printf("\n");
11   return 0;
12 }
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- Compile with `-fsanitize=address`

ASan Example #2

```c
#include <stdlib.h>

int main(void) {
  int *a =
    malloc(sizeof(int) * 100);
  free(a);
  return a[5]; // DOOM!
}
```

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2. array is freed
3. array is dereferenced!

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7    free(s);
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1. array is allocated
2. array is freed
3. array is double-freed

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- Built into gcc and clang!

UBSan Example #1

```
1  #include <limits.h>
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3  int main(void) {
4    int n = INT_MAX;
5    int m = n + 1;
6    return 0;
7  }
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1. Signed integer overflow is undefined

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2. So value of `m` is undefined

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3. Compile with `-fsanitize=address`

UBSan Example #2

```
1  #include <limits.h>
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3  int main(void) {
4    int n = 65
5    int m = n / (n - n);
6    return 0;
7  }
```

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1. Division-by-zero is undefined

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1. Division-by-zero is undefined
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3. Any possible behaviour is legal!

UBSan Example #3

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3  struct foo {
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7  int main(void) {
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1. Accessing a null pointer is undefined

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- **Seriously consider** using it in production

Valgrind

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- UBSan and ASan don't catch accesses to unitialized memory

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- Enter *Valgrind*!

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- UBSan and ASan don't catch accesses to unitialized memory
- Enter *Valgrind*!
- Instruments binaries to detect numerous errors

Valgrind Example

```c
#include <stdio.h>

int main(void) {
  char s[10];
  for (int i = 0; i < 10; i++)
    printf("%c", s[i]);
  printf("\n");
  return 0;
}
```

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1. Accessing elements of `s` is undefined

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2. Program prints unitialized memory

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4. Invoke `valgrind` with binary name

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- Still: a **must-use** tool during testing

Assessed Exercise

See "Head of Department's Announcement"

- To be completed by noon on Monday 22 January 2018
- Viva examinations 1330-1630 on Thursday 25 January 2018
- Viva examinations 1330-1630 on Friday 26 January 2018
- Download the starter pack from:
  `http://www.cl.cam.ac.uk/Teaching/1718/ProgC++/`
- This should contain eight files:

  `server.c client.c rfc0791.txt rfc0793.txt`
  `message1 message2 message3 message4`

Exercise aims

Demonstrate an ability to:

- Understand (simple) networking code
- Use control flow, functions, structures and pointers
- Use libraries, including reading and writing files
- Understand a specification
- Compile and test code
- Comprehending man pages

Task is split into three parts:

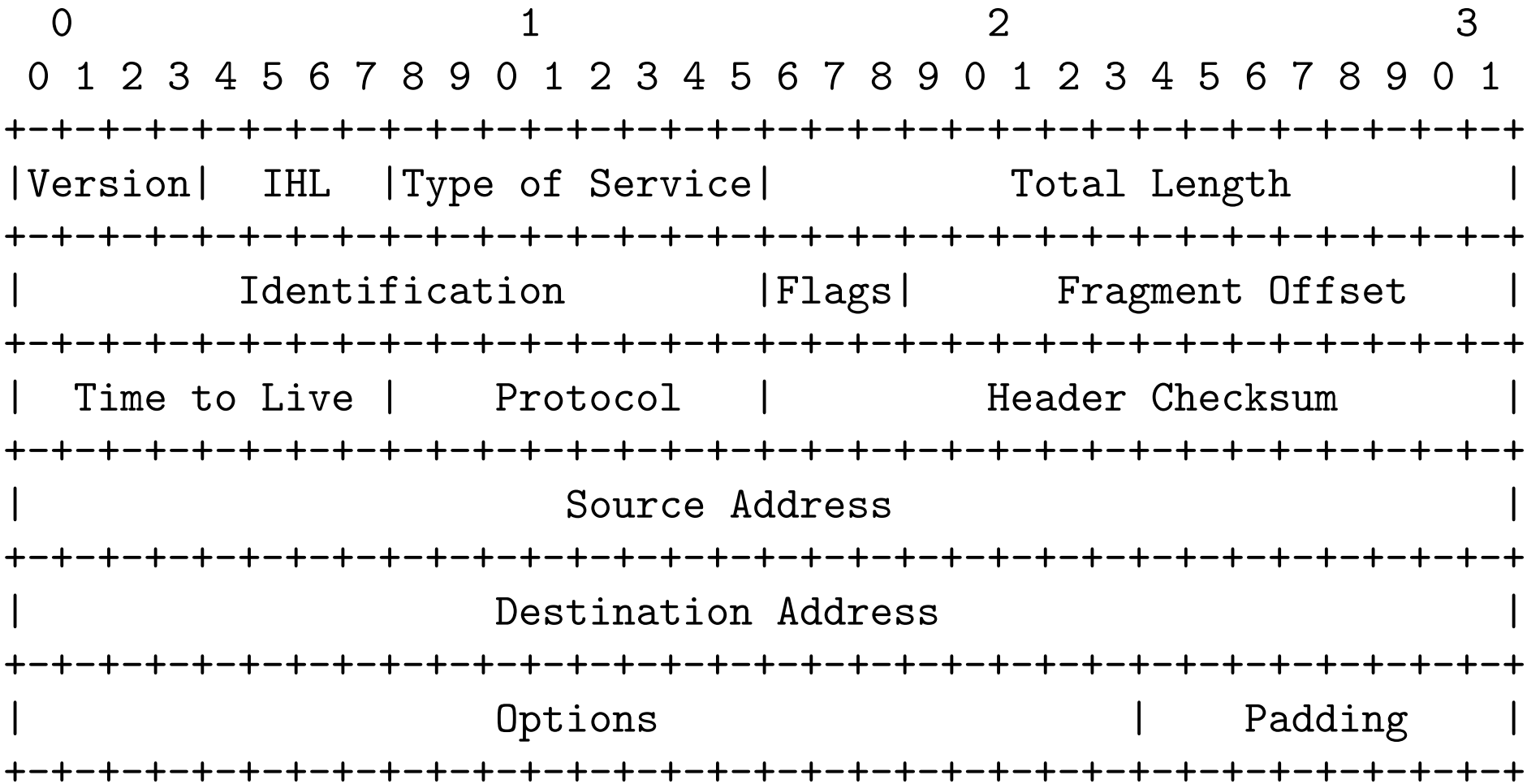
- Comprehension and debugging
- Preliminary analysis
- Completed code and testing

Exercise submission

- Assessment is in the form of a 'tick'
- There will be a short viva; remember to sign up!
- Submission is via email to `c-tick@cl.cam.ac.uk`
- Your submission should include seven files, packed in to a ZIP file called crsid`.zip` and attached to your submission email:

```
answers.txt   client1.c   summary.c   message1.txt
              server1.c   extract.c   message2.jpg
```

Hints: IP header



Hints: IP header (in C)

```c
#include <stdint.h>

struct ip {
  uint8_t hlenver;
  uint8_t tos;
  uint16_t len;
  uint16_t id;
  uint16_t off;
  uint8_t ttl;
  uint8_t p;
  uint16_t sum;
  uint32_t src;
  uint32_t dst;
};

#define IP_HLEN(lenver) (lenver & 0x0f)
#define IP_VER(lenver) (lenver >> 4)
```

Hints: network byte order

- The IP network is big-endian; x86 is little-endian; ARM can be either
- Reading multi-byte values requires possible conversion
- The BSD API specifies:
  - `uint16_t ntohs(uint16_t netshort)`
  - `uint32_t ntohl(uint32_t netlong)`
  - `uint16_t htons(uint16_t hostshort)`
  - `uint32_t htonl(uint32_t hostlong)`

  which encapsulate the notions of host and network and their interconversion (which may be a no-op)