Recap: Protection

- Protection
  – Prevent unintended/unauthorized accesses
- Protection domains
  – Class hierarchy: *root* can to everything a normal *user* can do + alpha
- Access control matrix
  – Domains (Users) ← → Resources (Objects)
  – Resource oriented: Access control list
  – Domain oriented: Capability list

Recap: Security

- Stack and buffer overflow
  - Failure to check bounds on inputs, arguments
  - Write past arguments on the stack into the return address on stack
  - Unauthorized user or privilege escalation

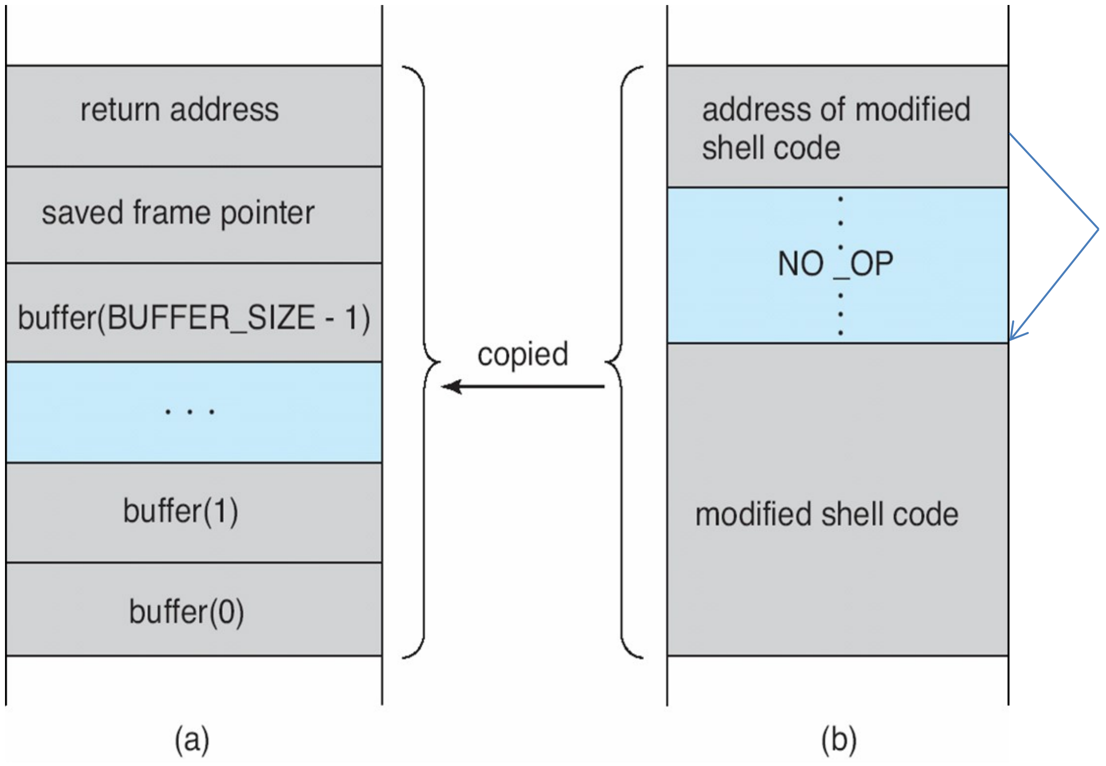
Recap: Code with Buffer Overflow

```
#define BUFFER_SIZE 256
int process_args(char *arg1)
{
    char buffer[BUFFER SIZE];
    strcpy(buffer,arg1);
    ...
}

int main(int argc, char *argv[])
{
    process_args(argv[1]);
    ...
}
```

- What is wrong in this code?

Recap: The Attack: Buffer Overflow



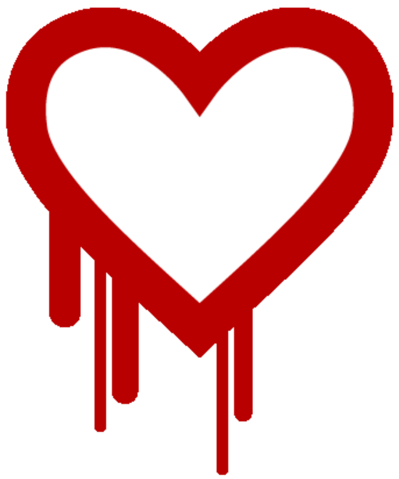
Before

After executing
`strcpy(buffer, arg1)`

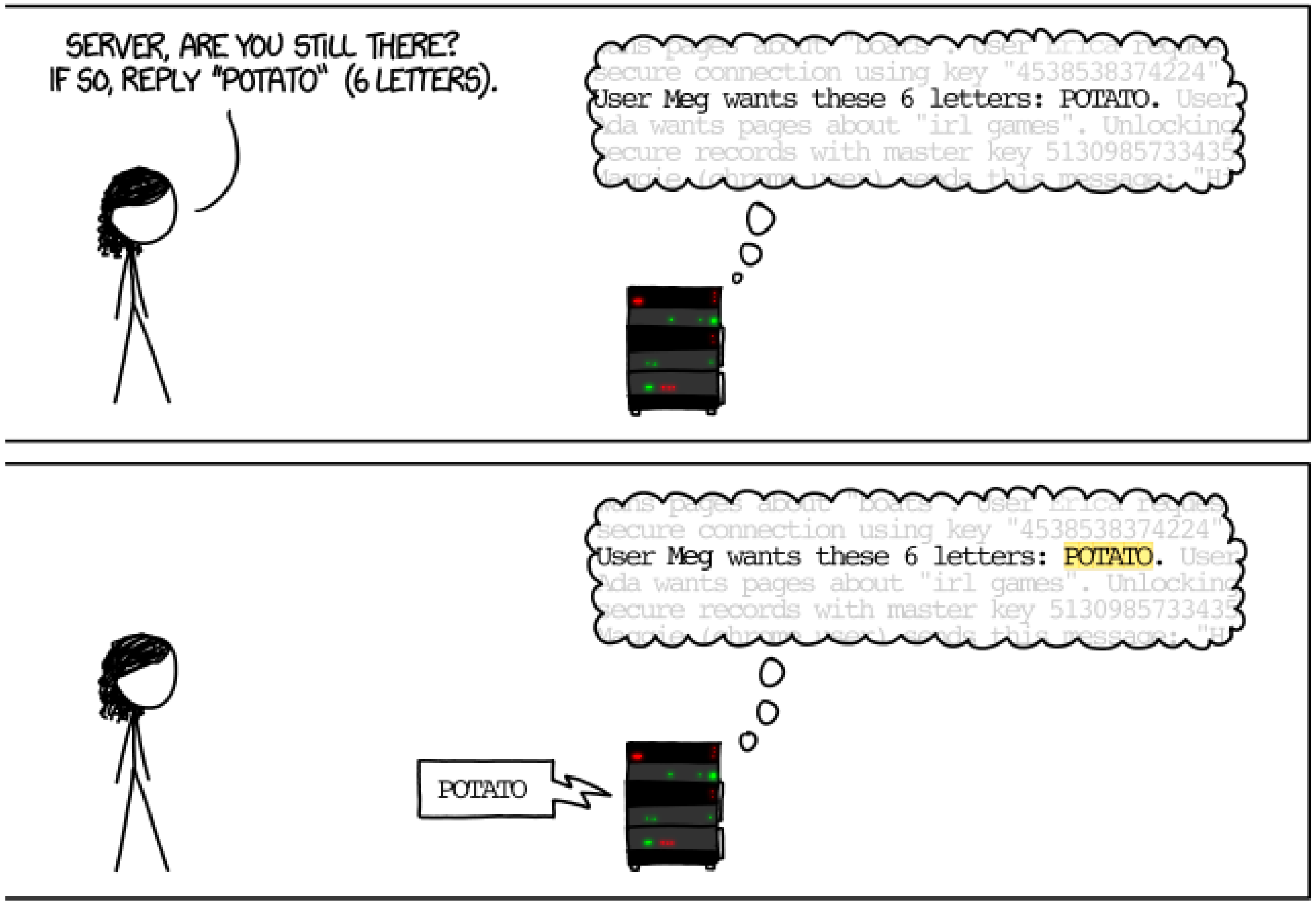
the crafted string containing the illegitimate code

Heartbleed Bug

- Synopsis
  - Due to a bug in OpenSSL (popular s/w for encrypted communication), web server's internal memory can be dumped remotely



Heartbleed Bug



SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
ants pages about "boats". User Erica reques
secure connection using key "4538538374224"
User Meg wants these 6 letters: POTATO. User
Ada wants pages about "irl games". Unlocking
secure records with master key 5130985733435
Meggie (chrome user) sends this message: "H
POTATO

Image source: xkcd.com

Heartbleed Bug

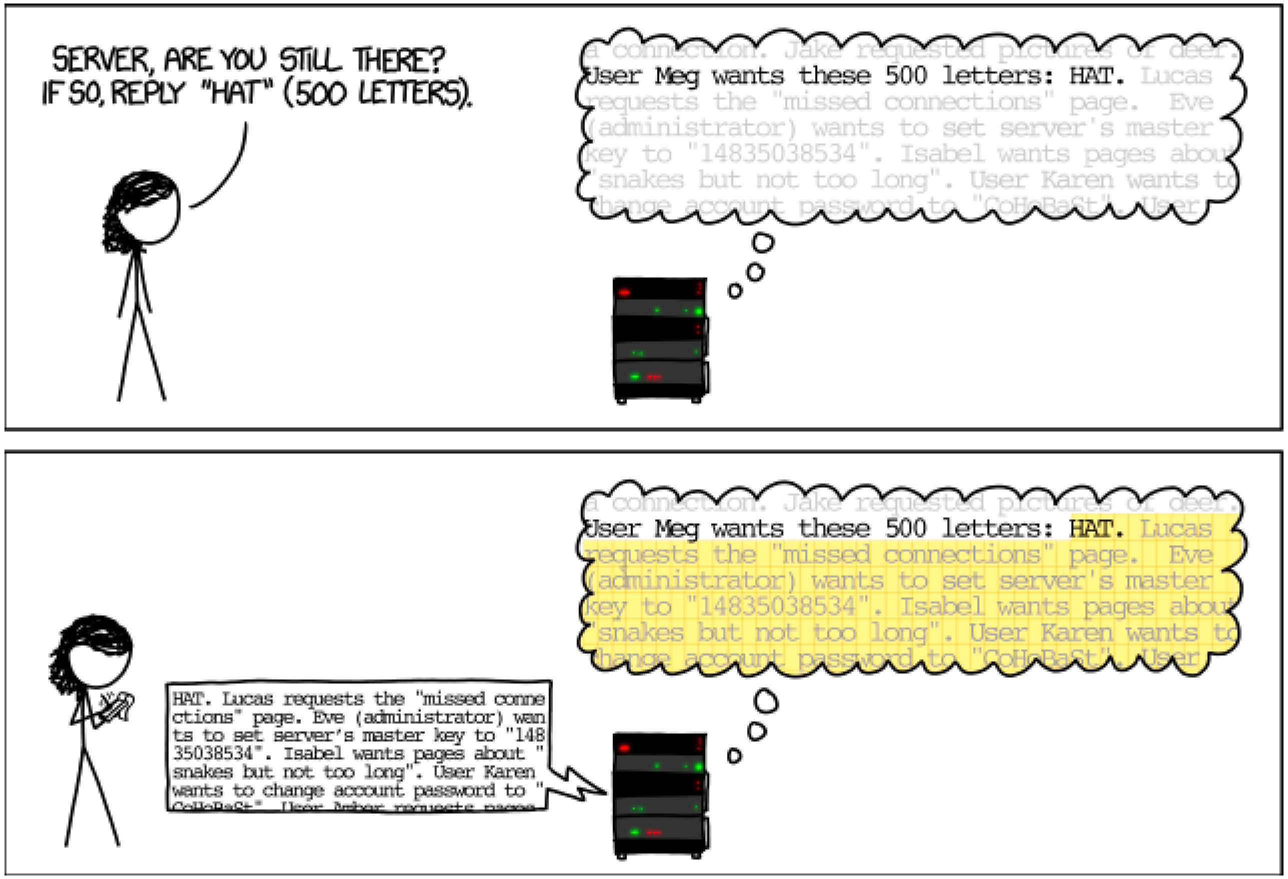

SERVER, ARE YOU STILL THERE? IF SO, REPLY "HAT" (500 LETTERS).
a connection. Jake requested pictures of deer. User Meg wants these 500 letters: HAT. Lucas requests the "missed connections" page. Eve (administrator) wants to set server's master key to "14835038534". Isabel wants pages about snakes but not too long". User Karen wants to change account password to "CoHoBaSt". User
HAT. Lucas requests the "missed connections" page. Eve (administrator) wants to set server's master key to "14835038534". Isabel wants pages about "snakes but not too long". User Karen wants to change account password to "CoHoBaSt". User Amber requests pages

Image source: xkcd.com

Heartbleed Bug

```
struct {
   HeartbeatMessageType type;
   uint16 payload_length;
   opaque payload[HeartbeatMessage.payload_length];
   opaque padding[padding_length];
} HeartbeatMessage
```

Heartbeat
req. message

```
int tls1_process_heartbeat(SSL *s)
{
   ...
   /* Read type and payload length first */
   hbtype = *p++;
   n2s(p, payload); // payload = recv_packet.payload_length
   pl = p;
   ...
   if (hbtype == TLS1_HB_REQUEST) {
      ...
      buffer = OPENSSL_malloc(1 + 2 + payload + padding);
      bp = buffer;
      memcpy(bp, pl, payload);
      r = ssl3_write_bytes(s, TLS1_RT_HEARTBEAT, buffer, 3 + payload + padding);
                 ...
```

Heartbeat
Response function

Shellshock Bug

- Synopsis
  - You can *remotely execute arbitrary programs* on a server running a web server by simply sending a specially crafted http request.
  - Example

```
curl -H "User-Agent: () { :; }; /bin/eject" http://example.com/
```

- The problem
  - Fail to check the validity of a function definition before executing it

For detailed explanation: security.stackexchange.com

Roadmap

- CPU management
- Memory management
- Disk management
- Network and security
- **Virtual machine**

Cloud Computing

Image Source: http://btstrategy.com/wp-new/2013/10/18/is-everything-really-going-to-the-cloud-advice-for-business-owners/

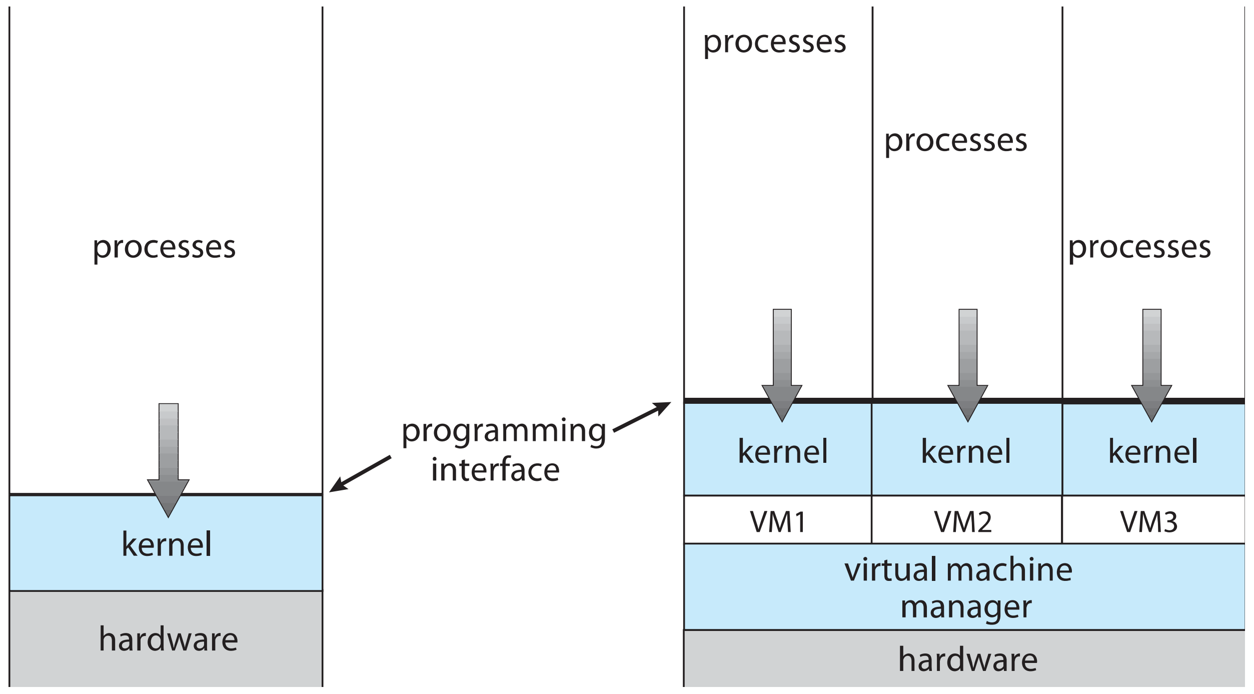
Cloud Computing

amazon web services™ | EC2

Microsoft Azure

Virtual Machines

- Enabling technology of cloud computing
- Basic idea: Provide **machine** abstractions



Virtual Machines

- Benefits
  - Can run **multiple OSes**, each in its own virtual machine
  - Can **copy** a VM image and run it on a different machine
  - Can create a **snapshot** of the state and restore it later
  - Can create a **customized** VM with specific OS version and libraries to avoid version dependency problems
  - More **efficient** resource utilization is possible
- Downsides?
  - Overhead
  - Interference

History

- Late 1960s
  – IBM introduced first full VMM on mainframes
- Late 1990s
  – **Xen** was developed for Intel PCs
- Mid 2000s
  – Hardware support was introduced (e.g.,Intel VT-x)
  – Widely adopted in data centers.

Topics

- How to implement VMMs?
- How to reduce overhead?