University of Stuttgart
Institute of Parallel and Distributed Systems

Distributed Systems

Fachpraktikum / Lab-Course

Software-Defined and Time-Sensitive Networking

Tutorial: Networking Basics
Part 1: Networking in Linux

Frank Dürr

Summer Term 2023

IPVS

Agenda

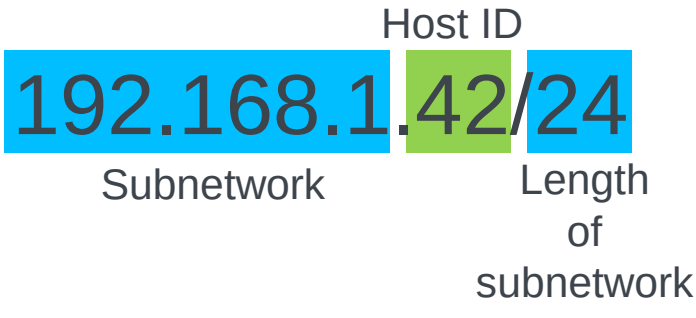
- IP addresses
  - Notation, subnetworks
  - Address configuration of network interfaces in Linux
- Network namespaces in Linux
  - Creating namespaces
  - Connecting namespaces
- Network applications
  - netcat
  - cURL
- Monitoring network traffic
  - tcpdump
  - tshark

IP Addresses

- Addresses of **network layer**
- Used for **routing** packets between hosts
- **Assigned to network interfaces** of **hosts** and **routers**
  - **Multi-homed hosts** with several network interfaces might be reachable through different IP addresses
    - Example: laptop with WiFi interface and Ethernet interface
- **IPv4** (32 bit) and **IPv6** (128 bit) addresses used in Internet today
  - We will use IPv4 for readability reasons

IP Addresses

IPv4 Address Notation

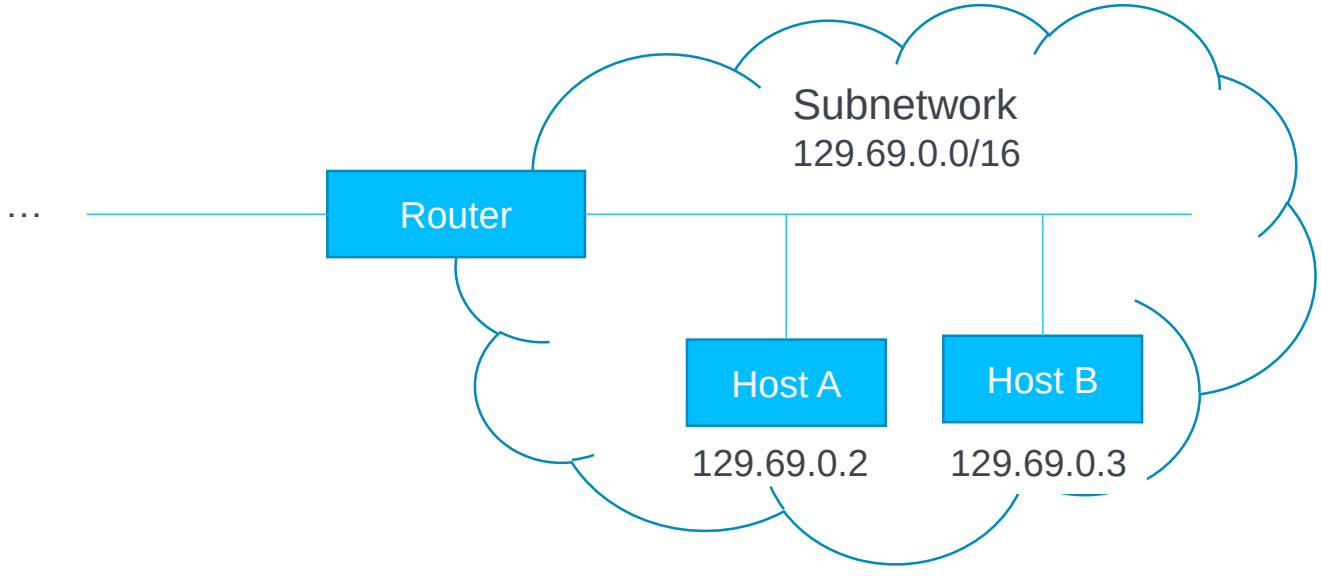


192.168.1.42

Subnet mask: 255.255.255.0

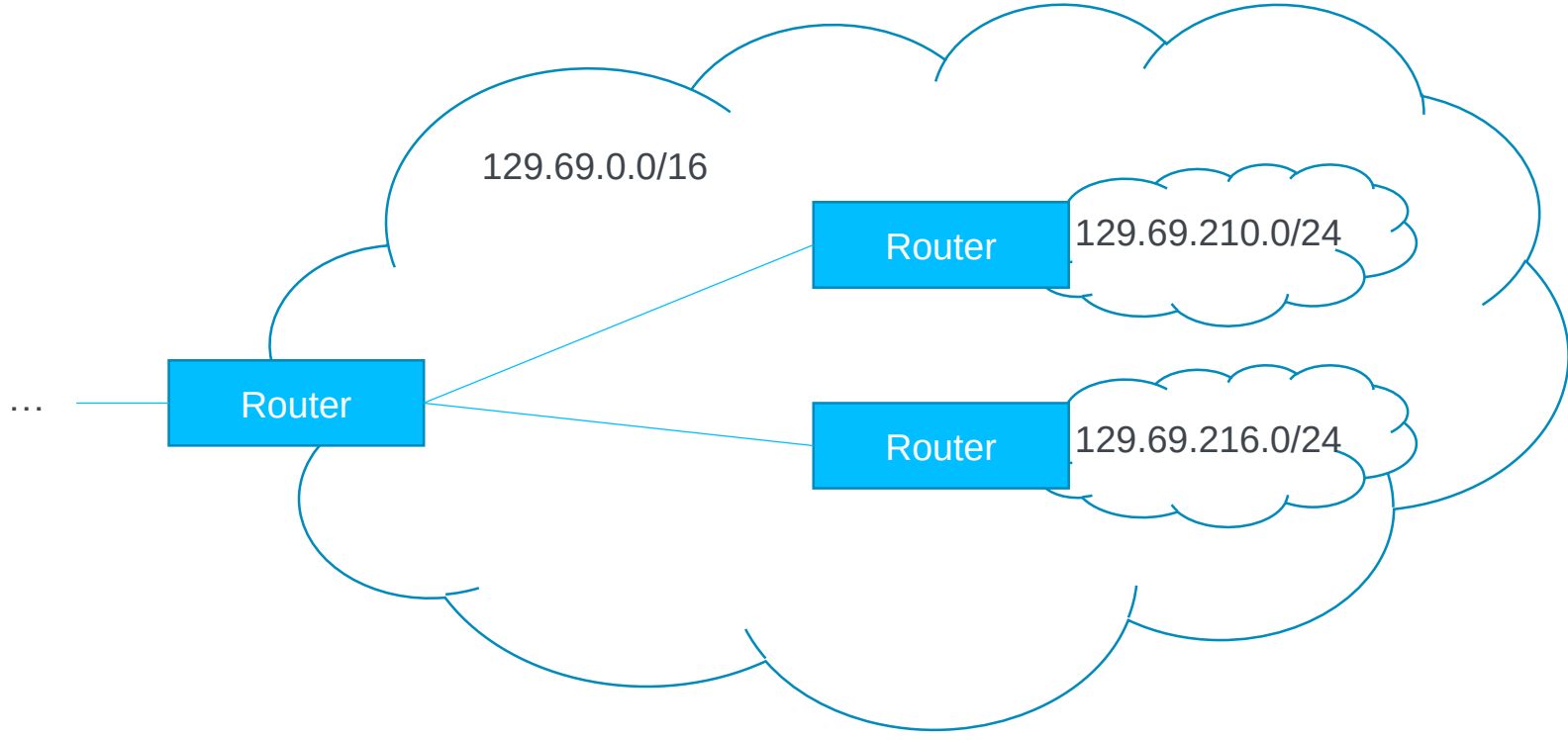
IP Addresses

Subnetworks



IP Addresses

Subnetworks



IP Addresses

Public and Private IP Addresses

- **Public IP address**
  - Globally unique and globally routable in Internet
  - Example: 129.69.210.42
- **Private IP addresses**
  - Only unique within private network, only routed within private network
    - Connection to Internet requires network address translation at gateway (NAT)
  - Same addresses can be reused between organizations
  - Reserved private IP address ranges for IPv4:
    - 10.0.0.0/8
    - 192.168.0.0/16
    - 172.16.0.0/12

IP Addresses

Public and Private IP Addresses

In the lab:

- Use only private IP addresses from 10.0.0.0/8
  - In particular 192.168.0.0/16 is used already within IPVS networks
- Can create smaller subnetworks, e.g., 10.x.0.0/16

IP Addresses

Special IP Addresses

- Localhost: 127.0.0.1
- Broadcast to all hosts in subnet: all host bits 1
  - Example: 192.168.1.255 for broadcast in subnet 192.168.1.0/24
- Multicast group addresses: 224.0.0.0 – 239.255.255.255
- Bind to all network interfaces on this host (INADDR_ANY): 0.0.0.0

IP Addresses

Configuration of Network Interfaces in Linux

Assign IP address 192.168.1.1/16 to network interface eth0:

```
$ ip address add 192.168.1.1/16 dev eth0
```

Delete IP address 192.168.1.1/16 from network interface eth0:

```
$ ip address del 192.168.1.1/16 dev eth0
```

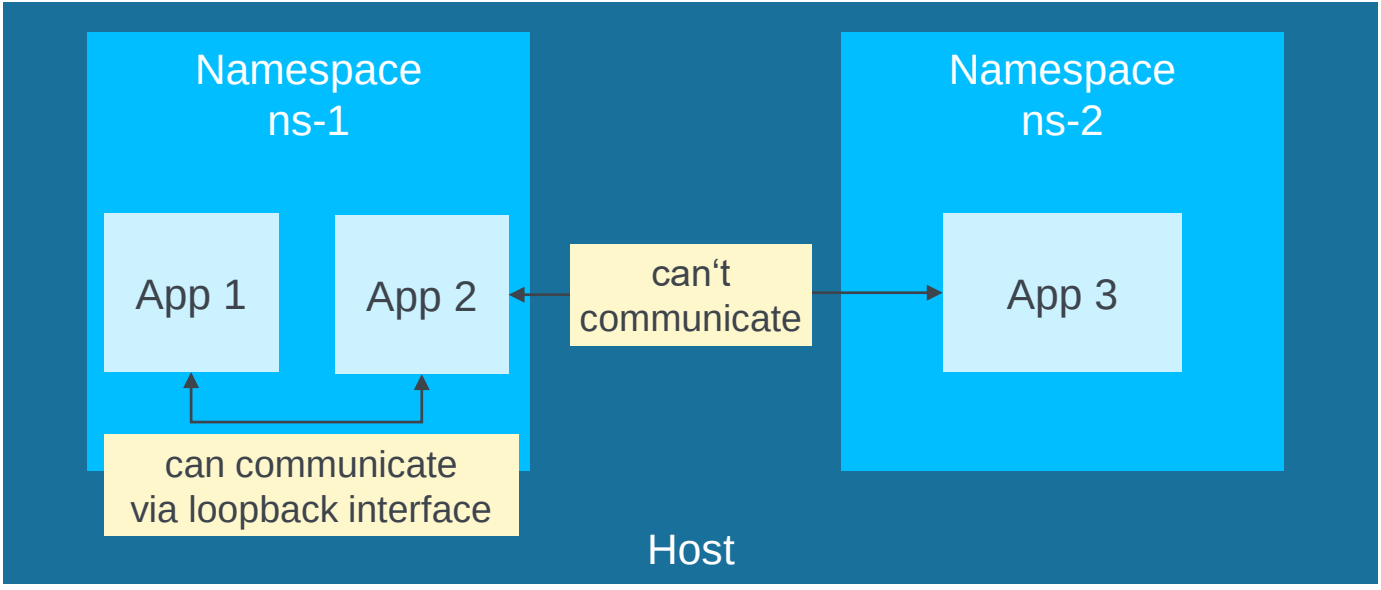
Note: before using the network interface, you have to bring it up:

```
$ ip link set eth0 up
```

Network Namespaces

Goal: Isolation of virtual network environments on a host

- Used, for instance, to implement containerized apps
- In lab used to implement virtual network environments on single host



Network Namespaces

Namespaces in Linux

Creating namespace ns-1

```
$ ip netns add ns-1
```

Listing all namespaces

```
$ ip netns list
```

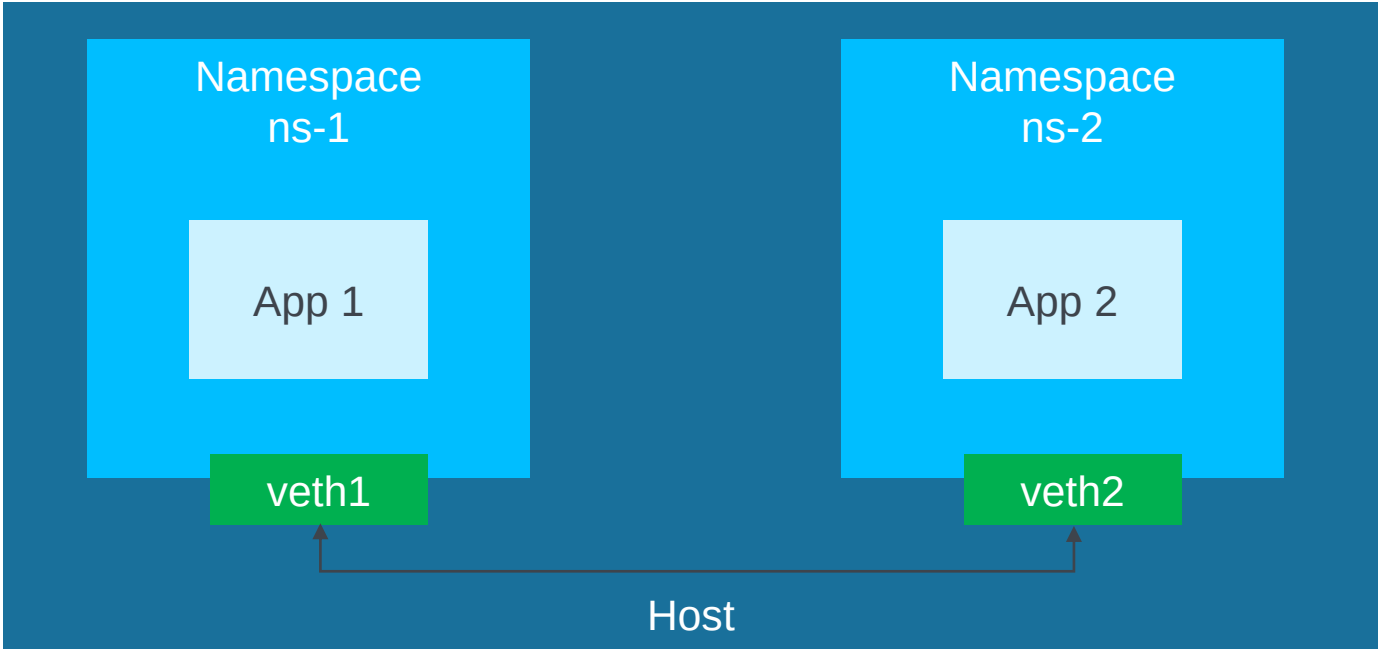
Executing a command (here an interactive shell) in namespace ns-1

```
$ ip netns exec ns-1 /bin/bash
```

Network Namespaces

Communication through Virtual Ethernet Devices

Communication through pair of connected veth devices



Network Namespaces

Virtual Ethernet Devices in Linux

Create virtual Ethernet devices veth1 and veth2:

```
$ ip link add veth1 type veth peer name veth2
```

Assign veth1 device to a namespace ns-1 (same for veth2):

```
$ ip link set veth1 netns ns-1
```

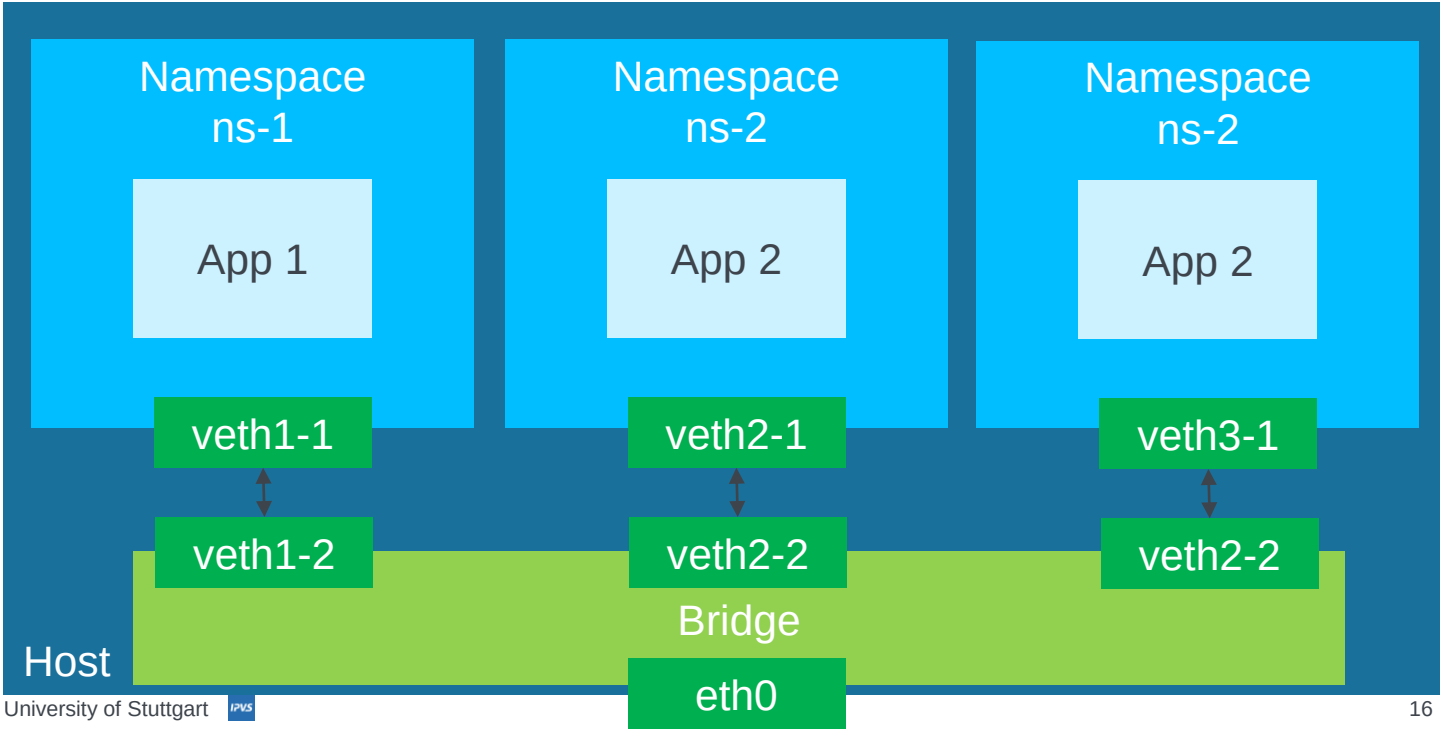
Notes:

- When a namespace is deleted, all assigned devices will return to the default namespace

Network Namespaces

Communication through Virtual Bridge

- Bridge connects several namespaces on same host
- Bridge connects namespaces to other hosts via physical Ethernet



Network Namespaces

Virtual Bridges in Linux

Create virtual bridge vbridge and bring it up:

```
$ ip link add name vbridge type bridge
$ ip link set dev vbridge up
```

Assign virtual Ethernet device veth1 to bridge vbridge (same for physical devices):

```
$ ip link set veth1 master vbridge
```

Network Applications

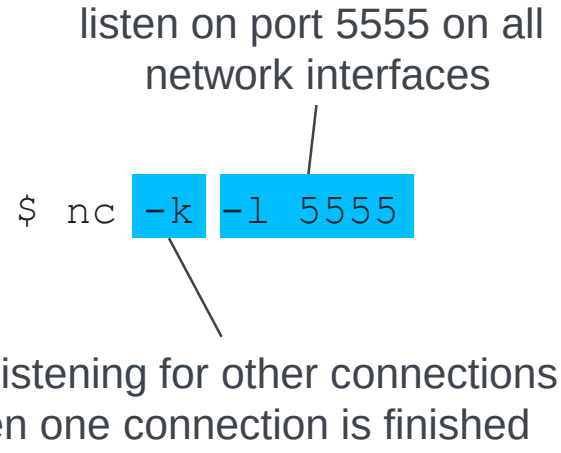
Netcat

Swiss army knife for communication

- Simple client/server applications without programming
- Integration with scripts
- Supports TCP, UDP, UNIX domain sockets, IPv4 & IPv6, etc.

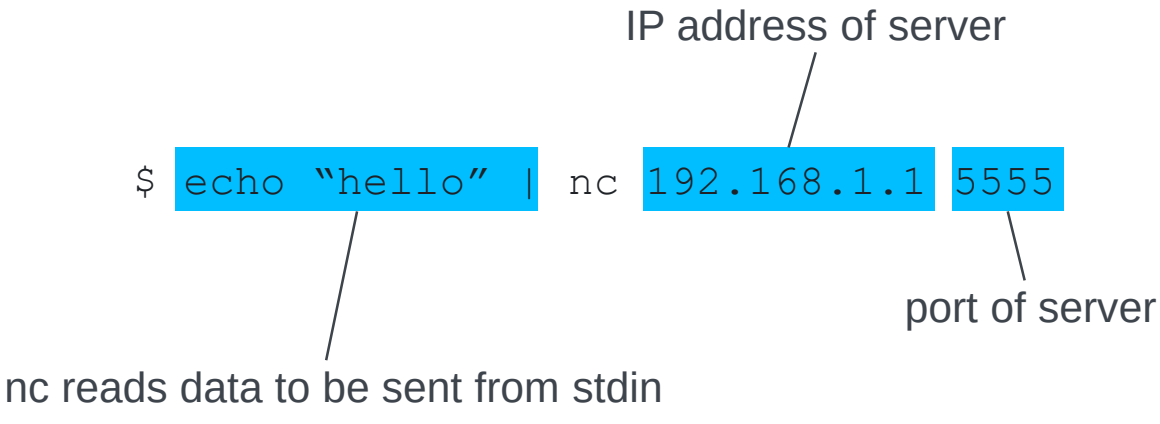
Network Applications

Simple TCP Server with netcat



Network Applications

Simple TCP Client with netcat



Network Applications

Further Useful netcat Options

- UDP: `-u`
- Timeout idle connections after 5 seconds: `-w 5`
- Set source port 6666: `-s 6666`
- Use only IPv4: `-4`

Network Applications

cURL

Transferring data to/from server using one of many protocols:

DICT, FILE, FTP, FTPS, GOPHER, GOPHERS, HTTP, HTTPS, IMAP, IMAPS, LDAP, LDAPS, MQTT, POP3, POP3S, RTMP, RTMPS, RTSP, SCP, SFTP, SMB, SMBS, SMTP, SMTPS, TELNET or TFTP

Download HTML page from web server of University of Stuttgart via HTTPS:

```
$ curl https://www.uni-stuttgart.de
```

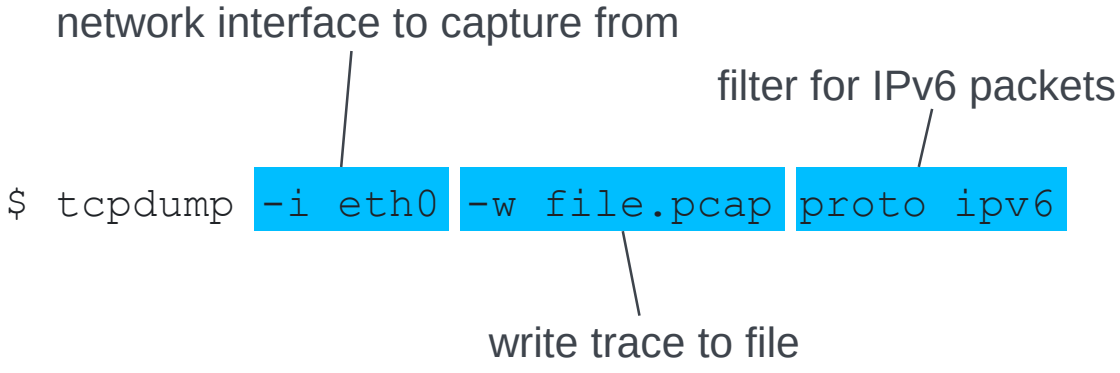
Monitoring Network Traffic

tcpdump

- Record network traffic in promiscuous mode from network interface
  - Does not replace server application (connection would be refused)
- Record to file in pcap format
  - Can be read by other tools such as tshark
- Filters to filter relevant traffic

Monitoring Network Traffic

tcpdump example



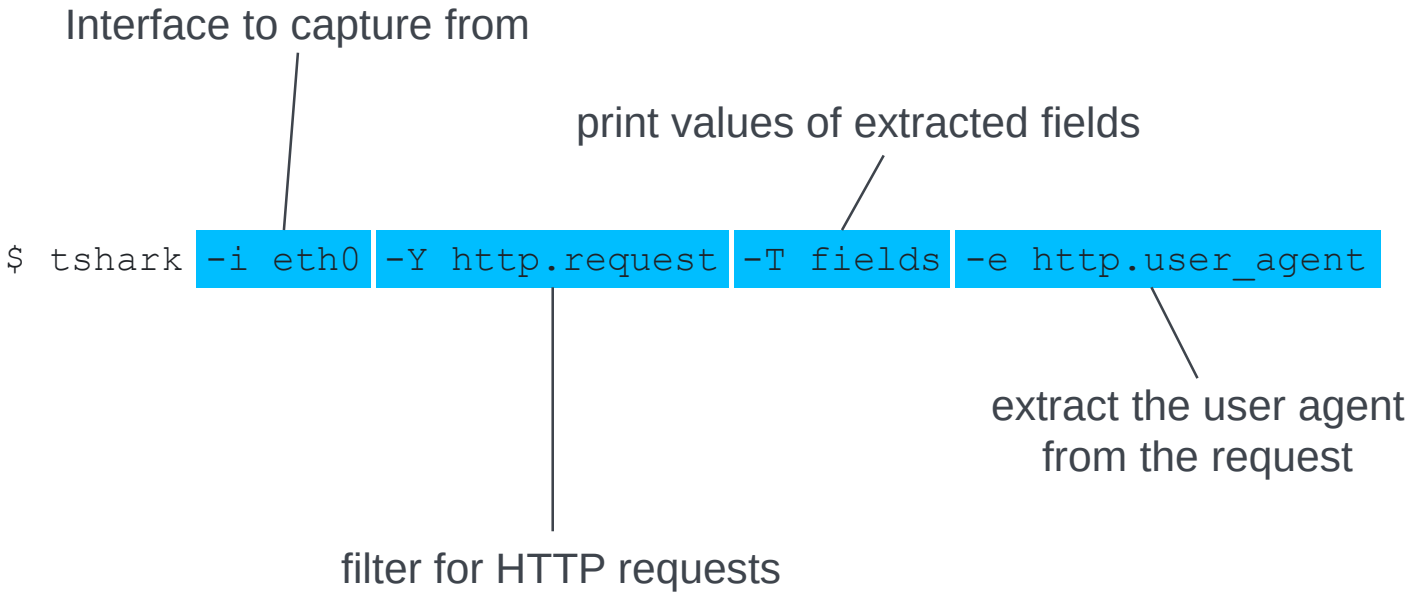
Monitoring Network Traffic

Wireshark / tshark

- Another tool for capturing packets
- Wireshark: interactive GUI for controlling capturing, viewing traces, applying filters, etc.
- tshark: terminal (command line) version of Wireshark
- Can also be used to capture from interface or filter recorded pcap files after capturing

Monitoring Network Traffic

Wireshark / tshark example



Questions?