Lecture 1: Introduction to Communication Protocols and "Non-Intrusive" Testing

Passive Testing Techniques for Communication Protocols

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National Research Tomsk State University

February 9, 2016

OUTLINE

COURSE INFORMATION

Sessions:

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- 3 Weeks

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- Tuesdays Lectures (1.5h) @ 12:25(?)
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  - Short(~15mins) quizzes of the week's lectures
- Laboratories are due before the beginning of the subsequent laboratory (@ 10:29:59 GMT + 6)

COURSE INFORMATION (CONT.)

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- Communication protocols and non-intrusive testing methods
- Static code analysis (for protocol implementations)

Course Information (cont.)

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- Communication protocols and non-intrusive testing methods
- Static code analysis (for protocol implementations)
- Passive network trace analysis

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GNU/Linux environment!

You choose the distro, but, make sure your code compiles with a 'Makefile'

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Others

Make a PDF. Use LaTeX, MS Word, OpenOffice writer, ...

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WhatsApp

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WhatsApp

Important

Testing such applications / systems is crucial!

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Reasons not interfere the system?

- The data on the system is susceptible to change with the tests
- Certain functionality is not available if "real" data is not entered
- Even if a system can be interrupted, it can be wanted to perform tests against the "real" service / application / data

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Let's take a look a quick look at each of them

STATIC ANALYSIS

```
/*Test equal distribution of random number generation algorithm*/
#include <stdio.h>
#include <stdlib.h>
#define NUM 30
#define MEM_SIZE 512*1024 //512MB
int main()
{
        short i = 0 , j;
        long acc = 0;
        if(!numbers)
        {
                printf(``Can't allocate memory\n'');
                exit(-1);
        }
        while (1)
        {
                numbers[i] = rand() % NUM ;  //random numbers from 0 - NUM
                acc = 0;
                for (j = 0; j < i; j++)
                        acc += numbers[j];
                printf(``New average: %ld\n'',  acc/++i); //should converge to NUM/2
        }
}
```

Do you see any problems with the code?

STATIC ANALYSIS (CONT.)

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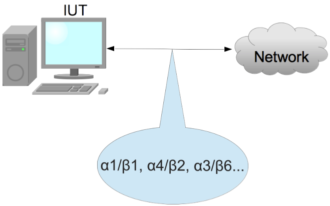
Hard to see, hard to detect (iteration # 32,768)

Passive Network Trace Analysis

PASSIVE NETWORK TRACE ANALYSIS

Interaction



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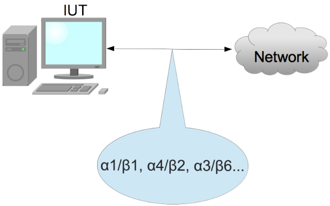

Interpretation

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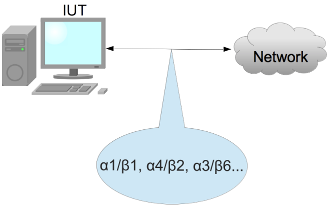

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- The IUT interacts over the network.

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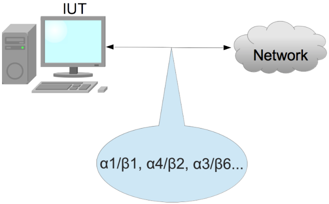

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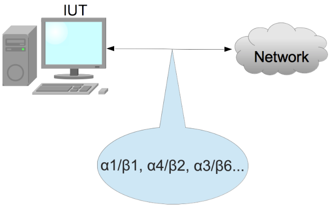

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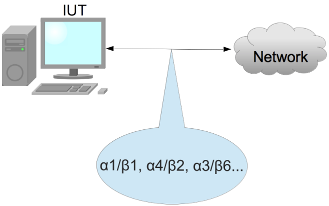

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How do we test this then?

PASSIVE NETWORK TRACE ANALYSIS (CONT.)

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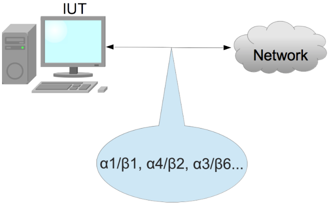

Invariants — very popular

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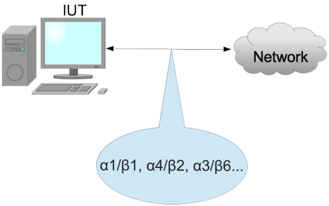

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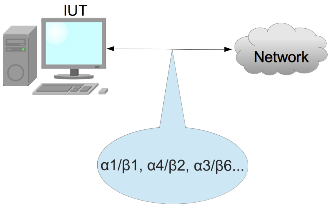

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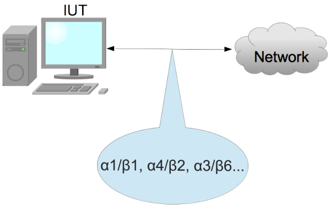

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- E.g., It is not allowed to observe $\beta 6$ before an occurrence of $\alpha 4$ (this holds for our presented trace)
- **Many** languages proposed to express invariants

LET'S START GOING DEEPER

Preview is over...

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- I hope you are looking forward to this as much as you're looking forward for a fresh beer on a Friday night!

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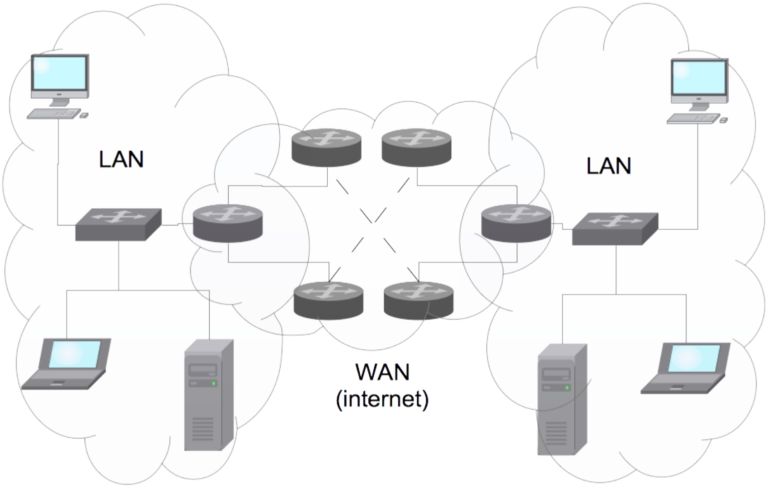
- Let's understand network protocols and how to easily interact with them

Communication Protocols
(for data/computer networks)

COMPUTER NETWORKS

Simplified Network Architecture



COMPUTER NETWORKS — TYPICAL NOTATIONS

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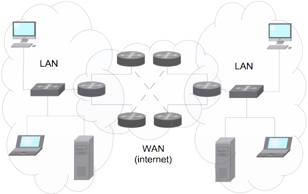

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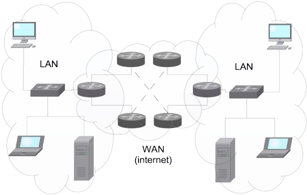

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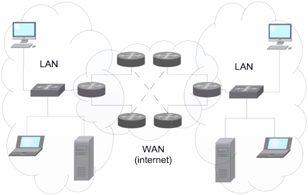

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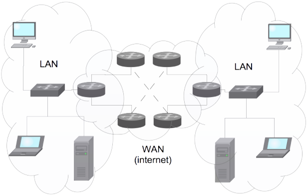

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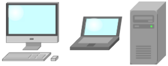
- Hosts (computers, data sources): 

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Computer Networks — Communication

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- For the communication between hosts and LAN
- From the LAN to WAN, and WAN to WAN (this is grouped equally)

THE PHYSICAL LAYER (PHY)

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  - The voltage used to interpret 0s and 1s, which pin/cable has which data, the speed to transmit, the radio-frequency, the multiplexing, the time-slots to transmit, how to handle collisions between wireless-packets and many other parameters are part of the PHY later

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message.zip: Used to transmit data from a device to other *physically* connected devices

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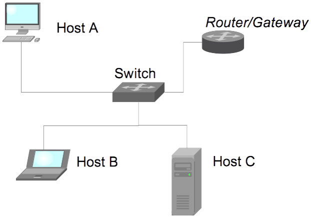
Typical LAN architecture



The Data Link Layer (cont.)

Switching

THE DATA LINK LAYER (CONT.)

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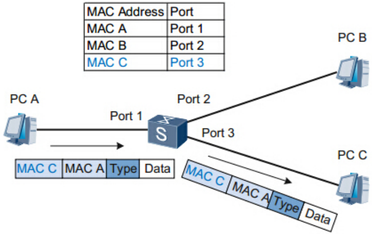

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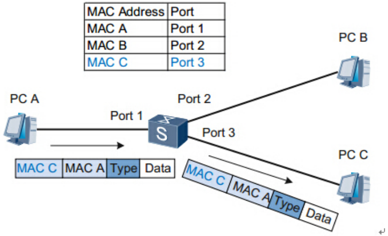

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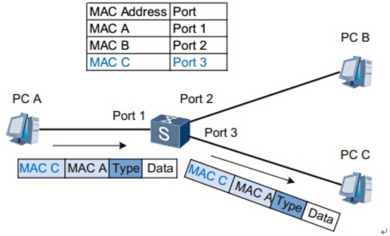

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- Answer: In a single port many devices!

THE DATA LINK LAYER (CONT. 2)

The **Ethernet** Protocol Frame Structure

Preamble	Start Delim	Dest MAC	Src MAC	Ether Type	Payload	FCS
(7 bytes)	*(1 byte)*	*(6 bytes)*	*(6 bytes)*	*(2 bytes)*	*(1500-46 bytes)*	*(4 bytes)*

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- Frame Checking Sequence: error detection and correction code (Prof. Yevtushenko's class (:)

MOVING FROM LAYER 2...

What we know now

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- How to move <<*data*>> from one host to another in the same local area network

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- The holly grail of networking, **THE Internet**

THE NETWORK LAYER

Network (A.K.A Layer 3) Layer functions?

THE NETWORK LAYER

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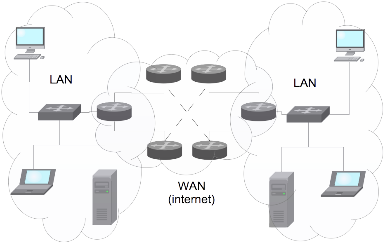
Typical Inter-network architecture



THE NETWORK LAYER (CONT.)

Routing

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- The core of L3, based on the routing (moving textit<<data>>) from one network to the other
- Based on Internet Protocol (IP) addresses, e.g.: 91.221.61.55 (typically represented with 4 decimal octets separated by a '.')
- Local networks have IP addresses, which belong to the **same** network
- Network masks determine the local network. A "netmask" is nothing more than a 4 byte *and* bitwise mask. A common notation is the Classless Inter-Domain Routing (CIDR), the most significant bits are the network address. For example, "/16" means the netmask is equal to: 11111111111111110000000000000000

THE NETWORK LAYER (CONT. 2)

Example

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- The CIDR (IP address/netmask) 192.168.1.124/24

The Network Layer (cont. 2)

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$$
\begin{aligned}
IPaddress\ :& 11000000101010000000000101111100 \\
& \&(bitwise) \\
Netmask\ :& 11111111111111111111111100000000 (255.255.255.0) \\
Network\ :& 11000000101010000000000100000000 = 192.168.1.0/24 \\
NetRange\ :& 192.168.1.1 - 192.168.1.255
\end{aligned}
$$

- First address is *associated* to the gateway, the device in charge of inter-routing (more about this later)

THE NETWORK LAYER (CONT. 2)

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- First address is *associated* to the gateway, the device in charge of inter-routing (more about this later)
- Last address is the broadcast address. When data is sent to this address, it is routed to **all** nodes in the network

THE NETWORK LAYER (CONT. 3)

For you

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THE NETWORK LAYER (CONT. 3)

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$$\begin{aligned} IPaddress &: 192.168.1.124 \\ Netmask &: 255.255.255.224 \\ Network &: 192.168.1.96/27 \\ NetRange &: 192.168.1.97 - 192.168.1.127 \\ BroadcastAddress &: 192.168.1.127 \end{aligned}$$

The Network Layer (cont. 3)

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- What is the gateway address?

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- What is the gateway address?
  - Not enough information...
- Speaking about gateways, how do they decide where to send the <<*data*>>?

The Network Layer (cont. 00000100)

The **IPv4** Datagram Structure

<table>
<tr><td>Version
(1 nibble)</td><td colspan="2">IHL
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THE NETWORK LAYER (CONT. 00000100)

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- DSCP: Differentiated Services Code Point, classify traffic, e.g., voice applications vs. web pages

THE NETWORK LAYER (CONT. 00000100)

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- Flags: 0 = always 0 (reserved), DF = don't fragment (send this packet complete), MF = more fragments coming from this packet.

The Network Layer (cont. 00000100)

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- Flags: 0 = always 0 (reserved), DF = don't fragment (send this packet complete), MF = more fragments coming from this packet.
- Fragment offset: if a packet is fragmented, this shows the position of this fragment relative to the beginning of the original IP packet

THE NETWORK LAYER (CONT. 00000100)

The **IPv4** Datagram Structure

<table>
<tr><td>Version
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- The gateway decides to which peer (router) to forward the traffic based on the destination IP address
- Classical shortest path-finding algorithm application, e.g., Bellman-Ford algorithm for classical Routing Information Protocol (RIP) protocol
- Shortest path is not not always the “best” path, specially for exterior gateway protocols, Internet service providers might prefer to pass traffic to a longer path which is less expensive (in terms of ₽, €, $), e.g., the Border Gateway Protocol — governs the Internet

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THE TRANSPORT LAYER

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THE TRANSPORT LAYER (CONT.)

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Transmission Control Protocol (TCP)!

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- Source Port, Destination Port = UDP
- Sequence Number: If SYN = 1, first data byte reference, corresponding Acknowledgment number is this number + 1. If SYN = 0, accumulated data byte from initial synchronization

TRANSPORT LAYER — TCP

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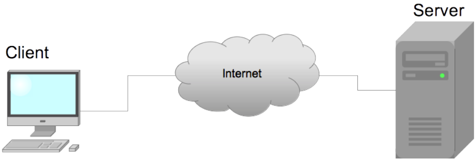
What’s <<*data*>>?

Data interchanged by applications! Finally we know what data is, right? ;)

THE APPLICATION LAYER

Typical Architecture



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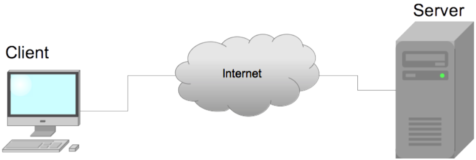

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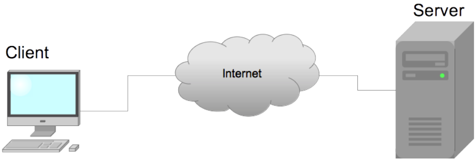

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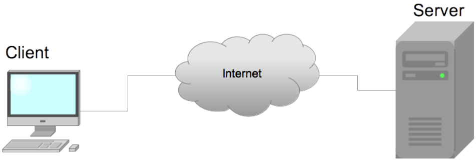

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- Each protocol chooses the message structure according to its necessities and design
- Some are like traditional message structure as the whole TCP/IP Stack, some others are “text-based”

The application layer – The Hyper Text Transfer Protocol

Text-based, request-response scheme

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HTTP REQUEST-RESPONSE EXAMPLE

Request

```
GET / HTTP/1.1
Host: google.ru
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```

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GET / HTTP/1.1
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```

Response

```
HTTP/1.1 301 Moved Permanently
Location: http://www.google.ru/
Content-Type: text/html; charset=UTF-8
Date: Mon, 08 Feb 2016 19:09:10 GMT
Expires: Wed, 09 Mar 2016 19:09:10 GMT
Cache-Control: public, max-age=2592000
Server: gws
Content-Length: 218
X-XSS-Protection: 1; mode=block
X-Frame-Options: SAMEORIGIN

<HTML><HEAD><meta http-equiv="content-type" content="text/html;charset=utf-8">
<TITLE>301 Moved</TITLE></HEAD><BODY>
<H1>301 Moved</H1>
The document has moved
<A HREF="http://www.google.ru/">here</A>.
</BODY></HTML>
```

TO WRAP UP...

The story of how the previous request reached the server

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- Then, packet encapsulation...

Packet encapsulation

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PACKET ENCAPSULATION

TCP Headers *DST PORT 80*	HTTP Request

Packet encapsulation

IP Headers *DST IP* 79.136.239.38	TCP Headers *DST PORT 80*	HTTP Request

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Data-Link Headers	IP Headers *DST IP* `79.136.239.38`	TCP Headers *DST PORT 80*	HTTP Request	Data-Link Footer

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- Along the way, the packet was opened just in the corresponding layer
- The packet gets “d-encapsulated”, and delivered to the receiving application

Out of the scope, but important...

Encrypted protocols

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