**Session Plan: Internet Explained**

**Objective**

In this lecture, the students should be introduced to the concepts of Internet and the way it works. They should be introduced to packets, an overview of the Internet protocol should be made. Students should be introduced to TCP and the OSI model. Examples of network hardware should be introduced.

**Motivation**

This topic aims to introduce students to Internet basically so that they can then easily understand how the web works.

**Content**

### Indtroduction to Internet (~25 min)

* What is the Internet?
  + **Vast** **network** that connects billions of devices together all over the globe
    - Through **fiber optics**, **copper**, **satellites** or **cell phone network**
  + We get indirectly **connected** though **ISP**s(**I**nternet **S**ervice **P**roviders)
* **History – Overview** 
  + Begins with the development of electronic computers in the 1950s
  + Packet switching networks were developed in the late 1960
  + The internet protocol was developed in the 1970s
  + In the 1980s at CERN Tim Berners-Lee created the [**World Wide Web**](http://info.cern.ch/hypertext/WWW/TheProject.html)– the first website, linking hypertext documents into an information system, accessible from any node on the network
* **What is a Network?**
  + **Network** ==a group of **two or more devices** that can communicate
  + It is comprised of a number of **different computer systems** connected by **physical and/or wireless** connections
  + The scale can range from **a single PC sharing** out basic peripherals to **massive data centers** located around the World, to the Internet itself
* **Networks and Internet**
  + **The internet** is made of hundreds of thousands of **networks** and billions of computers and devices connected physically
  + These different systems **connect to each other**, **communicate with each other** and **work together** because of standards for how data is sent

### Q&A [Sli.do] (~5 min)

### How does the Internet work? (~25 min)

* **Web Server Work Model**
* **Important Definitions**
  + To understand how **the Internet works**, first we need to get acquainted with a few definitions
  + **What is?**
    - Server and Client
    - Network Protocol
    - Packets
    - TCP vs UDP
* Servers and Clients
  + All of the machines on the Internet are either **servers** or **clients**
    - **Servers** are the machines that provide services to other machines
    - **Clients** are the machines that are used to connect to those services
* **Network Protocol**
  + **Network Protocol** == a set of rules and standards, that allow communication between network devices
  + Network protocols include **mechanisms** for devices to identify and make **connections** with each other
  + Examples for standard network protocols
    - TCP, QUIC, UDP, IP, ARP
    - HTTP, FTP, TFTP, SMPT, SSH

### Q&A [Sli.do] (~5 min)

### BREAK: 15 min

### Packets (~20 min)

* **Packets**
  + Everything that is created on a computer is translated into digital information using **bits**
  + Bits need to have a way to be transmitted over the internet
  + Every message, file or stream of information is broken down into small chunks, called **packets**
  + When packets are sent on the internet, they usually travel the network together
  + But they might have to take a different route to get to the destination
  + Each packet contains some **important information** inside of it, called **the header**:
    - Where it came from
    - Where is it going
    - How long it is
      * This is how the packet is known to be complete
      * All the packets in the message are the same size
  + How many packets there are in the overall message
* **Traveling of the Packets in the Network**

### Internet Protocol (~30 min)

* **Internet Protocol**
  + One of the most important protocols used in Internet communication is the **Internet Protocol** (**IP**)
  + All the devices on the Internet have **addresses**
  + Theyarecalled **IP Addresses**
  + The IP address is **unique** to each computer or a device at the edge of the network
* **IP Address**
  + An **IP Address** has many parts, organized in a hierarchy
  + This version of IP Addressing is called **IPv4** 
    - Provides more than 4 billion **32 bits** unique addresses
* **IPv4**
  + **IPv4** == sequence of four, three-digit numbers separated by a period
    - Each number can be a number from 0 to 255
    - **IPv4** is not enough for all network devices connected to the internet
  + In 1995, a new version of the internet protocol was created, it's called **IPv6**
* **IP Address classes**
* **What Is CIDR (Classless Inter-Domain Routing)**
  + Classless Inter-Domain Routing, is an IP addressing scheme that improves the allocation of IP addresses
  + It replaces the old system based on classes A, B and C
  + This scheme also helped greatly **extend the life of IPv4** as well as slow the growth of routing tables.
* **IPv4 Private Address Space and Filtering**
* **IPv6** 
  + **IPV6** uses **128 bits** - 340 undecillion unique addresses
    - That's more than the atoms on the surface of the Earth
  + These **128** bits are organized into eight 16-bit sections
  + Each 16 bit block is converted to hexadecimal and it's separated with a colon
  + This is a full IPV6 address:
    - **3FFE:F200:0234:AB00:0123:4567:8901:ABCD**
  + The **leading zeros** in **IPv6** can usually be left out
* What is a **DNS**?
  + The **domain name** is a human way to access IP addresses for devices and websites around the world
  + It is a sequence of phrases that **map** to a giant **Internet-wide database** of **IP addresses**
  + When a domain name is entered in the browser, a request is made to something called a **DNS** (**Domain Name Server**)
  + This server holds a cache of tons of domain names, and their matching IP addresses
* **DNS Example**

### Q&A [Sli.do] (~5 min)

### BREAK: 15 min

### Reliability and TCP (~25 min)

* **Reliability**
  + When packets are transmitted from one location to another, they can take different paths
  + When they get to the destination, they are unorganized and sometimes not complete
  + So the message needs to be audited and reviewed in order to put it together in the right way
  + The **Transmission Control Protocol** or **TCP** does exactly that
* **TCP**
  + **TCP** uses a process, where it looks at **all the packets** in a message and **checks them**
  + Using the header information in each packet, it knows
    - How many there are
    - How large they should be
    - In which order the packets should be in
  + Using this checklist, it is able to rearrange the packets
  + If it finds that a packet doesn't match the expected characteristic, it is discarded
  + **TCP** verifies that all the packets are
    - In the right order
    - Free of any issues
  + After that it **certifies the data** and the packets are **merged** together to recreate the **original** file that was on the sender's device
* **User Datagram Protocol**
  + UDP does not establish a session and it does not guarantee data delivery
  + It is known as the "**fire-and-forget**" **protocol**
  + It sends data and it doesn't really care if the data is received at the other end
* **TCP vs UDP**
  + **TCP** places **reliability** in a higher priority than speed or latency
  + For instances where reliability isn't as important, but **speed** is, **UPD** is used
  + UDP doesn't do excessive reliability checks, but it can send information at a faster rate
  + TCP is the foundation of how a majority of data is transmitted over networks
* **QUIC Protocol**
  + **QUIC** == new transport protocol designed for **mobile-heavy** Internet usage
  + Uses **UDP** as its basis, not TCP
  + Packets are encrypted **individually**
  + Exchange of supported protocols is a part of the initial **handshake process**

### Q&A [Sli.do] (~5 min)

### The OSI Model (~30 min)

* What isthe **OSI Model?**
  + **OSI** model stands for **O**pen **S**ystem **I**nterconnect
  + It consists of **7 layers**
    - Each layer serves the layer above it and in return, is served by the layer below it
  + Understanding each layer of the model helps us with
    - **Troubleshooting**
    - **Communicating** better with technical and non-technical individuals about any system
* **OSI Layers**
* **Application Layer (7)**
  + Only layer that **directly** **interacts** with the **user**
  + Software applications, e.g., **web browsers** and **e-mail clients**, rely directly on its protocols
  + Protocol examples
    - DNS, FTP, HTTP, SMTP, POP3, IMAP
  + Most **important** layer for **software engineers**
* **Presentation Layer (6)**
  + This layer is a part of an operating system (OS)
  + **Converts** incoming and outgoing **data** from one presentation format to another
  + Responsible for **translation**, **encryption**, and **compression** of **data**
  + Protocol examples
    - SSL, TSL
* **Session Layer (5)**
  + Controls the **dialogues** (connections) between computers
  + Establishes, manages and terminates **connections** between the local and remote application
  + Its services include **authentication** and **reconnection** after an interruption
  + Protocol examples
    - RPC, PPTP
* **Transport Layer (4)**
  + Responsible for end-to-end communication over a network
  + Transfers data, splitting it into pieces (**segments**)
  + Provides logical communication between application processes
  + Responsible for the management of error correction, providing quality and reliability to the end user
  + Important concept for web devs – **port number**
  + Protocol examples – **TCP**, **QUIC**, **UDP**
* **Network Layer (3)**
  + Transfers **packets** from one node to another
  + Responds to service requests from the transport layer and issues service requests to the data link layer
  + Protocol examples
    - **IP**, **IPv6**, **IPSec**, **ICMP**, **IGMP**
  + Important concept for web devs – **IP address**
* Data Link Layer (2)
  + Provides **node-to-node data transfer**
  + The data transferred is split into packets – **frames**
  + It **detects** and possibly **corrects** errors that may occur in the **physical layer**
  + Divides into two sublayers
    - **Medium access control (MAC)** layer - controlling how devices in a network gain access to a medium and permission to transmit data
    - **Logical link control (LLC)** layer – identifying and encapsulating network layer protocols, controls error checking and frame synchronization
  + Example protocols – **ATM**, **Ethernet**, **MAC**
* **Physical Layer (1)**
  + It is responsible for the physical connection between two or more parties
  + Converts the **binary** from the upper layers into **signals**, **transmits** them over local media (electrical, light, or radio signals)
  + Examples
    - **Ethernet**
    - **USB**
    - **Bluetooth**
    - **802.11a/b/g/n**
* **Protocol Suite**

### BREAK: 10 min

### Q&A [Sli.do] (~5 min)

### Network Hardware (~10 min)

* **Basic Hardware Components**
  + Cables
  + Routers
  + Repeaters, Hubs and Switches
  + Bridges
  + Gateways
  + Network Interface Cards
* **Cables** **and** **Routers**
  + Network **cables** – the **transmission** **media** to transfer data from one device to another
  + **Router** – **connecting** **device** that transfers data packets between different computer networks (operates on level 3 of OSI)
* **Repeaters, Hubs and Switches**
  + **Repeaters**, **hubs** and **switches** **connect** network **devices** together so that they can function as a single segment
    - **Repeater** – **receives** a **signal** and regenerates it before re-transmitting, so that it can travel longer distances
    - **Hub** – multiport **repeater** (operates on level 1 of the OSI model)
    - **Switch** – **receives** **data** from a port, uses packet switching to resolve the destination device and forwards the data to the particular destination (operates on level 2 of the OSI model)
* **Bridges and Gateways**
  + **Bridge**
    - Connects two separate but **similar** Ethernet network segments
    - Forwards packets from the source network to the destined network (operates on level 2 of OSI)
  + **Gateway**
    - Connects networks that work upon **different** protocols
    - The entry and the exit point of a network (controls the access to other networks)
    - Level 4, 5, 6 or 7 of the OSI model (same as Firewalls)
* **Network Interface Cards – NIC**
  + **NIC** – a computer component that connects it to the network
  + There are two types of network cards:
    - Internal
    - External

### Future of the Internet (~5 min)

* Future of the Internet
  + A typical modern home consists of: PC, Laptop, Tablet,  
    Phones, TV, Security Camera, Air Conditioner,  
    Smart Watch, Printer, Music Player, Light, etc.
  + The "**Internet of Things**"will expand:
    - Healthcare, agriculture, wearables, manufacturing
    - Smart homes, cars and cities (pollution, parking, energy)
    - In 2030 there will be **50 billion devices** connected to the Internet of Things

### Q&A [Sli.do] (~5 min)

**Exercise**

Because this is a theoretical topic, there are no practical exercises.

**Evaluation & Exam**

Because this is a theoretical topic, it is not included in the final exam.