What’s an Internet

Dr. A’s Lecture notes for Chapter 1.1-1.3

# Goals/Objectives

1. Name the components of the internet and identify their function
2. Describe what a services model of the internet looks like.
3. Define a **protocol**
4. Describe Network Edge Entities technically
   1. Identify/describe internet end-systems (🡪Hosts: Clients | Servers | Both)
   2. Describe the types of networks found at the edge (basically all types)
      1. Distances
      2. Speeds
5. Describe **circuit** **and packet switched network characteristics**. Be able to do problems!
6. Differentiate different tiers of networks.

# What’s the internet anyway?

## 1.1.1 Nuts and Bolts Description

**Q: Ask the students to list as many of the pieces of the internet as possible. (CHECK THEM OFF AS THEY NAME THEM)**

* Host / Mobile end system (Laptop/cell phone/…)
* Communication links (fiber optic / coaxial cable / copper wire / radio spectrum 🡪 Different rates )
* [packet] switch (Routers and Link layer switches)
* Router
* Modem (Cable/DSL)
* Cell Tower
* wireless access point
* PROTOCOLS – probably the most important on the list. We’ll talk a lot about protocols (TCP/IP)

**SLIDE 1**

## 1.1.2 Service Description

**T**: Suppose you have an internet application that will make you rich and famous. You write it in C/Python/C#/Java and it communicates with other hosts on the internet. How do you get your program to communicate with another host? THAT IS, how does a program instruct the internet to deliver a piece of data? (BY THE TIME YOU GET DONE WITH CHAPTER 3, you will be doing just that!)

A: Hosts attached to the internet provide (have installed on them) an API that specifies how a software piece running on one host asks the internet to infrastructure to deliver data to a specific destination software piece funning on another host.

**T**: POST OFFICE ANALOGY…

Q: What kind of services do you suspect the internet provides?

A: Show **SLIDE 2** KEEP IT SHORT! We’ll talk in depth about this later!

## 1.1.3 Protocols

**Example: Stop, go to a student, say excuse me what time it is, …, thank you. PROTOCOL COMPLETE Discuss it. Now discuss the more complicated protocol in the classroom. Don’t forget the idea of setting up a session via registration.**

**Slide 3 🡪 Slide 4**

(TQ p 9) Definition: A **protocol** defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or *other event*.

Trivia:

* 600 Million systems attached to the internet on a continuous basis as of July 2009 [ISC 2009]
* 10 terabits/sec 2008 internet capacity [PriMetrica 2009].

# The network edge

## 1.2.1 Client Server Programs

**Q: out of all that stuff on the board, what is the Network edge made up of?**

**A: Hosts / End systems. We can break these systems down into two groups: Clients and Servers. But a host can be both, so we define it as follows.**

**Slide 5**

Definition: A **client program** is a program running on one end system that requests and receives a service from a **server program**. This is known as the **client-server** model.

Definition: Client-server internet applications are by definition, **distributed applications**.

## 1.2.2 Access Networks

Definition: **Access networks** connect end systems to the first router.

Q: Is your Linksys home router/wireless access point/firewall/NAT device considered part of the access network or is it the first router?

A: It’s part of the Access network because it will only route for your network, it does not route to multiple networks. Since it is running NAT (99.999% of the time) it is THE end system recognized by the internet.

**For not so Nostalgic Purposes:**

* **telco** = local telephone provider
* **central office (CO)** houses a **telco switch** from which your twisted pair copper wire runs to your house.
* A telco owns hundreds of COs and will link each of its customers to the nearest CO.

Really move through this stuff!

### Dial-up

Trivia: about 10% of all residential users still use Dial-up [Pew 2008]

### DSL

**Q: What does DSL stand for?**

**A: Digital Subscriber Line (DSL)**

Trivia: USA 50/50 for DSL vs Cable. In Europe its about 90% DSL

**Q: Who provides DSL?**

**A: Your local Telco.**

**Q: What is the provider called?**

**A: Internet Service Provider (ISP)**

For DSL you split the signal from a Digital subscriber line access multiplexer (DSLAM) into three bands.

* 0-4 kHz ordinary telephone
* 4-50 kHz upstream (or upload 128 kbps – 1 Mbps)
* 50 kHz - 1 Mhz downstream (download 1-2 Mbps).

Since the bands are different widths and provide different speeds, this is usually called Asymmetric Digital Subscriber Line (ADSL)

* Always on
* Talk and surf at the same time

**Q: If it only takes 4 kHz of bandwidth to talk on a phone, why does voice over IP sometimes loose parts of the conversation or jump to a different part of the conversation?**

**A: Good question! It has to do with how the internet provides services to applications vs. how the phone company provides a “connection” from your phone to another phone.**

### Cable

* Shared both up and down! 🡪 Bandwidth shared between houses
* Both fiber and coax 🡪 hybrid fiber coax (HFC)
* Usually faster for small numbers of houses on a network.

### Fiber to the Home (FTTH)

Of course this is what we all want!

* The best is **direct fiber** as in direct from the CO to your home.
* Next best is shared fiber which comes in two varieties:
  + active optical networks (AON) which is essentially switched Ethernet over fiber.
  + passive optical networks (PON). PON uses a spliter from the CO’s optical line terminator (OLT) to each houses optical network terminator (ONT). Signals reaching the OLT are replicated to each ONT. This is essential HUB type architecture which is SHARED! Verizon uses this type for it’s FTTH.

### WiFi

We should all at least know what this is. Wireless is based on IEEE 802.11 a/b/n which gives 10/54/<108 depending on the hardware. (Show Wigle.net – maybe not the best, but one of several wifi locators)

* Distance: 10s of meters
* Speed: 54 Mbps

### Wide Area Wireless Access

WiMAX 802.16

* Diastance: 10s of kilometers
* Speed 5-10 Mbps

Trivia Sprint-Nextel committed billions of dollars to WiMAX in 2007.

## 1.2.3 Physical Media

### Guided

* UTP (Ethernet)
  + 99% of all wired connections
  + 10 Mbps – 1[0] Gbps
  + ~100 Meters
* Coax
  + 1-12 Mbps (typical shared)
  + ~200 meters
* Fiber Optics
  + 100s Gbps 🡪 Optical Carrier standard link speeds: OC- where the speed is in Mbps.

**Q: So what speed is an OC-768 link?   
A: 39782.4 Mbps or about 40 gigabits per second!**

* + 100 Km
  + High cost of hardware, but cheap medium

### Unguided

* Terrestrial Radio (WiFi, WiMAX, Cell Phones), and we talked about this earlier.
* Satellite Radio
  + Geostationary Satellites
    - 36000 kilometers above the earth’s surface
    - introduces 280 milliseconds of signal propagation delay.
    - 100s of Mbps
    - Used where DSL/Cable is not available
  + Low Earth Orbit (LEO) satellites
    - constantly moving is a problem,
    - yet there are many “constellations” of satellites that support communication in some way.

# Network Core

**SLIDE**

## 1.3.1 Circuit Switching & Packet Switching

Let’s look at the core, the switches and links that actually transport our information from one host, across the world to another host (sometimes right next door).

**Q: How do you carry all the information that may arrive from Ethernet networks (to keep it simple), 10 – 1 gigabit edge networks (like on our campus) to a single internet connection that is only say 48 Mbps? To complicate things further, suppose that 50 people are streaming 50 different lectures from off campus to more than overload the main internet connection?**

**A: You don’t!**

**Q: How do you decide who gets the bandwidth?**

**Ansrs:**

* **First come first server FIFO queue (when someone tries to queue a piece of data to be moved from one space to another and the queue is full, data gets dropped. (Packet switched networks)**
* **Reservations for extended connections like phones. (when you run out of available connections people don’t get to send data) Circuit switch networks which we’ll talk about first.**

(VoCon: packet; circuit, session, guaranteed bandwidth, end-to-end connection / reservation)

**Q: What techniques can we use to allow multiple connections or packets of data to be transmitted virtually at the same time?**

**SLIDE**

**A: Multiplexing: Specifically frequency-division multiplexing (FDM), time-division multiplexing (TDM) or some statistical method of multiplexing without guarantees. (SEE SLIDE 1-33 as a good example)**

### Circuit Switching

Let’s start by considering circuit switching since circuit switching is easier to understand and which uses FDM and TDM.

Circuit is made up of an **end-to-end connection** in which **reservations** **are made on each link and router** to support and **guarantee** a consistent **amount** of data **flowing at a predictable rate**. If we have a range of frequencies to use to transmit the data (think distinguishable colors of light), we could use a prism to separate the frequencies and read the individual pulses for each frequency as a signal. This is essentially **frequency-division multiplexing (FDM)**. However you “discretise” the different frequencies, you will need a certain number of them to move the data in the time allotted. The range of frequencies that you use is the bandwidth requirement. Literally the amount of data that can be moved is measured in the width of the band. ***This is where the term bandwidth comes from***. How much data? That depends on how well you can distinguish the difference between one frequency and another.

DEMO IDEA: Make a box with several lights of different colors that is long and therefore puts the beam out in an approximate straight line. Place a prism at the edge and show the lights going on and off in different intervals. What you should see on the board is the different colors going on and off as they are separated by the prism.

Trivia: For phones the required bandwidth is only 4 KHz.

**Q: If you have a bandwidth of 80 KHz how many phone lines could you support?**

**A: You could support 20 phone lines and that’s it.**

EXAMPLE PROBLEM: We could use all the bandwidth for each circuit and assign the circuit a time slot out of a repeating time interval, which we call a frame. E.g. if you have a time frame of 200 Milliseconds and you assign each circuit a 10 Milliseconds time slot to transmit, you can support 20 circuits. If the bandwidth is 80 KHz, each circuit could support a phone line.

Now, we’ve been talking in Hz, but lets switch to Mbps:

**SLIDE**

**Example**: Q: How long will it take to send a 640,000 bits from Host A to Host B over a circuit switched network with:

* TDM: 24 slots
* Frame rate of 1.536 Mbps write like per frame or .
* 500 msec circuit setup time before transmission can start

A: Each circuit gets per circuit. Now we just divide the number of bits to transmit by the bit rate to get circuit setup time to give 10.5 seconds. MAKE SURE THE UNITS WORK. IF THEY WORK …, if they don’t ….

P28 Gives an example for FDM by assigning a value of bits transmitted per frame. This is basically the same math once you discover the per circuit bandwidth. You should read that.

Q: If you are the only one transmitting, who gets the remaining bandwidth?

A: No one!

There must be a better way! In fact it’s the way the internet works.

### Packet Switching

**SLIDE**

Packet switching is much more complex in nature since we don’t have concrete, reserved, continuous flows of data to work with. Instead streams of data are broken into packets (or messages) and each packet traverses the network independently.

**SLIDE**

Discuss the elements of Figure 1.14.

1. Someone sends a packet from a host and the packet traverses the wire to a packet switch
2. The packet switch STORES the packet until it is ready to FORWARD the packet onto the next link (wire)
3. Store and Forward architecture
   1. Input buffers or queues (FIFO)
   2. Output buffers or queues (FIFO)
   3. Both introduce:
      1. queuing delays
      2. Packet loss

**SLIDE EXAMPLE**

**EXAMPLE (Difference between packet switching and Circuit switching)**

**Suppose:**

1. **Circuit switch**
2. **Users generate 100 kps, 10% of the time**
3. **Frame size is 1 Mbps**

**🡪 10 circuits 🡪 10 users.**

**Suppose:**

1. **Packet switch using FIFO Queues (called statistical multiplexing)**
2. **Probability P of a user transmitting is 10%, or .**
3. **If there are 35 users, what is the probability that the number of users that are transmitting is ? Stop: Why do we even care?** 
   1. **If more than 10 users are transmitting, some packet is going to get dropped eventually or at least slowed down in a queue that is waiting for a link to become available. Think about that for a minute. You should be able to convince yourself that this is true!**
   2. **How do we calculate the probability? We are looking at a binomial distribution (why? Because either someone is transmitting or is not transmitting. Two options mutually exclusive.)**

The binomial distribution gives the [discrete probability distribution](http://mathworld.wolfram.com/DiscreteDistribution.html) of obtaining exactly successes out of [Bernoulli trials](http://mathworld.wolfram.com/BernoulliTrial.html) (where the result of each [Bernoulli trial](http://mathworld.wolfram.com/BernoulliTrial.html) is true with probability and false with probability ). The binomial distribution is given by (Weisstein 2009) **[**By the way **]**

**Let’s work it out in excel!**

**Q: At what point are we going to really have packets dropped? How many users can we support? … If we have 35, then only .0004 or .04% of the time are we growing the queue. Let’s say a reasonable amount is 30% of the time. Let’s go back to Excel to find the answer.**

**Q: What happens if User A suddenly sends a huge amount of data while others are dormant?**

**A: User A gets the bandwidth! AND no one else suffers.**

DEF: Such on demand, rather than pre-allocated, sharing of link resources is referred to as *statistical multiplexing*.

## 1.3.2 How do packets traverse a packet-switched network?

Q: How does a router (a packet switch) know where to send a packet?

A: Use the address to index into a forwarding table that gives the link on which to transmit the packet.

How do we build the table? That’s all of chapter 4 on routing protocols. For now consider that routers FORWARD packets from input to output based on tables of information.

DEF: Forwarding is the process of moving a packet from an input port to an output port.

## 1.3.3 ISPs and internet Backbones

Run through Tier Slides

1. Tier 1 providers are:
   1. Connected directly to every other tier 1 provider.
   2. Connected to a large number of tier 2 providers
   3. Have international coverage
2. Tier 2 Providers are connected to only a few tier 1 providers and typically has only regional or national coverage
3. …
4. ISPs