Class Notes

Any questions from the previous lecture(s) or the textbook chapter 1?

First sessional syllabus: First two chapters of the textbook

Textbook reading: Please finish whole chapter 1 by 31st August

Physical Link Multiplexing:

Multiplexing means that a system resource is shared among multiple users.

At an intuitive level, multiplexing can be explained by analogy to a time-sharing computer system, where a single physical processor is shared (multiplexed) among multiple jobs, each of which believes it has its own private processor.

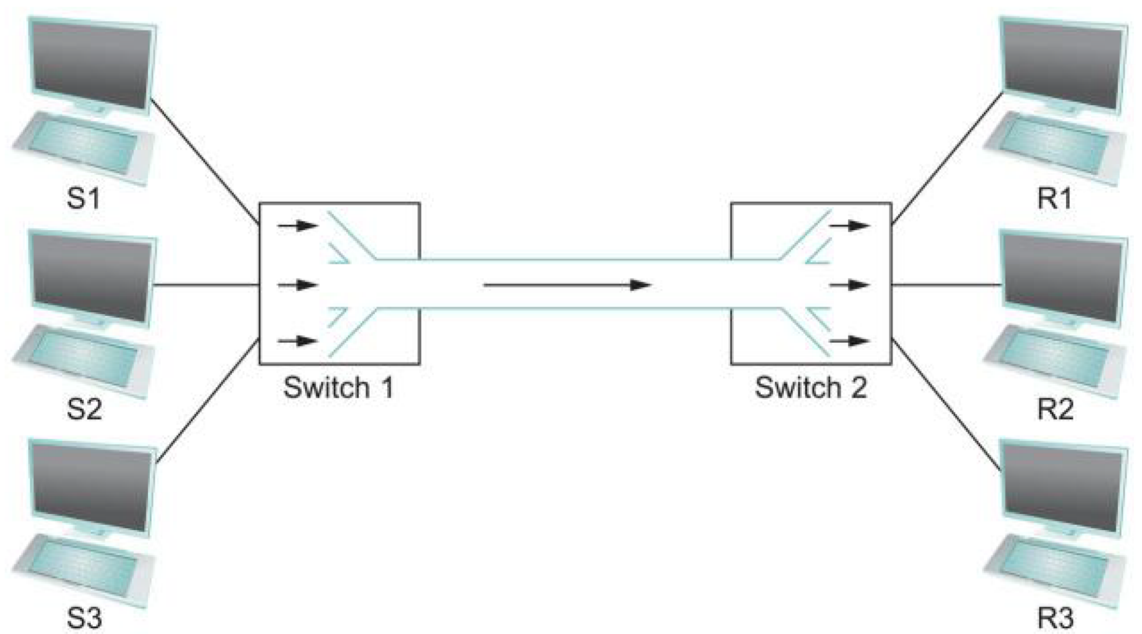

FIGURE 1.5 Multiplexing multiple logical flows over a single physical link.

Source: Computer networking: a systems approach by Peterson and Davie

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There are several different methods for multiplexing multiple flows onto one physical link. One common method is ***synchronous time division multiplexing*** **(STDM)**. The idea of STDM is to divide time into equal-sized quanta and, in a round-robin fashion, give each flow a chance to send its data over the physical link. In other words, during time quantum 1, data from S1 to R1 are transmitted; during time quantum 2, data from S2 to R2 are transmitted; in quantum 3, S3 sends data to R3. At this point, the first flow (S1 to R1) gets to go again, and the process repeats.

Another method is ***frequency-division multiplexing*** **(FDM).** The idea of FDM is to transmit each flow over the physical link at a different frequency, much the same way that the signals for different TV stations are transmitted at a different frequency over the airwaves or on a coaxial cable TV link.

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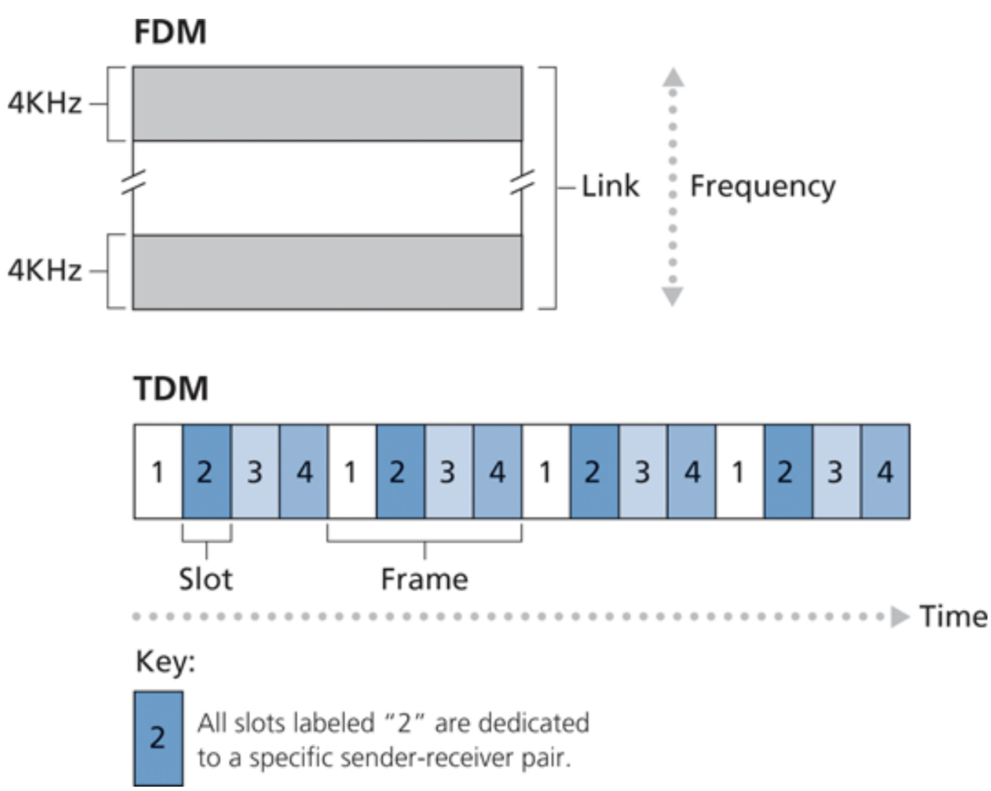
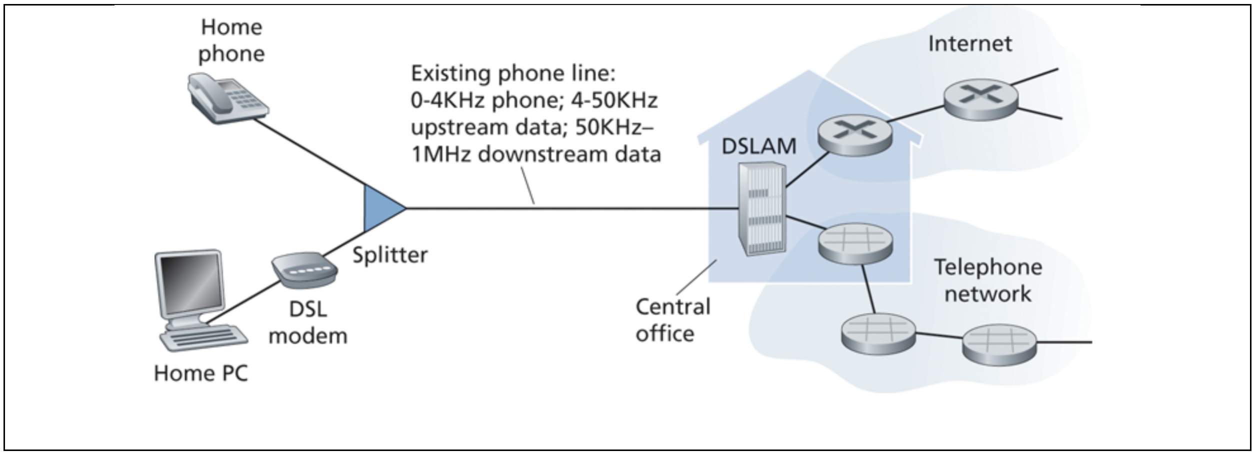


Source: Fig 1.14 of the textbook.

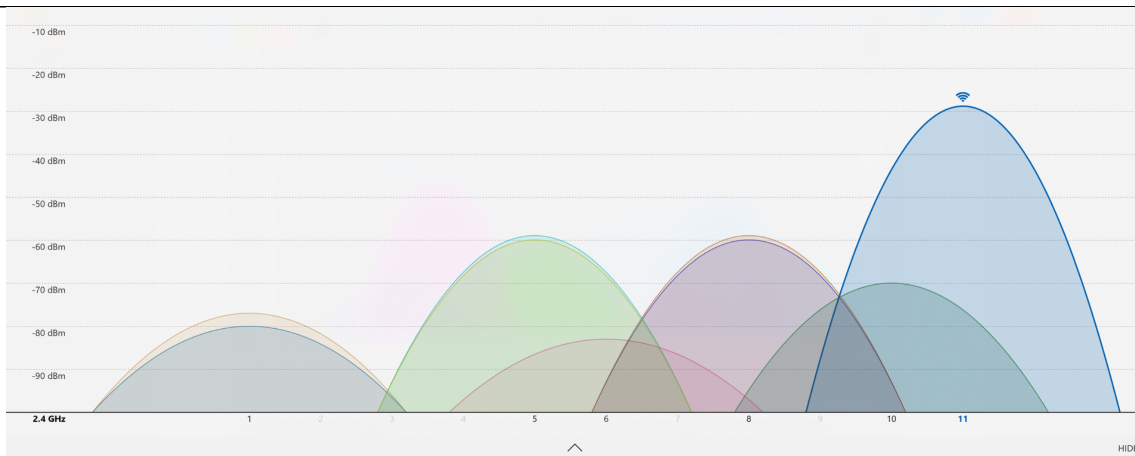
Examples:

DSL: Frequency Division Multiplexing

Note: Downstream data has larger spectrum than upstream spectrum. Why?



WiFi: Frequency Division Multiplexing



Above was for 2.4 GHz spectrum, following is for 5 GHz spectrum.

What is HZ (Hertz)?

Hertz is the specific unit of measurement for frequency in the International System of Units (SI).
1 Hz: One hertz equals one cycle per second.

Frequency is a key characteristic of a signal and refers to how many cycles of a periodic waveform occur in one second.
It is a measure of bandwidth (width of a frequency band).

Time division multiplexing:

4G LTE (Long-Term Evolution) uses a combination of multiple access techniques, including Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM), but it is more specifically based on **Orthogonal Frequency Division Multiple Access (OFDMA)** and **Single-Carrier Frequency Division Multiple Access (SC-FDMA)**.

DOCSIS (Data Over Cable Service Interface Specification) uses Time Division Multiplexing (TDM) as part of its overall strategy for managing data transmission over cable networks, but it primarily utilizes a combination of **TDM** and **Frequency Division Multiplexing (FDM)**.

Shortcomings of FDM and TDM:

(1) If one of the flows (host pairs) does not have any data to send, its share of the physical link—that is, its time quantum or its frequency—remains idle, even if one of the other flows has data to transmit.
(2) Both STDM and FDM are limited to situations in which the maximum number of flows is fixed and known ahead of time. It is not practical to resize the quantum or to add additional quanta in the case of STDM or to add new frequencies in the case of FDM.

Statistical Multiplexing:

(1) The form of multiplexing that addresses these shortcomings, and of which we make most use in the packet switched Internet, is called *statistical multiplexing*.
(2) It is like STDM but data from each flow is transmitted on demand. This avoidance of idling the link gives packet switching its efficiency.
(3) To limit that for how long a flow can go on the link is necessary so that everyone could get its turn on the link.

Packet Switching VS Circuit Switching:

Why is packet switching more efficient? Let's look at a simple example. Suppose users share a **1 Mbps** link. Also suppose that each user alternates between periods of activity, when a user generates data at a constant rate of **100 kbps**, and periods of inactivity, when a user generates no data. Suppose further that a user is active only 10 percent of the time (and is idly drinking coffee during the remaining 90 percent of the time).

Thus, the circuit-switched link can support **only 10 (=1Mbps/100kbps) simultaneous users**.

With packet switching, the probability that a specific user is active is 0.1 (that is, 10 percent). If there are 35 users, the probability that there are 11 or more simultaneously active users is approximately 0.0004. (**Homework Problem P8 outlines how this probability is obtained.**)

When there are 10 or fewer simultaneously active users (which happens with probability 0.9996), the aggregate arrival rate of data is less than or equal to 1 Mbps, the output rate of the link. Thus, when there are 10 or fewer active users, users' packets flow through the link essentially without delay, as is the case with circuit switching. When there are more than 10 simultaneously active users, then the aggregate arrival rate of packets exceeds the output capacity of the link, and the output queue will begin to grow. (It continues to grow until the aggregate input rate falls back below 1 Mbps, at which point the queue will begin to diminish in length.) **Because the probability of having more than 10 simultaneously active users is minuscule in this example, packet switching provides essentially the same performance as circuit switching, but does so while allowing for more than three times the number of users.**

Internet: Network of networks:

Figure 1.15 **Interconnection of ISPs**

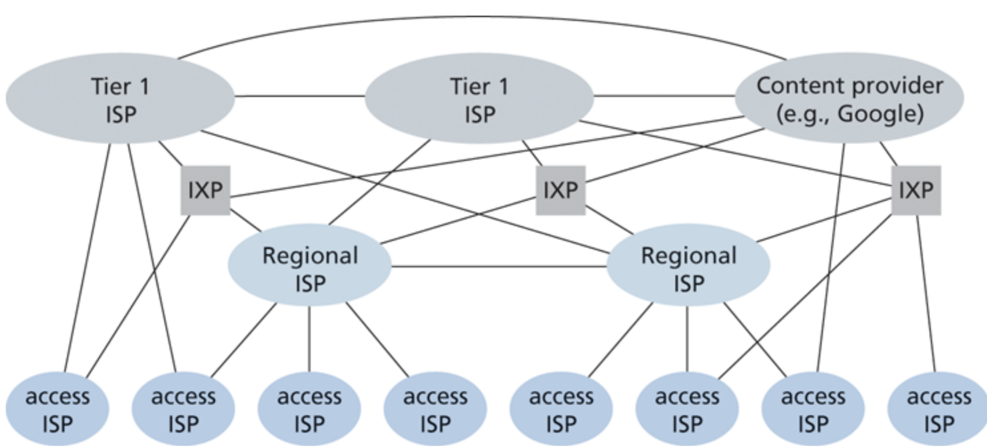


Figure 1.15 Full Alternative Text

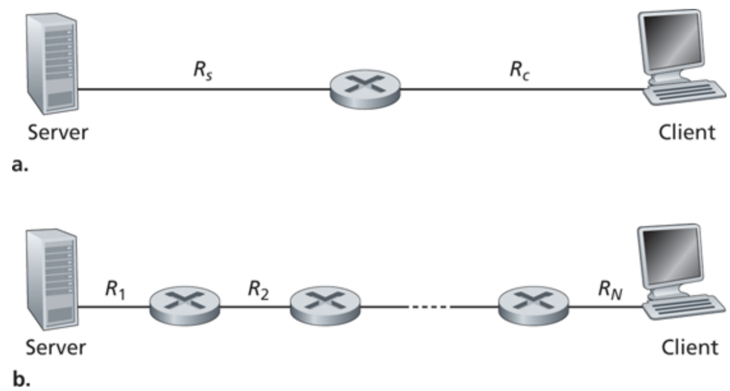
Source: Figure 1.15 from the textbook

Above "graph" of ISP (Internet Service Provider) is the way it is primarily due to business reasons + technical reasons. Actually figuring out this graph for the real ISPs has been an active area of research in networking.

End-to-End Throughput:

The concept of **bottleneck link**: The effective throughput depends on the bottleneck link on the path from the source to the destination.

Figure 1.19 **Throughput for a file transfer from server to client**



Source: Fig 1.19 of the textbook

How big is a "mega"?

There are several pitfalls you need to be aware of when working with the common units of networking, such as MB and Mbps. The first is to distinguish carefully between bits and bytes. Throughout this book, we always use a lowercase *b* for bits and a capital *B* for bytes. The second is to be sure you are using the appropriate definition of giga (G), mega (M), and kilo (K). *Mega,* for example, can mean either 2^{20} or 10^6. Similarly, *kilo* can mean either 2^{10} or 10^3, and *giga* can mean either 2^{30} or 10^9. What is worse, in networking, we typically use both definitions. Here is why.

Network bandwidth, which is often specified in terms of Mbps, is typically governed by the speed of the clock that paces the transmission of the bits. A clock that is running at 10 MHz is used to transmit bits at 10 Mbps. Because the *mega* in MHz means 10^6 hertz, Mbps is usually also defined as 10^6 bits per second. (Similarly, Gbps is 10^9 bits per second.) On the other hand, when we talk about a message that we want to transmit, we often give its size in bytes. Because messages are stored in the computer's memory, and memory is typically measured in powers of two, the *K* in kB is usually taken to mean 2^{10}. (Similarly, MB usually means 2^{20} and GB usually means 2^{30}.) When you put the two together, it is not uncommon to talk about sending a 64-kB message over a 100-Mbps channel, which should be interpreted to mean $64 \times 2^{10} \times 8$ bits are being transmitted at a rate of 100×10^6 bits per second. This is the interpretation we use throughout the book, unless explicitly stated otherwise.

The good news is that many times, we are satisfied with a back-of-the-envelope calculation, in which case it is perfectly reasonable to make the approximation that 10^6 is really equal to 2^{20} (making it easy to convert between the two definitions of mega). This approximation introduces only a 5% error. We can even make the approximation in some cases that a byte has 10 bits, a 20% error but good enough for order-of-magnitude estimates.

While we are making quick-and-dirty calculations, 100 ms is a reasonable number to use for a cross-country round-trip time—at least when the country in question is the United States—and 1 ms is a good approximation of an RTT across a local area network. In the case of the former, we increase the 48-ms round-trip time implied by the speed of light over a fiber to 100 ms, because there are, as we have said, other sources of delay, such as the processing time in the switches inside the network. You can also be sure that the path taken by the fiber between two points will not be a straight line.

Source credit: Computer Networks by Peterson and Davie

Security:

We define security as:

(1) Need for confidentiality
(2) Need for integrity
(3) Availability of the system

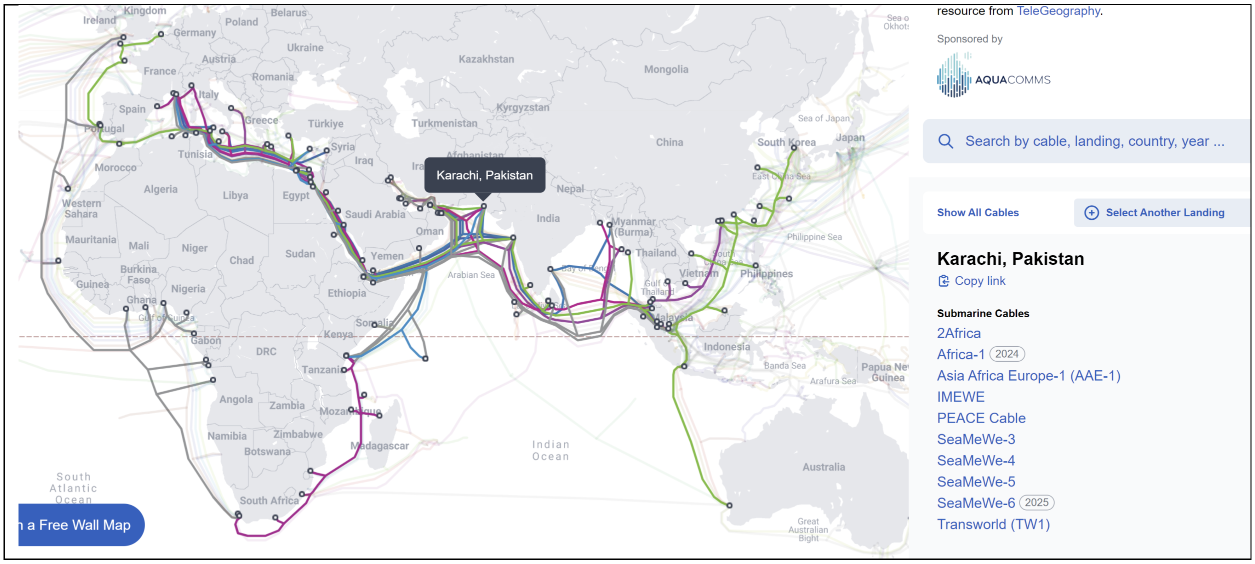
Bad actors can target all three above by sniffing network data passively or actively, and by Distributed Denial of Service Attacks (DDoS). As David Clark tells in the following paper, security was never a top-level goal of the initial Internet design. Security has been retrofitted over time. But security is such a difficult problem that its almost always an arms-race with the bad actors!

The design philosophy of the DARPA internet protocols by David Clark

Source: Wikipedia, https://en.wikipedia.org/wiki/David_D._Clark

Aside: Submarine cable map:

You can see a map of the world's submarine cables at: https://www.submarinecablemap.com



At this point, I believe we have discussed all of the important concepts in chapter one. There is a lot more discussion, with many more examples in the textbook in chapter one (that I hope you are reading).