Lecture 1 (Background)

1 Older Form of Communication - Telephone

- Developed by Alexander Graham Bell
- Breakthrough was converting voice to electrical signals
- Telephone is technically not a network but an application

1.1 How did Tele-Communication via Telephones happen?

- Multiple "nodes" present - clients are end nodes
- Metadata about the connection stored at each node on the route, hence reservation of resources needed
- If resources not available (client or a middle node), network is *busy*
- Since path fixed, destination address not sent during the conversation (only during initialisation), only a unique identifier to the call
- Information transmitted as continuous stream of data
- Source tears down the circuit when call ends
  This approach is called **circuit switching**

1.2 History of "Switches"

1. Manual human switch
2. Modern switch developed by Almon Brown Strowger ("girl-less, cuss-less") - electromechanical device

1.3 Timing in Circuit Switching

The connection completion and destruction combined has a high overhead

1.4 Sharing a link (multiplexing)

1. **Time Division Multiple Access (TDMA)**
   - Divide every "cycle" into n sub-cycles
   - Need to sync the sub-cycle (dynamically)
   - Capacity is lost when not all sub-cycles being used

2. **Frequency Division Multiple Access (FDMA)**: different frequencies for each "call"

1.5 Strengths and Weaknesses

- **Predictable**: known delays but not drops
- **Easy to control**: centralised management
- **Not resilient to failures**:
  i. Failure of any node on the path prevents transmission (new routes are not created dynamically)
  ii. Each transmission had a huge overhead
- **Wastes bandwidth**: peak bandwidth (P) larger than average bandwidth (A), A/P about 1/3 for a telephone call but 1/100 or lower for data transfer
  Resolution: Using **Statistical Multiplexing**, this strategy aims to support about $2 - 3x$ of average behaviour
- Optimised only for voice communication
- Setup time high

1.6 Fixes and Ways to Overcome the Weaknesses

Paul Baran was one of the pioneers for improvements. His paper "On Distributed Communications" (1964) contained the following three points: 1. Distributed control 2. Message blocks (packets) 3. Store-and-forward delivery

The above points solved the problem of connectivity, however, to resolve the issue of wasted bandwidth, Len Kleinrock analysed packet switching and statistical multiplexing

2 Taxonomy of Networks

Communication network can be classified into:

1. **Broadcast Communication Network**
2. **Switched Communication Network**

2.1 Broadcast Communication Network

- Information transmitted by any node is heard by every other node on the network
- Limited range (usually of the order of LAN)
- Has issues of coordination (Multiple Access Problem) and privacy as well

2.2 Switched Communication Network

1. **Circuit-Switched CN** (discussed above)
2. **Packet-Switched CN**

2.2.1 Packet-Switched Communication Network

- Each packet is made up of a header, data and (optionally) trailer
- **Routing** is determined dynamically using header information
- At each node, the packet is stored temporarily before it is forwarded to the next node (**store-and-forward**)

Packet-Switched is further divided into:

1. **Datagram Network**
2. **Virtual Circuit Network** - "Hybrid" of circuits and packets where a *virtual* circuit is established and communication then done in packets

2.2.1.1 Datagram Network

- Each packet is independently switched and hence header contains complete destination address
- Routing decision is made independently for each packet
- Uses **statistical multiplexing**, will fail in the ideal worst-case when *all* packets arrive at the same time, assumes independence of traffic sources and computes the *expected* scenario