**Pulse Code Modulation (PCM)**

**Sampling**
8000 discrete signal measurements are taken at equal intervals every second.

**Quantization**
The level of each sample is rounded to the nearest expressible value.

**Encoding**
Digital values are encoded as binary numbers for encapsulation.

**Compression (Optional)**
The digital signal is compressed in real time to consume less bandwidth.

---

**Voice Codecs**

<table>
<thead>
<tr>
<th>Codec</th>
<th>MOS</th>
<th>Bandwidth</th>
<th>Complexity</th>
<th>Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.722 SB-ADPCM</td>
<td>4.13</td>
<td>48-64 kbps</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>G.711 PCM</td>
<td>4.1</td>
<td>64 kbps</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>iLBC</td>
<td>4.1</td>
<td>15.2 kbps</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>G.729 CS-ACELP</td>
<td>3.92</td>
<td>8 kbps</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td>G.726 ADPCM</td>
<td>3.85</td>
<td>32 kbps</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>G.729a CS-ACELP</td>
<td>3.7</td>
<td>8 kbps</td>
<td>Medium</td>
<td>No</td>
</tr>
<tr>
<td>G.728 LD-CELP</td>
<td>3.61</td>
<td>16 kbps</td>
<td>High</td>
<td>No</td>
</tr>
</tbody>
</table>

**Calculating Required Bandwidth**

**G.711/Ethernet Example**

- **Codec Payload**: Bitrate × Sample Size
  - 64 Kbps × 20 msec = 160 B
- **L2 Overhead**: Ethernet (18) + 802.1Q (4) = 22 B
- **L3 Overhead**: IP (20) = 20 B
- **L4 Overhead**: UDP (8) + RTP (12) = 20 B
- **Packets per Second**: 1000 msec / 20 msec × 50 pps = 250 packets per second
- **Total Bandwidth**: 88.8 Kbps

---

**IP Phone Boot Process**

1. **Power Over Ethernet (Optional)**
   - Power is supplied via IEEE 802.3af/at or Cisco ILP

2. **VLANs Learned via CDP or LLDP**
   - Voice and data VLANs communicated via CDP/LLDP

3. **IP Assignment via DHCP**
   - The phone sends a DHCP request in the voice VLAN; the response includes an IP and DHCP option 150

4. **Configuration Retrieved via TFTP**
   - The phone retrieves its configuration from one of the TFTP servers specified in the DHCP option

5. **Registration**
   - The phone registers with the call server(s) specified in its configuration

---

**Access Switch Port Configuration**

```sh
interface FastEthernet0/1

! Configure data and voice access VLANs
switchport access vlan <VLAN>
switchport voice vlan <VLAN>

! Trust ingress QoS markings
mls qos trust cos

! Optionally pre-allocate power for the port
power inline static [max <wattage>]
```