EEEN 462 – ANALOGUE COMMUNICATION SYSTEMS

STUDY GUIDE: ANALOG TELECOMMUNICATION SWITCHING SYSTEMS

I. OBJECTIVES

Upon completing this guide, you should be able to:

1. Explain the fundamental need for switching in a telecommunications network.
2. Describe the evolution of switching systems from manual to crossbar to electronic Stored Program Control (SPC).
3. Differentiate between circuit switching and message/packet switching (conceptually).
4. Understand the key components of a telephone: the transmitter (carbon microphone), receiver, and hybrid circuit.
5. Analyze the standard subscriber loop, including ringing, supervision, and dialing (pulse and DTMF).
6. Diagram and explain the operation of a basic electromechanical switch (Strowger/Step-by-Step and Crossbar).
7. Describe the architecture and advantages of a Stored Program Control (SPC) switching system.
8. Interpret the concept of a numbering plan (e.g., World/Africa/Kenya Numbering Plan).
9. Define fundamental traffic engineering concepts like Grade of Service (GOS) and Erlang B.

2. CORE CONCEPTS & MODULES

The subject can be broken down into four logical modules.

2.1. The "Why" - Introduction to Telecommunication Networks

a) **Basic Problem:** Connecting N subscribers directly to each other requires N(N-1)/2 links (a "mesh network"), which is impractical for large N.

b) **Solution: Switching.** A central office (exchange) allows any subscriber to be connected to any other through a shared network of switches and trunks. This is the foundation of **Circuit Switching**.

c) **Circuit Switching vs. Packet Switching (Analog Context):**

I. **Circuit Switching (Focus of this study guide):** A dedicated physical (or virtual) path is established between two parties for the entire duration of the call. Resources are reserved end-to-end. *Think: Traditional phone call*.

II. **Packet Switching (Mention for context):** Data is broken into packets, each sent independently and possibly over different paths, then reassembled at the destination. Resources are used on demand. *Think: The Internet*.

2.2: The "What" - The Subscriber Loop & Telephone Instrument

1. **The Local Loop:** The pair of copper wires connecting the subscriber's telephone to the central office.
2. **Telephone Functions:**
    - **Signalling:** Communicating the desire to make a call, the number to be called, and to terminate the call.
    - **Supervision:** Monitoring the state of the line (on-hook, off-hook).
    - **Transmission:** Sending and receiving the voice signal.
3. **Key Components Inside a Telephone:**
    - **Carbon Microphone (Transmitter):** Converts sound pressure waves into a varying electrical current. Understand its basic operation.
    - **Receiver:** Converts the electrical signal back into sound.
    - **Hybrid Circuit (2-Wire to 4-Wire conversion):** The critical circuit that allows a single pair of wires (2-wire) to carry both transmit and receive signals simultaneously by separating them internally. Understand the concept of sidetone.
4. **Signalling on the Loop:**
    - **Supervision:** On-Hook (loop open, ~48V DC from Central Office), Off-Hook (loop closed, current flows).
    - **Alerting:** Ringing Voltage (~90V AC, 20 Hz) superimposed on the DC voltage.
    - **Addressing (Dialing):**
        a) **Pulse Dialing:** Briefly opening the loop to create breaks (e.g., 10 breaks for the digit '0').

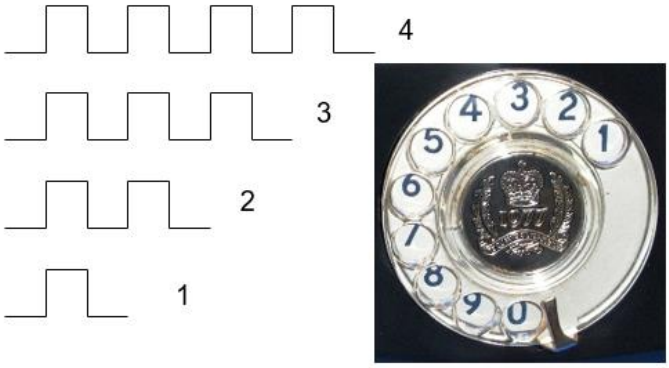

Figure 1. Pulse dialling

b) **Dual-Tone Multi-Frequency (DTMF):** Sending a unique pair of sine waves for each digit (e.g., 697 Hz + 1209 Hz for '1'). Know the standard DTMF matrix.

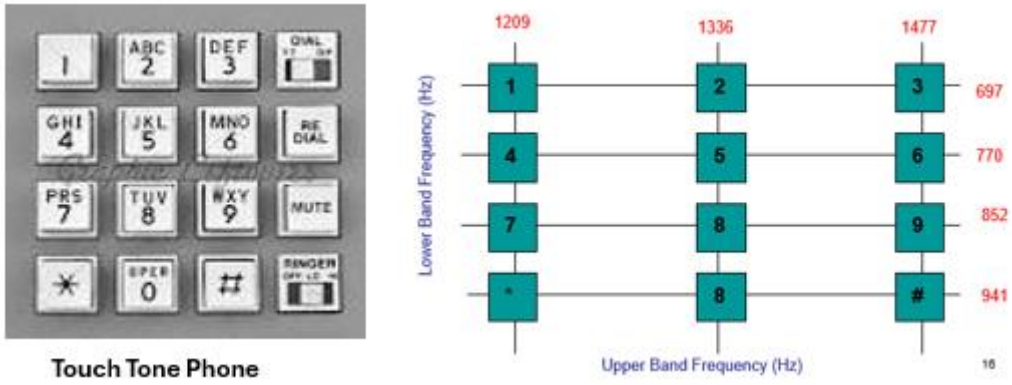

Figure 2. Dual-Tone Multi-frequency

2.3. The "How" - Switching System Technologies (The Evolution)

This is the core of the switching technology progression.

2.3.1 Manual Switching: The operator manually connects calls using cords and jacks.

2.3.2 Electromechanical Switching:

a) **Strowger (Step-by-Step) Switch:**

- **Concept:** Directly controlled by the subscriber's dial pulses. Each pulse advances a switch step-by-step.
- **Components: Line Finder** (seizes the calling line), **Selector** (responds to dial pulses to find a path).
- **Advantage:** Fully distributed control, no common logic.
- **Disadvantage:** Noisy, slow, wears out, limited features.

b) **Crossbar Switch:**

- **Concept:** A matrix of horizontal and vertical bars with electromagnets. A specific crosspoint is closed by energizing its corresponding horizontal and vertical magnets. **This is a "marker" based system.**
- **Advantage:** Faster, quieter, more reliable than Strowger. Common control allows for features like call waiting (in later versions).
- **Disadvantage:** Still electromechanical.

2. **Electronic Switching (Stored Program Control - SPC):**

a) **Concept:** Replaces moving parts with solid-state switches (initially reed relays, then semiconductors) and, most importantly, uses a computer (processor and memory) to control the switching.

b) **Architecture:**

- **Switching Network:** A space-division or time-division network of digital or analogue switches.
- **Central Control (CPU):** The brain of the system. It executes programs stored in memory to process calls.
- **Scanners:** Monitor subscriber lines for off-hook/on-hook status.
- **Distributors:** Apply ringing voltage, etc.

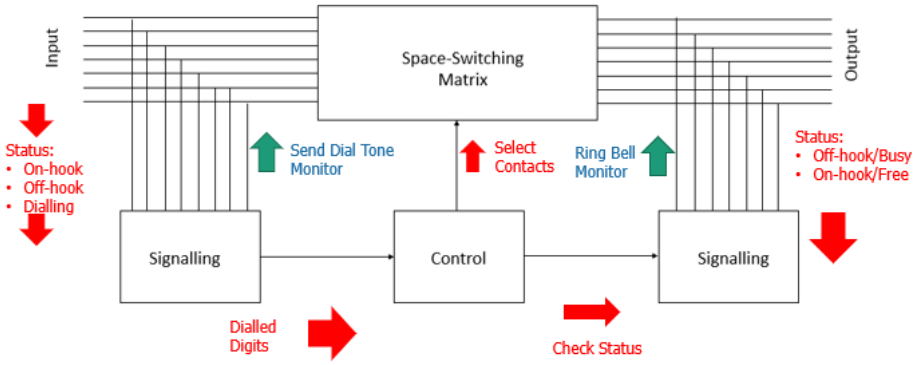

Figure 3. Elements of Space switching Architecture

c) **Major Advantages:**

1. **Flexibility:** New features can be added by changing software.
2. **Speed:** Much faster call setup.
3. **Maintenance:** Self-diagnostic capabilities.
4. **Compactness:** Smaller physical size.

d) **Example Systems:** AT&T's **1ESS** and **5ESS** (a hybrid analog/digital system).

2.4: The "Big Picture" - Network Hierarchy & Traffic Engineering

2.4.1 **Network Hierarchy:** How multiple central offices are interconnected.

- **End Office (Class 5):** The local switch to which subscribers are directly connected.
- **Toll Centres (Class 4, 3, 2, 1):** Transit switches that connect end offices over long distances via **trunks** (lines connecting switches).

2.4.2 **Numbering Plan:** World telecommunication numbering plan. Africa Telecommunication numbering plan.

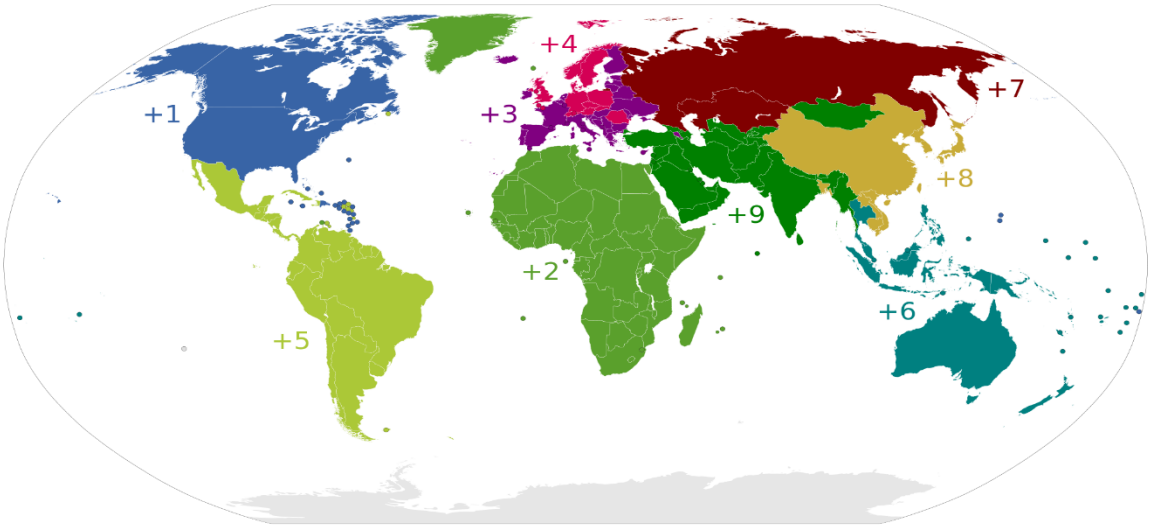

Figure 4. World zone: International Subscriber Dialling Codes

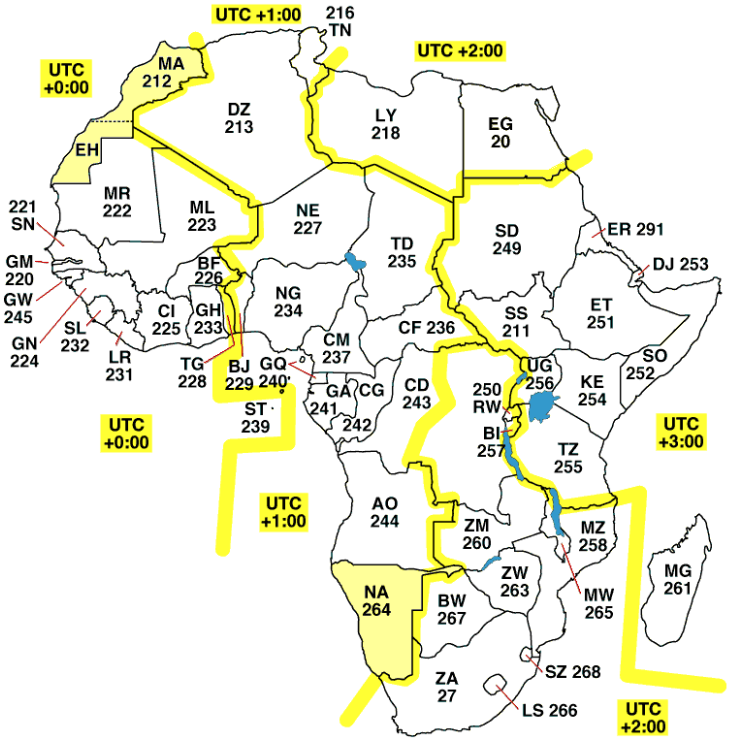

Figure 5. Subscriber Dialling Codes Country Codes for Africa

2.5. Basic Traffic Engineering:

2.5.1 Busy Hour: The peak continuous 60-minute period of call traffic.

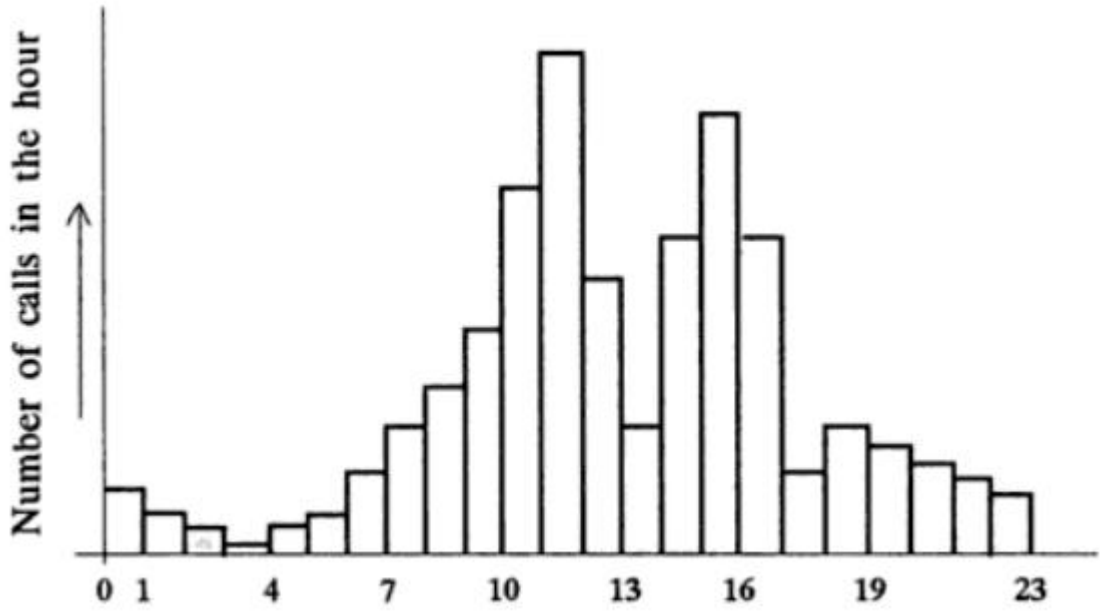

Figure 6. Typical telecommunication traffic over 24 hours

2.5.2 Traffic Intensity (Erlang): A measure of channel usage. 1 Erlang = 1 circuit occupied for 1 hour.

2.5.3 Grade of Service (GOS): The probability that a call will be blocked due to insufficient trunks (e.g., a GOS of 0.01 means a 1% chance of blockage during the busy hour).

2.5.4 Erlang B Formula: The fundamental formula used to calculate the number of trunks required for a given traffic load and a desired GOS. You should understand its inputs and outputs, even if you don't memorize the formula itself.

3. KEY TERMINOLOGY

- Subscriber Loop
- Central Office (CO) / End Office
- On-Hook / Off-Hook
- Pulse Dialing / DTMF
- Circuit Switching / Packet Switching
- Strowger Switch / Crossbar Switch
- Common Control / Stored Program Control (SPC)
- Trunk
- Blocking vs. Non-Blocking Switch

- Grade of Service (GOS)
- Erlang
- Hybrid Circuit

4. STUDY TIPS

1. **Draw Diagrams:** Don't just read about the Strowger switch—draw the mechanism and trace the path for a dialed digit. Draw a block diagram of an SPC system.
2. **Trace a Call:** Verbally explain the step-by-step process of a local call, from lifting the handset to hearing the ring-back tone, including all signalling and switching events.
3. **Compare and Contrast:** Create a table comparing Strowger, Crossbar, and SPC systems across criteria like Technology, Control Method, Speed, Reliability, and Features.
4. **Solve Problems:** Practice simple traffic engineering problems using the Erlang B table (readily available online). *Example: "An office receives 5 Erlangs of traffic during the busy hour. How many trunks are needed for a GOS of 0.005?"*
5. **Relate to the Modern World:** Understand that while the core network is now digital (Voice over IP - VoIP), the fundamental concepts of circuit establishment, signaling (now via SIP protocol), and hierarchical networks are direct descendants of these analog systems.

5. SAMPLE EXAM QUESTIONS

1. **Short Answer:** Explain the primary function of the hybrid circuit in a telephone set. What is sidetone and why is a small amount of it desirable?
2. **Comparison:** Compare and contrast the control mechanisms of a Strowger step-by-step switch and a Crossbar switch.
3. **Problem:** A subscriber dials the digit '5' using pulse dialing. If the make/break ratio is 60%/40% and the pulse rate is 10 pulses per second, how long is the loop *open* for this single digit?
4. **Description:** Describe, with the aid of a block diagram, the key components of a Stored Program Control (SPC) switching system and the function of each.