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Question 1:

An ISP's communication system uses FDM and TDM over copper cables. Customers report distorted audio, slow data, and noise issues. As a telecommunications student, identify the potential causes of these problems and propose solutions to improve system performance.

SOLUTION

First things first:
FDM and TDM are types of Multiplexing, know the definitions together with the pros and cons.
Know the limitations of copper cables.

Definitions

Multiplexing – A technique that combines multiple signals into a single signal for transmission over a shared medium.

FDM (Frequency Division Multiplexing) - Type of multiplexing where the bandwidth of a single physical medium is divided into a number of smaller, independent frequency channels.

TDM (Time Division Multiplexing) - Instead of sharing a portion of the bandwidth in the form of channels, in TDM, time is shared. Each connection occupies a portion of time in the link. In Time Division Multiplexing, all signals operate with the same frequency (bandwidth) at different times.

Wavelength Division Multiplexing (WDM) - Used to increase the capacity of optical fibre by transmitting multiple optical signals simultaneously over a single optical fibre, each with a different wavelength. Each signal is carried on a different wavelength of light, and the resulting signals are combined onto a single optical fibre for transmission.

Solution formulation

Potential Causes of These Problems

Copper Cable Limitations
- **Attenuation**: Signal strength weakens over distance, affecting data integrity and audio quality.
- **Crosstalk**: Electromagnetic interference from other cables causes noise and distortion.
- **Aging infrastructure**: Corroded or degraded copper wires introduce resistance and noise.

FDM-Specific Issues
- **Insufficient guard bands**: Overlapping between adjacent frequency bands leads to signal interference and distorted audio.
- **Poor filter design**: Inadequate filtering allows noise to bleed into adjacent channels.

TDM-Specific Issues
- **Synchronization errors**: If time slots aren't perfectly synchronized, data meant for one user might be delayed or misdelivered.
- **Timing jitter**: Fluctuations in time slot arrival cause variable delays and degrade data quality.

External Noise Sources
- **Electromagnetic Interference (EMI)**: From nearby power lines, motors, or radio equipment.

Bandwidth Bottlenecks
- **Shared medium**: Many users sharing the same FDM/TDM lines can congest the system.

Proposed Solutions

1. Cable Infrastructure Upgrades
- **Replace aging copper** with **shielded twisted pair (STP)** or **fibre-optic cables** where possible.

2. Signal Conditioning
- **Use equalizers and amplifiers** to counteract attenuation.
- **Enhance filtering** in FDM systems to minimize channel interference.

3. Noise Mitigation

- **Improve grounding and shielding** of copper cables to reduce EMI and ground loops.

Question 2:

In a smart home IoT ecosystem, would a star topology (central hub) or mesh topology (self-healing nodes) be more effective? Consider power consumption, latency, and device failures.

Solution

Star Topology (Central Hub)

Structure: All IoT devices connect to a central hub
Advantages:

- Lower power consumption (for end devices): Devices sleep and only communicate with the hub.
- Lower latency (for small networks): Direct communication with the hub is fast and efficient.
- Simple management: Easy to configure and monitor via a single point.

Disadvantages:

- Single point of failure: If the hub fails, the entire network is down.
- Scalability issues: Performance degrades as more devices are added.
- Range limitations: Devices far from the hub may lose signal or require repeaters.

Mesh Topology (Self-Healing Nodes)

Structure: Each device can connect to multiple nearby devices, forming a decentralized network.
Advantages:

- Resilience to device failures: If one device/node fails, traffic is automatically rerouted.
- Better coverage: Devices relay messages, extending network range.
- Scalability: Supports more devices without overloading a central hub.

Disadvantages:

- Higher power consumption: Routing devices stay active to relay messages.
- Increased latency: Multi-hop communication can cause delays.
- Complex setup and maintenance: Routing and device discovery require more overhead.

Answer: Which Is More Effective for Smart Homes?

For Small to Medium Smart Homes , Star topology is usually more power-efficient, easier to manage, and fast enough for things like lights, sensors, and thermostats.

Question 3:

Why does a full-mesh topology scale poorly in large networks? Use the formula for links (n(n-1)/2) to calculate the overhead for 50 nodes.

Solution:
A full-mesh topology requires every node to connect directly to every other node. But is scales poorly because as the number of nodes (**n**) increases, the number of required links grows.

High Cost and Complexity - Each new node requires connections to all existing nodes. Cabling, hardware interfaces, and configuration overhead increase dramatically.

Example: For 50 nodes we would need 50(50-1)/2 = 1225 links.

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Question 4:

1. In what ways could a failure in the network layer's routing functionality impact the overall performance and reliability of a multi-layered network architecture?

Answer:
A failure in the **routing functionality** of the network layer can:

- **Cause packet loss**: Packets may be dropped if no valid route exists.
- **Increase latency**: Suboptimal or looping routes cause delays.
- **Interrupt connectivity**: Devices or subnets become unreachable.
- **Reduce throughput**: Congested or incorrect routes lead to bottlenecks.
- **Affect higher layers**: Applications (transport/application layer) may time out or behave unpredictably.

2. How do guided (wired) and unguided (wireless) transmission media differ in terms of bandwidth, latency, and security? Provide real-world examples where each is preferable.

Feature	Guided (Wired)	Unguided (Wireless)
Bandwidth	Higher	Lower
Latency	Lower and more consistent	Higher and variable (affected by interference)
Security	More secure (physical access needed)	Less secure (easily intercepted over air)

3. How might the choice of network cabling (e.g., twisted pair, fibre optic) impact the scalability of a large-scale enterprise network?

Twisted Pair (e.g., Cat 6):

- Scalable for short distances (~100m).
- Inexpensive and easy to install.
- Limited bandwidth (~1–10 Gbps).

Fibre Optic:

- Extremely scalable (tens of kilometers).
- High bandwidth (>10 Gbps up to Tbps).
- Ideal for backbone and data centers.

Impact: Choosing fiber enables better long-distance expansion, future-proofing, and high-performance growth for large enterprise networks.

4. What strategies could be developed to mitigate signal degradation in long-distance network cabling installations?

- Use repeaters or signal boosters: Regenerate signals to maintain strength.
- Switch to fiber optic cables: Immune to EMI and supports long-range, high-speed transmission.
- Use shielded cables (e.g., STP): Reduces interference and crosstalk.

References

1. https://www.geeksforgeeks.org/computer-networks/types-of-multiplexing-in-data-communications/