**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 loT 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.

**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.
  1. 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.

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| --- | --- | --- |
| **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) |

* 1. 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.

* 1. ﻿﻿﻿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/