Course :- Computer Networks for Communication
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→ Project 1 : Energy-Efficient Communication in Smart Grids.

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Assignment Unit-1

Project: Energy-Efficient Communication in Smart Grids 03

Scenario:
In smart grids, devices like smart meters and sensors frequently transmit data such as energy usage, voltage levels, and system health. To reduce energy consumption, efficient communication method must be used.

a) Identify Power-Efficient Transmission Media
Best Power-Efficient Transmission Media:

1. Fiber Optic Cable
   - Power usage: Very low during signal transmission.
   - Advantages: High bandwidth, low signal loss, immune to electromagnetic interference.

2. Wirless (Low-power)- ZigBee / LORaWAN
   - ZigBee: ideal for short-range, low-data-rate communication between smart meters.
   - LORaWAN: Suitable for longer ranges and still energy Efficient.

3. Power line Communication (PLC):
   - Uses existing power lines to send data - Saves cost and energy of installing new media.

b) Suggests Error Detection Method for Analog Data.

Analog Data Error Detection Techniques:

1. Signal Redundancy and Sampling
   - Convert analog to digital using ADC (Analog to Digital converter)
   - Then apply CRC (Cyclic Redundancy check) or parity Bit on digital signals.
2. Noise Filtering (Prevention at Analog Level):
   - Use low-pass filters to reduce noise and distortion.
3. Data Averaging Technique:
   - Sample multiple times and average the value to detect anomalies.

Note:

Direct error detection in analog signals is difficult, so conversation to digital is common practice before apply checks.

c) Compare ZigBee and Cellular for Energy Usage.

Feature	ZigBee	Cellular (3G, 4G, 5G)
Power consumption	Very low (~1 mW)	High (~800 - 3000 mW)
Range	Short (~10-100 meters)	Long (Several Kilometers)
Cost	Low	High (Sim + Data + modules.
Data Rate	Low (~250 Kbps)	High (Up to Several Mbps)
Use case fit	ideal for home/ Industrial IoT	Better for remote locations

Conclusion:

→ ZigBee is more Energy-Efficient for Smart meter network due to lower power and Cost.

→ Cellular is suitable for wide-area Communication but drains more power.

2) Propose a Topology for Smart Meter Network.

Recommended Topology: Mesh Topology

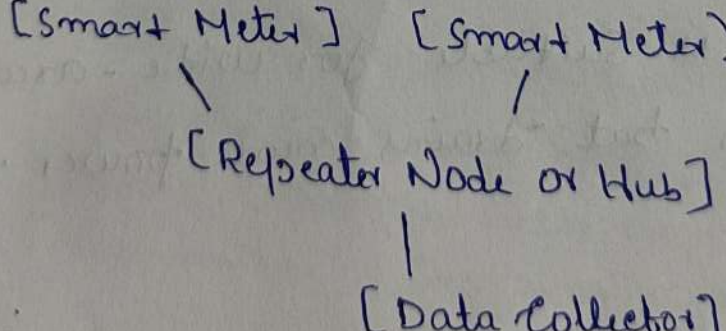
Why Mesh:?

- Devices (Smart meters) relay data to each other.
- No single point of failure.
- Saves energy by selecting shortest / optimal paths.
- Self-healing and scalable.

Alternative Topology (for Smaller Systems):

Star Topology - Central collector node with all meters around it (simple but less scalable).

Example



Real-World Example: Smart Grid in India

India's power sector is slowly adopting smart grid technologies to improve energy efficiency and reduce transmission losses.

- Example: Tata Power in Mumbai uses smart meters to monitor and control electricity usage in real-time.
- These meters communicate using ZigBee and RF mesh topology, allowing data to be collected efficiently and wirelessly.
- The system helps reduce peak load, detect faults faster, and give users control over their energy use - contributing to a more sustainable grid.

Conclusion:

Energy-Efficient communication is at the heart of smart grid systems. By selecting low-power technologies like ZigBee, applying accurate error detection methods, and using scalable topologies such as mesh networks, we can build a sustainable and reliable energy infrastructure.