SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)
Approved by AICTE, New Delhi, Affiliated to Anna University, Chennai
Accredited by NAAC-UGC with 'A++' Grade (Cycle III) &
Accredited by NBA (B.E - CSE, EEE, ECE, Mech & B.Tech.IT)
COIMBATORE-641 035, TAMIL NADU

Efficient Routing Protocols & Ambient Energy Harvesting

1. Efficient Routing Protocols

Routing protocols are critical in networks, especially **Wireless Sensor Networks (WSNs)** and **IoT-based systems**, where devices are energy-constrained, and efficient data transmission is essential.

1.1 Objectives of Efficient Routing Protocols

Minimize **energy consumption**

Extend **network lifetime**

Ensure **data reliability** and **low latency**

Support **scalability** and **mobility**

Handle **dynamic topologies**

1.2 Classification of Routing Protocols

A. Based on Network Structure

i) Flat Routing

All nodes are peers.

Data-centric approach: queries are disseminated to all nodes (e.g., **Directed Diffusion**).

Suitable for small networks but not scalable.

ii) Hierarchical Routing

Nodes are grouped into clusters; cluster heads aggregate and forward data.

Reduces redundant data transmission.

Examples:

LEACH (Low Energy Adaptive Clustering Hierarchy)

TEEN (Threshold sensitive Energy Efficient sensor Network)

iii) Location-Based Routing

Uses GPS or location estimation to route data.

Reduces routing overhead by limiting search space.

Example: **GPSR (Greedy Perimeter Stateless Routing)**

B. Based on Protocol Operation

i) Proactive (Table-driven)

Maintains routing tables continuously.

Low latency, but high control overhead.

Examples: DSDV, OLSR

ii) Reactive (On-demand)

Routes created only when needed.

Lower overhead, but higher latency.

Examples: AODV (Ad hoc On-Demand Distance Vector), DSR

iii) Hybrid Protocols

Combines proactive and reactive elements.

Example: ZRP (Zone Routing Protocol)

C. Energy-Efficient Routing Techniques

Power-aware routing: Minimizes total transmission power.

Energy-aware clustering: Rotating cluster heads (e.g., LEACH).

Sleep scheduling: Nodes go into sleep mode when idle.

1.3 Challenges in Routing for WSNs

Node mobility in IoT applications.

Heterogeneity of nodes (energy, processing power).

Data redundancy and congestion.

Security concerns (data interception, spoofing).

1.4 Recent Trends

AI/ML-based adaptive routing.

Cross-layer optimization.

Integration with energy harvesting systems.

2. Ambient Energy Harvesting

Ambient Energy Harvesting refers to the process of capturing energy from the environment to power electronic devices, especially low-power sensors in IoT and remote systems.

2.1 Sources of Ambient Energy

Source	Description	Example Applications
Solar	Photovoltaic cells convert light to electricity	Outdoor sensors, wearables
Thermal	Converts temperature gradients to electricity (Seebeck effect)	Industrial environments
Vibration	Mechanical vibrations converted via piezoelectric materials	Bridges, machinery
RF (Radio Frequency)	Captures EM waves from radio/TV/Wi-Fi signals	Urban sensor nodes
Wind & Air Flow	Small turbines or airflow energy	Remote weather stations
Bioenergy	Microbial fuel cells using organic materials	Soil sensors in agriculture

2.2 Energy Harvesting Components

Transducer – Converts ambient energy to electrical energy.

Power Management Unit (PMU) – Manages and regulates harvested energy.

Energy Storage – Supercapacitors or rechargeable batteries.

Load/Node – IoT device or sensor that uses the energy.

2.3 Advantages

Enables **battery-less** operation.

Reduces **maintenance cost** (no battery replacement).

Supports **long-term deployment** in inaccessible areas.

Promotes **green and sustainable** technology.

2.4 Challenges

Intermittent energy supply: Ambient energy is variable and unpredictable.

Low power output: Harvested energy is often insufficient for heavy-duty applications.

Energy conversion efficiency: Still relatively low.

Storage limitations: Supercapacitors have limited energy density.

2.5 Applications

Smart Agriculture: Soil moisture sensors, animal trackers.

Wearables: Health monitoring using body heat/movement.

Smart Cities: Air quality monitors, traffic sensors.

Industrial IoT: Vibration-powered machine health monitoring.

2.6 Integration with IoT and Routing

Routing protocols must be **energy-aware** and compatible with harvesting cycles.

Energy Harvesting Aware Routing Protocols (EHARP): Adapt routing decisions based on the current and predicted energy availability.

2.7 Future Directions

Hybrid Harvesting Systems: Combine multiple sources (e.g., solar + vibration).

AI-Based Energy Prediction: Machine learning models for adaptive operation.

Ultra-low-power electronics: Reduced consumption extends viability.

Energy Trading: Nodes may share or trade harvested energy in future smart grids.