MOBILE COMPUTING

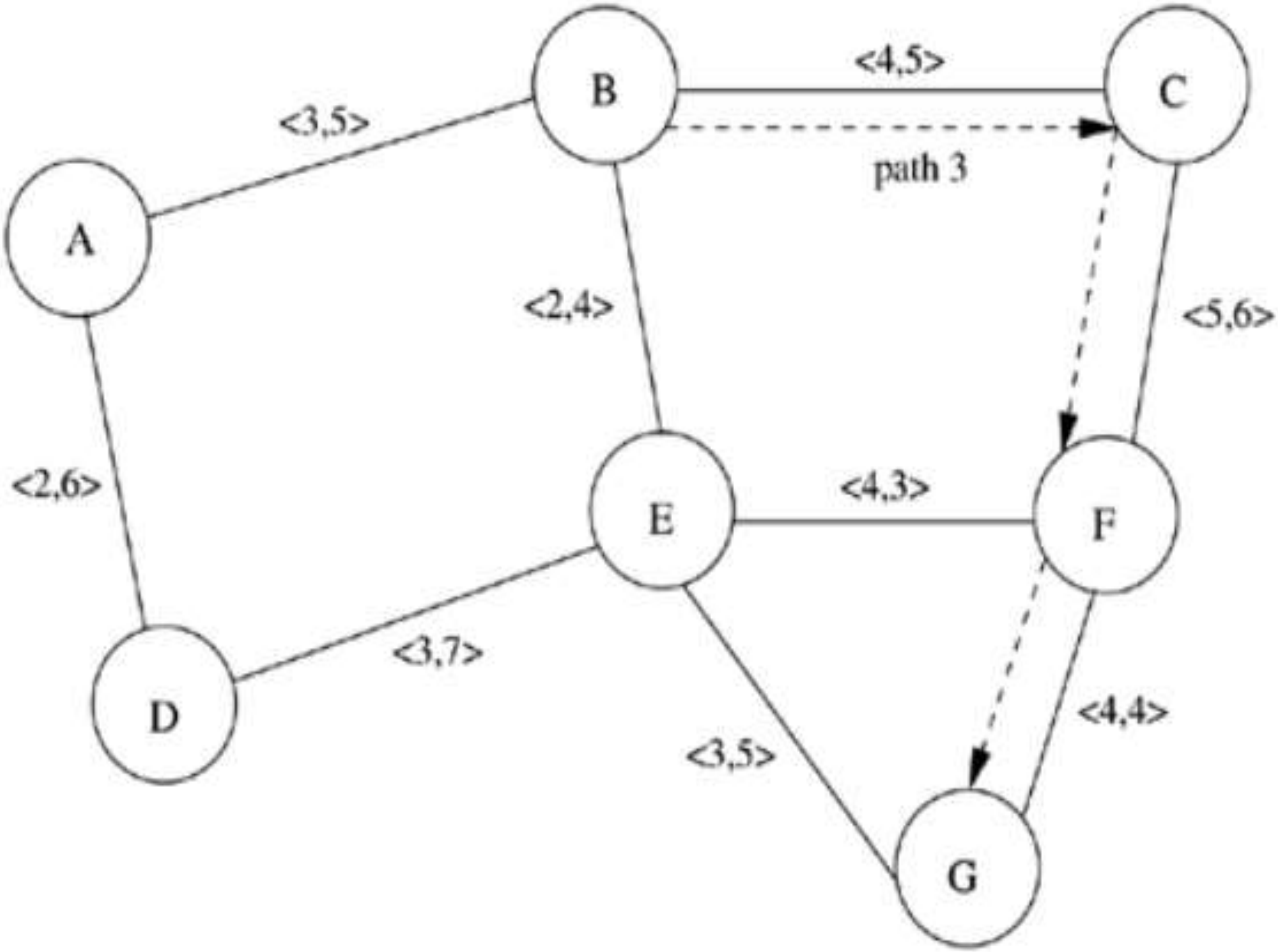
UNIT-4

INTRODUCTION

- Quality of service (QoS) is the performance level of a service offered by the network to the user.

- The goal of QoS provisioning is to achieve a more deterministic network behavior, so that information carried by the network can be better delivered and network resources can be better utilized.

An example of QoS routing in ad hoc wireless network



Available paths from node *B* to node *G*

No.	Path	Hop Count	End-to-end Bandwidth (Mbps)	End-to-end Delay (milliseconds)
1	$B \rightarrow E \rightarrow G$	2	2	9
2	$B \rightarrow E \rightarrow F \rightarrow G$	3	2	11
3	$B \rightarrow C \rightarrow F \rightarrow G$	3	4	15
4	$B \rightarrow C \rightarrow F \rightarrow E \rightarrow G$	4	3	19
5	$B \rightarrow A \rightarrow D \rightarrow E \rightarrow G$	4	2	23
6	$B \rightarrow A \rightarrow D \rightarrow E \rightarrow F \rightarrow G$	5	2	25

1. *Real-Time Traffic Support in Ad Hoc Wireless Networks* :

- Real-time applications can be classified as
  - → hard real-time applications
  - → soft real-time applications.

- **Hard real-time applications :**

- A hard real-time application requires strict QoS guarantees. Some of the hard real-time applications include nuclear reactor control systems, air traffic control systems, and missile control systems.

- In these applications, failure to meet the required delay constraints may lead to disastrous results.

- **Soft real-time applications :**

- On the other hand, soft real-time applications can tolerate degradation in the guaranteed QoS to a certain extent.

- Some of the soft real-time applications are voice telephony, video-on-demand, and video conferencing.

- In these applications, the loss of data and variation in delay and delay jitter may degrade the service but do not produce hazardous results.

2 . QoS Parameters in Ad Hoc Wireless Networks :

- As different applications have different requirements, the services required by them and the associated QoS parameters differ from application to application.

- **For example**, in case of multimedia applications, bandwidth, delay jitter, and delay are the key QoS parameters,
- whereas military applications have stringent security requirements.
- For applications such as emergency search-and-rescue operations, availability of the network is the key QoS parameter.

ISSUES AND CHALLENGES IN PROVIDING QOS IN AD HOC WIRELESS NETWORKS

- **Dynamically varying network topology**

- **Imprecise state information:**

In most cases, the nodes in an ad hoc wireless network maintain both the **link-specific state information and flow-specific state information.**

The state information is inherently imprecise due to dynamic changes in network topology and channel characteristics.

- **Lack of central coordination**

- **Error-prone shared radio channel**

- **Hidden terminal problem**

- **Limited resource availability**

- **Insecure medium**

- **Hard state versus soft state resource reservation:**

1. Hard state : Resources are reserved at all intermediate nodes throughout the duration of the QoS session

2. Soft state: Resources are reserved at small time intervals

- **Stateful versus stateless approach:**

→In the **stateful approach**, each node maintains either *global state* information or only *local state* information,
→ In the case of a **stateless approach**, no such information is maintained at the nodes.

- **Hard QoS versus soft QoS approach** :

→ **Hard QoS approach** – If QoS requirements of a connection are guaranteed to be met for the whole duration of the session.

→ **Soft QoS approach -** If the QoS requirements are not guaranteed for the entire session

CLASSIFICATIONS OF QOS SOLUTIONS

The QoS solutions can be classified in **two ways.**

→ One classification is based on the **QoS approach employed**,

→ other one classifies **QoS solutions** based on the layer at which they operate in the network protocol stack.

1 . Classifications of QoS Approaches :

The QoS approaches can be classified based on :

→ the interaction between the routing protocol and the QoS provisioning mechanism

→ the interaction between the network and the MAC layers,

→ the routing information update mechanism.

i) Based on the interaction between the routing protocol and the QoS provisioning mechanism, QoS approaches can be classified into **two categories: *coupled* and *decoupled*** QoS approaches.

In the case of the **coupled QoS approach**, the routing protocol and the QoS provisioning mechanism closely interact with each other for delivering QoS guarantees. If the routing protocol changes, it may fail to ensure QoS guarantees.

But in the case of the **decoupled approach**, the QoS provisioning mechanism does not depend on any specific routing protocol to ensure QoS guarantees.

ii) Similarly, based on the interaction between the routing protocol and the MAC protocol, QoS approaches can be classified into **two categories: *independent* and *dependent* QoS approaches.**

In the **independent QoS approach**, the network layer is not dependent on the MAC layer for QoS provisioning.

The **dependent QoS approach** requires the MAC layer to assist the routing protocol for QoS provisioning.

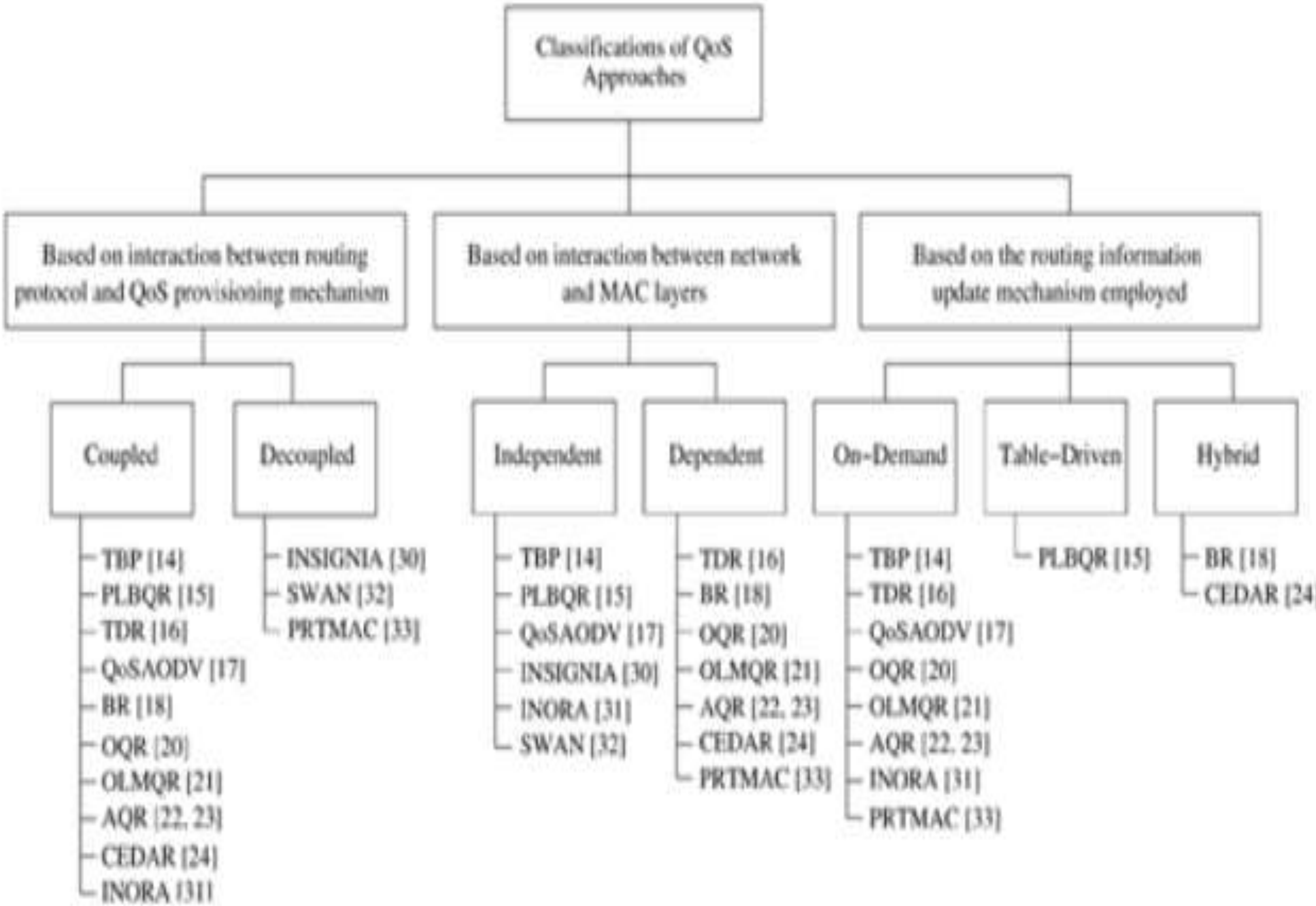
iii) Finally, based on the routing information update mechanism employed, QoS approaches can be classified into **three categories, namely, *table-driven*, *on-demand*, and *hybrid* QoS approaches.**

In **the table-driven approach**, each node in the network maintains a routing table which aids in forwarding packets.

In the on-demand approach, no such tables are maintained at the nodes, and hence the source node has to discover the route on the fly.

The hybrid approach incorporates features of both the table-driven and the on-demand approaches.

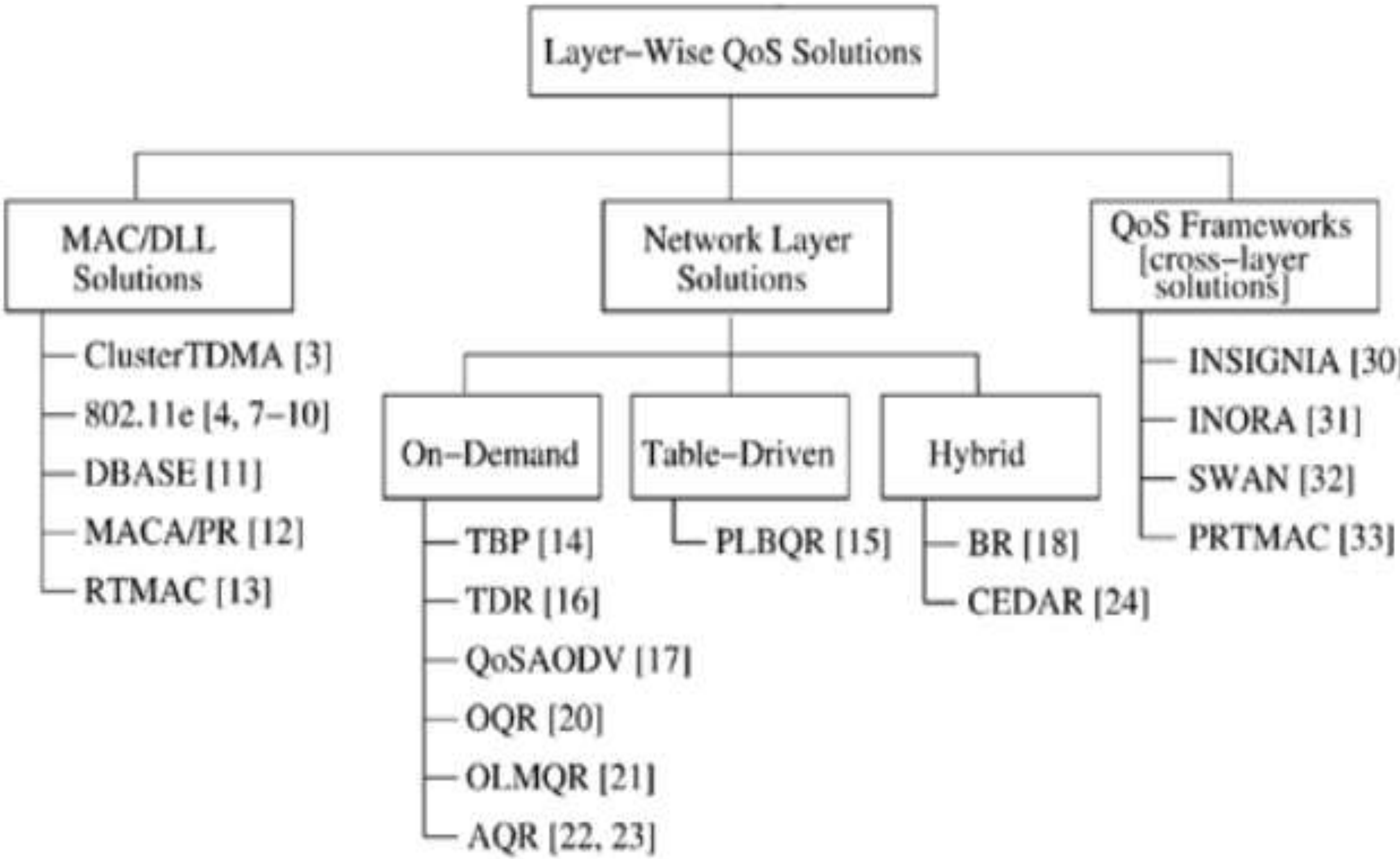
Classifications of QoS approaches.



2 . Layer-Wise Classification of Existing QoS Solutions :

The existing QoS solutions can also be classified based on which layer in the network protocol stack they operate in.

Layer-wise classification of QoS solutions.



MAC LAYER SOLUTIONS

- The MAC protocol determines which node should transmit next on the broadcast channel when several nodes are competing for transmission on that channel.

- The existing MAC protocols for ad hoc wireless networks use channel
sensing and random back-off schemes

- Supporting real-time traffic in these networks is a very challenging task.

- MAC protocols that provide QoS support for applications in ad hoc wireless networks have been proposed. Some of these protocols are described below.

1 . Cluster TDMA :

- Gerla and Tsai proposed Cluster TDMA for supporting real-time traffic in ad hoc wireless networks.

- In bandwidth-constrained ad hoc wireless networks, the limited resources available need to be managed efficiently. To achieve this goal, a dynamic clustering scheme is used in Cluster TDMA.

- In this clustering approach, nodes are split into different groups. Each group has a cluster-head which acts as a regional broadcast node and as a local coordinator to enhance the channel throughput.

- Every node within a cluster is one hop away from the cluster-head. The formation of clusters and selection of cluster-heads are done in a distributed manner.

- Clustering algorithms split the nodes into clusters so that they are interconnected and cover all the nodes.

- **Three** such algorithms used are

  → **lowest-ID algorithm,**

  a node becomes a cluster-head if it has the lowest ID among all its neighbors.

  → **highest degree** (degree refers to the number of neighbors which are within transmission range of a node) algorithm,

  a node with a degree greater than the degrees of all its neighbors becomes the cluster-head

  → **least cluster change** (LCC) algorithm.
  cluster-head change occurs only if a change in network

- The time division multiple access (TDMA) scheme is used within a cluster for controlling access to the channel.

- A synchronous time division Frame is defined to support TDMA access in a cluster and to exchange control information.
- Each synchronous time division frame is divided into slots.
- Slots and Frames are synchronized through the Network.
- A time division Frame is split into two phase:
  - Control Phase : Control Functions such as Routing, Clustering, synchronization
  - Data Phase : For Data Transmition
- ACK packets for each frame is send in Control phase

2 . IEEE 802.11e :

(i) IEEE 802.11 MAC Protocol :

It supports **two modes of operation**, namely,

→D**istributed Coordination Function (DCF)**
This mode does not use any kind of centralized control

→ **Point Coordination Function (PCF).**
this mode requires an access point (AP, *i.e.*, central controller) to coordinate the activity of all nodes in its coverage area.

- All implementations of the 802.11 standard for WLANs must provide the DCF mode of operation, while the PCF mode of operation is optional.

- The time interval between the transmission of two consecutive frames is called the inter-frame space (IFS).

- There are four IFSs defined in the IEEE 802.11 standard, namely, short IFS (SIFS), PCF IFS(PIFS), DCF IFS (DIFS), and extended IFS (EIFS).

- The relationship among them is as follows:

$$SIFS < PIFS < DIFS < EIFS$$

(ii) **Distributed Coordination Function :**

- If a station *A* wants to transmit data to station *B*, station *A* listens to the channel.

- If the channel is busy, it waits until the channel becomes idle. After detecting the idle channel, station *A* further waits for aDIFS period and invokes a back-off procedure.

- After detecting the channel as being idle for a DIFS period, station *A* starts decrementing the back-off counter. Once the back-off counter reaches zero, station *A* transmits a request-to-send (RTS) frame and waits for a clear-to-send (CTS) frame from the receiver *B*.

(iii) Point Coordination Function :

- Introduced to let stations have priority access to the wireless medium

- Uses a point coordinator (PC), which operates at an AP

- PC decides which station should gain access to the channel

- Useful only in infrastructure based network

- PCF is not scalable to support real time traffic for a large number of users.

(iv) QoS Support Mechanisms of IEEE 802.11e :

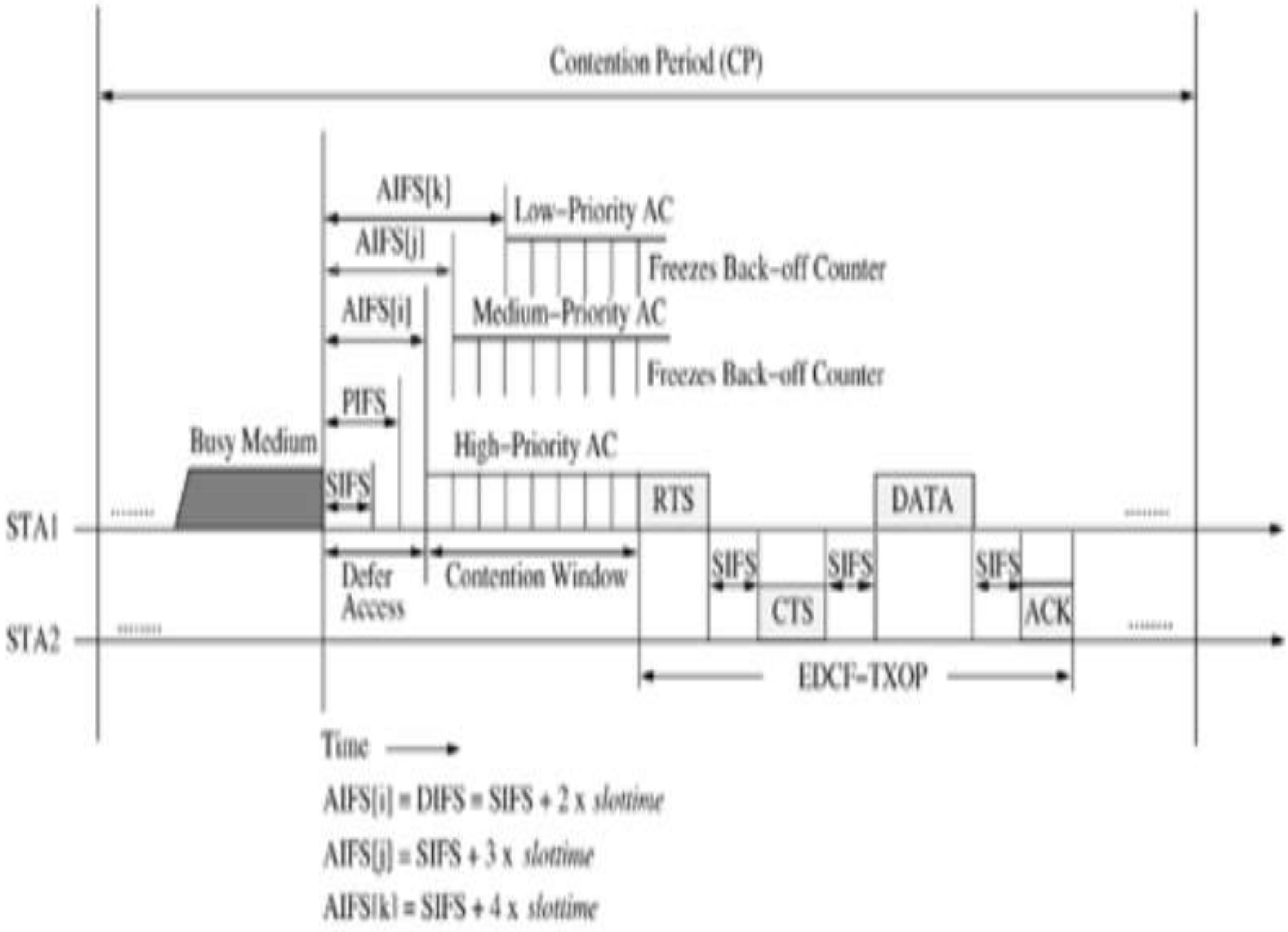
- **IEEE 802.11e** – new standard to support real time traffic (QoS in both infrastructure and infrastructure less networks)

  → **Enhanced DCF (EDCF)**
  → **Hybrid coordination function (HCF)**

- **Enhanced Distributed Coordination Function :**

- Support real time traffic by providing differentiated and distributed DCF access to the wireless medium

An example of EDCF access mechanism



- **Hybrid Coordination Function :**

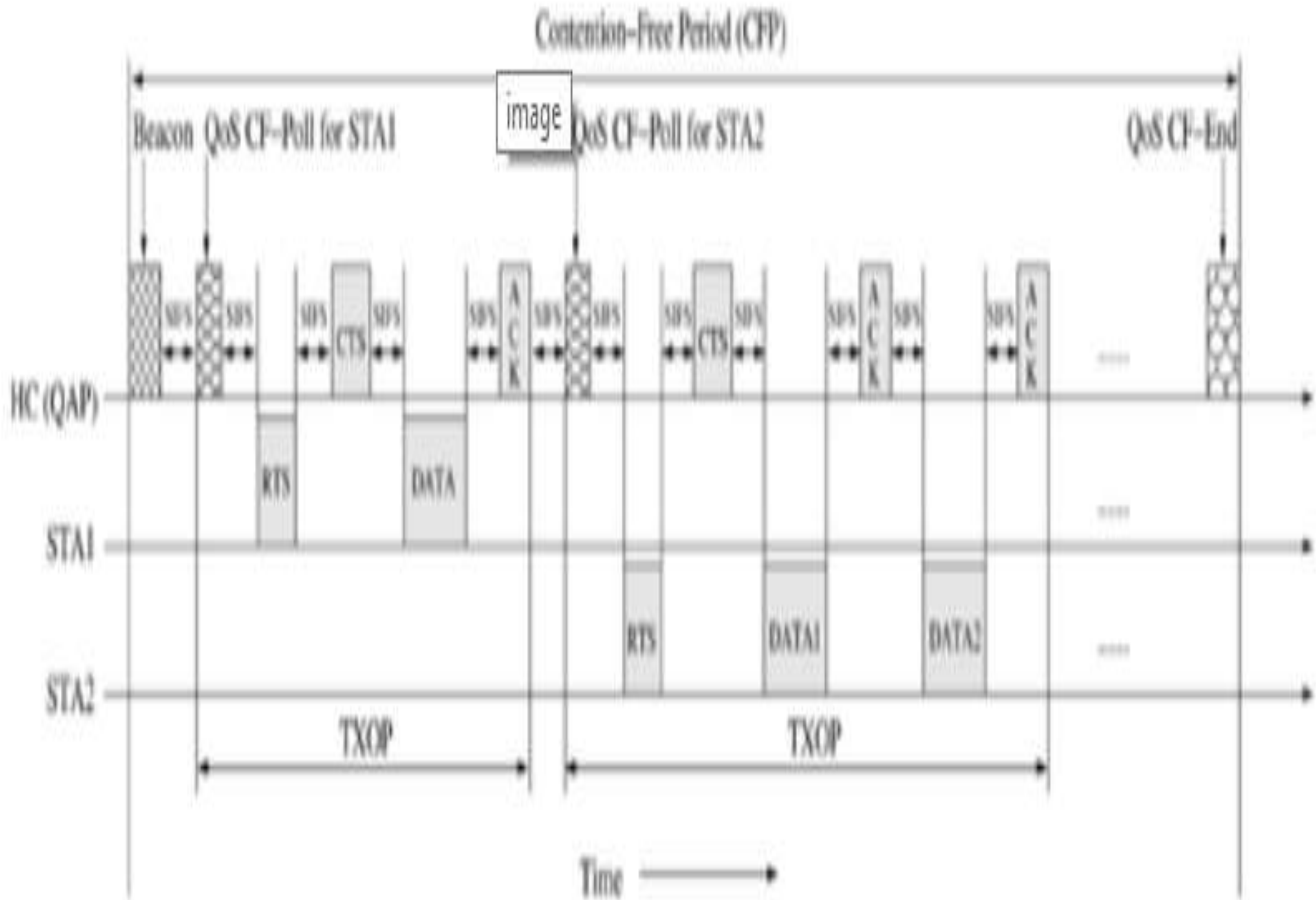
- Combines feature of EDCF and PCF to provide the capability of selectively handling MAC service data unit (MS-DU)

- Has upward compatibility with DCF and PCF.

- Usable only in infrastructure based BSS that provide QoS

- Use a QoS aware point coordinator called HC .

An example of HCF access mechanism



3 . DBASE :

- **Distributed bandwidth allocation/sharing/Extension** protocol supports multimedia traffic(both variable rate and constant bit rate over adhocWLANs.

- In an adhoc WLAN, there is no fixed infrastructure to coordinate the activity of individual stations.

- For real time traffic, a contention based process is used in order to gain access to the channel.

- DBASE protocol permits real time station to acquire excess bandwidth on demand.

- The non real time stations regulate their accesses to the channel according to the standard CSMA/CA protocol.

(i) The Access Procedure for Non Real-Time Stations :

- The channel access method for *nrt*-stations is based on conventional DCF.

- An *nrt*-station with data traffic has to keep sensing the channel for an additional random time called data back-off time (DBT) after detecting the channel as being idle for a DIFS period. The DBT is given by

$$DBT = rand(a,\ b) \times slottime$$

(ii) The Access Procedure for Real-Time Stations :

- Each *rt*-station maintains a virtual reservation table (RSVT).

- In this virtual table, the information regarding all *rt*-stations that have successfully reserved the required bandwidth is recorded.

- Before initiating an *rt*-session, the *rt*-station sends an RTS in order to reserve the required bandwidth. Before transmitting the RTS, a corresponding entry is made in the RSVT of the node.

- Every station that hears this RTS packet also makes a corresponding entry in its RSVT. After recording into the RSVT successfully, an *rt*-station need not contend for the channel any more during its whole session.

(iii) Bandwidth Reservation

NETWORK LAYER SOLUTIONS

The bandwidth reservation and real-time traffic support capability of MAC protocols can ensure reservation at the link level only, hence the network layer support for ensuring end-to-end resource negotiation, reservation, and reconfiguration is very essential.

This section describes the existing network layer solutions that support QoS provisioning.

1 . QoS Routing Protocols :

- QoS routing protocols search for routes with sufficient resources in order to satisfy the QoS requirements of a flow.

- The information regarding the availability of resources is managed by a resource management module which assists the QoS routing protocol in its search for QoS feasible paths.

- The QoS metrics can be classified as :

  → **additive metrics,**

  → **concave metrics,**

  → **multiplicative metrics.**

(i) An **additive metric** *Am* is defined as , where $L\ i(m)$ is the value of metric *m* over link $L\ i$ and $L\ i \times$ P. The hop length of path P is *h*.

(i) A **concave metric** represents the minimum value over a path P and is formally defined as

$$C\ m = min(L\ i(m)),\ L\ i(m)\ \varepsilon\ \mathrm{P}.$$

(iii) A **multiplicative metric** represents the product of QoS metric values and is defined as , $L\ i(m)\ \varepsilon$ P.

Some examples for metrics :

→ while cost, delay, and delay jitter are additive metrics.

→ Bandwidth is a concave metric

→ The reliability or availability of a link, based on some criteria such as link-break-probability, is a multiplicative metric.

2 . Ticket-Based QoS Routing Protocol :

- The basic idea of the ticket-based probing protocol is that the source node issues a certain number of tickets and sends these tickets in probe packets for finding a QoS feasible path.

- Each probe packet carries one or more tickets. Each ticket corresponds to one instance of the probe.

- For example, when the source node issues three tickets, it means that a maximum of three paths can be probed in parallel.

3 . Predictive Location-Based QoS Routing Protocol :

- On demand routing protocol

- QoS aware admission control is performed.

- The QoS routing protocol takes the help of an update protocol and location and delay prediction schemes.

- The update protocol aids each node in broadcasting its geographic location and resource information to its neighbors.

- The update protocol has two types of update messages, namely type 1 update and type 2 update.

- Each node generates a type 1 message periodically.

- A type 2 message is generated when there is a considerable change in the node’s velocity or direction of motion.

- From its recent update messages, each node can calculate an expected geographical location where it should be located at a particular instant and then periodically checks if it has deviated by a distance greater than from this expected location. If it has deviated, a type 2 message is generated.

4 . Trigger-Based Distributed QoS Routing Protocol :

- The trigger-based (on-demand) distributed QoS routing (TDR) protocol was proposed by De *et al.*for supporting real-time applications in ad hoc wireless networks.

- When a link failure is imminent, TDR utilizes the global positioning system-based (GPS) location information

- Each node maintains the local neighborhood information and active routes only

- For a quick rerouting with reduced control overhead, rerouting is attempted in **two ways** :

→ INIR (Intermediate Node Initiated Rerouting)

Rerouting is attempted from the location of an imminent link failure

→ SIRR (Source Initiated ReRouting)

Rerouting is attempted from the source

(i) Database Management :

All nodes in the network maintain the local neighborhood information. For each neighbor, every node maintains *received power level*, current geographic coordinates, velocity, and direction of motion in the database.

(ii) Activity-Based Database :

- The node maintains a source table (STn), a destination table (DTn), or an intermediate table (ITn)

- Depending on the role of the node in current session
  - → A flag indicating the node's activity – NodActv
  - → NodActv = 0, means idle

- Also maintains an updated residual bandwidth (ResiBWn) which indicates its ability to participate in a session.

- Databases are refreshed when packets belonging to the on-going sessions are received

(iii) Routing Protocol :

(a) Initial Route Discovery :

- The entry in source table is made, and NodActv sets to 0 (idle). Selects the neighbors lying closely toward the destination with power level more than a threshold (Pth1) and forward them a route discovery packet.

- The intermediate node checks if such packet was received already discard it, otherwise checks the ResiBW to meet the requirements an entry in IT is made, and NodActv sets to 0 (idle) forwards the packets with hop count +1

- Upon receiving the first packet, if destination is able to satisfy the ResiBW and MaxBW, the route is made, and the ACK is sent back to source along the route

(b) Route/Reroute Acknowledgment :

- After accepting the route, the destination node *D* builds *DT D* table with the NodActv flag set to 1 (*i.e.*,active) and sends an ACK to the source *S* along the selected route.

- On receiving the ACK packet, all intermediate nodes and the source *S* set the NodActv flags in their respective tables to 1 and refresh their *ResiBW* status.

- The packet transmission for the session follows immediately.

(c) Alternate Route Discovery :

- **In SIRR** When the received power level at an intermediate node falls below a threshold Pth2, the intermediate node sends a rerouting indication to source

- **In INIR** When the power level falls below the threshold Pth1 (Pth1 > Pth2), a status query packet is sent toward the source with a flag route repair status (RR_stat) set to 0

- If the upstream nodes are in rerouting process , The RR_stat is set to 1, and reply back to the querying node.

- If the query packet reaches source, the packet is discarded.

- If the querying node receives no reply then, the SIRR could be triggered (power level falls below Pth2) or simply give up the control of rerouting

(d) Route Deactivation :

▪ The source sends a route deactivation packet toward the destination The nodes received the packet update their ResiBW, and IT

▪ **Advantages**

→ Reduced control overhead

→Reduced packet loss during path breaks

▪ **Disadvantages**

→ Threshold value?

→ multi-path propagation/ velocity …etc

5 . QoS-Enabled Ad Hoc On-Demand Distance Vector Routing Protocol

- To provide QoS, packet formats have been modified in order to specify the service requirements which must be met by the nodes forwarding a*RouteRequest* or a *RouteReply*.

- Several modifications have been carried out for the routing table structure and *RouteRequest* and*RouteReply* messages in order to support QoS routing.

- The following fields are appended to each routing table entry:
  - →Maximum delay
  - → Minimum available bandwidth
  - →List of sources requesting delay guarantees
  - →List of sources requesting bandwidth guarantees

6 . Bandwidth Routing Protocol :

- The bandwidth routing (BR) protocol consists of an end-to-end path bandwidth calculation algorithm to inform the source node of the available bandwidth to any destination in the ad hoc network,

- A bandwidth reservation algorithm to reserve a sufficient number of free slots for the QoS flow,

- A standby routing algorithm to reestablish the QoS flow in case of path breaks.

7 . On-Demand QoS Routing Protocol :

- In On-demand routing, there is no need to exchange control information periodically and maintain routing tables at each node.

- Similar to the bandwidth routing (BR) protocol, the network is time-slotted and bandwidth is the key QoS parameter.

- The path bandwidth calculation algorithm proposed in BR is used to measure the available end-to-end bandwidth.

8 On-Demand Link-State Multipath QoS Routing Protocol :

- The on-demand link-state multipath QoS routing (OLMQR) protocol searches for multiple paths which collectively satisfy the required QoS.

- The original bandwidth requirement is split into sub-bandwidth requirements. Notably, the paths found by the multipath routing protocol are allowed to share the same sub-paths.

- OLMQR has better call acceptance rate in ad hoc wireless networks where finding a single path satisfying all the QoS requirements is very difficult.

9 . Asynchronous Slot Allocation Strategies :

- The asynchronous QoS routing (AQR) scheme and slot allocation strategies proposed in provide a unique mechanism to reserve asynchronous end-to-end bandwidth for real-time calls in ad hoc wireless networks.

- These strategies utilize the real-time MAC (RTMAC) protocol that can effect bandwidth reservation in asynchronous ad hoc wireless networks.

- AQR is an extension of dynamic source routing (DSR) protocol . The **three major phases** in the operation of AQR are :

  → bandwidth feasibility test phase,

  → bandwidth allocation phase, and

  → bandwidth reservation phase.

QOS FRAMEWORKS FOR AD HOC WIRELESS NETWORKS

- A framework for QoS is a complete system that attempts to provide required/promised services to each user or application.

- The key component of any QoS framework is the QoS service model which defines the way user requirements are met.

- Those Components are given below :

→ ***Routing protocol***: Similar to the QoS routing protocols, the routing protocol module in any QoS framework is used to find a path from the source to the destination and to forward the data packet to the next intermediate relay node.

→***QoS resource reservation signaling*:** Once a path with the required QoS is found, the next step is to reserve the required resources along that path. This is done by the resource reservation signaling protocol.

→***Admission control*:** Even though a QoS feasible path may be available, the system needs to decide whether to actually serve the connection or not. If the call is to be served, the signaling protocol reserves the resources; otherwise, the application is notified of the rejection.

→***Packet scheduling*:** When multiple QoS connections are active at the same time through a link, the decision on which QoS flow is to be served next is made by the scheduling scheme.

1 . QoS Models :

- A QoS model defines the nature of service differentiation.

- In wired network QoS frameworks, several service models have been proposed. Two of these models are
  - → **the integrated services (IntServ) model**
  - → **the differentiated services (DiffServ) model .**

- **The IntServ model** provides QoS on a per flow basis, where a flow is an application session between a pair of end users.

- However, **per flow information is difficult** to maintain precisely at a node **in an ad hoc wireless network** due to limited processing capability, limited battery energy, frequent changes in network topology,

- **The DiffServ model** was proposed in order to overcome the difficulty in implementing and deploying IntServ model and RSVP in the Internet.

- In this model, flows are aggregated into a limited number of service classes. Each flow belongs to one of the DiffServ classes of service. This solved the scalability problem faced by the IntServ model.

(i) Flexible QoS Model for Mobile Ad Hoc Networks :

- The flexible QoS model for mobile ad hoc networks (FQMM) takes advantage of the per flow granularity of IntServ and aggregation of services into classes in DiffServ.

- In this model the nodes are classified into three different categories, namely,

→ ***ingress* node** (source),

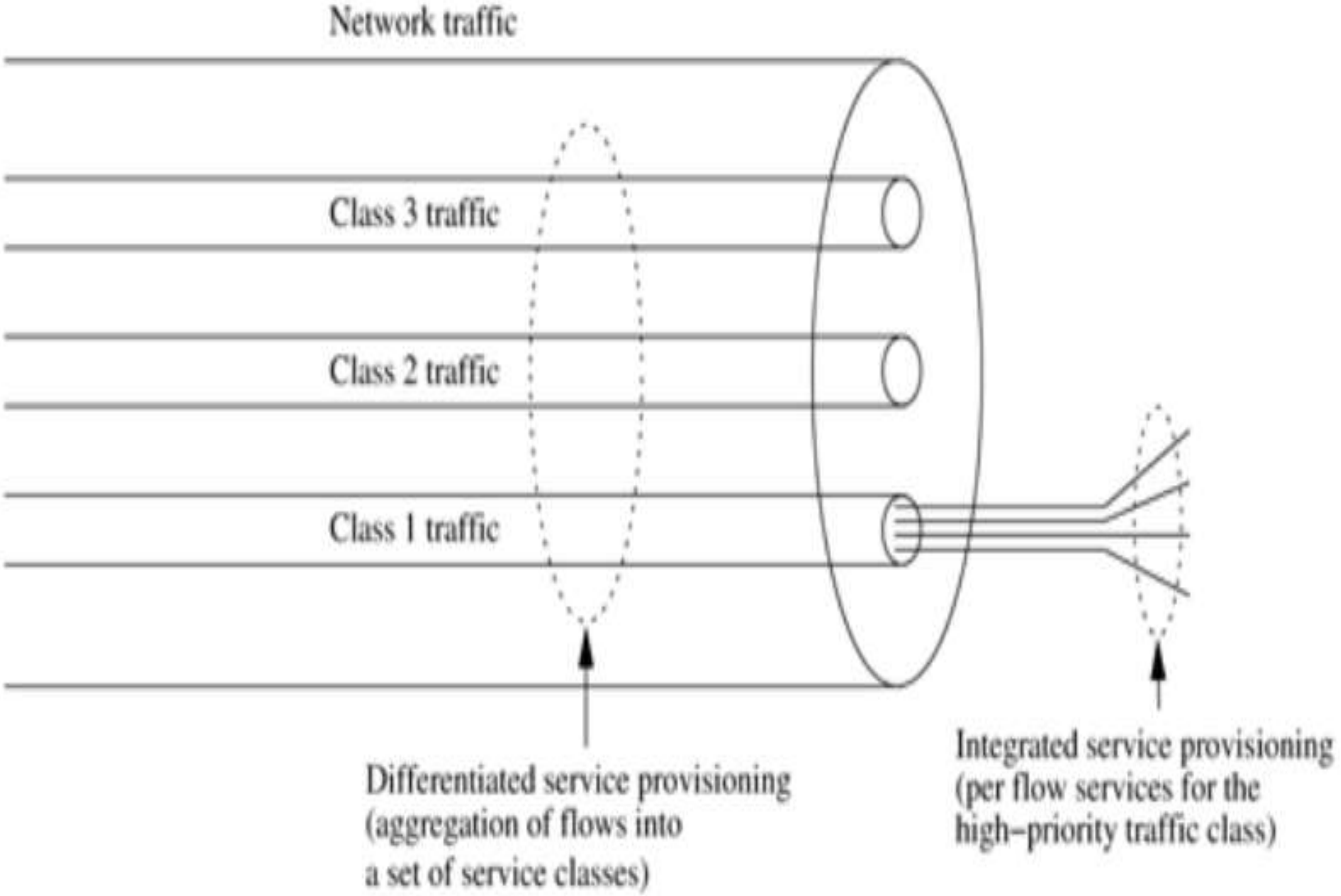
→ ***interior* node** (intermediate relay node),

→ ***egress* node** (destination) on a per flow basis.

- The FQMM model provides per flow QoS services for the

high-priority flows while lower priority flows are aggregated into a set of service classes .

FQMM model


Network traffic
Class 3 traffic
Class 2 traffic
Class 1 traffic
Differentiated service provisioning
(aggregation of flows into
a set of service classes)
Integrated service provisioning
(per flow services for the
high−priority traffic class)

Advantages

- Provides the ideal per flow QoS services
- Overcomes the scalability problem

Disadvantages

- Several issues remain un-solved
- Decision upon traffic classification
- Allotment of per flow or aggregated service for the given flow
- Amount of traffic belonging per flow service

2 . QoS Resource Reservation Signaling :

- The QoS resource reservation signaling scheme is responsible for reserving the required resources and informing the corresponding applications, which then initiate data transmission.

- Signaling protocol consists of **three phases**, namely,
  - → connection establishment,
  - → connection maintenance,
  - → connection termination.

(i) MRSVP: A Resource Reservation Protocol for Cellular Networks :

The MRSVP is an extension of RSVP protocol for mobile hosts.

- The protocol proposes **two types** of reservations:

→***Active Reservation :*** The reservation made over a path for a QoS flow is said to be active if data packets currently flow along that path. Made by local proxy agent .

→**Passive Reservation** : A reservation is said to be passive if the path on which resources have been reserved is to be used only in the future. Made by remote proxy agent .

3 . INSIGNIA :

- The INSIGNIA QoS framework was developed to provide adaptive services in ad hoc wireless networks.

- Adaptive services support applications that require only a minimum quantitative QoS guarantee (such as minimum bandwidth) called *base QoS*.

- The service level can be extended later to *enhanced QoS* when sufficient resources become available.

- The INSIGNIA framework has the following key components for supporting adaptive real-time services:

- ***Routing module*****:** The routing protocol finds a route from the source to the destination.

- ***In-band signaling*****:** This module is used to establish, adapt, restore, and tear down adaptive services between source-destination pairs.

- ***Admission control*****:** This module allocates bandwidth to flows based on the maximum/minimum bandwidth requested.

- ***Packet forwarding***: This module classifies the incoming packets and delivers them to the appropriate module.

- ***Packet scheduling*****:** Packets that are to be routed to other nodes are handled by the packet-scheduling module.

- ***Medium access control (MAC)*****:** The MAC protocol provides QoS-driven access to the shared wireless medium for adaptive real-time services.

(i) Operation of INSIGNIA Framework :

- The INSIGNIA framework supports adaptive applications which can be applications requiring best-effort service or applications with *base QoS* requirements or those with *enhanced QoS* requirements.

(ii) Releasing Resources in INSIGNIA :

- In order to release resources, the destination node sends a QoS report to the source so that the intermediate nodes release the extra resources.

(iii) Route Maintenance :

- Due to host mobility, an on-going session may have to be rerouted in case of a path break. The flow restoration process must reestablish the reservation as quickly and efficiently as possible.

Advantages

- An integrated approach provisioning QoS

- **Disadvantages**

- Supports only adaptive applications

  Multimedia applications

- Transparent to MAC protocol

  fairness and reservation scheme have a significant influence in provisioning QoS guarantees

- The QoS can be downgraded
- No suitable for real time application

4 . INORA :

- INORA is a QoS framework for ad hoc wireless networks that makes use of the INSIGNIA in-band signaling mechanism and the TORA routing protocol .

- TheTORA routing protocol provides multiple routes between a given source-destination pair.

- INORA can be classified into two schemes:

  → ***coarse feedback scheme***

  → ***class-based fine feedback scheme.***

(i) Coarse Feedback Scheme :

- If a node fails to admit a QoS flow either due to lack of minimum required bandwidth (*BW min*) or because of congestion at the node, it sends an out-of-band *admission control failure* (ACF) message to its upstream node.

- After receiving the ACF message, the upstream node reroutes the flow through another downstream node provided by the TORA routing protocol.

(ii) Class-Based Fine Feedback Scheme :

- In this scheme, the interval between *BW min* and *BW max* of a QoS flow is divided into *N* classes, where*BW min and BW max* are the minimum and maximum bandwidths required by the QoS flow. Consider a QoS flow being initiated by the source node *S* to destination node *D*.

Advantages

- Search multiple paths with lesser QoS guarantees (Compare with INSIGNIA)

- Use the INSIGNIA in-band signaling mechanism

Disadvantages

- May not be suitable for applications that require hard service guarantees

5 . SWAN :

- Ahn *et al*. proposed a distributed network model called stateless wireless ad hoc networks (SWAN) that assumes a best-effort MAC protocol and uses feedback-based control mechanisms to support real-time services and service differentiation in ad hoc wireless networks.

- SWAN uses a **local rate control mechanism** for regulating injection of best-effort traffic into the network,

- a **source-based admission control** while accepting new real-time sessions,

- an **explicit congestion notification (ECN) mechanism** for dynamically regulating admitted real-time sessions.

- In this model, intermediate nodes are relieved of the responsibility of maintaining per-flow or aggregate state information, unlike stateful QoS models such as INSIGNIA and INORA.

- Changes in topology and network conditions, even node and link failures, do not affect the operation of the SWAN control system. This makes the system simple, robust, and scalable.

6 . Proactive RTMAC :

- Proactive RTMAC (PRTMAC) is a cross-layer framework, with an on demand QoS extension of DSR routing protocol at the network layer and real time MAC (RTMAC) protocol at the MAC layer.

- PRTMAC is a tightly coupled solution which requires the bandwidth reservation and bandwidth availability estimation services from the underlying MAC protocol.

- It is designed to provide enhanced real-time traffic support and service differentiation to highly mobile ad hoc wireless networks such as that formed by military combat vehicles.

ENERGY MANAGEMENT

IN

AD HOC WIRELESS NETWORKS

INTRODUCTION

- The nodes in an ad hoc wireless network are constrained by limited battery power for their operation.

- Hence, energy management is an important issue in such networks.

- Battery power is a precious resource that must be used efficiently in order to avoid early termination of any node.

NEED FOR ENERGY MANAGEMENT IN AD HOC WIRELESS NETWORKS

- The main reasons for energy management in ad hoc wireless networks are listed below:

→ **Limited energy reserve**
→ **Difficulties in replacing the batteries**
→ **Lack of central coordination**
→ **Constraints on the battery source**
→ **Selection of optimal transmission power**
→ **Channel utilization**

CLASSIFICATION OF ENERGY MANAGEMENT SCHEMES

- Energy conservation can be implemented using the following techniques:

  → Battery management schemes
  → Transmission power management schemes
  → System power management schemes

- The system power management approach can be further divided into the following categories:

  → Device management schemes
  → Processor power management schemes

Classification of energy management schemes

BATTERY MANAGEMENT SCHEMES

- Battery-driven systems are those systems which are designed taking into consideration mainly the battery and its internal characteristics.

1 . Overview of Battery Characteristics :

- The major components of batteries are :

- A battery mainly consists of an anode, a cathode, an electrolyte medium, and a case. The anode is often a metal and the cathode a metallic oxide.

- The electrolyte is a salt solution that promotes the ion flow. The porous separator is used to prevent a short circuit between anode and cathode by keeping them from touching one another.

→Battery technologies

- comprised of nickel-cadmium, lithium ion, nickel metal-hydride, reusable alkaline, and lithium polymer.

- The main factors considered while designing a battery technology are the energy density , cycle life , environmental impact, safety, cost, available supply voltage, and charge/discharge characteristics.

→Principles of battery discharge:

- A battery typically consists of an array of one or more cells. "cell" are used interchangeably.

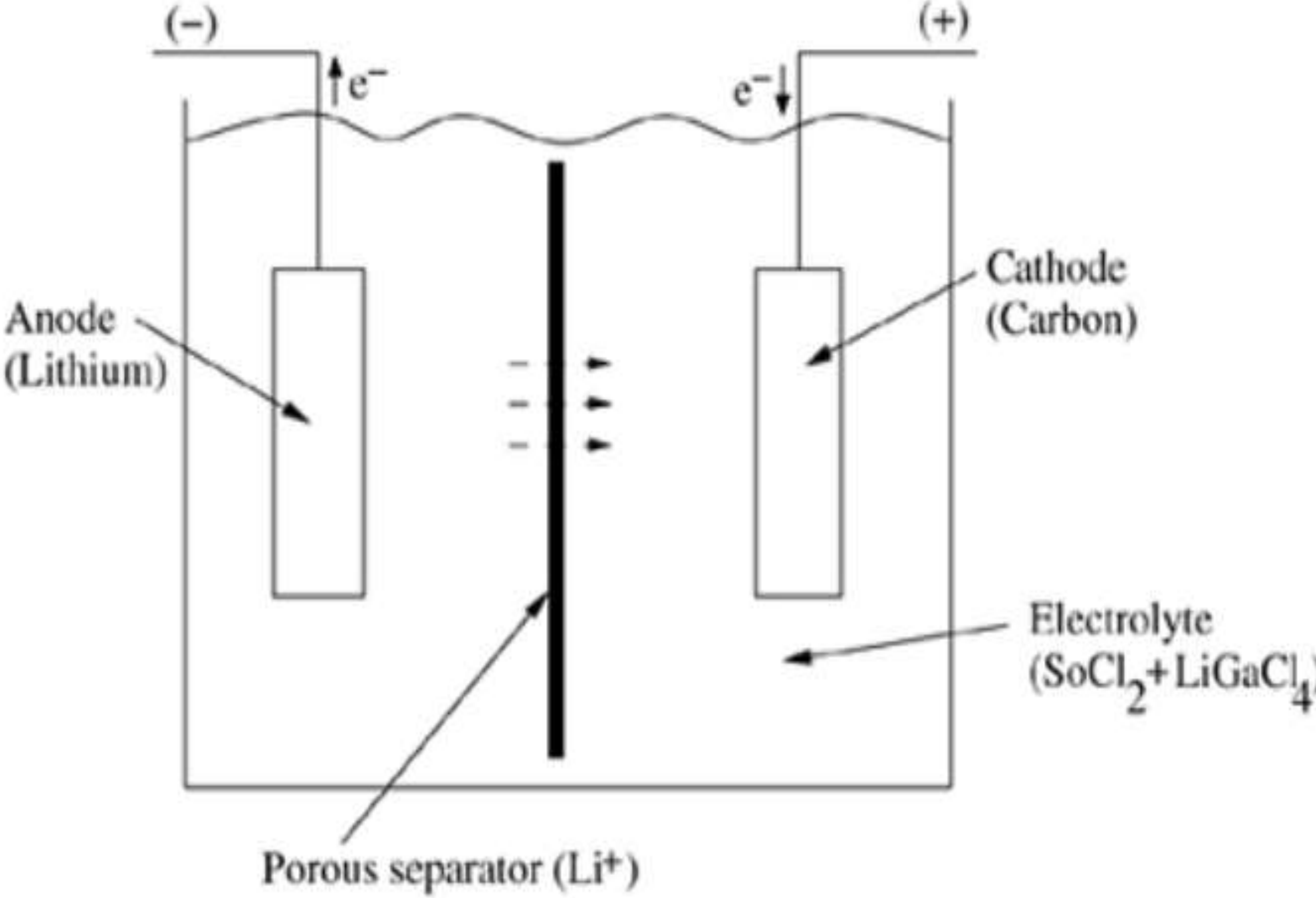
- The **three main voltages** that characterize a cell are:

(1) the **open circuit voltage** (V_{oc}), that is, the initial voltage under a no-load condition of a fully charged cell,

(2) the **operating voltage** (V_i), that is, the voltage under loaded conditions,

(3) the **cut-off voltage** (V_{cut}) at which the cell is said to be discharged.

Basic structure of a lithium/thionyl chloride battery



- All the cells are defined by three main capacities:

→**Theoretical capacity** : The amount of active materials contained in the cell refers to its theoretical capacity

→ **Nominal (standard) capacity**: This corresponds to the capacity actually available when discharged at a specific constant current.

→ **Actual capacity**: The energy delivered under a given load is said to be the actual capacity of the cell.

2 . Device-Dependent Schemes :

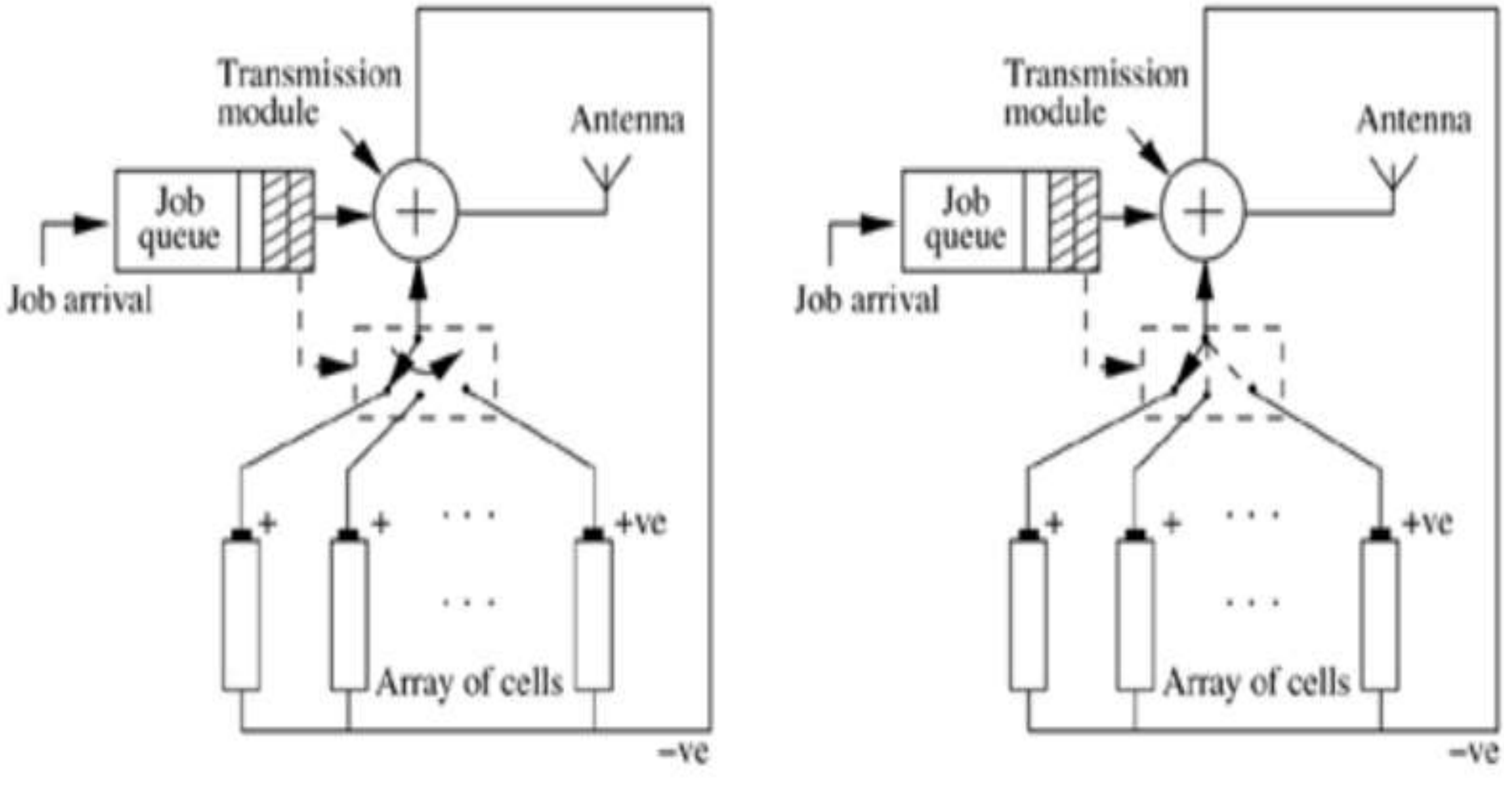
Battery-Scheduling Techniques :

→**Round robin technique (RR):** This scheme selects the battery in round robin fashion and the jobs are directed to the cells by switching from one to the next one.

- The job from job queue gets energy from the battery selected by the transmission module based on round robin technique.

→ **Random technique (RN):** In this technique, any one of the cells is chosen at random with a probability of . The selected cell provides the total supply required,

Battery-scheduling techniques: (a) round robin technique (b)random technique.



(a) (b)

3 . Data Link Layer Solutions :

- **Lazy Packet Scheduling:**
  - → Reduce the power
  - → Increase the transmission time

- **Battery-Aware MAC Protocol:**
  - → Packets carry remaining charge.
  - → Lower back off interval for nodes with higher charge

4 . Network Layer Solutions :

Goal: Increase the lifetime of the network

- **Shaping:** If battery charge becomes below threshold,stop next transmission allowing battery to recover

- **Battery Energy Efficient (BEE) Routing Protocol:**
  Minimize energy and use max battery charge

TRANSMISSION POWER MANAGEMENT SCHEMES

- The components used in the communication module consume a major portion of the energy in ad hoc wireless networks.

- We investigate some of the means of achieving energy conservation through efficient utilization of transmission power such as selection of an optimal power for communication.

1 . Data Link Layer Solutions :

→ Dynamic power adjustment policies
→ Distributed topology control algorithms
→ Constructing distributed power control loop
→ Centralized topology control algorithm

2 . Network Layer Solutions :

- → Common Power Protocol
- → Minimum Power Consumption Routing
- → Minimum Variance in Node Power Levels
- → Minimum Battery Cost Routing
- → Min-Max Battery Cost Routing
- → Conditional Min-Max Battery Cost Routing
- → Minimum Energy Disjoint Path Routing
- → Localized Power-Aware Routing Techniques

SYSTEM POWER MANAGEMENT SCHEMES

- System power consists of the power used by all hardware units of the node. This power can be conserved significantly by applying the following schemes:

  → Processor power management schemes
  → Device power management schemes

1 . Processor Power Management Schemes :

→Power-Saving Modes

→ **Remote Access Switch**: System sleeps. Only PHY receiver is on. On receipt of a particular signal, wakes up the system.

→ **Power Aware Multi-Access Signaling** (PAMAS): Power-off if you hear RTS/CTS for another node or if you have nothing to send.

2 . Device Power Management Schemes :

→ Turn off individual components: LCD display,
→ DRAM, CDROM, CPU, Drive
→ Run CPU at lower clock rate, lower voltages
→ Spin down disks when unused