Routing Strategies

- Fixed
- Flooding
- Random
- Adaptive

Fixed Routing

- Single permanent route for each source to destination pair
- Determine routes using a least cost algorithm
- Route fixed, at least until a change in network topology

Fixed Routing Tables

Problem:
Totally unresponsive to changes in network loading

CENTRAL ROUTING DIRECTORY

To Node \ From Node	1	2	3	4	5	6
1	—	1	5	2	4	5
2	2	—	5	2	4	5
3	4	3	—	5	3	5
4	4	4	5	—	4	5
5	4	4	5	5	—	5
6	4	4	5	5	6	—

Node 1 Directory

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Directory

Destination	Next Node
1	1
3	3
4	4
5	4
6	4

Node 3 Directory

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Directory

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

Node 5 Directory

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

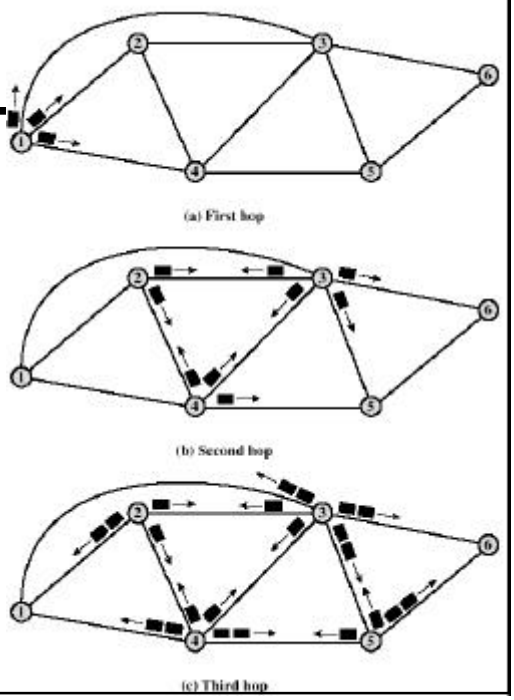
Node 6 Directory

Destination	Next Node
1	5
2	5
3	5
4	5
5	5

Flooding

- No network info required
- Packet sent by node to every neighbor
- Incoming packets retransmitted on every link except incoming link
- Eventually a number of copies will arrive at destination
- Each packet is uniquely numbered so duplicates can be discarded
- Nodes can remember packets already forwarded to keep network load in bounds
- Can include a hop count in packets

Flooding Example



Properties of Flooding

- All possible routes are tried
  - Very robust
- At least one packet will have taken minimum hop count route
  - Can be used to set up virtual circuit
- All nodes are visited
  - Useful to distribute information (e.g. routing)
- Problem: large number of packets generated

Random Routing

- Node selects one outgoing path for retransmission of incoming packet
- Selection can be random or round robin
- Can select outgoing path based on probability calculation
- No network info needed
- Route is typically not least cost nor minimum hop

Adaptive Routing

- Used by almost all packet switching networks
- Routing decisions change as conditions on the network change
  - Failure
  - Congestion
- Requires info about network
- Decisions more complex
- Tradeoff between quality of network info and overhead
- Reacting too quickly can cause oscillation
- Too slowly to be relevant

Adaptive Routing - Advantages

- Improved performance
- Aid congestion control
- Complex system
  - May not realize theoretical benefits
- Has costs as well

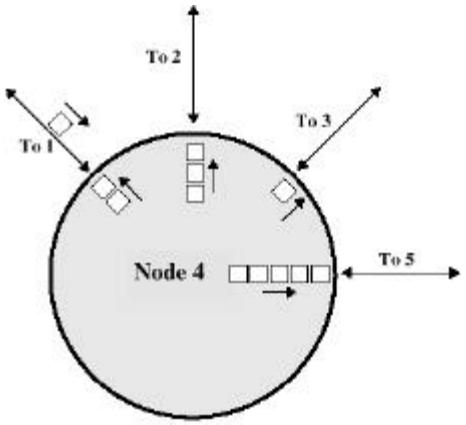
Classification

- Based on information sources
  - Local (isolated)
    - Route to outgoing link with shortest queue
    - Can include bias for each destination
    - Rarely used - do not make use of easily available info
  - Adjacent nodes
  - All nodes

Isolated Adaptive Routing

Node 4's Bias Table for Destination 6

Next Node	Bias
1	9
2	6
3	3
5	0



ARPANET Routing Strategies(1)

- First Generation
  - 1969
  - Distributed adaptive
  - Estimated delay as performance criterion
  - Bellman-Ford algorithm
  - Node exchanges delay vector with neighbors
  - Update routing table based on incoming info
  - Doesn't consider line speed, just queue length
  - Queue length not a good measurement of delay
  - Responds slowly to congestion

ARPANET Routing Strategies(2)

- Second Generation
  - 1979
  - Uses delay as performance criterion
  - Delay measured directly
  - Uses Dijkstra's algorithm
  - Good under light and medium loads
  - Under heavy loads, little correlation between reported delays and those experienced

ARPANET Routing Strategies(3)

- Third Generation
  - 1987
  - Link cost calculations changed
  - Measure average delay over last 10 seconds
  - Normalize based on current value and previous results

X.25

- 1976
- Interface between host and packet switched network
- was almost universal on packet switched networks and packet switching in ISDN
- Defines three layers
  - Physical
  - Link
  - Packet

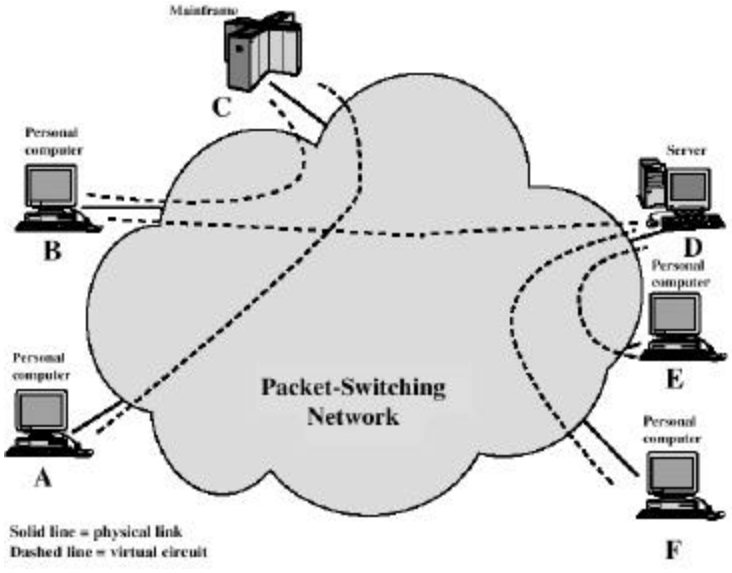
X.25 - Physical

- Interface between attached station and link to node
- Data terminal equipment DTE (user equipment)
- Data circuit terminating equipment DCE (node)
- Uses physical layer specification X.21
- Reliable transfer across physical link
- Sequence of frames
- X.25 - Link
  - Link Access Protocol Balanced (LAPB)
    - Subset of HDLC

X.25 - Packet

- External virtual circuits
- Logical connections (virtual circuits) between subscribers

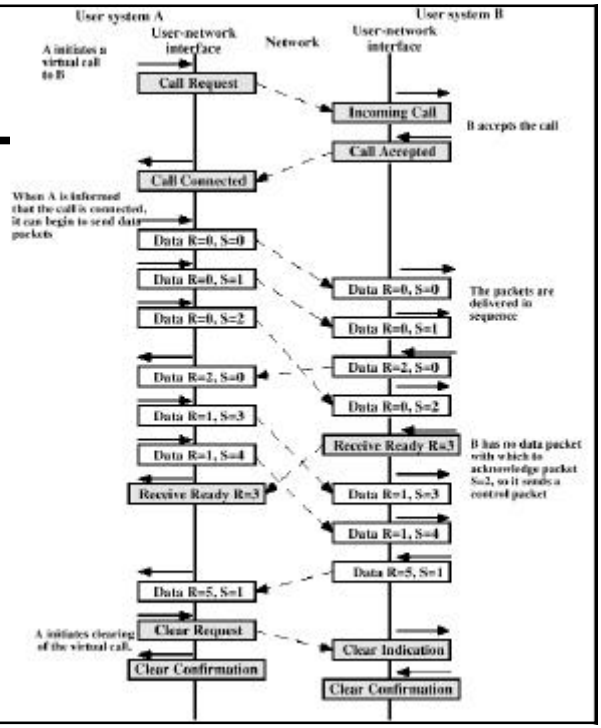
X.25 Use of Virtual Circuits



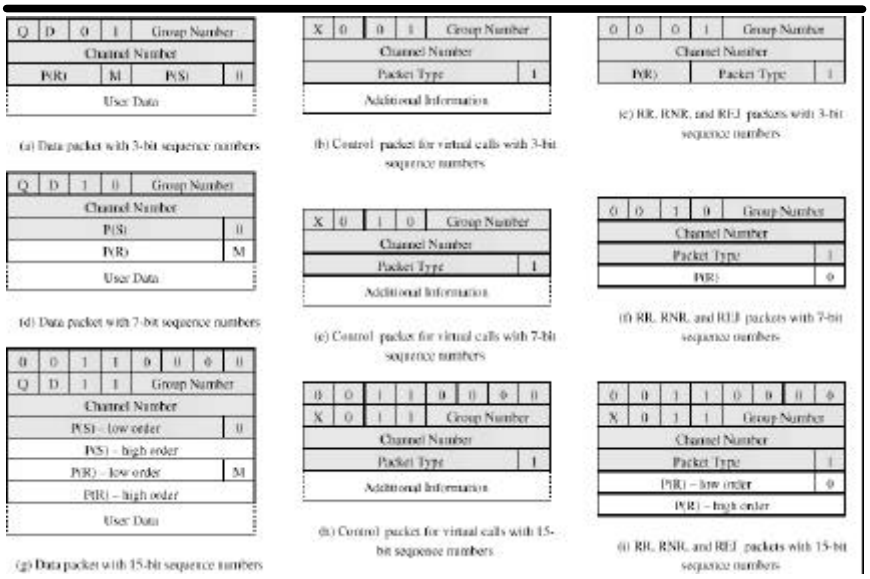
Virtual Circuit Service

- Virtual Call
  - Dynamically established
- Permanent virtual circuit
  - Fixed network assigned virtual circuit

Virtual Call



Packet Format



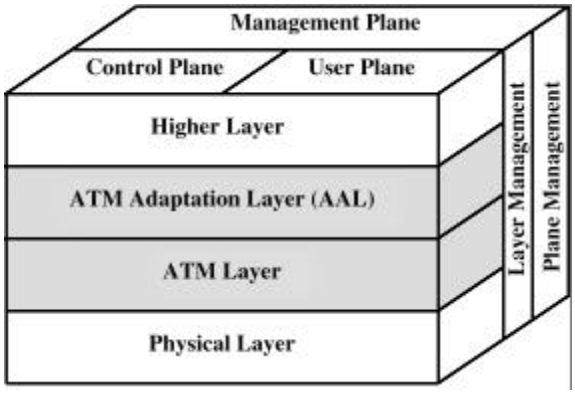
Reset and Restart

- Reset
  - Reinitialize virtual circuit
  - Sequence numbers set to zero
  - Packets in transit lost
  - Up to higher level protocol to recover lost packets
  - Triggered by loss of packet, sequence number error, congestion, loss of network internal virtual circuit
- Restart
  - Equivalent to a clear request on all virtual circuits
  - E.g. temporary loss of network access

ATM: Asynchronous Transfer Mode

- ATM and FR (Frame Relay) are recent developments
  - node-node transfer techniques
  - used where error rates are lower
  - (But still must cope with congestion)
- ATM is a form of packet switching
  - Transfer of data in discrete chunks
  - Multiple logical connections over single physical interface
- In ATM flow on each logical connection is in fixed sized packets called cells
- Minimal error and flow control

Protocol Architecture (diag)



Reference Model Planes

- User plane
  - Provides for user information transfer
- Control plane
  - Call and connection control
- Management plane
  - Plane management
    - whole system functions
  - Layer management
    - Resources and parameters in protocol entities

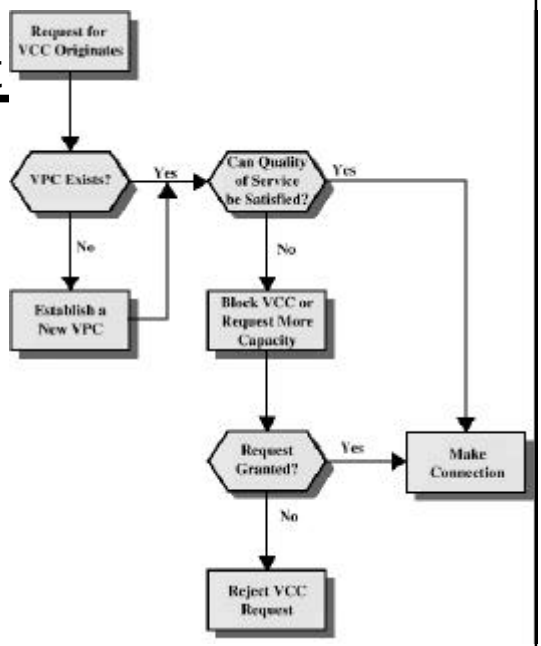
ATM Logical Connections

- Virtual channel connections (VCC)
- Analogous to virtual circuit in X.25
- Basic unit of switching
- Between two end users
- Full duplex
- Fixed size cells
- Data, user-network exchange (control) and network-network exchange (network management and routing)
- Virtual path connection (VPC)
  - Bundle of VCC with same end points

Advantages of Virtual Paths

- Simplified network architecture
- Increased network performance and reliability
- Reduced processing
- Short connection setup time
- Enhanced network services

Call Establishment Using VPs



VP/VC Characteristics

- Quality of service
- Switched and semi-permanent channel connections
- Call sequence integrity
- Traffic parameter negotiation and usage monitoring

- VPC only
  - Virtual channel identifier restriction within VPC

Control Signaling - VCC

- Done on separate connection
- Semi-permanent VCC
- Meta-signaling channel
  - Used as permanent control signal channel
- User to network signaling virtual channel
  - For control signaling
  - Used to set up VCCs to carry user data
- User to user signaling virtual channel
  - Within pre-established VPC
  - Used by two end users without network intervention to establish and release user to user VCC

ATM Cells

- Fixed size
- 5 octet header
- 48 octet information field
- Small cells reduce queuing delay for high priority cells
- Small cells can be switched more efficiently
- Easier to implement switching of small cells in hardware
- low level

ATM Cell Format