Concepts in Routing

Outline

- What is Routing
- Packet Switching and Layering Issues
- Performance Criteria
- Network Information Sources
- Decision Time
- Decision Place
- Network Information Update Timing

What is Routing?
Routing in Everyday Life-1

Consider you have to go from one part of the country to another to visit your relatives.

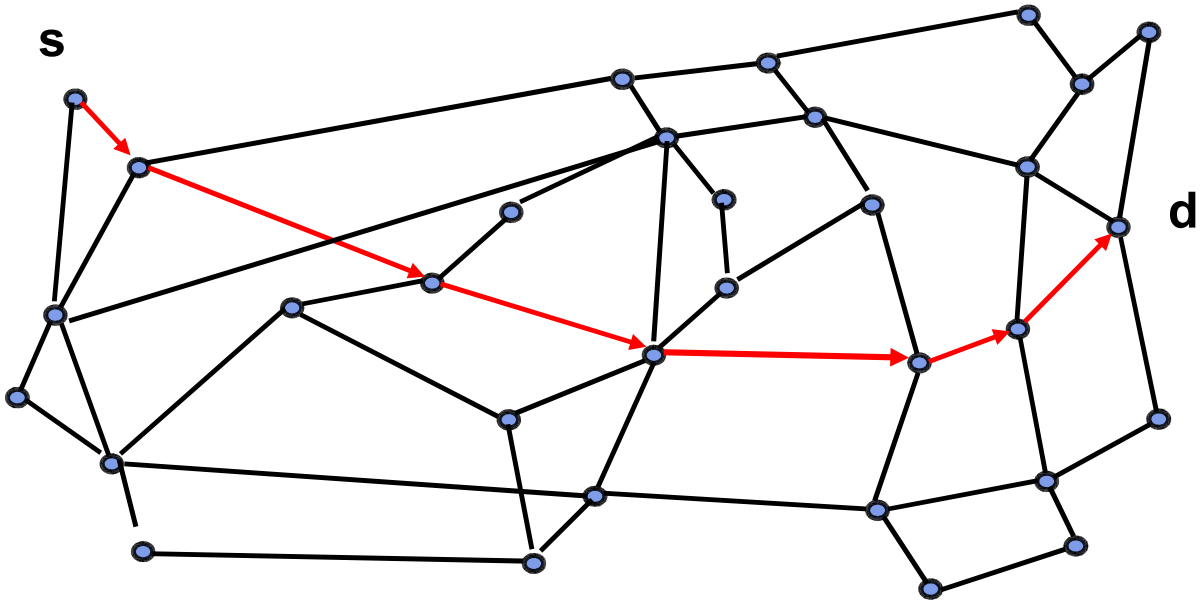
- You will get their address etc. and plan the journey
- You will consult a map of the country
  - First find the city
  - Find what mode of transport can take you there
- Next consult map of the city
  - First find the locality
  - Find what train or bus will take you there
- Next ask about a landmark near the house

What is Routing?
Routing in Everyday Life-2

- How soon you need to get there?
- How much money do you have to get there?
- Can you withstand the journey?
- How much time you have to plan your journey?
  - Is everything reserved and planned in advance? Or it is done moment-to-moment?
  - Who plans your journey? Do they send you tickets? Your agent? Or while you go?
- What happens if … Train Accident, Rasta-Roko, no accommodation on flight etc..?

Switching - 1

- Switched communication networks transfer data beyond a local area from source to destination through intermediate *switching* nodes



Switching - 2

- Types of Switching
- Circuit Switching (Telephone Networks)
  - Establishment-Transfer-Disconnect phases
  - Routing in connection establishment phase
  - Fixed Bandwidth transmission
- Packet Switching (Data Networks)
  - Datagrams
    - Independent Route for each packet
  - Virtual Circuits
    - Call setup delays; after route setup each packet has fixed route

Switching - 3

- Connection Oriented Services (Mostly VC)
  - Call setup request
  - Logical connection numbers setup
  - Packets labeled as to the logical connection and sequenced
- Connection Less Services (Datagram)
  - Packets treated independently
  - No reliability or ordering support

Layering Issues: Network Layer

Main Concern: getting packets from source to destination

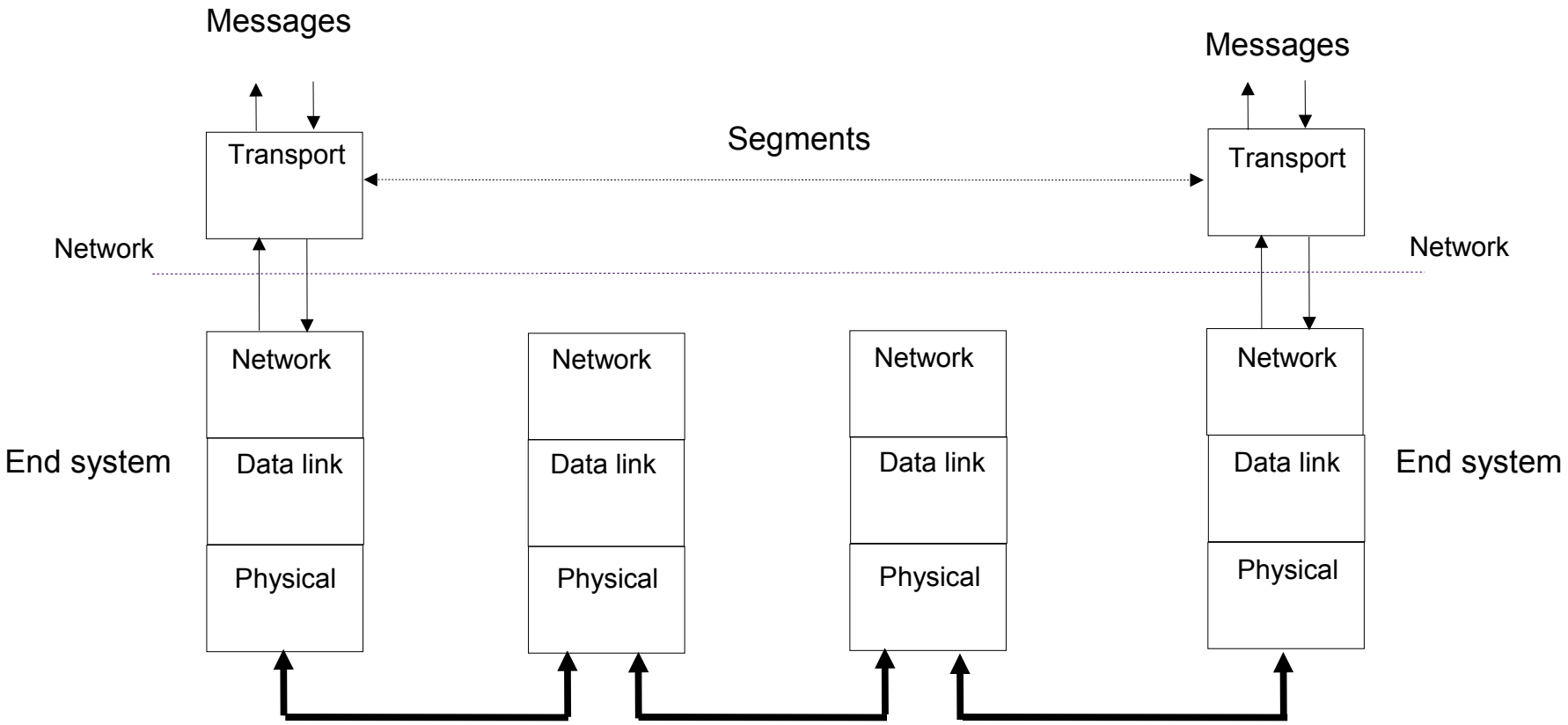
- Network layer must know the topology of the subnet and choose appropriate paths through it.
- When source and destination are in *different networks,* the network layer **(IP)** must deal with these differences.
- **Key issue:** *what service does the network layer provide to the transport layer* (connection-oriented or connectionless).

Layering Issues: Network Layer

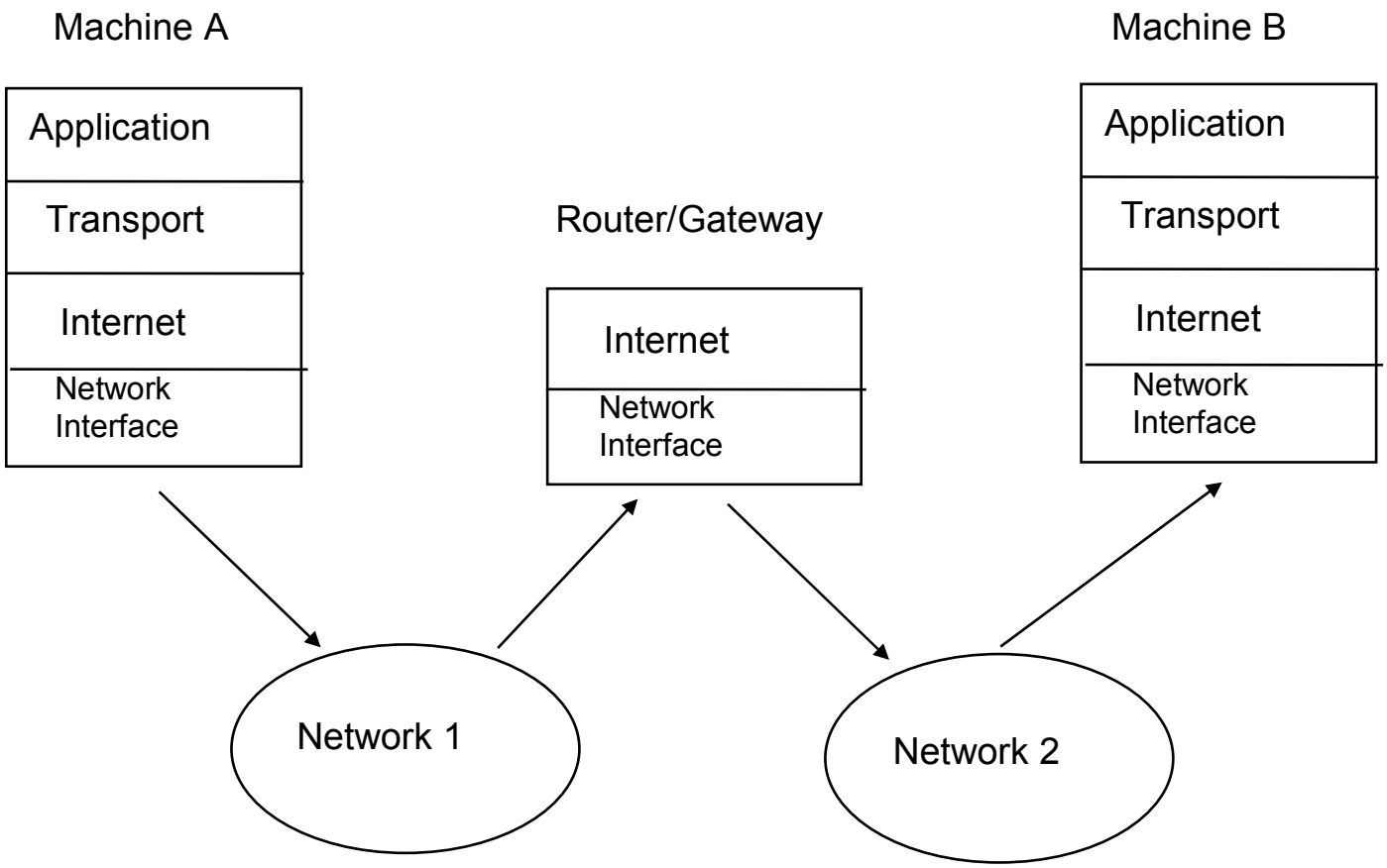
Other Issues:

- Inter-networking
  - Are Networks Homogenous or Heterogeneous
- Control and Signaling
  - Distinguish between and routed and routing protocols
  - If an error in routing/forwarding occurs how is it to be communicated?
  - Protocol to reserve and release network resources
- Congestion, Quality of Service and Load Balancing
- Security

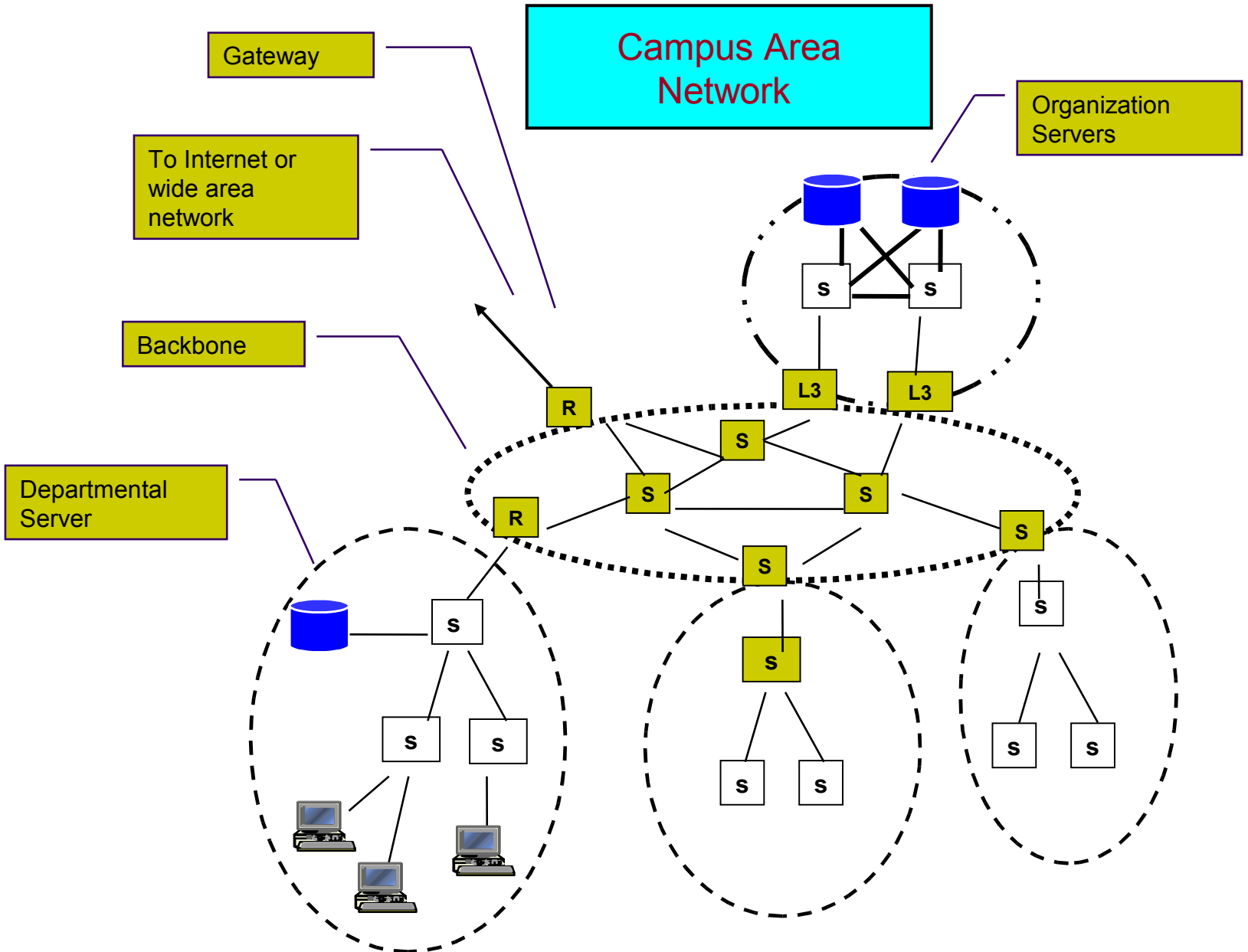
Layering Issues: Network Layer



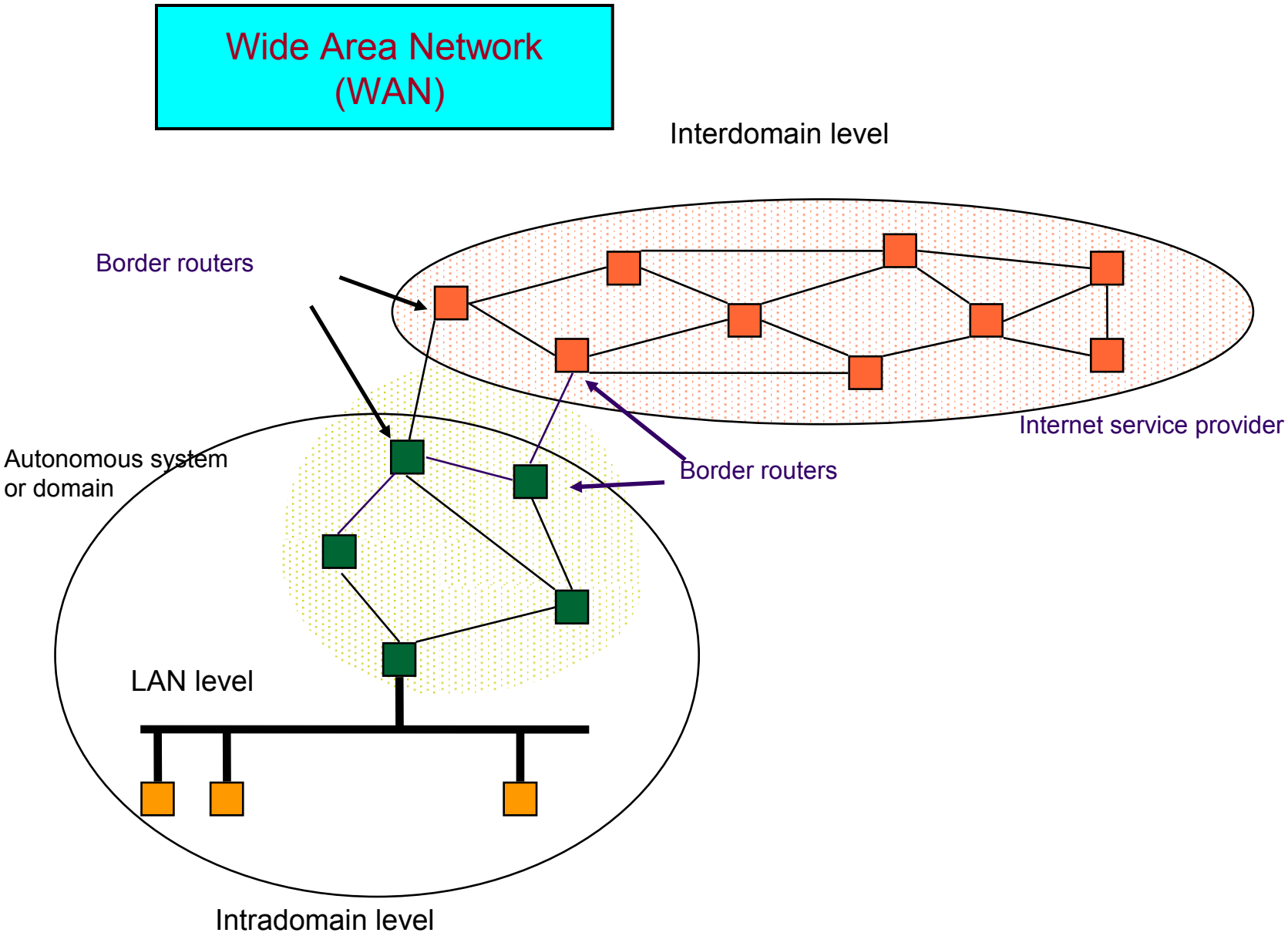
Layering Issues: Network Layer



Example Networks



Example Networks-2



Performance Criteria

Routing algorithms Desirable properties

- Correctness: If it is not, then what's the point ?
- Simplicity: for efficiency and ease in implementation, maintenance
- Robustness: must be able to sustain the changes in the networks (failures, overloads etc.)
- Stability: when run long enough, should converge to equilibrium
- Optimality: maximize performance criteria
- Fairness: trade off with optimality
- Efficiency: Overheads minimized

Performance Criteria

Routing Algorithms Metrics for Optimization

- Bandwidth
- Delay
- Load
- Reliability
- Hop counts
- Cost

Two Common Performance Measures

Quantity of Service (Throughput)

- How much data travels across the net?
- How long does it take to transfer long files?

Quality of Service (Average packet delay)

- How long does it take for a packet to arrive at its destination?
- How responsive is the system to user commands?
- Can the network support real-time delivery such as audio and video?

Making a Routing Decision-1

- **Decision time**
  - When forwarding each packet
  - When set up a virtual circuit
- **Decision place**

Routing decisions are usually based on knowledge of network (not always)

Distributed: made by each node/router
Centralized: made by a central location
Source: made by the sender

- Distributed routing
  - Nodes use local knowledge
  - May collect info from adjacent nodes
  - May collect info from all nodes on a potential route
- Central routing
  - A central station collects info from all nodes

Making a Routing Decision-2

- Update timing
  - When is network information held by nodes updated
  - Fixed - never updated
  - Adaptive - regular updates
- Routing strategies
  - Fixed,
  - Flooding,
  - Random,
  - Adaptive

Making a Routing Decision-3

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

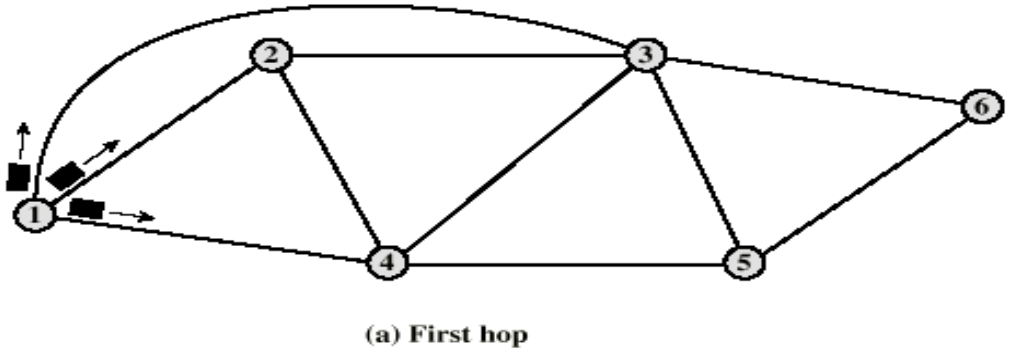
Node 6 Directory

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

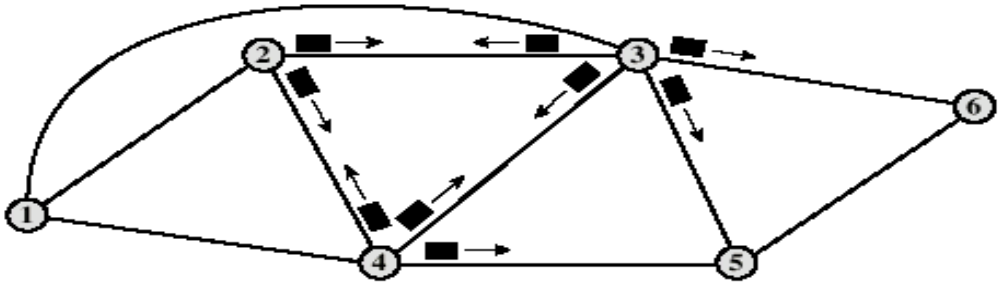
Fixed Routing

- 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

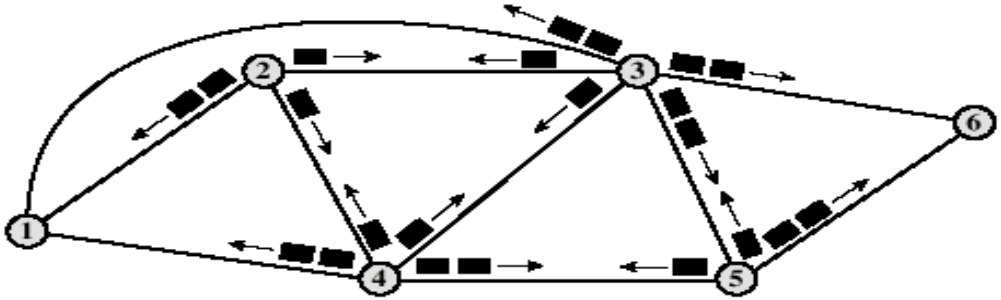
Making a Routing Decision-4



(a) First hop



(b) Second hop



(c) Third hop

Flooding

- No network information 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

Making a Routing Decision-4

- Optimizations in Flooding
  - 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
- 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)

Making a Routing Decision-5

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 information needed
- Route is typically not least cost nor minimum hop

Refinement of Random Routing:

Assign probability P_i to each outgoing link. It may be based on the data rate R_i of the link i

$P_i = R_i$ / sum(R_i) *over all links j*

•Lesser load than flooding,

•Works very well for highly connected networks

Making a Routing Decision-6

Adaptive routing

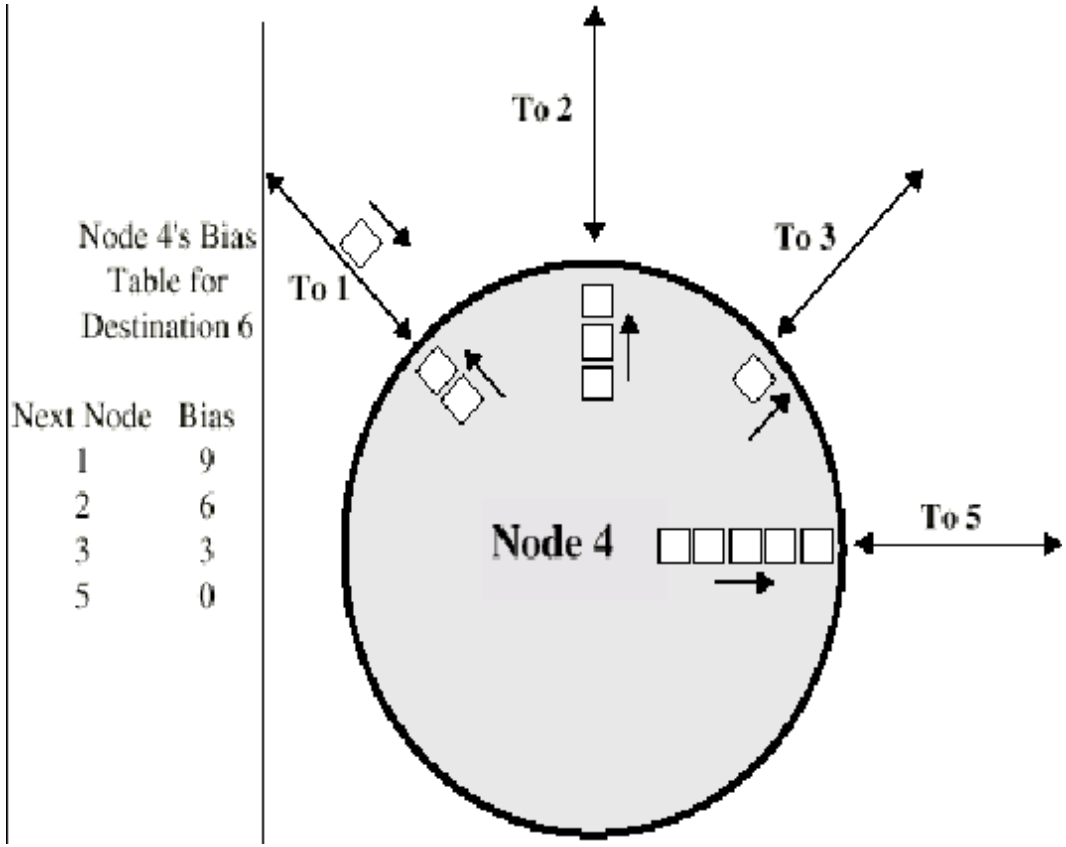
- Routing decisions change as conditions on the network change (not just topology but also traffic)
  - Failure
  - Congestion
- Classification based on information sources
  - Local (isolated)
  - Adjacent nodes
  - All nodes

- **Pros**
  - Improved performance
  - Aid congestion control
- **Cons**
  - Requires information about network
  - Decisions more complex
  - Tradeoff between quality of network information and overhead
  - Reacting too quickly can cause oscillation
  - Too slowly to be relevant

Adaptive Routing-1

Isolated Adaptive Routing

- Route to outgoing link with shortest queue
- Can include bias for each destination
  - Q+B is used to decide the route
- Rarely used - does not make use of easily available information



Adaptive Routing-2

Distance Vector Routing

- Developed by Bellman-Ford, also called Bellman-Ford algorithm or backward search algorithm
- Used in ARPANET until 1979
- Belongs to distributed adaptive algorithm
- Problems
  - Delay of link information
  - Count-to-infinity problem

- Estimated delay as performance criterion
- 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

Adaptive Routing-3

Link State Routing

- Based on Dijkstra's Shortest Path's Algorithm
- Used in ARPANET from1979
- Belongs to distributed adaptive algorithm
- Differs from DV as information LSP are exchanged by flooding routers

- Delay as performance criterion
- Node exchanges LSP with all routers
- Each router uses information to compute its shortest path based routing table
- Good performance under light and heavy loads
- Link cost calculations changed after 1987
- Average delay over last 10

Hierarchical Routing

Problem: Too much routing information is required to be stored for each node

- There may be too many nodes for each to have complete routing tables.

Solution: Group nodes into *domains* which are seen as independent networks

Domains may have further subdomains etc.

Example:

Telephone Numbering system:

- Country Code+NSD Code+ExchangeCode+Tel. No.
- +91-040-2300-1967

Summary

- Issues in routing
  - Cost
  - Decision time and place
- Routing classifications
  - Distributed
  - Central
  - Fixed
  - Adaptive

- Routing algorithms
  - Fixed
  - Flooding
  - Random
  - Adaptive
    - Isolated
    - Distance Vector Routing
    - Link State Routing
  - Hierarchical