ATM Routing

• ATM networks will consist of more than one switch
• Inter-switch protocol needed
  – Topology discovery
  • Distribution of reachability information
  – Hierarchical routing and addressing
  – QoS support
• Private Network to Network Interface or Private Node to Node Interface (PNNI)
  – is the dynamic solution for private ATM

PNNI Overview

• Contains two major protocols
  – PNNI routing
  – PNNI signaling
• Between ATM switches
• Might also be used between ATM end-systems and switches
  – Dual-homed end system
  – PNNI may be used to select the proper interface
PNNI Model

- Route Determination
- Topology Database
- Topology Exchange
- Management Interface Protocol
- UNI Signaling
- Cell Stream
- Switching Fabric
- Topology Protocol (VPI/VCI = 0/18 (PNNI Routing))
- UNI Signaling
- Cell Stream
- NNI Signaling
- VPI/VCI = 6/5 (Q.2931 signaling)

PNNI Overview

- **Goal of PNNI routing**
  - To create a signaling path from the source end-node to the intended destination end-node
- **Routing decision**
  - Switches exchange information with each other about the topology of the network
- **PNNI is based on Link-State technique**
- **Topology database**
  - Every switch maintains a database representing the states of the links and the switches in a PNNI routing network
  - = Roadmap

PNNI Data Transfer

- **Routing protocol information**
  - Is sent between adjacent switches
  - Dedicated connection, using VPI = 0 and VCI = 18
- **Information is sent in packet format**
- **All packets are using AAL 5 for ATM SAR**
- **All cells use UBR traffic class by default**
  - Though UBR, these cells are never dropped by a switch
    - Using a designated system-queue
  - Some vendors implement VBR to ensure specific treatment of PNNI information

Link State Overview

- **Every switch exchanges “Hellos” with direct neighbors to determine local topology**
- **Every switch advertises its local topology throughout the network**
- **Switches calculate routes based on network topology**
- **Topology State Routing**
  - Extension to link state routing!
  - Announce status of node (!) as well as status of links
  - Contains dynamic parameters versus static-only parameters of OSPF (link up/down, node up/down, nominal bandwidth of link)
**Virtual Circuit Support**

- ATM is based on virtual circuits
- Call setup (VC establishment) picks a path through the network
- Resources are reserved for the VC, path is used by all cells in the VC
- Path must be loop free!
  - Switches specify source routes
  - If there is an error during connection setup, crankback to source and try another path

---

**Agenda**

- PNNI - Overview
- PNNI - Routing
- PNNI - Hierarchy
- Interim Inter Switch Protocol

---

**PNNI Routing**

- **Topology map**
  - Enables the switch to calculate possible routes to destination endpoints
- **Network directory**
  - Enables the switch to locate destination endpoints
- **Up-to-date network state information**
  - Enables the switch to select the correct (best) route

---

**PNNI Routing**

- **PNNI uses source routing**
  - Better suited to deal with QoS and the connection oriented nature of ATM
  - Path computed by the source switch
  - Creates source route information (header) in front of the information to be transmitted (call setup message)
    - In PNNI, this header is called a designated transit list (DTL)
- **Weakness of source routing**
  - Does not provide an option for re-routing during a session
  - If a path fails, re-routing has to be triggered by the source
    - ATM edge device or first ATM switch
PNNI Routing

- Path determination uses path measurements called metrics
  - Much more complex than with standard routing protocols because of QoS support

Metrics (add up along a path)
- Cell delay variation
- Maximum cell transfer delay
- Administrative weight

Attributes (local to a link)
- Cell loss ratio
- Maximum cell rate
- Available cell rate
- Cell rate margin
- Variation factor

PNNI Metrics

- Peak-to-Peak Cell Delay Variation - CDV
  - The quantile of the cell transfer delay minus the fixed delay experienced by all cells crossing the link or node

- Maximum Cell Transfer Delay - maxCTD
  - The quantile of the elapsed time for transmission of cells across a link or node
  - This includes processing and queuing delays plus propagation delay

- Administrative Weight - AW
  - Indicates the relative preference of a link or node assigned by the private network operator
PNNI Attributes

- **Cell Loss Ratio - CLR**
  - The ratio of the number of lost cells to the total number of cells transmitted across the link or node

- **Maximum Cell Rate - MCR**
  - The maximum capacity usable by connections belonging to the specific service category
  - It's not the Traffic Attribute MCR (Minimum Cell Rate) of the ABR service class

- **Available Cell Rate - ACR**
  - Reflects the amount of equivalent bandwidth that is available on the link or node

Significant Changes

- **Switches will not advertise new resource information every time a call is established or removed**
  - Too many advertisements would flood the network

- **Switches will only produce new advertisements when there has been a “significant” change**
  - In general, a specified percentage change
  - Can be modified (changed)

- **General refresh limit of advertisements**
  - 10-15 minutes

Inaccuracy of Information

- **Aggregation influences accuracy of information**

- **QoS support is handled by the **Connection Admission Control****
  - Local to each switch
  - Checks whether requested QoS can be supported or not

- **With source routing, the first switch defines the path through the network**
  - Routing protocol has to ensure that call setup will pass CACs of individual switches
  - CAC is a function performed locally in each switch
  - Source route path determined can only be a best guess

PNNI Routing

- **Generic Connection Admission Control (GCAC)**
  - Used by the source switch to select a path through the network
  - Calculates the expected CAC behavior of another node
  - Uses the link state metrics described before

1. Support this QoS locally?
   
   CAC  \[ \rightarrow \]  UNI/NNI

2. Yes/No

3. Is it likely that path will deliver expected QoS?
PNNI Signaling

- Based on a subset of UNI 4.0 signaling
- Differs from UNI 4.0 signaling in that it is symmetric
  - Switch to switch signaling
- Extensions to UNI 4.0 signaling
  - Crankback and alternate routing
  - Designated transit lists (source routing information)
- Supports source routing
  - Switches which initiate calls specify the route for the call

PNNI Routing

- Operation of the GCAC
  - 1) Links not supporting requested CR are eliminated

Requested CR = 30
PNNI Routing

- Operation of the GCAC
  - 3) One path is chosen and source node S1 constructs a Designated Transit List (DTL) > source routing
    - Describes the complete route to the destination

PNNI Routing - Source Routing

- Operation of the GCAC
  - 4) DTL is inserted into signaling request and moved on to next switch
  - 5) After receipt, next switch performs local CAC
    - 5a) if ok -> pass PNNI signaling message to originator of DTL
    - 6a) signaling request will reach destination ATM-DTE -> VC ok

Crankback

- Source node issues signaling request including DTL
- One of the switches in the path may not allow connection because of local CAC
- Connection setup is rolled back to the DTL originator (specifier of the route)
  - Not necessarily the source node (hierarchy)
- Originating node uses GCAC to determine another path
  - Uses now more accurate or more actual network state information
  - Number of retries configurable on a switch basis
Agenda

- PNNI - Overview
- PNNI - Routing
- PNNI - Hierarchy
- Interim Inter Switch Protocol

PNNI Scalability

- Without hierarchy, every ATM switch would have to maintain a complete view of the total topology
  - Must include every physical link and the reachability information for every switch in the network
- Using a flat architecture with a single domain would create scalability problems
  - The topology database at each switch and the amount of flooded information would become unacceptably large
  - The learning process for this takes CPU and memory
  - Waste of bandwidth due to the advertisement of all link and switch information

PNNI Hierarchy

- Relates to the visibility of the network topology as seen by ATM switches
  - Address summarization and topology abstraction
- Switches have
  - Detailed information about local topology
  - Summarized information about other parts of the network
- Hierarchy support is much larger than with well known routing protocols
  - OSPF supports 2 levels of hierarchy
  - BGP adds another one
  - PNNI supports up to 105 levels
    - In practice a maximum of 10 is assumed
- Advantages of the hierarchical organization
  - Reduction in number of flooded packets
  - Reduction of database size
  - Less processing
  - Allows address summarization
- Disadvantages of the hierarchical concept
  - Hiding of information leads to lower quality path selection
- Tradeoff between optimal paths and scalability
PNNI Peer Group

- Group of nodes form a small domain called a Peer Group
- Share a Peer Group Identifier
  - Prefix of the ATM address space
- Exchange reachability information
  - Have an identical view of the group
- Each peer group is represented as a single node in higher level peer groups (Logical Group Node - LGN)
  - A single switch performs this required function
  - So called Peer Group Leader (PGL)
- PGL election based on ATM address or configuration
  - Peers with members of the next higher peer group
  - Propagates routing information to and from the higher layer

PNNI Addressing

- Addressing plays a critical role in PNNI
  - Drives the construction of the logical hierarchy of switches
  - Dictates how topology and resource information is aggregated, and therefore how the entire network scales
- Every routing protocol needs an addressing scheme
- Each switch is configured with a 20 byte address
  - Hierarchical addressing scheme

ATM Address 20 Bytes

- 13 byte address prefix field
- 6 byte node ID field
- 1 byte selector field

The 13 byte prefix is the most relevant in PNNI
  - It has to be interpreted in a strictly hierarchical fashion

Hierarchy based on ATM prefixes

- Flat private ATM network with 23 physical nodes and 18 bi-directional links
**Agenda**

- PNNI - Overview
- PNNI - Routing
- PNNI - Hierarchy
- Interim Inter Switch Protocol

**Interim Inter Switch Protocol**

- Interim trunking protocol to allow switch communication before the deployment of P-NNI
- Sometimes called P-NNI Phase 0
- Pure signaling protocol
  - uses UNI signaling between switches
  - one switch has to be master, the other slave
- Static configuration of reachability information
  - administrator configures ATM prefixes reachable over a specific trunk
- Supports some redundancy
  - allows a primary and a secondary trunk to be defined
Interim Inter Switch Protocol

- Summary
  - P-NNI Phase 0
  - Interim InterSwitch Signaling Protocol
  - UNI 3.1/3.0 signaling
  - static, prefix routes
  - no QoS support