

Appendix 7 - ATM PNNI Routing in Detail

ATM PNNI Routing

ATM Routing in Private Networks, Overview

Agenda

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

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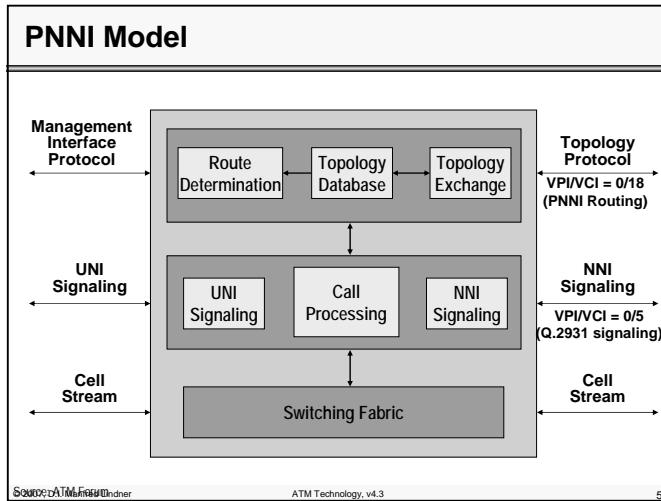
ATM Routing

- **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

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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

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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)

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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

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Agenda

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

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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

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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

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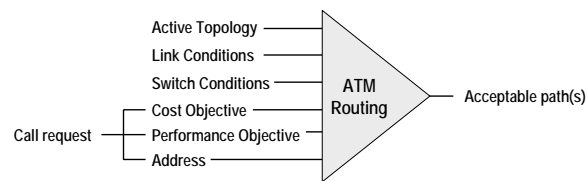
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PNNI Routing

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



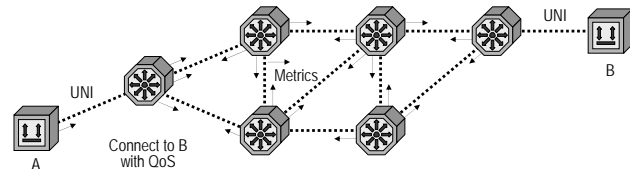
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PNNI Routing

- **PNNI advertises resource availability and supported traffic classes**
- **Advertisements exist per link and may exist per traffic class**



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PNNI Routing

- **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

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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

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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
 - don't mix it up with Traffic Attribute MCR (Minimum Cell Rate) of 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**
- **Significance is defined for each parameter**
 - In general a specified percentage change
 - Can be modified (changed)
- **General refresh limit of advertisements**
 - 10-15 minutes

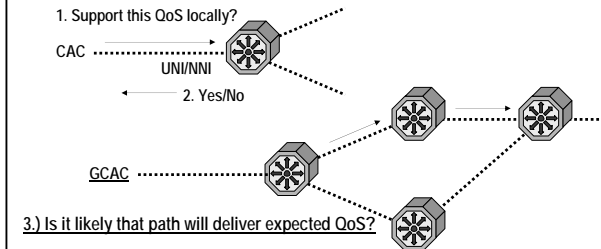
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Inaccuracy of Information

- **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



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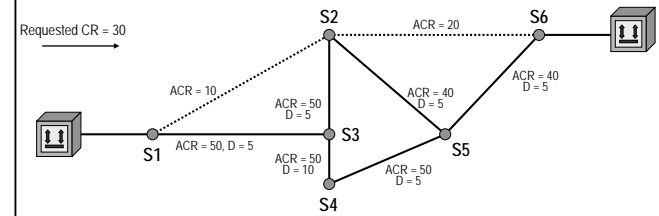
PNNI Signaling

- 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

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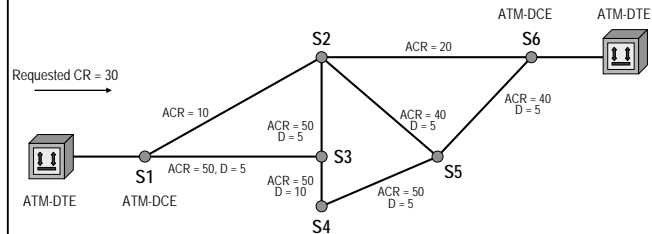
PNNI Routing

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



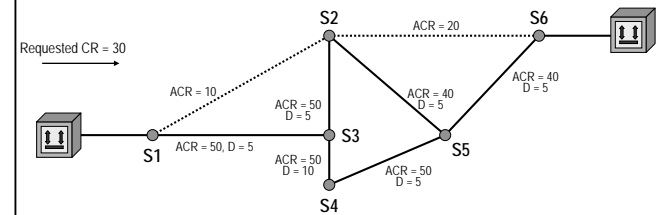
PNNI Routing

- Operation of the GCAC
 - CR ... Cell Rate
 - ACR ... Available Cell Rate
 - D ... Distance like OSPF costs



PNNI Routing

- Operation of the GCAC
 - 2) Next, shortest path(s) to the destination is (are) calculated



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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

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PNNI Routing - Crankbank

- **Operation of the GCAC**
 - 5) After receipt next switch perform local CAC
 - 5b) if nok -> return PNNI signaling message to originator of DTL
 - 6b) S1 will construct alternate source route

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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 perform local CAC
 - 5a) if ok -> pass PNNI signaling message to next switch of DTL
 - 6a) signaling request will reach destination ATM-DTE -> VC ok

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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 used GCAC to determine another path**
 - Uses now more accurate or more actual network state information
 - Number of retries configurable on a switch basis

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- 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

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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

PNNI Hierarchy

- **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**

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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

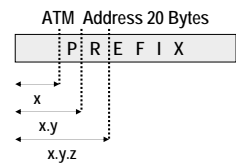
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PNNI Addressing

- **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



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PNNI Addressing

- **Uses recursive hierarchical aggregation**
 - The routing hierarchy is then defined recursively
- **Neighbor switches compare addresses**
 - Form peer groups based on their longest prefix in common
 - Each group behaves as a logical node at the next level
- **ATM address consists of**
 - 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

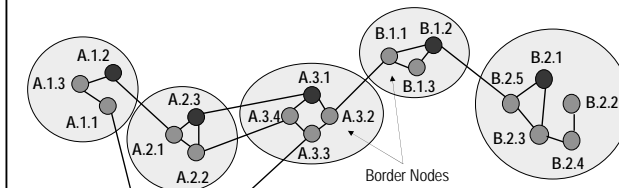
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Hierarchy based on ATM prefixes

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

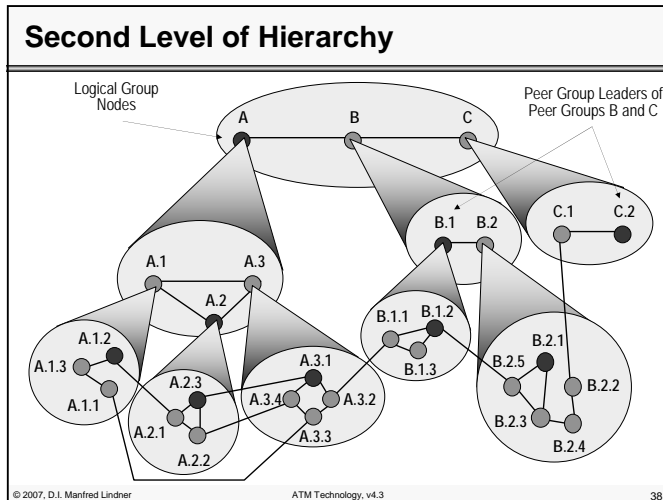
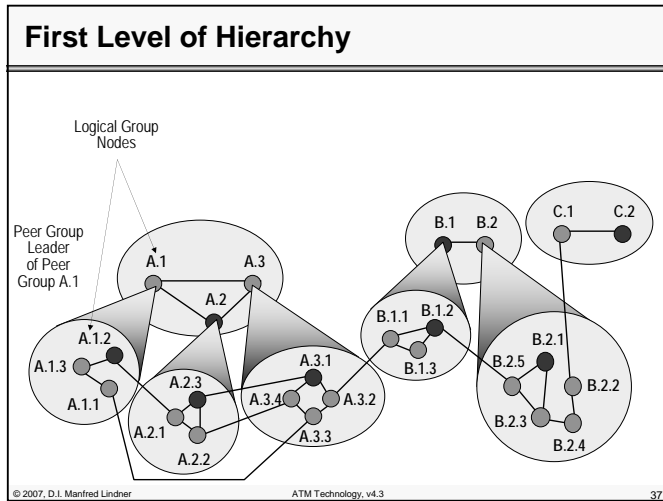


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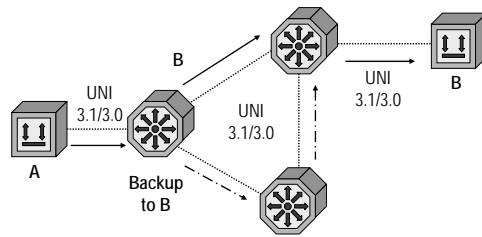
Interim Inter Switch Protocol

- 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

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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