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**

Appendix 7 - ATM PNNI Routing in Detail

ATM Routing

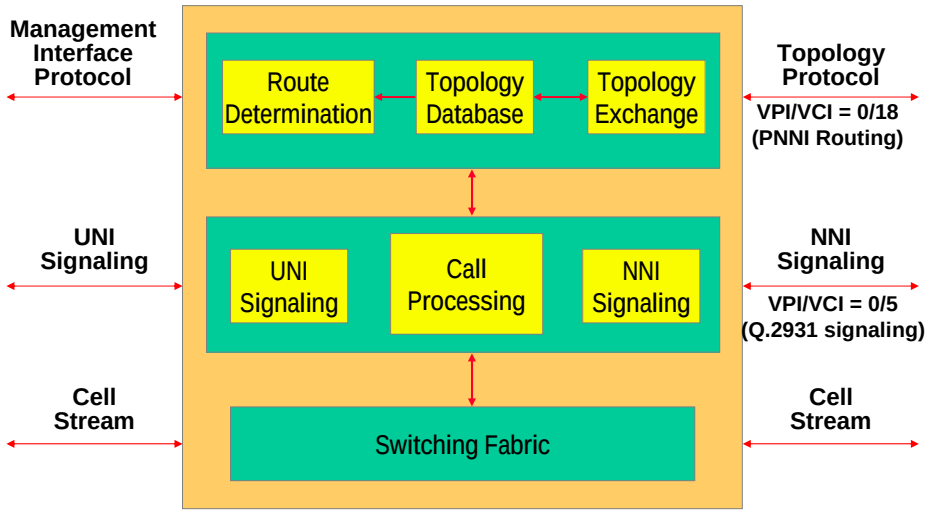
- **ATM networks will consist of more than one switch**
- **Inter-switch protocol needed**
  - Topology discovery
    - Distribution of reachability information
  - Hierarchical routing and addressing
  - QoS support
- **Private Network to Network Interface or Private Node to Node Interface (PNNI)**
  - 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

Appendix 7 - ATM PNNI Routing in Detail

PNNI Model



Source: ATM Forum

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

Appendix 7 - ATM PNNI Routing in Detail

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)

Appendix 7 - ATM PNNI Routing in Detail

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

Appendix 7 - ATM PNNI Routing in Detail

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

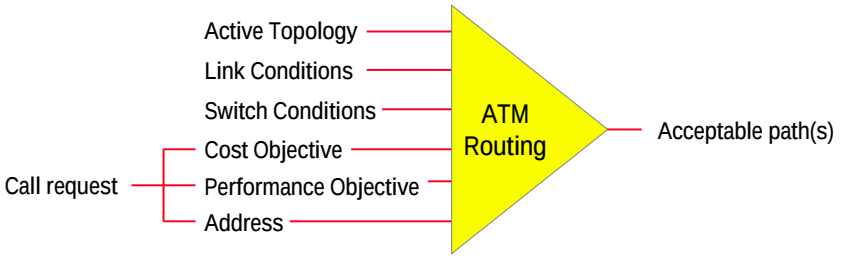
PNNI Routing

- **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

Appendix 7 - ATM PNNI Routing in Detail

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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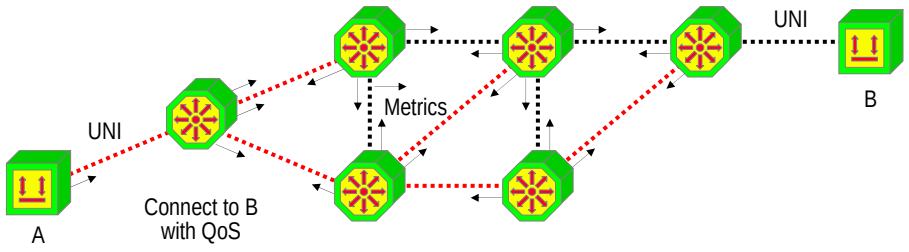
PNNI Routing

- **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

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

Appendix 7 - ATM PNNI Routing in Detail

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

Appendix 7 - ATM PNNI Routing in Detail

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

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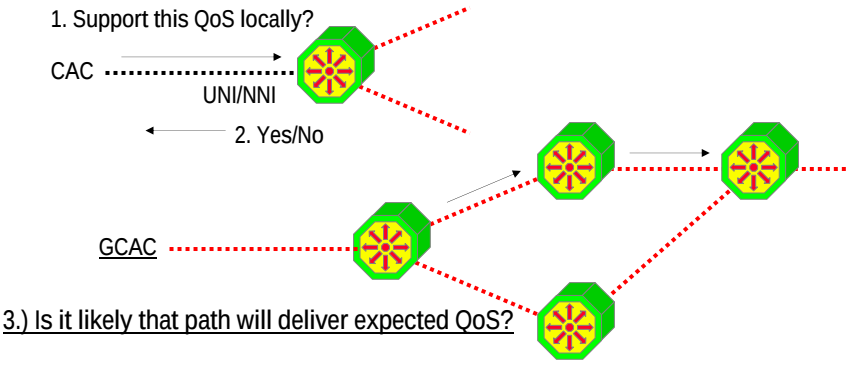
PNNI Routing

- **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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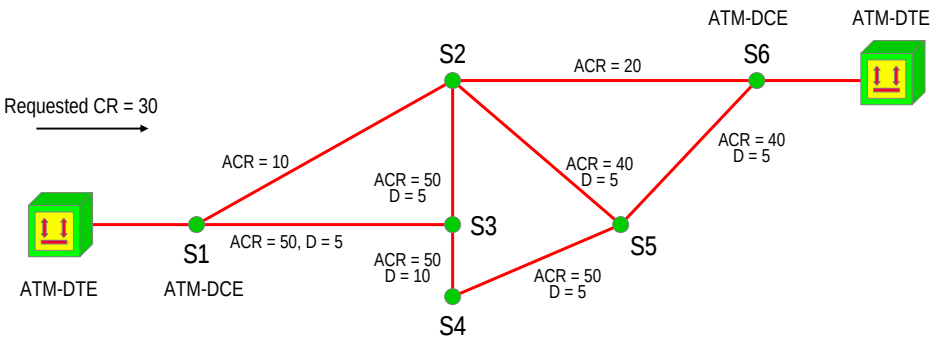
PNNI Routing

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



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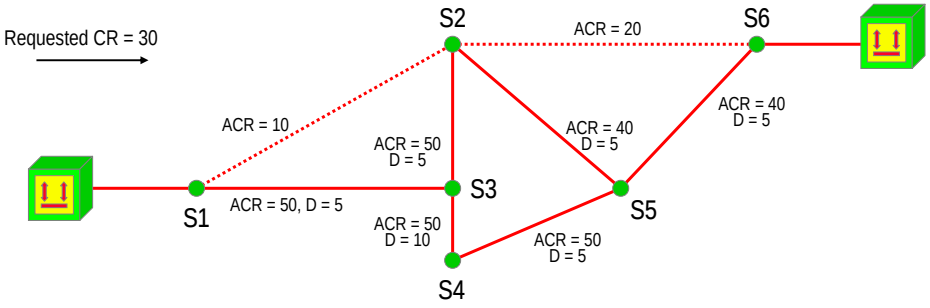
Appendix 7 - ATM PNNI Routing in Detail

PNNI Routing

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



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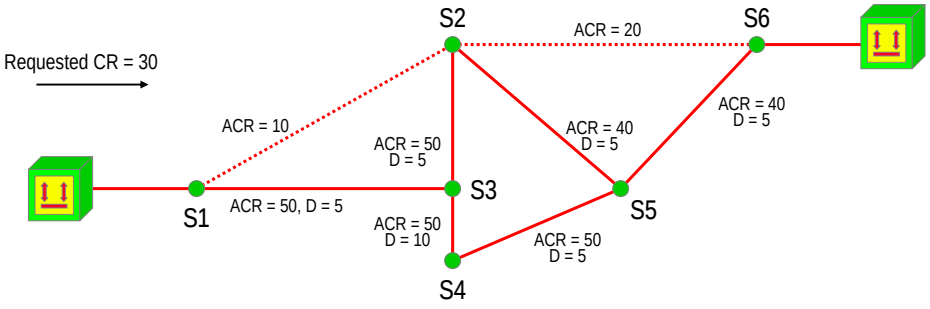
PNNI Routing

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



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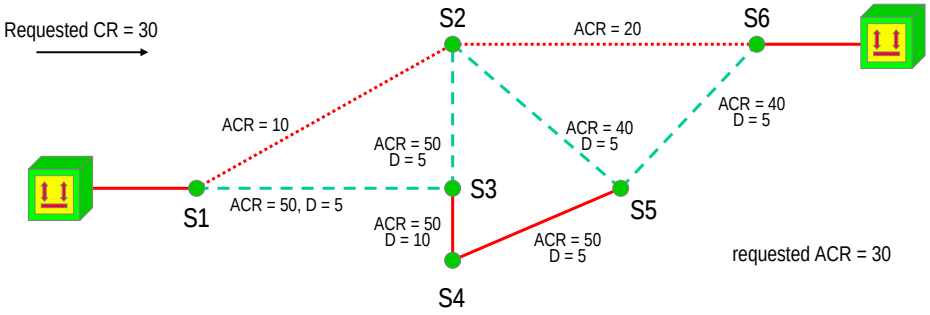
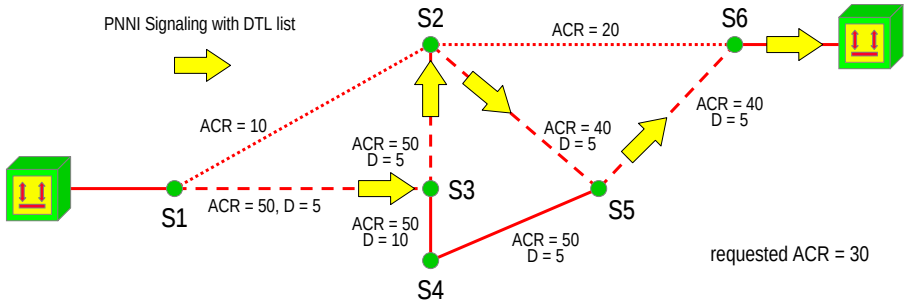
PNNI Routing

- **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



PNNI Routing - Source Routing

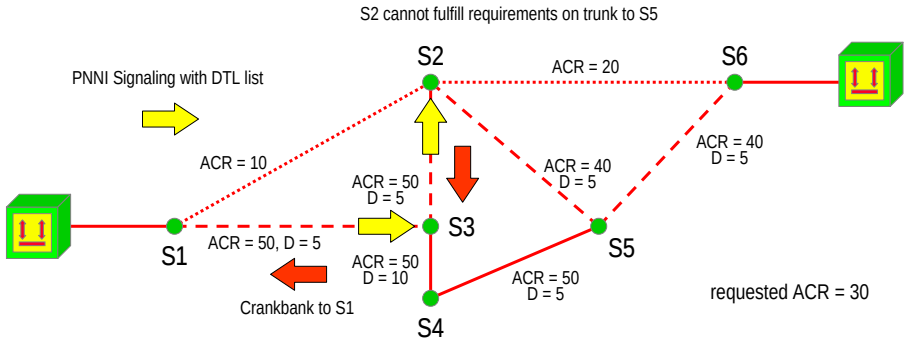
- **Operation of the GCAC**
  - 4) DTL is inserted into signaling request and moved on to next switch
  - 5) After receipt next switch perform local CAC
    - 5a) if ok -> pass PNNI signaling message on to next switch of DTL
  - 6a) signaling request will reach destination ATM-DTE -> VC ok



Appendix 7 - ATM PNNI Routing in Detail

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



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

Appendix 7 - ATM PNNI Routing in Detail

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

Appendix 7 - ATM PNNI Routing in Detail

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**

Appendix 7 - ATM PNNI Routing in Detail

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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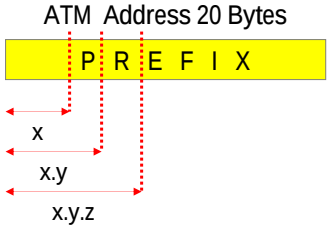
PNNI Addressing

- **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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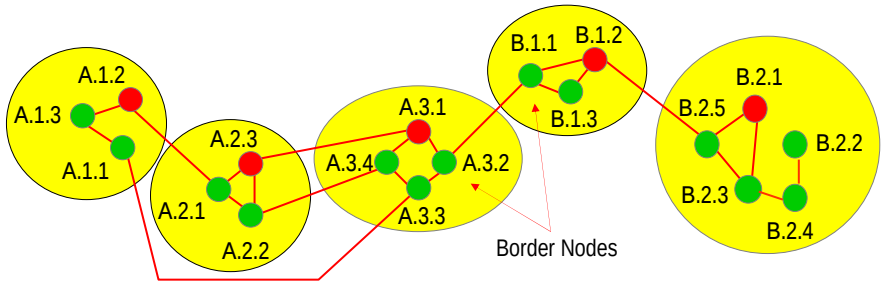
Hierarchy based on ATM prefixes

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



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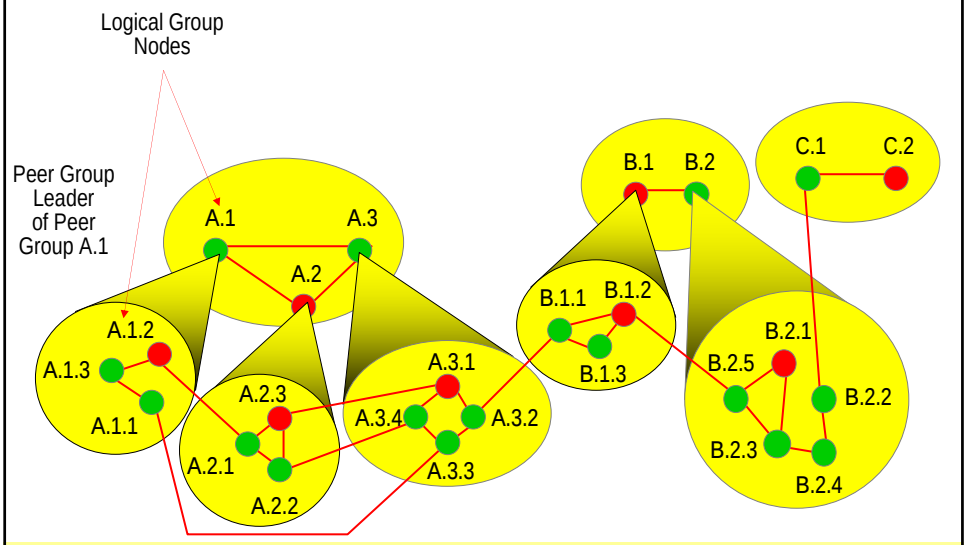
First Level of Hierarchy



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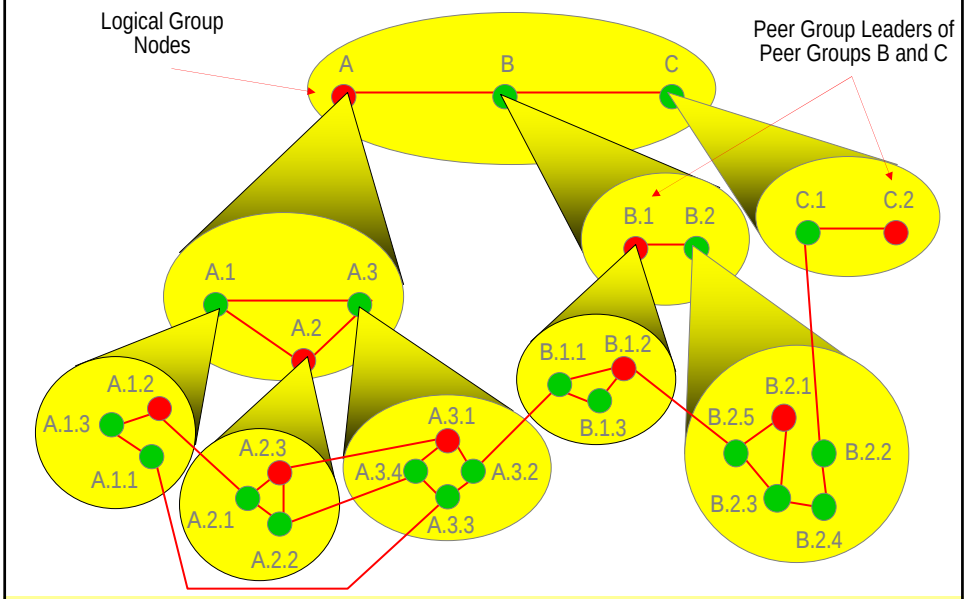
Second Level of Hierarchy



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Appendix 7 - ATM PNNI Routing in Detail

Agenda

- PNNI - Overview
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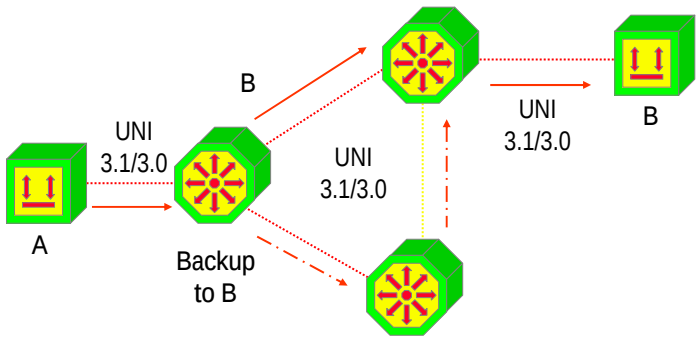
- Interim Inter Switch Protocol

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

Appendix 7 - ATM PNNI Routing in Detail

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

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