PNNI: How it Works
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Topics

- Introduction
- Background Concepts
- Key Phase 1 Requirements
- PNNI Routing
- PNNI Signalling
- Configuring the PNNI Hierarchy
- Future Capabilities
- Summary
What Is a “PNNI”? 

- PNNI: Private “Network-Network” or “Network-Node” Interface 
- UNI: User Network Interface
PNNI and Other ATM Interfaces

- **UNI** User Network Interface
- **NNI** Network Node Interface
- **B-ICI** BISDN Inter-Carrier Interface
- **DXI** Data eXchange Interface
ATM Layer Specification

NNI Cell Format

**UNI and NNI cell header difference:**

- **NNI:** 12-bit VPI field, no GFC
- **UNI:** 8-bit VPI field, 4-bit GFC

**Legend**

- **CLP** - Cell Loss Priority
- **GFC** - Generic Flow Control
- **VPI** - Virtual Path Identifier

**Cell structure:**

```
[header] [payload] [checksum]
```

- **Payload Type Identifier**
- **Virtual Channel Identifier**
- **Virtual Path Identifier**
- **Payload (48 bytes)**
- **Header Error Check**
- **CLP**

Diagram shows the breakdown of the cell header and payload areas.
Simple PNNI Solution: Interim Inter-switch Signalling Protocol (IISP)

**Purpose:** Enables Switched Virtual Circuit (SVC) interoperability in **small, static** environments.

- Uses UNI 3.0/3.1 Signalling between switches
- Requires manual configuration of static topology and resource tables
- Specification released: 3/95
**Advanced Solution: PNNI 1.0**

**Purpose:** Enables extremely scalable, full function, dynamic, multi-vendor ATM networks.
- Designed to support a multi-vendor, global ATM internet.
- Two key protocols:
  - **PNNI Routing:** Hierarchical, state-of-the-art routing protocol
  - **PNNI Signalling:** Based on Q.2931, extended as necessary.
- Specification released: 3/96
Concept of “Topology State Routing”

Each node periodically:

1. Exchanges “Hello” packets with directly neighboring nodes.
2. Constructs “PNNI Topology State Elements” (PTSEs), describing the node and listing links to direct neighbors, as shown above.
3. Floods PTSEs to all other nodes.

Each node uses own view of global topology to compute routes.

_A hierarchical topology state algorithm is the key to PNNI Routing._
Concept of “Source Routes”

- Ingress nodes choose a complete path to the destination
- Ingress node then adds full path to the message itself
- Transit nodes simply follow the given path

PNNI Signalling uses a hierarchical version of this concept.
Key Phase 1 Requirements

- Support **UNI 3.1 capabilities**
  - Point-to-point and point-to-multipoint connections
  - QoS classes
- Support **some UNI 4.0 (TM and Signalling) capabilities**
  - ABR
  - Individual QoS parameters
- Support **massive scalability**
- Support intra- and inter-domain functionality in a **single, integrated protocol**.
- **Leverage existing work**
  - PNNI Signalling: Use Q.2931 as base
  - PNNI Routing: Borrow / extend concepts from OSPF, IS-IS, IDR
PNNI Routing

Key Concepts

- **Addressing**
  - ATM End System Address (AESA) format
  - ATM Address Prefixes
  - Reachability Information

- **Hierarchical Aggregation of Information**
  - PNNI Routing Hierarchy
  - Aggregating Information “Up” the Hierarchy
  - Passing Summarized Information Back Down
  - Result: How a Switch Views the Global Topology

- **Enabling QOS-sensitive routing**
  - Advertising Topology State Parameters
  - Call Admission Control (CAC)
Address Format Used in PNNI

- ATM End System Addresses (AESAs)
  - Based on ISO NSAP
  - Come in multiple varieties, most notably
    - DCC (Data Country Code)
    - ICD (International Code Designator)
    - E.164 (E.164 address contained in AESA)
  - Other AESA formats may be supported

- No direct support of native E.164 numbers
  - May translate to E.164 AESA in PNNI network
AESA Format

20 octets

AFI | IDI | HO-DSP | ESI | SEL

7 octets

Domain Specific Part - Structured by the authority identified by IDI

Initial Domain Identifier - Identifies the ‘authority’ responsible for allocating structure of DSP

Authority and Format Identifier - Identifies what scheme is to follow

HO-DSP = Higher Order DSP
ESI = End System Identifier (MAC address)
SEL = Selector (for end system use only)
ATM Address Prefixes

- Address prefix of length $p$ is first $p$ bits of address
- Prefixes with length $0 \leq p \leq 152$ used to summarize portions of addressing domain
  - Represents reachability to all addresses that begin with stated prefix
  - Selector (20th) octet has only local significance to end system, ignored by PNNI routing
- Strictly hierarchical (left-to-right) interpretation
- Boundaries can be put at any bit position $p$
  - Allows variable levels of hierarchy
Reachability Information

- In addition to topology information, each node advertises list of reachable address prefixes

47.0091.8000.1122.0001.0F01.0001.00000C.5BD9A5.00  
C5.0079.0000.0000.0000.0000.0000.0000.00A03E.000001.00  (LECS)

47.0091.8000.1122.0001.0F01.0001.001011.BAD524.00

47.0091.8000.1122.0001.0F01.0001.00603E.7B190A.00

47.0091.8000.1122.0001.0F01.0001.001011.BAE247.00

matches summary address

Advertised reachable address prefixes:
47.0091.8000.1122.0001.0F01.0001  
C5.0079.0000.0000.0000.0000.0000.0000.00A03E.000001

- PNNI routes to nodes advertising the longest matching prefix for the destination address
Each switch is (manually) initialized with a full 20-byte address.

Routing hierarchy is then defined recursively:
- Neighboring nodes form *Peer Groups* based on their longest prefix in common.
- Each peer group then behaves as a *Logical Group Node (LGN)*, to form (next level) peer group, etc.
Aggregation of Topology Information

- Within each peer group, nodes (or LGNs) exchange PNNI Topology State Packets (PTSPs)
- A Peer Group Leader (PGL) is elected to represent its peer group as a single LGN at next level
- SVCs are set up as routing control channels between LGNs at the same level
Problem:
With PTSPs sent among peer group members alone, a switch would not know how to route to remote peer groups.

Solution:
Peer group leaders feed higher-level topology down into peer group.
Single Node’s Topology View

Global topology as seen by node A.1.1
Advertising QOS-related Topology State Parameters

Resource information (e.g. available bandwidth) also needs to be advertised in PTSPs.

- **Purpose:**
  - Allows better paths to be chosen
  - Makes call admission more efficient
QOS-Related Information: How Much / How Often to Advertise?

No QOS-related state exposed
No advertisements sent

Pro:
• simple
• no overhead

Con:
• high call blocking rate
• “blind” retries waste bandwidth
• low network utilization

All QOS-related state exposed
Frequent advertisements sent

Pro:
• near zero call blocking
• highest network utilization
• optimal routes possible

Con:
• most complex
• high overhead
Topology State Parameters Advertised in PNNI 1.0

Parameters advertised on per service category basis (may be different for CBR, rt-VBR, nrt-VBR, ABR, UBR)

- Administrative Weight (AW)
- Maximum Cell Transfer Delay (maxCTD)
- Peak-to-Peak Cell Delay Variation (CDV)
- Cell Loss Ratio for CLP=0 traffic (CLR₀)
- Cell Loss Ratio for CLP=0+1 traffic (CLR₀+₁)
- Available Cell Rate (AvCR)

Optional GCAC parameters:

- Cell Rate Margin (CRM)
- Variance Factor (VF)
Call Admission Control

- **Generic Call Admission Control (GCAC)**
  - Run by a switch choosing a source route
  - Determines if a path can (probably) support the call
- **Actual Call Admission Control (ACAC)**
  - Run by each switch in the chosen path
  - Determines whether or not the switch can support the call
PNNI Signalling
Key Concepts

- Complete Source Routing across each level of hierarchy
- Use of Designated Transit Lists
- “Crankback” and Alternate Path routing
Complete Source Routing Across Each Peer Group

- **Question:** How is a call setup progressed across the network?

**Answer:**
At the ingress entry switch of each peer group, a complete source route across the peer group is specified. Switch specifying the source route may or may not be the peer group leader.
Designated Transit Lists (DTLs)

- New Information Element (IE) appended to SETUP and ADD PARTY messages (to carry Source Route)

Actually implemented as a “push-down / pop-off stack”
Crankback and Alternate Path Routing

- **Question**: What happens when a call fails along a specified source route (e.g. due to insufficient bandwidth)?

- **Answer**: Call is “cranked back” to originator of the top Source Route DTL
  - Originator then generates a new Source Route, or
  - Originator cranks back call to generator of higher-level source route.

![Diagram showing Crankback and Alternate Path Routing]
Configuring the PNNI Hierarchy

- Hierarchical address assignment is the key
  - Minimize configuration
    - Use first level bits of switch address to generate peer group ID
    - Use prefix of switch address to generate default summary address prefix
    - Minimize number of routes
- Planning ahead is important to avoid renumbering
  - Can run with fewer levels in the beginning
  - Can add levels of hierarchy without renumbering
- PGL/LGN configuration also required
- Lots of other things may be configured
Hierarchical Address Assignment Example

Corporate Address Prefix
47.0091.8000.1122

London Main
47.0091.8000.1122.0001

London South
47.0091.8000.1122.0002

Berlin
47.0091.8000.1122.0101

Building A
47.0091.8000.1122.0001.01

Building O
47.0091.8000.1122.0001.0F

Building O, 1st Floor
47.0091.8000.1122.0001.0F.01

Building O, 2nd Floor
47.0091.8000.1122.0001.0F.02

level 56

level 72

level 72

level 80

level 88

level 88
PNNI 1.0 Addenda - Work In Progress

- Leaf Initiated Join
- Multipoint-to-Point Connections
- Closed User Groups
- Network Call Correlation Identifier
- Rerouting
- Path and Connection Trace
- PNNI Routing Authentication
- Transported Address Stack
- Vendor-Specific Signalling Information
- Soft PVC Interworking with Frame Relay
- Mobility Extension
  - Mobile ATM network linked to fixed ATM infrastructure e.g., an airplane
PNNI Augmented Routing (PAR)

- Allows distribution of information about non-ATM services via PNNI
- Examples
  - Automatic establishment of router overlay, e.g.
    - Discover routers running OSPF in same subnet
    - Establish full mesh of SVCs (in small networks)
  - Server detection (Classical IP, NHRP, MARS, DNS)
- Edge devices not running PNNI can use *Proxy PAR* protocol to interact with PAR capable switches.
Summary

- **Interim Inter-switch Signalling Protocol (IISP)**
  - Minimal functionality; Small, static environments only
- **PNNI 1.0**
  - Full functionality; Any-size, static / dynamic environments

- **Key PNNI Routing Concepts**
  - Addressing
  - Routing Hierarchy
  - Topology advertisement and aggregation
  - Resource advertisement and QOS-sensitive routing

- **Key PNNI Signalling Concepts**
  - Full source routing across peer groups (via DTLs)
  - Crankback and Alternate Path routing
This concludes the presentation provided by The ATM Forum