# A Benchmarking Methodology for Network Processors

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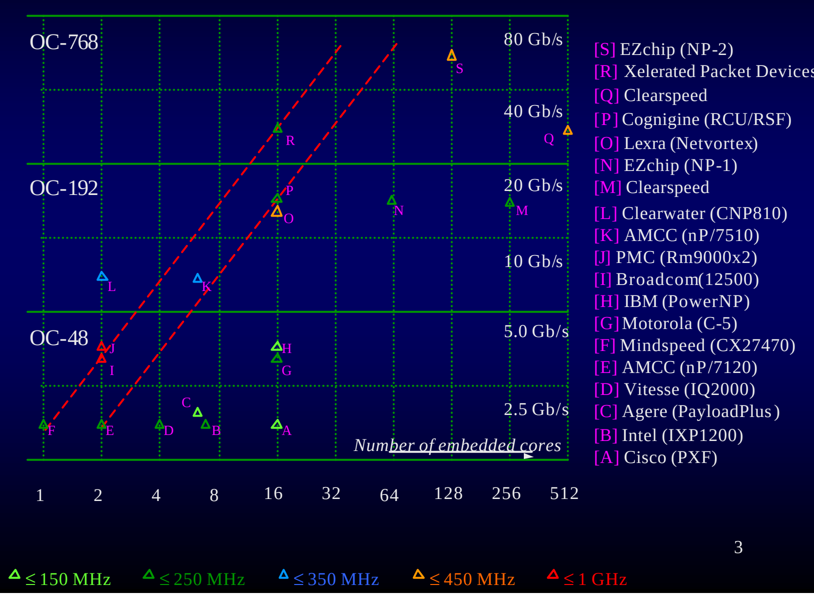
January 2002



## Outline

1) Motivation
2) Related Work
3) Principles of the Methodology
4) Choosing Benchmarks
5) Benchmark Comparability, Granularity, Specification
6) Results
7) Summary and Future Work

# NPU Architectures: Numerous and Diverse






# Architectural Diversity

- Diversity of NPU architectures requires a systematic approach to benchmarking

→ A benchmarking *methodology*

## Benchmarking Methodology Goals

1. Provide a means to choose benchmarks that are representative of the application domain
2. Provide a means to specify benchmarks whose results are indicative of real-world performance
3. Aims to provide benchmark results that are comparable across network processors



## Existing Approaches

- Current benchmarking approaches lack complete methodologies [NetBench, CommBench, NPForum, EEMBC]

→ Do not address the heterogeneity of architectures
  - Example: do not specify network interface parameters

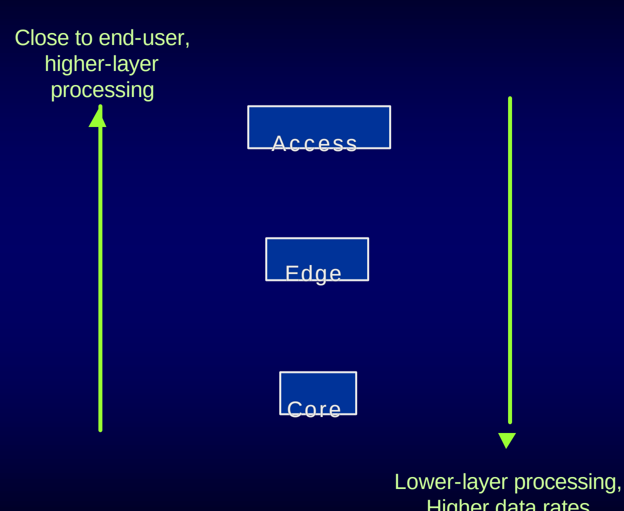
→ Mostly have ad-hoc methods of benchmark selection
  - Example: EEMBC's three simple benchmarks

# Principles of our Methodology

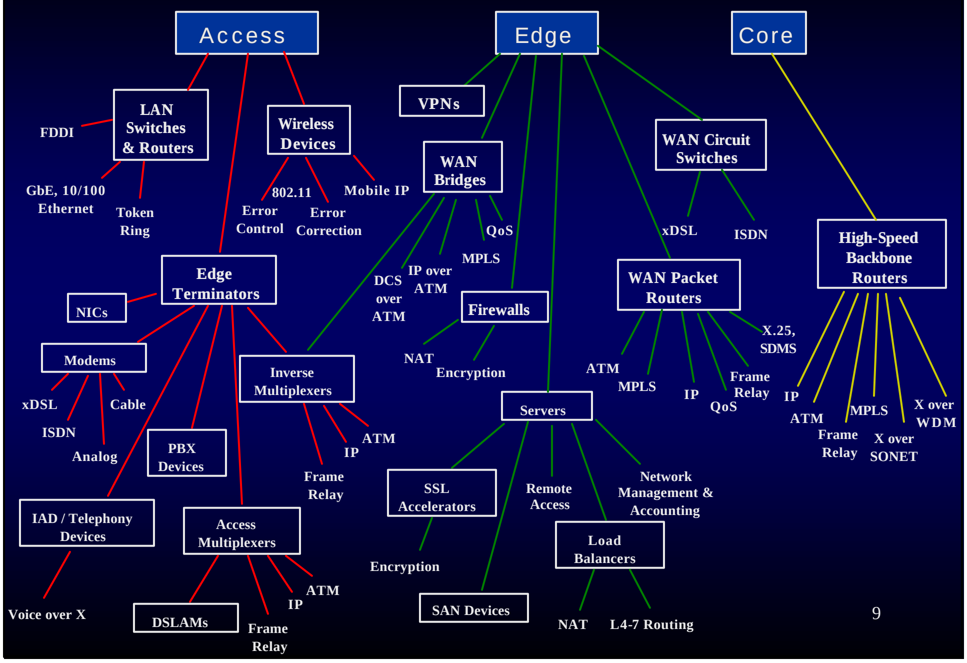
1. Benchmarks are chosen by application-domain analysis
2. Benchmarks expose performance bottlenecks
3. Benchmarks capture functionality and environment
4. Benchmarks are communicated with a precise specification



# Choosing Benchmarks: Classification



## Choosing Benchmarks: A Network Equipment-Centric View






# Exposing Performance Bottlenecks

Benchmark *kernels*

Advantages:

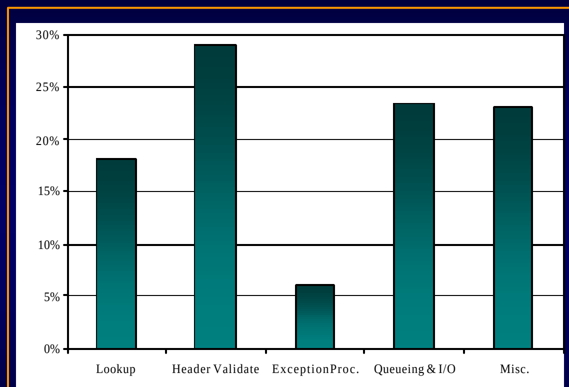
→ Simple to implement

→ Simple to analyze

Disadvantages

→ May not expose performance bottlenecks

## Exposing Performance Bottlenecks




Profile of IPv4 packet forwarding tasks
(IXP1200)



## Exposing Performance Bottlenecks

*Application-level* Benchmarks

Advantages:

→ Indicative of real-world performance

Disadvantages

→ Higher implementation effort

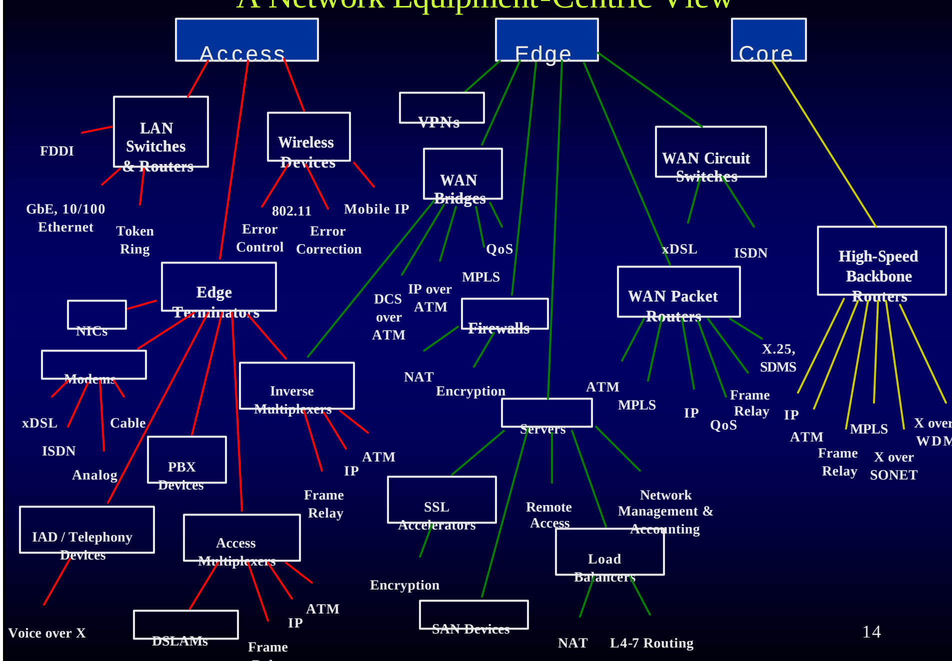
→ Requires profiling for detailed insight into performance

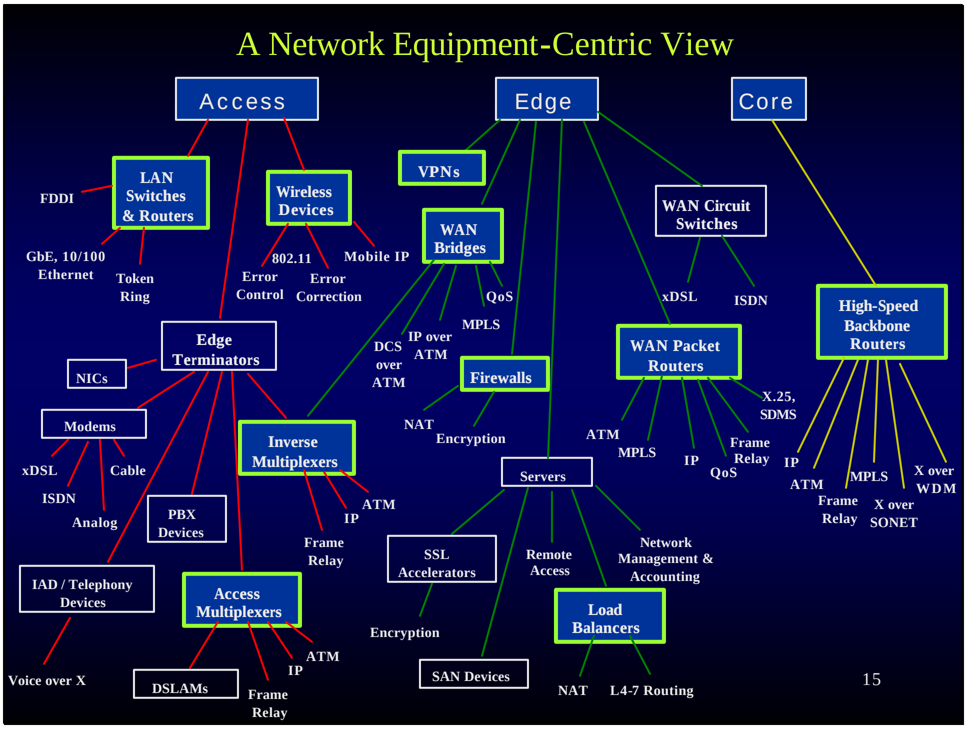
# Capturing Functionality and Environment

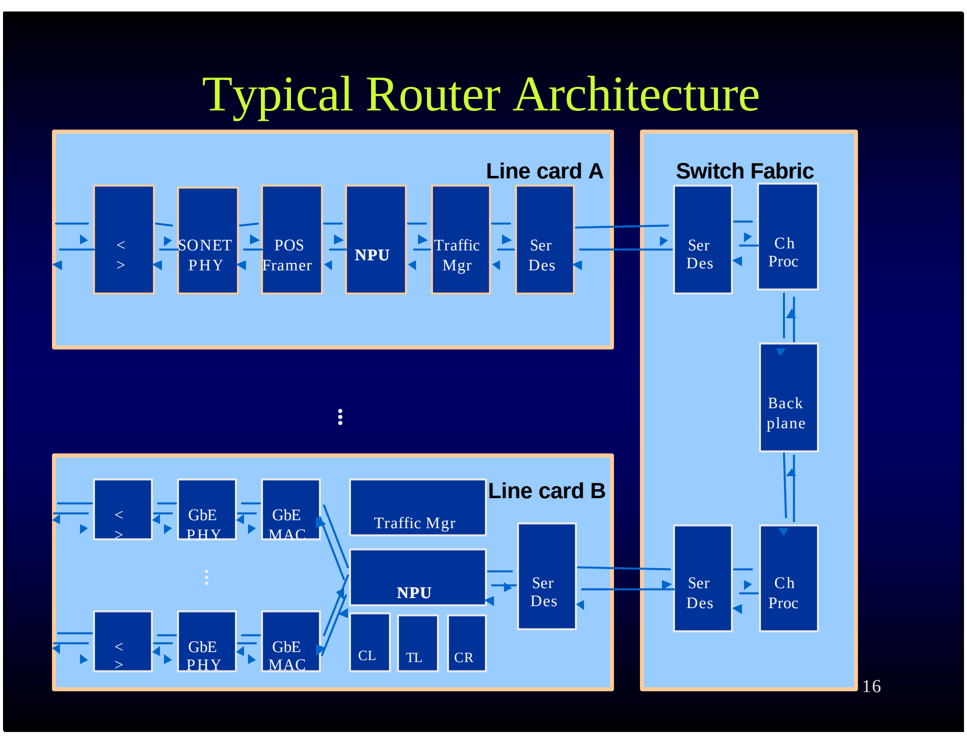
- Benchmark implementations must be comparable across NPUs
- Our solution also considers the system-level environment
- How do we define our system-level environment?



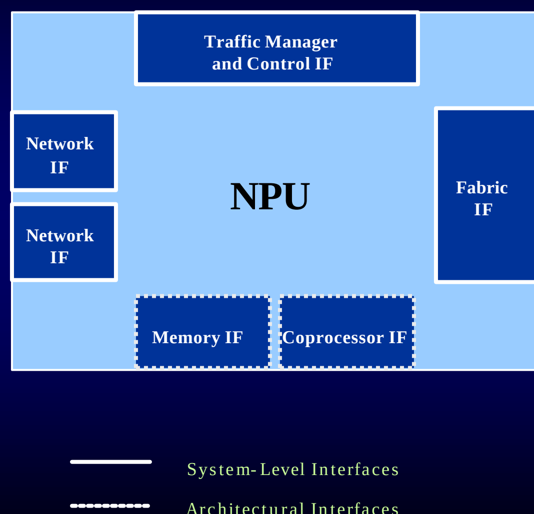
# A Network Equipment-Centric View




A Network Equipment-Centric View
Access
Edge
Core
LAN Switches & Routers
FDDI
GbE, 10/100 Ethernet
Token Ring
Wireless Devices
802.11
Error Control
Error Correction
Mobile IP
VPNs
WAN Bridges
QoS
MPLS
IP over ATM
DCS over ATM
WAN Circuit Switches
xDSL
ISDN
High-Speed Backbone Routers
Edge Terminators
NICs
Modems
xDSL
Cable
ISDN
Analog
PBX Devices
IAD / Telephony Devices
Voice over X
Inverse Multiplexers
ATM
IP
Frame Relay
Firewalls
NAT
Encryption
WAN Packet Routers
X.25, SDMS
ATM
MPLS
IP
QoS
Frame Relay
IP
ATM
MPLS
Frame Relay
X over SONET
X over WDM
Servers
SSL Accelerators
Encryption
Remote Access
Network Management & Accounting
Load Balancers
NAT
L4-7 Routing
SAN Devices
Access Multiplexers
ATM
IP
Frame Relay
DSLAMs
15


Typical Router Architecture
Line card A
< >
SONET PHY
POS Framer
NPU
Traffic Mgr
Ser Des
Switch Fabric
Ser Des
Ch Proc
Back plane
Ser Des
Ch Proc
Line card B
< >
GbE PHY
GbE MAC
< >
GbE PHY
GbE MAC
Traffic Mgr
NPU
CL
TL
CR
Ser Des
16

# NPU Interfaces






# Network Interface Parameters

- Environment model must account for differences in network interfaces: *number*, *type*, and *speed*
  - → Low-end deployment scenarios: 16 x Fast Ethernet
  - → High-end deployment scenarios: 4 x OC-48 POS

| Number of Ports | Type of Ports | Max Bandwidth (Aggregate), in Mb/s |
|---|---|---|
| 16 | Fast Ethernet | 100 (1,600) |
| 24 | Fast Ethernet | 100 (2,400) |
| 48 | Fast Ethernet | 100 (4,800) |
| 8 | Gigabit Ethernet | 1,000 (8,000) |
| 16 | Gigabit Ethernet | 1,000 (16,000) |
| 8 | OC-3 POS | 155 (1,242) |
| 4 | OC-12 POS | 622 (2,488) |
| 4 | OC-12 ATM | 622 (2,488) |
| 1 | OC-48 POS | 2,488 (2,488) |
| 4 | OC-48 POS | 2,488 (9,953) |
| 1 | OC-192 | 9,953 (9,953) |

# Precise Specification

*Functional Specification*
- Requirements and Constraints
- Behavior
- Executable Description

*Environment Specification*
- Network Interface
- Control Interface
- Traffic Mix and Load Distribution
- Executable Description

*Measurement Specification*
- Functional Correctness
- Quality of Results

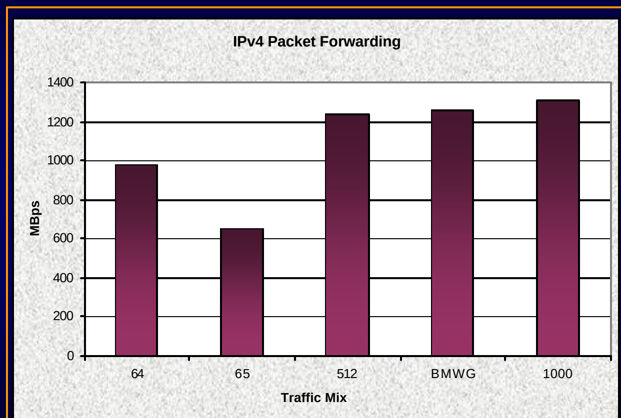
MIT's Click Router Language
- Effective environment for network application development
- Parallel
- Extensible
- Modular



# Applying our Methodology

1. Developed three benchmark specifications
   - IPv4 Packet Forwarding
   - Network Address Port Translation
   - Multiprotocol Label Switching
2. Developed Click implementations
3. Implemented benchmarks on the IXP1200

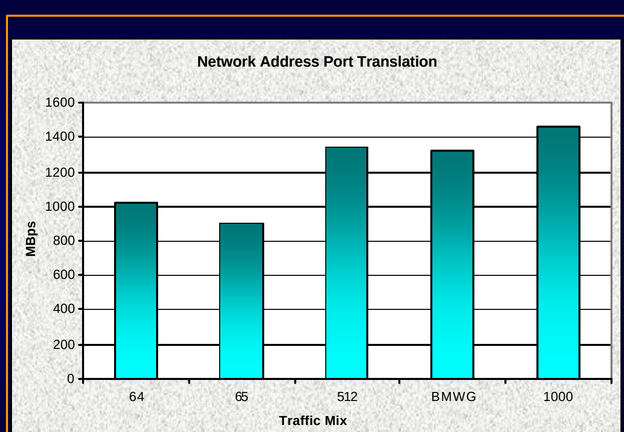
# IXP1200 IPv4 Results




Performance reduction: FIFO buffer alignment

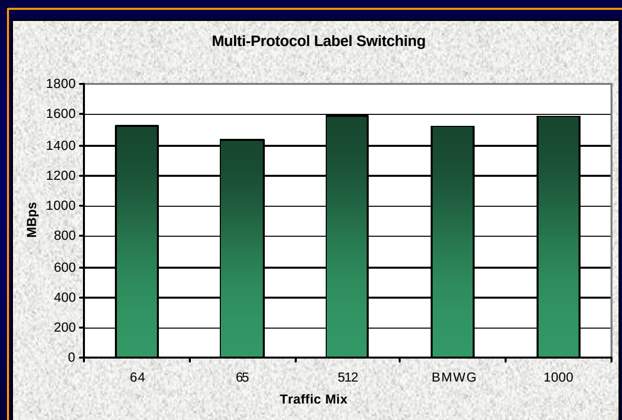


# IXP1200 NAPT Results




NAPT: Simpler processing, efficient use of hash unit

# IXP1200 MPLS Results




MPLS: Simplest processing, highest throughput



# Conclusions

- Chose application-level benchmarks
  → Demonstrated performance bottlenecks
- Captured functionality *and* environment
- Created precise specifications and implementations with the help of Click
- Have yet to demonstrate comparability and indicativeness

# Future Work

- Develop specifications for the remainder of our benchmark suite.
- Create further benchmark implementations for the IXP1200
- Complete preliminary C-Port C-5 benchmark implementations to demonstrate comparability
- Prove indicativeness by correlating our results to line-card-based systems