Open Programmable Architecture for Java-enabled Network Devices

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Programmable Network Devices

Openly Programmable devices enable

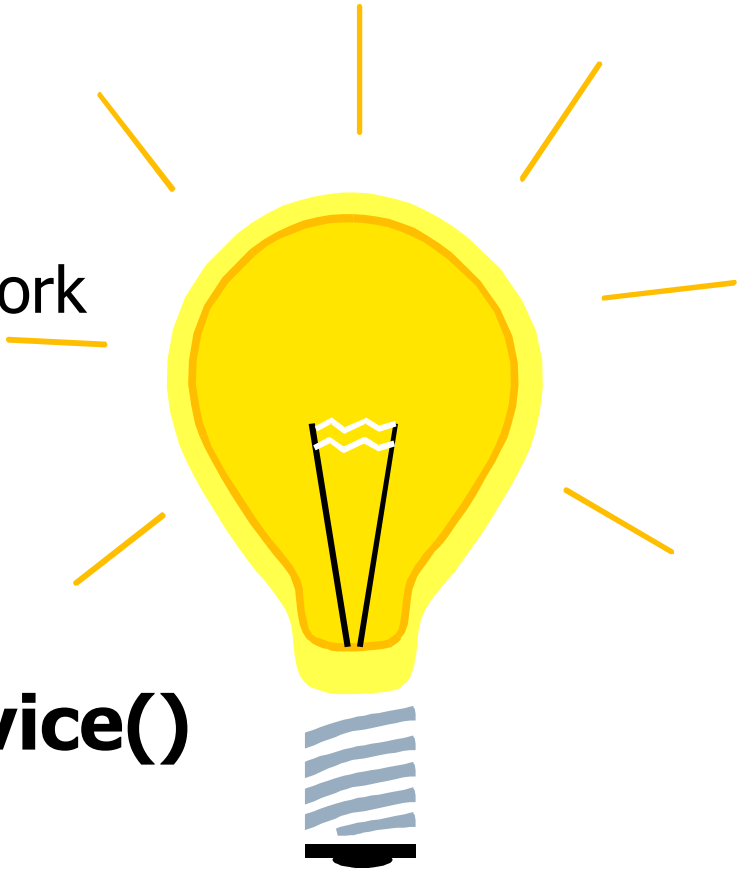
new types of intelligence on the network

Agenda

- Local Computation
- New types of applications
- Architecture
- API's
- Summary

Changing the Rules of the Game

- **Move** Turing Machine **onto device**
  - Add local intelligence to network devices

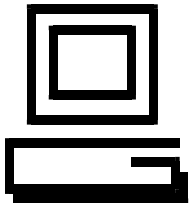


```
while (true) {
   doLocalProcessingOnDevice()
   }
```

Technology Concept

Web Server

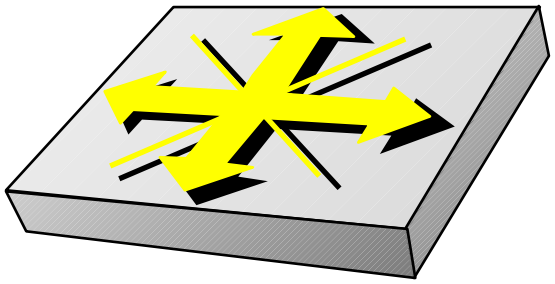
Applet



Web Browser

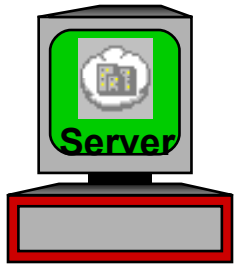
The JVM is in the Browser

Download applications for local processing



non-bundled application

Reversed Applet



The Web Changed Everything

- **Browsers**
  - Introducing JVM to browsers allowed dynamic loading of Java ***Applets*** to end stations
- **Routers**
  - Introducing JVM to routers allows dynamic loading of Java ***Oplets*** to routers

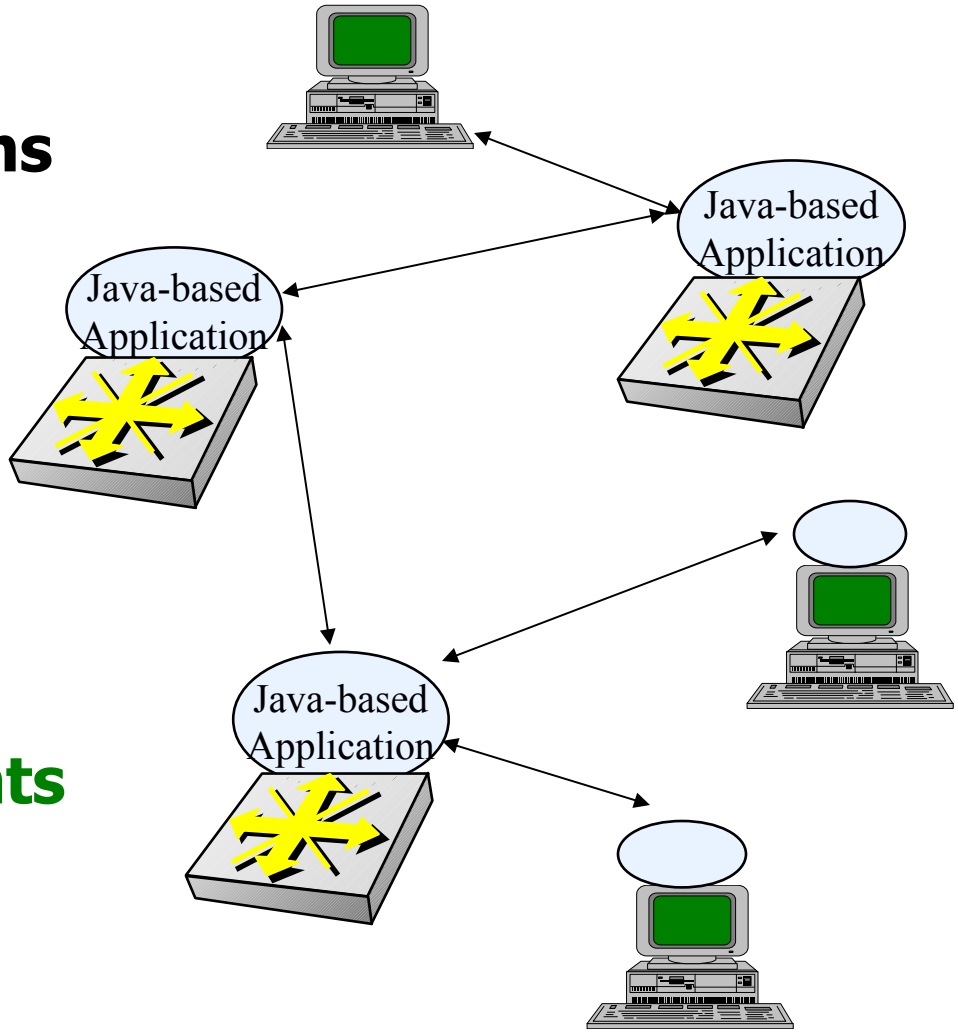
This Capability WILL Change Everything

Accomplishments

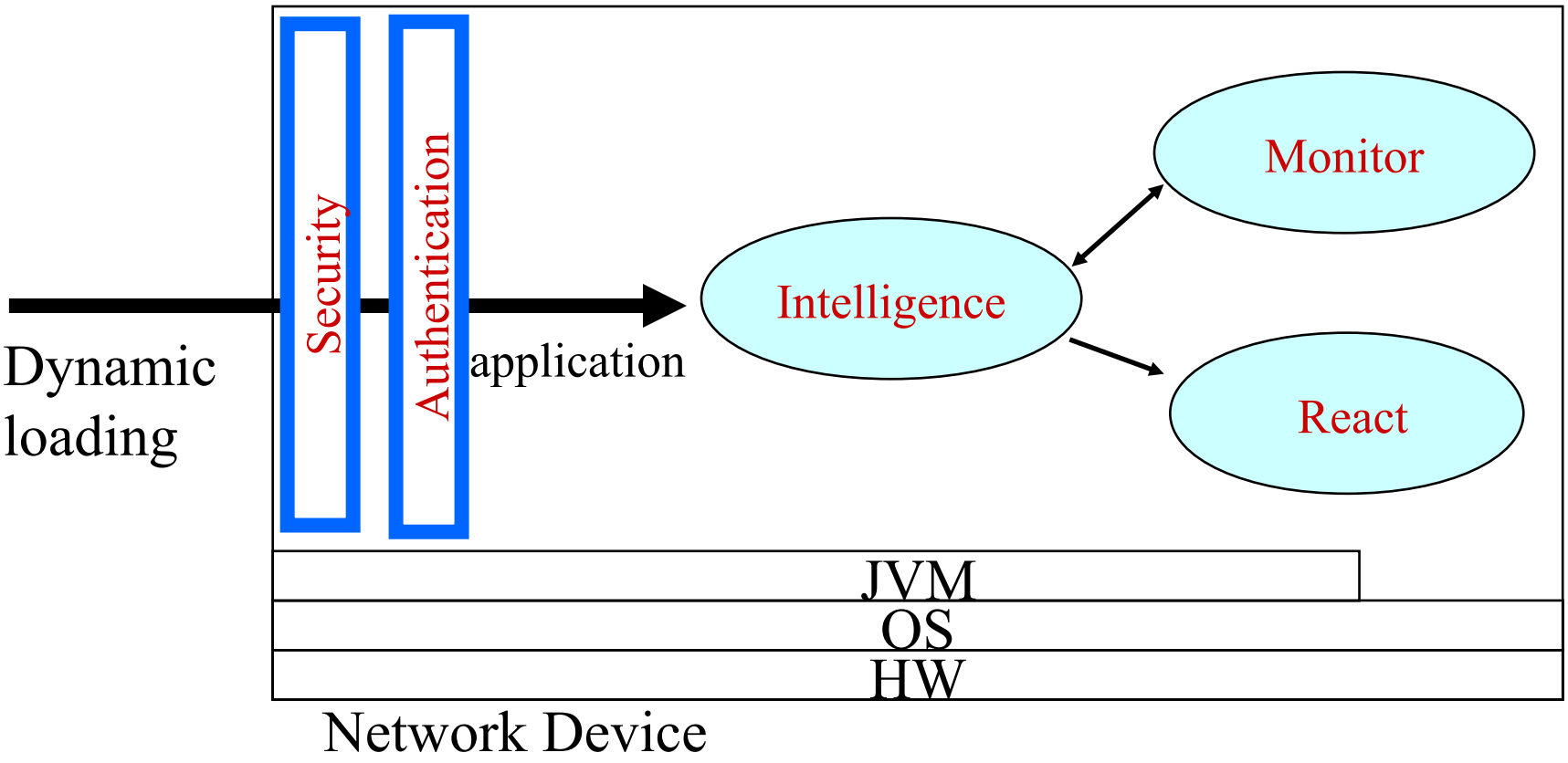
- JVM on a silicon-based Routing Switch
- ORE - Oplet Run-time Environment
- Java-enabled Device Architecture
- Java SNMP MIB API
- Implementation of Network Forwarding API
- All of this enables implementation of **Dynamic** Classification in Silicon-Based Forwarding

Paradigm Shift

- **Supports distributed computing applications in which network devices participate**
  - router to router
  - server to router
- **Supports Intelligent Agents**
- **Supports Mobile Agents**



Example: Downloading Intelligence



Security and Stability

- **secure download of Java Applications**
- **safe execution environment**
  - insulate core router applications from dynamically loaded applications

Device-based Intelligence

- **Static-vs-Dynamic Agents**
  - Static
    - SNMP set/get mechanisms
    - Telnet, User Interfaces (cli, web, etc…)
  - Dynamic closed-loop interaction on nodes
    - capable of dealing with new and difficult situations
    - autonomous and rational properties.
    - dynamically system monitoring & modification
    - report status and trends

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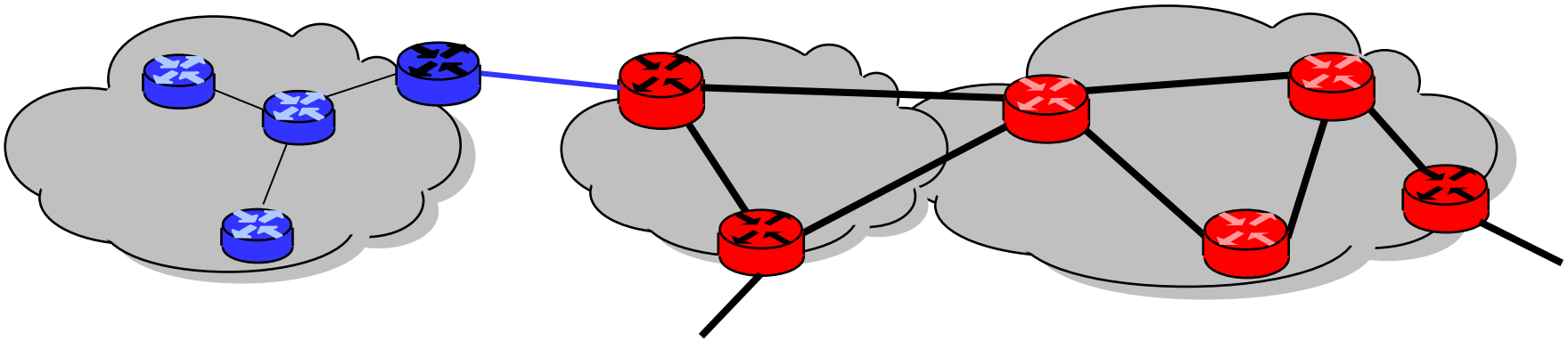
New Types of Applications

- Mobile Agents
- Local Intelligence for NMS
- Collaboration among routers
- Router & Server Collaboration
- E-commerce

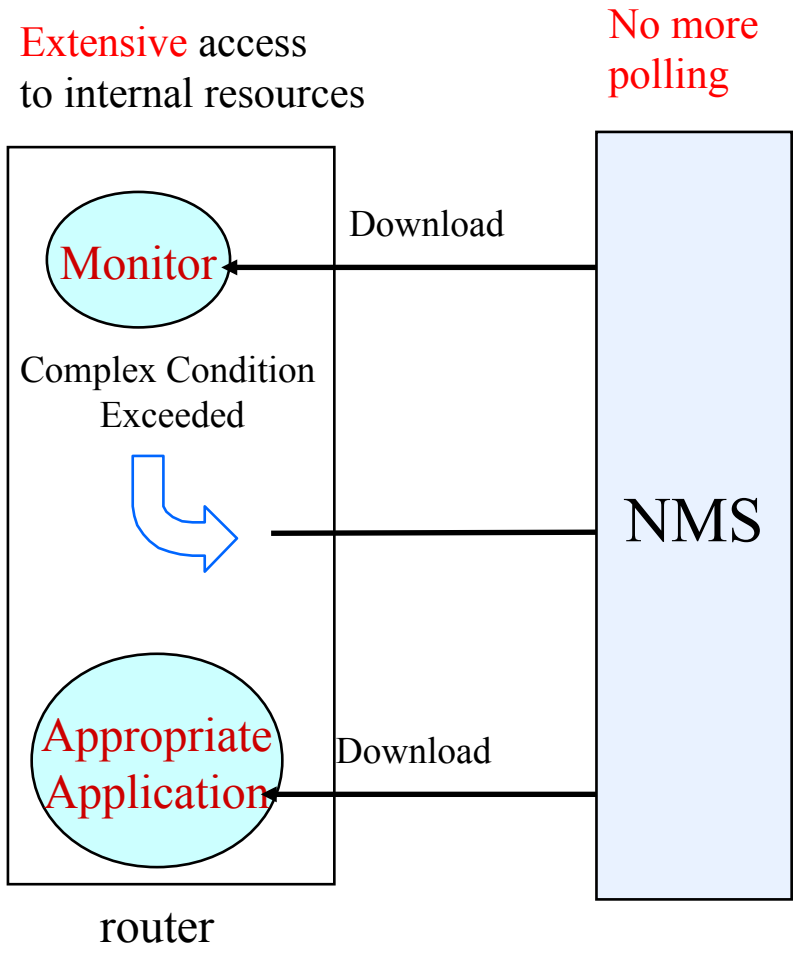
Mobile Agents

- **Intrusion Detection - Hacker Chaser**
- **Trace-route for Layer 2**
- **Mobile Connectivity Mapper**



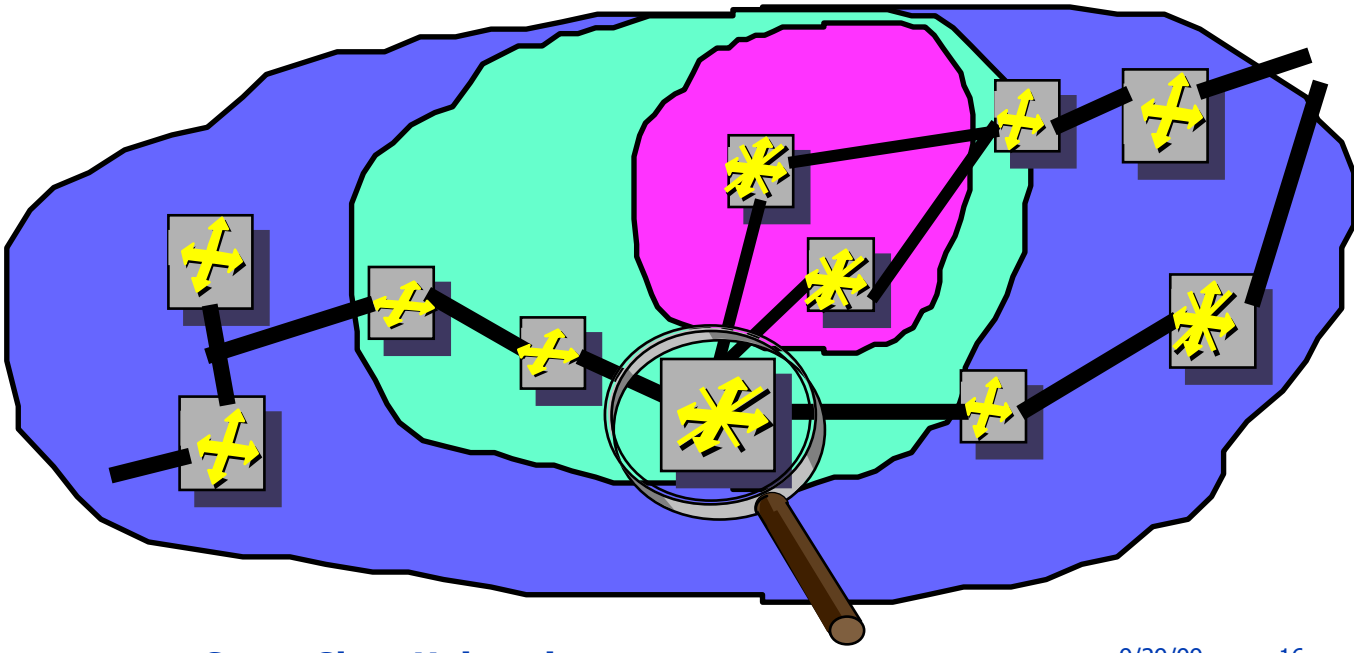
Local Intelligence for NMS: Diagnostic Agents

- **Download Intelligent Agent monitor from NMS to the device.**
- **Wait for threshold.**
  - Might be complex conditions
  - Trend analysis
- **Send "condition exceeded" event to NMS.**
- **Automatic download appropriate application**
- **Application takes action.**



Application Layer Collaboration Among Routers and Servers

- **Application aware routing**
- **Server farm load balancing**
  - server state monitored
  - rerouting based on congestion/load
- **Auctioning Applications**



Applications Aware Forwarding

Business logic based operation changes

- **Resize forwarding queues**
- **Modify congestion control algorithm**
- **Adjust Packet Scheduling**
- **Change routing table**

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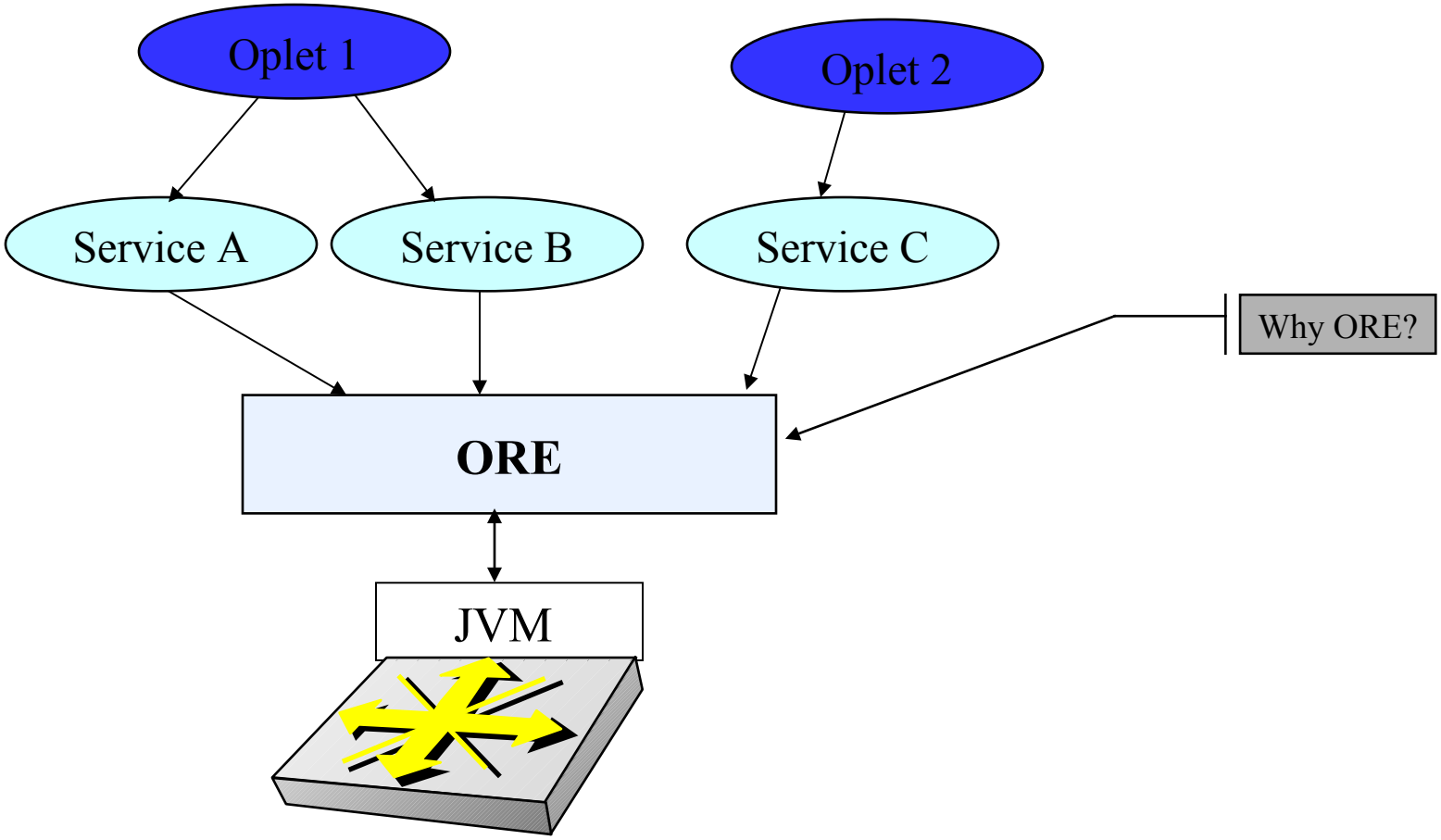
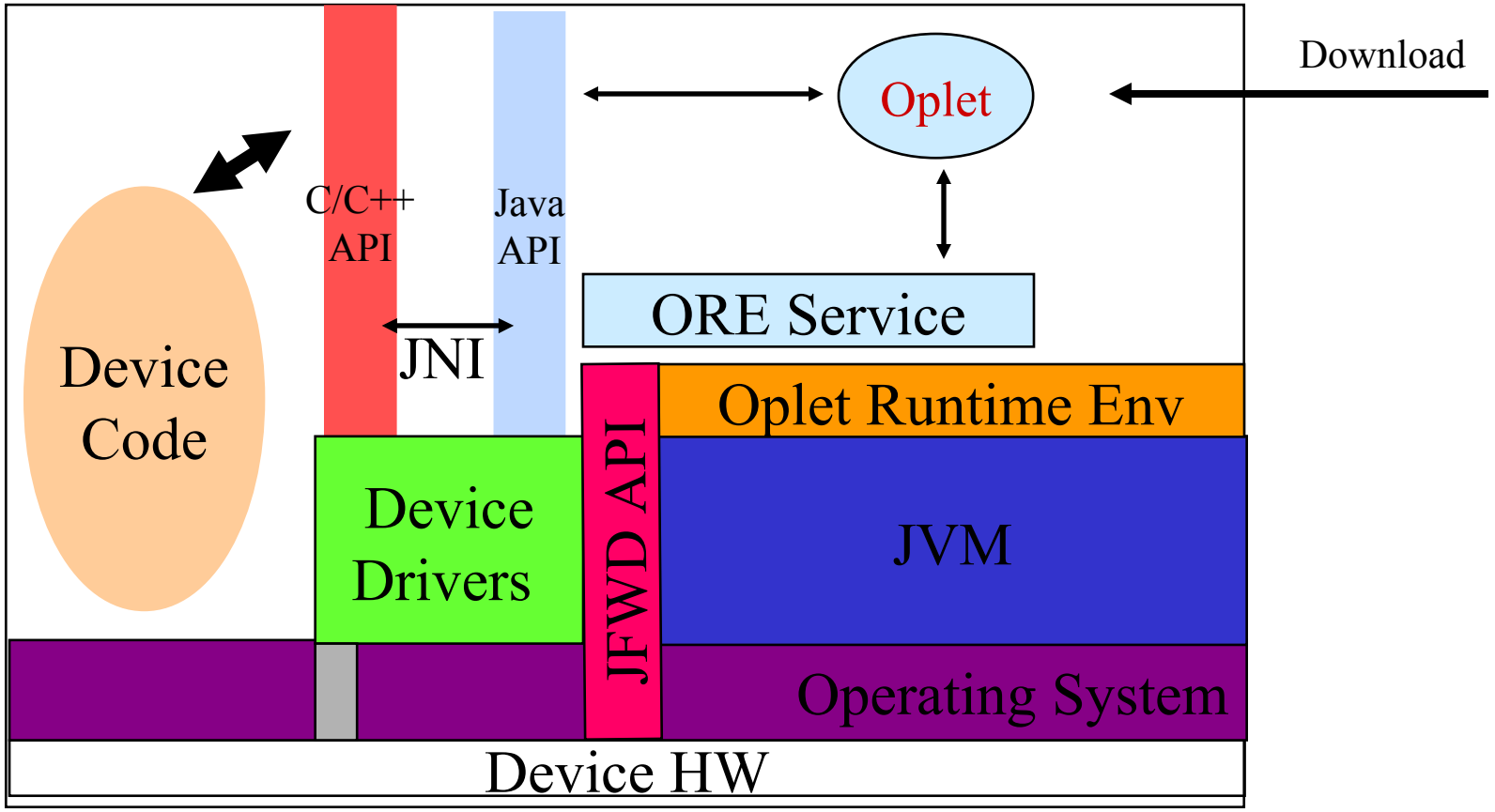
ORE - Oplet Run-time Environment



Node Architecture

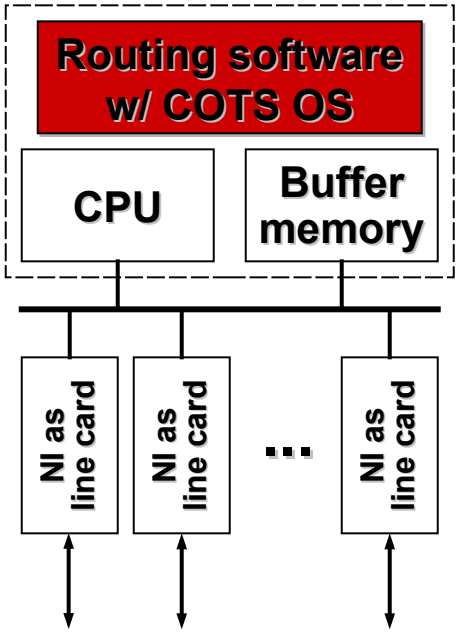


Architecture Issues

- **Green Threads -vs- Native Threads**
  - Native threads:
    - provides non-interference between Java applications
    - difficult thread-to-thread communication and sharing of data between threads
    - creates a dependency on underlying RTOS
    - multiple JVM instances consume resources
  - Green Threads
    - single JVM must manage CPU & memory resources between concurrently running threads

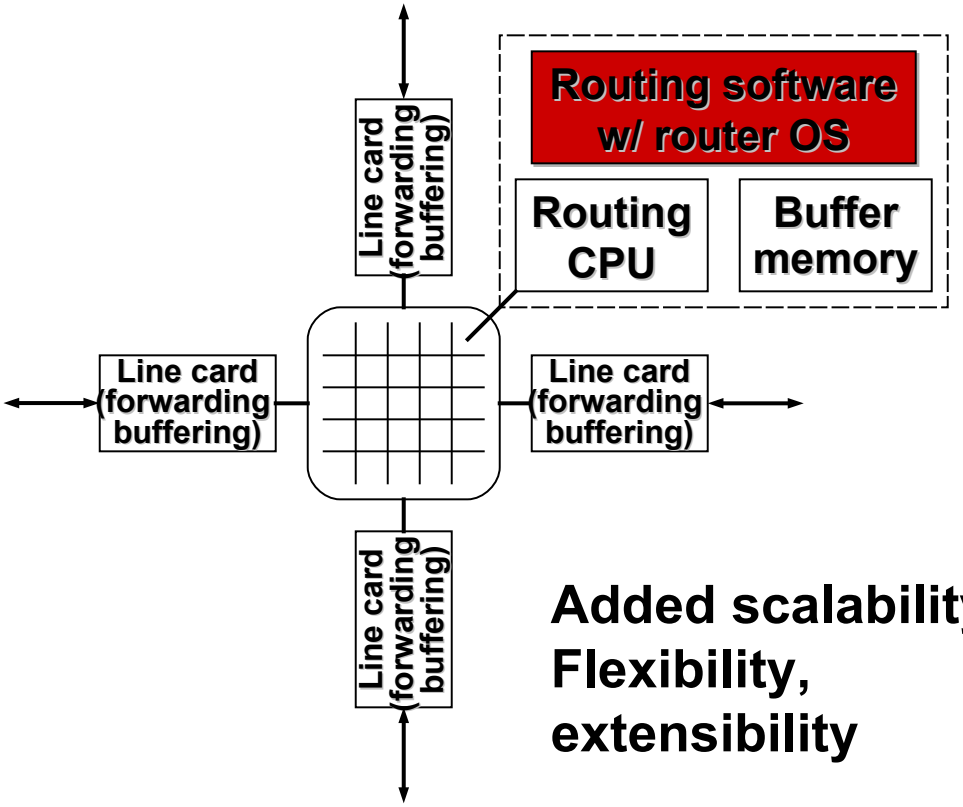
Evolution of Router Architecture

Centralized, CPU-based Model



Control + Forwarding Functions combined

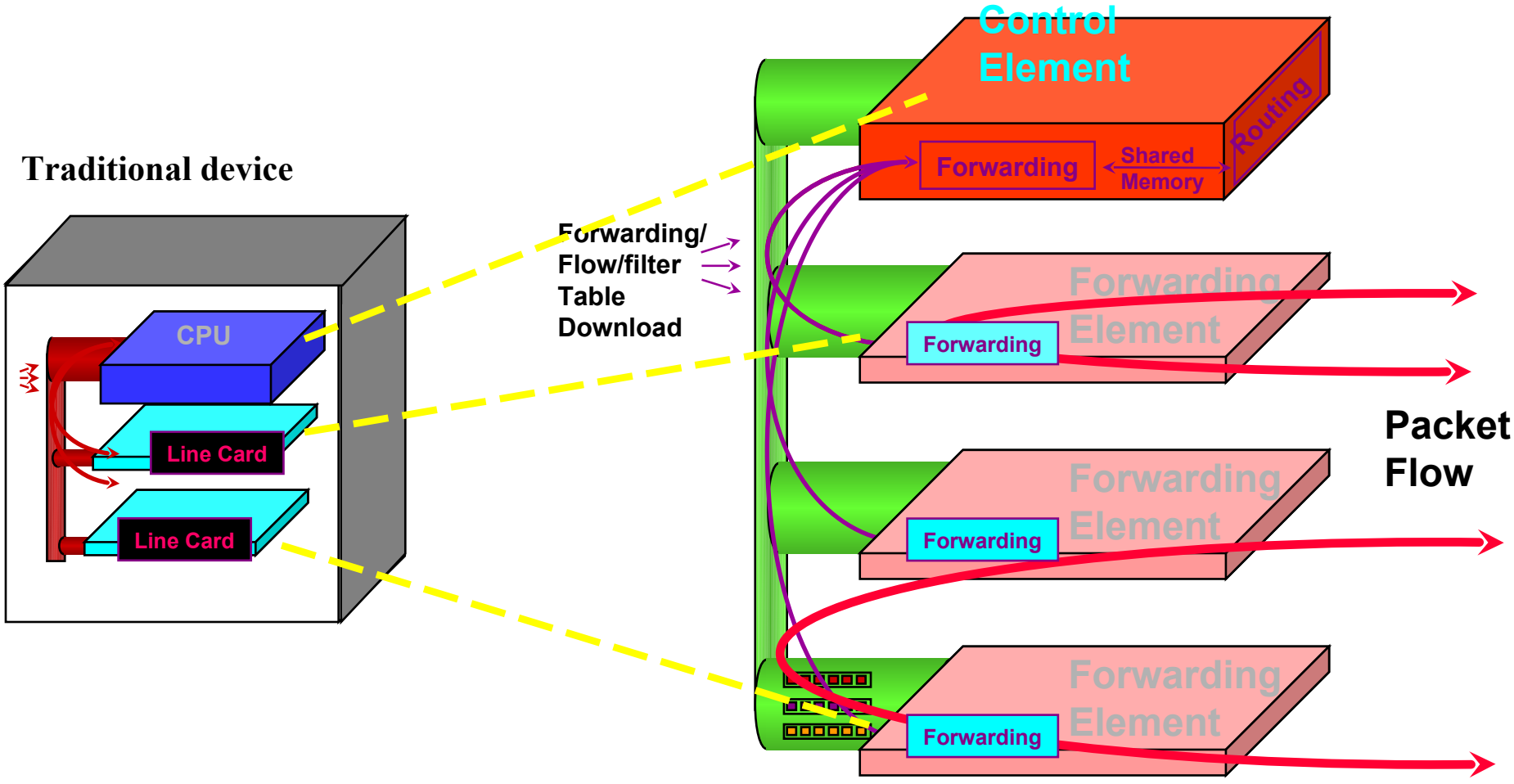
Distributed, line-card based Model



Added scalability, Flexibility, extensibility

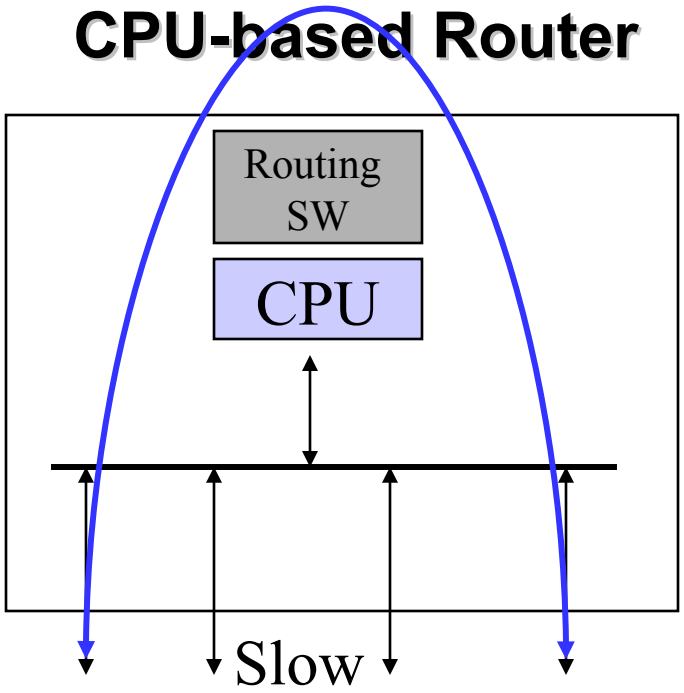
Control separated From forwarding

Explicit Separation of Control Plane from Data Forwarding



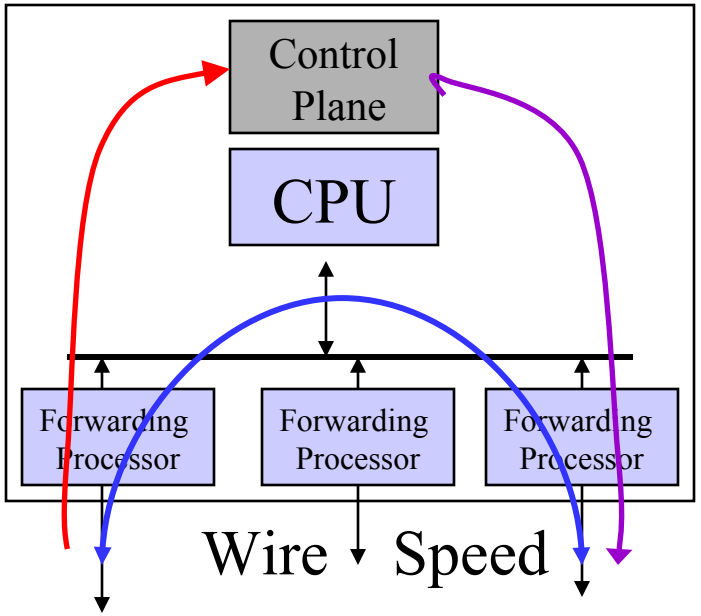
Separation of Control and Forwarding Planes

Centralized, CPU-based Router



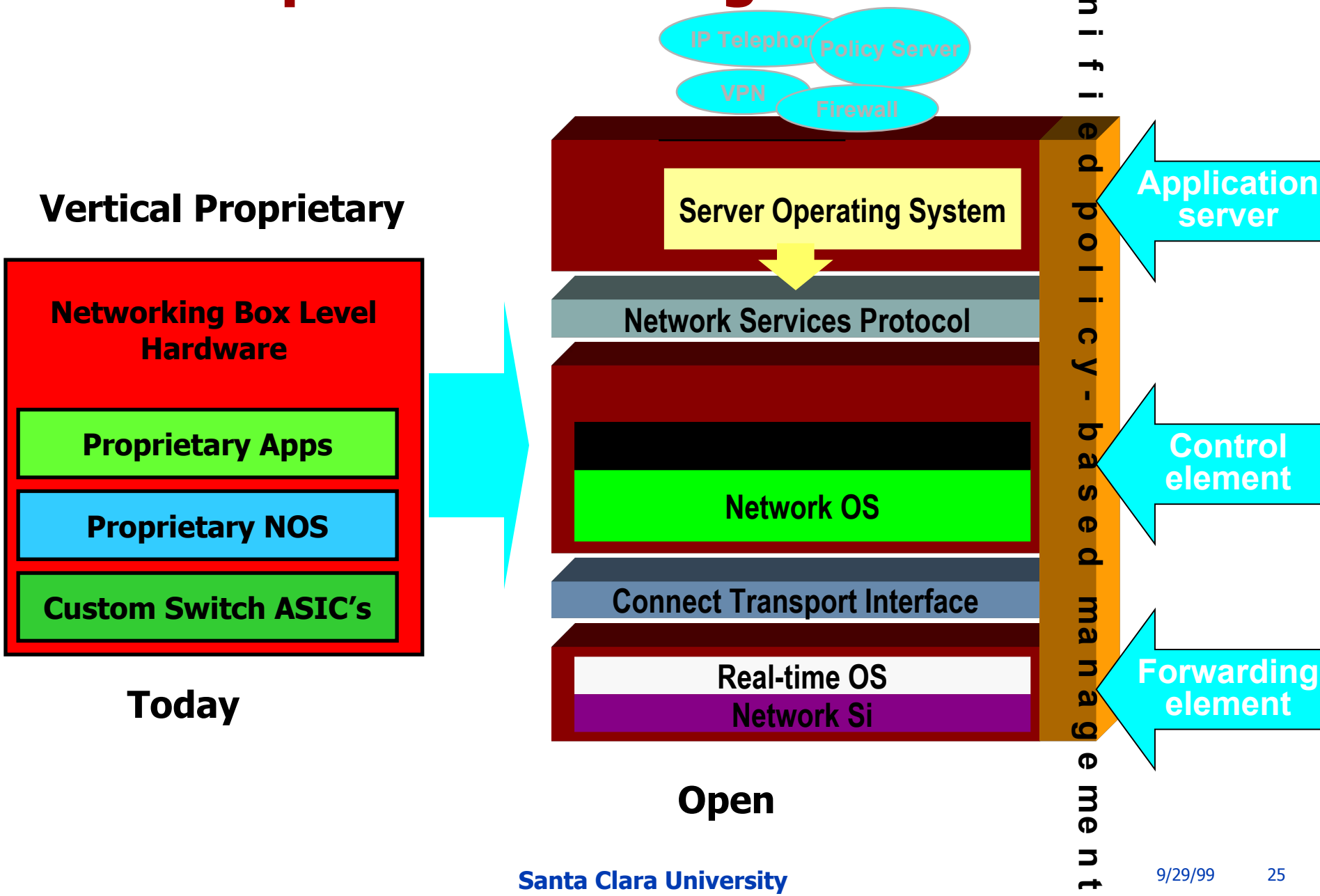
Control + Forwarding Functions combined

Forwarding-Processors based Router

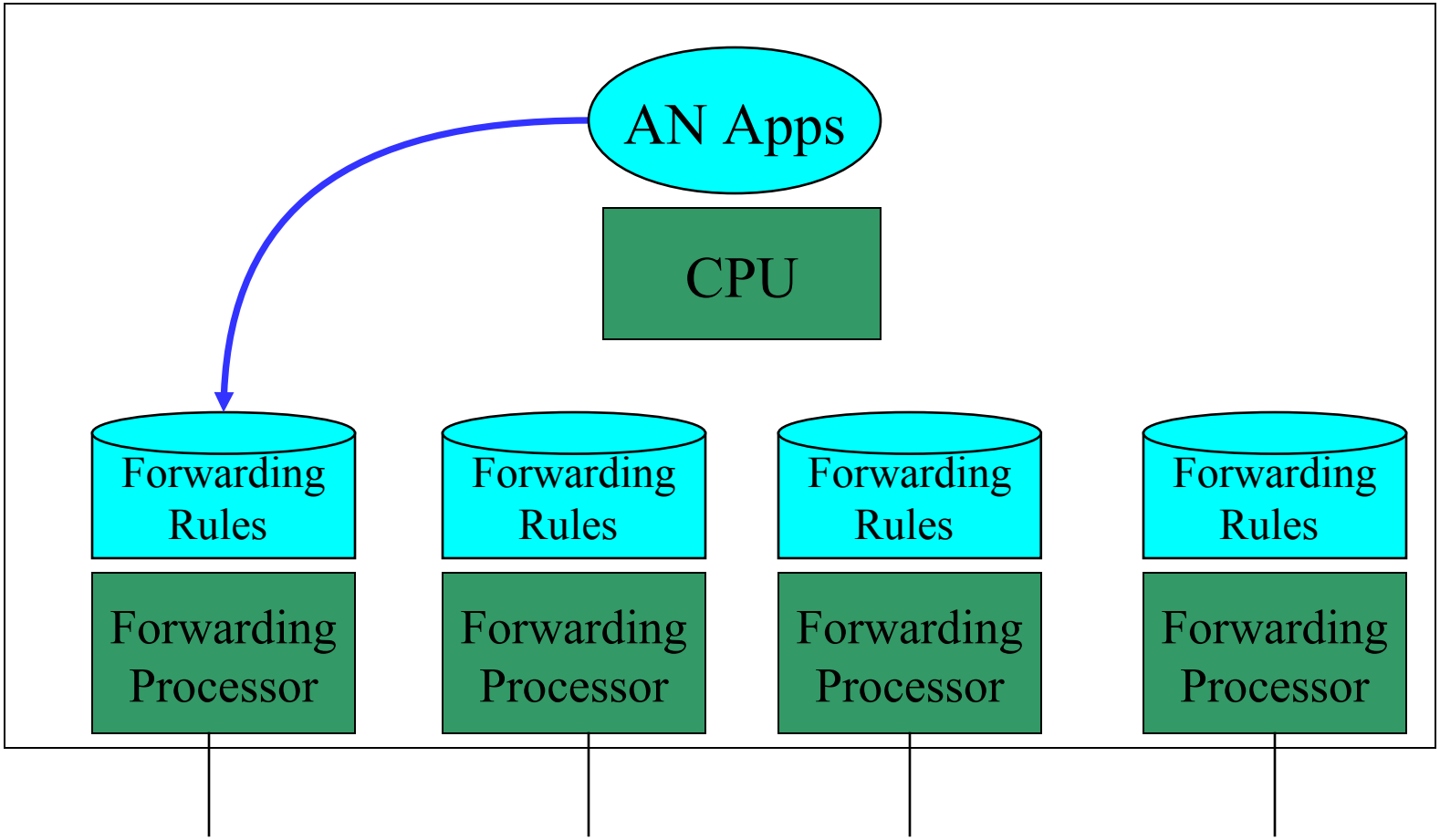


Control separated From forwarding

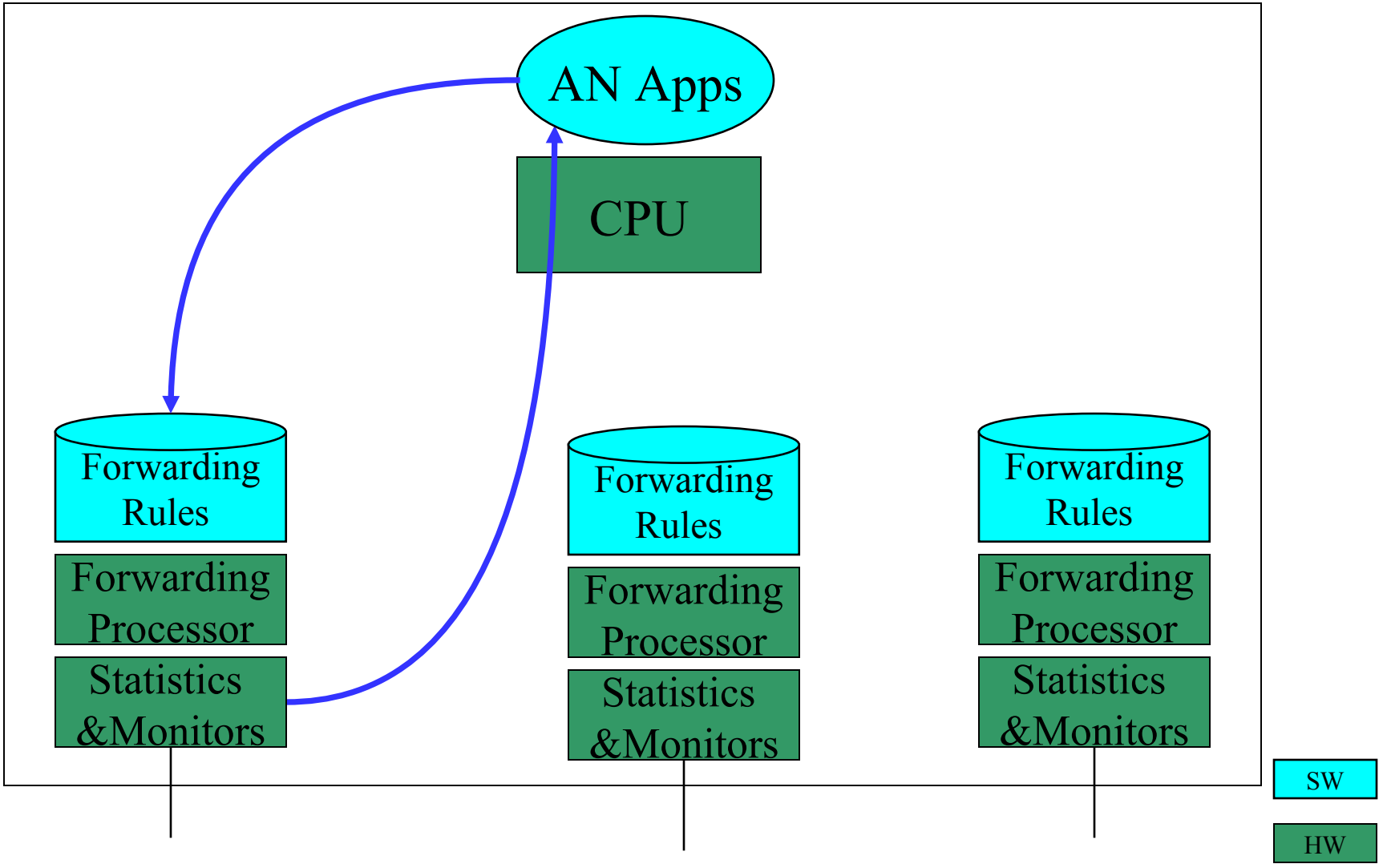
Open Networking Architecture



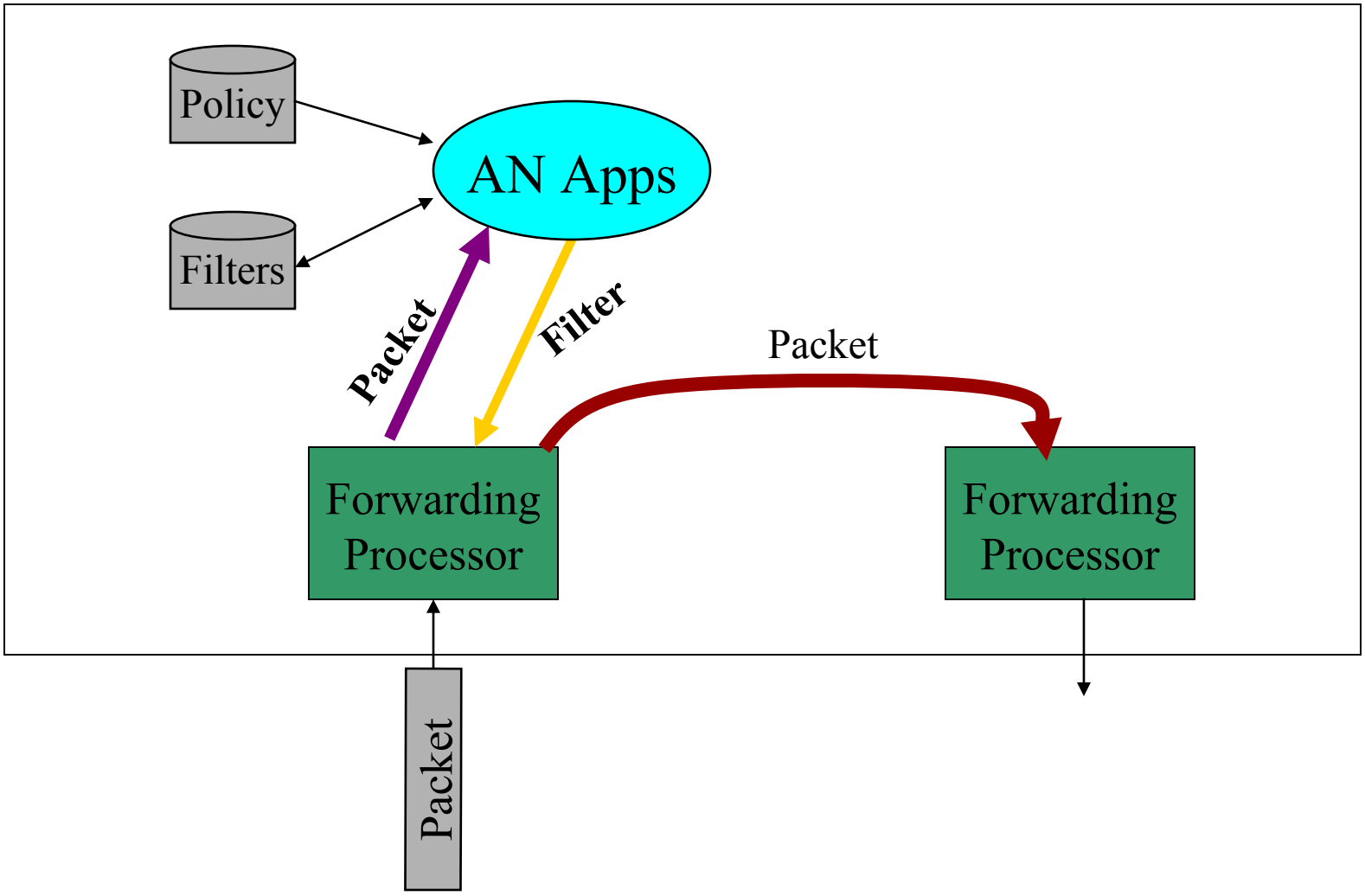
Dynamic Configuration of Forwarding Rules



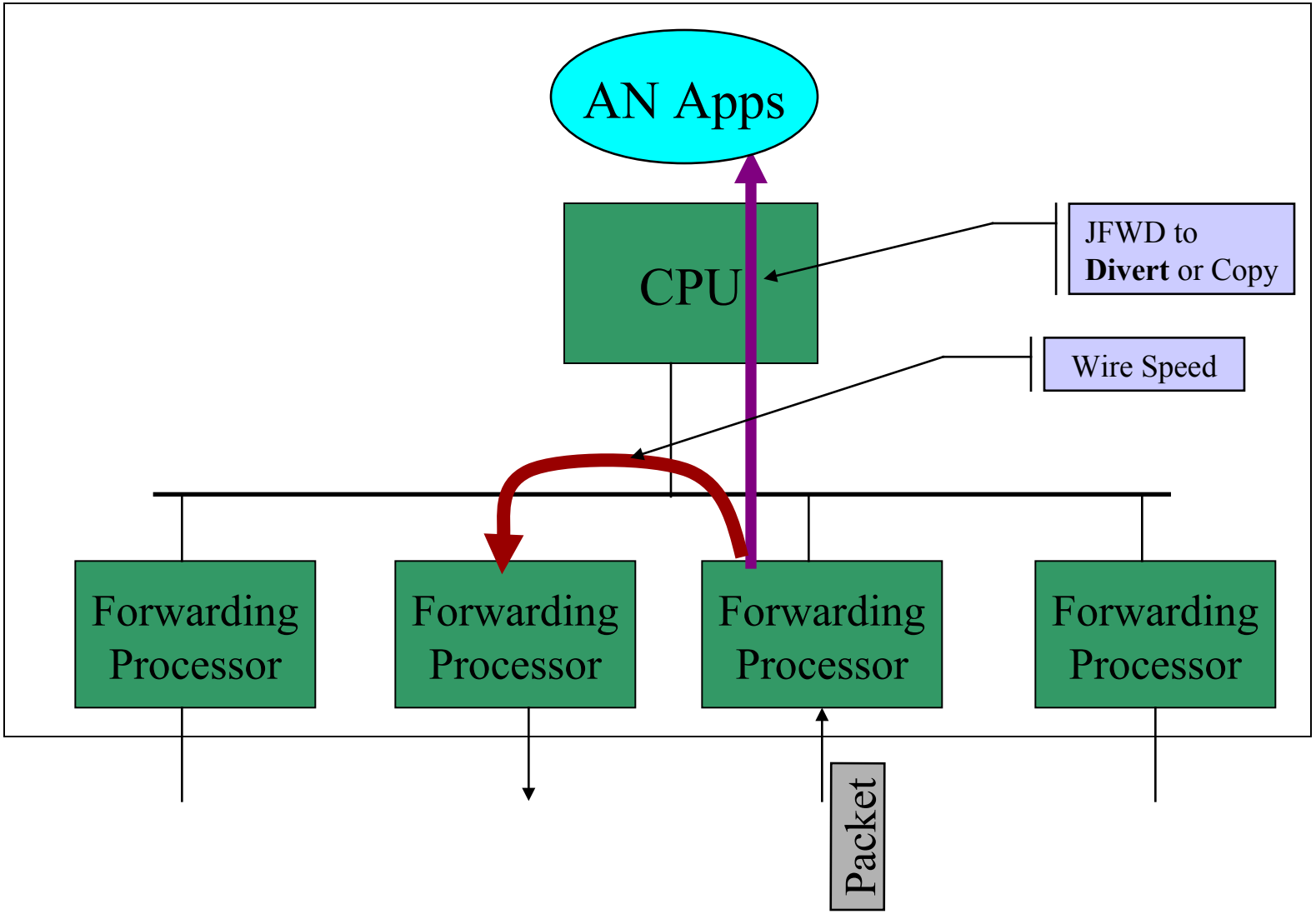
Real-time forwarding Stats and Monitors



Dynamic - On the Fly Configuration



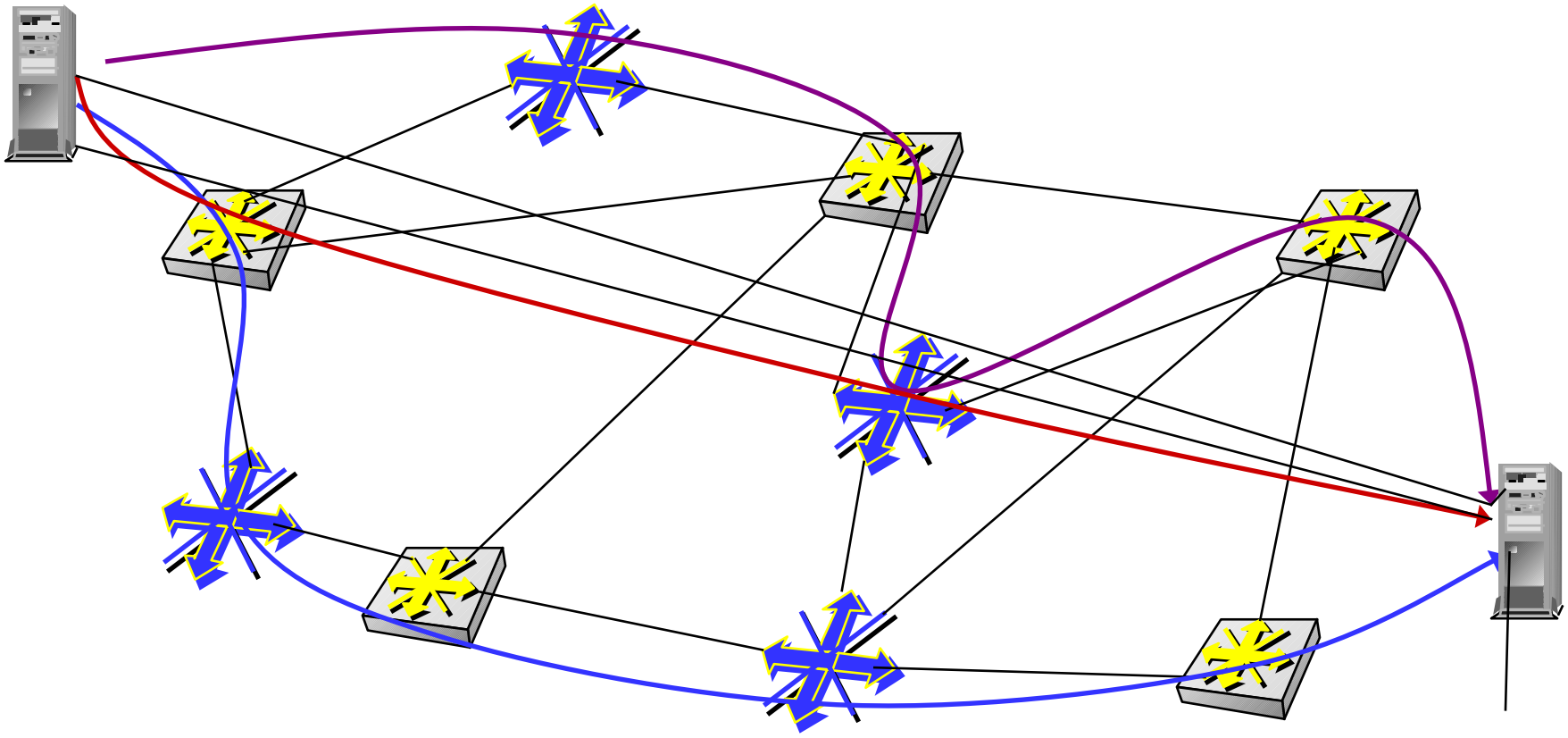
Active Networks Packet Capture



Scaling up Active Networks Routing Protocol to commercial networks

- Overcome the need to predefine the next hop
- No need to know AN topology a head of time
- Divert/CarbonCopy specific packets to control plane (e.g. packets on ANEP port)
- Wire speed of all other packets
- End to end forwarding
- Future: Active Networks Routing Protocols

Mixed Topology of AN system

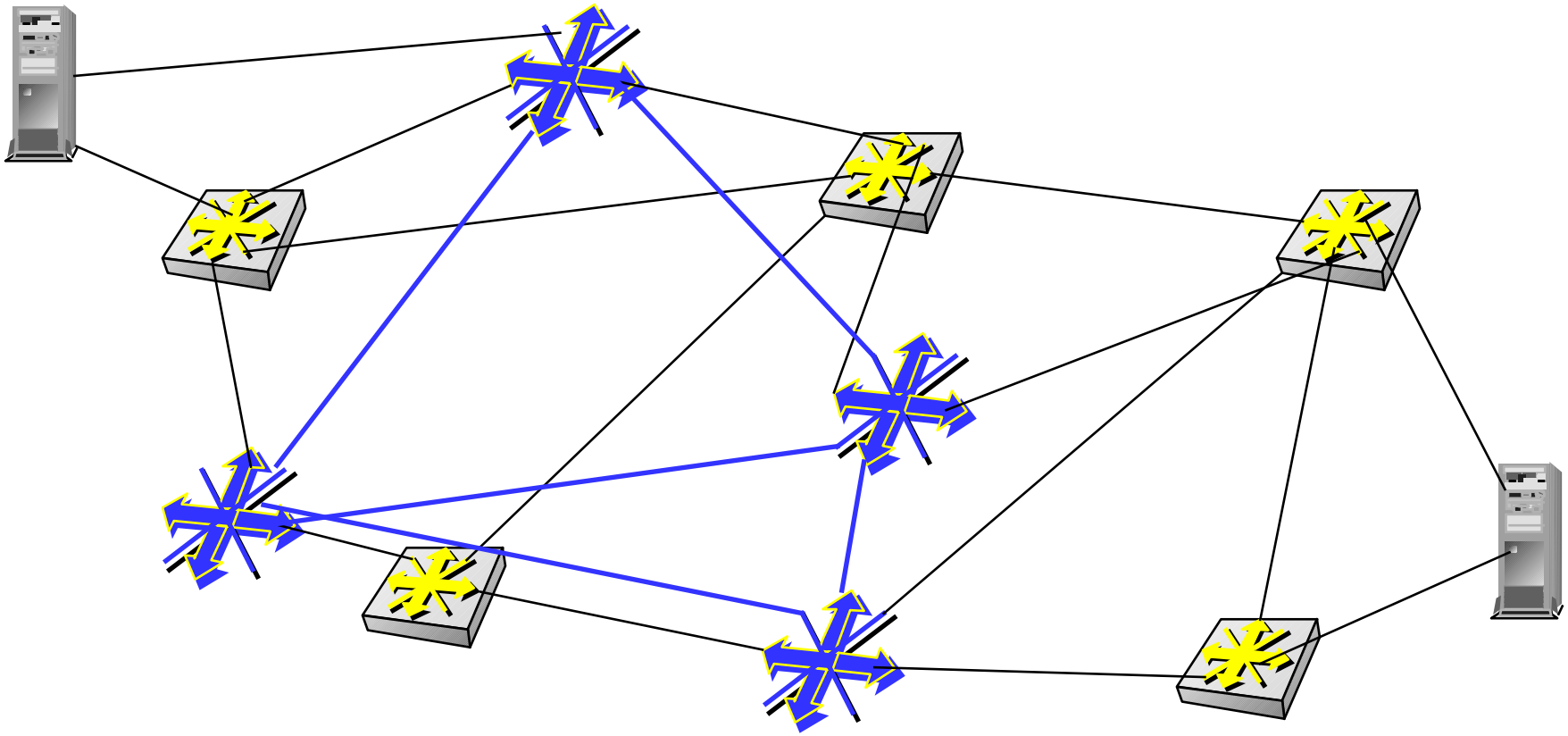


NO need to know the AN topology ahead of time

 - AN Node

 - Non AN Node

Virtual Topology of AN system



NO need to know the AN topology ahead of time

 - AN Node

 - Non AN Node

Java Environment

- **Green Threads -- Present RTOS with single unified task that includes:**
  - Java VM (JVM)
  - Java Resource Manager (JRM)
    - thread scheduling
    - manages CPU utilization
      - JVM time-slice is managed by the JRM preemptive thread scheduler
    - internal memory manager (intercepts "new")
    - garbage collection with priority based on available memory

Non-Interference w/ Single JVM

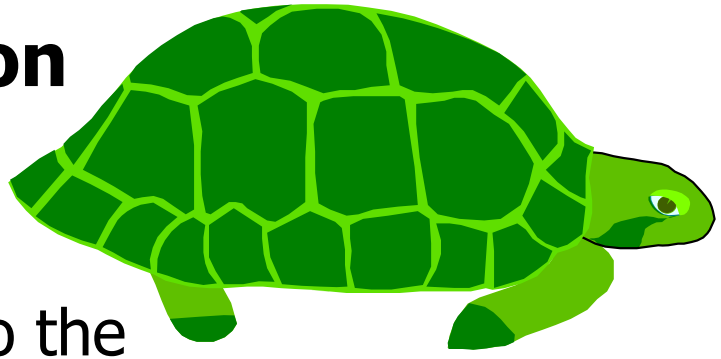
- **Multiple threads compete for resources**
  - memory
  - CPU
  - persistent storage
- **Denial-of-service attacks possible**
  - memory or CPU consumption attacks
  - trusted/untrusted service interactions

Why Java

- **Reuse security mechanisms**
  - byte-code verifier
  - security manager
  - classloader
- **System stability**
  - constrains applications to the JVM
  - Prohibits native code applications
- **Extensible, portable, & distributable services**

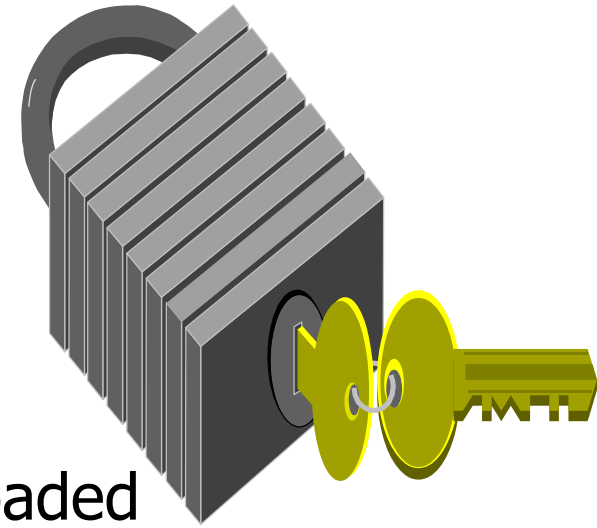
But Java is slooowwwww

- **Not appropriate in the fast-path data forwarding plane**
  - forwarding is done by ASICs
  - packet processing not affected
- **Java applications run on the CPU**
  - Packets destined for Java application are pushed into the control plane



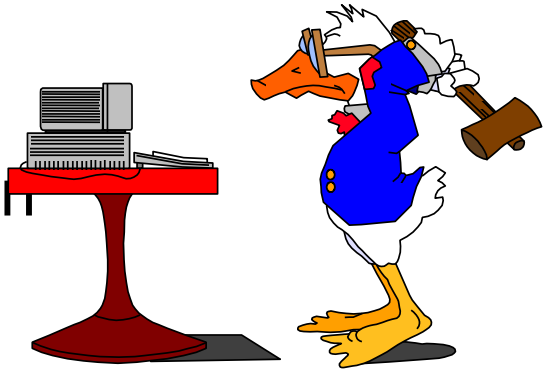
Strong Security in the new model

- **The new concept is secure to add 3rd party code to network devices**
  - Digital Signature
  - Administrative "Certified Optlet"
  - No access out of the JVM space
  - No pointers that can do harm
  - Access only to the published API
  - Verifier - only correct code can be loaded
  - Class loader access list
  - JVM has run time bounds, type, and execution checking



Old model Security (C/C++)

- **Old model: Not safe to add 3rd party code**
  - Dangerous, C/C++ Pointers
    - Can touch sensitive memory location
  - Risk: Memory allocations and Free
    - Allocation without freeing (leaks)
    - Free without allocation (core dump !!!!)
- **Limited security in SNMP**



Agenda

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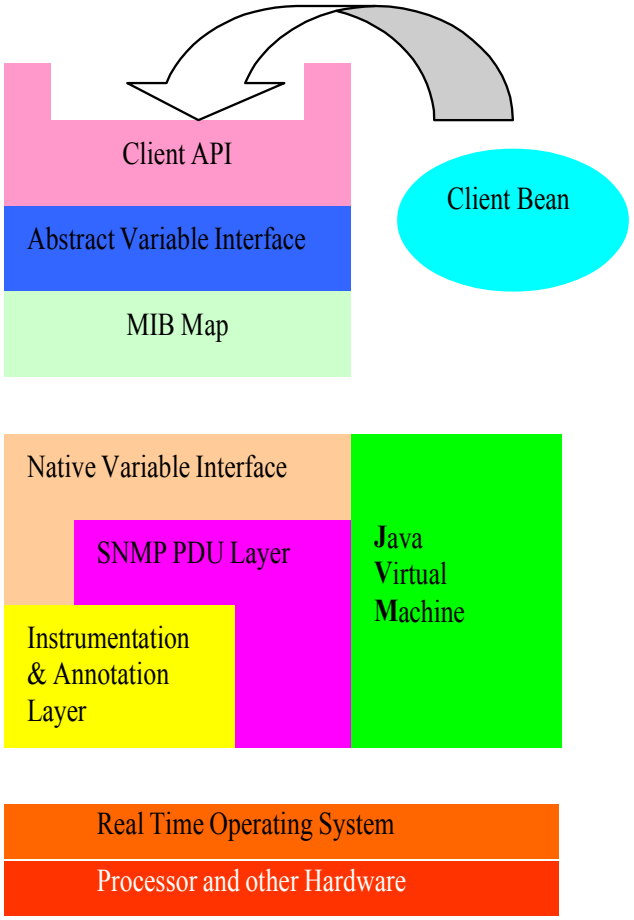
An Open Service API Example

- SNMP API for Network Management
  - generated automatically
  - allows device-based applications to query MIB
  - device-based application -- query local MIB
  - report trends or significant events
  - initiate downloading of problem specific diagnostic code
  - take corrective action

MIB API Example

- API uses a MIB Map to dispatch requests to variable access routines
- Different parts of the MIB tree can be serviced by different mechanisms
- Two main schemes:
- An ad hoc interface to the SNMP instrumentation layer
- A generic SNMP loopback



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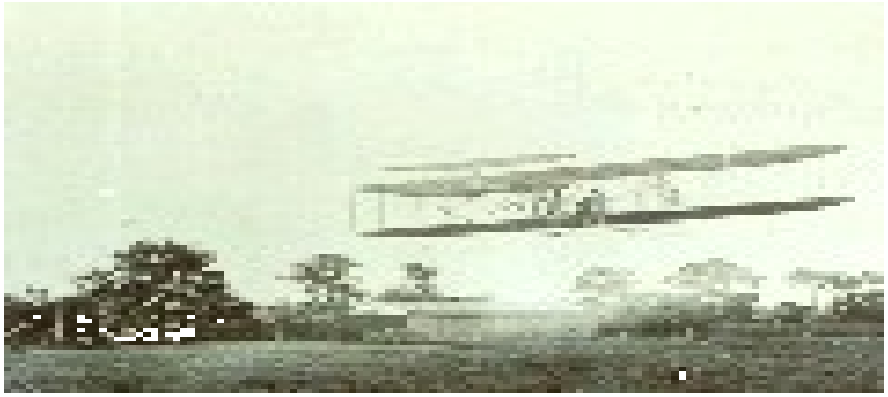
Summary

- **Programmable**
  - Turing Machine on network devices
  - *dynamic* agents vs. *static* agents
  - dynamic loading
  - strong security
- **Openness - successfully proven paradigm**
  - Facilitates innovation
  - Domain experts - virtual development community
- **Enabling Technology for the Revolution**

This is only the first step



1903 the Wright brothers

Compare to this first flight and look where aviation is today