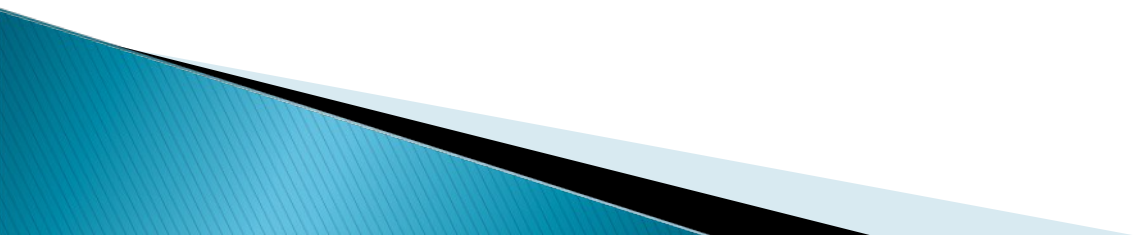
Open Programmable Architecture for Java-enabled Network Devices

A Revolution!

Tal Lavian
Technology Center
Nortel Networks
tlavian@IEEE.org



Programmable Network Devices

Openly Programmable devices enable new types of intelligence on the network

Agenda

- Our market is changing
- Local Computation
- Architecture
- New types of applications
- ORE - Oplet Run-time Environment
- API's
- Summary

Our Market is Changing

- Customers demand for Openness & programmability
- IEEE P1520
- Lucent's Programmable Networks
- Intel as driving force

Lucent in Open Programmable Networks

- Lucent's Programmable Network Conference 9/15-16
  - Cosponsored: Sun, HP, Oracle, Novell, Compaq …….
  - Over 500 participants, enthusiastic response
- SoftSwitch as programmable network
  - 70 developers
  - Jun 99 - PR, Sept 99 - Prog Conference, October 99 - SDK, Jan 00 - APIs, Feb 00 - Dev Conference, May 00 - 3rd party Test Lab
- 7 R/E program
- $1.7B- Excel Switching acquisition (Programmable switch)
- Other products and directions in Openness and Programmability
- Marketing and PR on Lucent's Openness

ES – Openet Center

- Create an open development community to deliver customer-valued solutions based on Nortel Networks' and partners' products and technologies
- Openet Center creates a focus to open network platforms
- Openet Center promotes Open Network Computing
- It potentially changes landscape and rules of the networking industry

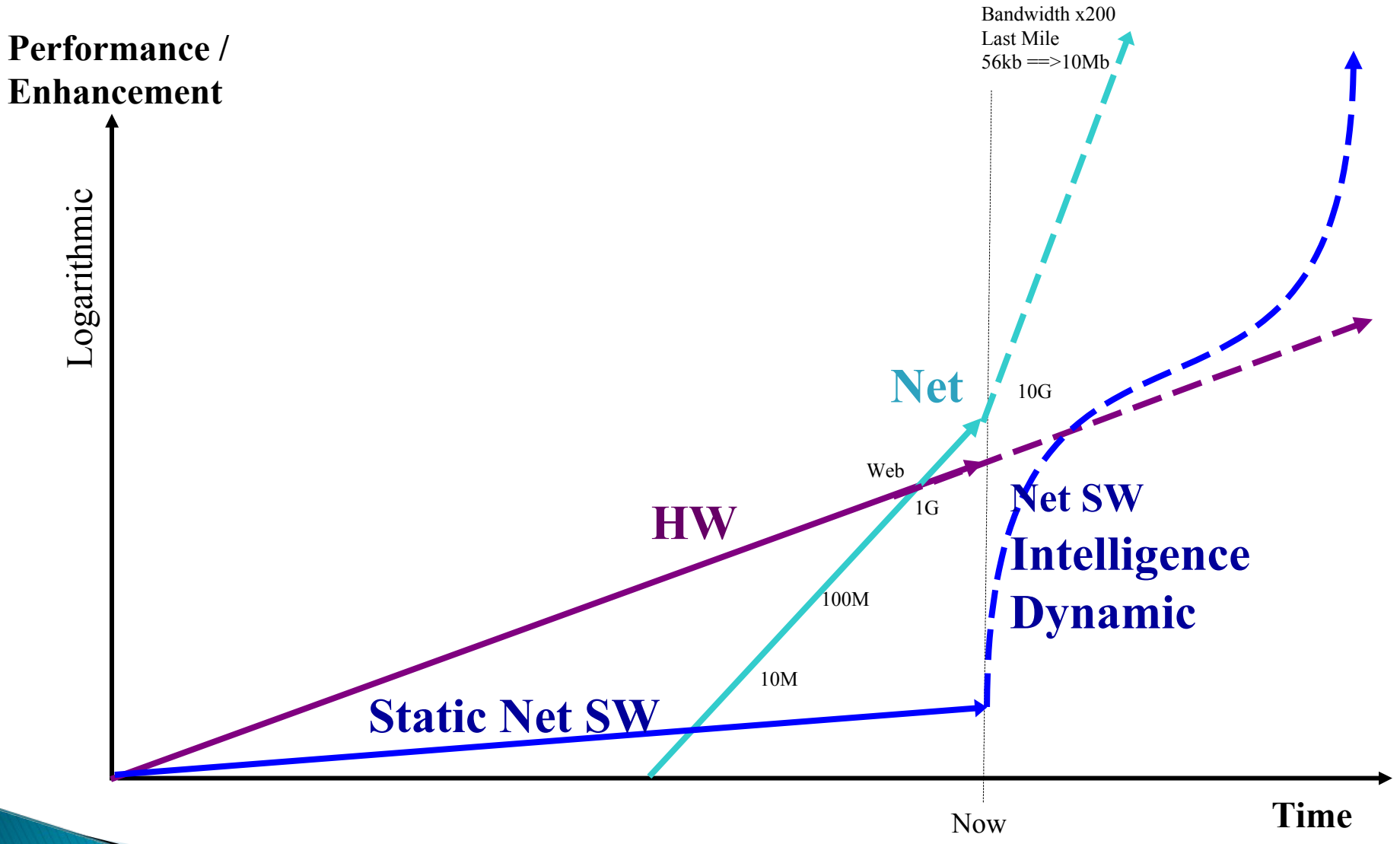
Accomplishments

- JVMs Network devices
  - Switch, Router, Net-device
- ORE - Oplet Run-time Environment
- Java-enabled Device Architecture
- Java SNMP MIB API
- Implementation of Network Forwarding API
- Dynamic applications

Agenda

- Our market is changing
- Local Computation
- Architecture
- Applications
- ORE - Oplet Run-time Environment
- API's
- Summary

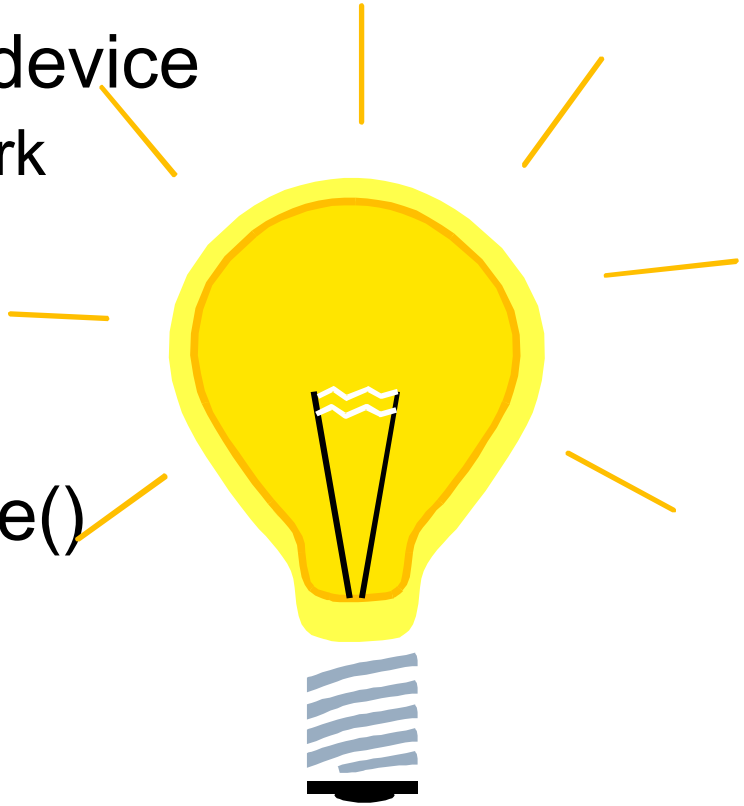
Evolution vs. Revolution



Changing the Rules of the Game

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

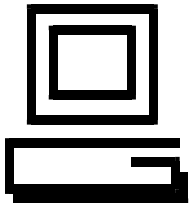
```
while (true) {
  doLocalProcessingOnDevice()
  }
```



Technology Concept

Web Server

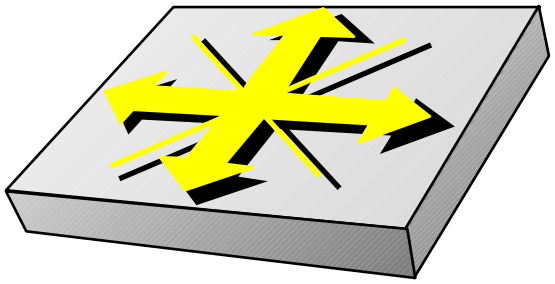
Applet



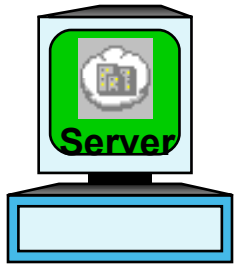
Web Browser

The JVM is in the Browser

Download applications for local processing



Reversed Applet

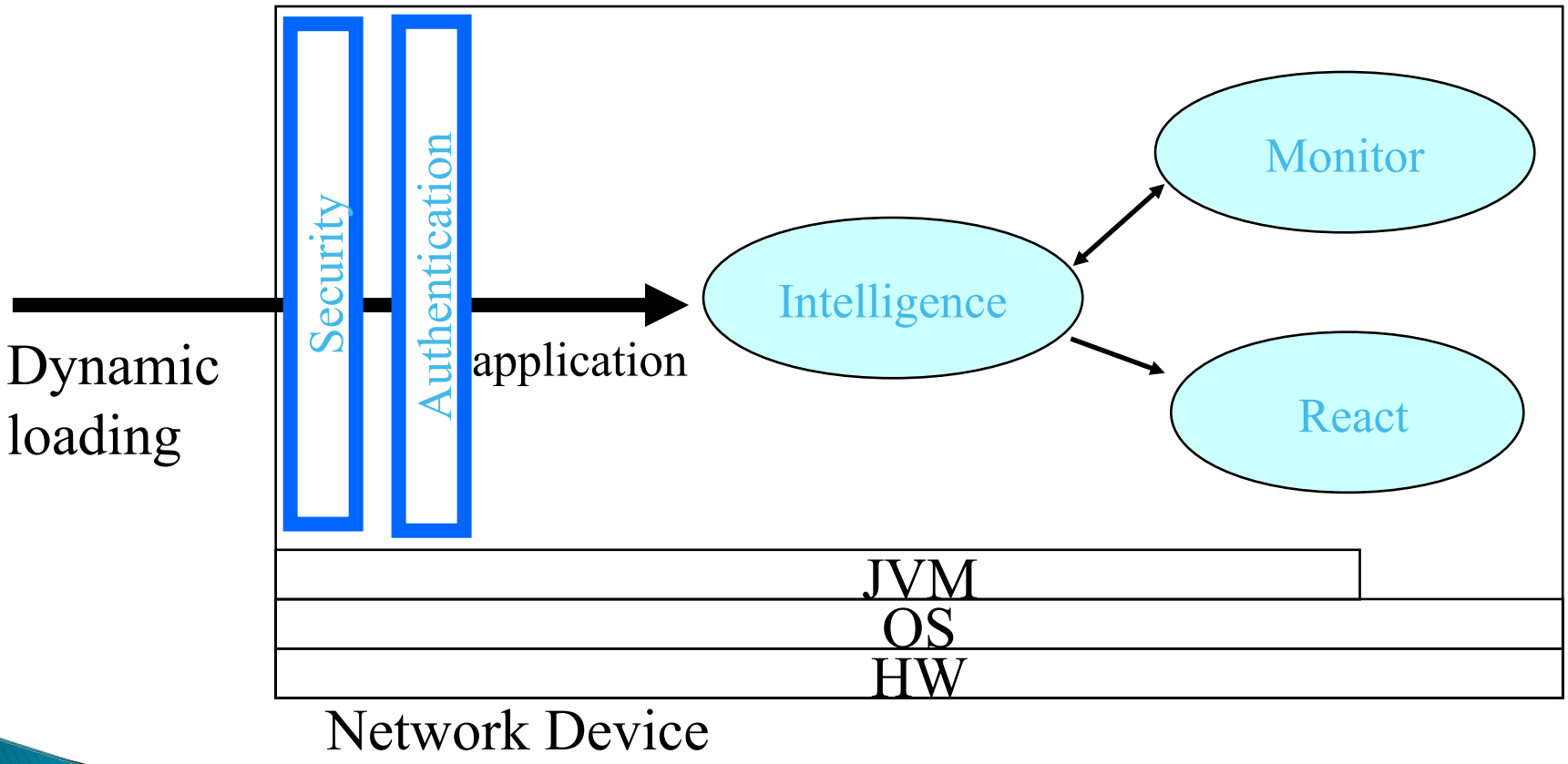


The Web Changed Everything

- 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

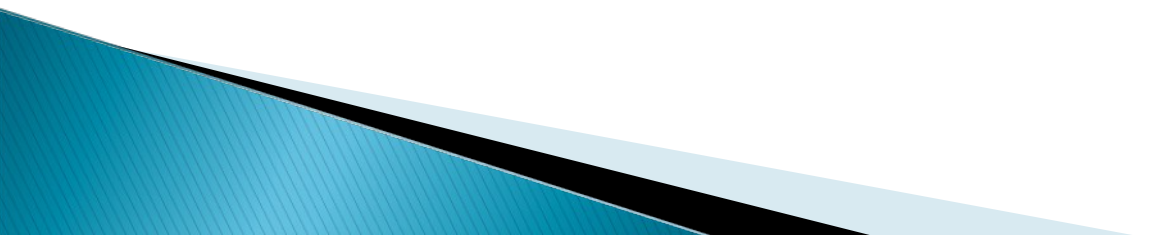
This Capability WILL Change Everything

Example: Downloading Intelligence



Security and Stability

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



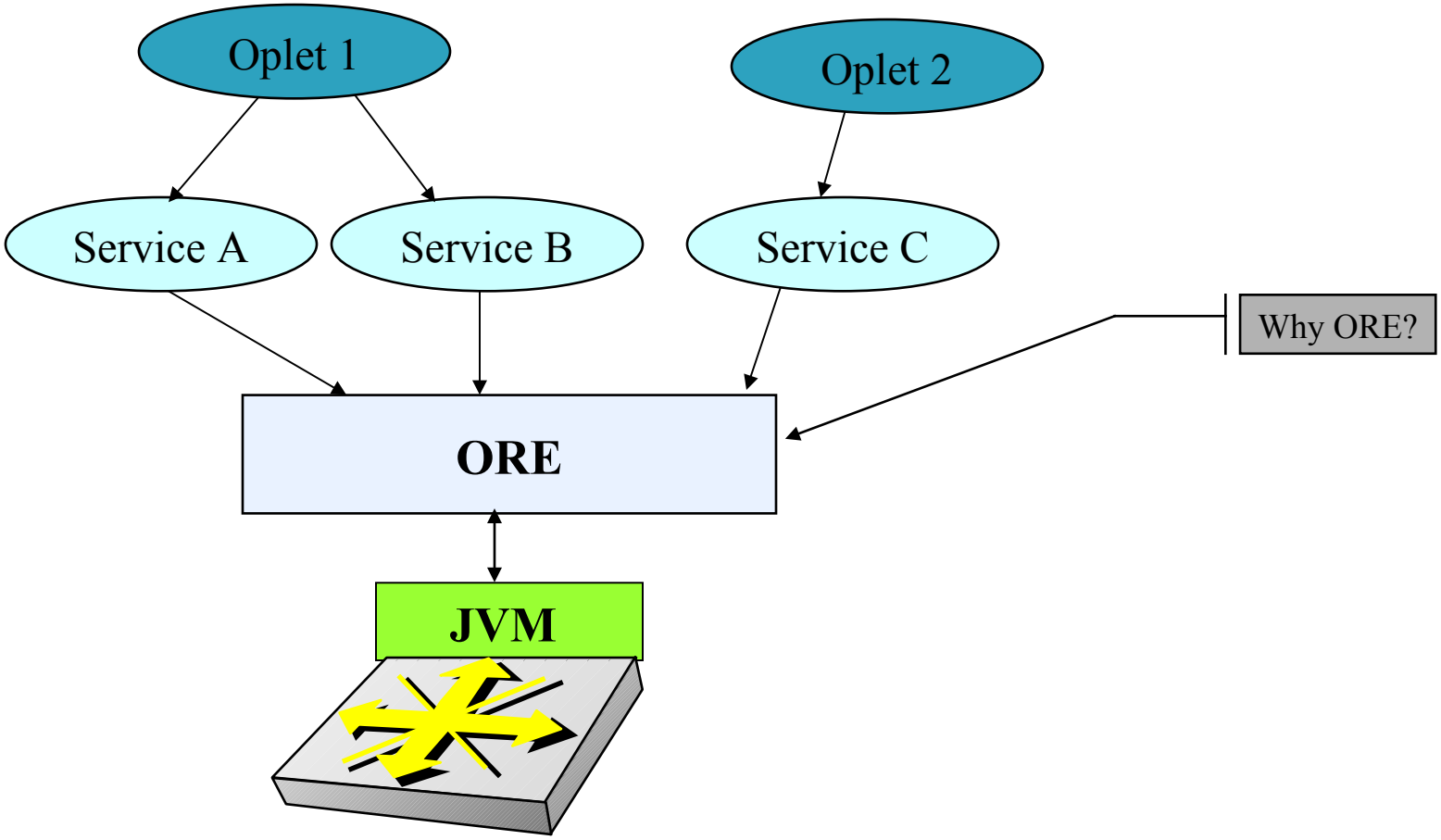
Device-based Intelligence

- 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

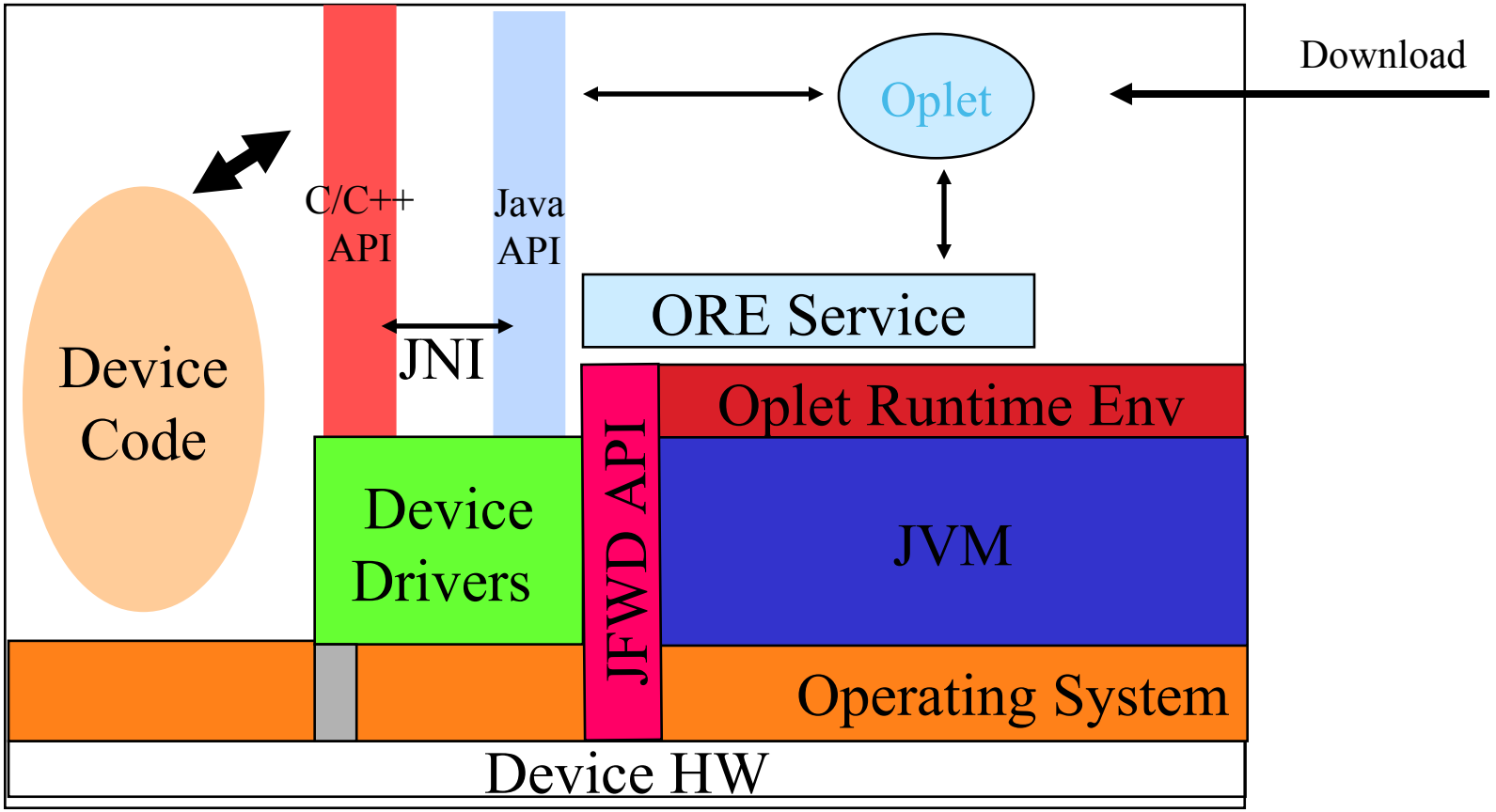
Agenda

- Our market is changing
- Local Computation
- Architecture
- Applications
- ORE - Oplet Run-time Environment
- API's
- Summary

ORE – Oplet Run-time Environment



Java-enabled Device Architecture

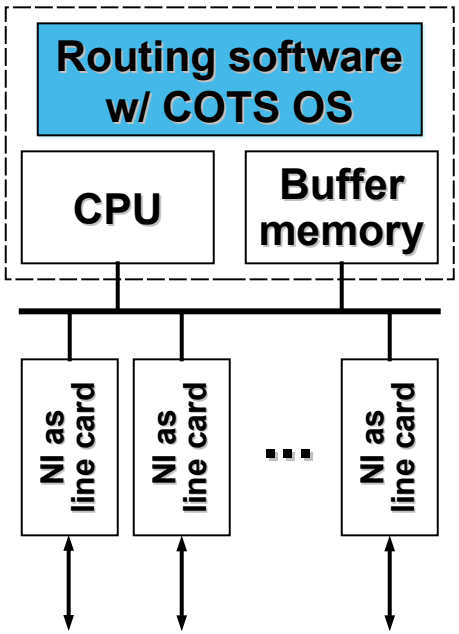


Architecture Issues

- 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

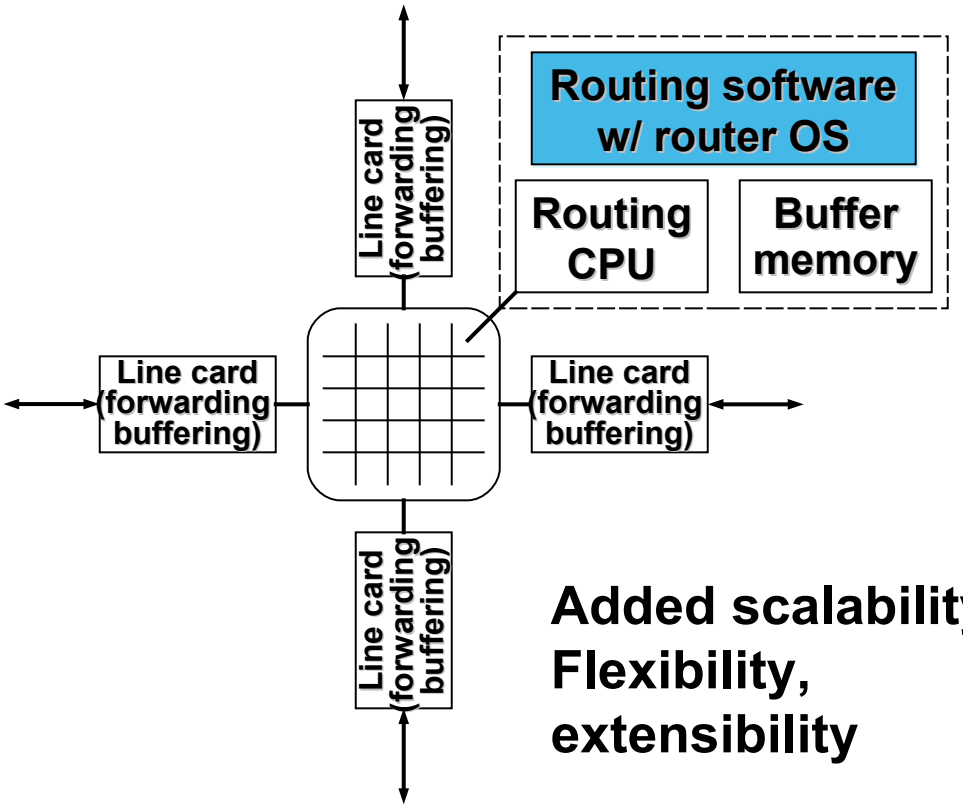
Evolution of Router Architecture

Centralized, CPU-based Model



Control + Forwarding Functions combined

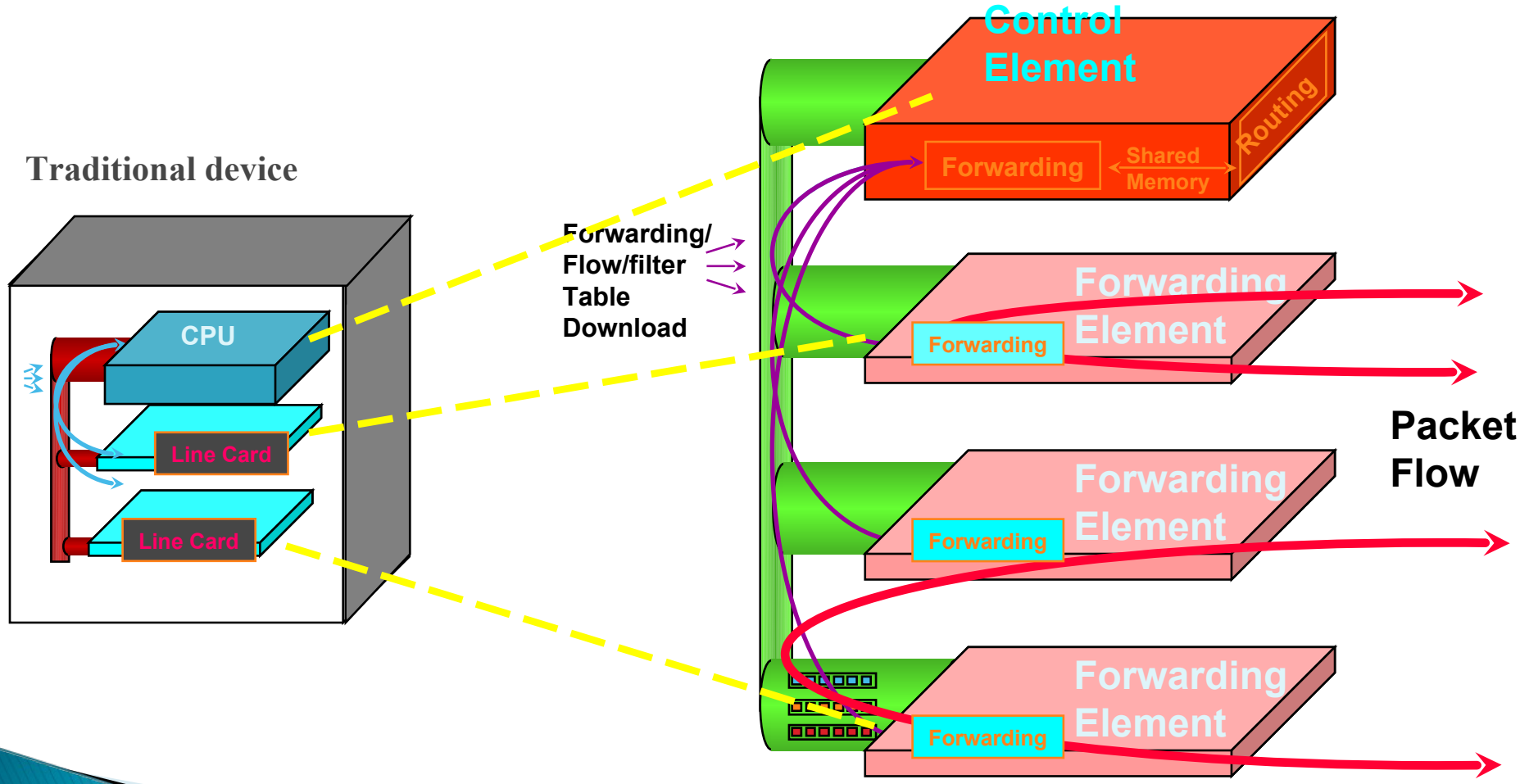
Distributed, line-card based Model



Added scalability, Flexibility, extensibility

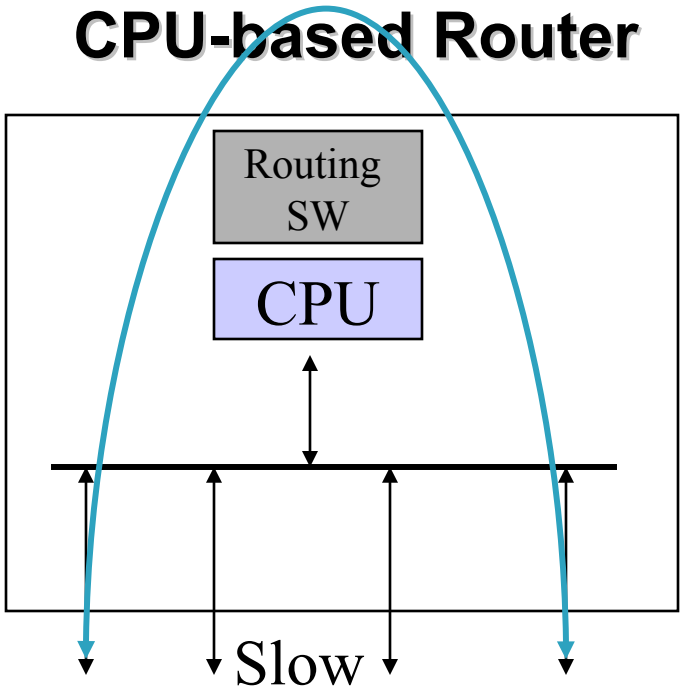
Control separated From forwarding

Explicit Separation of Control Plane from Data Forwarding



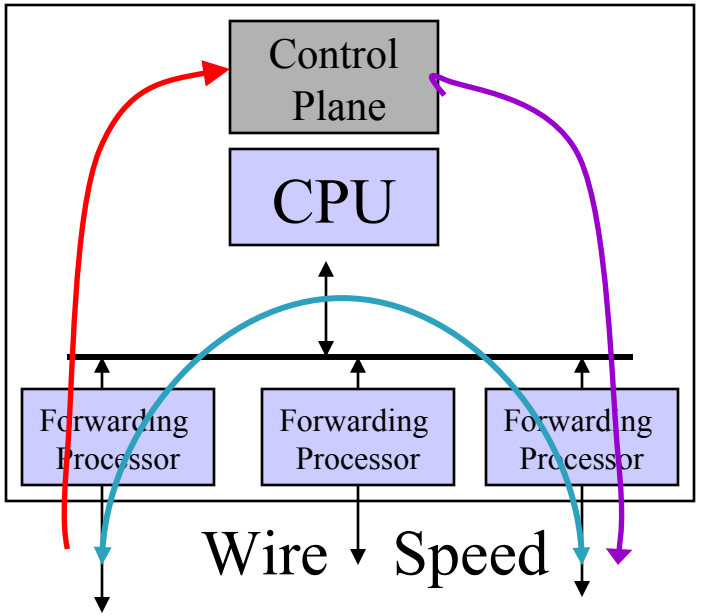
Separation of Control and Forwarding Planes

Centralized, CPU-based Router



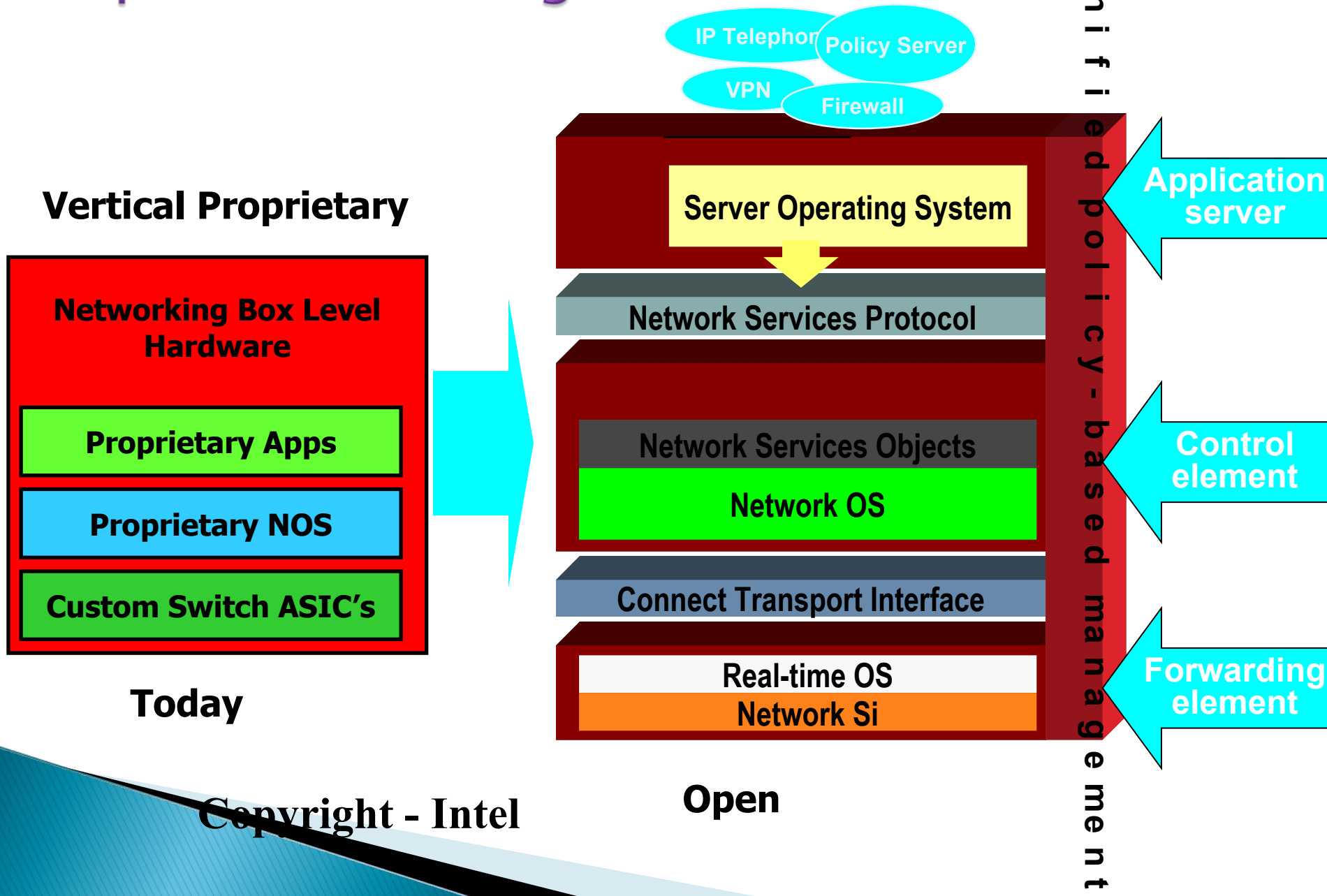
Control + Forwarding Functions combined

Forwarding-Processors based Router

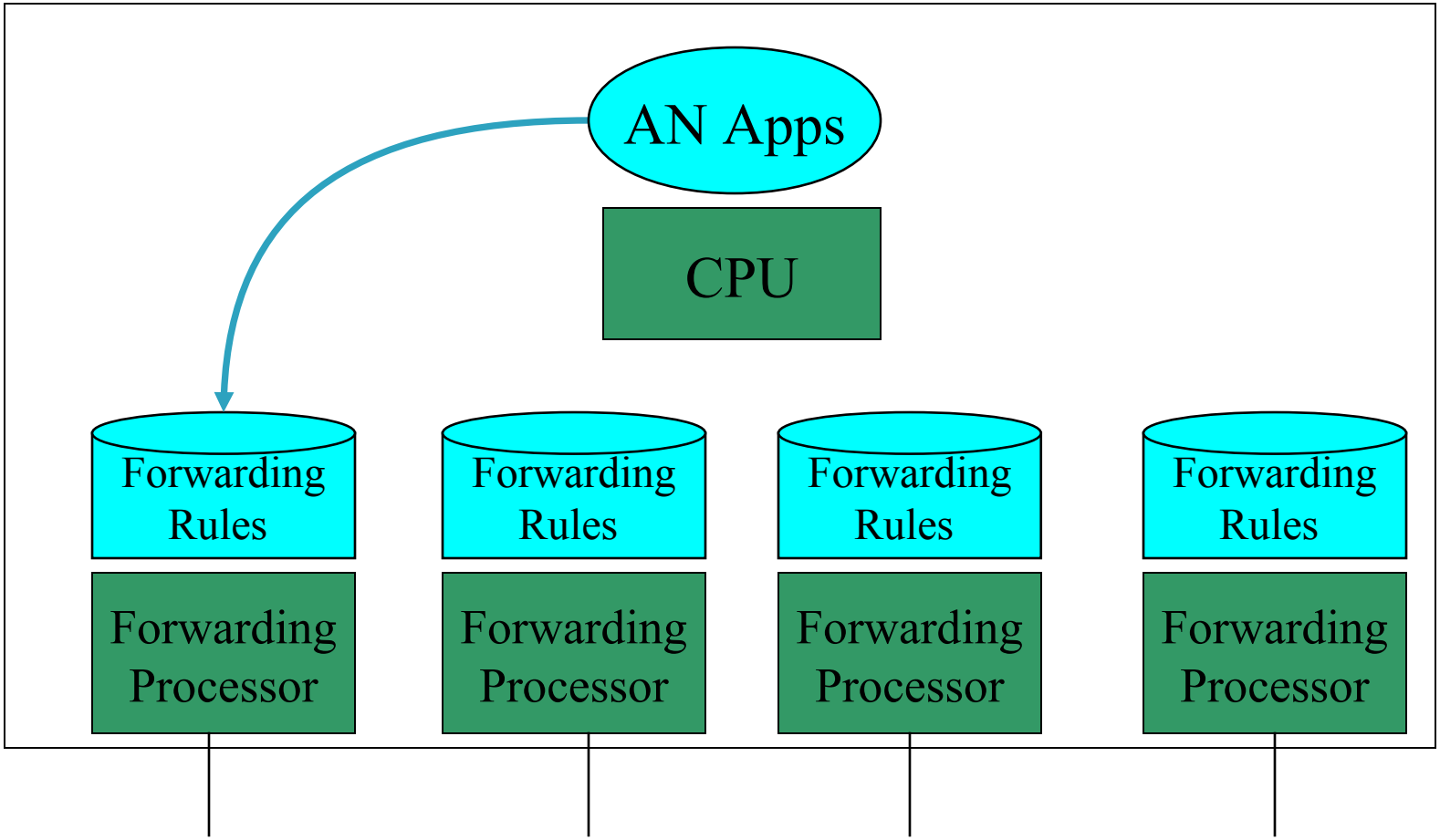


Control separated From forwarding

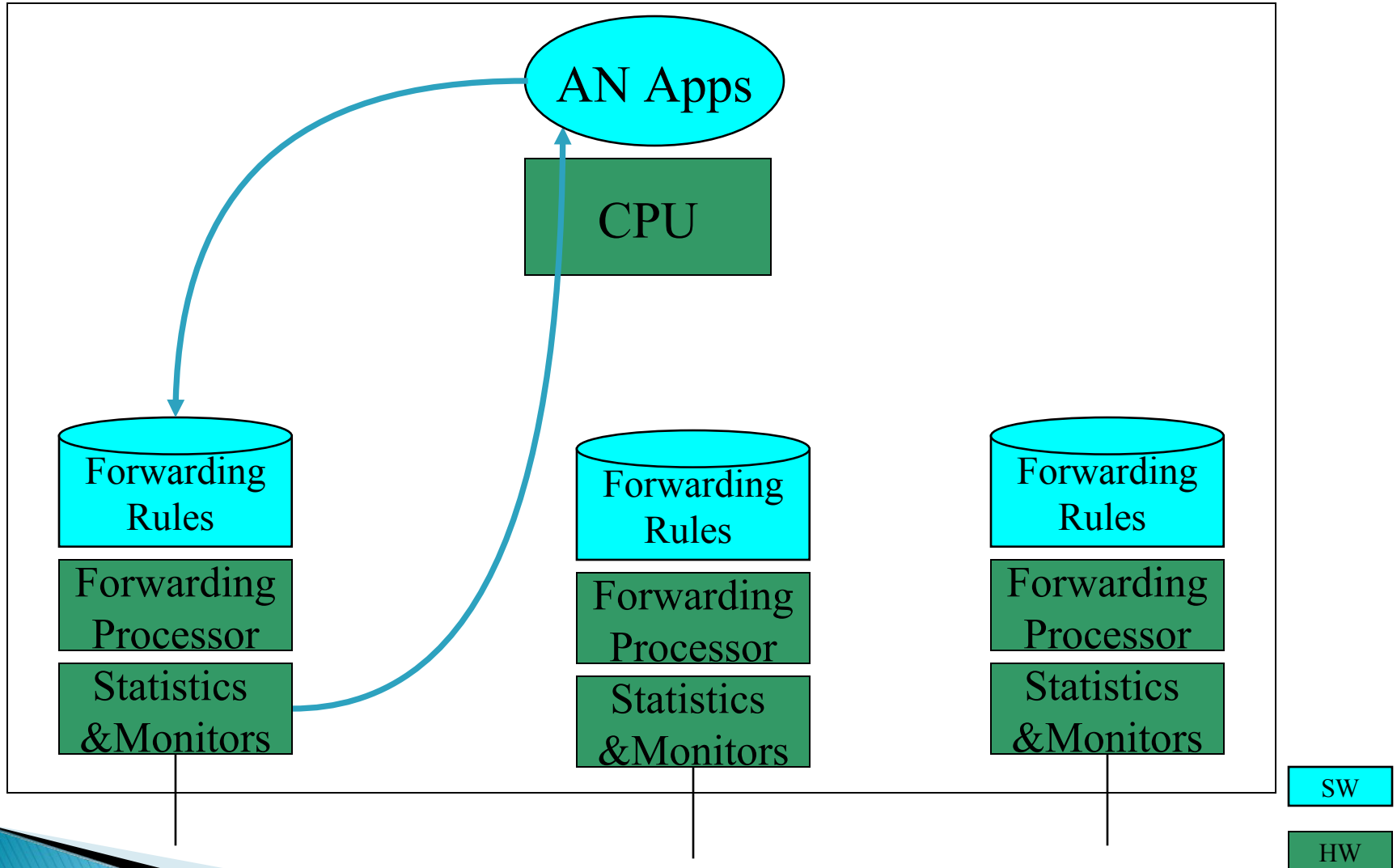
Open Networking Architecture



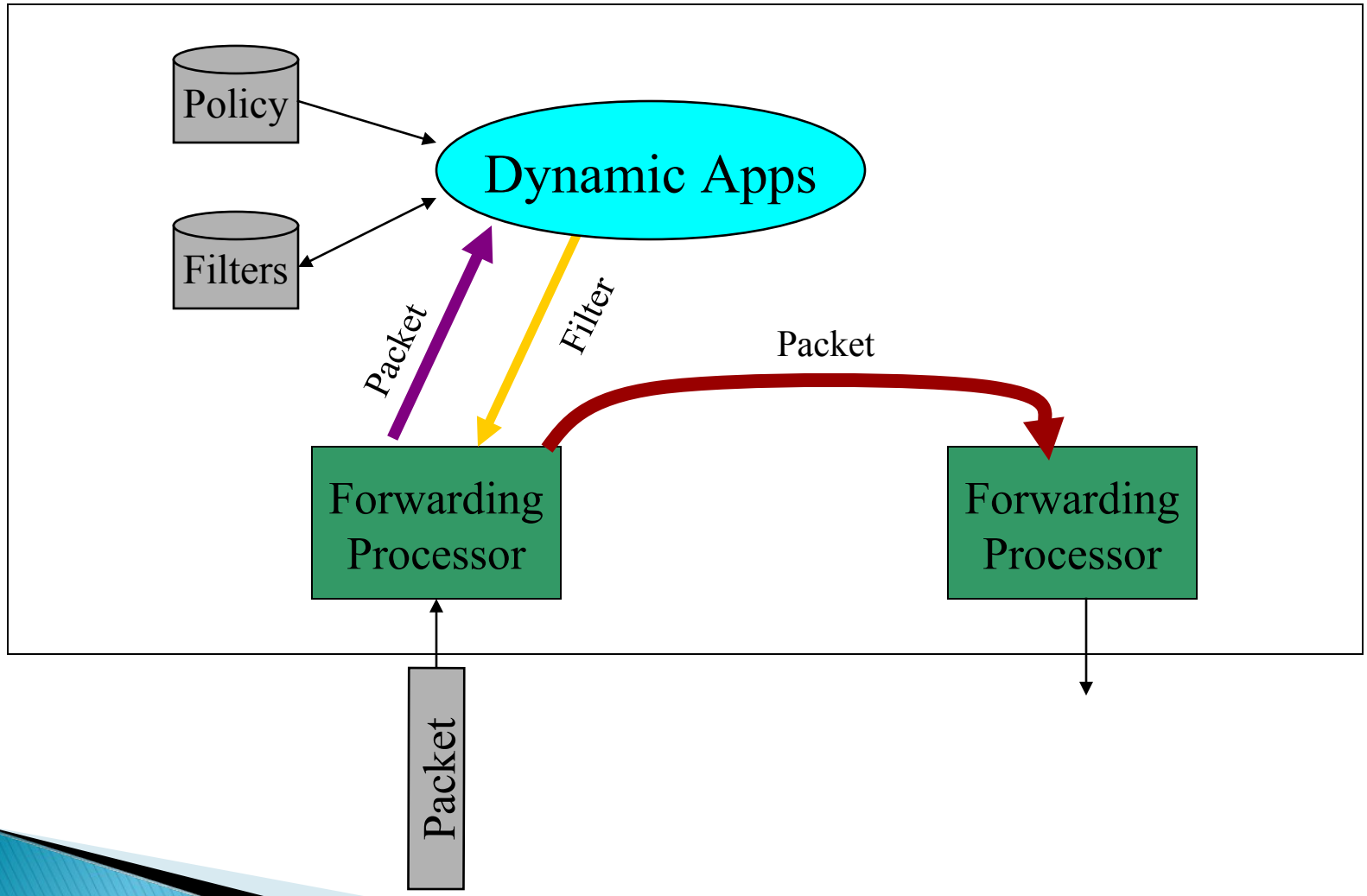
Dynamic Configuration of Forwarding Rules



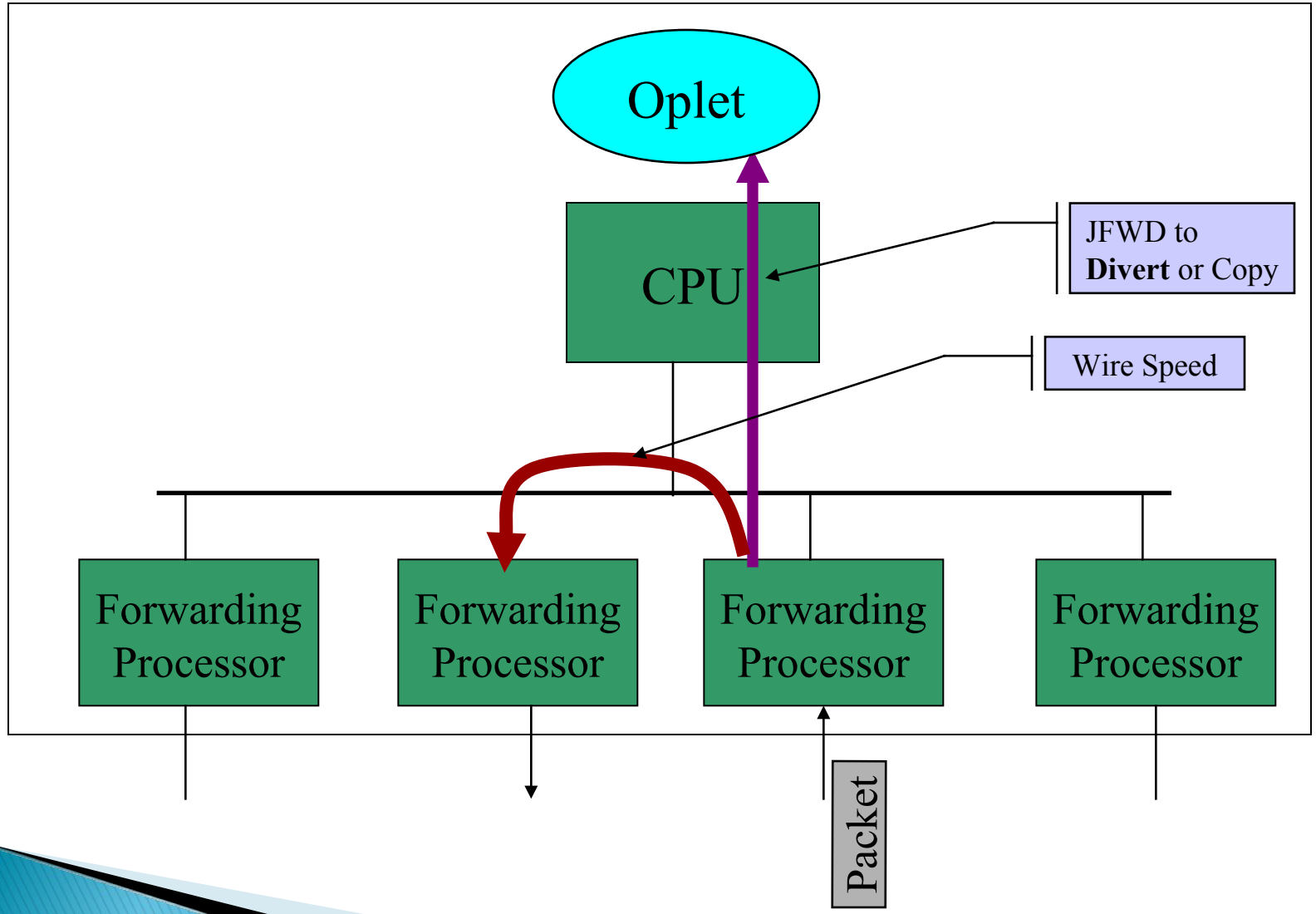
Real-time forwarding Stats and Monitors



Dynamic - On the Fly Configuration



Packet Capture



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

Agenda

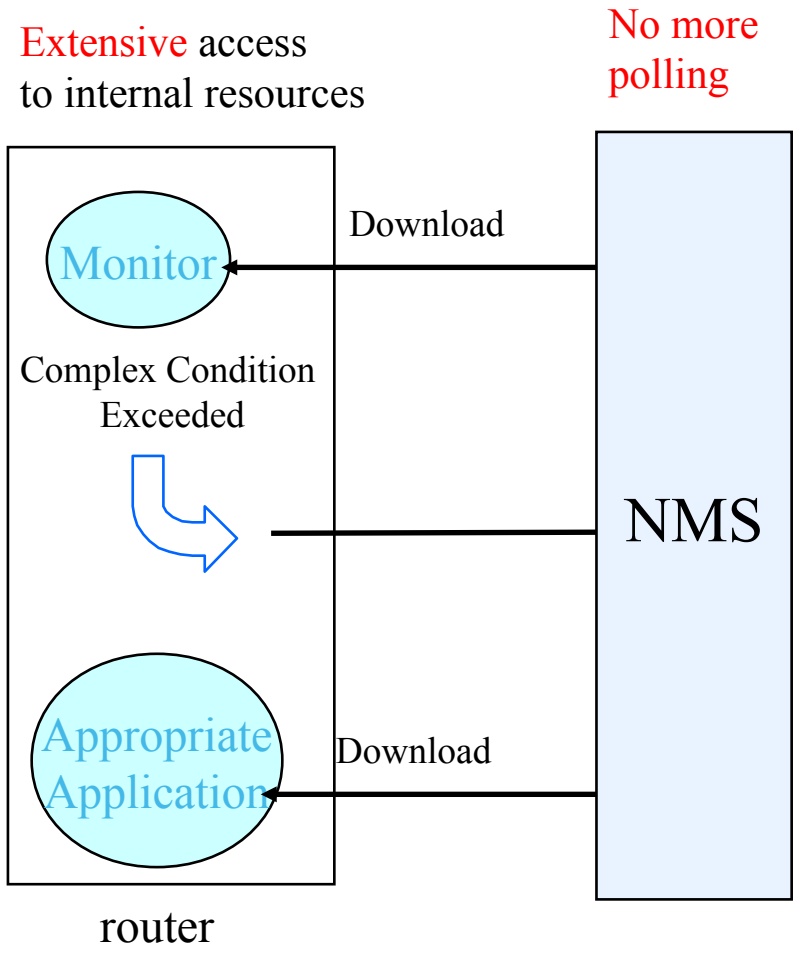
- Our market is changing
- Local Computation
- Architecture
- Applications
- ORE - Oplet Run-time Environment
- API's
- Summary

Applications

- Active Network Management
  - Proactive Network Management
  - Diagnostic Agents
- Dynamic DiffServ Classifier
- Active Intrusion Detection
- Multicast Caching
- IP Accounting
- Application-Layer Router-Server Collaboration
- Pseudo Default Drop Capability

Active Network Management

- Download Oplet Service to the device.
- Monitor MIB variables
  - Might be complex conditions
  - Trend analysis
  - DiffServ, RMON-II, etc… MIBs
- Report “events” to NMS
  - drop rate, packets/second
- Allow Service to take action
- Download application
- Adjust parameters based on direction from NMS



An Open Service API Example

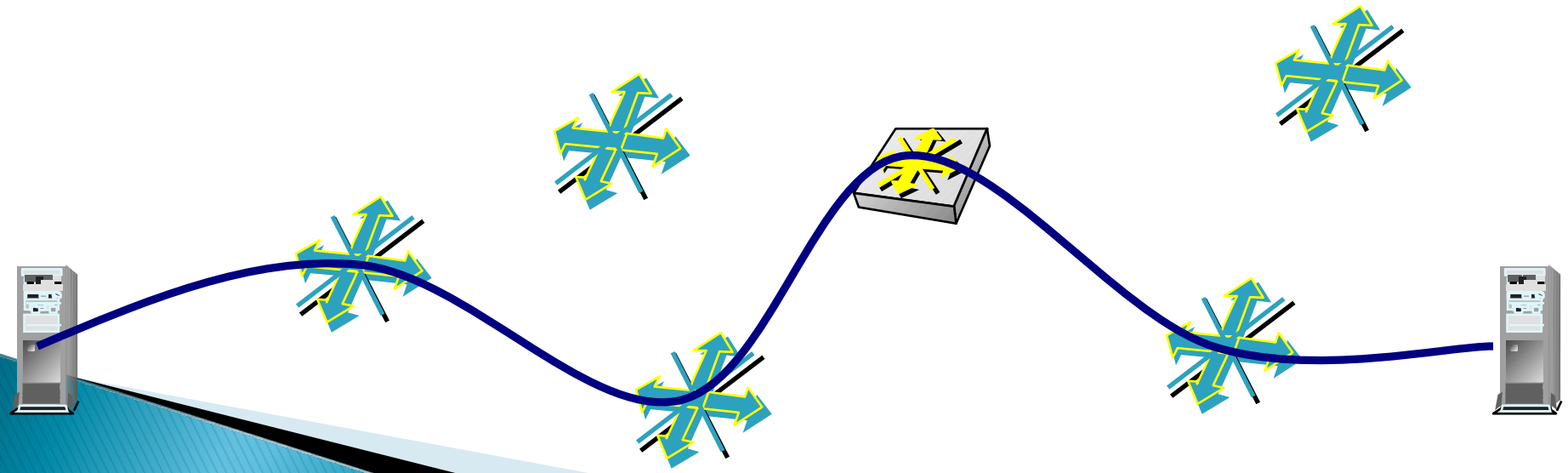
- SNMP API for Network Management
  - generated automatically
  - allows device-based applications to query MIB
  - device-based application -- query local MIB
  - report trends or significant events
  - initiate downloading of problem specific diagnostic code
  - take corrective action

Proactive Network Management

- Device-based Intelligence is Dynamic
  - Static Management
    - SNMP set/get mechanisms
    - Telnet, User Interfaces (cli, web, etc…)
  - Dynamic Closed-loop Management at Network Node
    - capable of dealing with new and difficult situations
    - autonomous and rational properties.
    - dynamically system monitoring & modification
    - report status and trends
  - Monitor MIB to identify poor performance and notify NMS prior to failures
  - Downloaded service can instantiate new services

Diagnostic Mobile Agents

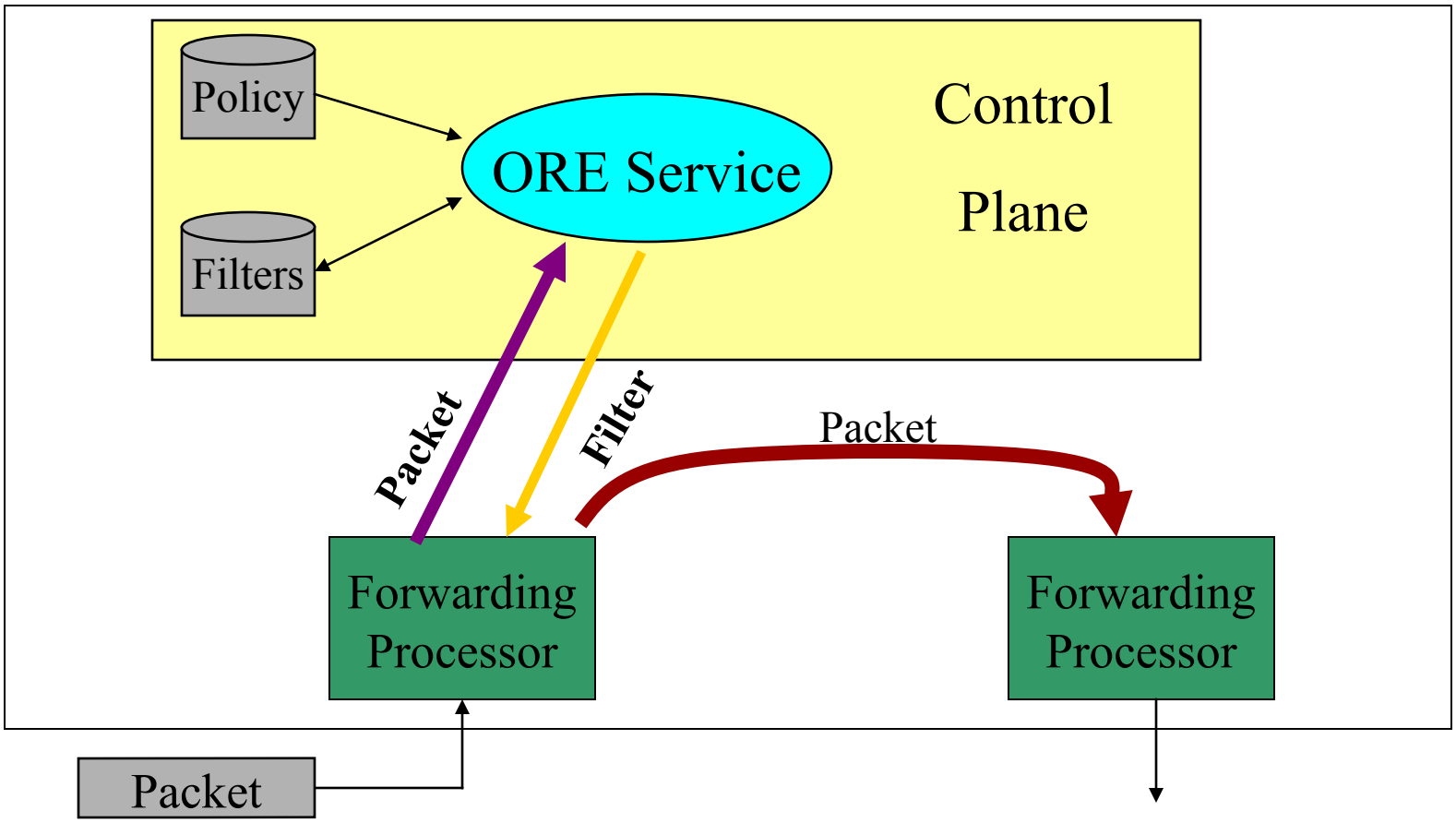
- Automatic trace-route from edge router where problem exists.
  - Each node reached generates a report to NMS
  - Trace-route code “moves” to next node in path
  - Mobile agents identify router health
  - Create logs for NMS



Dynamic DiffServ Classifier

- Set router filters to sample packets from edge device host ports
- Identify real-time traffic (RTP flows)
- Set filter on port to adjust DS-byte value based on policy
- Keep track of filters set
- Remove filters no longer in use

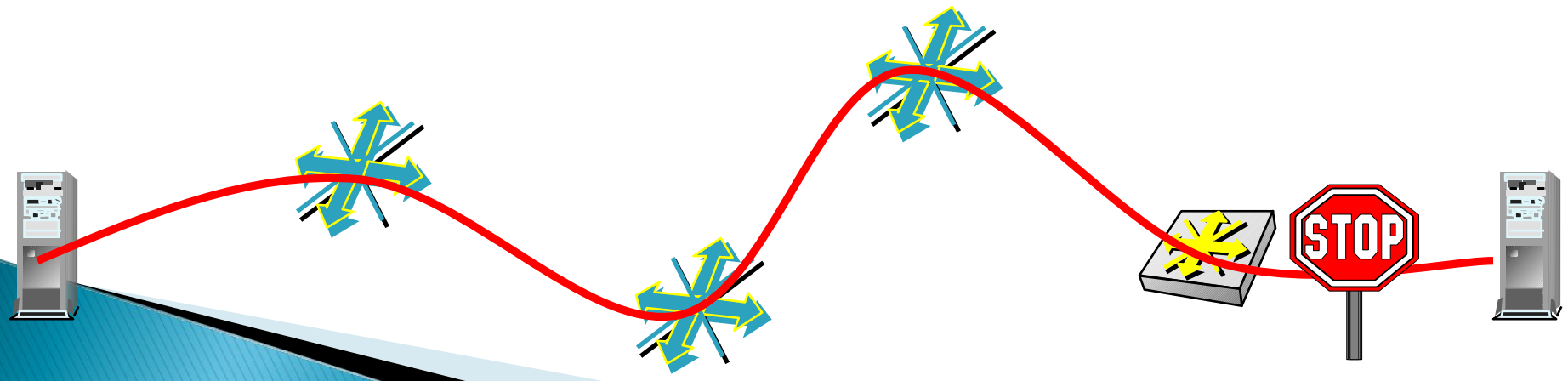
Dynamic DiffServ Classification



- **Sample packets, set filters to modify DS-byte for Per-Hop-Behavior modification**

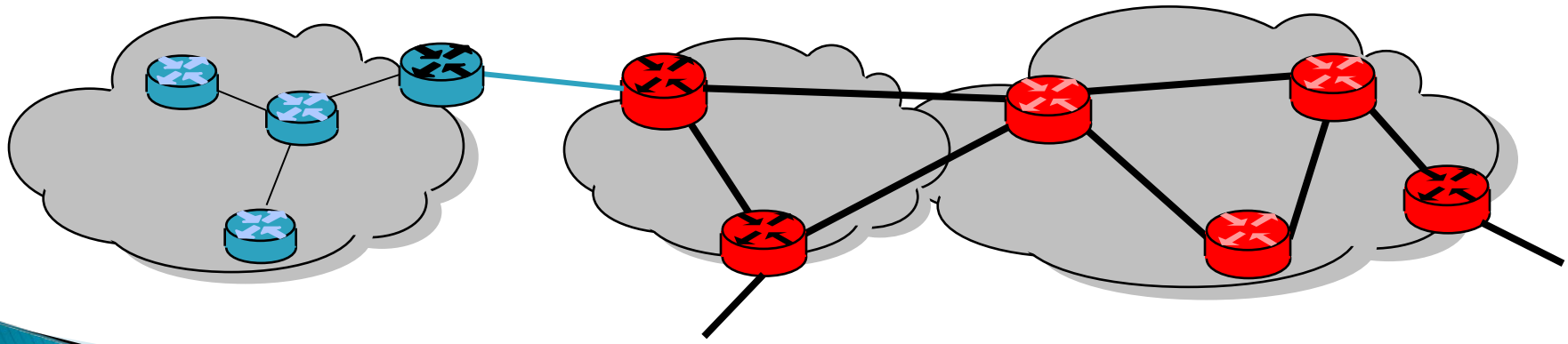
Active Intrusion Detection

- Intruder is identified by Intrusion Detection software
- Intruder signature is identified
- Mobile agent is dispatched in direction of intruder (based on physical port of entry)
- Mobile agent “chases” intruder and terminates him (shuts down link, reboot host, notify NMS)



Multicast Caching

- Reliable Multicasting
- Distribute error control throughout multicast tree
- Retransmission a local node keeps control close to lossy links
- Balances processor load away from multicast source

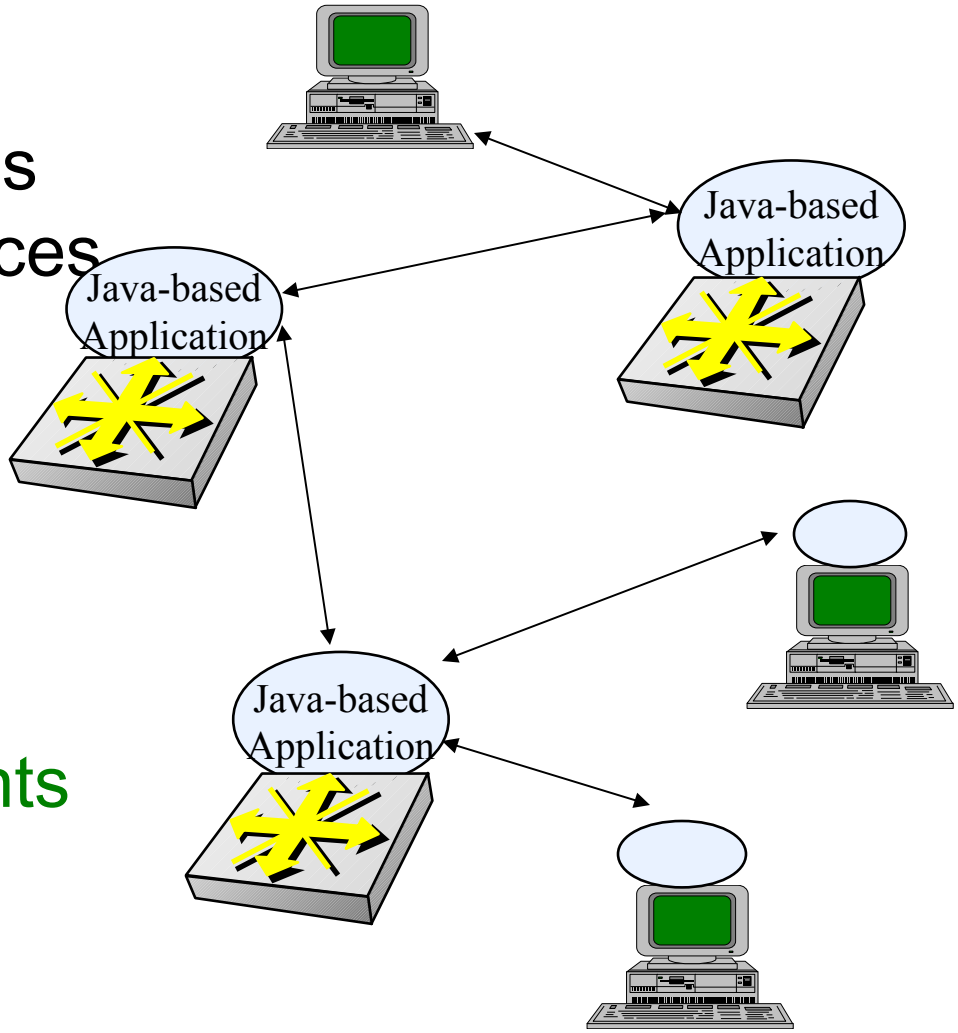


IP Accounting

- Project ABCD (Active Bean Counter in Device)
- Perform usage accounting at edge node
- PreCorrelate/aggregate/reduce accounting record on-site
- $1 rule for billing
- Real-time billing can be realized
- Customize billable resources

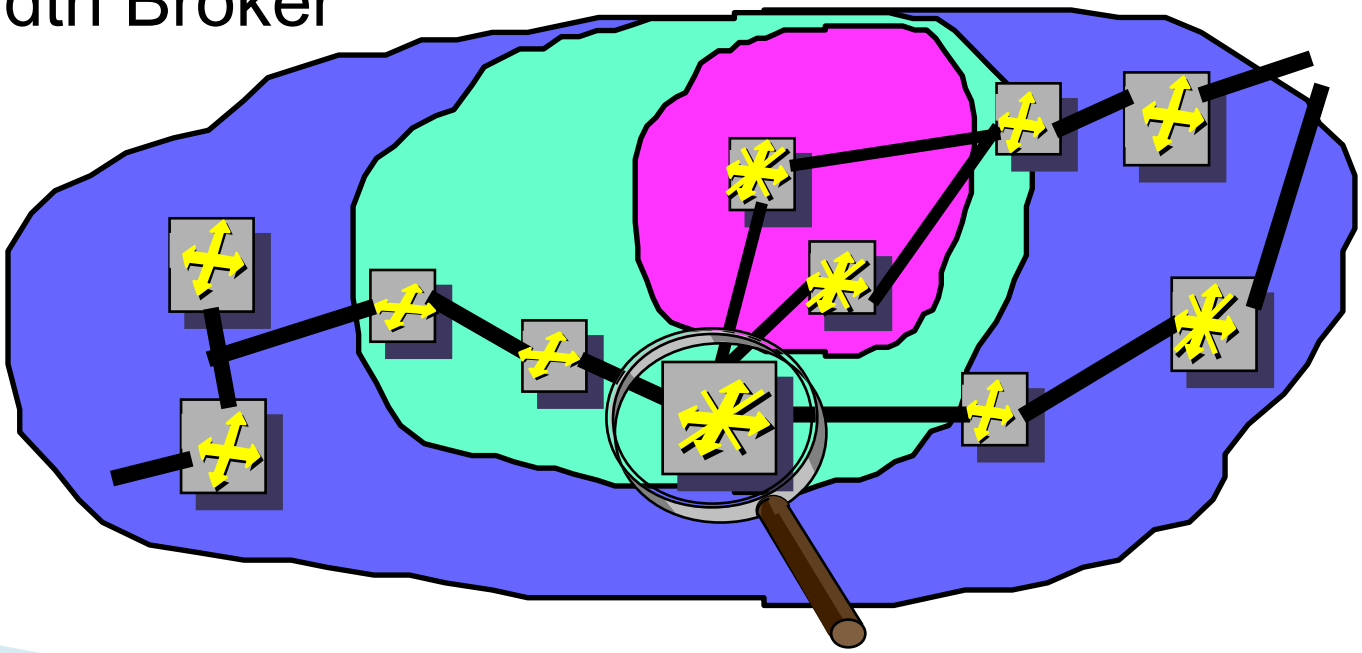
Server Collaboration

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



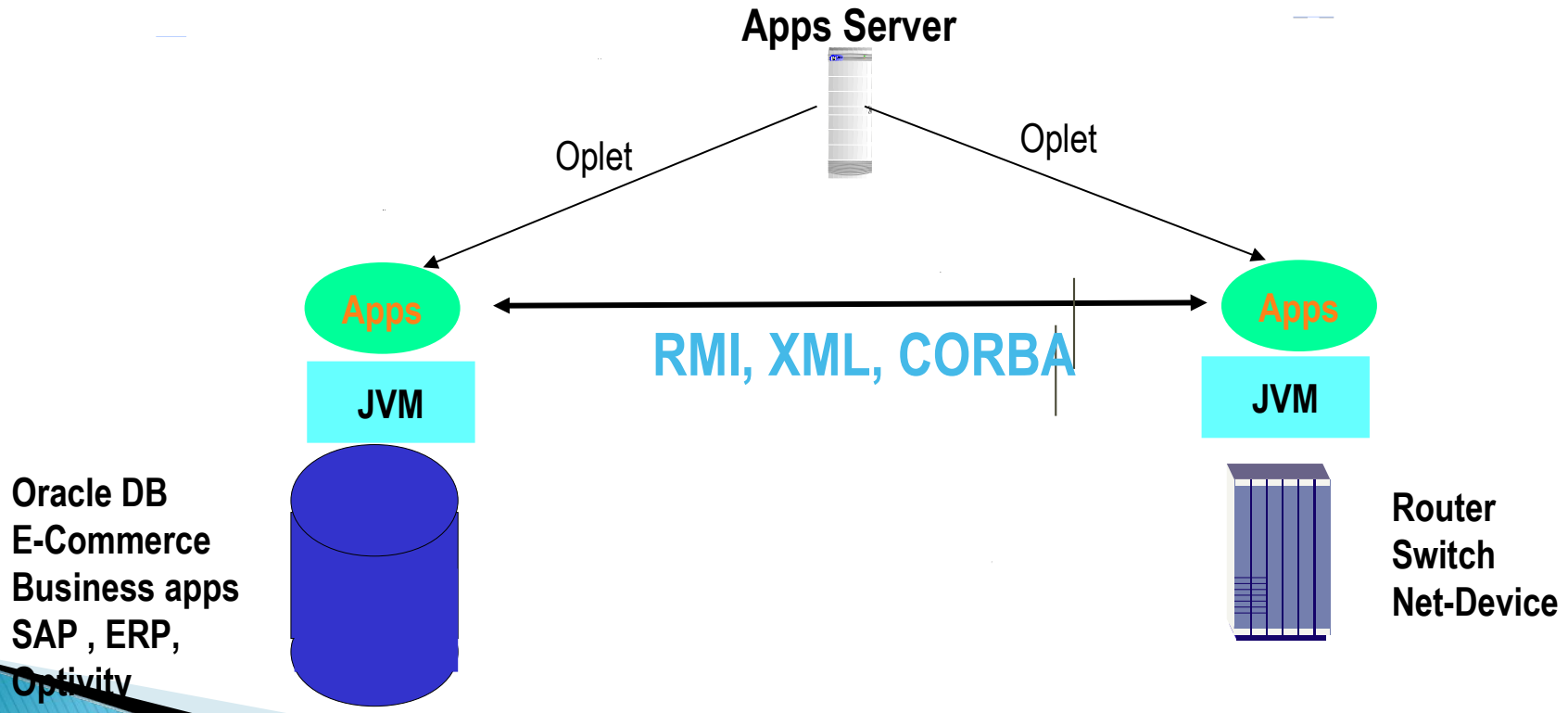
Application Layer Collaboration Among Routers and Servers

- Server farm load balancing
  - server state monitored; rerouting based on congestion/load
- Auctioning Applications
- Bandwidth Broker



Collaboration with Business Applications

- New paradigm of distributed applications
- Network devices collaborating with business applications
- Application aware routing



Bandwidth Broker Collaboration

- Routers Monitor RMON and DIFFSERV MIB
- Report Per-IPAddress, Per Protocol statistic to resource broker
- Adjust DS-byte and Per Hop Behavior based on Bandwidth Broker directions

Dynamic – On the Fly Configuration

- From downloadable Java application, we can modify the behavior of the ASICs

Agenda

- Our market is changing
- Local Computation
- Architecture
- Applications
- ORE - Oplet Run-time Environment
- API's
- Summary

Oplet Runtime Environment – An Overview

- A platform to dynamically deploy services on network elements
- Desirable properties
  - Portable to many different devices
  - Secure, reliable
  - Low impact on device performance
  - Open
  - Provide a framework to structure code
    - Reusable, maintainable, robust
- Implemented in Java

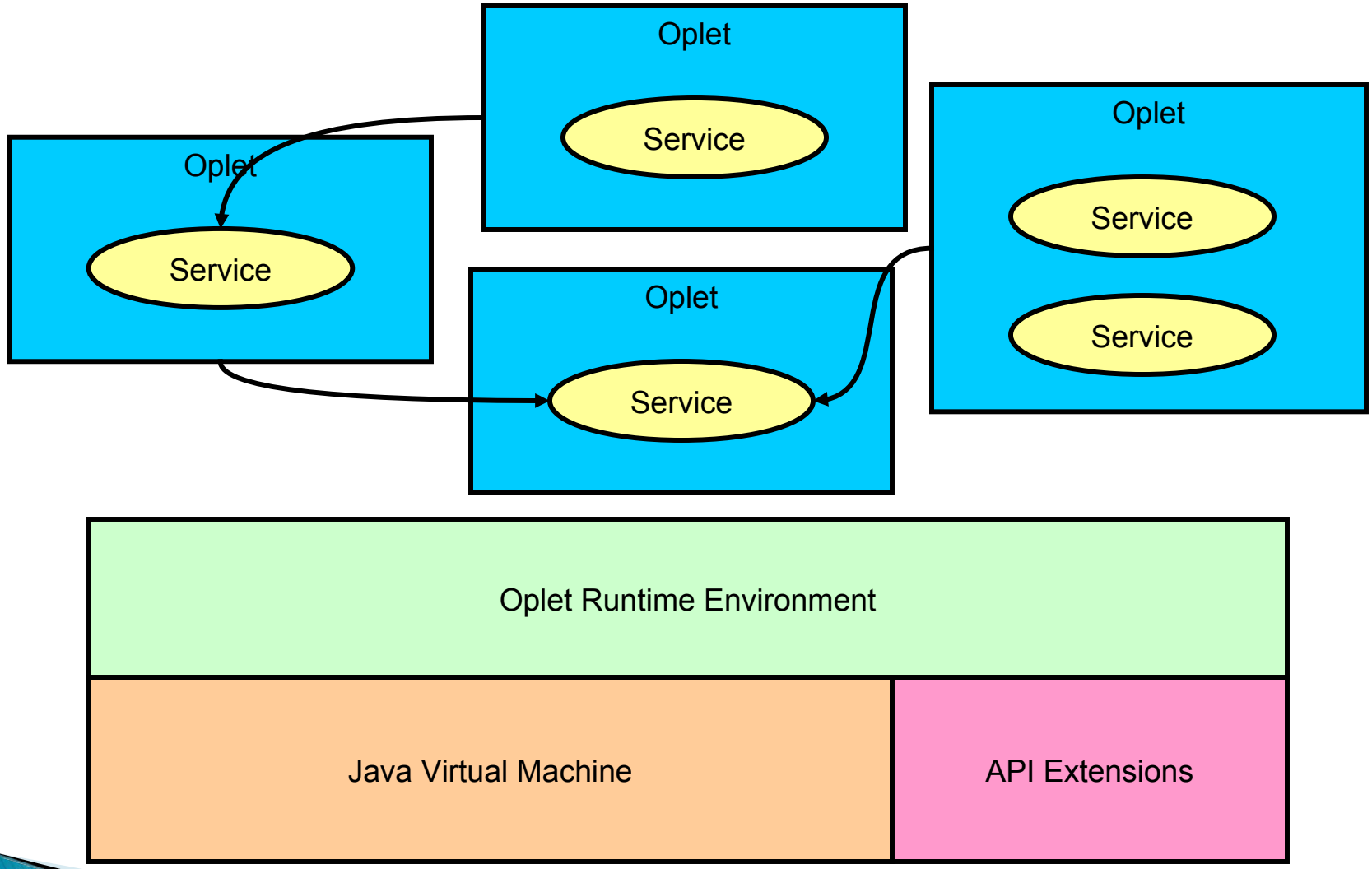
ORE – Basic Concepts

- Oplet Runtime Environment (ORE)
  - A kernel that manages the life cycle of oplets and services
  - Provides a registry of services
- Service
  - The value being added. Minimal constraints, could be anything…
  - Represented as a Java interface
- Oplet
  - The unit of deployment: a JAR file
  - Contains meta-data (eg signatures, dependency declarations)
  - Contains services and other resources (data files, images, properties, JAR files)

Dependencies

- A service S can use facilities provided by another service T
- This means that the oplet containing S has a dependency on service T
- Before an oplet can be started, all of its dependent services must have be started
- ORE manages dependencies and lifecycle of oplets and services

ORE Architecture



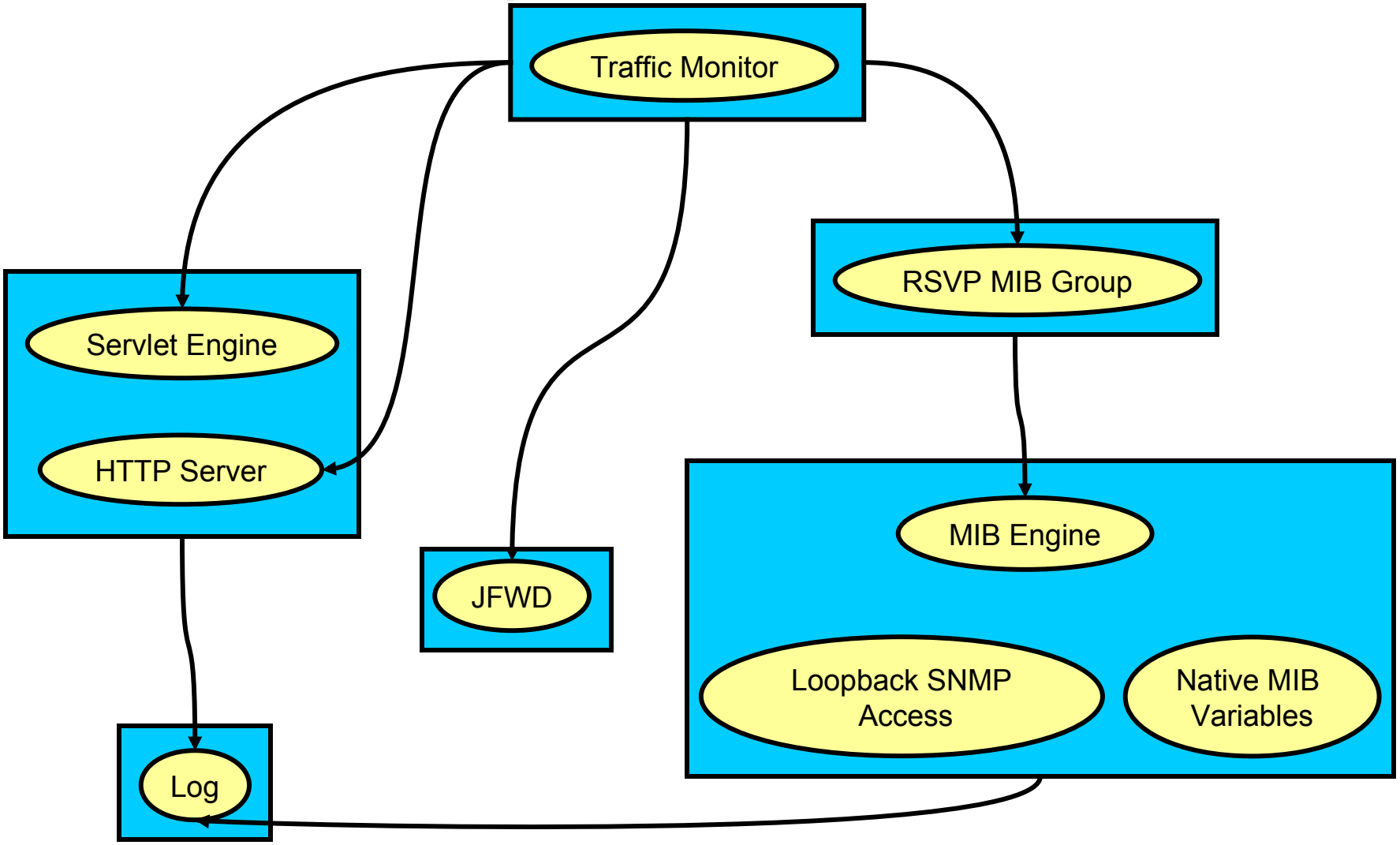
Oplet Lifecycle

- Install
  - Loaded from URL
- Start
  - Services that are depended on must already be started
- Stop
  - Any oplets that depend on this oplet's services will be stopped
  - Code and data can be unloaded from ORE
- Uninstall

Some services

- Bootstrap
  - Basic configuration
- Log
  - Centralized logging for oplets
- HTTP server
  - Simple servlet support
- Command line shell
- Administration commands
  - Manage oplets and services

An Example


Traffic Monitor
Servlet Engine
HTTP Server
JFWD
RSVP MIB Group
MIB Engine
Loopback SNMP Access
Native MIB Variables
Log

Security Issues

- Sandbox
  - Each oplet provides a Java name space and applet-like sandbox
- Signed oplets
  - Oplets can be signed for assigning trust
- Denial of service
  - Vulnerable to DoS (memory, cycle, bandwidth, peristent storage, monitors) like all Java applications

ORE Status

- Done now
  - Runs on Accelar and workstations
  - First release of ORE SDK available internally
- To be done
  - More APIs and services (MIB, JFWD, Wrapper)
  - Security (authentication)
  - Oplet updates
  - Persistent storage

ORE Future work

- Capabilities
  - Revocable services
- Security
  - Java 2 style permissions
- Resource limits, DoS protection
  - Probably requires support from JVM
- Jini, Oplet Directory
- Mobile Agents
- Open source

Agenda

- Our market is changing
- Local Computation
- Architecture
- Applications
- ORE - Oplet Run-time Environment
- API's
- Summary

Initial APIs

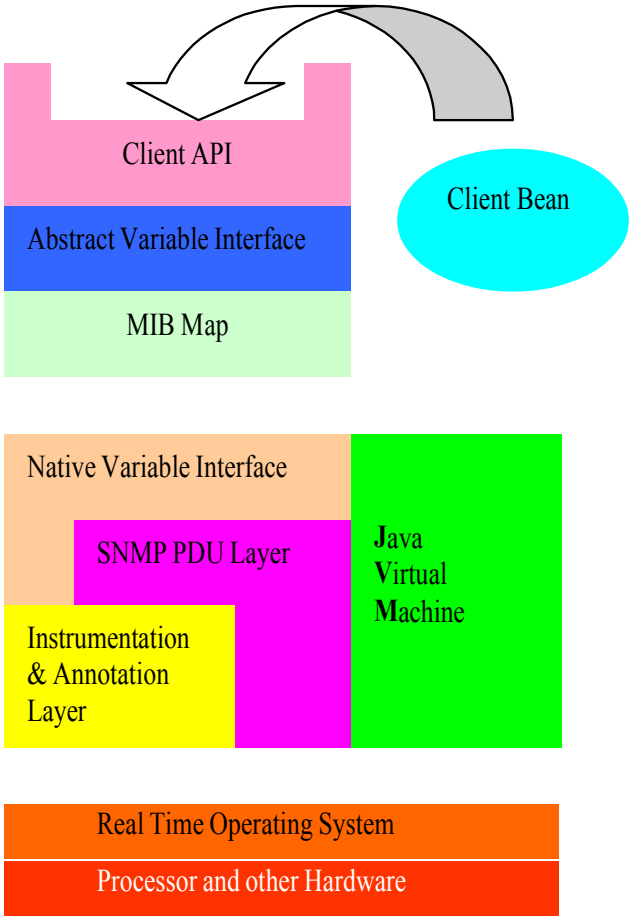
- Console Logging API
- Generic MIB Access API
- Optimized MIB Access APIs
- Trap Interception API
- Management Authentication API
- Web-Based Management Extensions API
- CLI Extensions API
- MIB Extensions API
- Pluggable Authentication API
- Network Forwarding API

Tools

- MIB API
  - Monitor device Management Information Base variables
    - MIB
    - RMON and RMON-II
    - DiffServ
- Network API (JFWD)
  - Interface to Filters
    - set packet drop filters
    - intercept packets
    - carbon copy packets while forwarding at line-speed

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

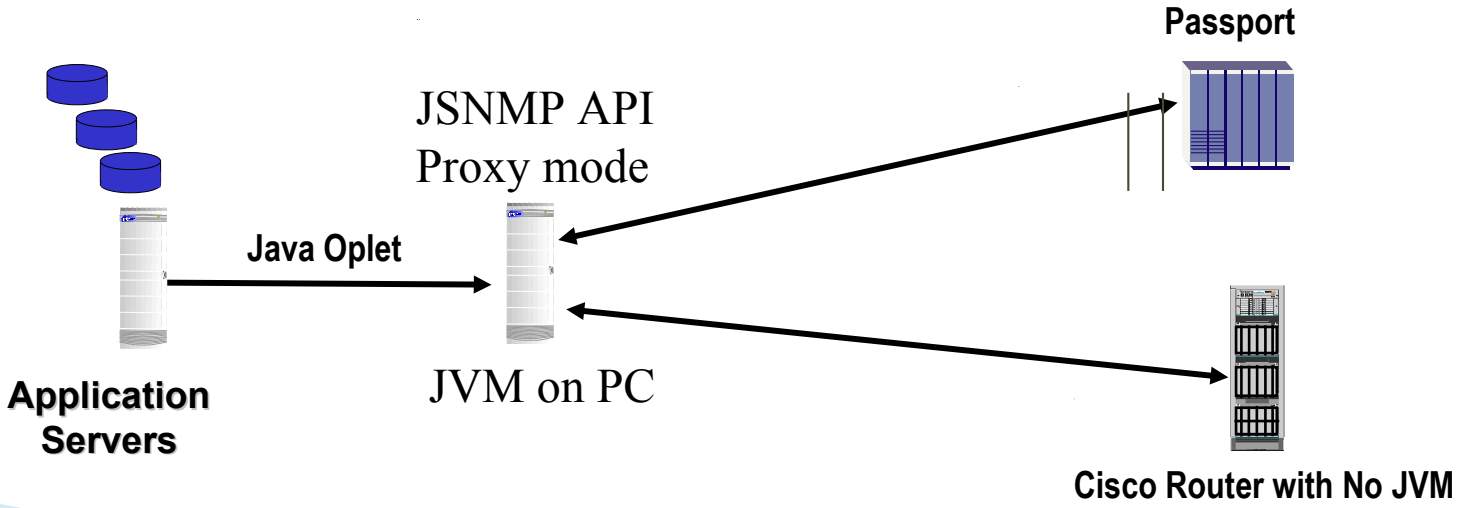


An Open Service API Example

- 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

Java MIB API – Proxy Mode

- **Uses SNMP loopback mechanism to target a remote network element**
- **API can be used to control devices that don't have an embedded JVM**



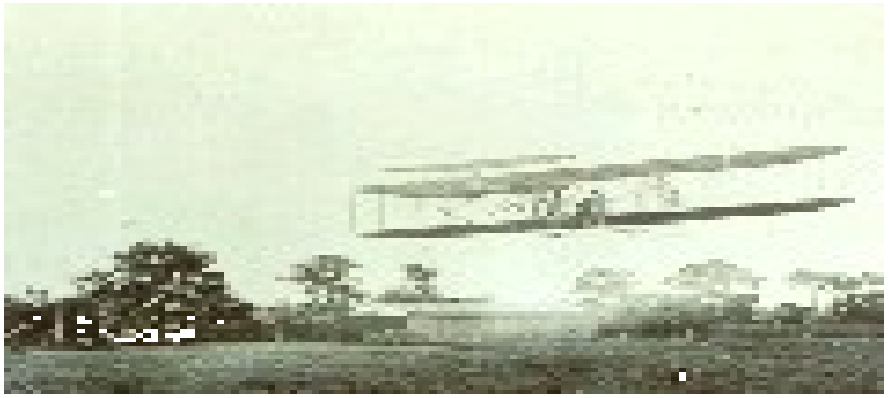
Agenda

- Our market is changing
- Local Computation
- Architecture
- New types of applications
- ORE - Oplet Run-time Environment
- API's
- Summary

Summary

- Programmable
  - Turing Machine on network devices
  - *dynamic* agents vs. *static* agents
  - dynamic loading
- Our market is changing
- Openness - successfully proven paradigm
  - Facilitates innovation
  - Domain experts - virtual development community
  - With 3rd parties we can change the networking landscape
- Application aware routing

This is only the first step



1903 the Wright brothers

Compare to this first flight and look where aviation is today

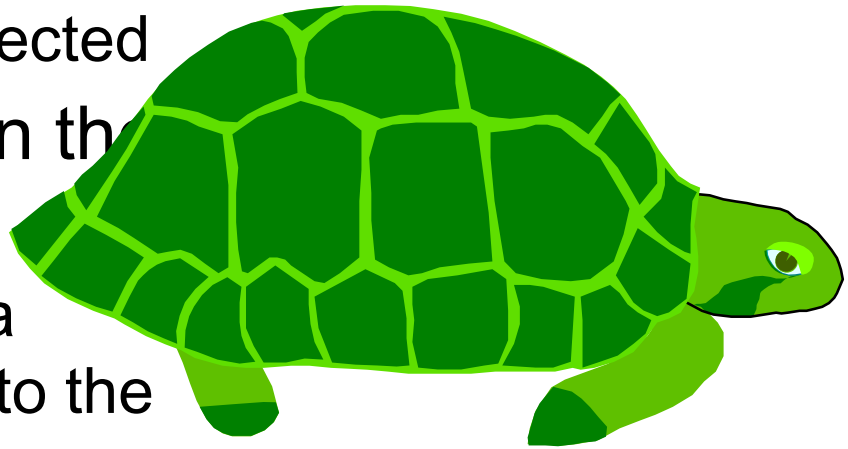
Appendix

Why Java

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

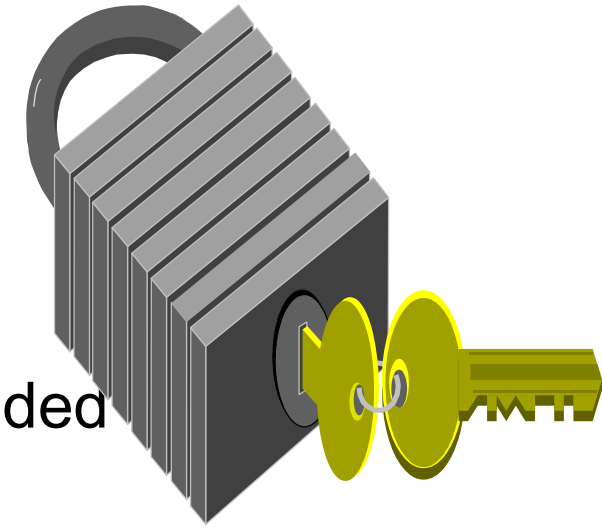
But Java is slooowwwww

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



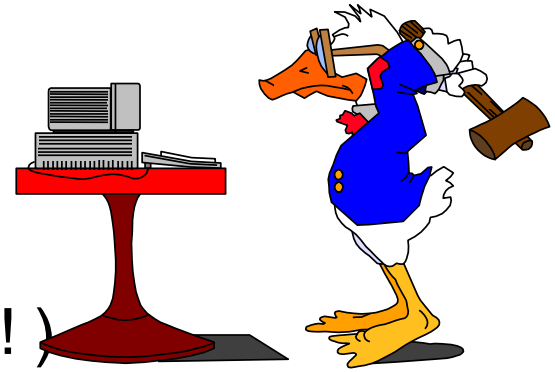
Strong Security in the new model

- 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



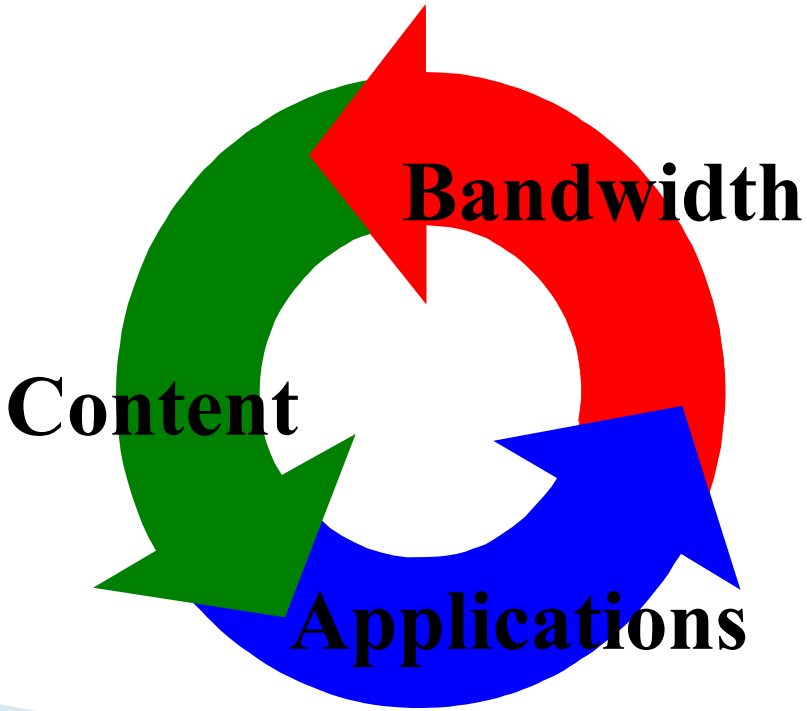
Old model Security (C/C++)

- 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

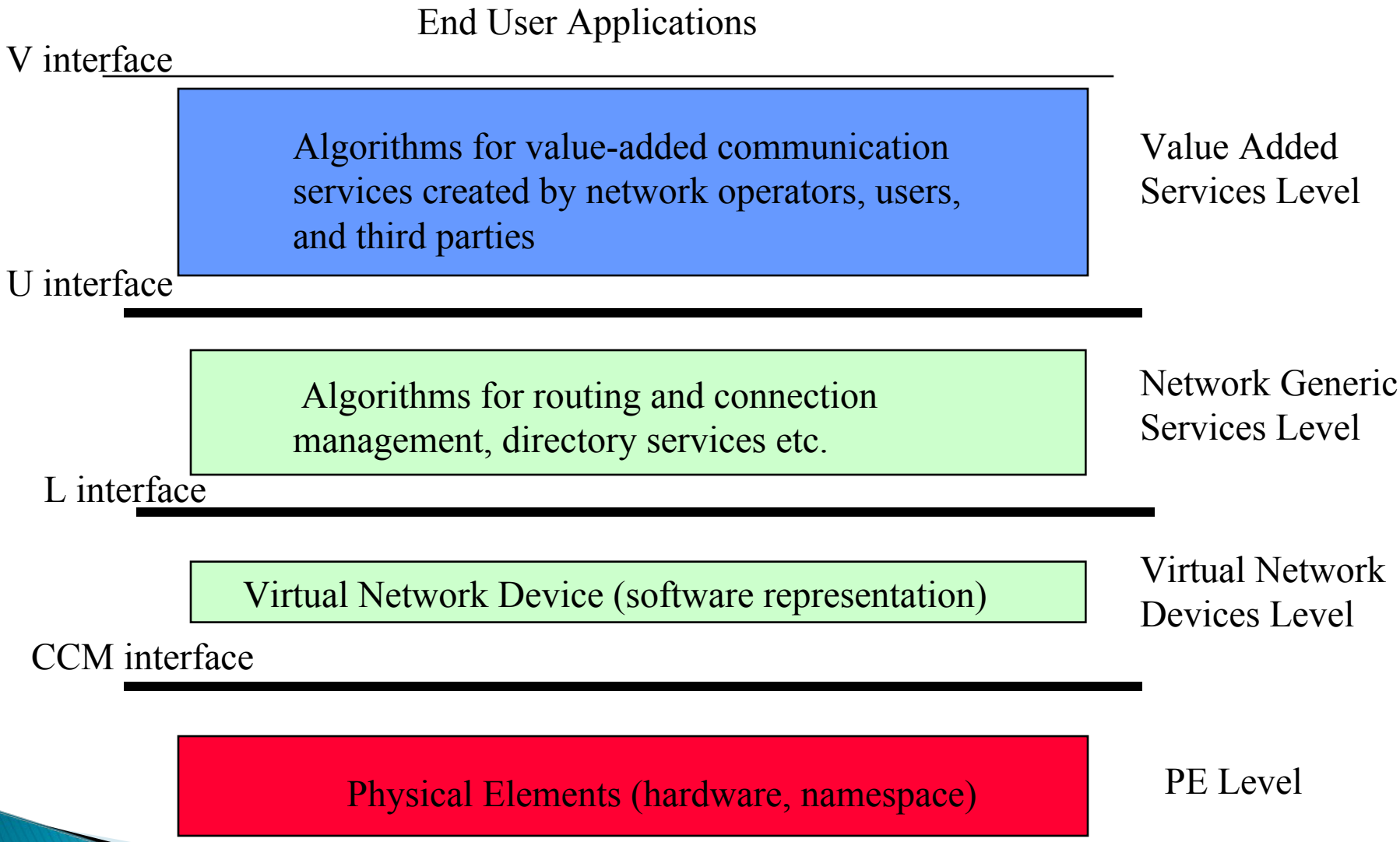


Bandwidth x200 – start of new demand

- Intel web hosting - BIG pipes
- Last mile bandwidth x 200
- Multimedia and new applications will drive the demand.



The P1520 Reference Model



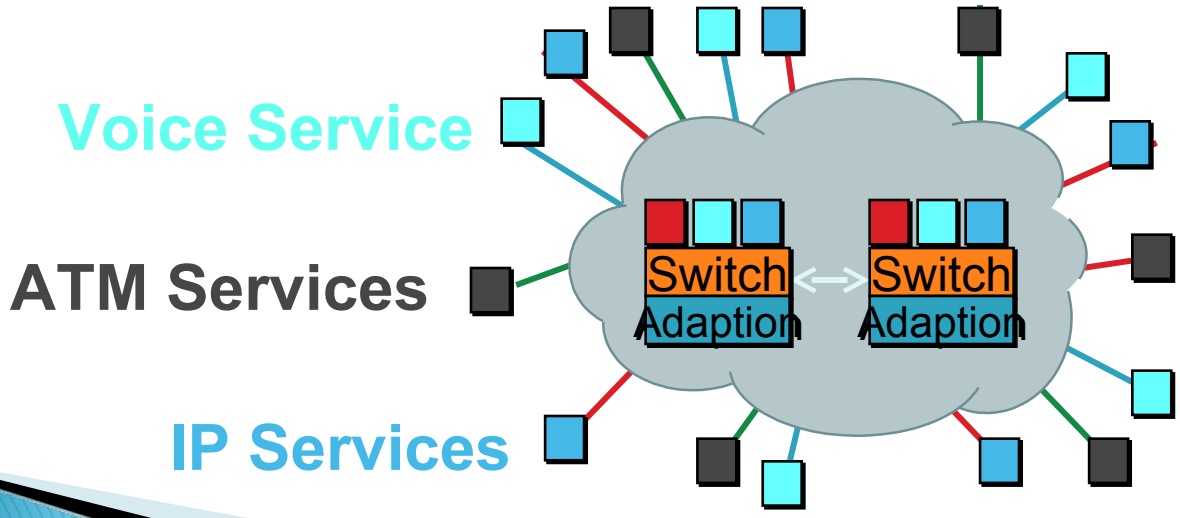
CSIX Consortium

- Common switch interface for switch fabric independence
  - www.csix.org
  - Detailed interface specification between port/packet processor logic and interconnect fabric logic
  - Similar to common media interface such as Utopia, but for switch fabric interface
  - Targeted at scalable switches at higher end
  - Permits mix-and-match of silicon and software components

Multi-Services Switching Forum (MSF)

www.msforum.org

- Open Multi-service Switching
  - Common transmission and switching infrastructure
  - Modular, layered architecture
  - Integration at a module level through open interfaces
  - Multi-vendor model with 3rd party software options



Source: MSS