Bowman: A Node OS for Active Networks

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Outline

- Background - Active Networking
- Bowman System Design
- Performance Measurements
- Configuration for Active Networking
- Concluding Remarks

Active Networking: What

- Programmable user-network interface(s)
- Control via:
  - mobile code in packets (capsules)
  - mobile code fetched from code repositories, based on packet header values
  - programmable signaling protocols
  - selection from set of fixed behaviors

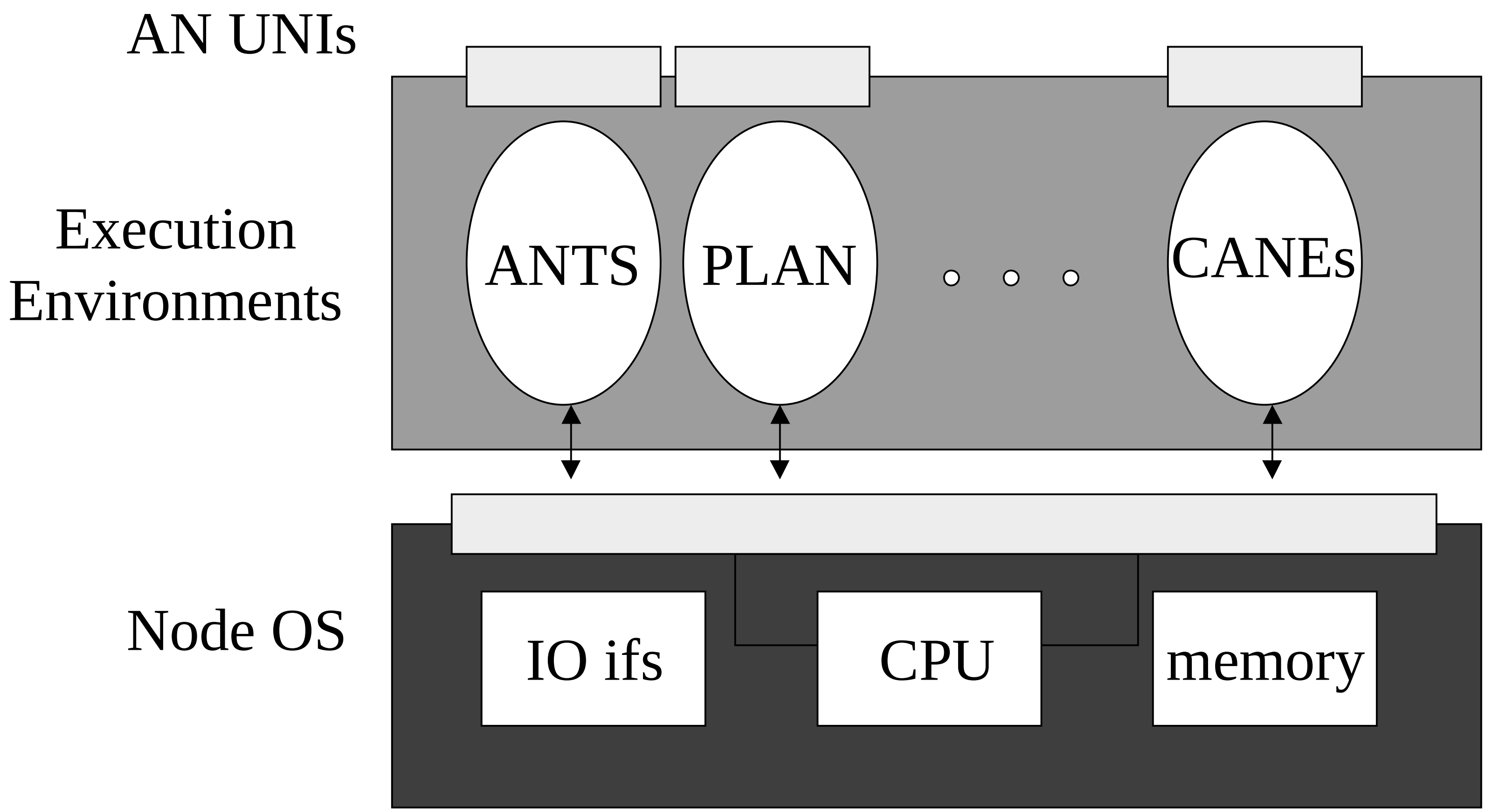
$\rightarrow$ Multiple *execution environments*

Active Networking: Why

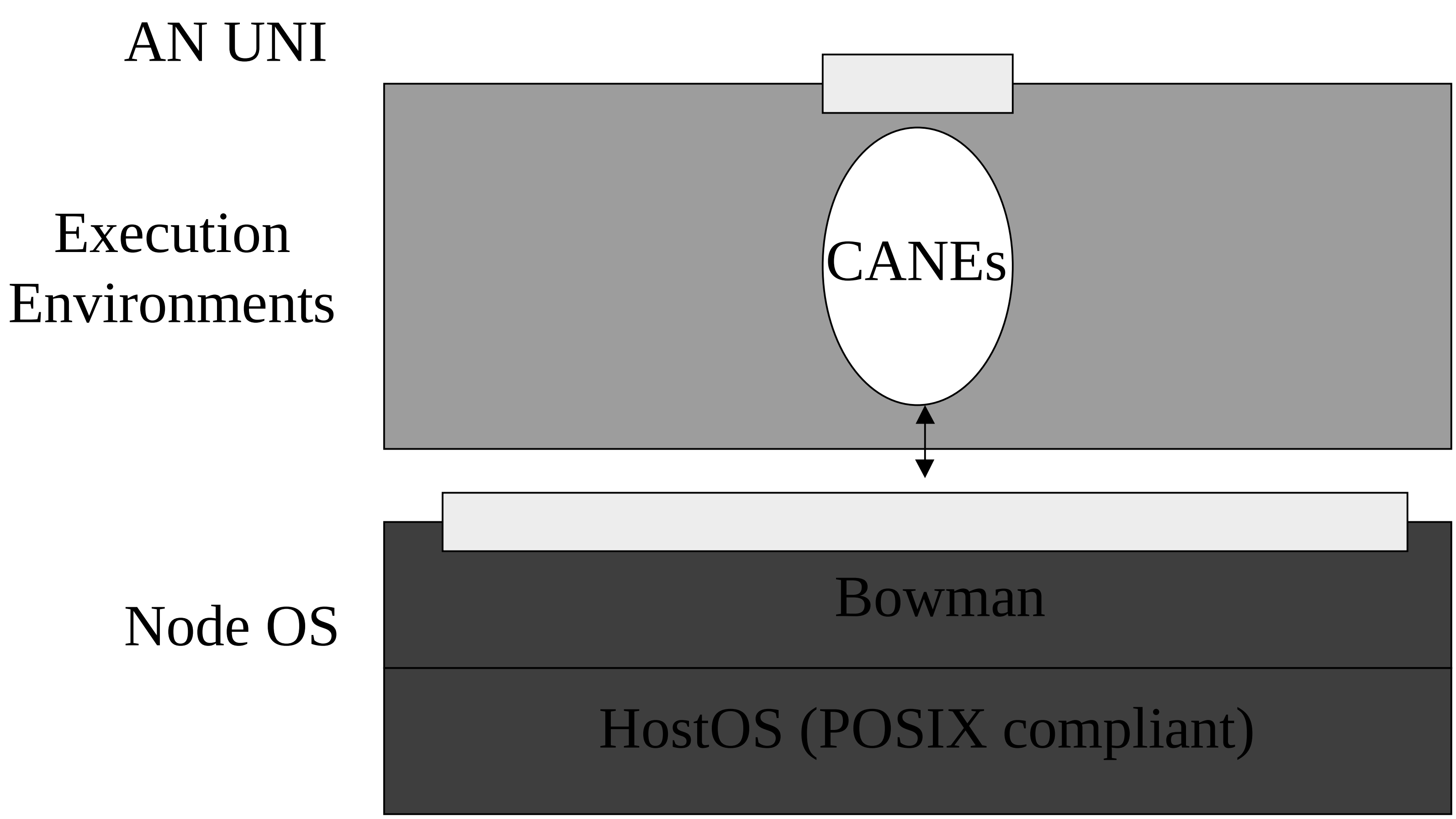
- Faster deployment of new protocols and services
- Platform for research
- Services that exploit app and network knowledge
  - reliable multicast
  - application-specific congestion control, e.g., MPEG
  - network caching
  - network monitoring

$\rightarrow$ High performance, access to low-level resources

DARPA Node Architecture



Bowman (and CANEs)



Bowman Design Goals

- Support per-flow processing
- Provide a fast path
- Enable a network-wide architecture
- Maintain reasonable performance
- Provide modularity and extensibility
- Leverage existing Host OS

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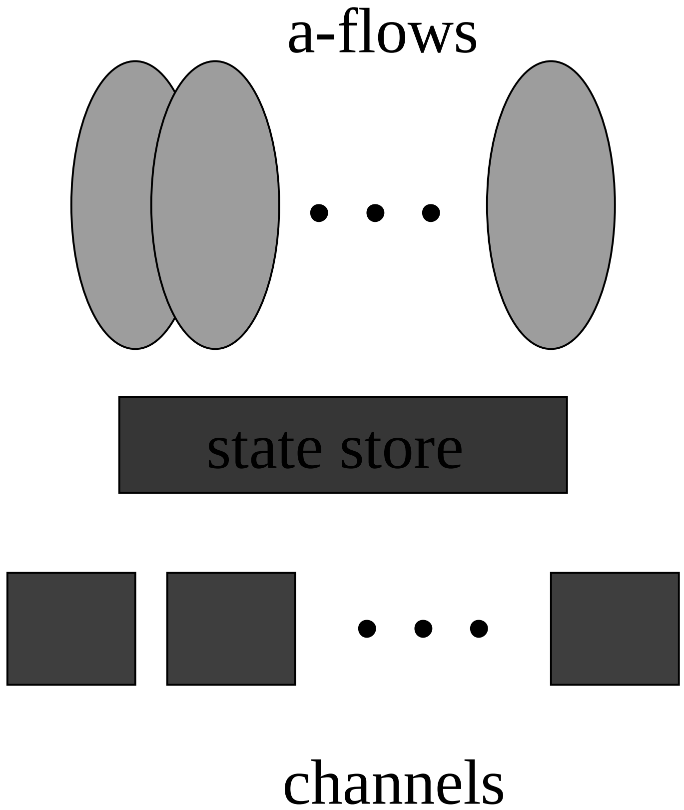
Primary Bowman Abstractions

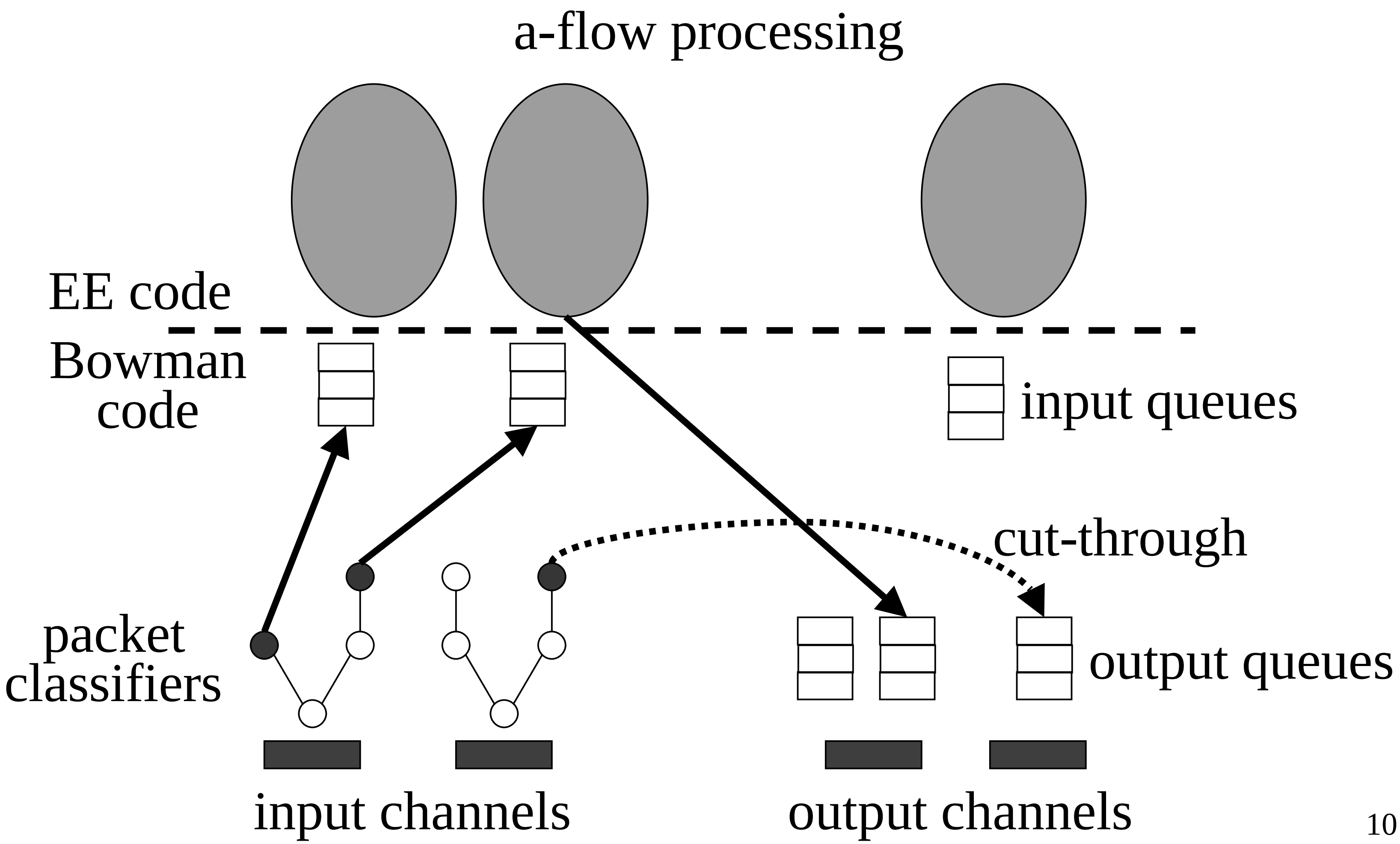
- Channels
  - communication endpoints
  - include protocol processing
- A-flows
  - computation
- State store
  - indexed by a unique key
  - includes named registries for data sharing between a-flows



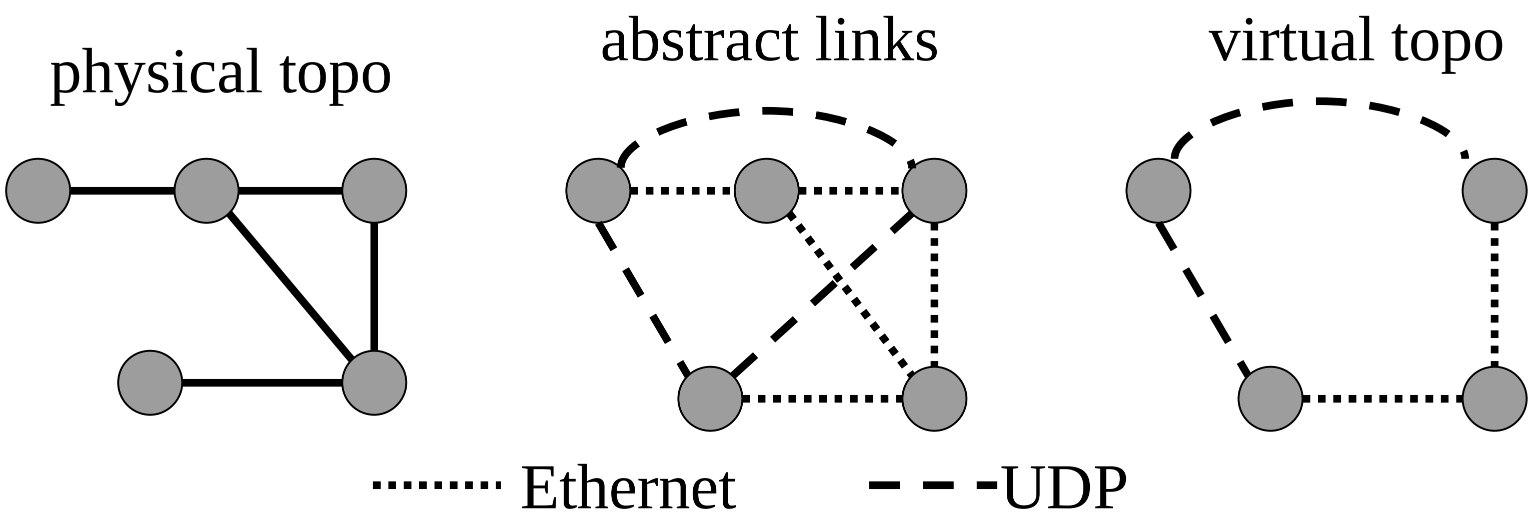
Additional Components

- Dynamic extension mechanism
- Efficient packet classifier
  - match arbitrary number of header fields
  - returns first, all, or best match (with costs associated with each field)
  - dynamically extensible to different protocols
- Timers
- Network architecture via abstract topologies

Packet Processing Path

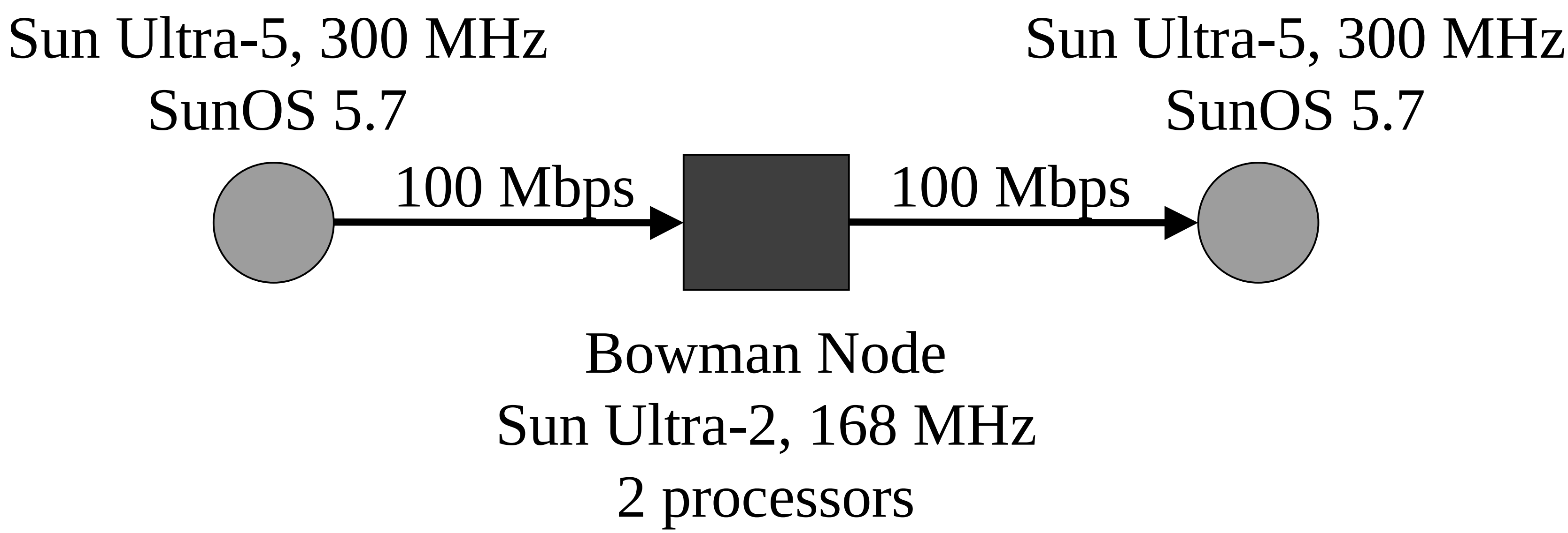


Bowman Network Architecture



- Configure abstract links: endpoints plus protocol processing over physical topology (ALP)
- Select set of abstract links for virtual topology (ATP)

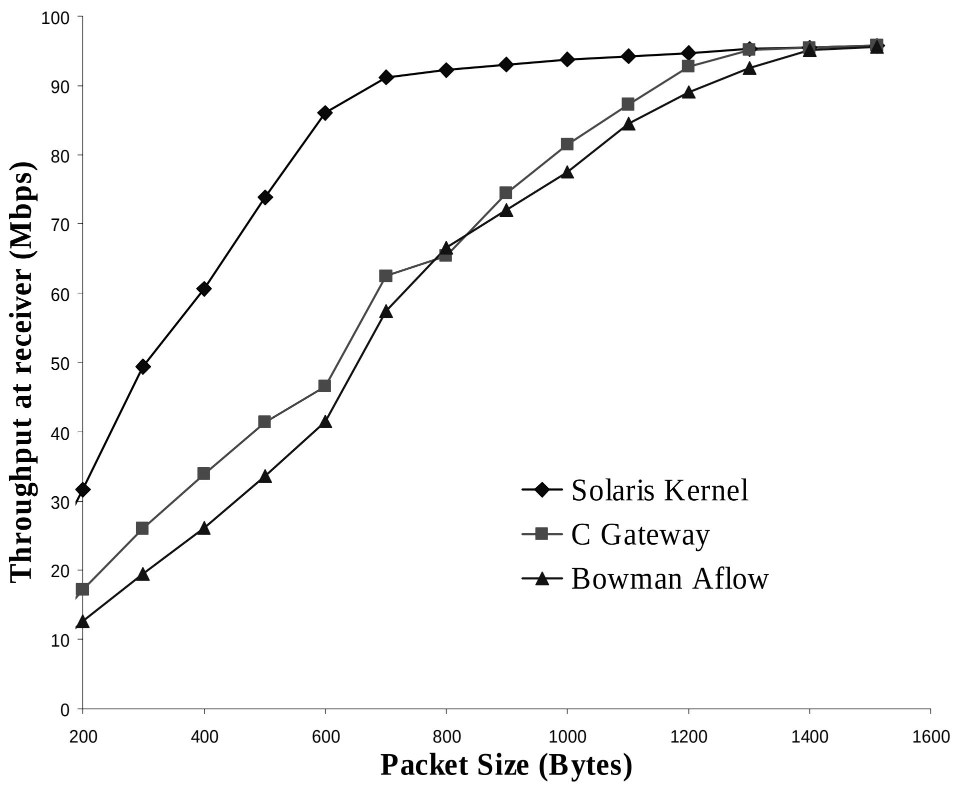
Performance Testing



Compare to:

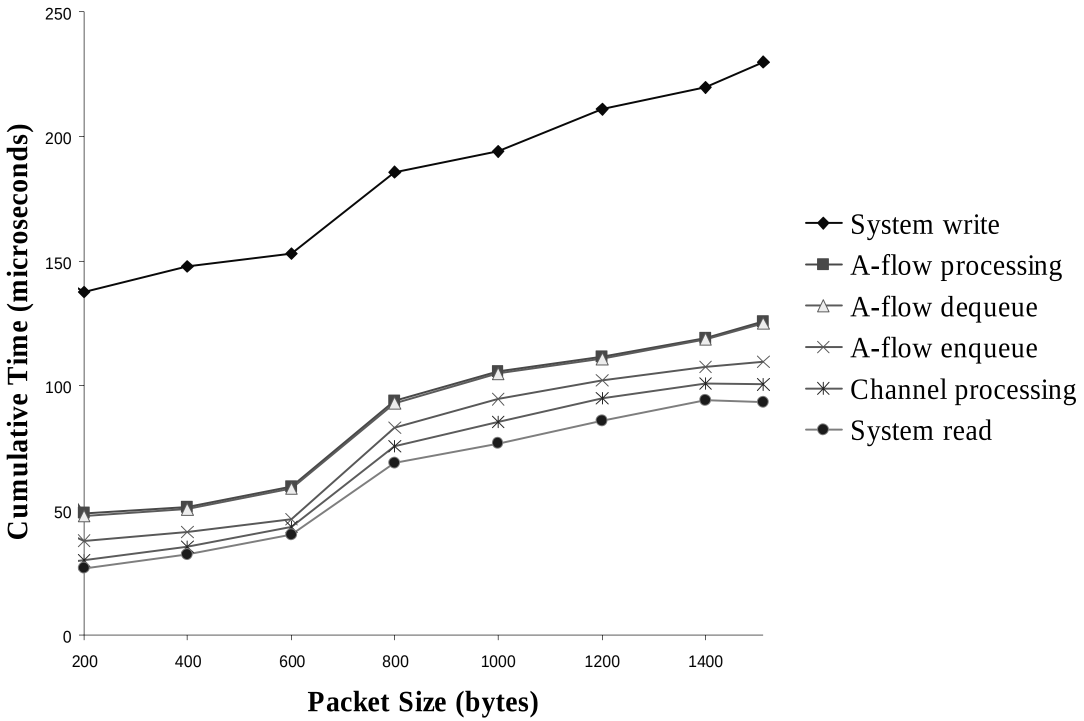
- Solaris kernel forwarding
- C gateway -- socket read/write of UDP segments

Forwarding Performance



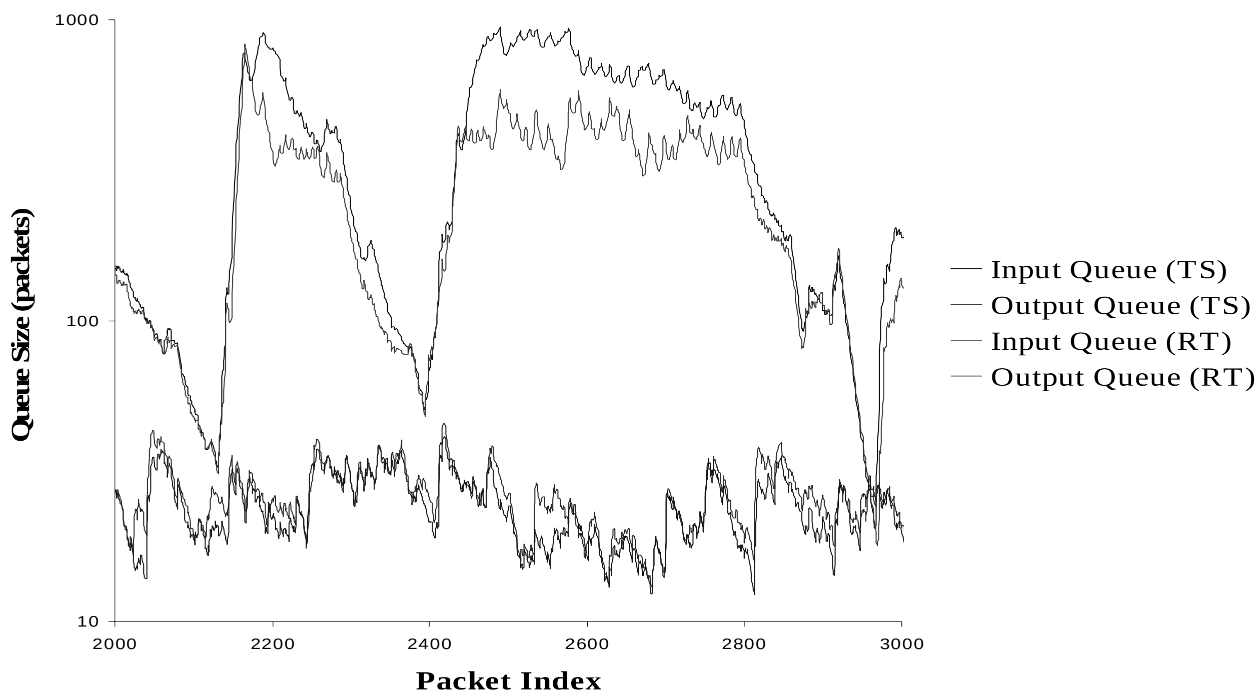
Saturates 100 Mbps Ethernet for packets over 1400 bytes

Packet Processing Overheads



Bowman overhead relatively constant (~25 usec)
System read and write calls dominate processing time

Effect of Real-time Scheduling



Comparison of time-sharing (TS) to real-time (RT) mode
Three kernel threads: input, a-flow, output

Configuration for AN

- Monolithic approach
  - EE creates exactly one a-flow that subscribes to all packets addressed to EE
  - EE manages own resources
- Multi-a-flow approach (CANEs)
  - EE creates one control a-flow used for EE signaling and management
  - New a-flow for each user’s packets
  - Bowman schedules user computation

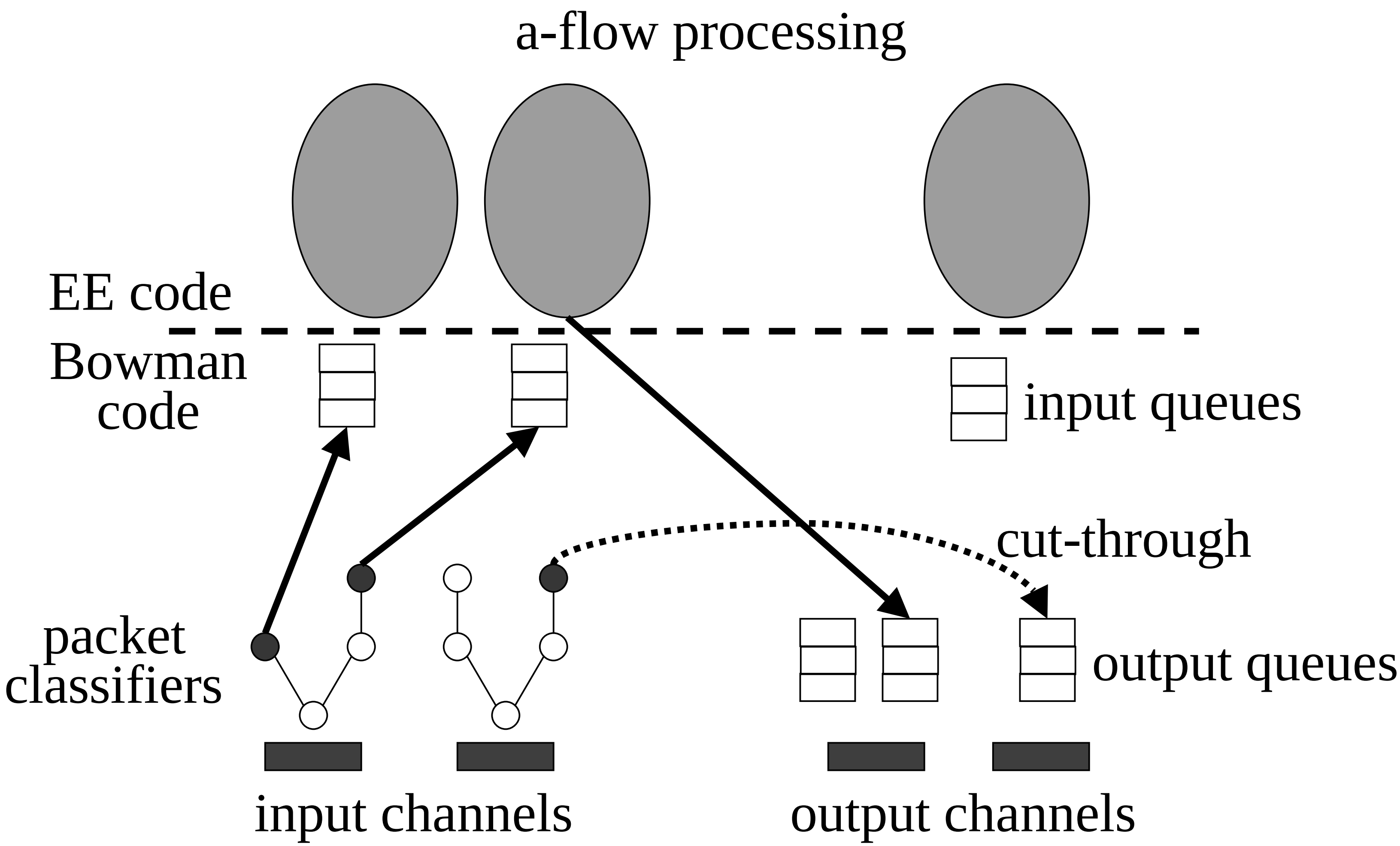
Selected Related Work

- Router plug-ins (WashU)
  - integrated EE (customizable IP) and NodeOS
  - NetBSD kernel modifications
- Janos (Utah)
  - Java-based NodeOS
- Extensible routers (Princeton)
  - Scout-based NodeOS

Future Work

- Security mechanism
- Resource management
- More complex output queueing disciplines
- Scalable topology instantiation

- EE-developers toolkit to run over DARPA NodeOS implementations?



a-flow processing
EE code
Bowman
code
input queues
cut-through
packet
classifiers
output queues
input channels
output channels