Interoperability of Active Networks

Presented By
Ramshankar

Active Networking…revisited

- Dynamic deployment of programs to process particular packet subflows within the network
  - Data plane – processing data subflows e.g., adaptive recoding of video
  - Control plane – e.g., dynamic installation of flow-specific control/signalling/ management algorithms

Standard Architecture

- Active Applications (AAs)
  - Fundamental unit of network programming
- Execution Environments (EEs)
  - Environment for AA execution
- Node Operating System (NodeOS)

Organization of this talk

- Part1: Introduction to ABone Testbed
- Part2: NodeOS Interface
- Parting thoughts

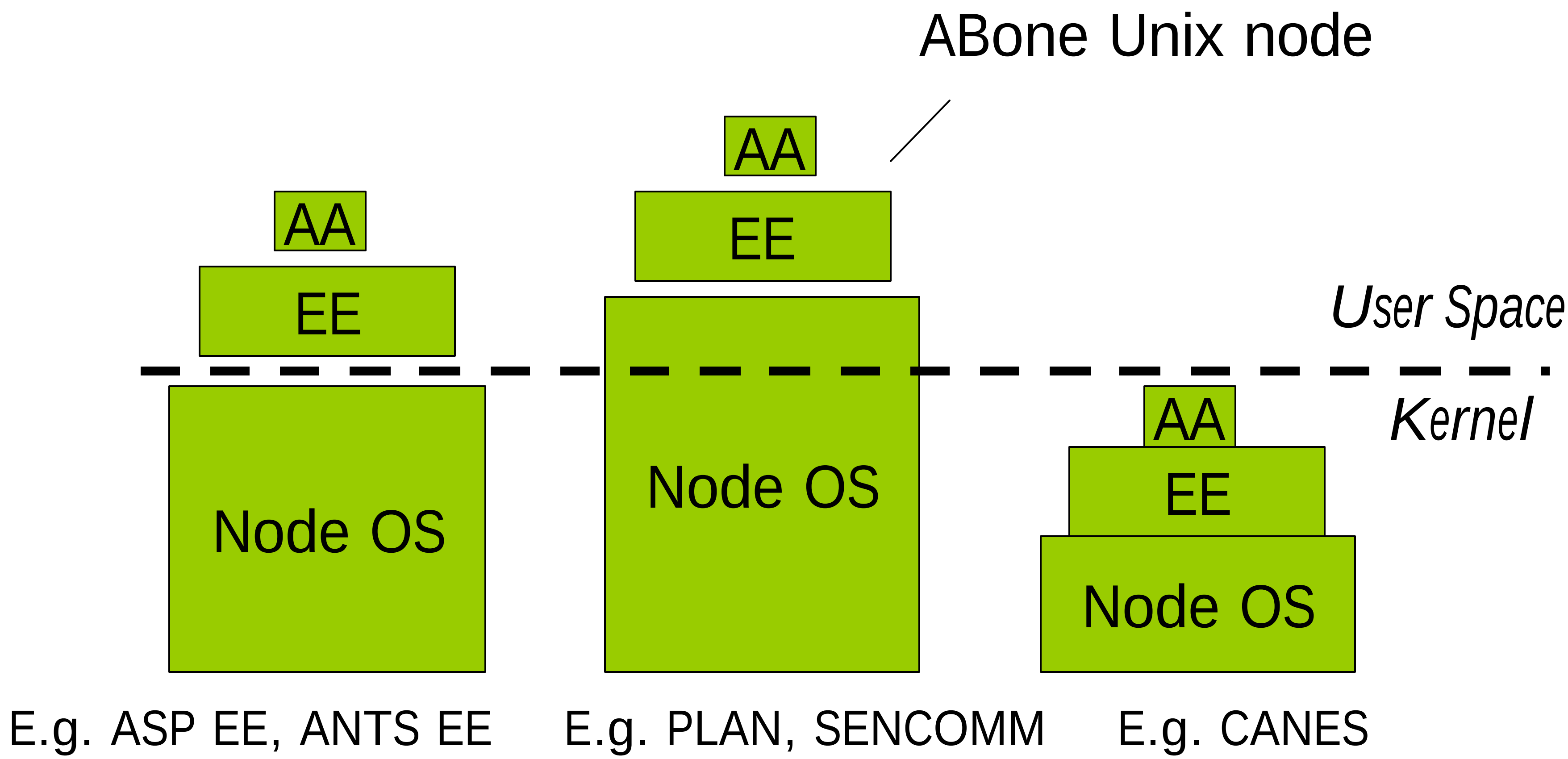
Part 1: ABONE Testbed

- Share facilities
- Extend research into realistic network environments
- Enable research collaborations
- Share tool development and software maintenance overhead
- Create a teaching plan

AN Node Architecture

- EE installed in a node by/under management control
- AAs are dynamically deployed and may be transient or persistent
- Model: 1 NodeOS, a few EEs, many AAs in each active node
- Kernel boundary not necessarily fixed

Model



ABone Unix node
AA
EE
Node OS
AA
EE
Node OS
User Space
Kernel
AA
EE
Node OS
E.g. ASP EE, ANTS EE
E.g. PLAN, SENCOMM
E.g. CANES

The ABone Architecture

- Abone:
  - Wide-area testbed
  - Nodes: diverse distributed OS platforms
  - Links: Internet overlays, plus dedicated links in DARPA's CAIRN testbed
  - AA/EE/nodeOS architecture
- AN researchers remotely install and manage EEs on locally administered nodes
- Client site accesses central site for registry.

Architecture Topologies

- Creating and using a Virtual EE topology
  - Allocate nodes
  - Build/allocate accounts on these nodes
  - Generate and install configuration files on Nodes
  - Start the EEs on the nodes
  - Monitor topology
  - Launch an AA to run the experiment

ABone Software Components

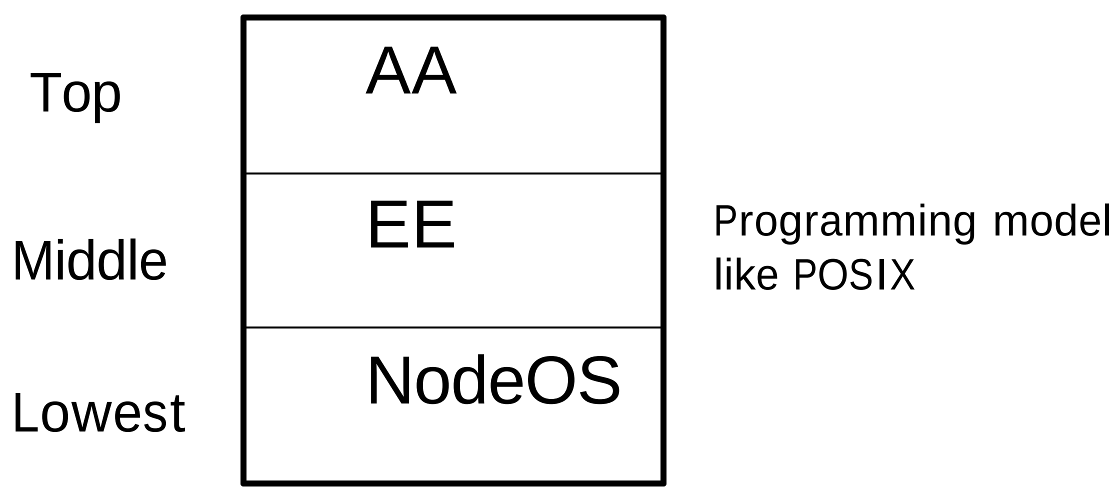
- Each ABone node has:
  - ABCd (Anetd): Remote EE management daemon
    - Load and launch an EE (Java or C) in a specific file subspace
    - Terminate, restart, configure and monitor EE
  - Netiod: Network I/O daemon
    - Runs as root for kernel filtering
    - Provides uniform interface across Unix platforms
- Client side
  - ABCd (Anetd) client and ABoneShell interface
- Central site
  - Web-based registry program

Interoperability

- A small number of EE are implemented universally among all nodes
- EEs differ across nodes depending on OS
- AAs are implemented to use at least one of these EEs
- This way,
  - A distributed set of OS specific EEs
  - AAs that run using at least one of them
  - Services are hence distributed among a number of nodes and a high utilization of network processing is possible

Part 2: NodeOS Interface

- A multilayer model with 3 layers
  - – AA, EE, NodeOS
- Or a multilayer model with 2 layers
  - – AA, NodeOS

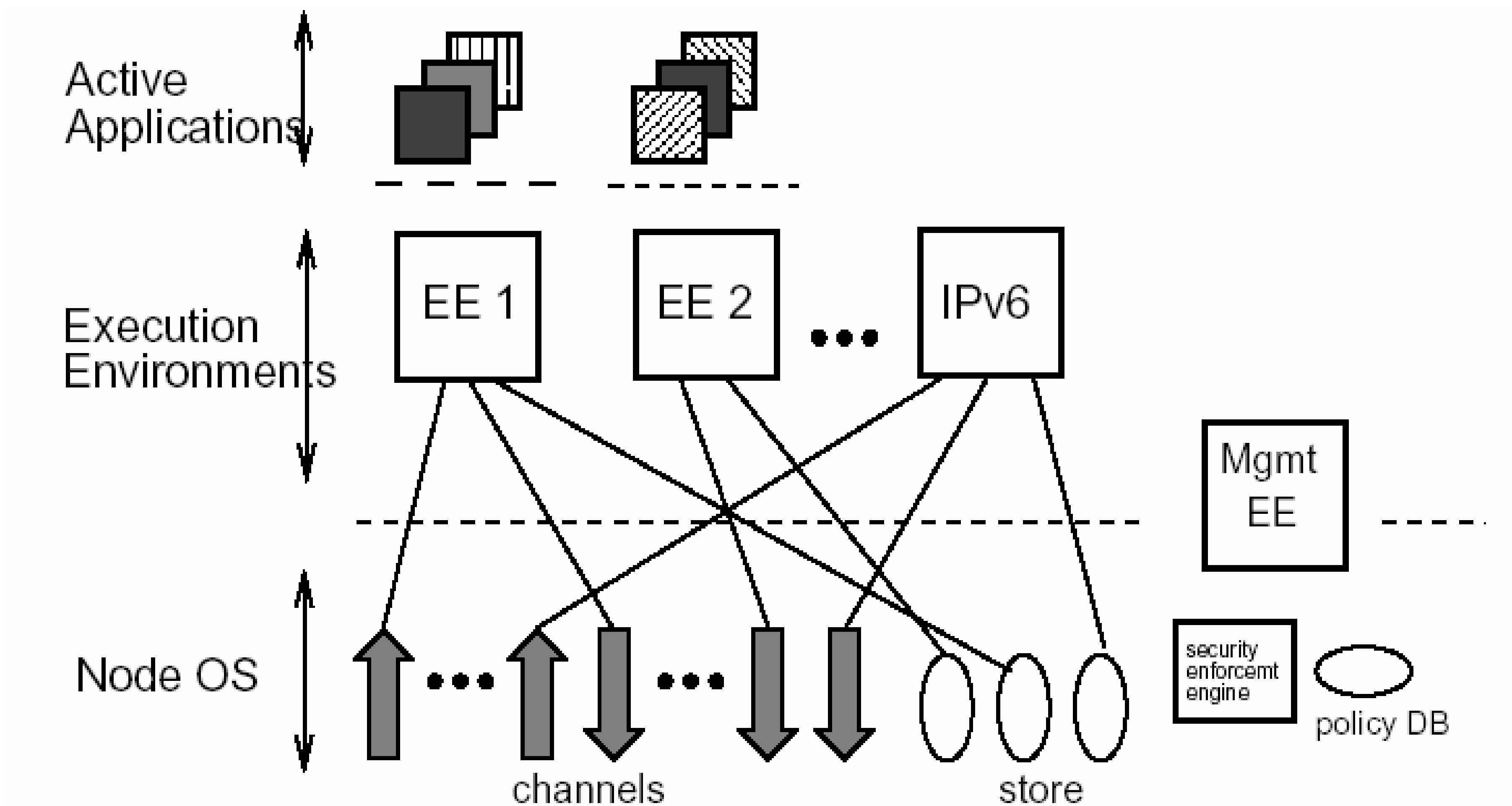


NodeOS Interface

- Option1:
  - Multiple languages can be supported
  - Any single language can be ported to many node types
- Option 2:
  - A language runtime system directly on hardware, like in some JavaOS

The working group upholds option 1 and justifies separation into two layers

Architecture Components



Broad Goals for EE and OS

- NodeOS:
  - Multiplex node's resources among various packet flows
- EE:
  - Offer AA a sufficiently rich, high-level programming environment

Elaboration of Goals

- For NodeOS interface
  - Primary role:
    - Support packet forwarding
  - Secondary role:
    - Arbitrary computations on select packets
- So,
  - Packet processing, accounting for resource usage and admission control are done on a per flow basis
  - Different granularities for packet flows
    - Port-port, host-host, per application

    => *Interface cannot prescribe single direction of flow*

Elaboration of Goals

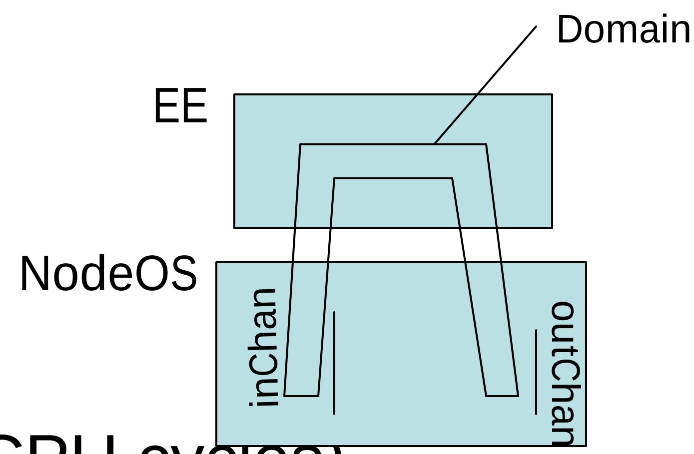
- Account for specific capabilities provided to each EE and hence AA
- Packets requiring minimal processing should incur minimal overhead
  - For e.g. Non-active IP
- Ability for EE to extend OS
- Use of standardized facilities for specific requirements
  - POSIX

Abstractions

- 5 Primary abstractions
  - Thread Pool: For computation
  - Memory Pool: For temporary storage
  - Channels: For communication
  - Files: For permanent storage
  - Domain: For aggregating control and scheduling of the other four abstractions

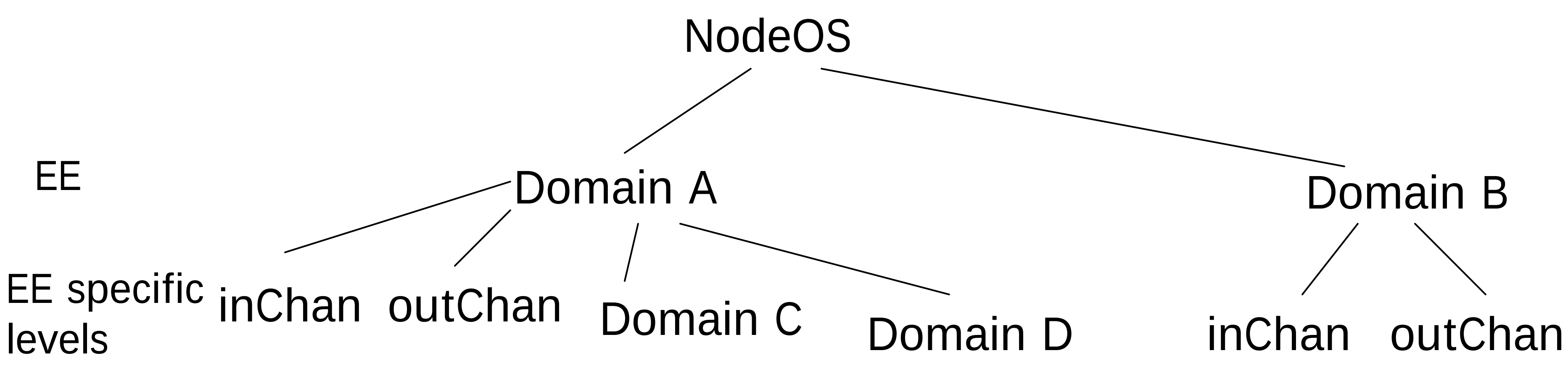
Domain

- Role:
  - Accounting
  - Admission Control
  - Scheduling
- Domain has,
  - Thread pool (translates to CPU cycles)
    - for computation by EE
  - Memory pool (temporary storage)
    - I/O buffers that queue messages on a domain's channel
  - Channels: inChan and OutChan



Domain

- Encapsulates resources used by both NodeOS and EE for a packet flow
- Could be created like processes: in context of another
  - Hierarchy with NodeOS as root



Domain Hierarchy

- Allows for easy domain termination
- Domain can be terminated
  - By itself
  - Parent domain
- Resources go back to NodeOS
- Parent uses a handler and clears a dying child's resources

Hierarchy does nothing to each domain's requirements.

Thread

- Abstraction for computation by a domain
- A thread pool is assigned to each domain during domain creation
  - Information maintained:
    - Max number of threads in a pool
    - Scheduler used
    - and so on

Thread pools

- Threads run end-end
  - Enables packet forwarding
  - Threads cuts across NodeOS into EE as domain does
- Special system threads are available
  - For e.g. Global garbage collection
  - Use POSIX style constructs like conditional signal, waits

Thread Pools

- "Data driven"
  - Threads in the pool are data driven entities with no need for explicit identities
  - Termination, creation are NodeOS specific
  - Only activation is performed for each before assigning to a pool for a domain
- Pools only for accounting purposes
  - Easy reclamation of a terminating domain's pool of threads

Memory Pools

- Primary abstraction for soft state storage
- Packet buffers
- Holds EE specific state
- Share memory between domains
- Domain to memory pool is a many-one mapping

Enable EE to manage memory themselves

Memory Pool

- Sharing data between domains means
  - Shared data has to be present even after one of the domains terminate
  - All data references should be checked before domain termination
- Pool simplify this process by
  - Not reclaiming shared memory pages

Memory Resources

- Assignment is EE's job and not NodeOS
  - Performed during domain creation
- Resource consumption is watched by NodeOS and EE are provided a grace time for cleanup over-utilization
  - "Callback" function for each memory pool
    - Invoked by NodeOS to access EE using this pool to clean up
    - Domain is terminated if cleanup is not performed in a timely fashion

Memory pools are implemented independently and not in a hierarchical manner

Pools are only for accounting purposes.

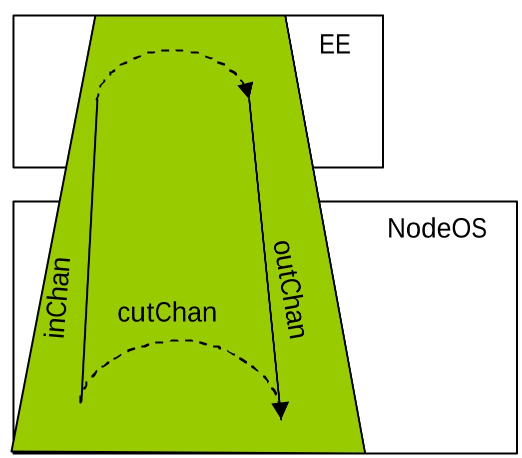
Their potential for security and protected domians are unexplored

Channels

- Primary abstraction for communication flow
- For inChan domain specifies
  - Arriving packets
  - Buffer pool to queue packets
  - A function to handle the packets
    - The handler is used to execute this packet in the context of the domain’s thread pool
- For OutChan domain specifies
    - Where packets are to be delivered
    - How much link bandwidth the channel is allowed to consume (guaranteed to get) as present in [17]

Channels

- Cut-through channels
  - Receive and transmit packets
  - EE calls a convenience function with all arguments used by inChan and outChan



Channels

- Packets are resolved by using addressing information and a demux key
- “Anchored”
  - inChan for incoming flow
  - outChan for outgoing flow
- “Cut-through”
  - No packet processing and only forwarding

Revisiting Design Goals

- Domain encapsulates resources for a flow
- Channel specifies
  - Packets belonging to flow and
  - Function applied to flow
- Cut-through channels directly forward packets

Other Abstractions

- File:
  - Loosely follow POSIX 1003.1
  - Hierarchical name space
- Name space:
  - Distinct view of a persistent file system at a directory chosen at configuration time
- Event:
  - Domain can schedule an asynchronous event in the future

Other Abstractions

- Heap:
  - Memory management
- Packet:
  - Encapsulate data that flow thro channel
- Time:
  - EE get time calls