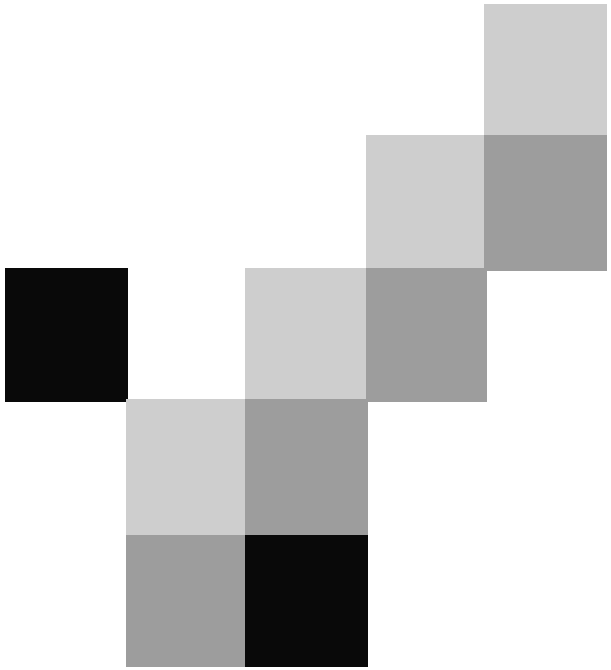

Hybrid Resource Control for Active Extensions

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The Problem

- Resource-greedy active code
- Resource control of untrusted code
  - CPU, memory, network bandwidth

- Context: Active Extensions
  - Code downloaded via the control channel
  - Examples: Application Layer Gateways, Multicast scoping agents

Current Solution #1: Dynamic

- “Sandbox” the active code
- Run-time checks in the critical path
- Asynchronous termination
  - Requires checks at the “user-kernel” boundary to protect integrity of the “kernel” code
- Flexible
- Examples: Janos, Smart Packets, RCANE, OKE Corral

Current Solution #2: Static Analysis

- Constrained programming model bounds resource consumption
- Admission control == Resource control
- Examples: PLAN, SNAP, PCC

Issue: Existing work does not yet address the problem with pessimistic estimates, valid code gets rejected.

Current Solutions - Summary

- dynamic checking
  - run-time overhead
  - asynchronous termination
- static checking is very conservative

Hybrid Resource Control #1

- Static checking
  - Constrained programming model to bound the resources and guarantee termination
  - Static analysis rejects resource greedy code from the “kernel” fast-path environment
  - Liberal resource limits

Hybrid resource control #2

- Dynamic resource accounting
  - Detects misbehavior
  - Misbehaving code is detected and unloaded only when idle (between packets)
  - Limits overall resource consumption

Poll points

- Extension could cause packet drops at device input queue
- Split the active extension code and poll network interfaces
- Adds some runtime cost

Merits of Hybrid Resource Control

- No asynchronous termination
  - Implies no runtime checks at the "user-kernel" boundary
- Reduced runtime overhead
  - Runtime accounting checks are inexpensive
- Flexibility via "poll points"
- DoS prevention

Outline

- Prototype: resource bounded Click or RBClick
  - Building blocks
  - The big picture
  - Preliminary evaluation

Cyclone

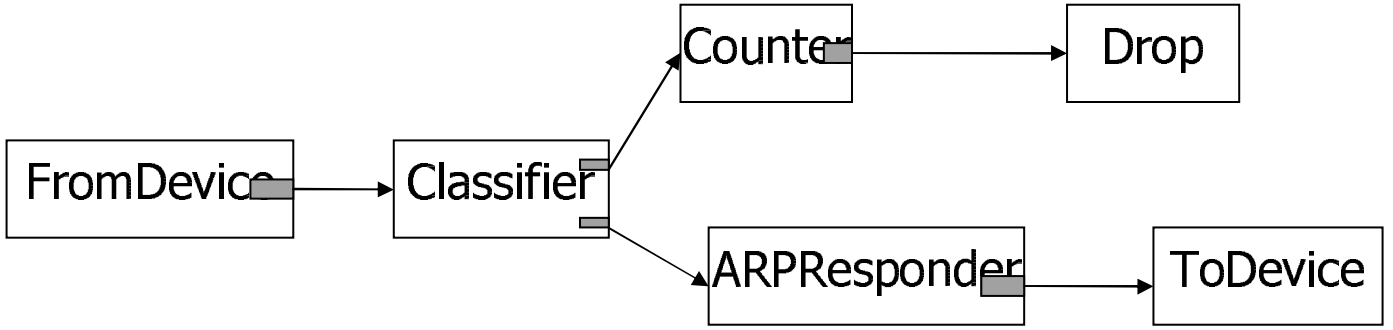
- Cyclone: typesafe C-like language from Cornell and AT&T
  - Region-based memory management
  - control over data-representation
  - Easy to interface with C
  - Namespaces

Resource-bounded Cyclone

- Namespace control
- Restricted programming constructs (bounded loops)
- Memory management via 4 distinct dynamic regions
  - Per-packet
  - Packet-cache
  - Inter-packet
  - Global memory

Click

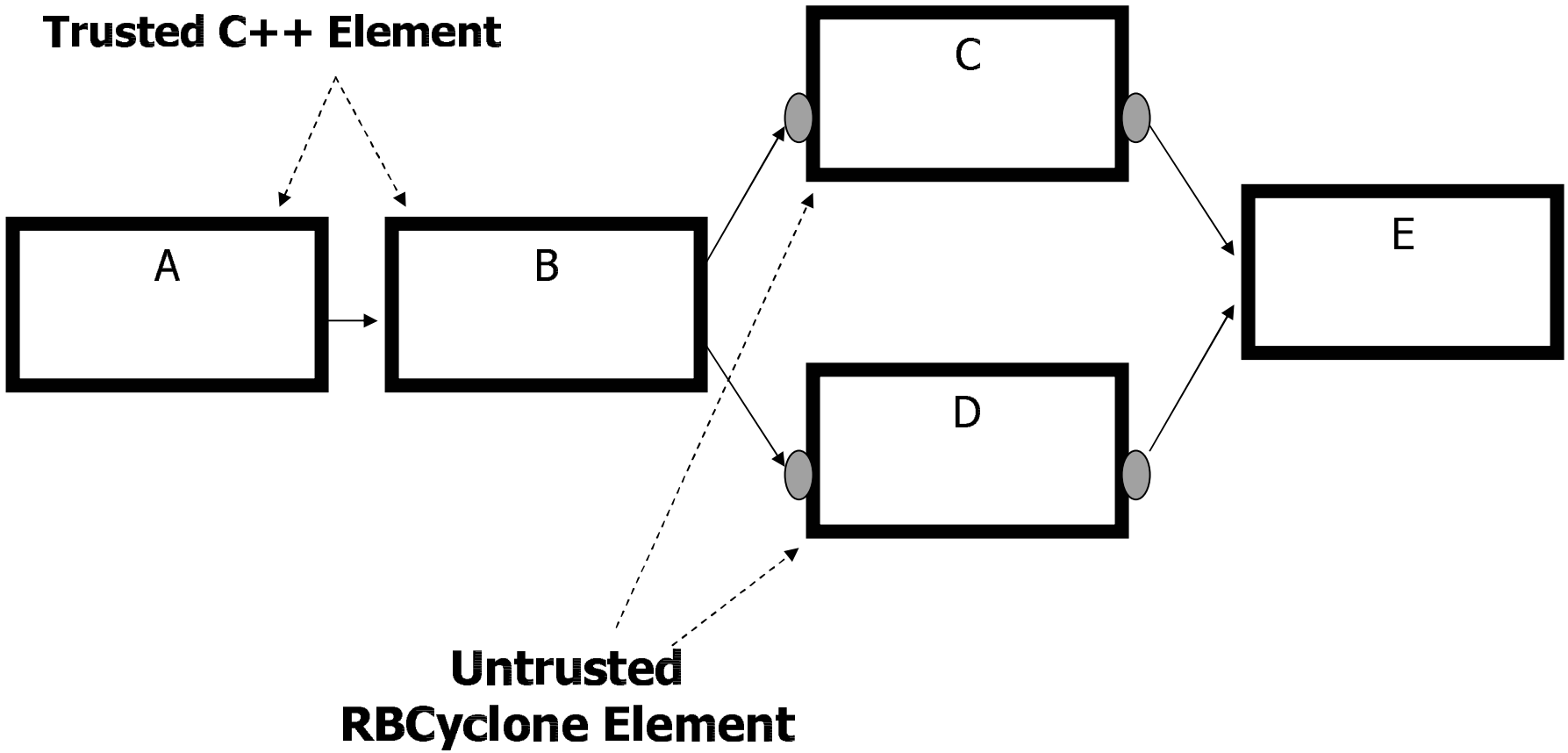
- Modular router toolkit from MIT
- Data-flow programming model
- Has an increasingly large base of router extensions



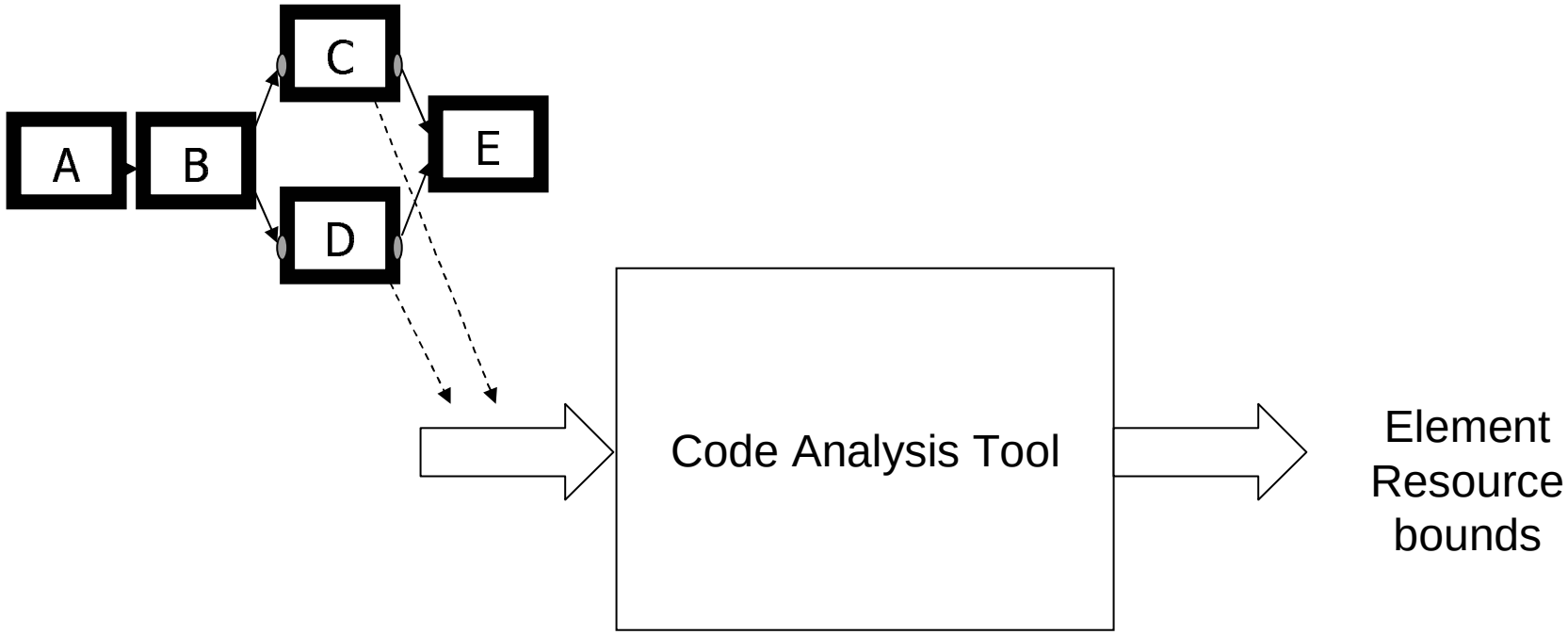
Prototype: Architecture

- An active extension is a special Click graph
  - Mix of trusted and untrusted elements
  - Statically analyzed
- Admitted to kernel fast-path

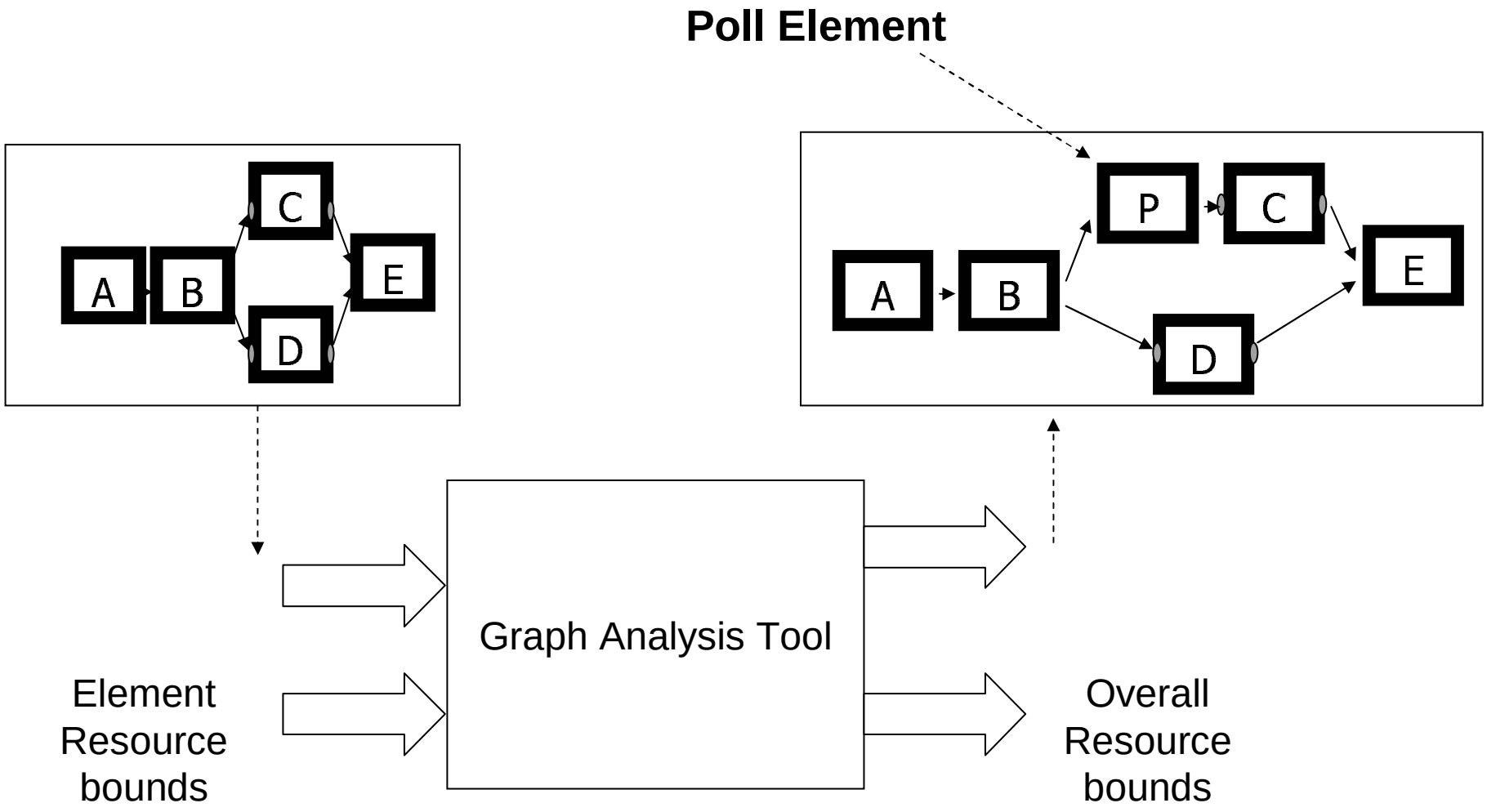
An Active Extension



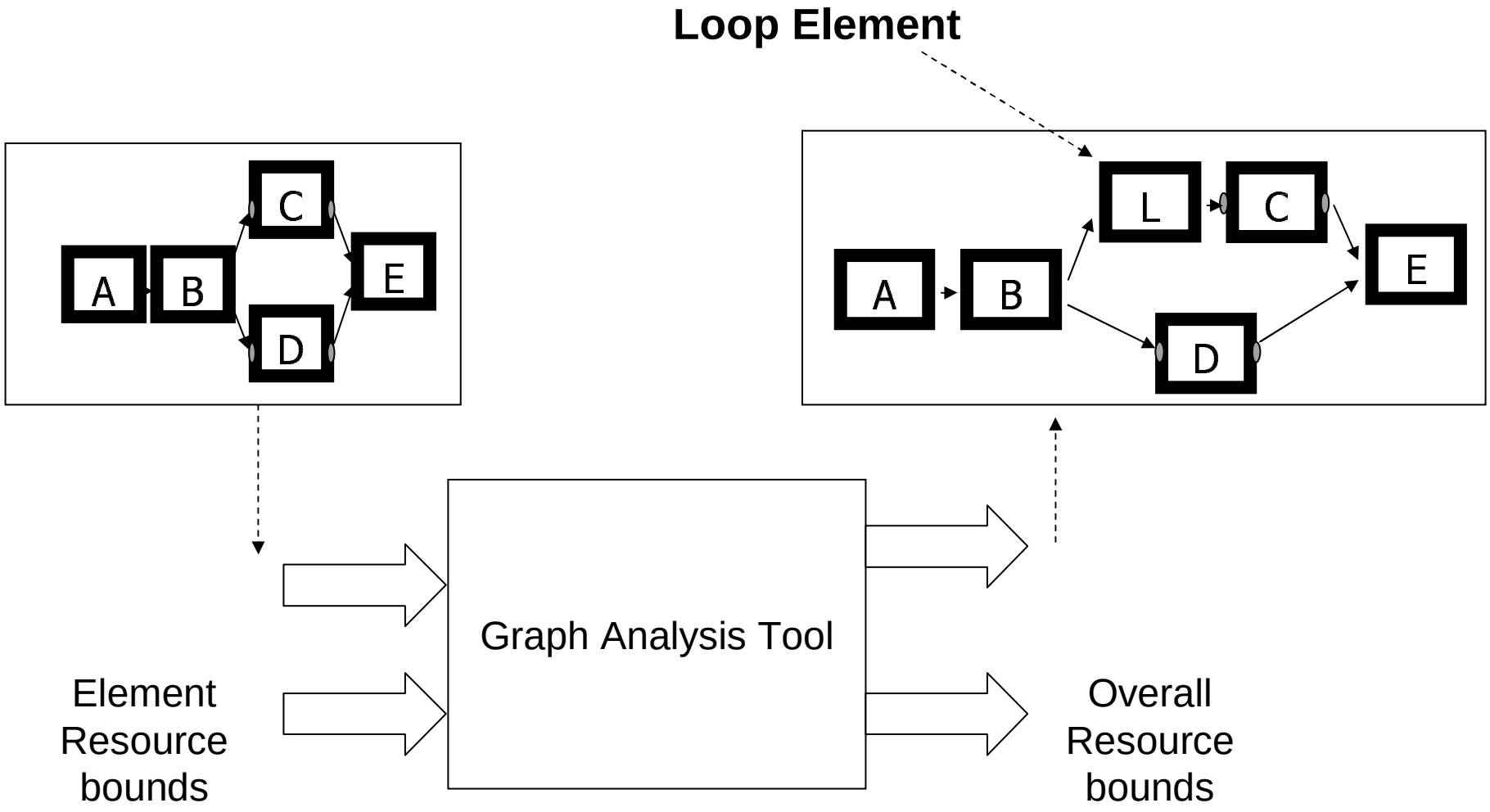
The big picture



The big picture



Loop configuration



Evaluation

- Flexibility of programming model
- Experimental performance gains

Classification of Click elements

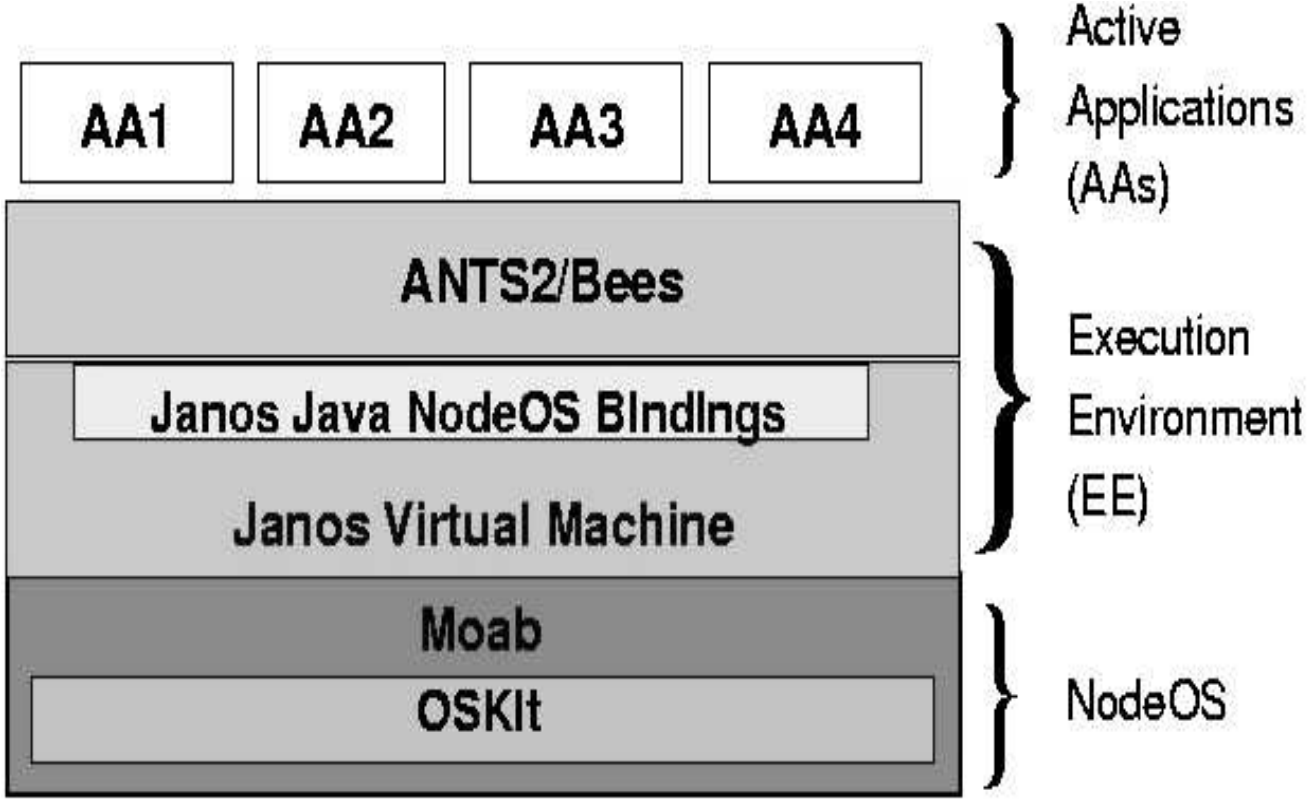
- Categorized all 234 Click v1.2.1 elements into 7 different classes based on their resource use
  - E1 - *Constant* resource consumption
  - E2 - ~ *length of the packet*
  - E3 - ~ *length of some protocol header*
  - E4 - ~ *length of element configuration*
  - E5 - ~ *some value in the configuration* of an element.
  - E6 - ~ *field in a protocol header*
  - E7 - Potentially *unbounded*

Evaluation: flexibility

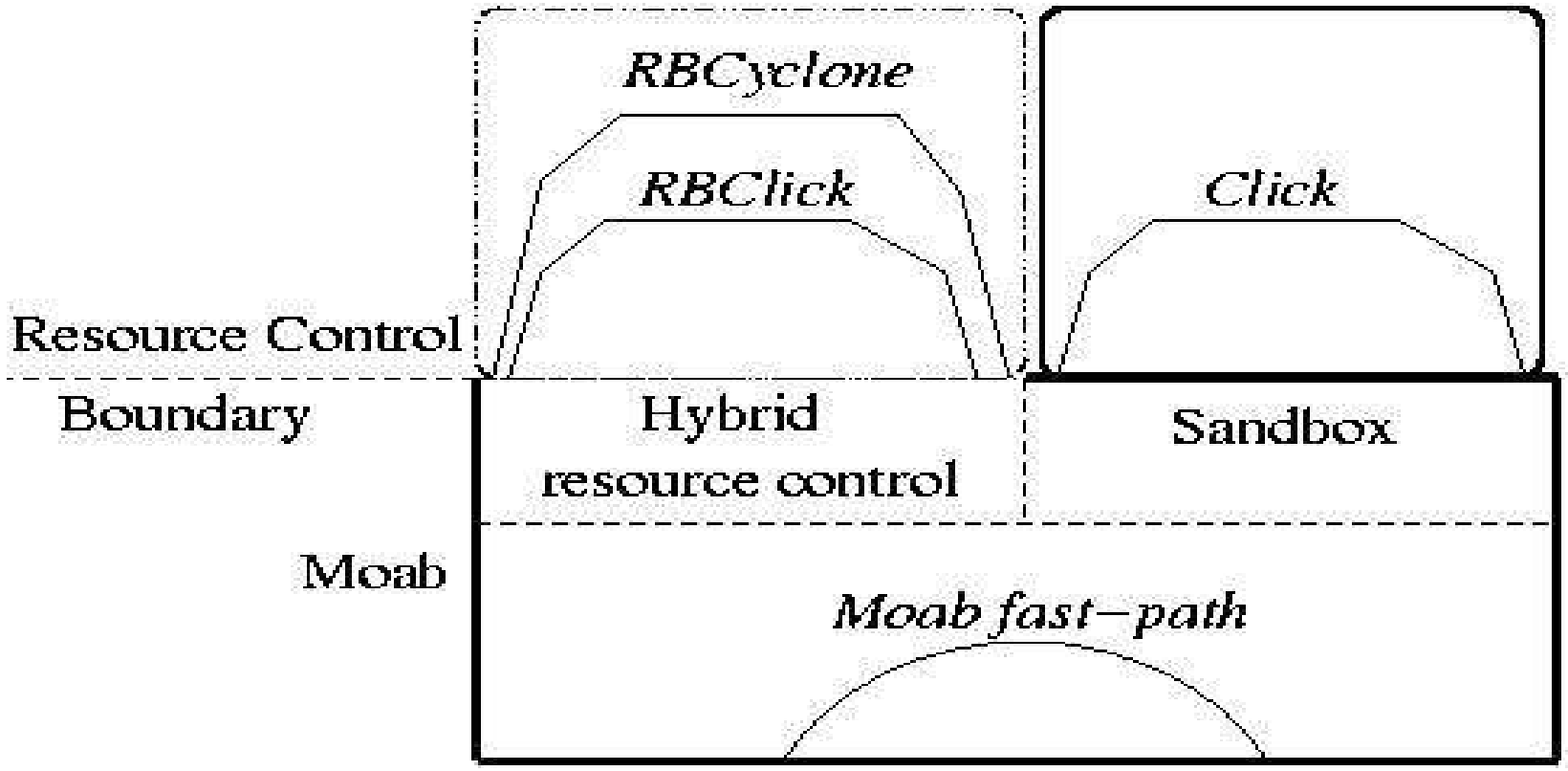
- Results:
  - 88% resource-bounded
  - The rest can be easily rewritten to be bounded
- Demonstrates that RBClick can reuse a rich set of Click elements
- Strongly suggests that RBCyclone programming model is sufficiently expressive

Prototype Context

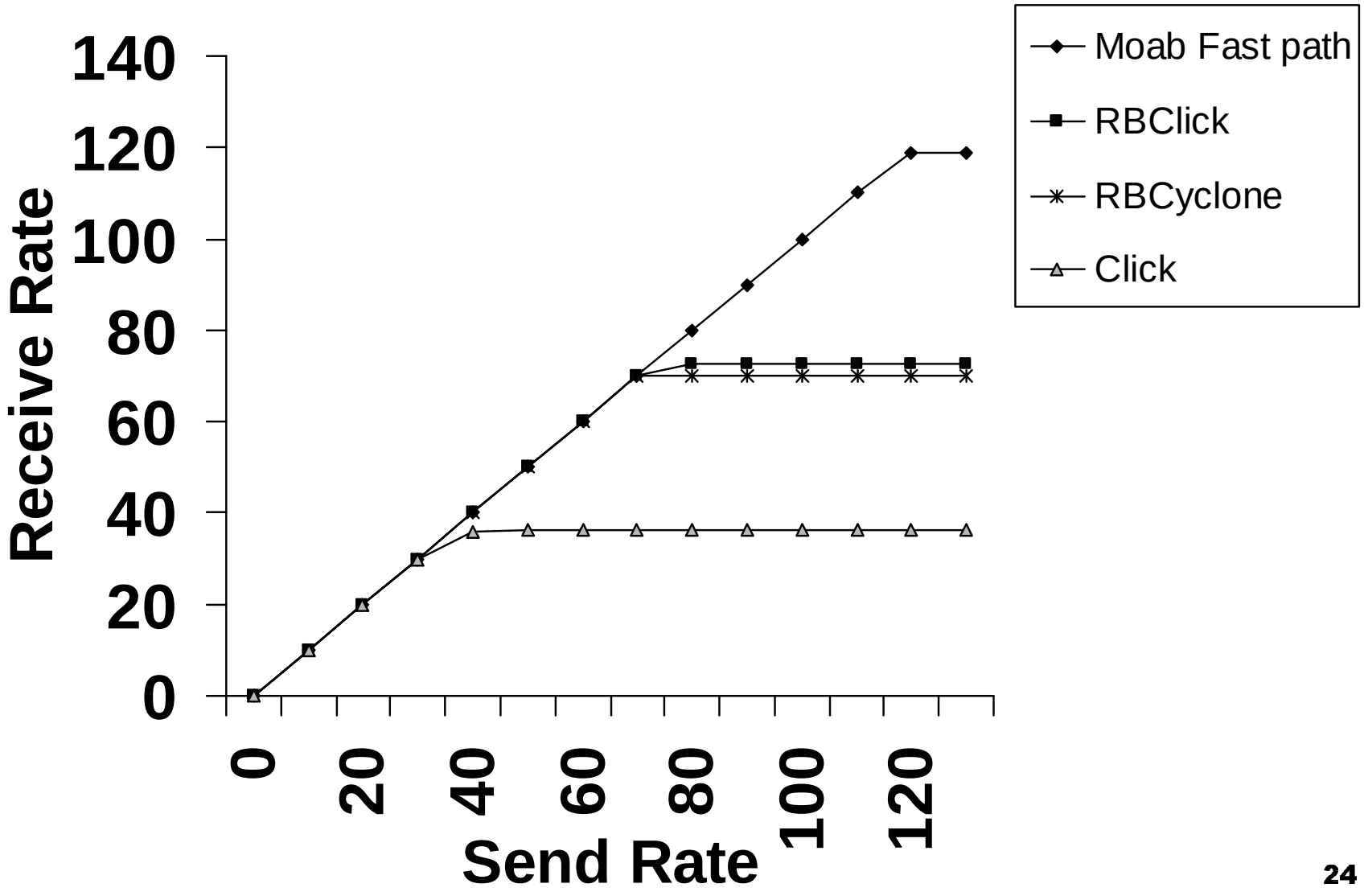
- Janos



Evaluation – experiment configurations



Evaluation: performance



Conclusion

- Hybrid resource control
  - Static analysis reduces runtime overhead
  - Dynamic accounting allows liberal admission control
- RBCyclone is expressive and practical ("tastes great")
- RBClick doubles forwarding rate in Janos ("less filling")