EffiCuts: Optimizing Packet Classification for Memory and Throughput

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Packet Classification

- Goal
  - Categorize packets by matching it against the highest priority rule
- Why classify packets?
  - Firewall / NAT
  - Quality of service
  - Traffic analysis
- Rule example

Rule ID	Network-layer destination	Network-layer source	Transport-layer destination	Transport-layer protocol	Action
R1	128.2.190.69/32	128.2.80.11/32	*	*	Deny
R2	128.3.3.0/24	128.2.200.157/32	eq www	UDP	Allow

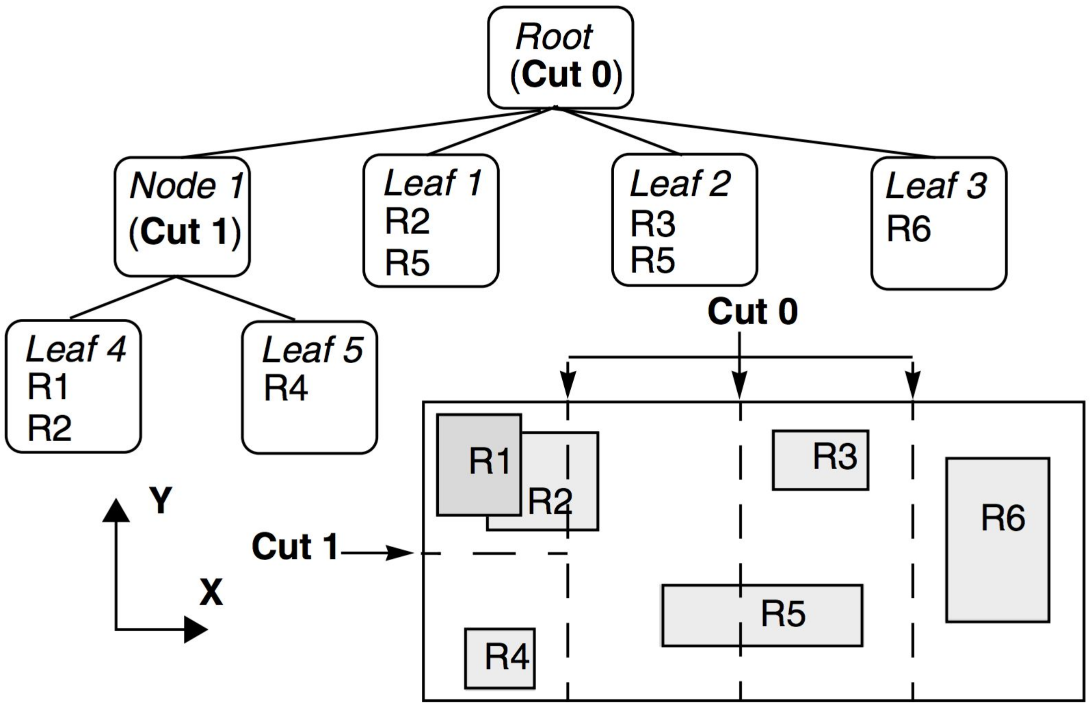
Challenges Facing Modern Classifiers

- Classifiers growing in size
  - Custom rules of more virtual networks
  - QoS demands finer-grained differentiation on rules
  - Increasing number of hosts

- Increasing line-rates

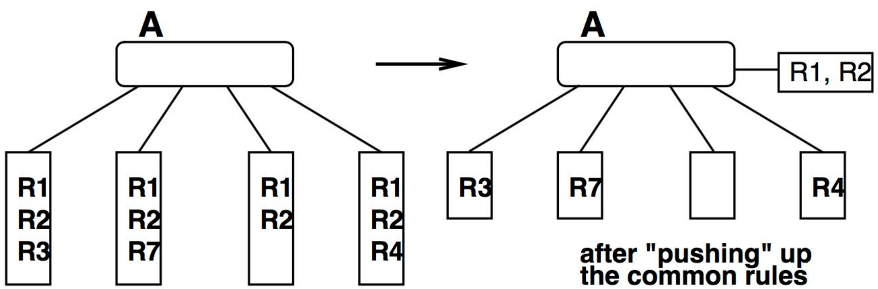
Previous Approach: HiCuts

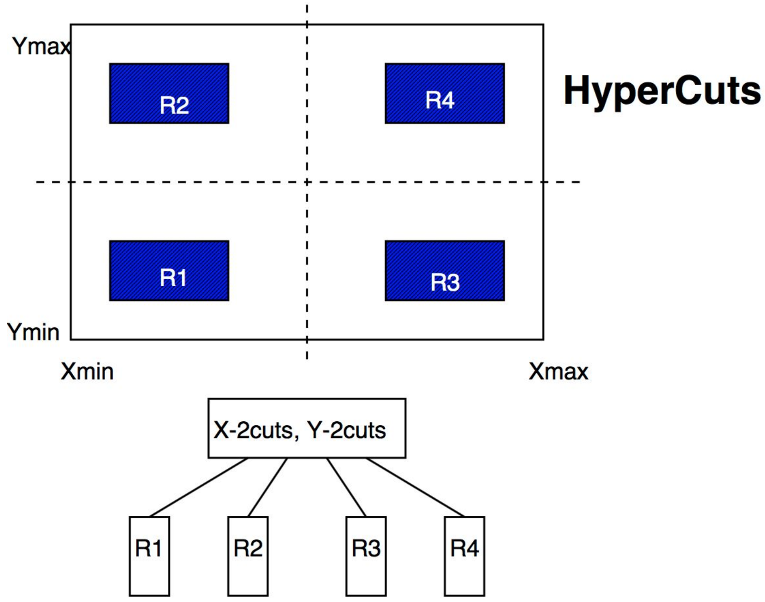
- Represents rules as cubes in multidimensional space
- Constructs a decision tree by recursively cutting the space and separating rules into different sub-space
- Eventually, rules fall into the leaf nodes
- Upon receiving a packet, the classifier traverses the tree to identify matching rules



Previous Approach: HyperCuts

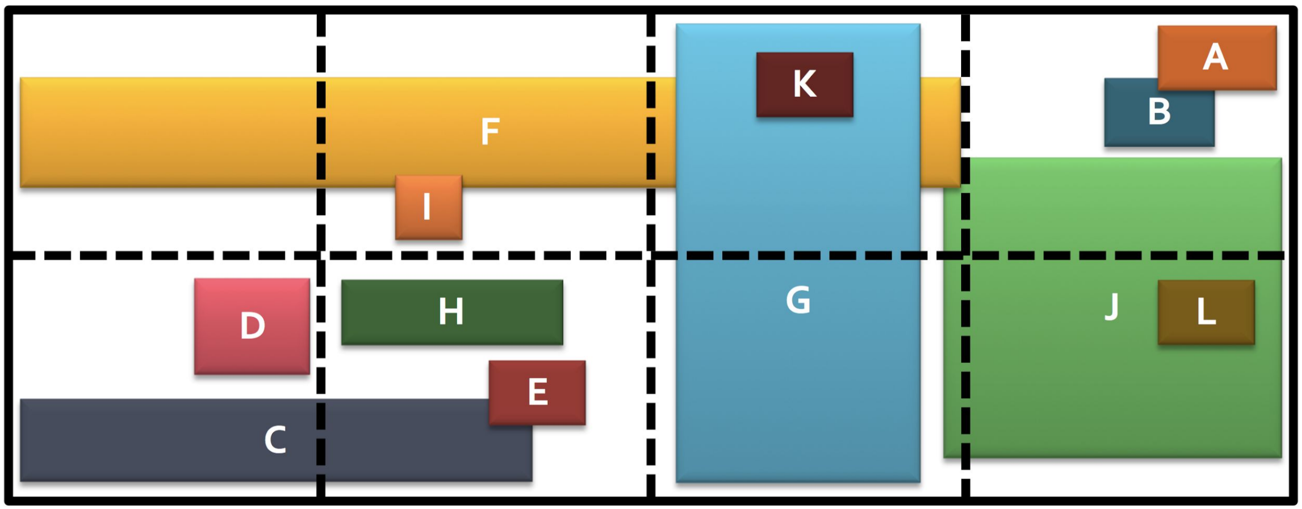
- Improves upon HiCuts
- Supports multidimensional cutting at tree node
  - Collapse subtrees to reduce tree depth
- Percolates common rules from siblings up to the parent nodes
  - Reduces replication





Memory Overhead of HiCuts and HyperCuts

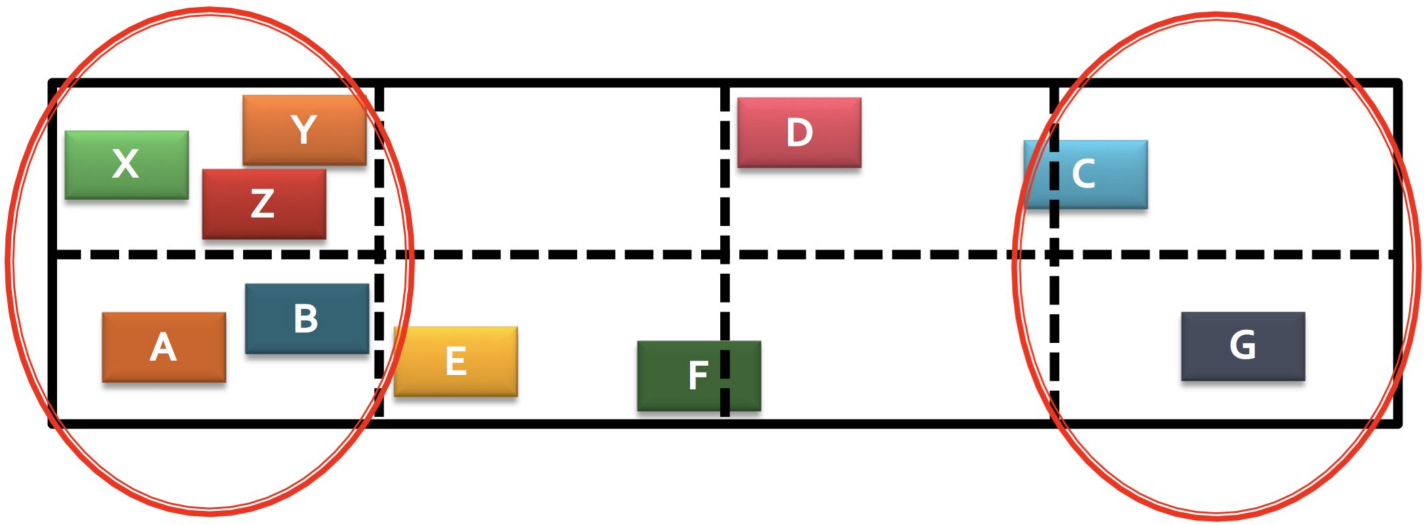
- Varying size of overlapping rules
  - Necessary to apply fine cuts for separating the small rules
  - Inevitably **replicating** the large rules



Picture adapted from authors' SIGCOMM presentation

Memory Overhead of HiCuts and HyperCuts

- Varying rule-space density
  - Both HiCuts and HyperCuts adopt **equi-sized** cuts
  - Inadvertently partition sparse space when partitioning dense space
  - Leading to more sub-spaces/tree nodes containing few rules



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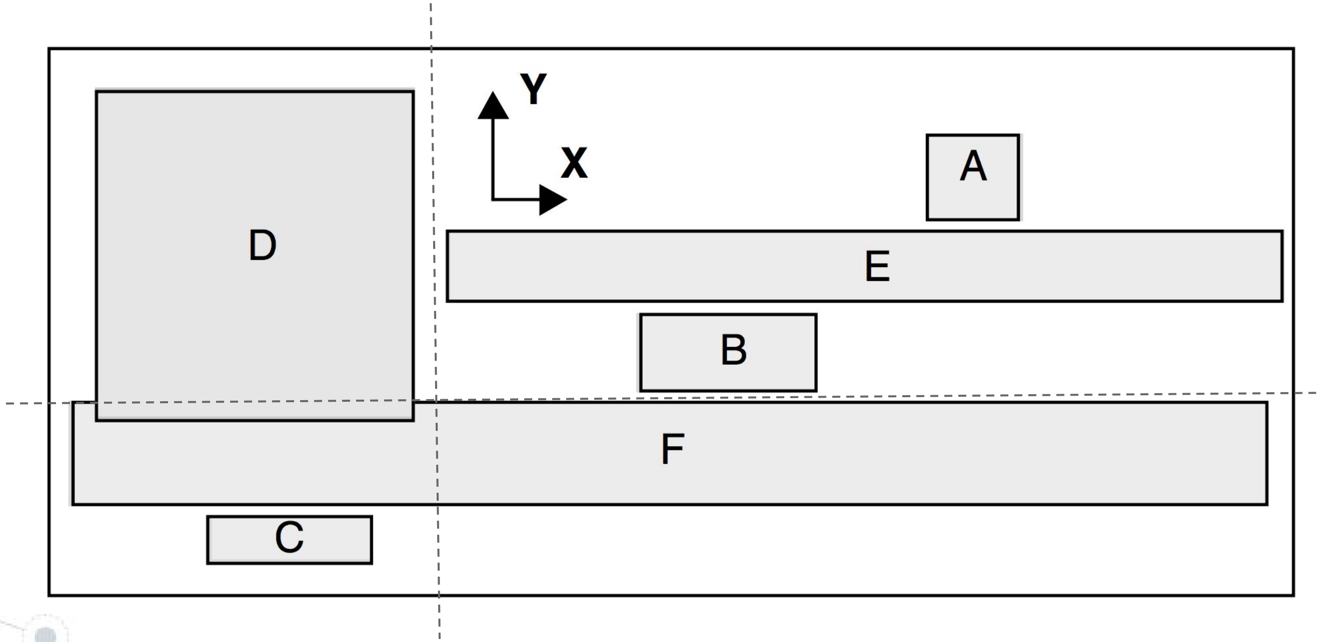
Optimizations in EffiCuts

- Separable trees
- Selective Tree Merging
- Equi-dense cuts
- Node Co-location

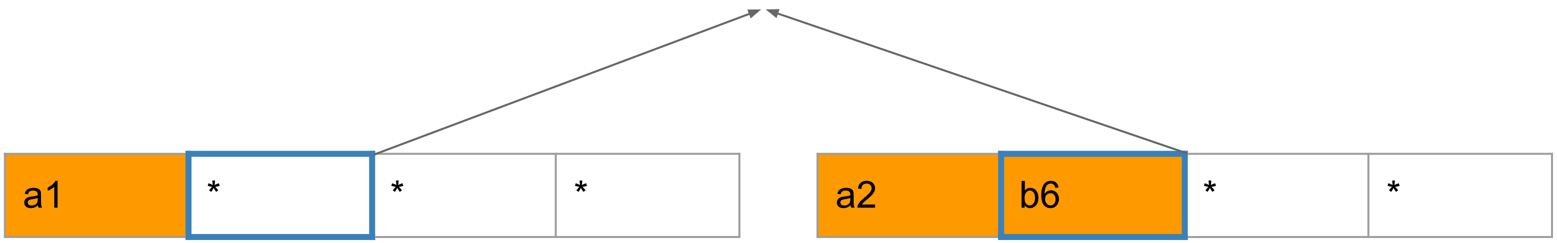
Separable Trees

- Intuition: Separate small (fewer wildcards) and large (more wildcards) rules into different trees
  - Tree1: {A, B, C}, Tree2: {D, E, F}
- Refinement: A subset of rules are separable if **all** rules in the subset are **either small or large** in **each** dimension
  - Tree1: {A, B, C}, Tree2: {D}, Tree3: {E, F}



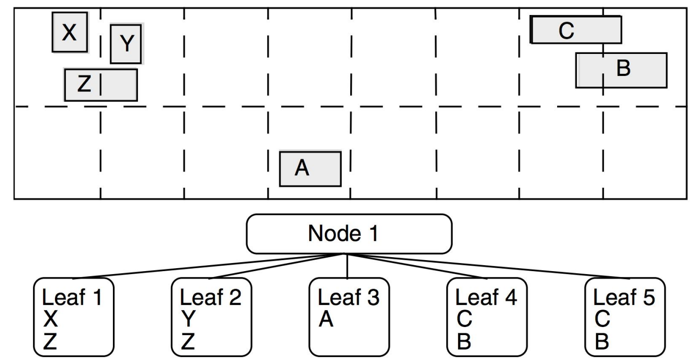
Selective Tree Merging

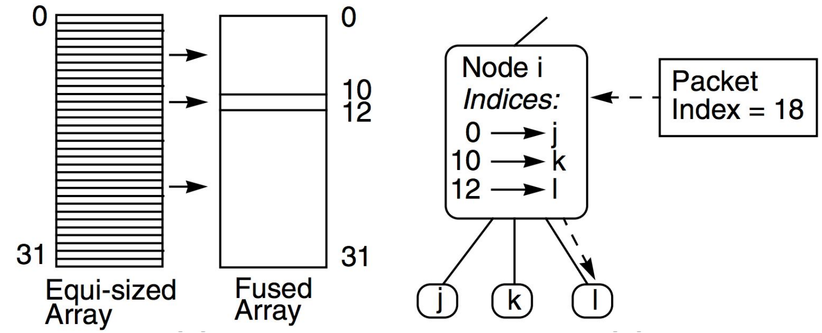
- Pitfall of separable trees: more lookups during packet processing and thus lower throughput
- Idea: selectively merge trees
- Complication: merging trees is a compromise on separability
  - Need to minimize replication
  - Merge trees mixing rules that are small or large in at most one dimension



Equi-dense Cuts

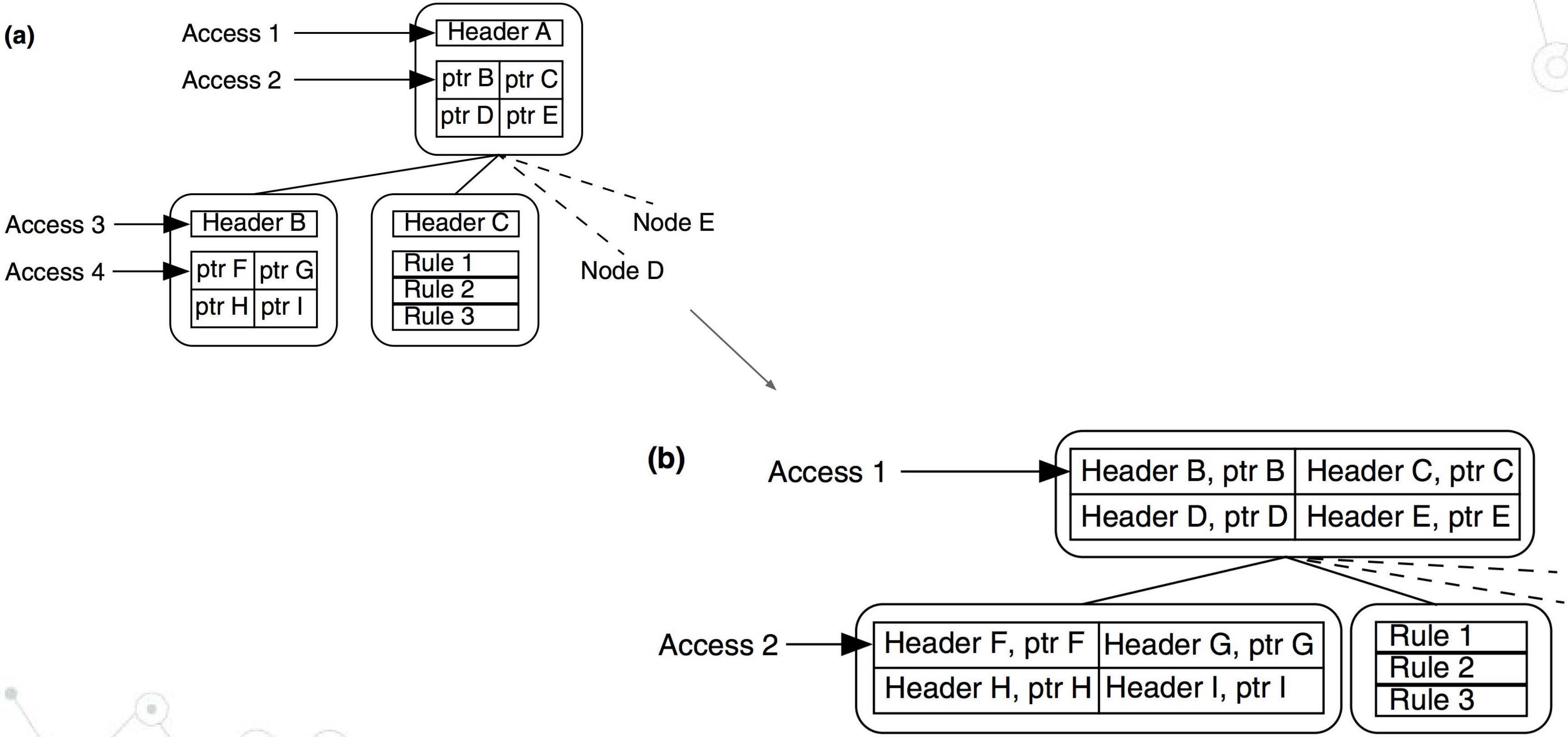
- Equi-size cuts simplify indexing of matching child but lead to redundancy due to rule-space density variation
- Equi-dense cuts produce partitions of **similar density** to distribute rules evenly among fewer children by **fusing adjacent equi-sized cuts**





Node Co-location

- Reduces the amount of memory access



Evaluation

- Substantial reduction in memory with modest increase in memory access