Firewall Architectures for High-Speed Networks

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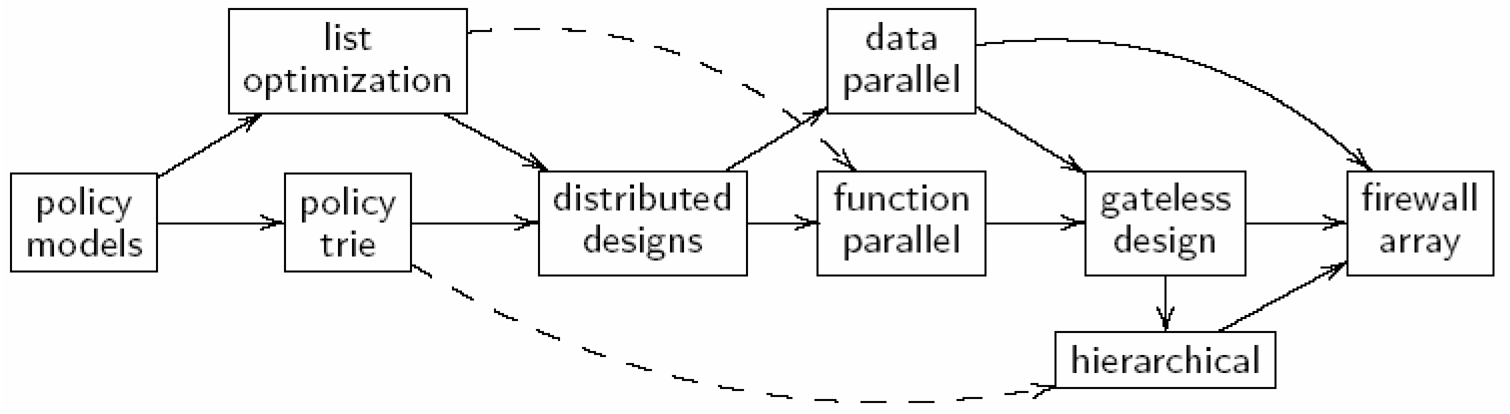
Project Objectives

Methods that improve network firewall performance

1. Develop **policy optimization** techniques
   - Formal models for rules and security policies
   - Reduce processing requirement per packet
   - Low impact solutions for current and future firewalls
   - Models used to distribute rules in parallel firewalls
2. High-speed **firewall designs**
   - One policy, distributed firewalls, parallel processing
   - Maintain QoS requirements and differentiation
   - Scalable with increasing speeds and volumes
   - Robust (highly available), able to survive DoS attacks

Research Progress

- Three year DOE ECPI project
  - **First year**: firewall policies and analytical models
  - **Second year**: firewall designs and rule distribution

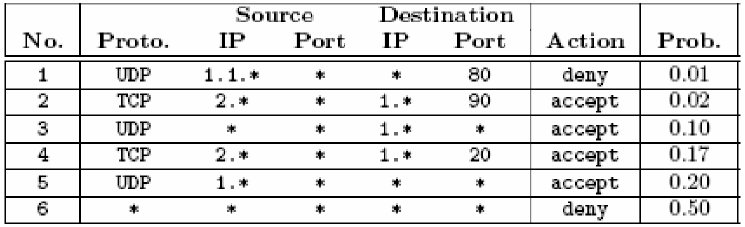


  - **Third year**: hybrid and dynamic firewall designs
- Network Security Group at Wake Forest University
  - Errin Fulp, Ryan Farley, and Steve Tarsa

Policy Optimization

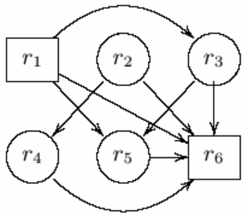
Reduce comparisons while maintaining integrity

1. **Optimize** the policy, best arrangement (NP-hard)

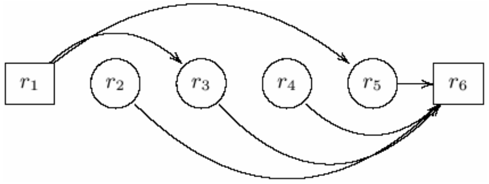


No.	Proto.	Source IP	Source Port	Destination IP	Destination Port	Action	Prob.
1	UDP	1.1.*	*	*	80	deny	0.01
2	TCP	2.*	*	1.*	90	accept	0.02
3	UDP	*	*	1.*	*	accept	0.10
4	TCP	2.*	*	1.*	20	accept	0.17
5	UDP	1.*	*	*	*	accept	0.20
6	*	*	*	*	*	deny	0.50

Firewall policy



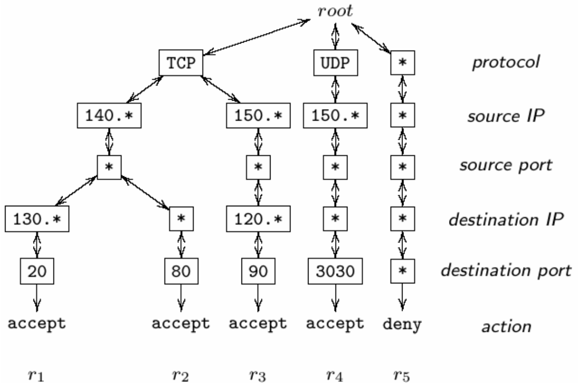
Policy DAG



Linear arrangement

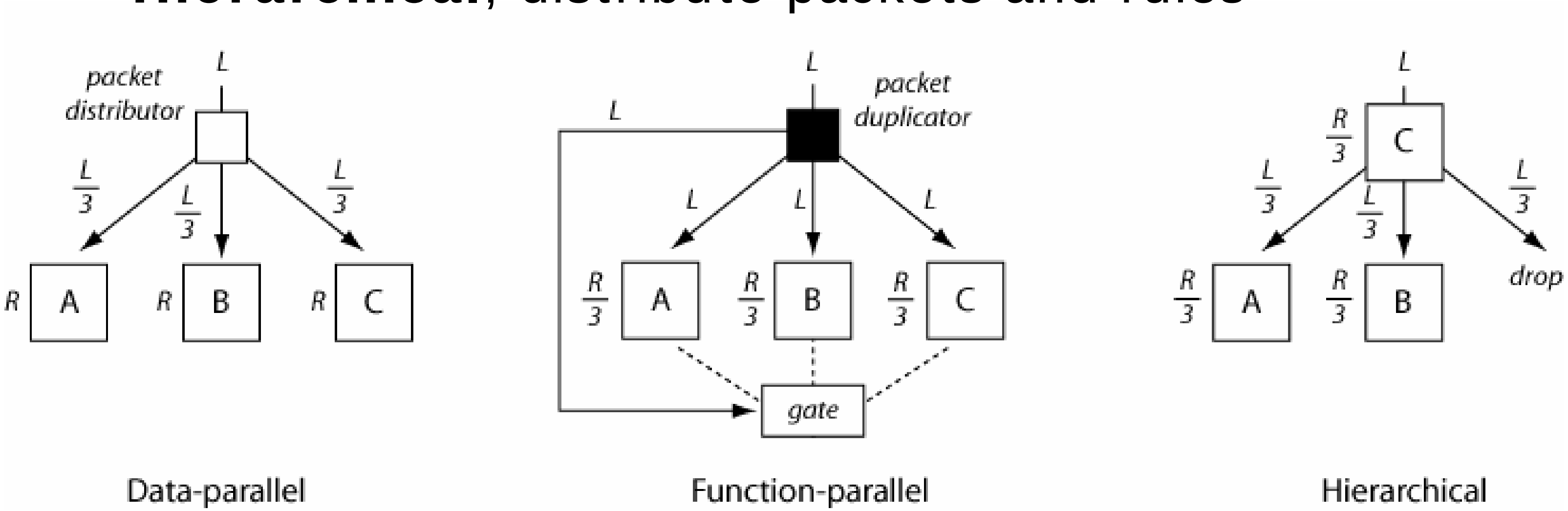
- *Optimized* list reduces number of compares (upto 80%)
- Rule compression and expansion

2. New **non-linear** representation
   - Policy trie requires $1/k$ compares
   - Policy trie optimization



Distributed Firewall Designs

- Three distributed designs
  - **Data parallel**, distribute packets
  - **Function parallel**, distribute rules
  - **Hierarchical**, distribute packets and rules



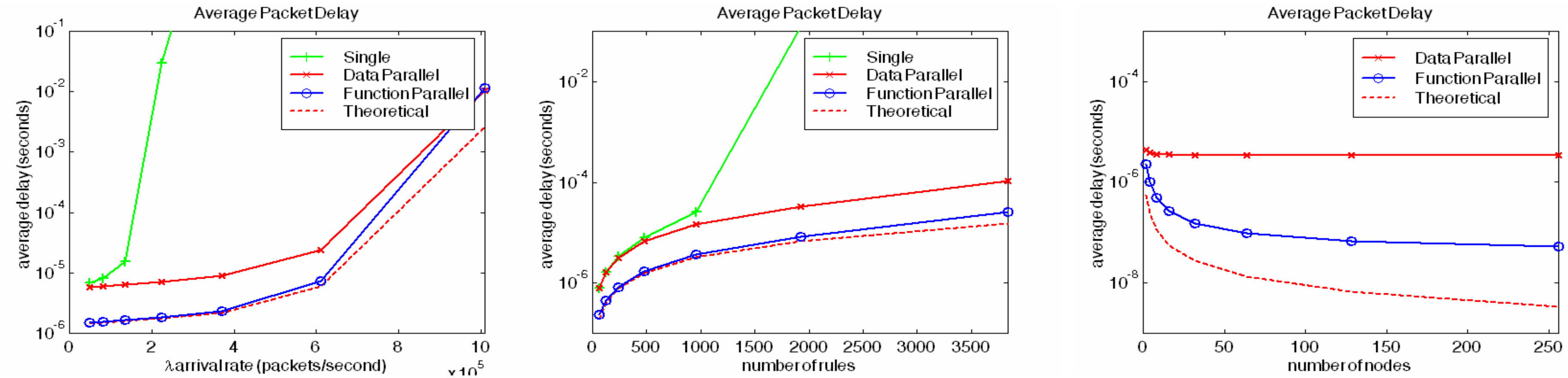
scalable, redundant, stateful inspection difficult, no differentiation

faster than data, scalable stateful, redundant?, no differentiation

potentially fastest, stateful, differentiation possible, rule distribution difficult

Function Parallel

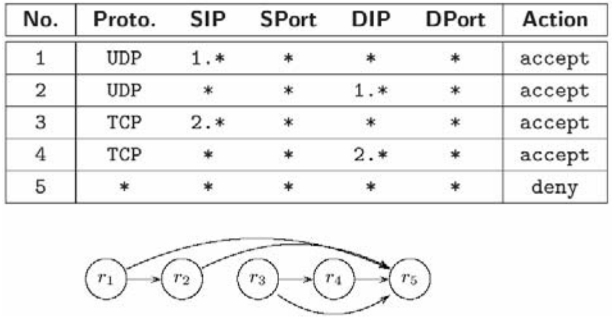
- Each node has a portion of the policy
  - Every packet processed by each node, and informs gate
  - Gate make final decision based on the policy DAG
- Results for 4-node parallel firewall



  - Function parallel 3 to 3.5 times better than data-parallel
- Gate is an additional delay, prefer to eliminate

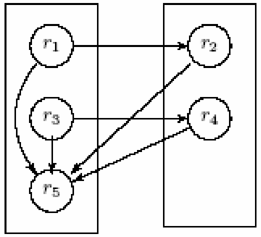
Eliminating the Gate

- Possible to remove the gate machine
  - Must distribute rules so only one node accepts
  - Use policy DAG and trie to guide decisions (*integrity*)
- Consider a policy and two node function-parallel

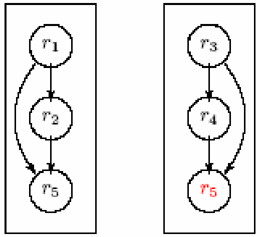


No.	Proto.	SIP	SPort	DIP	DPort	Action
1	UDP	1.*	*	*	*	accept
2	UDP	*	*	1.*	*	accept
3	TCP	2.*	*	*	*	accept
4	TCP	*	*	2.*	*	accept
5	*	*	*	*	*	deny

r_1
r_2
r_3
r_4
r_5



Odd-even distribution, requires gate

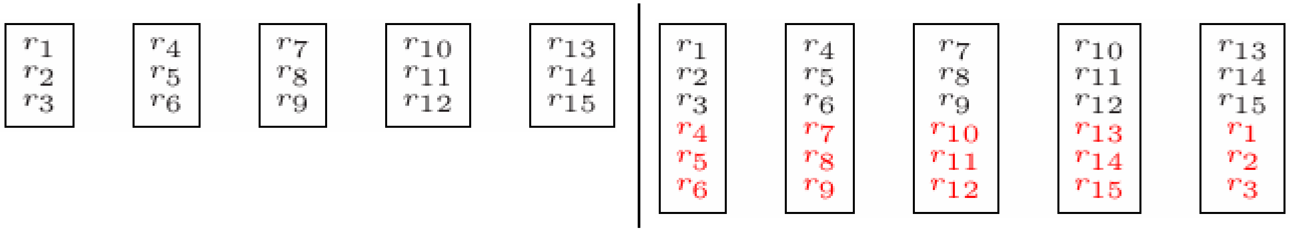


Distribution using DAG, requires no gate

- *Function parallel design is becoming hierarchical*
  - Nodes are designed to handle certain types of traffic
  - Maintains QoS, isolate DoS attacks

Continuing Research

- Finalize proofs for rule distribution
  - Eliminate gate and maintaining integrity
  - Use policy profile to optimize performance
- Create a redundant gate-less design


r_1 r_2 r_3
r_4 r_5 r_6
r_7 r_8 r_9
r_{10} r_{11} r_{12}
r_{13} r_{14} r_{15}
r_1 r_2 r_3 r_4 r_5 r_6
r_4 r_5 r_6 r_7 r_8 r_9
r_7 r_8 r_9 r_{10} r_{11} r_{12}
r_{10} r_{11} r_{12} r_{13} r_{14} r_{15}
r_{13} r_{14} r_{15} r_1 r_2 r_3

  - Use policy DAG and trie to distribute rules
  - Gateless performance with redundant attributes
- Dynamic array of firewall nodes
  - *Function parallel is not always better…*
  - Use queueing theory to determine optimal design
  - Data and/or function parallel distribution

Synergistic Activities

- **Cyber Security Group at PNNL**, *Summer 2005*
  - Deborah Frincke, John McCoy, Tom McKenna, and Patrick Wheeler (UC Davis)
  - High-speed firewall and IPS designs
  - Developed policy optimization techniques
- New **Start-up Company**, *Spring 2005*
  - High-speed firewall and IDS/IPS solutions
  - Two patents pending (*firewall optimization, rule distribution, and distributed architectures*)
  - Business plan developed
  - Initial implementation at WFU and testing at NC State
  - Seeking funding/initial investors, *possible SBIR*