An API for dynamic firewall control and its implementation for Linux Netfilter

3. Essener Workshop "Neue Herausforderungen in der Netzsicherheit"

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Agenda

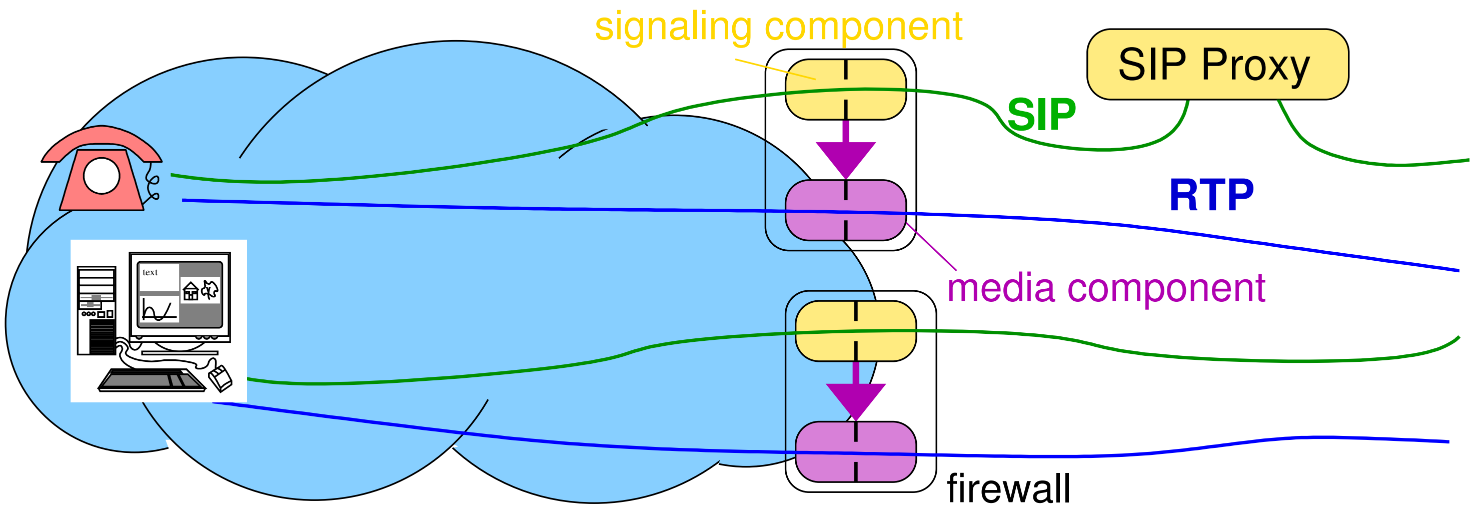
- Problem statement
- API requirements and design
- Implementation for Netfilter
- Performance evaluation: measurement results
- Possible improvements
- Conclusion and Outlook

Problem statement

Dynamic firewall control

Security at network edge: Open firewalls for legitimate connections

- for VoIP: SIP/SDP and RTP
  - strict policies – authorization of SIP sessions
  - open firewall (pinhole) for media stream, parameters negotiated with SIP/SDP
  - two firewall parts: signaling component and media component
- several approaches possible
  - distributed vs. monolithic (Session Border Controller – SBC)
  - packet filter vs. RTP proxy

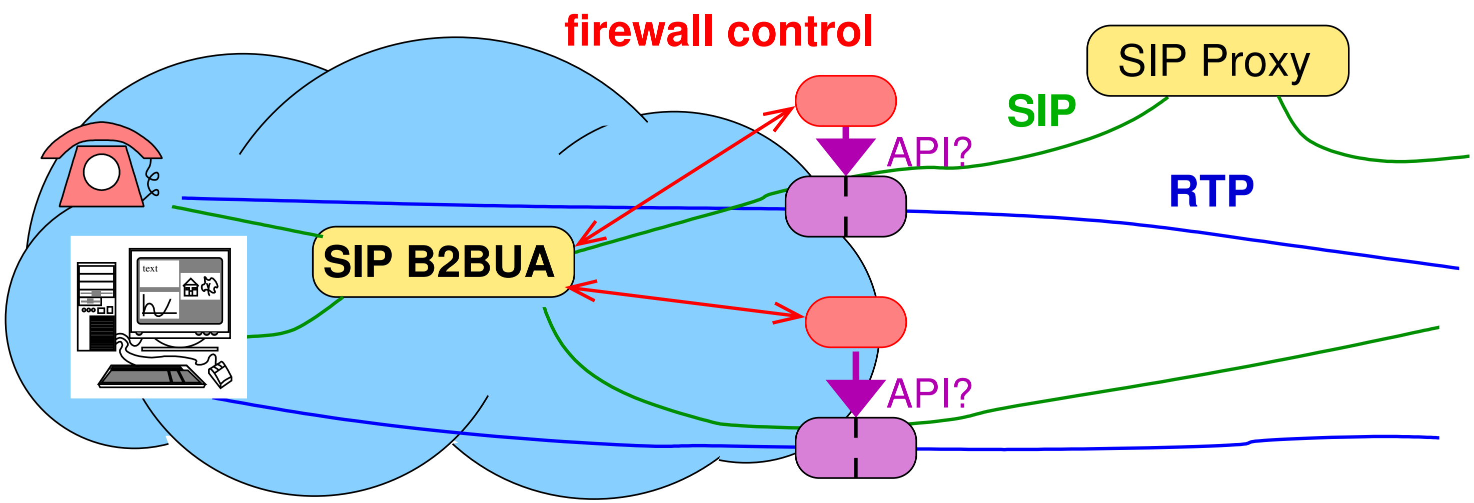


Problem statement

Dynamic firewall control

Approach: distributed + packet filter (using firewall control protocols)

- server process running on firewall machines manages pinholes
- accepting only messages from authorized machines
- session stateful server (SIP B2BUA)
  - extracts RTP-flow parameters from signaling messages
  - authorizes calls
  - signals pinholes to open/close
- several controlling instances (e.g. also Intrusion Detection Systems)



Problem statement

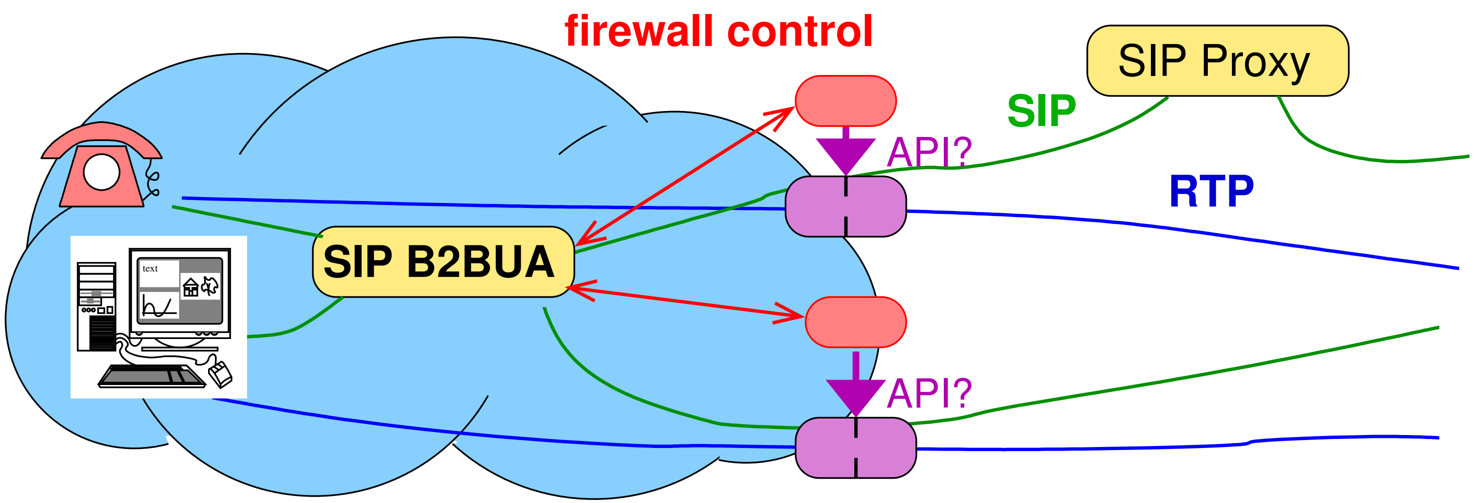
Dynamic firewall control

Design of firewall control daemon @IKR (SIMCO server)

- how to open pinholes?
  - calling command line tools?
  - using libraries (libiptc, nfnetlink)?
- daemon runs on different Operating Systems, what about packet filter dependencies?

  → packet filter interface is very OS-specific (and even in Linux there are several)

→ general pinhole API, not only for SIMCO server



API design

Requirements from firewall control frameworks

MIDCOM/SIMCO

- implementation of Midcom:
  simple middlebox control protocol (SIMCO), (RFC 4540)
- NAT + packet filter signaling – our focus: packet filter
- enable (PER) and prohibit (PDR) pinholes (white list)

  → PDR closes affected pinholes (bulk change)
- pinhole
  - two "address tuples" (transport protocol, address, prefix, port, portrange)
  - ports and address wildcarding
  - inbound/outbound/bidirectional

→ pinhole: five tuple with ranges/prefix, white list

problem: multiple packet filters at network edge

- must be handled by client, independent of packet filters
- 1st possibility: know routing
- 2nd possibility: open pinholes in every packet filter

API design

Requirements from firewall control frameworks

IETF NSIS (next steps in signaling)

- framework for path-coupled signaling
  - idea: signal nodes on path independent of IP routing (e.g. for QoS)
  - generic messaging layer (General Internet Signaling Transport)
    - Datagram/Connection Mode
    - TCP, UDP, IPSec
  - NSIS Signaling Level Protocols (NSLP) on top of GIST
- NAT/Firewall Control
  - NAT/Firewall control NSLP (draft-ietf-nsis-nslp-natfw-18.txt)
  - authorization possible with tokens (draft-manner-nsis-nslp-auth-03.txt)

API design

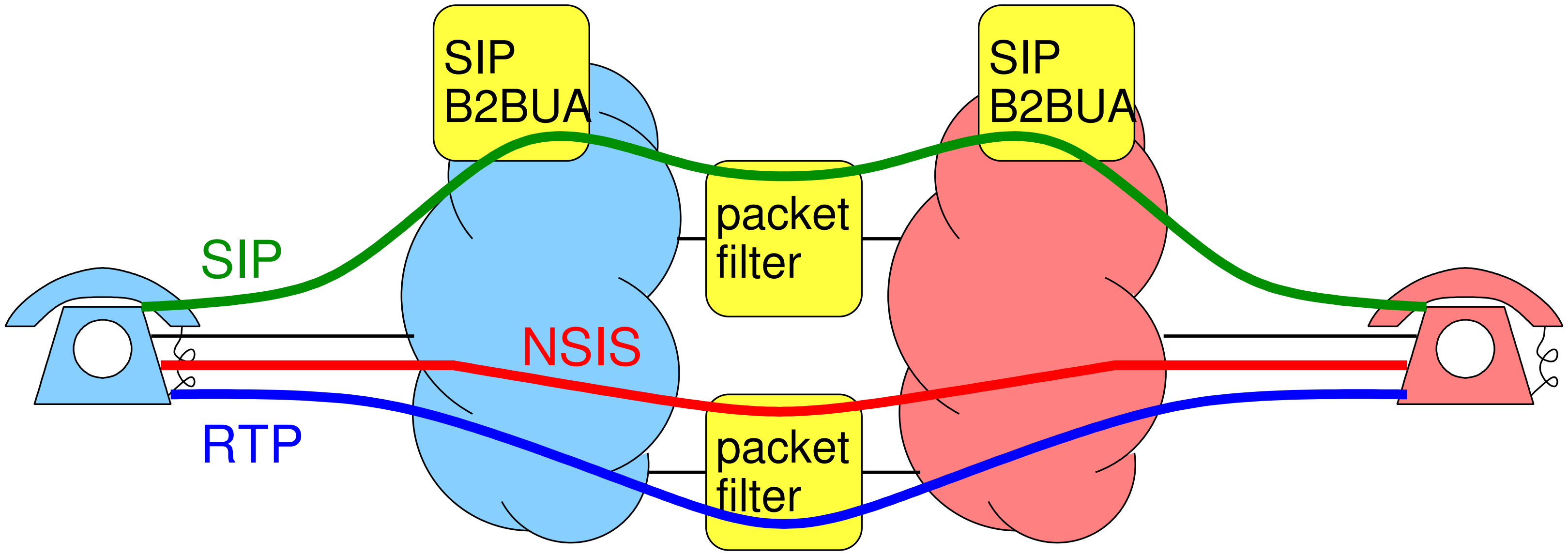
Requirements from firewall control frameworks

IETF NSIS (next steps in signaling)

- pinhole description based on NSIS-flow
  - `sub_ports`: number of contiguous ports (0..1)
  - typically white list approach for pinholes
  - also traffic blocking mode with `EXT` messages (for whole prefix, port wildcard)

→ pinhole as five tuple, range definitions are subset of simco

→ white list feasible. Blocking can be mapped to shrinking the white list



API design

Requirements from firewall control frameworks

Requirements

- open/close pinholes
- unidirectional pinhole: five tuple (incl. subnets + port ranges)
  - bidirectional: two pinholes
  - for TCP: direction of connection establishment
- independent of filter implementation (and OS)
- transaction semantics (typically, several rules are added at once)
- performance
  - frequent rule changes (VoIP)
  - high packet rate
- security
  - no control over whole packet filter, only dedicated rule sets
  - controlling entity must not be root, else a compromised firewall control daemon is fatal

API design

Managing pinholes using the pinhole API

features

- white list approach
- rules defined by five tuple
  - + prefix length
  - + port range
- adding rules by definition (returns ID)
- removing rules by ID

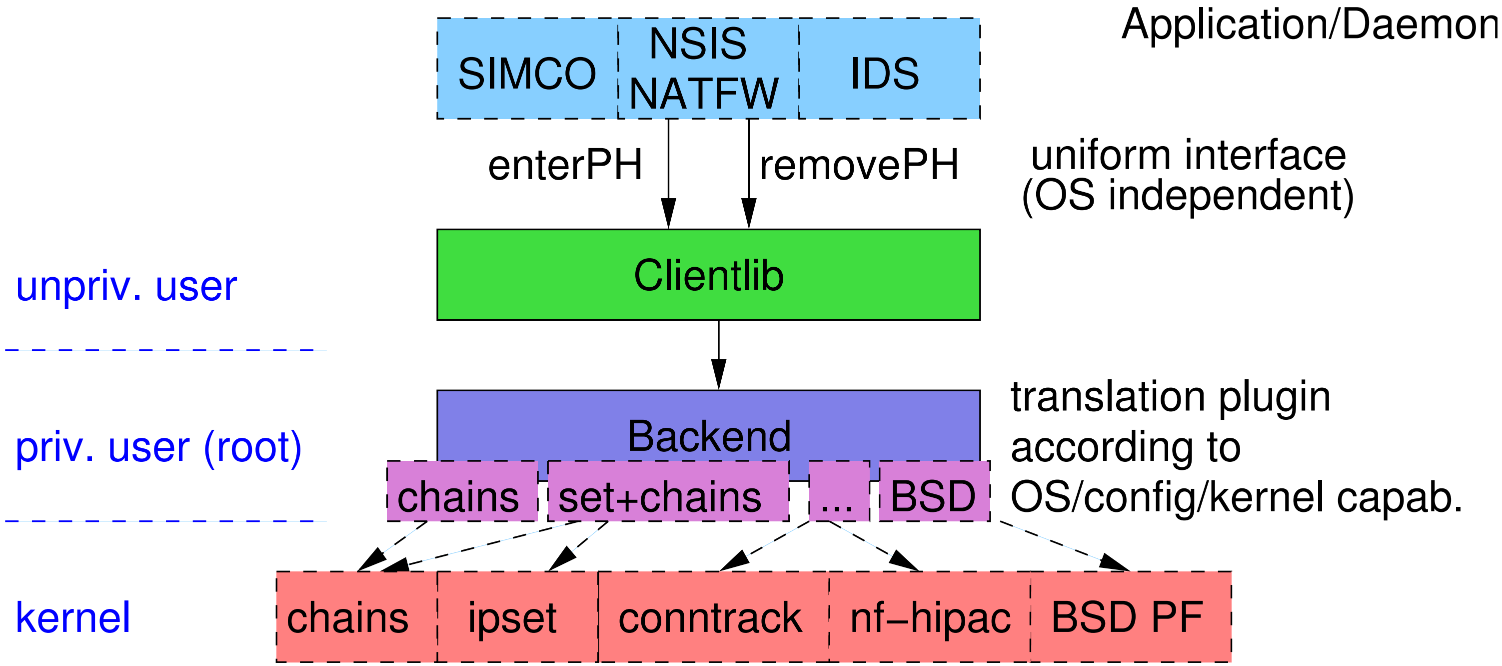
simple transaction mechanism

1. start transaction
2. add/delete rules
3. commit

API design

Implementation aspects

The big picture



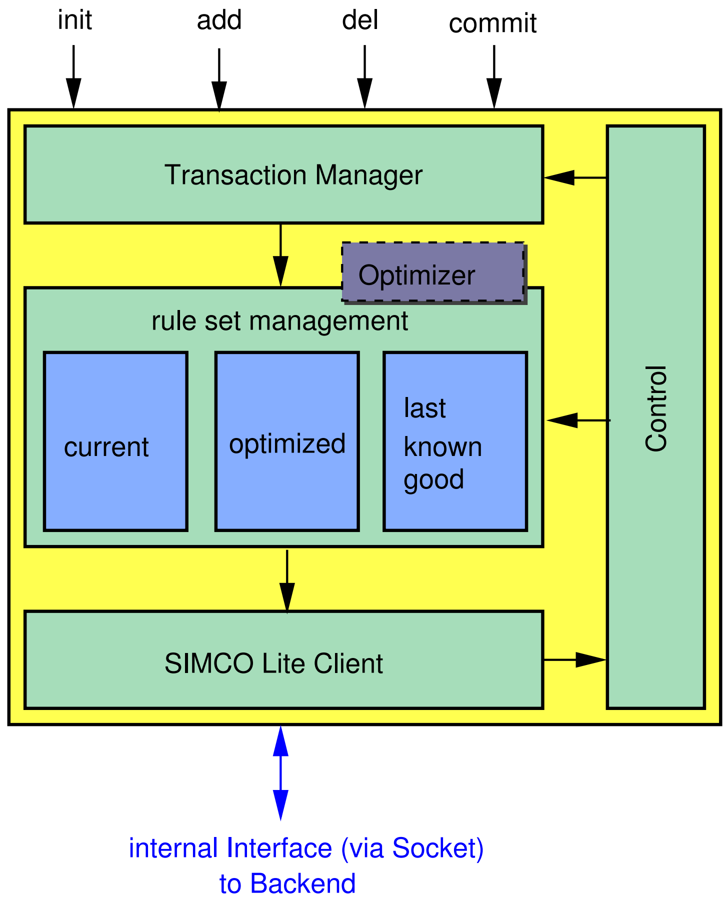
- application design independent of operating system
- use of different packet filter by changing translation plugin
- use of different packet filters depending on rule type (optimization possible)

API design

Implementation aspects

Frontend

- keeps all rules/pinholes
  - optimization possible (hook) while still being able to delete rules per ID
  - enables differential updates
  - failure: last known good
- commit rules as batch to backend
- socket communication: reuse of SIMCO message definition + added new control messages

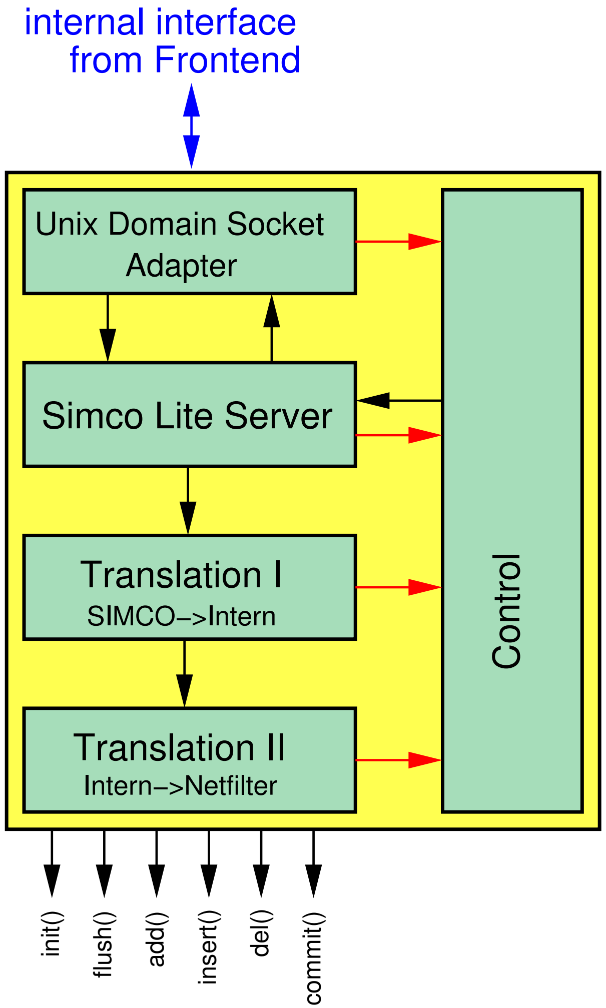


API design

Implementation aspects

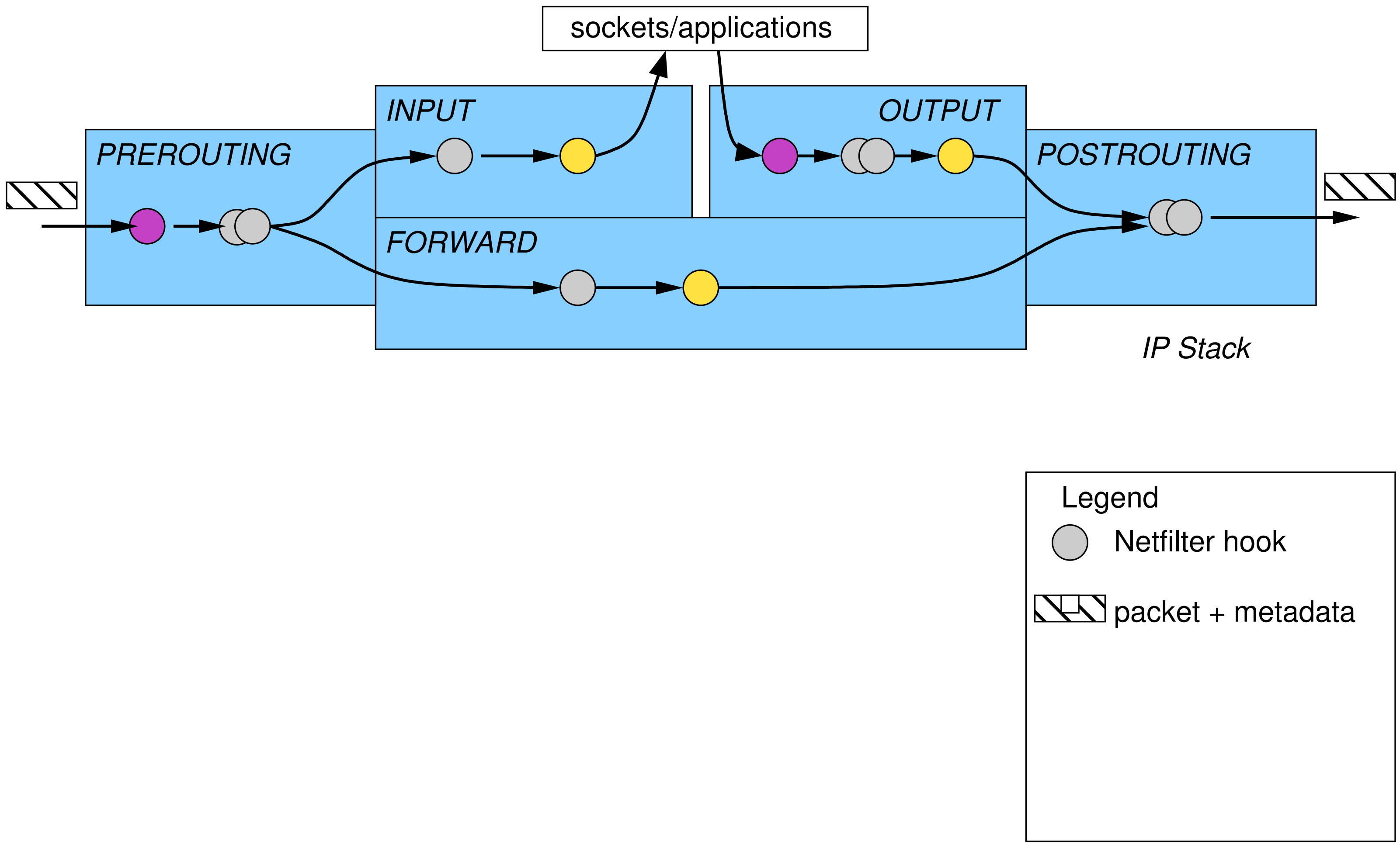
Backend

- processing of frontend requests
- translation of pinholes to netfilter rules
- notify frontend about status
- failure recovery, e.g. frontend crash
- only Translation module II is packetfilter-dependent



Implementation for Linux Netfilter

Mapping rules to Netfilter



Implementation for Linux Netfilter

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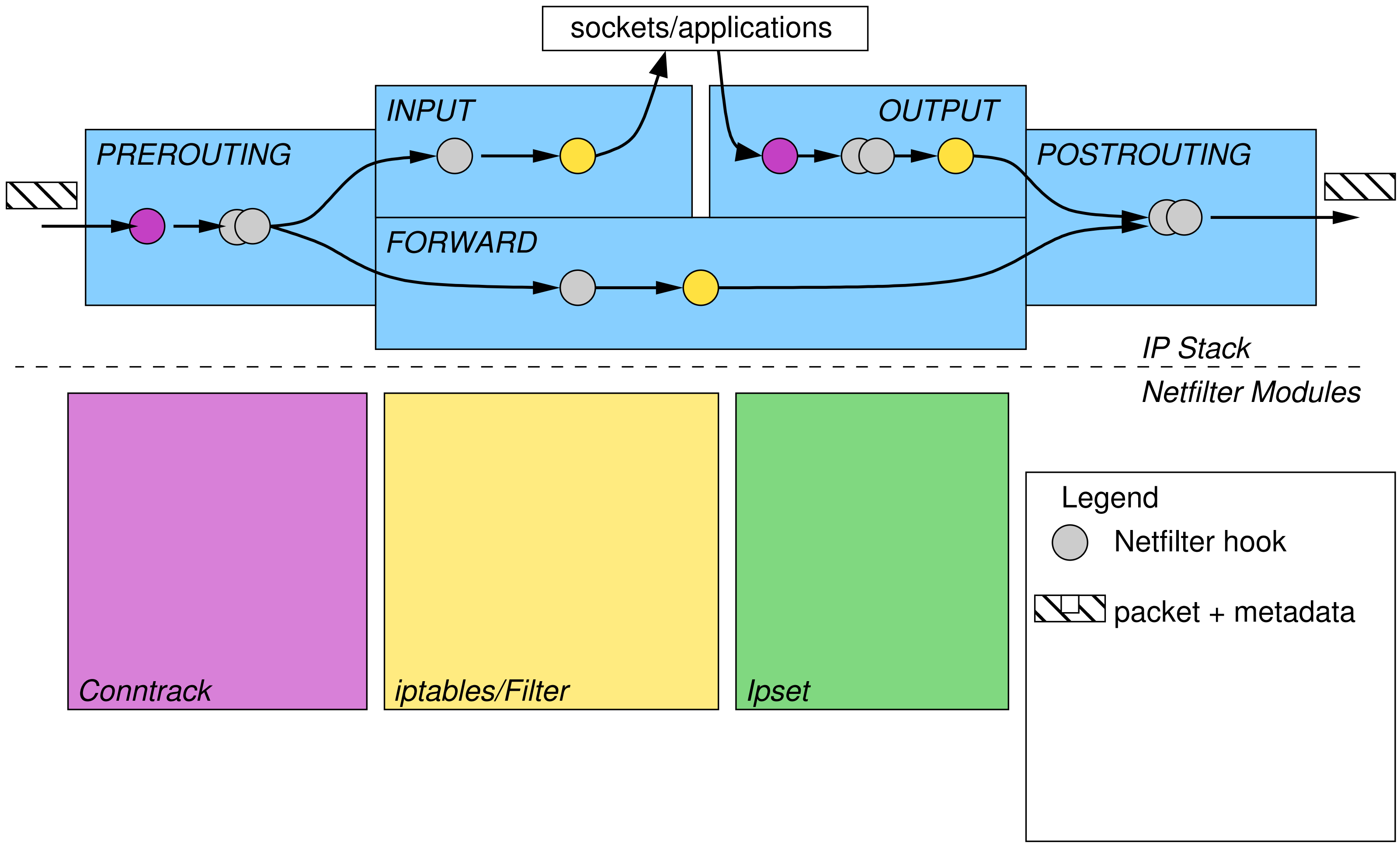

Implementation for Linux Netfilter

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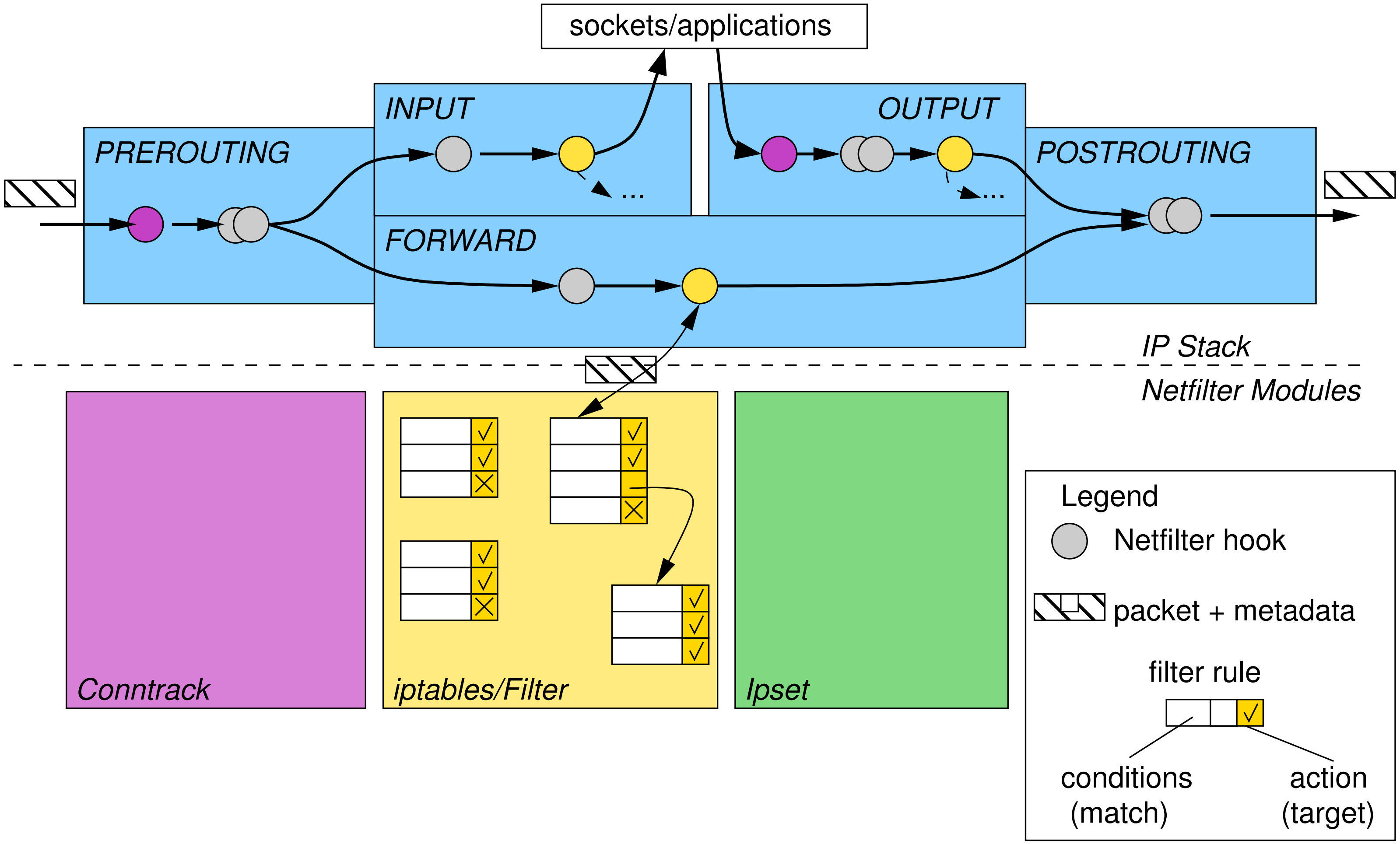
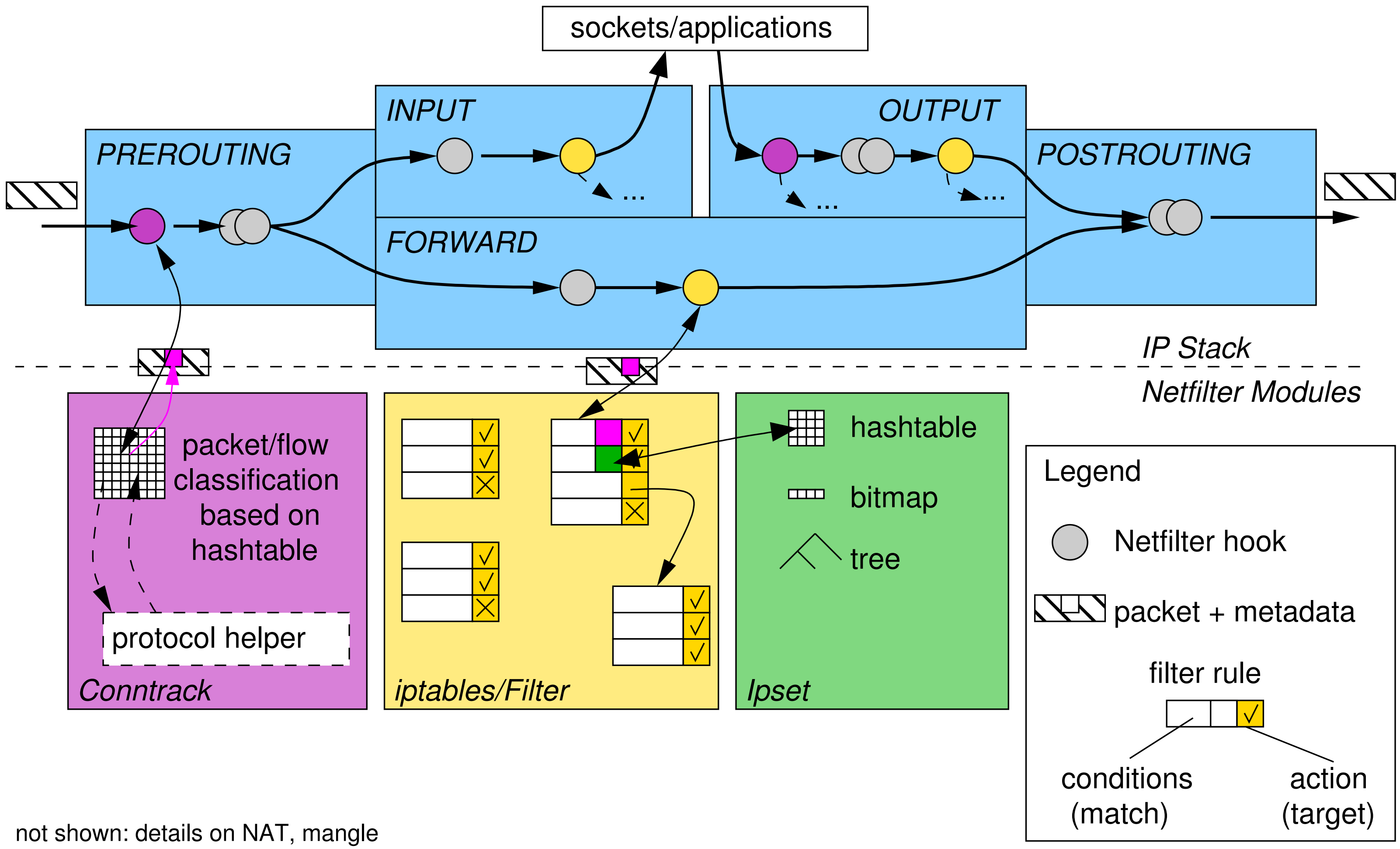


Implementation for Linux Netfilter

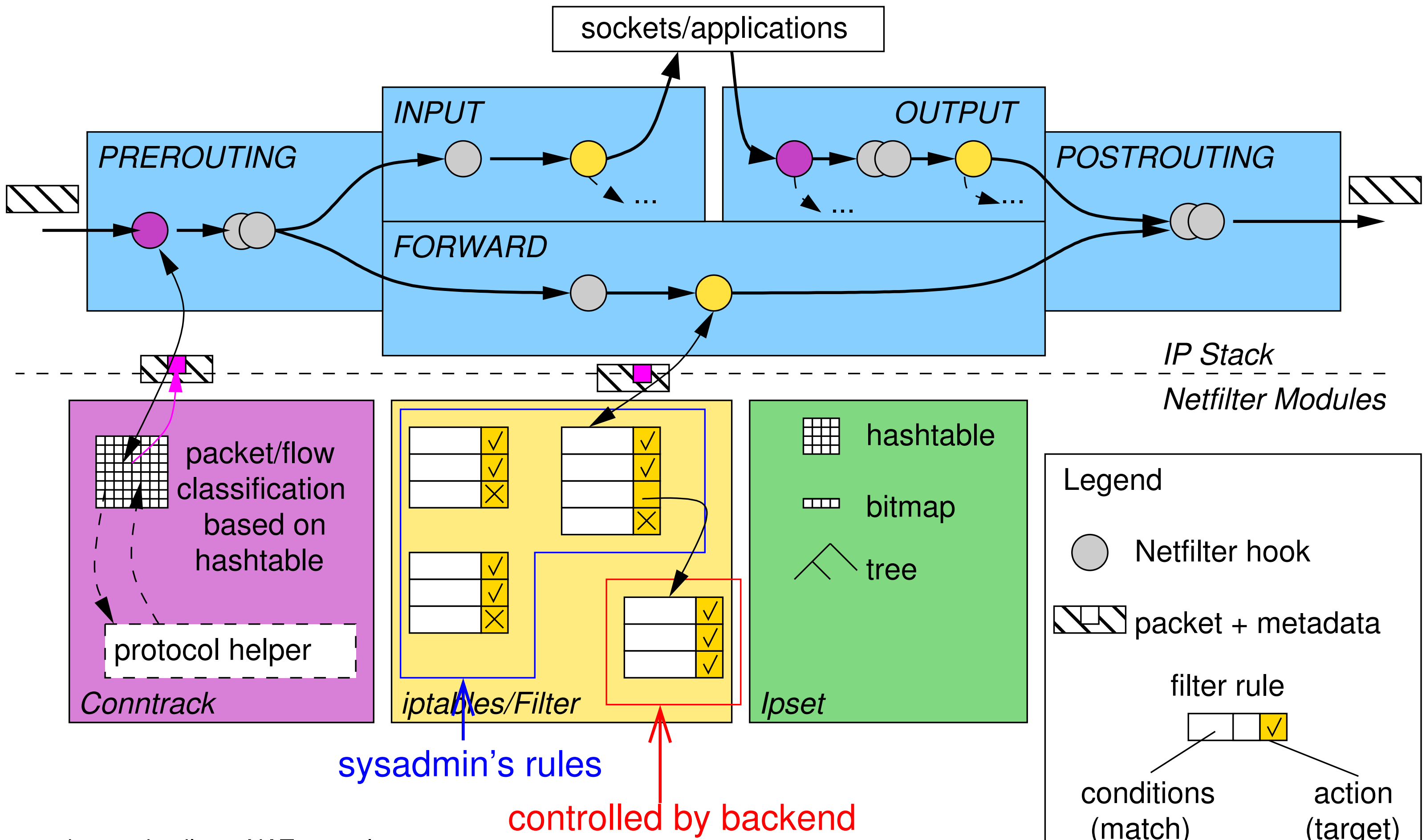
Mapping rules to Netfilter



not shown: details on NAT, mangle

Implementation for Linux Netfilter

Mapping rules to Netfilter



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Implementation for Linux Netfilter

Netfilter Modules

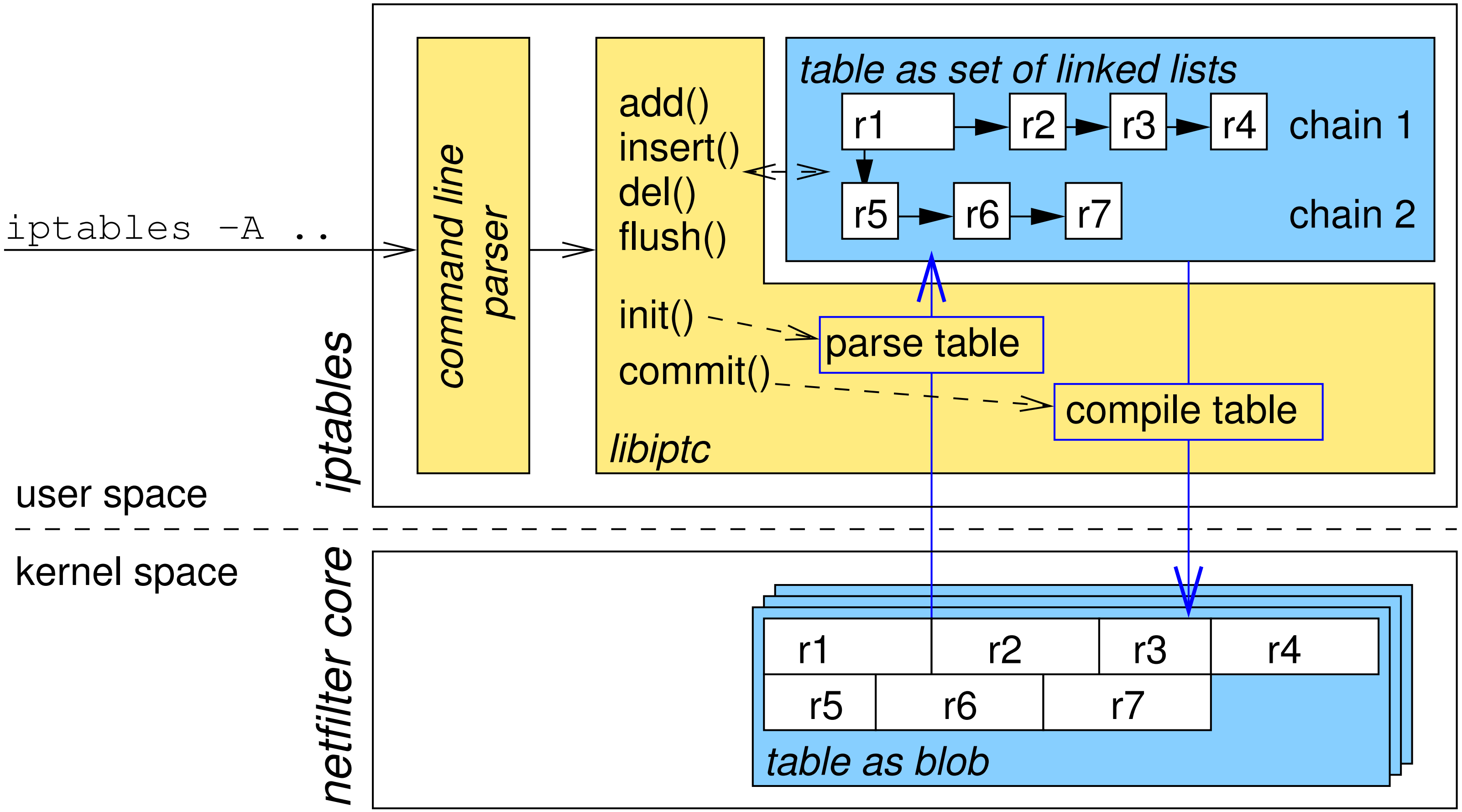
- iptables
  - linear search over lists (chains)
  - extensible by sophisticated "matches"
- connection tracking (contrack)
  - stateful packet filter
  - hash-based connection table
  - determines connection state and stores it to packet metadata
- ipset
  - hash-, tree- and bitmap based filter modules
  - realized as iptables march – stateless
- nf-HiPAC (High Performance PAcket Classification)
  - fast for high number of rules
  - possible replacement for chains/tables
  - patch for older kernels

→ pinhole API implemented for tables/chains, since port ranges and subnets required. (conntrack and ipset work for exact match only, nf-HiPAC is not integrated)

Impementation for Linux Netfilter

Managing netfilter rules

Accessing iptables – LibIPTC



- different represenations in user and kernel space
- translation of complete ruleset before and after modifications

Performance Evaluation

Measurements with libiptc backend (VoIP Scenario)

Parameters

- 20 ms packetizing time: 100 pps/call (bidirectional), no bursts
- 2 pinholes per call: asymmetric RTP

$\rightarrow$ rate and rule set depending on number of simultaneous cals

- Pentium 4, 2.53 GHz

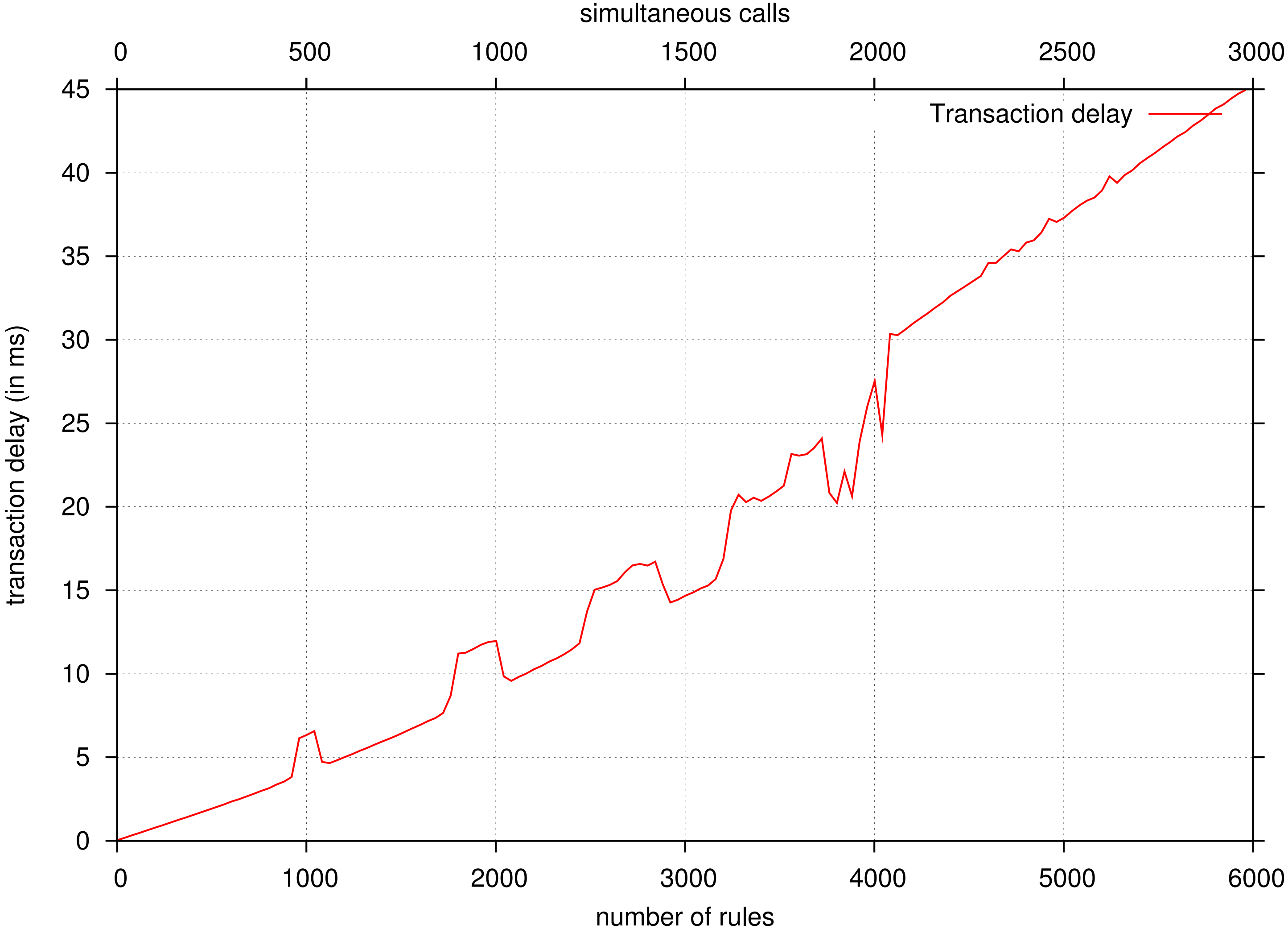
Measurement Scenarios

- transaction delay for entering/removing rules without network traffic
- packet loss and delay for traffic traversing the packet filter
  1. legitimate traffic only
  2. additionally with "bad" traffic, that will be filtered
     - contributes to overall packet rate
     - check against every rule (other packets match after half of the rules)

Performance Evaluation

Changing rules

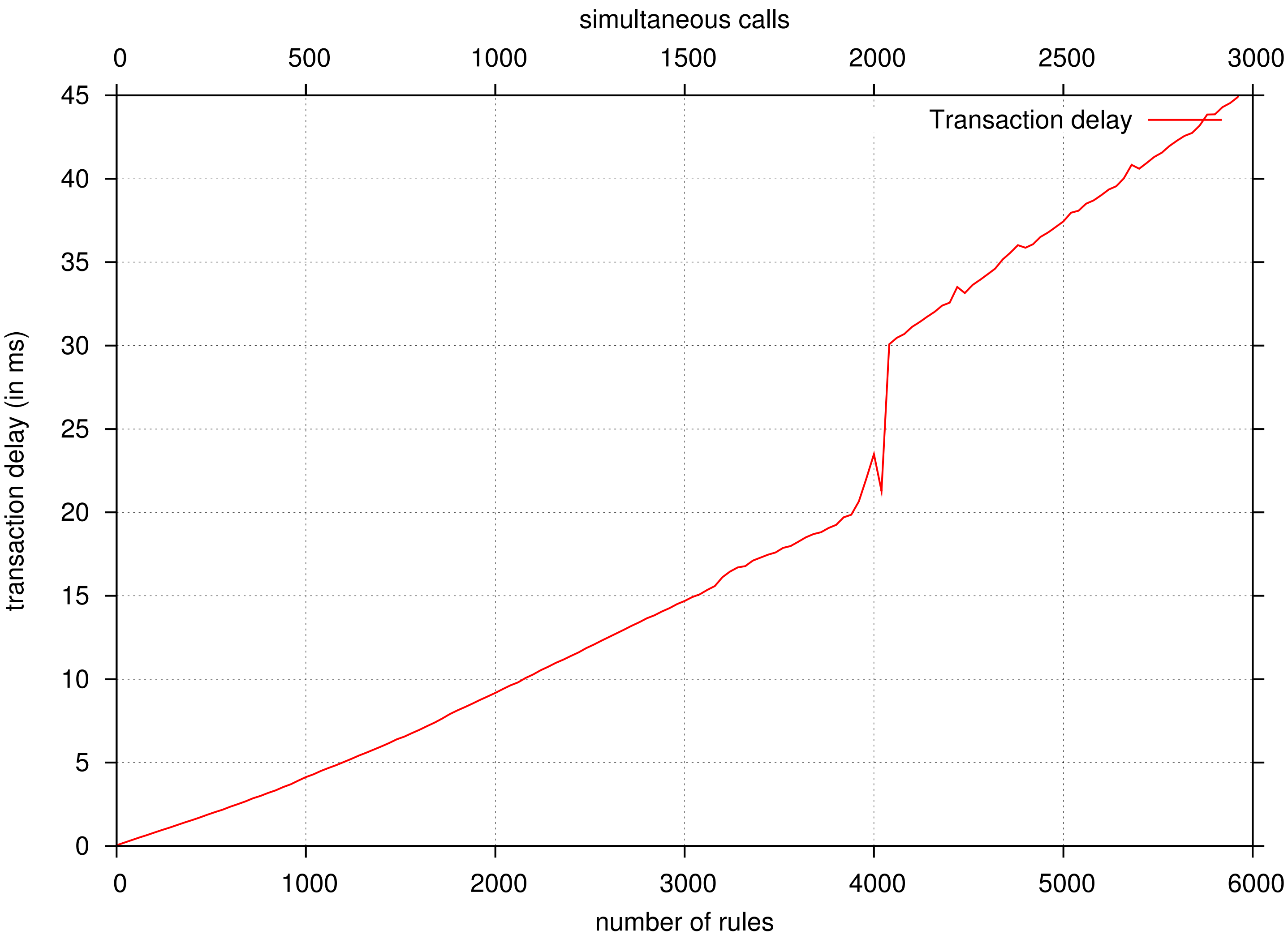
Rule entry delay without traffic



Performance Evaluation

Changing rules

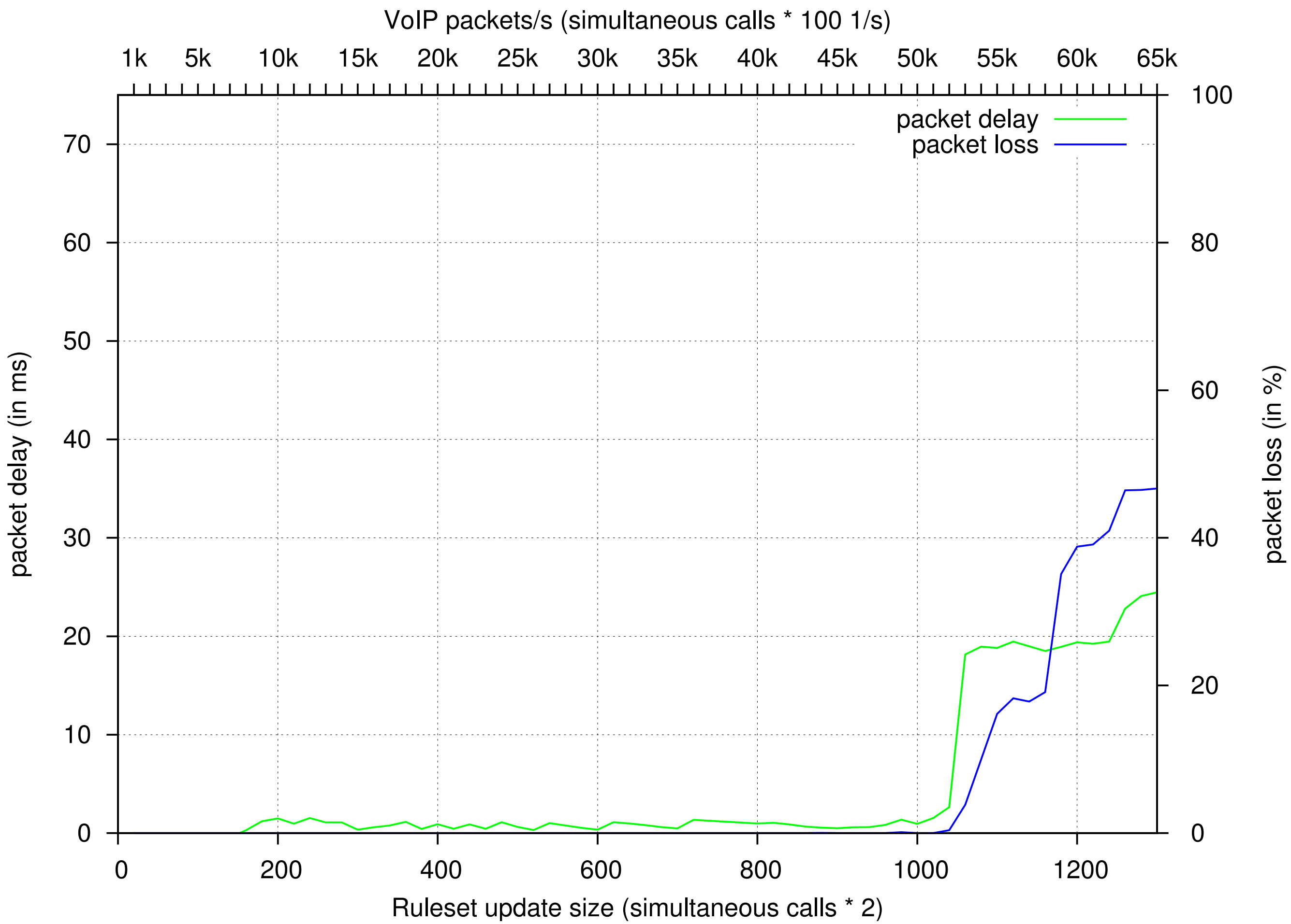
Rule deletion delay without traffic



Performance Evaluation

Throughput

Delay and loss over rule size and rate



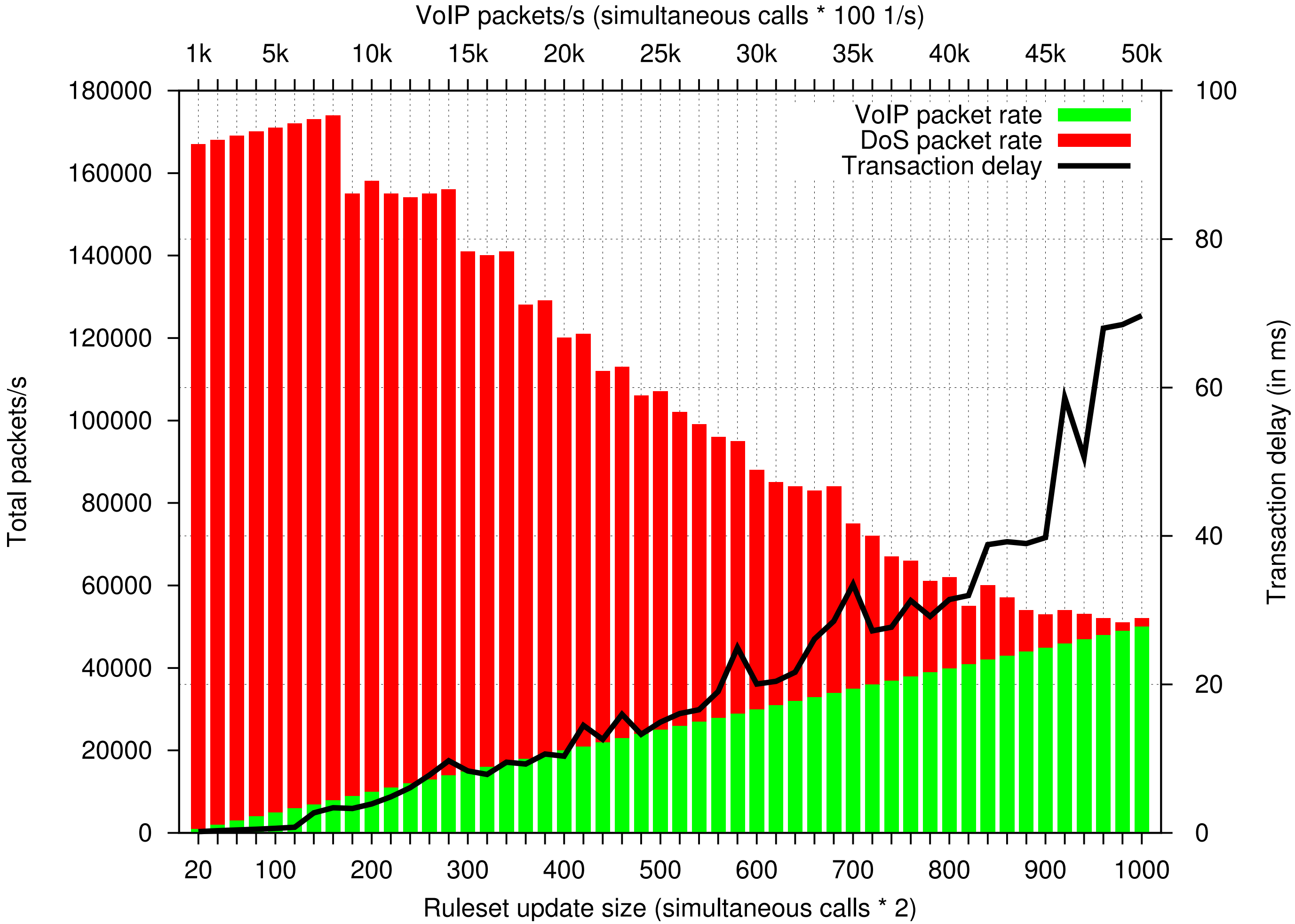
→ performance sufficient for 500 simultaneous calls

Performance Evaluation

Throughput

Throughput while discarding bad traffic

rate of illegitimate packets (DoS) increased until 0.1 % loss occured



Performance Evaluation

Measurement summary

Rule management

- effort mainly depends on ruleset size

    reason: translation between kernel and user space representations
- spikes in rule entry delay due to caching effects?
- saltus at ~4096 rules due to paging effects?

Throughput

- sufficient for ~500 calls (pure good traffic)
- for dimensioning: consider max packet rate of bad traffic!
- delay negligible, if not in overload - there are only very small Queues

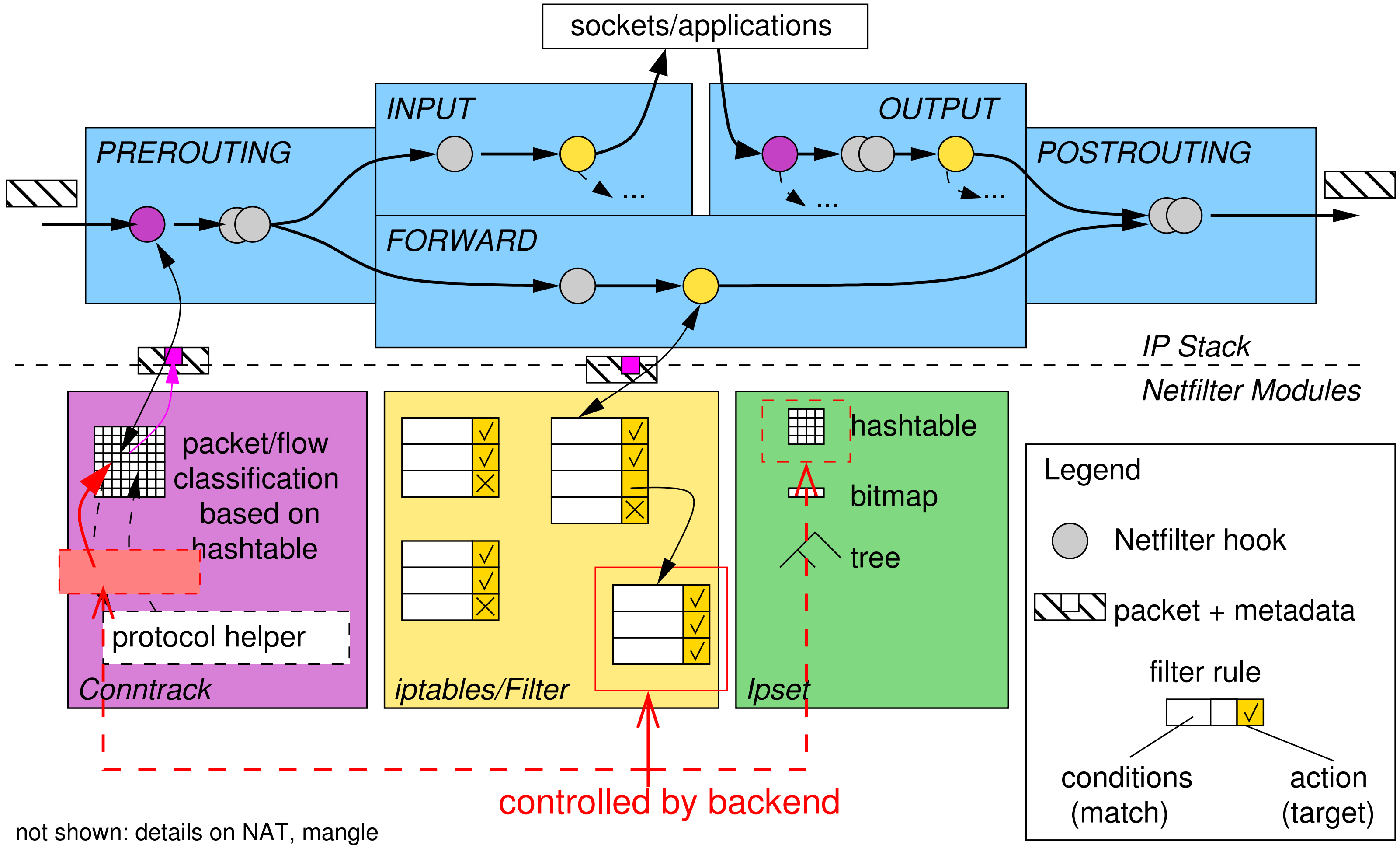
→ still decent performance for standard hardware

e.g. enterprise with 20 Mbit/s link: 250 simultaneous calls (each 80 Kbit/s)

- performance sufficient, even with DoS traffic
- corresponds to 5000 users (0.05 Erlang)

Possible Improvements

Changes in backend to improve performance



- same API but better mapping to netfiter
- keep it simple: no additional protocol checks in Conntrack (like checking RTP)

Conclusion and Outlook

Conclusion

- API for dynamic firewall control (phapi) designed and implemented
- can integrate with our SIMCO-Server (sourceforge.net/projects/simco-firewall/)
- pinhole api implementation (phapi): www.ikr.uni-stuttgart.de/Content/firewall/
- filter/chains based on linear search **perform quite well**
- **interaction with Conntrack** cannot be easily solved (conntrack must be disabled)

Outlook

- interface between Conntrack and backend
  - keep information about mapping between conntrack entry and pinhole
  - stateful fast filtering
  - resolves interaction issue
  - still use iptables chains for large ranges/wildcards
  - optimal mapping? what is large? How costly are filter rules compared to Conntrack entries?
- implementation for other packet filters (OpenBSD, Network Processors, FPGA, ...)