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A userspace API for netfilter control

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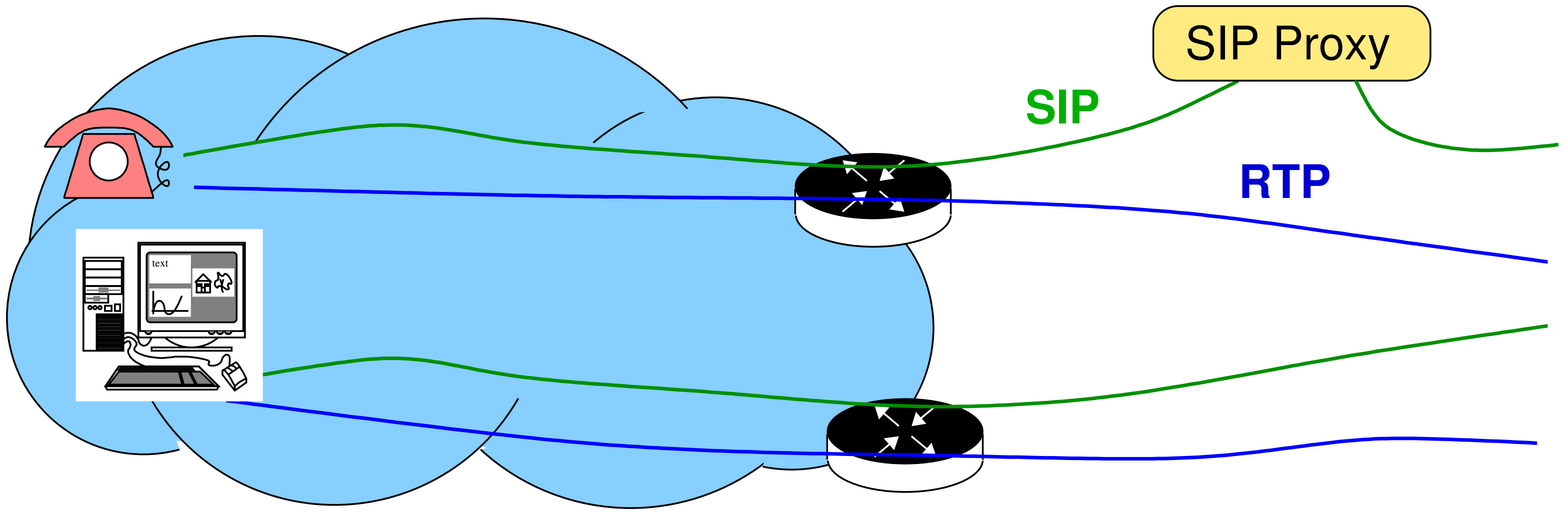
Agenda

- **Problem statement**
  - limitations of connection tracking
  - alternatives
- **Firewall Control Frameworks: Overview**
- ➥ **Requirements on a Pinhole API**
- **Pinhole API for netfilter**
  - Design considerations
  - Implementation status
  - Mapping of pinholes to netfilter
- **Conclusion and Outlook**

Problem Statement

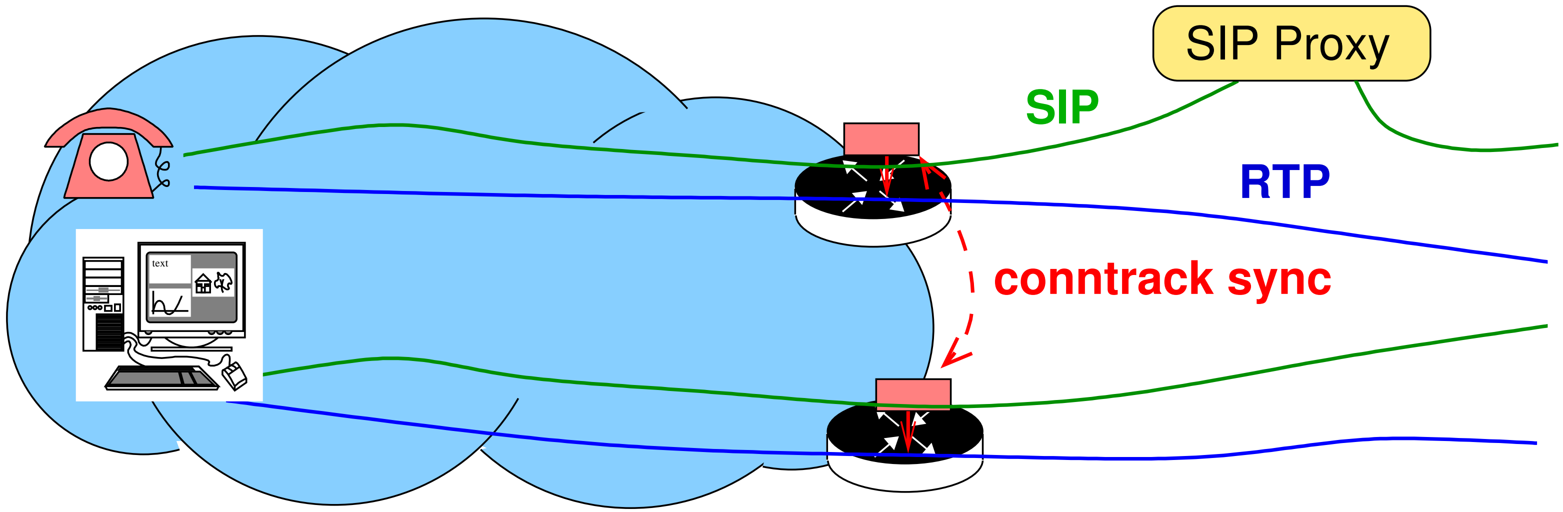
Scenario



- **control flow and RELATED media flow**
  - VoIP: SIP and RTP
- **strict fine-grained policies**
  - not -A OUTPUT -p UDP -j ALLOW
  - more than allow/not allow connection from/to
- **more than one border element (load-balancing, protection, multi-homing,..)**

Problem Statement

Approach 1: Connection Tracking only

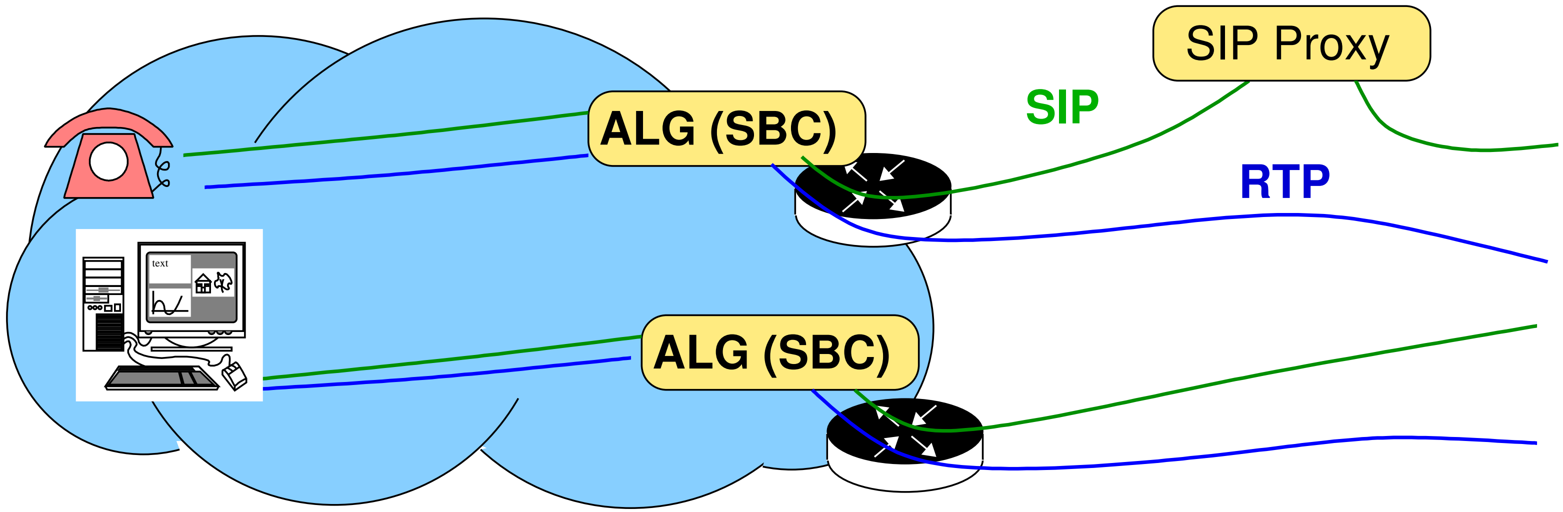


problems

- extensibility/maintainability:
  new kernel modules for new or changed control protocols
- robustness/security risk:
  parsing of complex protocols in the kernel
- no authorization/fine-grained policies
  requires additional internal SIP-proxy/B2BUA

Problem Statement

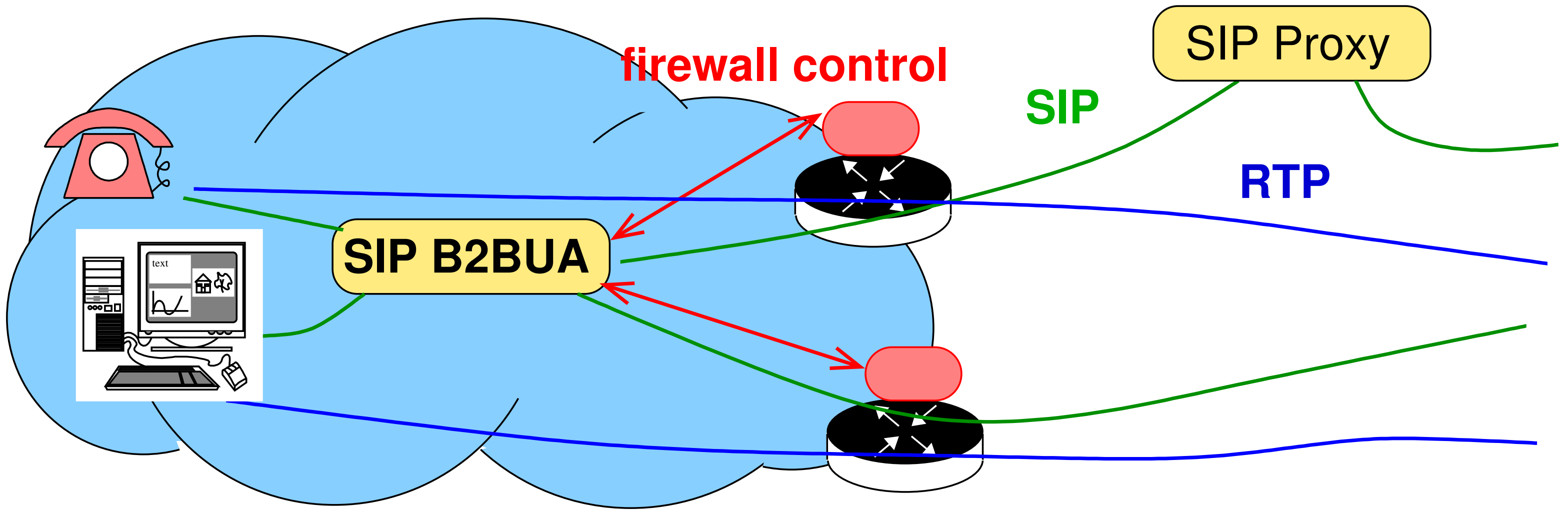
Apporach 2: Application Layer Gateways (ALG)



- **SIP-ALG: Session Border Controller (SBC)**
  - Processing of signaling and media (all in user space)
  - All RTP routed through ALG independent of IP-Routing
  - SBC needs full application knowledge (RTP codecs, ...)
  - packet filter in front of SBC: completely open to UDP? Conntrack?

Problem Statement

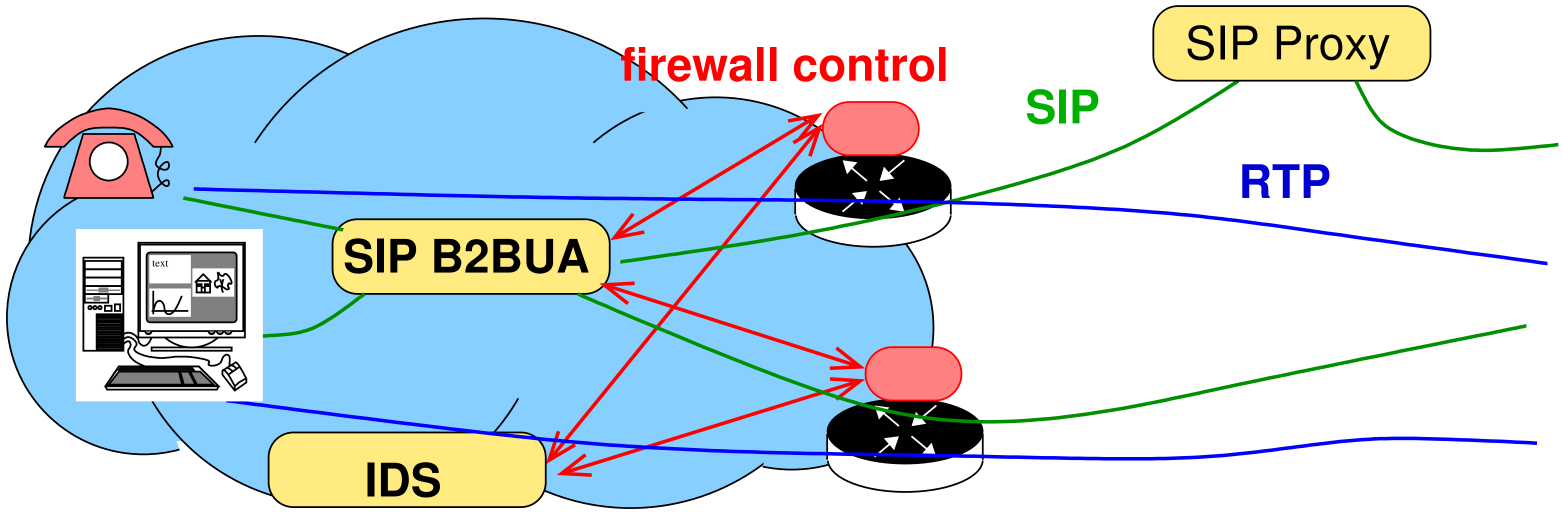
Approach 3: Firewall Control Protocol



- **firewall control daemons**
  - running on firewall machines
  - 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

Problem Statement

Approach 3: Firewall Control Protocol - prohibiting flows (IDS)



Firewall control daemon: how to control packet filter?

- calling command line tools
- using libraries (libiptc, nfnetlink)

➥ lots of dependencies on filter implementation, libraries, formats, OS

➥ **general API makes sense**

➥ **detailed requirements? first have a look at firewall control...**

Firewall Control Frameworks

Firewall/NAT Control protocol zoo

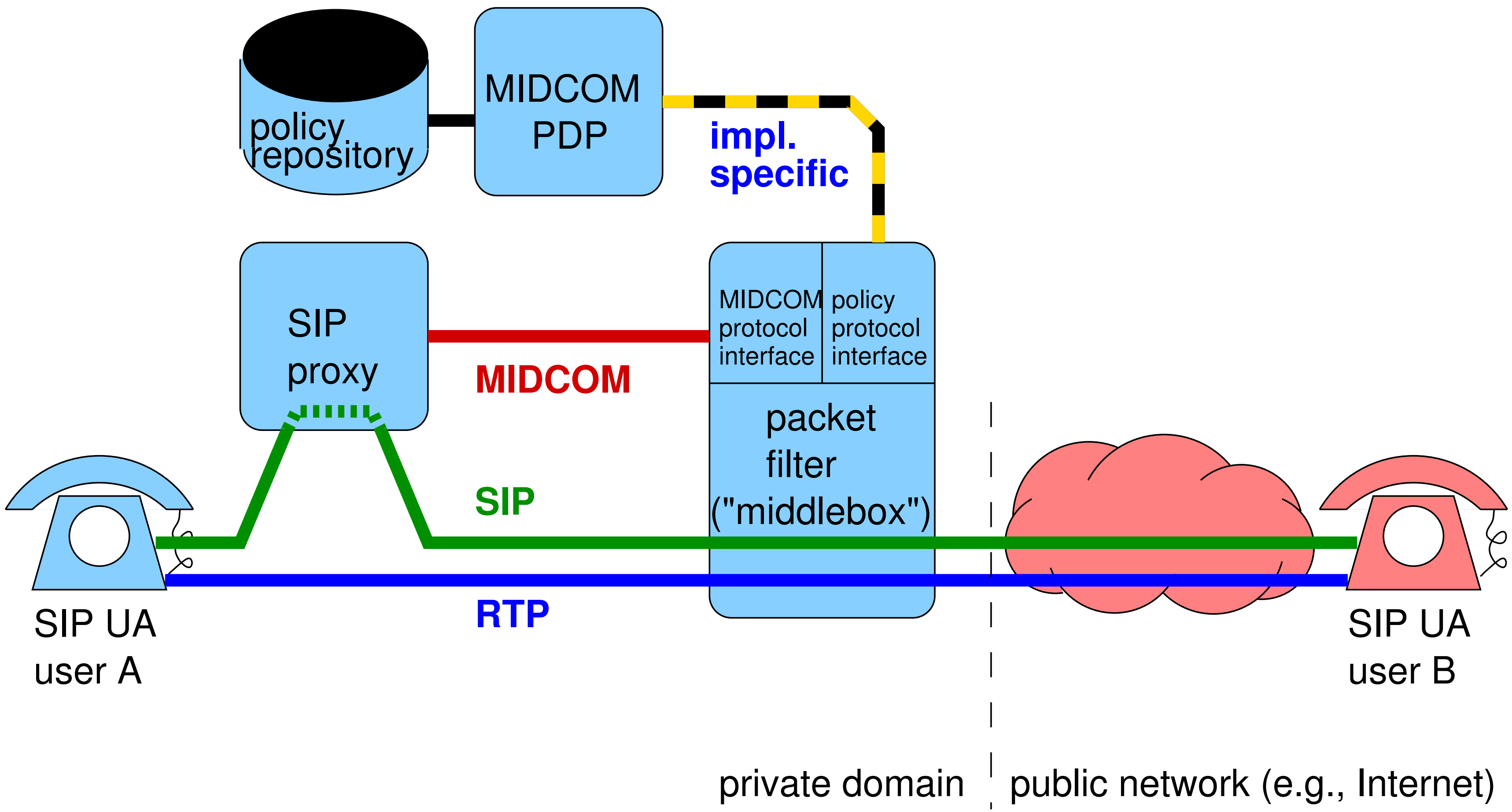
- **IETF MIDCOM Framework**
  - Implemetation: Simco
- **IETF NSIS**
  - path-coupled signaling framework (QoS requests, NAT, firewall)
- **H.248 MEGACO**
  - ETSI: Profile for controlling media relays (BGF)
  - H.248.37: signal SBC to replace addresses for NAT traversal

➥ **Focus on firewall control: MSimco, NSIS**

Firewall Control Frameworks

MIDCOM Framework (RFC 3303)

- **abstract protocol semantics for NAT/FW control**
- **abstract protocol entities**



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)**
- **Pinhole**
  - two "address tuples" (transport protocol, address, prefix, port, portrange)
  - ports and address wildcarding
  - inbound/outbound/bidirectional
  - ➥ can be mapped on 5-Tuple with ranges

Problem: multiple packet filters at network edge

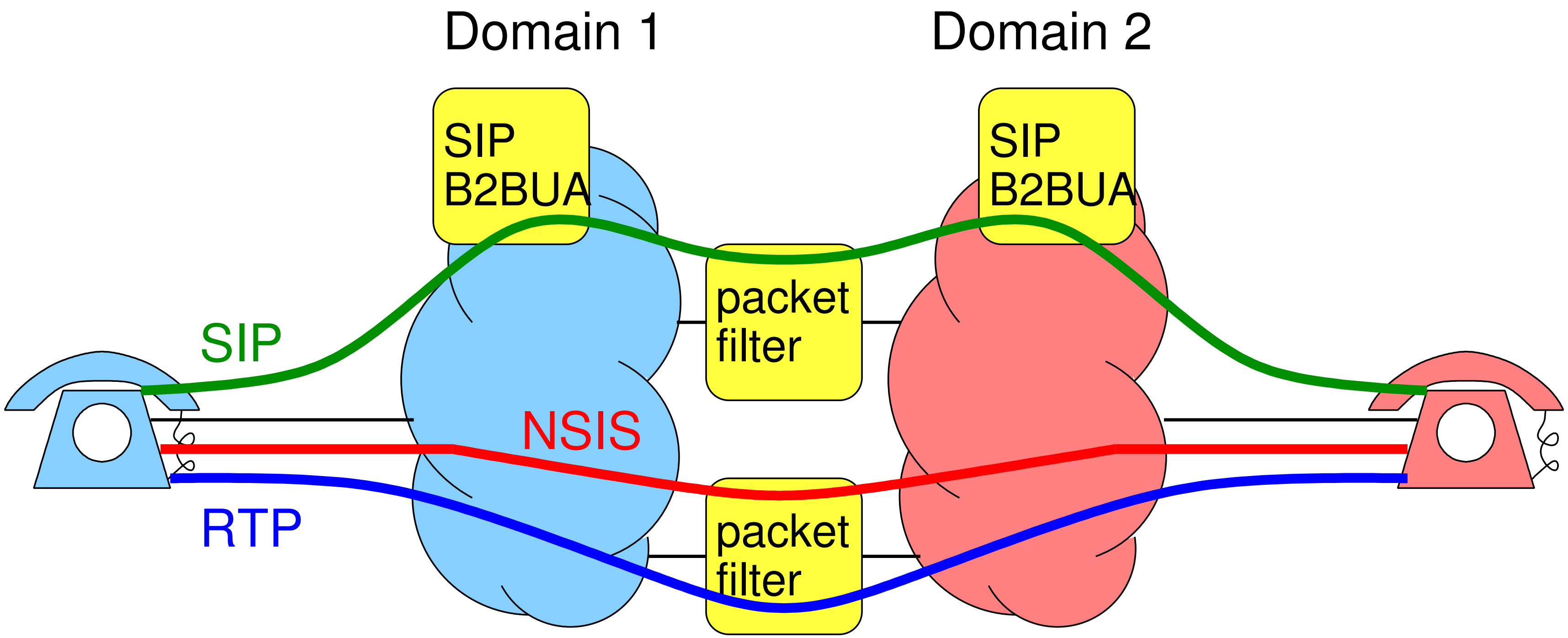
- **must be handled by client, independent of packet filters**
- **1st possibility: know routing**
- **2nd possibility: open pinholes in every packet filter**

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-15.txt)
  - Authorizationbased on tokens (draft-manner-nslp-auth-03.txt)

Firewall Control Frameworks



NSIS Firewall Signaling:

- **Pinhole description based on existing flow**
  - sub_ports: how many contiguous ports (0..1)
  - Allow/Deny
  - blocking traffic with EXT messages (for whole prefix, port wildcard)

Requirements on an API

There are several reasons for changing packet filter rules dynamically

- firewall control protocols (our motivation)
- ALG implementations
- Intrusion detection systems

Often realized by calling iptables, but libraries available are very specific (libiptc). Strong dependency on filter realization.

➥ **Why not designing a common (high-level, userspace) API?**

➥ **We started based on requirements from a SIMCO-Prototype**

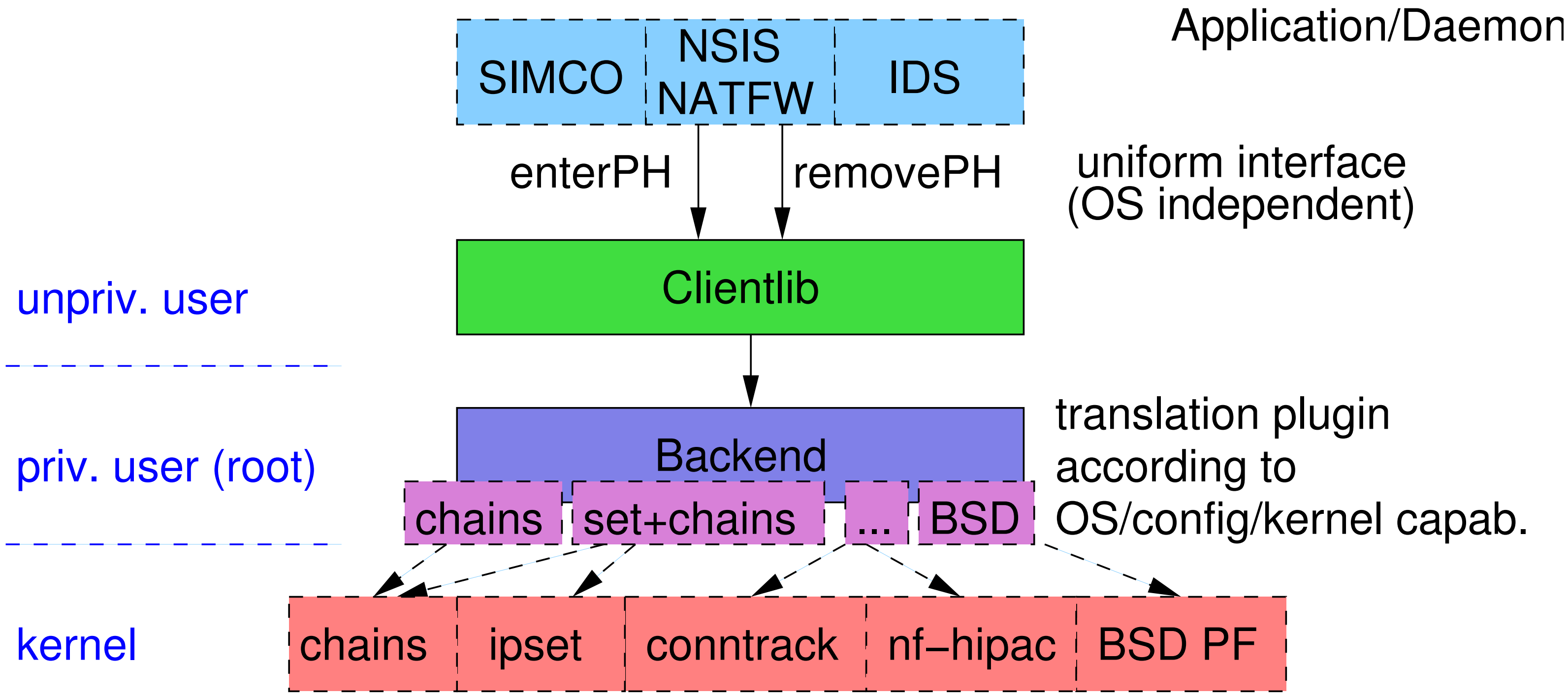
Requirements on an API

(Our) Requirements

- **open/close pinholes**
- **pinhole: 5-Tuple (incl. subnets + port ranges)**
  - bidirectional: two pinholes
- **independent of filter-implementation (and OS)**
- **transaction semantics**
- **no control of whole packet filter, only dedicated rule sets (e.g. one chain)**
- **fast**
  - frequent rule changes (VoIP)
  - high packet rate

Pinhole API for netfilter

Vision



Have a look into the details..

Pinhole API for netfilter

Interface

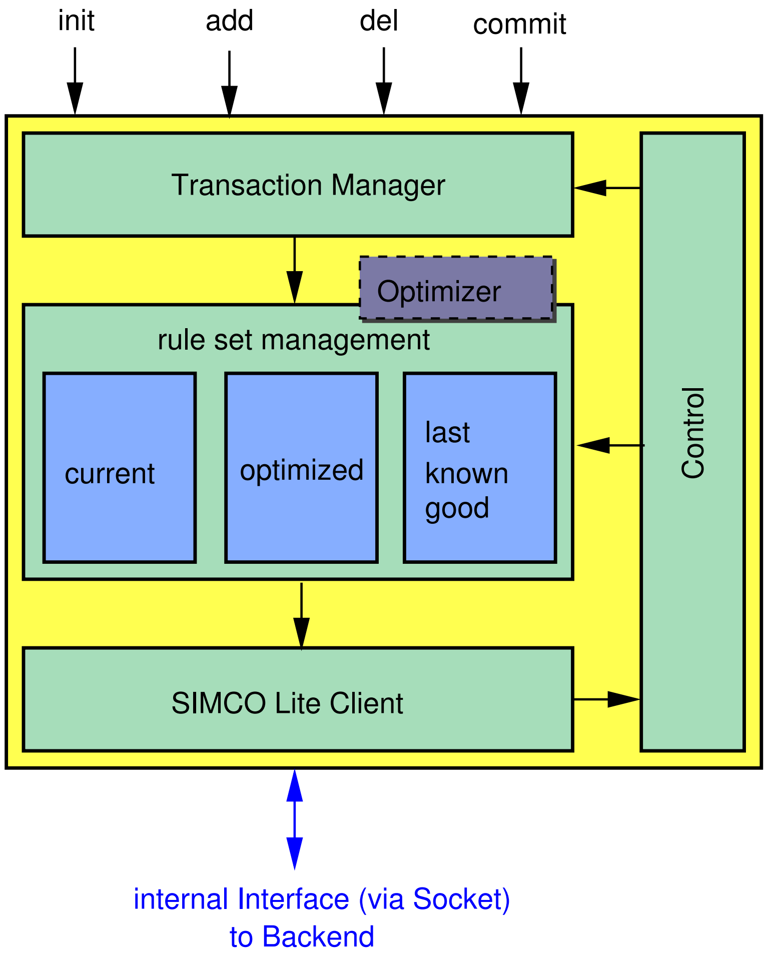
Example: C++ interface

```
ruleManager.request(MODIFY_RULESET);
int ruleID1 = ruleManager.addRule(
   "1.2.3.4", 24,
   100, 200,
   "2.3.4.5",24,
   300, 400,
   IPPROTO_UDP, AF_INET);
ruleManager->commit();

ruleManager.request(MODIFY_RULESET);
ruleManager.delRule(ruleID1);
int ruleID2 = ruleManager.addRule(
   "5.6.7.8", 24,
   100, 200,
   "6.7.8.9",24,
   300, 400,
   IPPROTO_UDP, AF_INET);
ruleManager->commit();
```

Pinhole API for netfilter

Frontend

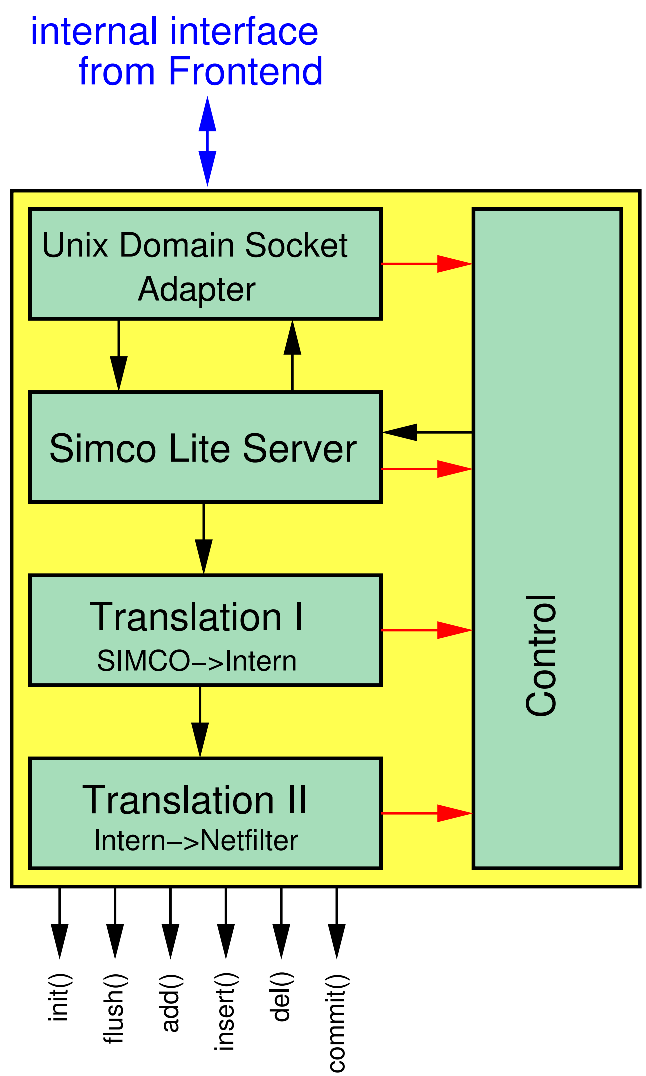
- **keeps all rules/pinholes**
  - optimization possible (hook) while stil being able to delete rules per ID
  - enables differential updates
  - failure: last known good
- **commit rules as batch to backend**
  - in intervals (with backoff-Alg)
  - currently: complete rule set
  - libiptc backend performance: changing or rewriting rules takes almost the same time
  - socket communication: reuse of SIMCO message definition + added new control messages



Pinhole API for netfilter

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**



Pinhole API for netfilter

Backend

- works on predefined chain
- integrate this chain into your packet filter configuration
- configure the rest of packet filter as you like

Example configuration of a packet filter using phapi

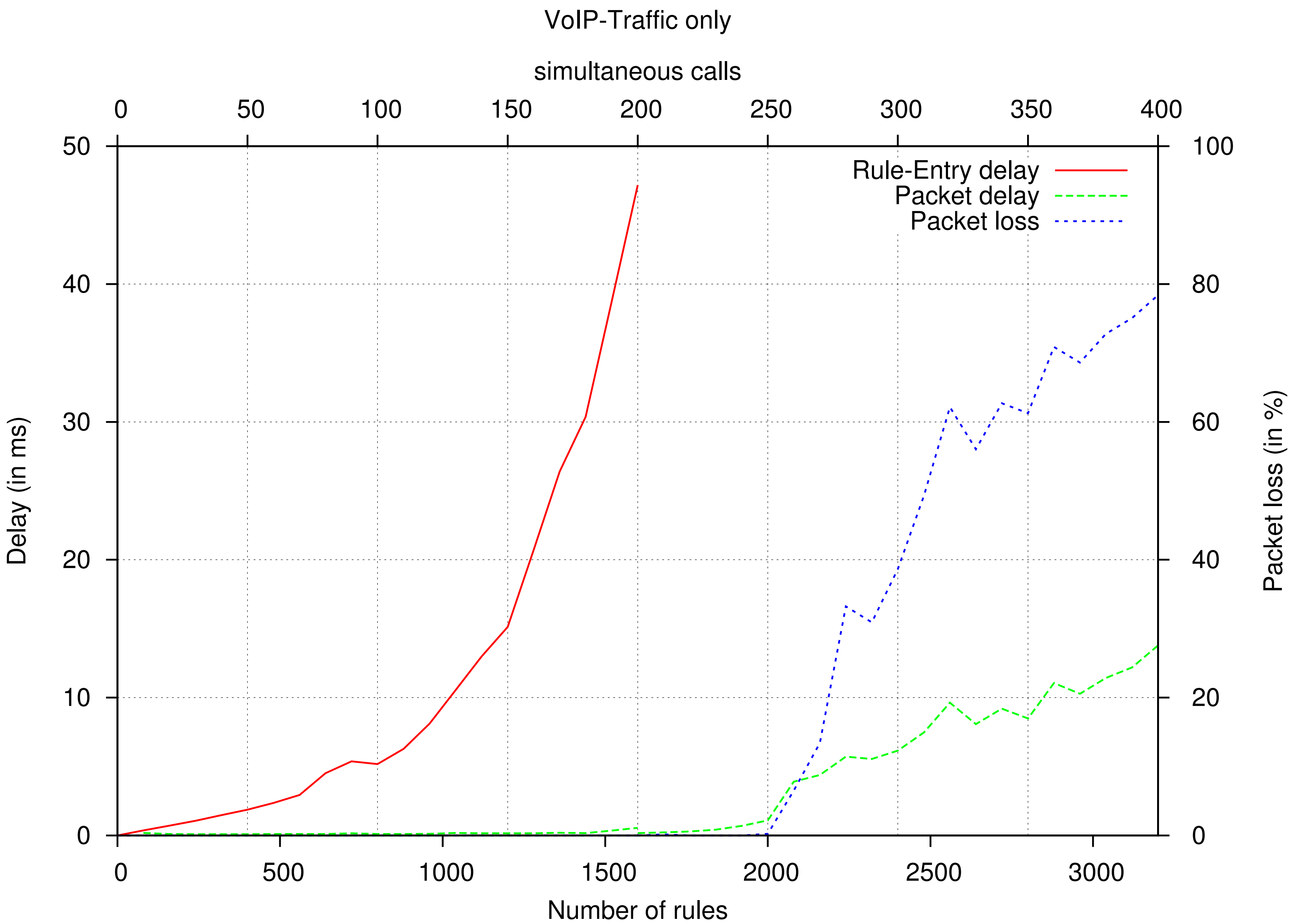
```
iptables -N phapi #chain to be used by daemon

iptables -A FORWARD -j phapi
iptables -A FORWARD -j DROP


#starting daemon
#syntax: phapi_backend -s <socket> -u <socket_user> -c <chain_name>
[-t <target>]
phapi_backend -s /tmp/phapi -u koegel -c phapi
```

Performance

Measurements with libiptc backend (VoIP Scenario)

- 20 ms packetizing time: 100 pps/call (bidir.), no bursts
- 8 pinholes per call: (asymmetric RTP + RTCP) x 2
- "bad/unwanted traffic" - will be filtered, but
  - also contributes to overall packet rate
  - check against every rule (other packets match after half of the rules)
- entering changed pinhole set into netfilter chain
  - in fixed time intervals (every ??100 ms)
  - effort depends on amount of pinholes
  - effort independent of number of changes
  - at high packet rates
- P4 2,53 GHz

Pinhole API for Netfilter



Summary

Current stage

- preview version: http://www.ikr.uni-stuttgart.de/Content/firewall/
- C++ API
- backend based on libiptc

Open issues

- C interface
- rule optimizer?
- handling TCP direction
- improving performance
- Nat support

How to map pinholes to netfilter?

Mapping to netfilter

TCP direction

- **meaning of direction different than for UDP:**
  not direction of packet flow but direction of connection establishment
- **One TCP-pinhole signaled**
  - source->destination (for every packet)
  - destination -> source (RELATED, !--syn)
  - if using conntrack – closing pinhole means removing conntrack entry
    ➥ makes API implementation complicated and dependant on static configuration
  - therefore: first go for simple !--syn
- **Two pinholes signaled (bidirectional)**
  ➥ two rules, direction of connection establishment does not matter

➥ **more intelligence in the backend**

Improving performance

Criteria

- faster rule changes
- faster filtering

Hash-based?

- exact flow match only (no ranges)
- thus: combination of hash and list
  - pinhole without range: use hash
  - pinhole with range: use list
  - pinhole with small range: several hash-entries (what is small? 4, 10, 100?)
- conntrack? ipset?

Mapping to netfilter

1. **Conntrack**
   - pinholes in conntrack table (permanent/timeout?)
   - already present in most configuration, implicit semantics
     ... --state ESTABLISH, RELATED -j ACCEPT
2. **IPset**
   - currently no 5-tuple match, extension possible
   - simple configuration, just like using chains
   - fast: 10.000 entries are no problem

Idea for fast netfilter backend

- extension of backend - ipset for small pinholes, chains for ranges
- how to combine this with TCP-direction-problem?
  - two 5-tuple ipsets + list
  - first set for all pinholes, target: tcp !--syn
  - rule filtering on TCP --syn
  - second set with pinholes allowing SYN
  - ...or extending the 5-tuple ipset with flag for --syn?

Conclusion and Discussion

Conclusion

- **simple Pinhole API**
  - 5-tuple + ranges + direction sufficient for most firewall control tasks
  - transaction semantics: defined state and less communication effort
- **current prototype implementation phapi**
  - daemon + socket communication: privilege separation
  - uses netfilter chains: decent performance, could be better

Discussion

- **Additional requirements?**
  - rate limiting
  - NAT support
- **Better performance by suitable mapping of pinholes to netfilter**
  - ipset for 5-tuples? conntrack?
  - suitable for large scale setups?