Columbia - Verizon Research
Securing SIP: Scalable Mechanisms
For Protecting SIP-Based Systems

Henning Schulzrinne
Eilon Yardeni
Somdutt Patnaik
Columbia University
CS Department

Gaston Ormazabal
Verizon Labs

David Helms
CloudShield

Agenda

- Denial of service threats: RTP & SIP
  - Pinhole filtering
  - SIP DOS detection and mitigation strategy
- Implementation: CloudShield
- Testing methodology and results

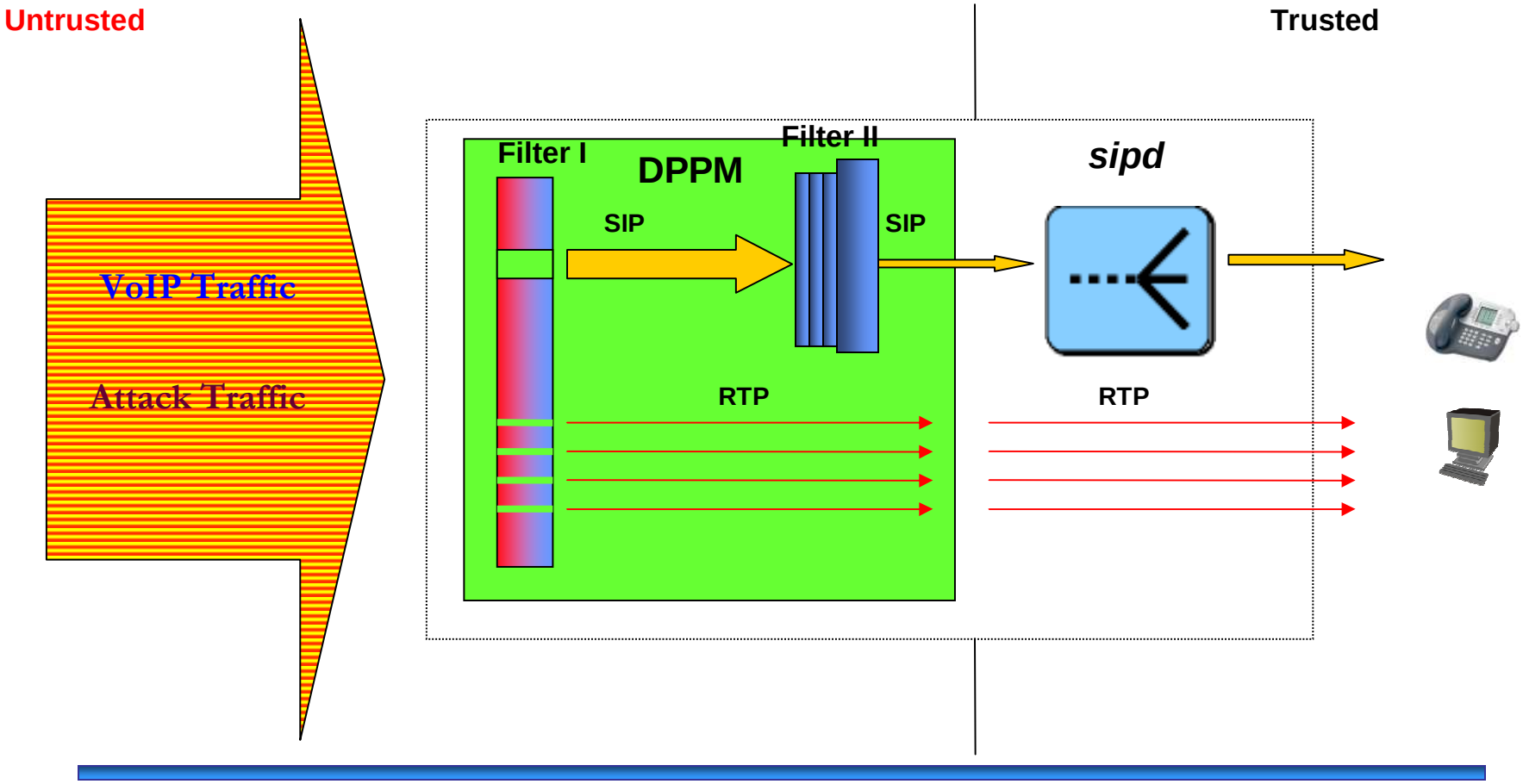
Background

- Telephony services migrating to IP becoming attractive DoS targets
- Attack traffic traversing the perimeter reduces availability of signaling and media for VoIP service
- Attack targets:
  - SIP infrastructure elements (proxy, softswitch, SBC)
  - End-points (SIP phones)
  - Supporting services (e.g., DNS)
- Carriers need to solve perimeter protection problem for security of VoIP services
  - Protocol-aware application layer gateway
  - SIP DoS/DDoS attack detection and prevention
- Test tools verify performance & scalability

Goals

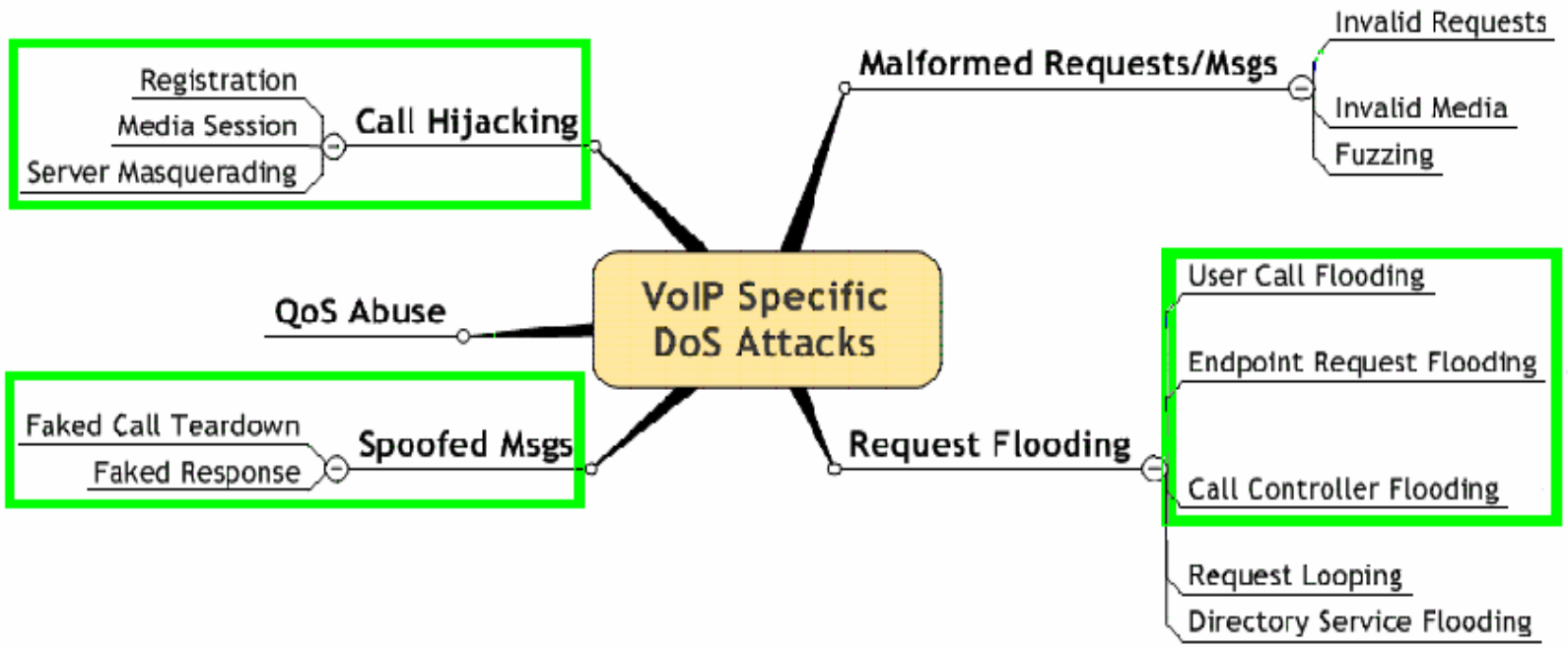
- Build a prototype of the fastest dynamic pinhole filter firewall for RTP media
- Study VoIP DoS for SIP signalling
  - Definition – define SIP specific threats
  - Detection – how do we detect an attack?
  - Mitigation – defense strategy and implementation
  - Validation – validate our defense strategy
- Generate requirements for future security network elements
- Generate the test tools and methodology strategies for their validation

Problem Overview



Scope of Our Research

Scope of current work



Basic Strategy and Motivation

- Implementation flaws are easier to deal with:
  - Systems can be tested before used in production
  - Systems can be patched when a new flaw is discovered
  - Attack signatures could be integrated with a firewall
- Protocol & flooding attacks are harder to defend against
- Commercially available solutions for general UDP/SYN flooding, but none for SIP
- → address protocol and flooding attacks *specifically* for SIP

Main Focus of our Strategy

- **VULNERABILITY: SIP over UDP → spoofing SIP requests**
  - **Registration/call hijacking**
  - **Modification of media sessions**
  - **Session teardown**
  - **Request flooding**
  - **Error message flooding**
  - **SIP 'Method' vulnerabilities**
- **STRATEGY: Two detection and mitigation filters**
  - **Media: SIP-aware dynamic pinhole filtering**
  - **SIP: Rule-based detection and mitigation filters**

Media Filters

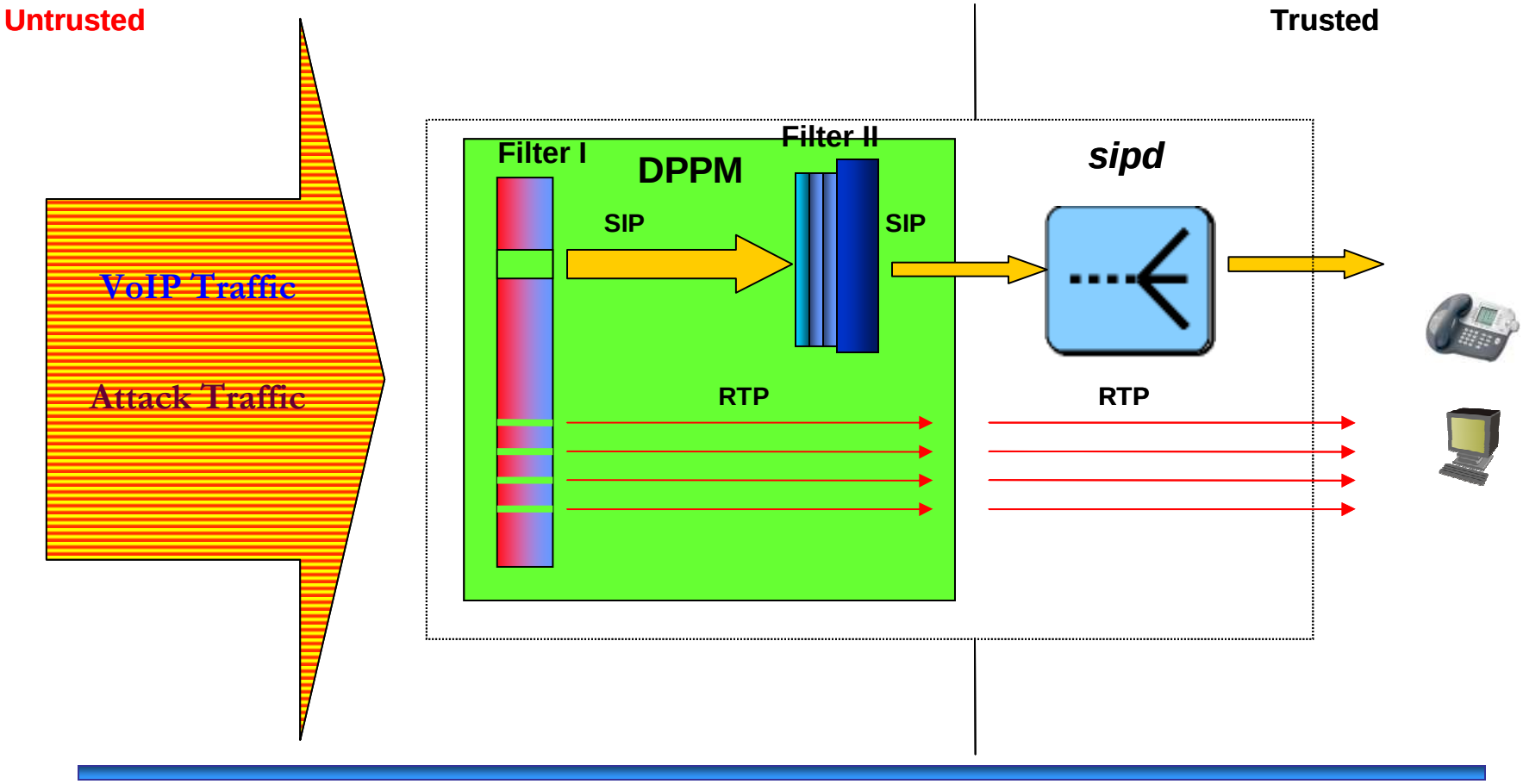
Implemented large scale SIP-aware firewall using dynamic pinhole filtering

- **Media filter as first-line of defense against DoS attacks:**
  - **Only signaled media channels can traverse the perimeter**
  - **End systems are protected against flooding by random RTP**
- **The RTP pinhole filtering approach is a good first-line of defense, but…**
  - **Signaling port is subject to attack**

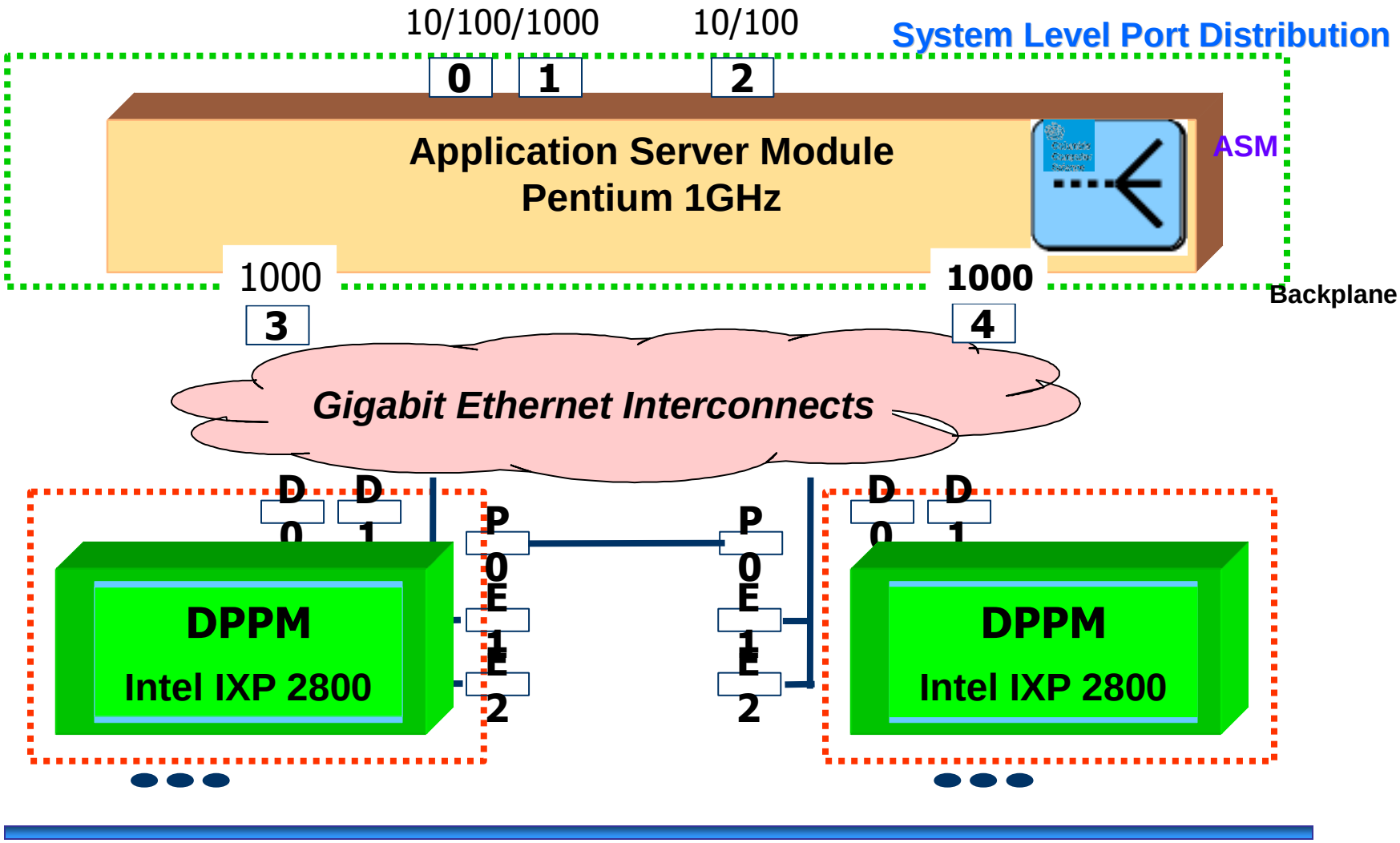
Ongoing - SIP DoS Detection and Mitigation Filters

- Authentication based - Return Routability Check
  - For UDP use SIP's built-in digest authentication mechanism
    - Use null-authentication when no shared secret is established
    - Filter out spoofed sources
- Rate limiting
  - Transaction based
    - Thresholding of message rates
      - ✓ INVITE
      - ✓ Errors
    - State Machine sequencing
      - ✓ Filter "out-of-state" messages
      - ✓ Allow "in-state" messages
  - Dialog based
    - Maintain a database of INVITE sources (Contacts) to verify and accept a BYE message only from legitimate source addresses
- Method vulnerability based

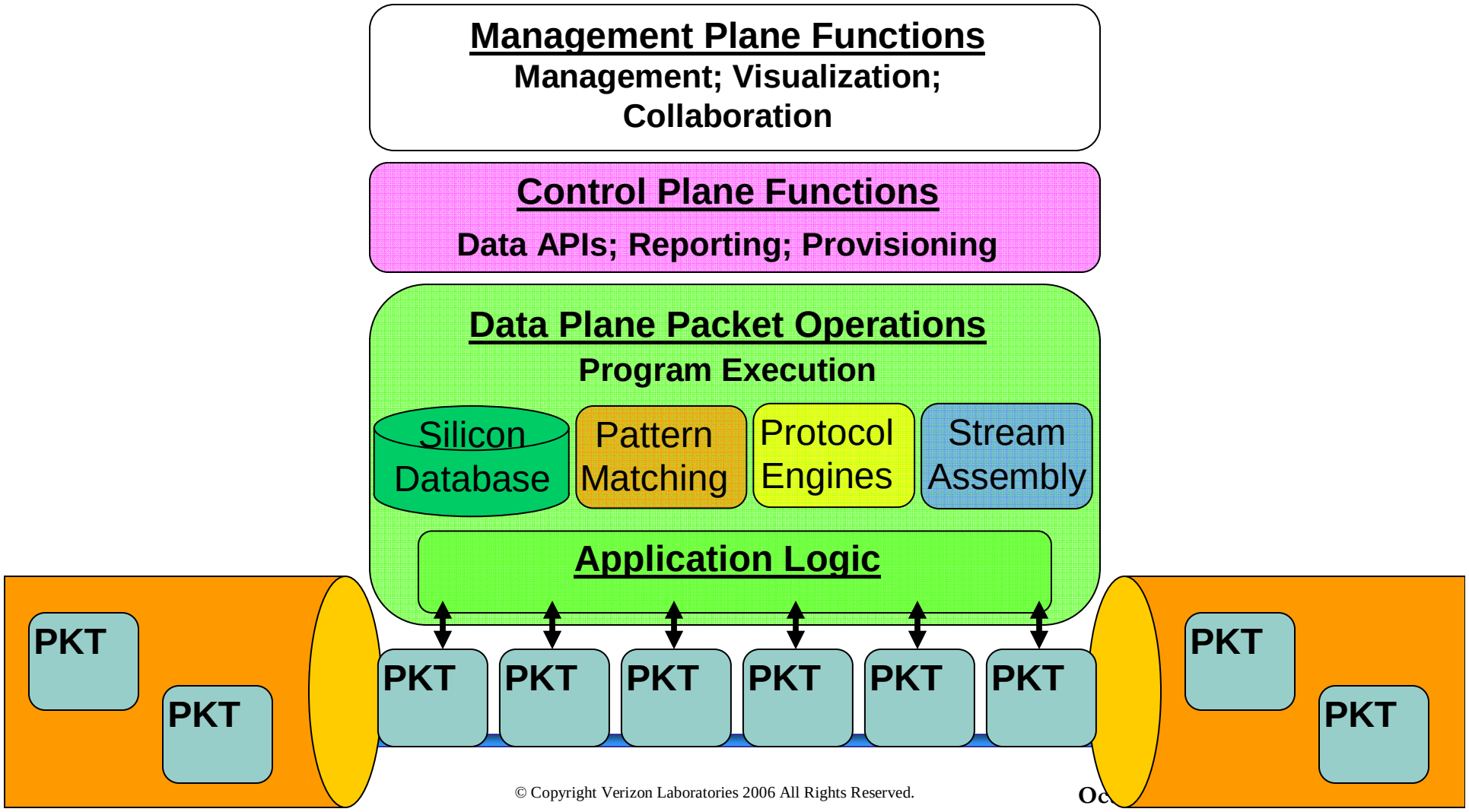
Mitigation Solution Overview



CloudShield CS-2000



CS-2000 Processing Pipeline



Prototype Implementation

- Use network processor to filter RTP media and SIP authentication attempts to the proxy and rate-limit messages based on particular heuristics:
  - Utilize wire-speed deep packet inspection
  - Thresholds are kept internal in the DPPM
  - State is only kept at CloudShield in CAM tables
- Use the firewall controlling proxy model for media filtering and the authentication filter
  - Columbia's SIP Proxy *sipd* controls the CloudShield Deep Packet Inspection Server
  - Utilize the *Firewall Control Protocol* to establish filters in real time
  - Insert filters for Media Ports and SIP UAs that are being challenged

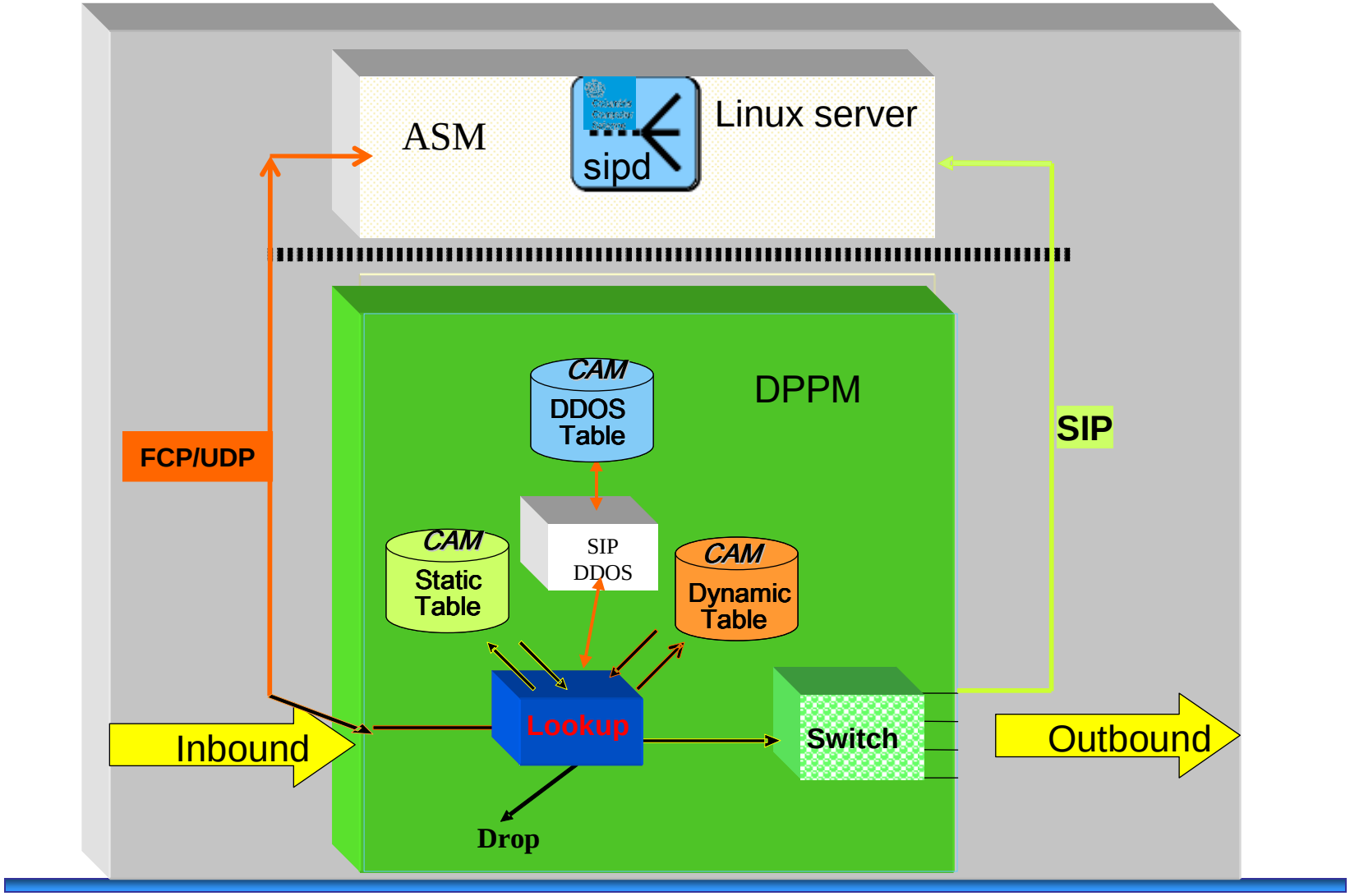
Pinhole Firewall Components

- Static Filtering
  - Filtering of pre-defined ports (e.g., SIP, ssh)
- Dynamic Filtering
  - Filtering of dynamically opened ports (e.g., RTP)
- Switching Layer
  - Perform switching between the input ports
- Firewall Control Module
  - Intercept SIP call setup messages
  - Get RTP ports from the SDP
  - Maintain call state
- Firewall Control Protocol
  - The way the Firewall Control Module talks with the CloudShield
  - Push dynamic table updates to the data plane
  - Could be used by multiple SIP Proxies that control one or more CloudShield firewalls

CS-2000 Data Plane Execution

Part of SIP-proxy Executed in the Linux Control Plane

Integrated DDOS and Dynamic Pinhole Filter

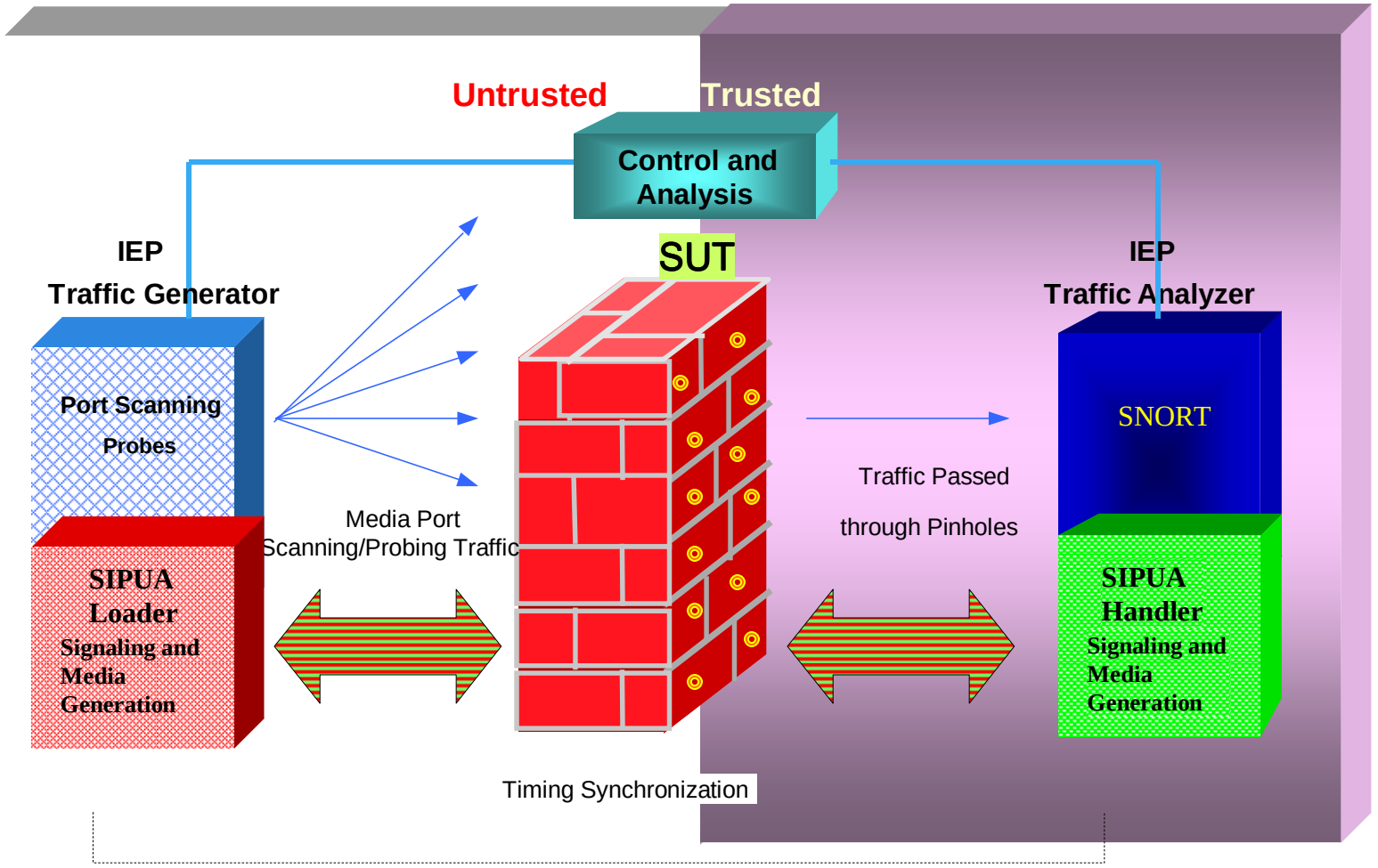


Integrated Testing and Analysis Tool

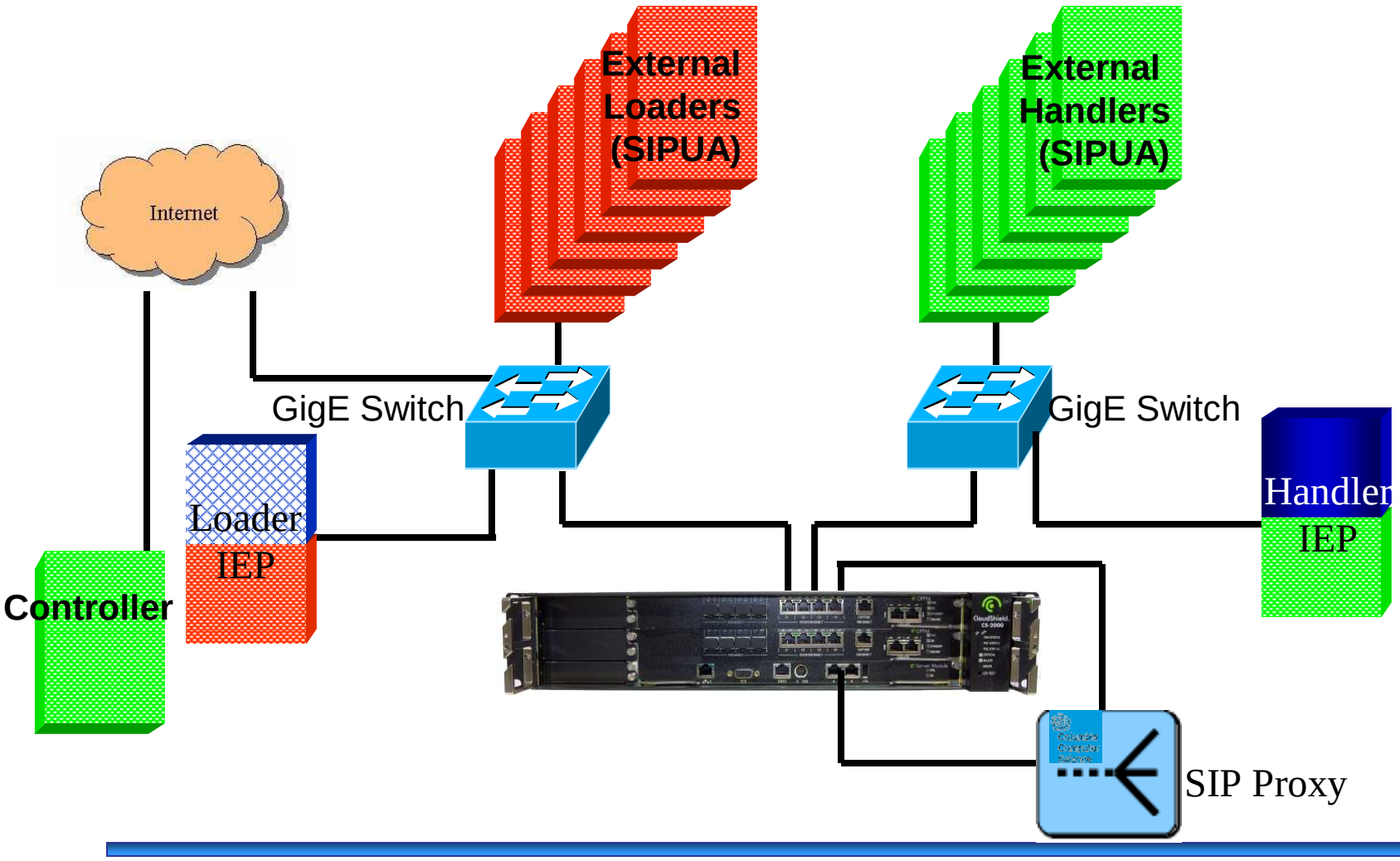
Pinhole Filter Integrated End Point Tool Components

- SIPUA Test Suite
  - Loader/Handler
  - Establishes calls using SIP
  - Sends 160 byte RTP packets every 20ms
    - Settable to shorter interval if needed for granularity
  - Starts RTP sequence numbers from zero
  - Dumps call number, sequence number, current timestamp and port numbers to a file
- Scanning Probes
  - nmap
- Automated Script based Control Software
- Timing Devices
- Data Analysis Module
  - Analyze handler's file for initial and teardown call delays,
    - Number of packets dropped before pinhole opening
    - Number of packets crossing after pinhole closing
  - Scan results for pinhole coverage
- Protocol Analyzer
  - SNORT
- Graphical Displays

Integrated End Point



Testbed Architecture



Testing And Analysis Methodology

- Problem parameterized along two independent vectors
  - Call Rate (calls/sec)
    - Related to performance of SIP Proxy in Pentium
  - Concurrent Calls
    - Related to performance of table lookup in IXP 2800
- Generate external load on the firewall
  - SIPUA Loader/Handler in *external* load mode
  - Generates thousands of concurrent RTP sessions
  - For 30K concurrent calls have 120K open pinholes
  - CAM table length is 120K entries
    - Search algorithm finds match in one cycle
- When external load is established, run the IEP analysis
  - SIPUA Loader/Handler in *internal* load mode
  - Port scanning and Protocol analyzer
  - Increment calls/sec rate
- Measure pinhole opening and closing delays
  - Opening delay data provided in units of 20 ms packets
  - Closing delay data provided in units of 10 ms packets
- Detect pinholes extraneously open

Pinhole Filter Data Results

Concurrent calls	Calls/Sec	SIP Proxy		SIP RAVE	
		Open delay	Close delay	Open delay	Close delay
10K	300	0.75	0	0.25	0
15K	300	0.74	0	0.33	0
20K	300	0.73	0	0.34	0
25K	300	0.75	0	0.26	0
30K	300	0.8	15.51	0.26	0
30K	200	0.83	0.02		

Conclusions

- Demonstrated SIP vulnerabilities in media and signaling
- Implemented some "carrier-class" mitigation strategies
- Built a validation testbed to measure performance
- Need to generalize methodology to cover a broader range of cases and apply anomaly detection, pattern recognition and learning systems

Thank You!

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