Dipartimento di Informatica
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Tackling Control Plane DoS Attacks in Software-Defined Networking

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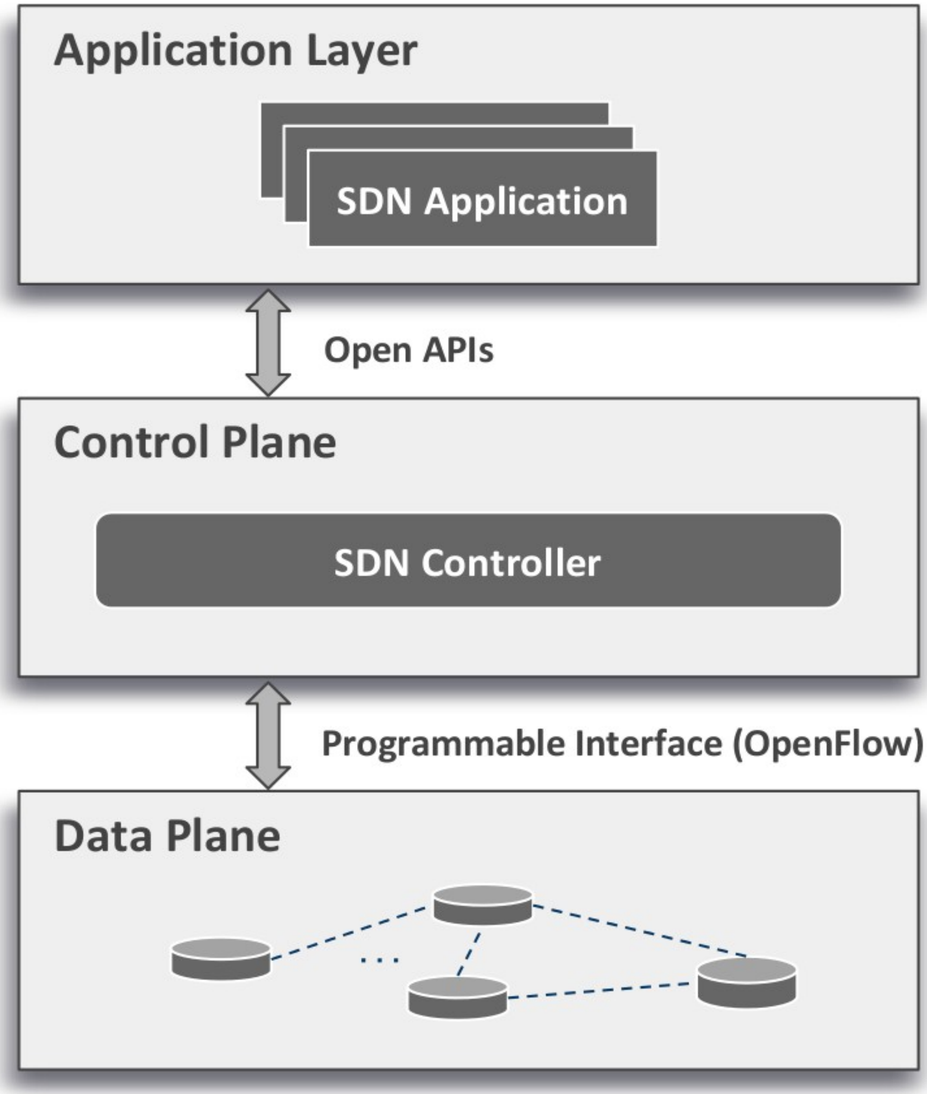
Outline

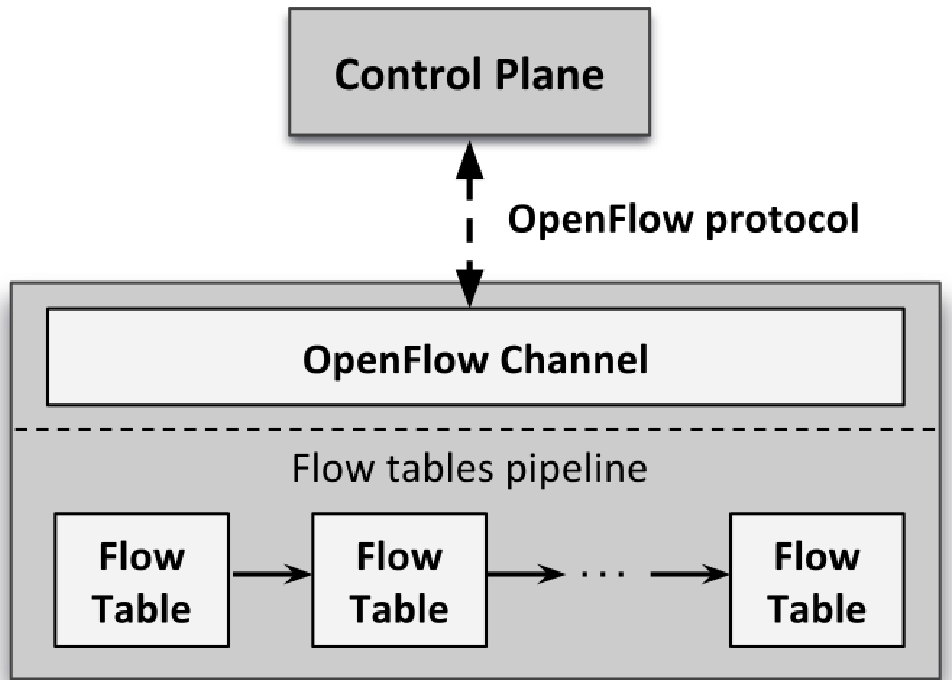
- SDN Overview
  - OpenFlow
- DoS attacks in SDN
  - Control plane saturation attack
- State-of-the-art (AvantGuard) and its limitations
- Our solution: LineSwitch
- Evaluation
- Conclusion

Intro: Software Defined Networking



- Logic/infrastructure decoupling
  - Reduces switch complexity while enhancing flexibility
- Control plane as middleware
  - Exposes set of open APIs to applications
- Switches programmable through standard interface
  - OpenFlow is the most widely accepted switch-related standard

Intro: OpenFlow



OpenFlow Switch

- Switch maintains a set of *Flow Tables*
  - Organised in a pipeline
- Each flow table hosts a set of *Flow Rules*
  - Flow rules define what actions to perform on a given network flow
- Control plane installs flow rules
  - Either statically or dynamically

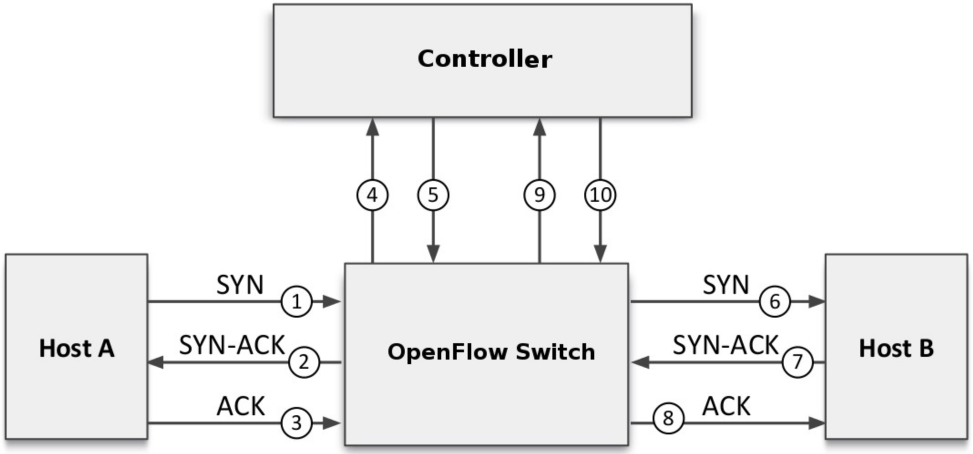
Control Plane Saturation Attack

- Exploits extensive communication between data and control plane
- Attacker floods an OF-switch with unique network flows
- For each flow, the OF-switch contacts the controller to ask for a flow rule
- Controller needs to analyse requests, define actions and send back a response
- With a high enough flood rate, the controller can be overwhelmed

AvantGuard 1/3

- AvantGuard (AG) is a switch-level SDN extension which aims at defeating SYN-based flooding
- Applies a set of well-known SYN-flooding mitigation techniques to SDN
  - Syn Cookies
  - Syn Proxy
- AG is composed of two distinct modules
  - Connection Migration module
  - Actuating Trigger module

AvantGuard 2/3: Connection Migration



- Switch acts as a SYN Proxy
- Switch contacts controller *iif* handshake with A is completed
- Upon receiving permission, switch completes connection with Host B
- Switch enters relay phase

AvantGuard 3/3: Limitations

- The switch can not know Host B's ISN during the TCP handshake with Host A
  - For each packet, it is forced to translate sequence and ACK number
- Connecting to Host B, the switch can not use Host A's IP
  - For each packet, the switch needs to translate IP addresses
  - Needs to use different ports to migrate connections to an <*IP, port*> pair
- Therefore, the switch:
  - Is forced to maintain state *for each connection*
  - Can not migrate more connections than the available port numbers

Buffer Saturation Attack

- Exploits the need for a translation table for each connection
- The attacker generates a high number of complete TCP handshakes
- The switch will create an entry in the translation table for each one of them
- When the table is saturated, the switch will not be able to migrate any legit connection
- Experimental data shows buffers can be saturated in under 100 seconds with a modest attack rate of 1Mbps

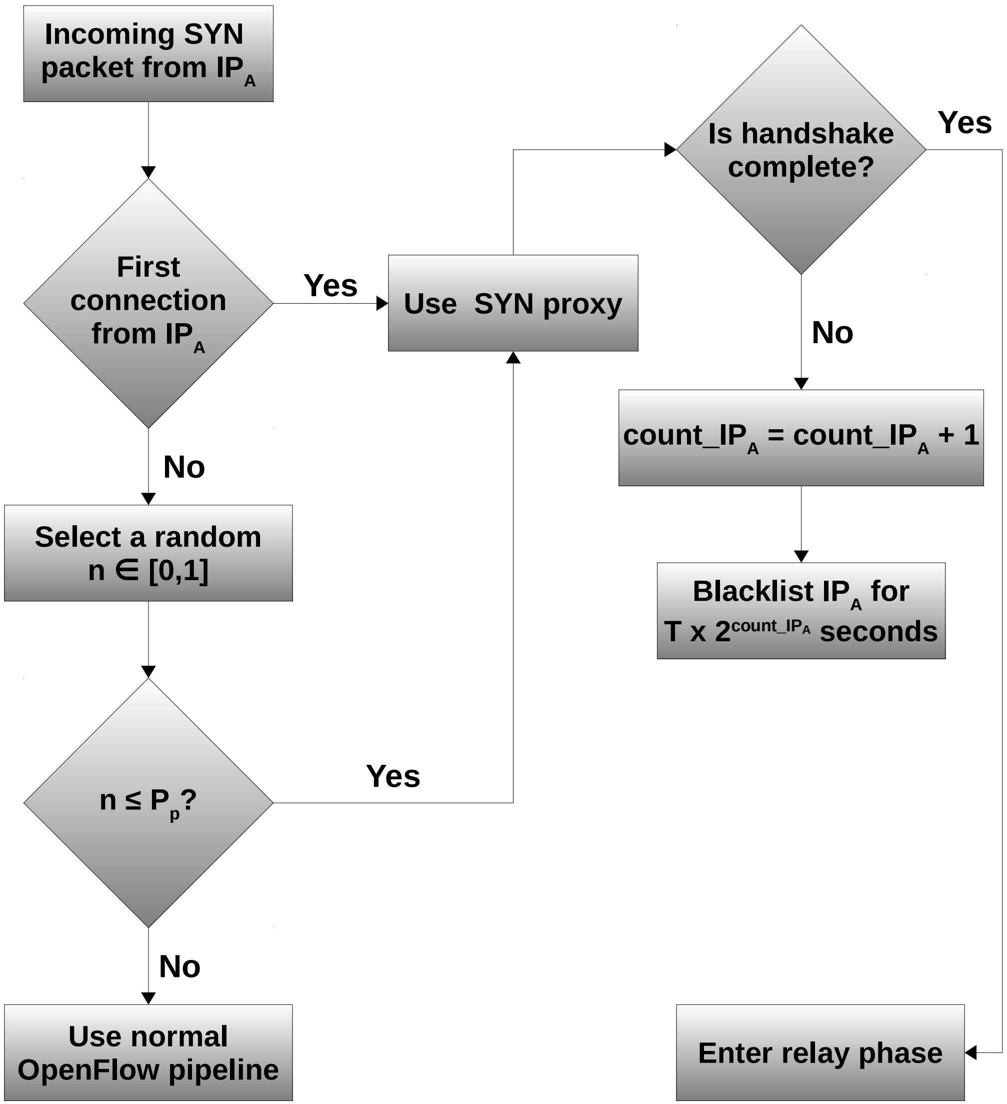
Breaking the end-to-end Semantics

- Spoofed lower layer information can break higher level applications
- Proxying prevents proper setup of TCP options
  - None of the options for high performance can be used
  - MSS must be set to a conservative low value, increasing fragmentation
- A change in the traffic path from the switch will destroy the TCP connection
  - Since the switch uses its IP address for the migration, the destination host has no knowledge of the real client.

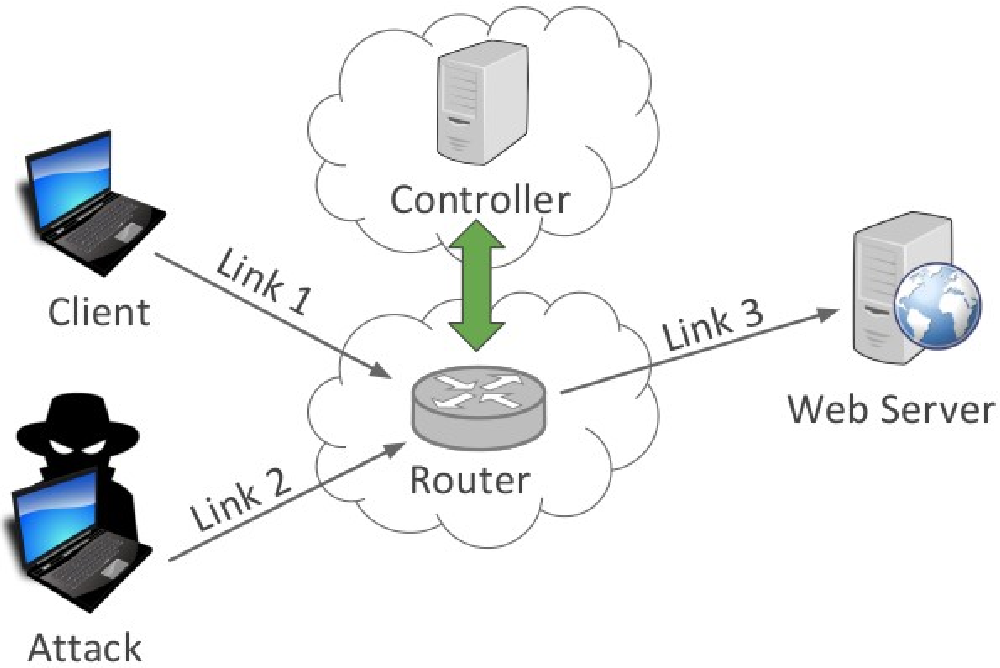
Our Solution: LineSwitch 1/2

- LineSwitch (LS) combines probabilistic proxying and blacklisting
- High resilience to buffer saturation attack
  - Configurable through proxying probability parameter P_p
- Minimal use of proxying preserves TCP semantics
- Exponentially increasing blacklist duration for attackers
- Reduced overhead: LS is on average 30% faster than AG

Our Solution: LineSwitch 2/2

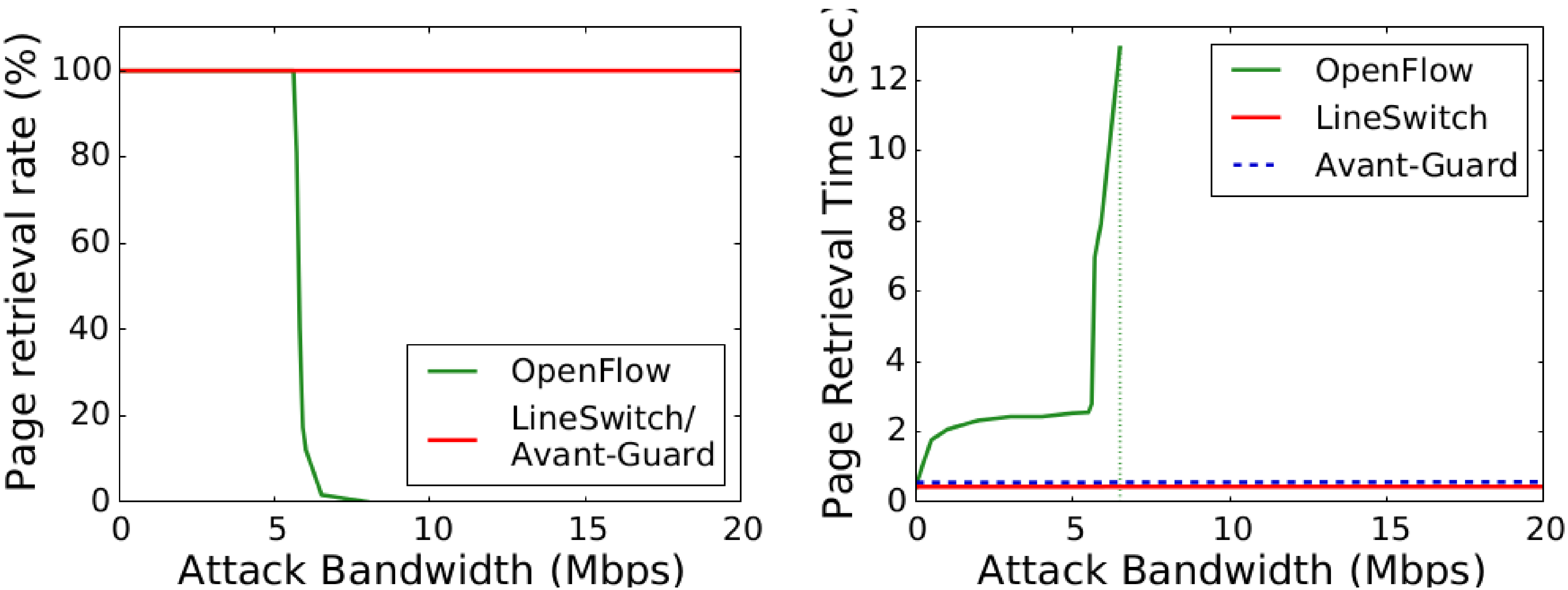


Evaluation 1/3: System Model



- Attacker, client and server connected to single OF-switch
- Evaluated web page retrieval times under different attack rates
- Evaluated resilience to buffer saturation attack, with varying attack rates and buffer sizes

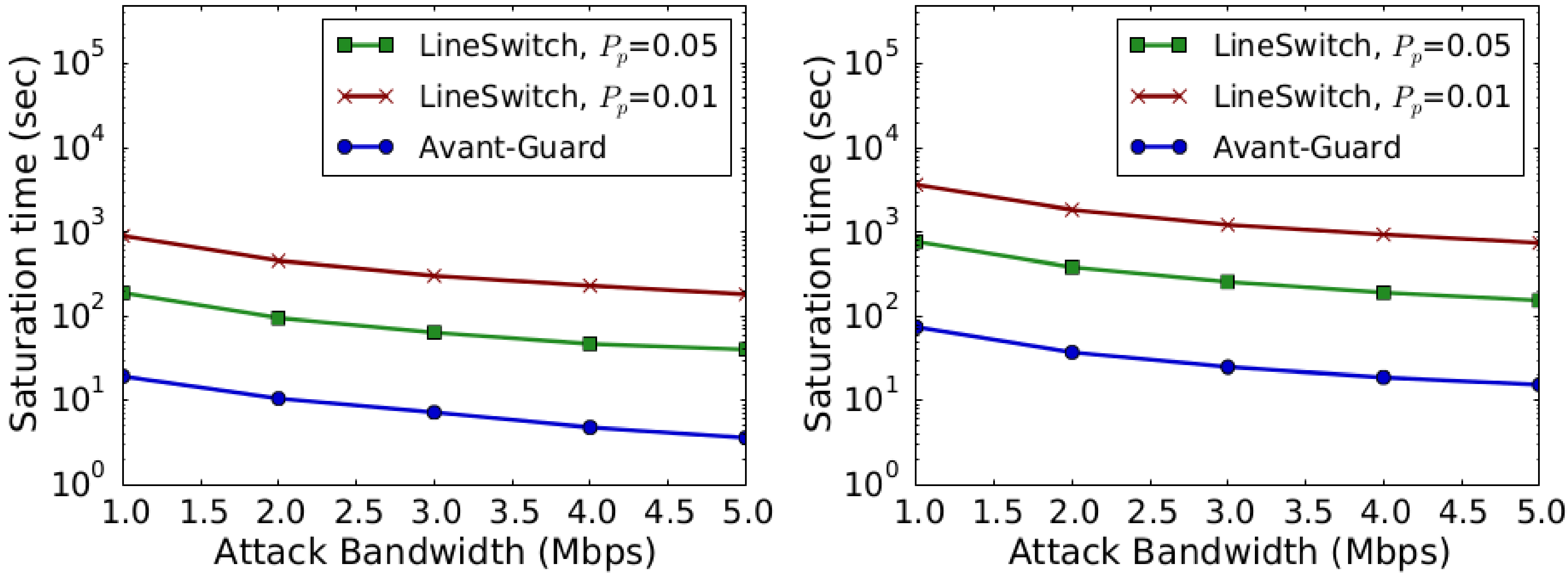
Evaluation 2/3: Web Page Retrieval



(a) Success rate (b) Average retrieval time

Average retrieval time and success rate under different attack rates

Evaluation 3/3: Buffer Saturation Attack



(b) buffer size 2^{20}Bytes (c) buffer size 2^{22}Bytes

Time required to saturate translation table with varying size and attack rate

Conclusion

- Extensive communication between data and control plane opens exploitable vulnerabilities in SDN
- Current state-of-the-art solution suffers from major design flows
- LineSwitch offers the same level of protection as AvantGuard, whilst reducing overhead by ~30% and protecting against buffer saturation attacks
- SDN is a promising alternative to current network architecture, but needs through security evaluation by specialists before adoption.

End Presentation

Thank you

Q&A

Offerta formativa del Dipartimento di Informatica

LA SCADENZA DELLA DOMANDA E’ PREVISTA PER IL 10 DICEMBRE 2015

Grazie

Per maggiori informazioni

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Appendix: Experimental Data

Implementation	Avg. Time	Std. Dev.	Overhead
OpenFlow	0.404 s	0.001 s	N.A.
AVANT-GUARD	0.573 s	0.014 s	41.83%
LineSwitch	0.435 s	0.030 s	7.67%

Page retrieval with no flooding

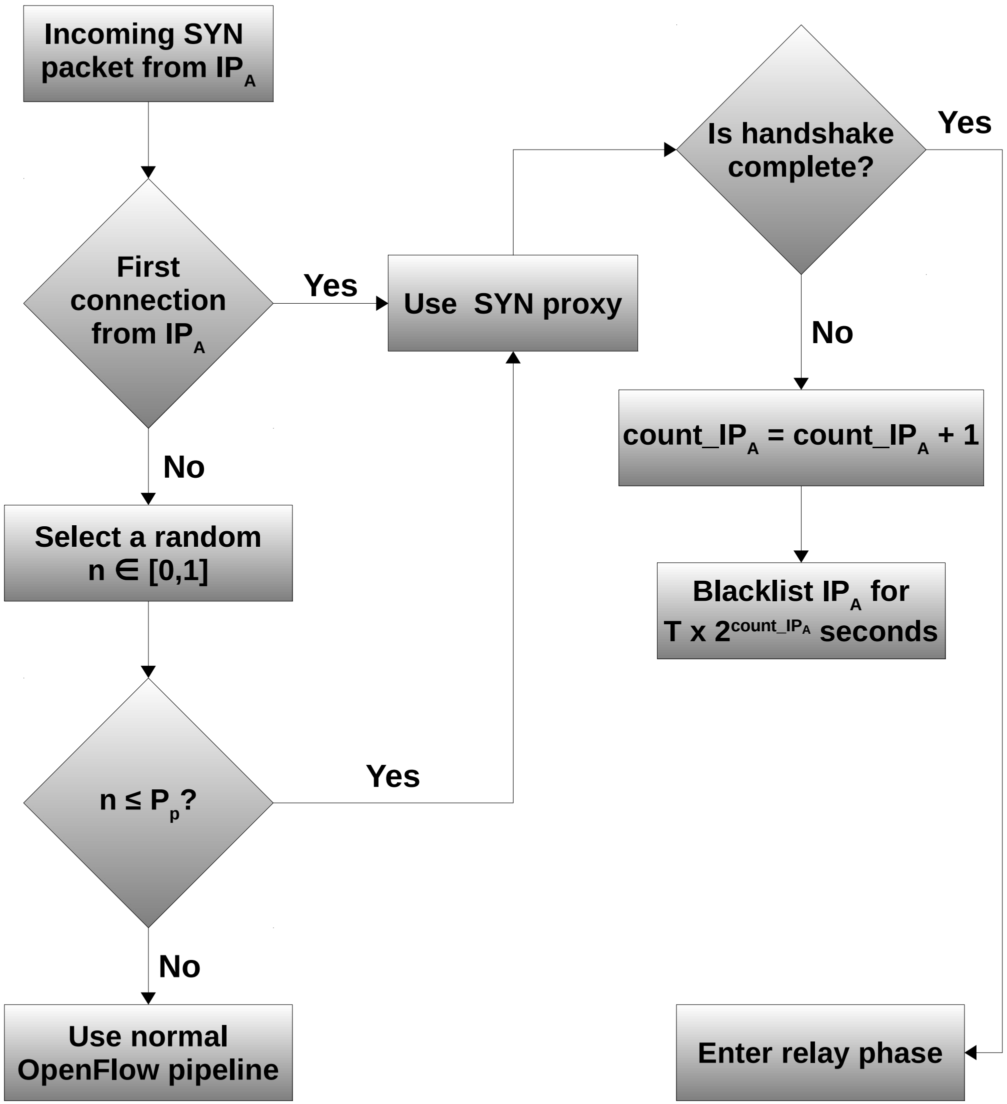
Implementation	Avg. Time	Success Rate	Overhead
OpenFlow	2.406 s	100%	495.54%
AVANT-GUARD	0.565 s	100%	39.85%
LineSwitch	0.411 s	100%	1.73%

Page retrieval with 3Mbps flooding

Implementation	Avg. Time	Success Rate	Overhead
OpenFlow	∞	0%	∞
AVANT-GUARD	0.568 s	100%	36.92%
LineSwitch	0.426 s	100%	5.45%

Page retrieval with 6.5Mbps flooding

LineSwitch Flow



- First connection flag is cleared after a configurable time δ of inactivity
- P_p value of 0 degenerates in the standard OF pipeline, removing proxying benefits
- P_p value of 1 degenerates in proxying every packet, exposing the switch to buffer saturation attacks