Formal Analysis of SDNsec: Attacks and Corrections for Payload, Route Integrity and Accountability

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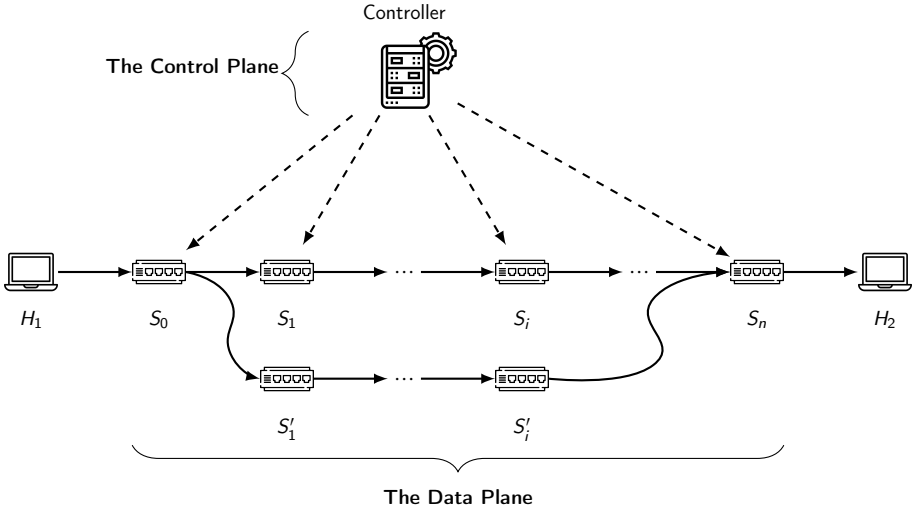
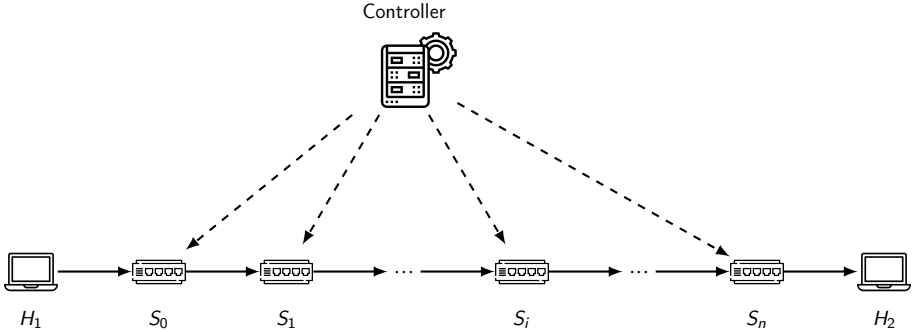
AsiaCCS'2025
August 29th, 2025

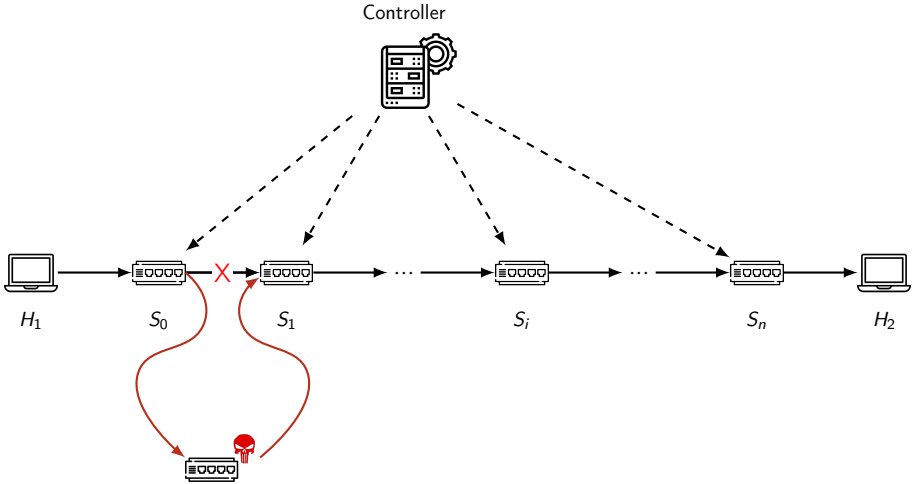
SDN Networks and Routing



Attacks against SDN Routing



Attacks against SDN Routing



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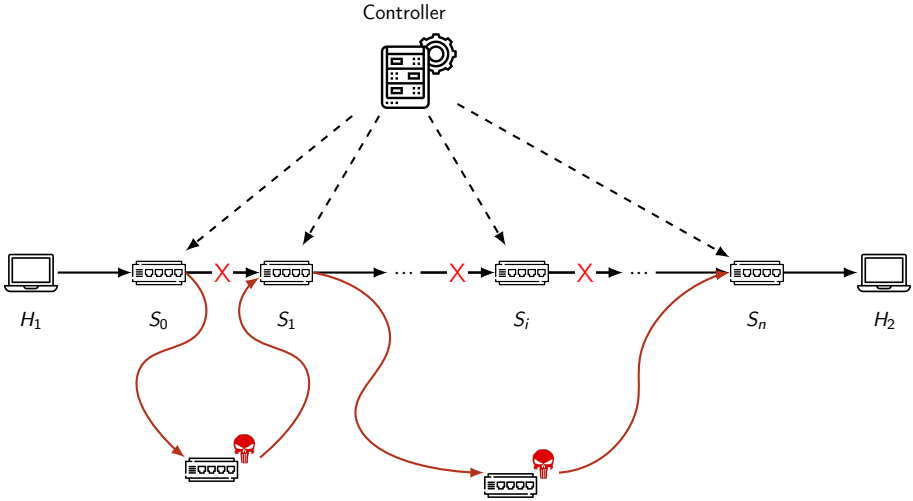

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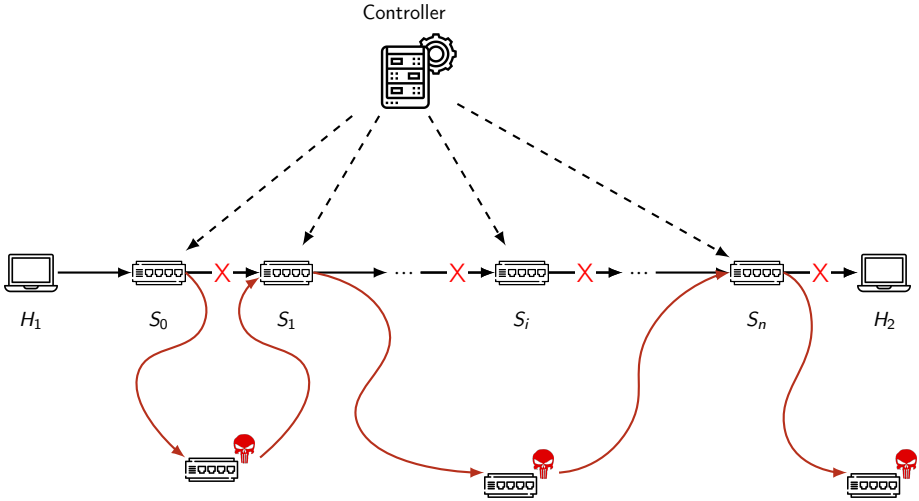
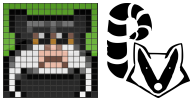


Formal Verification of Cryptographic Protocols



Crucial to **verify** that protocols guarentee security properties!

Numerous tools exist (e.g.: Tamarin [MSCB13] or ProVerif [Bla01]):

- **Formally** verify the protocol **in presence of attacker** (Dolev-Yao [DY81]).
- Check secrecy, authentication, observational equivalence, and other trace properties.

Research Question

How can we **model and verify SDN security protocols** to check if they guarantee **route integrity**, **payload integrity**, and **accountability**?

Related Works

Solution	Cryptography	Misrouting Detection	Payload Integrity
VeriFlow [KZZ+12]	X	X	X
Avant-Guard [SYG13]	X	X	X
FortNox [YFT+12]	X	X	X
Sphinx [DPMM15]	X	X	X
FlowMon [KF15]	X	X	X
WedgeTail [SKJ17]	X	✓	X
FOCES [ZXY+20]	X	✓	X
WhiteRabbit [SKOY19]	X	✓	X
REV [ZWZL20]	✓	✓	X
SDNsec [SPL+16]	✓	✓	X

✓: **Property claimed** X: **Property absent**

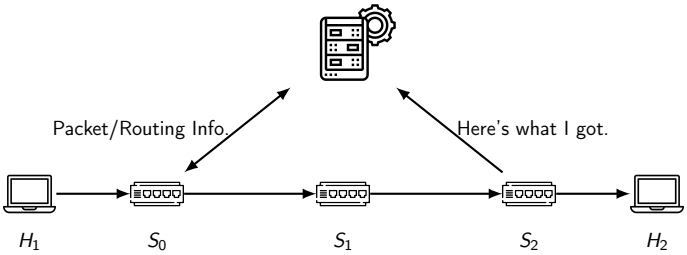
Modeling SDN Protocols

- 1x Controller
- 1x Ingress switch
- Nx Core switches
- 1x Egress switch
- (N+2)x Private channels between controller and each switch
- 1x Source host
- 1x Destination host

⇒ Attacker completely controls the network and can freely choose the topology **but cannot attack** between source host and ingress switch (resp. destination host and egress switch).

⇒ Controller chooses the genuine route and sends it to the switches according to the protocol.

Modeling Security Properties for SDN Protocols



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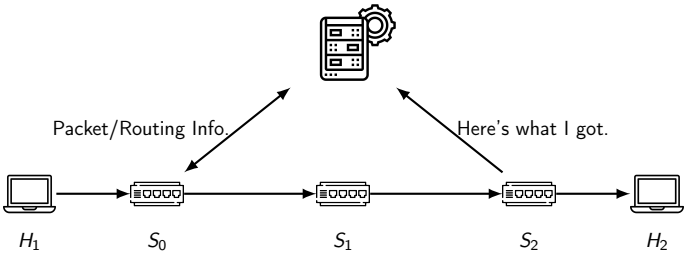
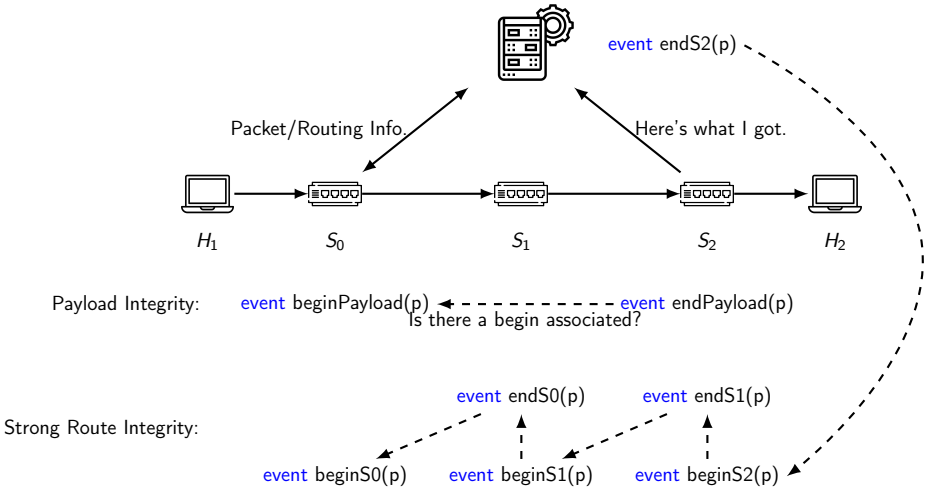
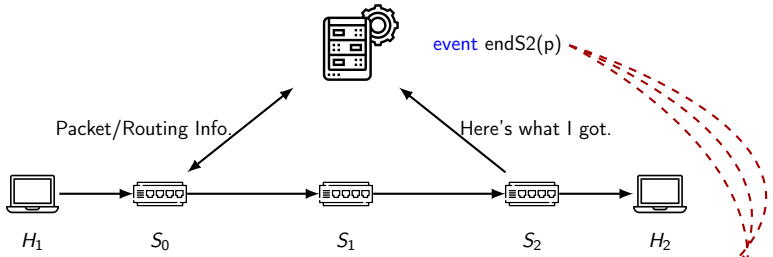


Payload Integrity: event beginPayload(p) ◄- - - - - - - - - - - - event endPayload(p)
Is there a begin associated?

Modeling Security Properties for SDN Protocols



Modeling Security Properties for SDN Protocols



Payload Integrity: event beginPayload(p) ← event endPayload(p)

Is there a begin associated?

event endS0(p) event endS1(p)

Weak Route Integrity:

event beginS0(p) event beginS1(p) event beginS2(p)

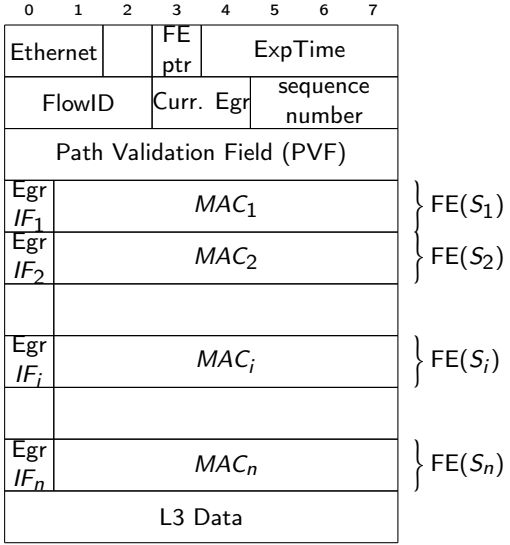
SDNsec [SPL+16]

Preemprive check by each switch:

$$B = FlowID \parallel ExpTime$$
$$FE(S_i) = egr(S_i) \parallel MAC(S_i)$$
$$MAC(S_i) = MAC_{K_i}(egr(S_i) \parallel FE(S_{i-1}) \parallel B)$$

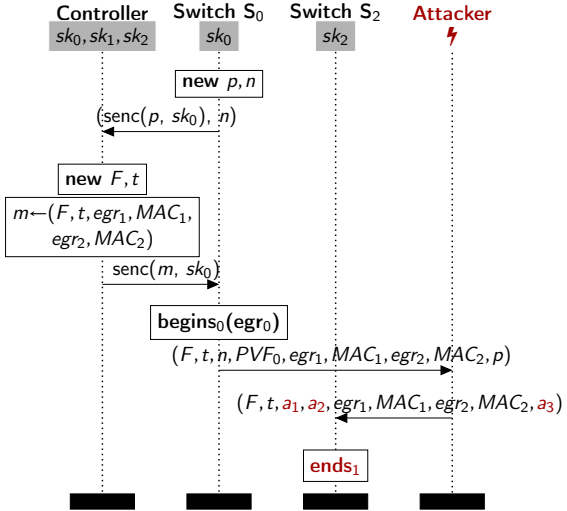
Retro-active check by the controller:

$$C = FlowID \parallel SeqNo$$
$$PVF(S_0) = MAC_{K0}(C)$$
$$PVF(S_i) = MAC_{K_i}(PVF(S_{i-1}) \parallel C)$$



An Attack on Strong Route Integrity against SDNsec

Retrospectively a poor candidate as extremely unsecure:



Proposed Correction and Results

$$B = FlowID \parallel ExpTime$$
$$FE(S_i) = egr(S_i) \parallel MAC(S_i)$$
$$MAC(S_i) = MAC_{K_i}(egr(S_i) \parallel FE(S_{i-1}) \parallel$$
$$B \parallel \mathrm{H}(\mathrm{p} \parallel \mathrm{PVF}(\mathrm{S_{i-1}}) \parallel \mathrm{SeqNo_{i-1}}))$$

	Payload Integrity	Route Integrity				Accountability	
		Local RI	Trans. RI	Weak RI	Strong RI	Soundness	Completeness
SDNsec [SPL+16]	UNSAFE	SAFE	UNSAFE	UNSAFE	UNSAFE	SAFE	UNSAFE
SDNsec⋆	SAFE	SAFE	SAFE	SAFE	SAFE	SAFE	SAFE

Conclusion

- Formal analysis of the SDNsec protocol, focusing on three key security properties: payload integrity, route integrity, and accountability.
- Implementation with RYU [RYU14] and Mininet [GNN+84].

- Formal modeling on SDN protocols,
- Formal definitions of these security properties,
- Future work: Verify other SDN security protocols!

Thanks for your attention!

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