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MODEL BASED TESTING TECHNIQUES FOR SOFTWARE DEFINED NETWORKS

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Motivation & Research Questions

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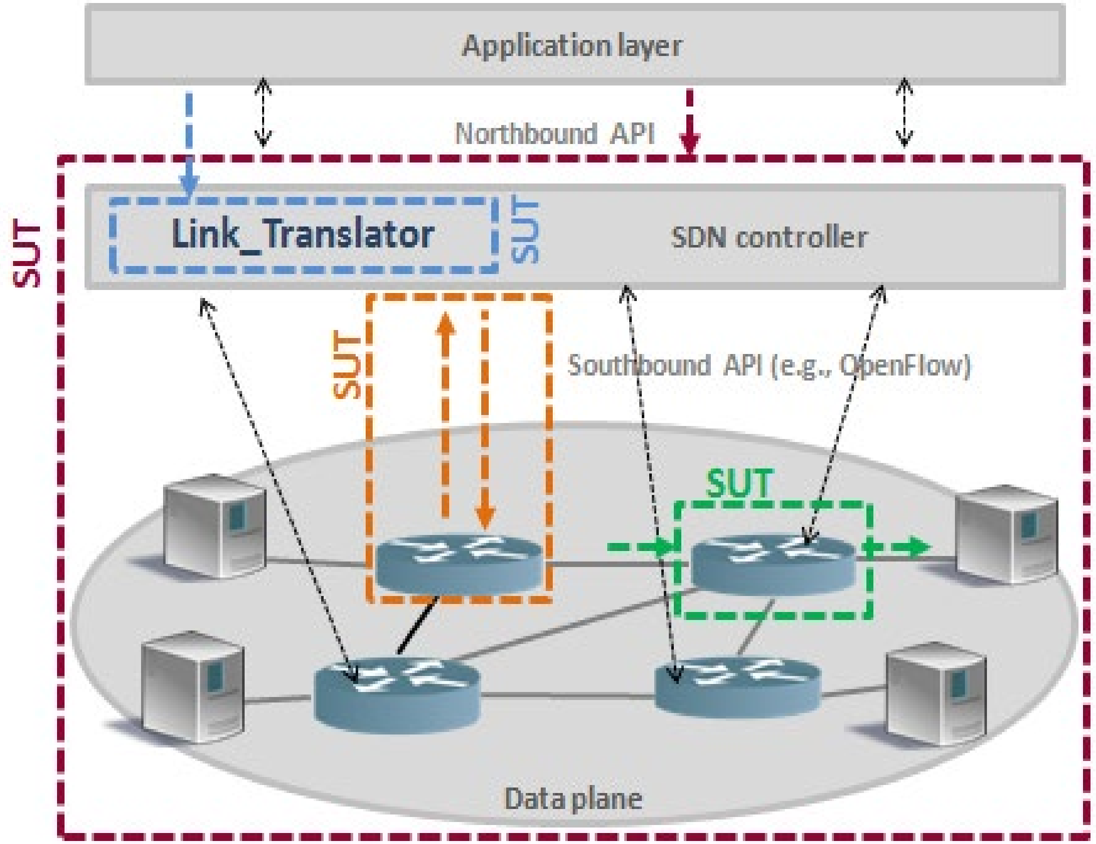
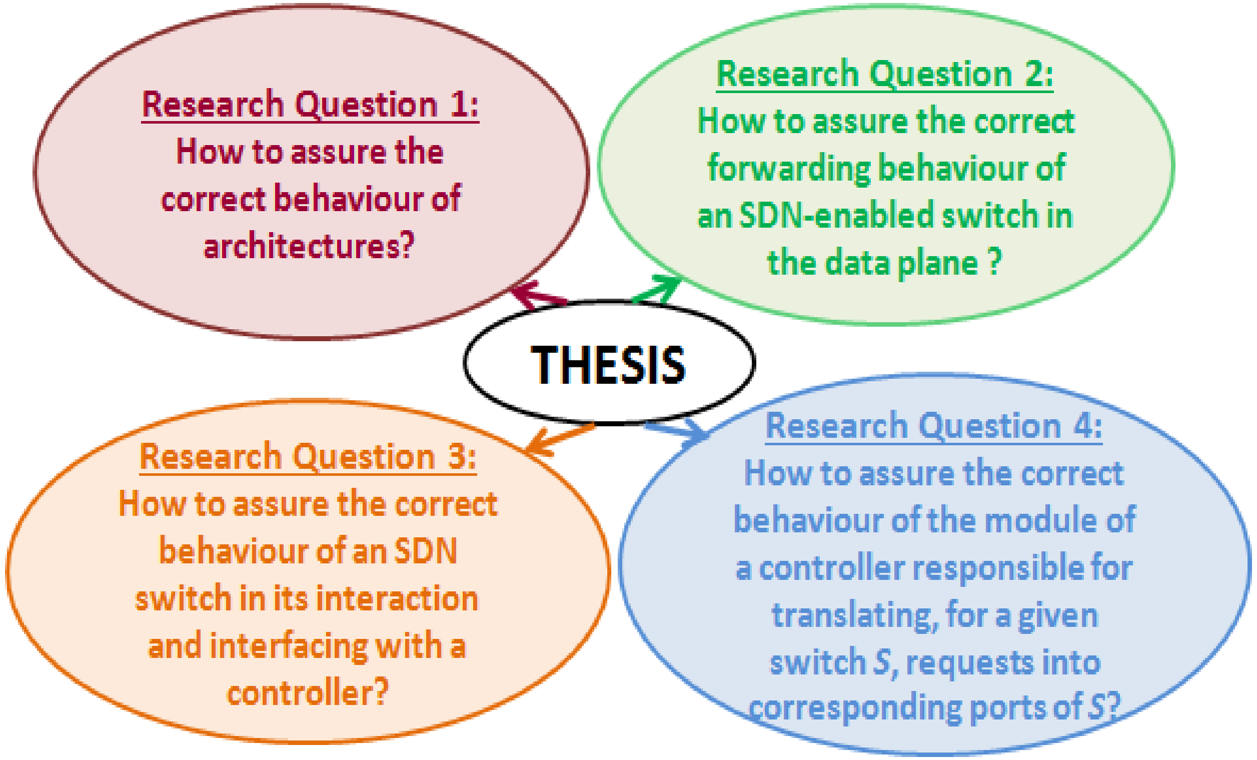
MOTIVATION & RESEARCH QUESTIONS





Research Question 1: How to assure the correct behaviour of architectures?

Research Question 2: How to assure the correct forwarding behaviour of an SDN-enabled switch in the data plane ?

THESIS

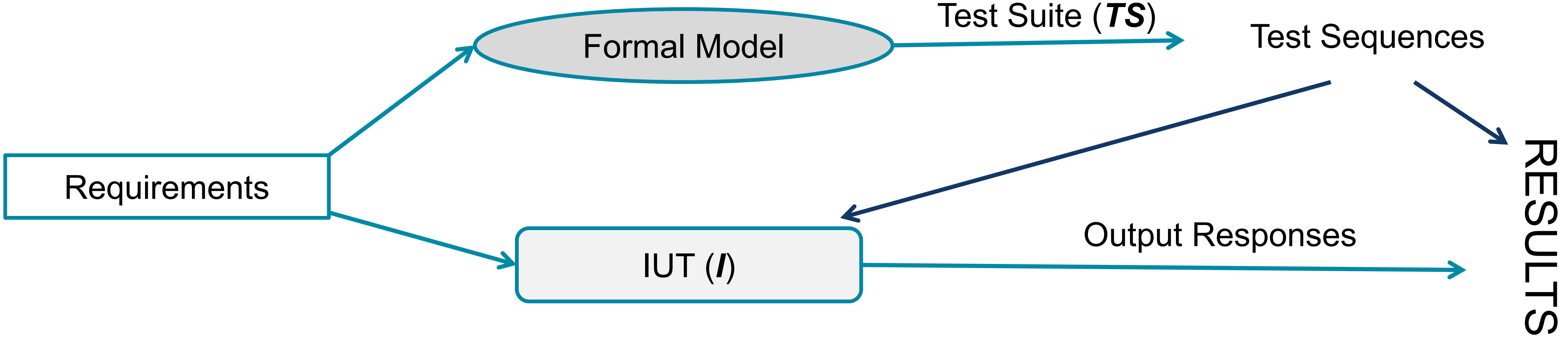
Research Question 3: How to assure the correct behaviour of an SDN switch in its interaction and interfacing with a controller?

Research Question 4: How to assure the correct behaviour of the module of a controller responsible for translating, for a given switch *S*, requests into corresponding ports of *S*?

We focus on

- Model Based Testing for SDN architectures and their components
- Test Generation

UNDERLYING MODELLING FRAMEWORK



Estimate the fault coverage of a *TS*?

- Mutation Analysis

Fault model *FM* = <*S*, @, *FD*>

- ***S***: specification
- **@**: conformance relation
- ***FD***: fault domain

Goal: w.r.t. *FM*, a *TS* that is

- ***Exhaustive***: $\forall\, I \in FD$, $I \not@\ S$ is detected by ***TS***
- ***Complete***: $\forall\, I_1, I_2 \in FD$, $I_1 @ S$ passes ***TS*** while $I_2 \not@\ S$ fails ***TS***

Contribution-I
Model Based Testing for ***SDN Architectures***
A ***Graph / Path Enumeration*** based Approach

Contribution-II
Test Derivation for ***SDN-enabled Switches***
A ***Logic Circuit*** based Approach

Contribution-III
Test Generation for ***OpenFlow Switches***
An ***Extended Finite State Machine*** based Approach

Contribution-IV
Test Derivation for a ***Controller Application***
An ***Adaptation of the Logic Circuit*** based Approach

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MODEL BASED TESTING FOR SDN ARCHITECTURES: A GRAPH / PATH ENUMERATION BASED APPROACH

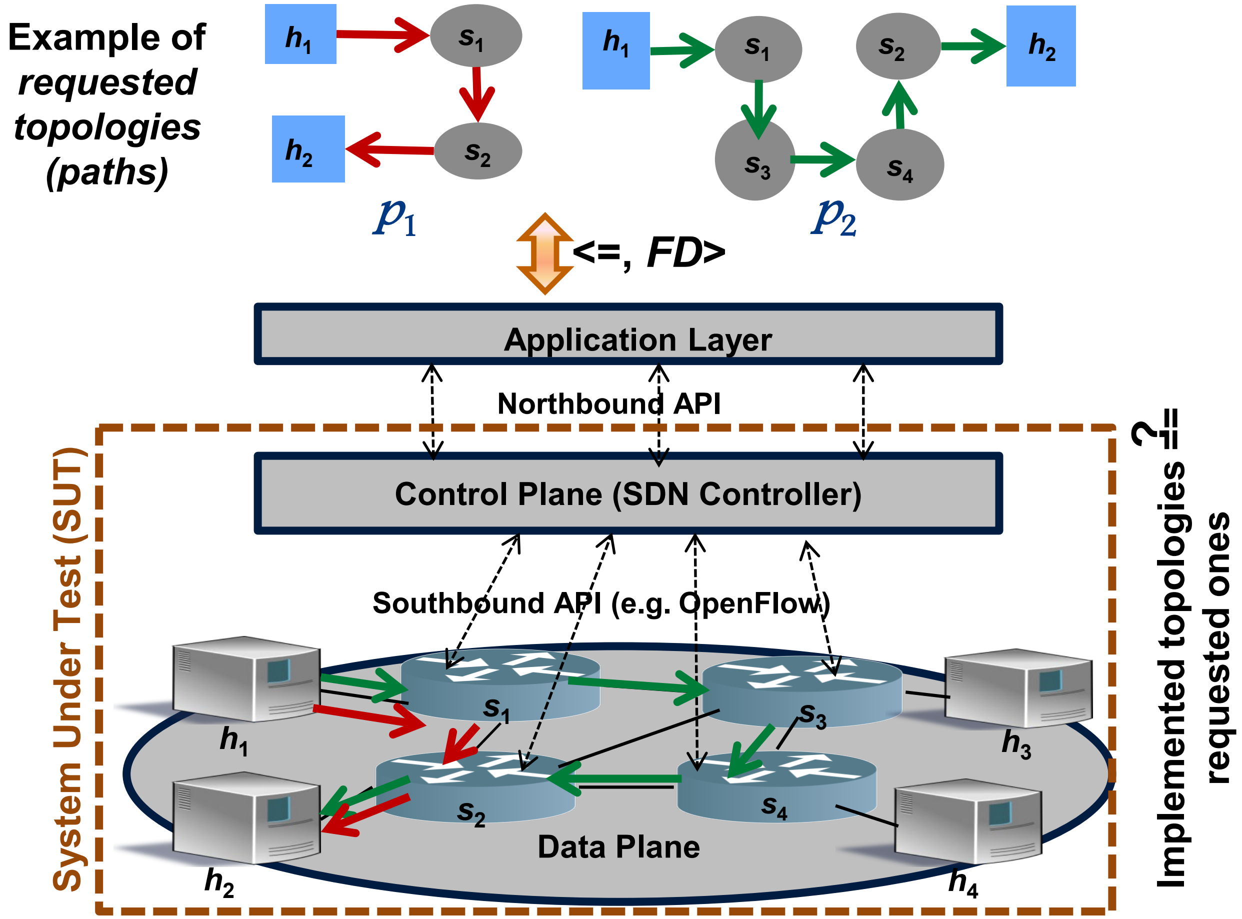
Test the ***entire SDN architecture***

to check ***implemented*** *network* ***topologies conform*** *to the* ***requested*** *ones*

✓Proposed ***FM = <=, FD>*** *where* ***FD*** containing the network topologies and the *conformance relation is the "equality"*

✓Proposed a ***novel test generation approach*** based on ***path enumeration***

✓Deriving ***complete test suites*** w.r.t. ***FM,*** for detecting inconsistencies



Example of *requested topologies (paths)*

A. Berriri et al. (2018). “Towards Model based Testing for Software Defined Networks.” In Proceedings of the 13th International Conference on Evaluation of Novel Approaches to Software Engineering, pp. 440–446

TEST DERIVATION FOR SDN-ENABLED SWITCHES: A LOGIC CIRCUIT BASED APPROACH

Derive ***test sequences*** that guarantee the desired ***fault coverage*** by formally modelling the switch via ***Logic Circuit (LC)***

Test the **forwarding functionality** of the **switch** as a “**stateless system**”
A specification ***S*** as a **set of rules** installed in the switch

✓Proposed ***FM = <S, =, FD>***

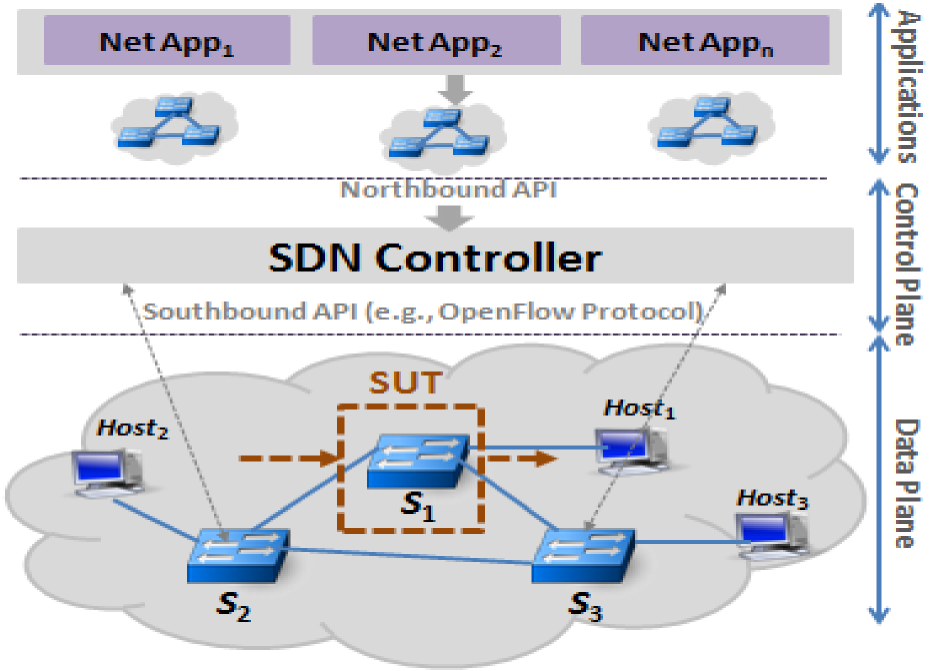
✓Proposed an algorithm for obtaining a ***LC*** simulating ***S***

✓Proposed ***novel test generation approaches***

✓Active

✓Deriving ***exhaustive/complete TSs*** w.r.t. ***FM*** for detecting inconsistencies

✓Passive (run-time verification)



J. Lopez, N. Kushik, A. Berriri, N. Yevtushenko, and D. Zeghlache (2018). “Test Derivation for SDN-Enabled Switches: A Logic Circuit Based Approach”. In Proceedings of the IFIP International Conference on Testing Software and Systems. Springer, pp. 69–84

TEST GENERATION FOR OPENFLOW SWITCHES: AN EXTENDED FINITE STATE MACHINE BASED APPROACH

Derive ***test sequences*** that guarantee the desired ***fault coverage*** by formally modelling the switch via ***Extended Finite State Machine (EFSM)***

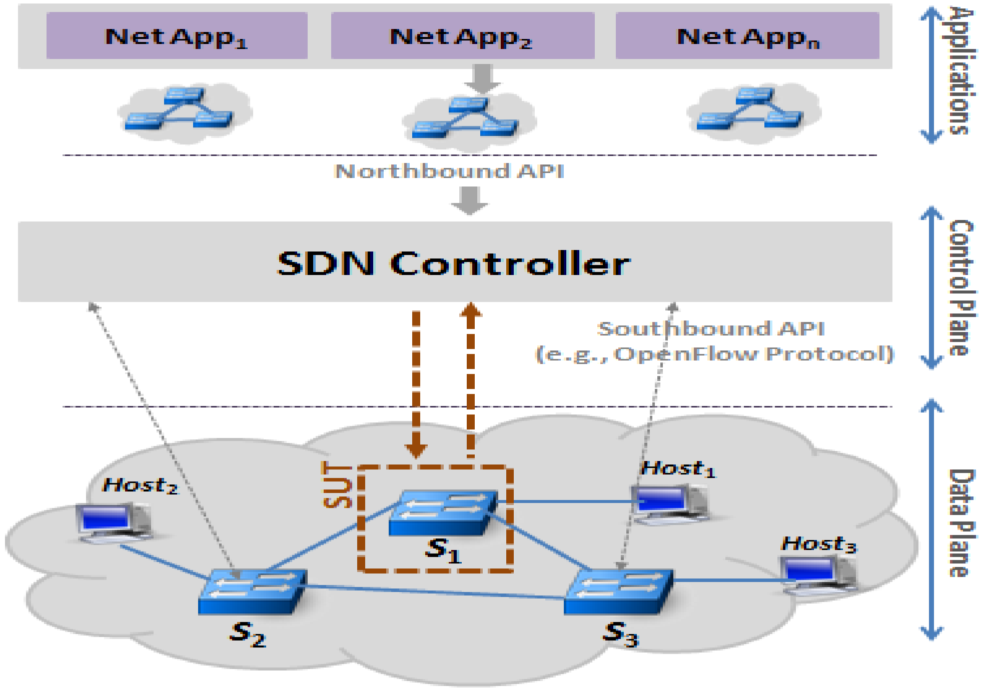
Test the switch in its interaction with the controller as a "stateful system"

✓Proposed an EFSM model (***S***) derived from the OpenFlow requirements

✓Proposed ***FM = <S, ≃, FD>***

✓Proposed a ***novel test generation approach***

✓Deriving ***exhaustive TSs*** w.r.t. ***FM*** for detecting inconsistencies



Asma Berriri et al. (2019). "Extended Finite State Machine based Test Generation for an OpenFlow Switch". working paper or preprint. url: https://hal.archives-ouvertes.fr/hal-02262841

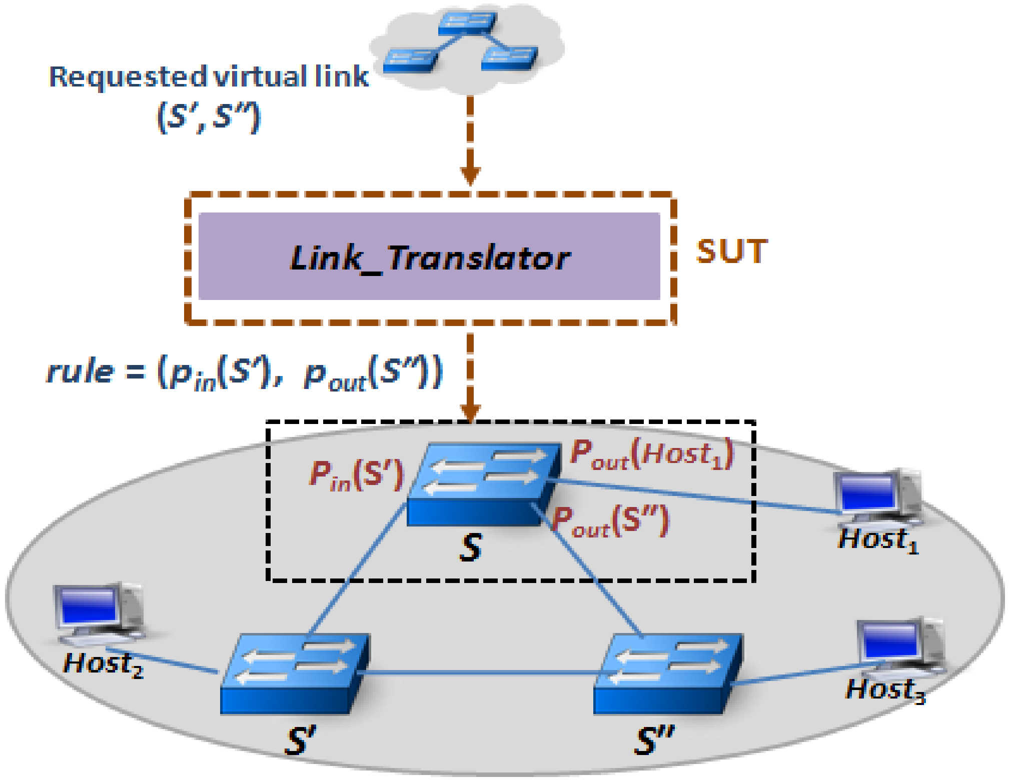
TEST DERIVATION FOR A CONTROLLER APPLICATION
AN ADAPTATION OF THE LOGIC CIRCUIT BASED APPROACH

Derive ***test sequences*** that guarantee the desired ***fault coverage*** by adapting the ***LC*** based approach (*Contribution*-II)

Test a module of the controller: the *Link_Translator*

A specification *S* as a set of mappings w.r.t. a switch *s*

- ✓Proposed an algorithm for obtaining a ***LC*** simulating ***S***
- ✓Proposed ***the adaptation of LC based test generation approach***
- ✓Proposed an algorithm for test execution



- ➢Given a requested “topology” w.r.t. a given switch ***s***, the problem is to check that the *Link_Translator* translates it into the correct pair of ports of ***s***
- ➢*Link_Translator* has prior knowledge about the data plane

EVALUATION

Experimental Set Up

- Experiments have been carried out in virtualized environments using
  - Open vSwitch (different versions)
  - Different SDN controllers
- A number of software tools have been developed

The experimental results have shown

Contribution I	✓The ***effectiveness*** of the proposed approaches in ***detecting implementation bugs*** in the ***SDN architecture*** under test
	✓The ***efficiency/'power'*** of the derived ***TS***s
Contribution II	✓The ***high fault coverage*** of the ***TS***s, derived based on ***LC*** fault models, for SDN-enabled switch faults
	✓The ***effectiveness*** of the ***run-time verification*** approach for switches
Contribution III	✓The ***effectiveness*** of the proposed ***EFSM*** based approach comparing it to a random generation approach as a baseline
	✓Its ***effectiveness*** in ***detecting switch-to-controller interaction errors/bugs***

CONCLUSION AND FUTURE WORK

Thesis Contributions: Novel Model Based Testing Approaches for SDN Architectures and their Components

- Advance the state of the art in the field
- Have been shown to be efficient in detecting errors
- Allow to provide guarantees about the quality of tests

Future Work & Perspectives

- Extending fault models
- Optimizing test generation and test execution
- Estimating the complexity of the proposed algorithms
- Enhancing experiments

Thank you for your attention!

Questions?..