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НОВЫЕ ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ В ИССЛЕДОВАНИИ СЛОЖНЫХ СТРУКТУР

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ON USING FINITE STATE MACHINES FOR OPTIMIZATION AND TESTING OF SDN CONTROLLERS

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As communication systems are becoming more and more complex, the problem of checking functional and non-functional requirements of their (embedded) components is becoming central. The same reason continuously motivates researchers to seek novel solutions for their optimization techniques. This problem usually arises for any types of communication networks, and it is of a great importance nowadays for virtual networks as they allow 'smart' resource sharing and allocation. The flexibility provided by the virtualization enables substitution of existing components (proprietary and complex network components) by less complex ones regarding time constraints, number of communication nodes, allocation, load balancing, etc. [1]. Moreover, this problem remains essential for any critical part of the network that is responsible for its configuration. For virtual networks a critical component, acting as a "network brain", is usually an SDN controller that decides which network component to use and for which purpose [2]. Any optimization of a system under design also requires thorough testing with respect to its functional and non-functional requirements. Therefore, after any module of an SDN controller has been optimized, it needs to be carefully verified that the overall behaviour of the controller is preserved. For example, if the scheduler module of the SDN controller is optimized with respect to its non-functional parameters such as QoS parameters identified through the corresponding SLA or any user preferences, the substitution of this module with a new one can affect the functionality of the whole SDN controller. Moreover, optimization criteria for one SDN component often contradict with the ones for the other. Therefore, a general solution that can be applied to various types of virtual networks, and in particular to SDN controllers need to be provided.

In this presentation, we discuss formal models that can be used for providing such general solutions for optimization and testing of SDN controller components. Among different formal models we propose to use Finite State Models, and in particular Finite State Machines (FSMs) that include the 'natural reactivity' (characteristic) of such controllers and their components. An FSM [3] has finite non-empty sets of states, inputs and outputs; when an input is applied, the FSM moves to the next state producing an output. The behaviour of the FSM is represented by a set of input / output sequences (traces) that correspond to a set of permissible sequences of queries and responses for a given (protocol, service, application) implementation. This set of traces, on one hand, can preserve a flexibility that can be used for the optimization purpose, and on the other, can contain a (finite) subset of critical sequences that can be applied to an implementation under test (IUT) to verify its correctness.

The flexibility of a given SDN controller component can be represented by a nondeterministic FSM [4] that captures all permissible implementations of this component. For example, for the SDN component that is responsible for the planning of the content delivery to the users, such FSM contains as sub-machines or its reductions, all possible scheduler implementations. Several heuristics can be later applied for extracting the solution which is optimal or close to optimal with respect to (non-functional) SDN requirements. Moreover, the corresponding non-functional requirements for an optimal design of the SDN controller can include different network criteria such as time constraints, restrictions on the path length, bandwidth, data streams, chaining requirements, etc. Therefore, in this presentation, we discuss various finite state models that can be effectively used when modelling virtual networks and their components, taking into account functional and non-functional requirements. In particular, we discuss how Extended and Timed FSMs can be used for describing the behaviour of SDN controllers and their components. These Extended FSMs augment the classical ones with the set of context variables, input and output parameter values as well as the set of predicates that ‘show’ which transition can be executed at a given point. Correspondingly, we discuss some heuristics for optimizing SDN controller components by extracting ‘close to the best’ implementation from the nondeterministic extended / timed machine.

As future work, we plan to implement the proposed solutions and perform the experimental evaluation with ‘real-life’ virtual networks for optimizing and testing SDN controllers and their modules.

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SYNCHRONIZING SEQUENCES FOR EFFECTIVE NETWORK MONITORING: AN APPLICATION TO TCP

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The rapid development of information technologies requires that all network interactions are thoroughly checked. Traditional firewalls and intrusion detection systems (IDS) such as snort [1] inspect and filter network traffic based on the information contained on a single network packet (stateless inspection). In order to analyse complex network properties, the correlation between packets from the network traces, is now an emerging concept [2].

It should be mentioned that in passive testing or network monitoring, the implementation under test (IUT) cannot be interrupted or manipulated. Therefore, the current execution state of the IUT is considered to be a priori unknown. However, the number of properties to be verified at a given time instant can be significantly reduced if the IUT state is known and thus, only critical properties for this state are verified. Therefore, existing solutions for the so-called state identification problem [3] can be effectively used to determine the current IUT state. This approach have been proposed in [4] and in this presentation, we discuss how it can be applied for passive testing of the transmission control protocol (TCP) implementation [5].

The approach is based on the derivation of synchronizing sequences for a Finite State Machine (FSM) [6] that describes the TCP behavior. The FSM moves from one state to another when an input is applied; when the corresponding transition is executed the appropriate output is produced. The FSM can be brought to a known current state by the application of a synchronizing sequence, i.e. independently on the initial FSM state and the output reaction the current FSM state becomes known.

In order to apply this technique for the TCP passive testing, we adapted a state model for it, taken from [7]. The resulting FSM that describes the TCP behavior is complete and deterministic; it has nine states and ten inputs. We performed experimental evaluation to estimate how likely is that a synchronizing sequence can be observed during the monitoring process of the TCP implementation. The likelihood of a synchronizing sequence to appear among all network traces being observed we estimate as the probability of, where is the number of all the synchronizing sequences of length, and denotes all possible input sequences of length. Experimental results show that there do not exist synchronizing inputs for the TCP FSM. However, even when five input sequences of length two are synchronizing for this FSM. These sequences transfer the FSM from any of initial states to one three possible states, i.e. whenever of synchronizing pair of inputs is observed, only properties that are interesting for one of these three reachable states need to be checked. Moreover, if the length increases, the number of ‘good’ sequences of this length increases as well. In fact, if during the monitoring process a test engineer analyzes the traces of length five and more, then with a probability more than 30% a synchronizing sequence that uniquely identifies the current state of the TCP implementation can be observed. The later proves the applicability of the approach as it allows to reduce the number of properties to be checked during the network monitoring.

We mention that not all the input sequences can be observed when analyzing network traces. It can happen that among 30% of ‘good’ input sequences only 10% can be actually observed due to the IUT environment, observation