The Next 700 Network Programming Languages (Invited Talk)

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ABSTRACT

Specification and verification of computer networks has become a reality in recent years, with the emergence of domain-specific programming languages and automated reasoning tools. But the design of these frameworks has been largely ad hoc, driven more by the needs of applications and the capabilities of hardware than by any foundational principles. This talk will present NetKAT, a language for programming networks based on a well-studied mathematical foundation: regular languages and finite automata. The talk will describe the design of the language, discuss its semantic underpinnings, and present highlights from ongoing work extending the language with stateful and probabilistic features.

CCS CONCEPTS

• **Software and its engineering** → **Formal language definitions**; • **Networks** → *Programming interfaces*;

KEYWORDS

Domain-specific languages, software-defined networking, formal verification, Kleene algebra with tests, NetKAT.

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1 INTRODUCTION

NetKAT is a domain-specific language for network programming [1–5]. It offers rich abstractions for specifying the behavior of network devices such as routers and firewalls, and accompanying tools for reasoning formally about network-wide properties such as connectivity and traffic isolation. In this talk, I will describe the design of NetKAT, including primitives for filtering, modifying, and transmitting packets; union and sequential composition operators; and a Kleene star operator that iterates programs. I will also present the semantics of the language, which can be formulated in three different ways: as a denotational semantics based on functions from packet histories to sets of packet histories, as an axiomatic semantics based on a sound and complete deductive system, and as an operational semantics based on finite automata. I will discuss

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Syntax

Predicates	$a, b ::= \text{true}$	<i>Identity</i>
	$\mid \text{false}$	<i>Drop</i>
	$\mid f = n$	<i>Test</i>
	$\mid a + b$	<i>Disjunction</i>
	$\mid a \cdot b$	<i>Conjunction</i>
Programs	$\mid \neg a$	<i>Negation</i>
	$p, q ::= a$	<i>Filter</i>
	$\mid f \leftarrow n$	<i>Modification</i>
	$\mid p + q$	<i>Union</i>
	$\mid p \cdot q$	<i>Sequencing</i>
	$\mid p^*$	<i>Iteration</i>
	$\mid \text{dup}$	<i>Duplication</i>

Semantics

Denotational	$\llbracket p \rrbracket \in \text{History} \rightarrow \mathcal{P}(\text{History})$
Axiomatic	$\vdash p \equiv q$
Automata-theoretic	$\mathcal{A}(q)$

Figure 1: NetKAT syntax and semantics.

applications of the language to practical compilation and verification problems. Finally, I will present highlights from recent work extending the language with stateful and probabilistic features.

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