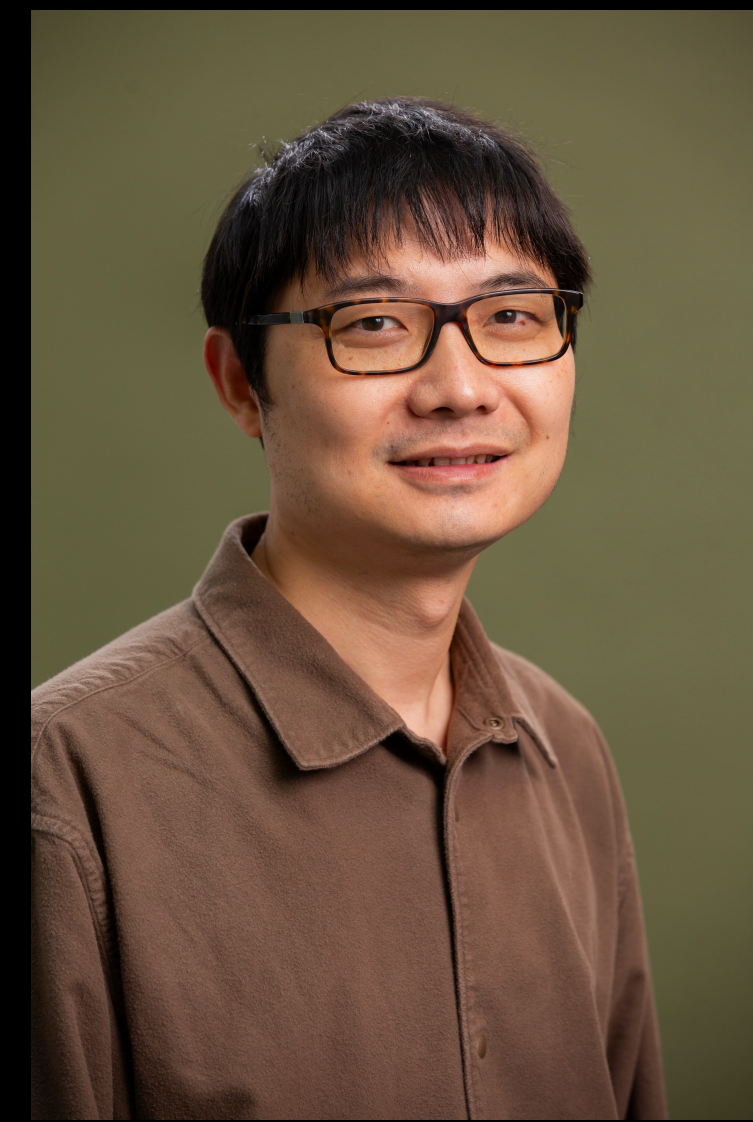# FMitF: Track I: Flexible Data Plane Programming

Award ID # 2319425

Xiaokang Qiu: Purdue University, West Lafayette, IN, xkqiu@purdue.edu
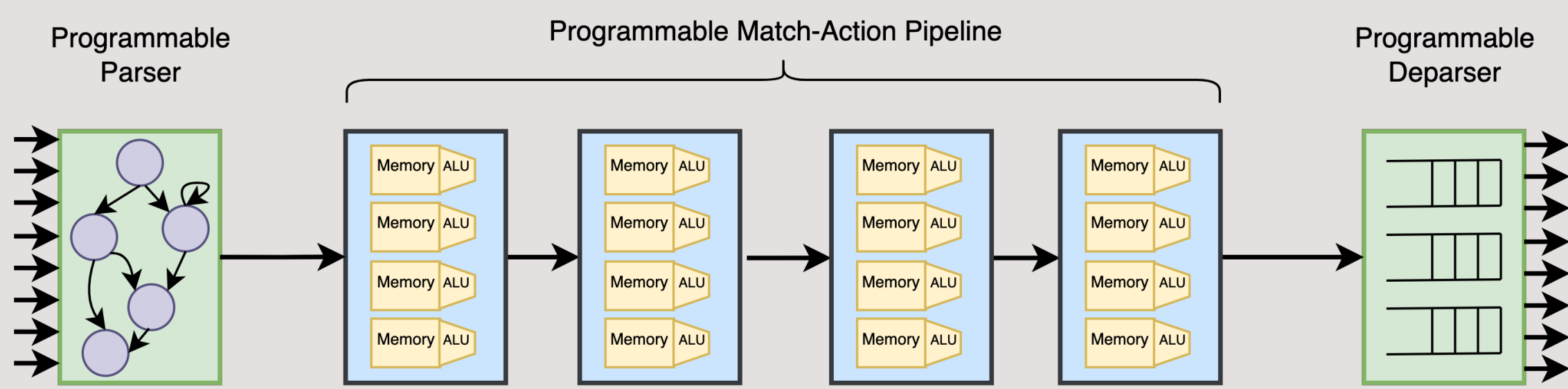Sanjay Rao: Purdue University, West Lafayette, IN, sanjay@purdue.edu

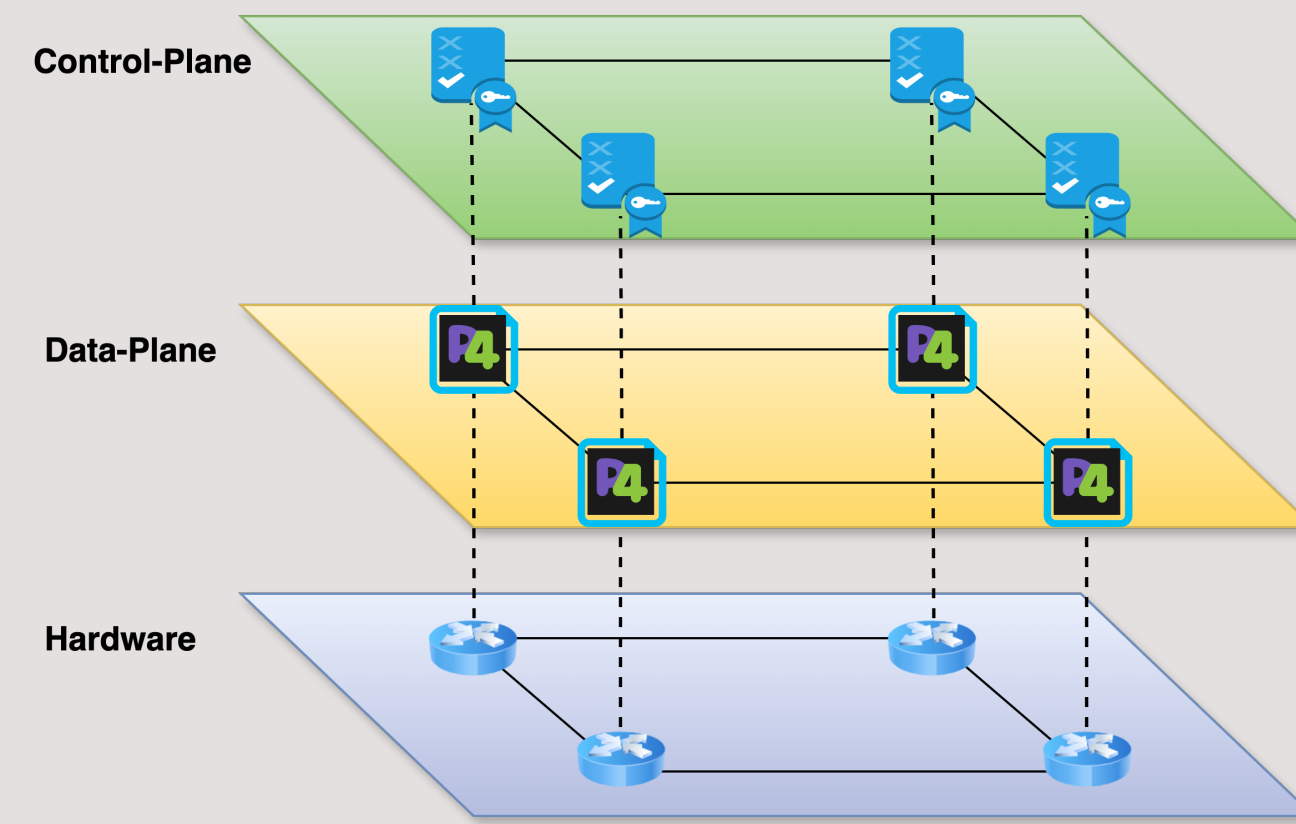URL: https://purdue-isl.github.io/projects_pages/Program-Synthesis-Approach

Motivation

Programmable Switches Architecture

Hard to program with low-level, hardware-specific constraints

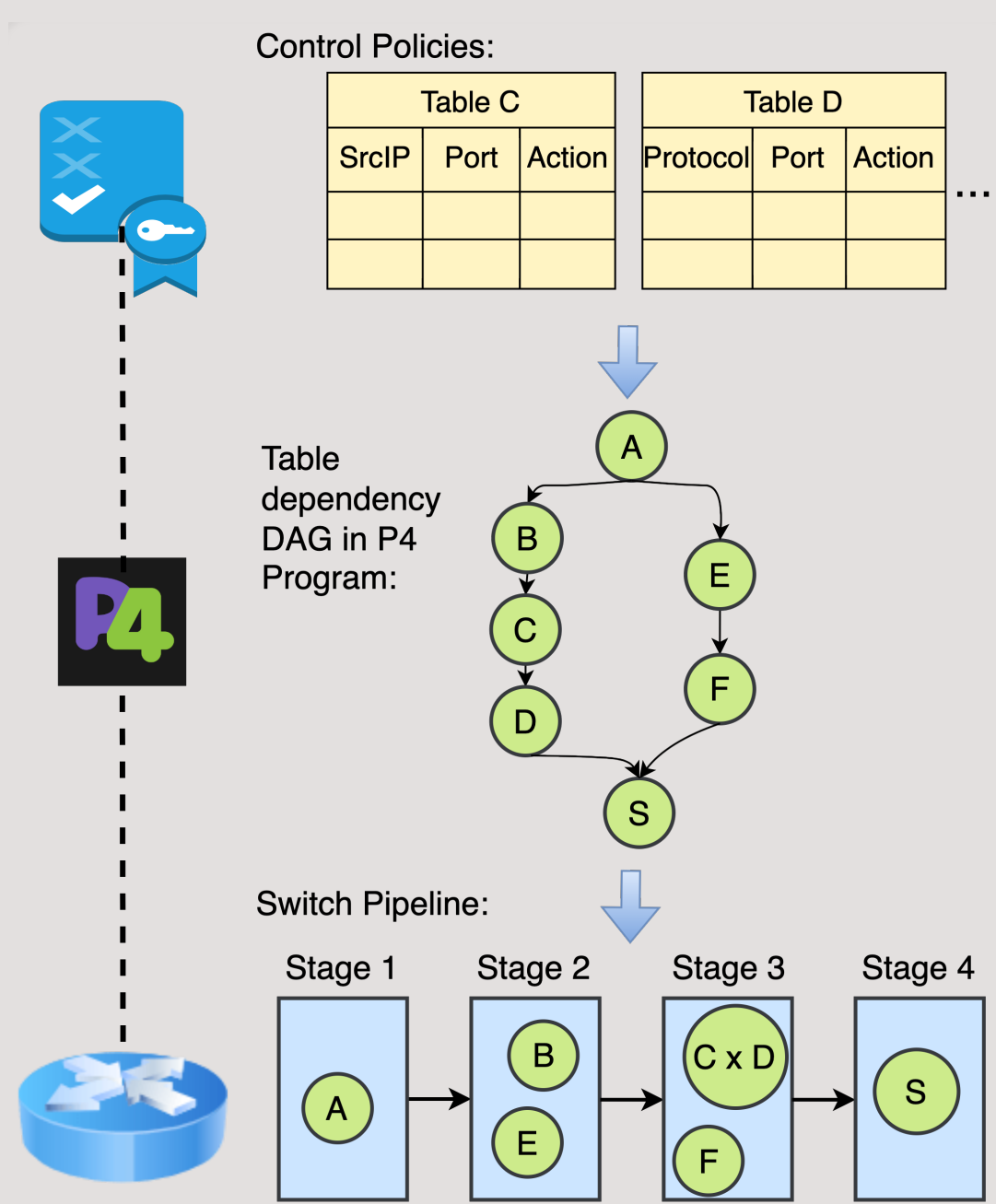- Limited number of stages
- Limited memory - SRAM and TCAM, etc.

P4 programming

Lack of support for customizable optimization

- Flexible optimization targets (latency, resource allocation, etc.)
- Network-wide optimization
- Accommodation to specific control plane and hardware

Challenges

How to make data plane programming more flexible?

- Describing control plane and hardware assumptions
- Describing global optimization targets

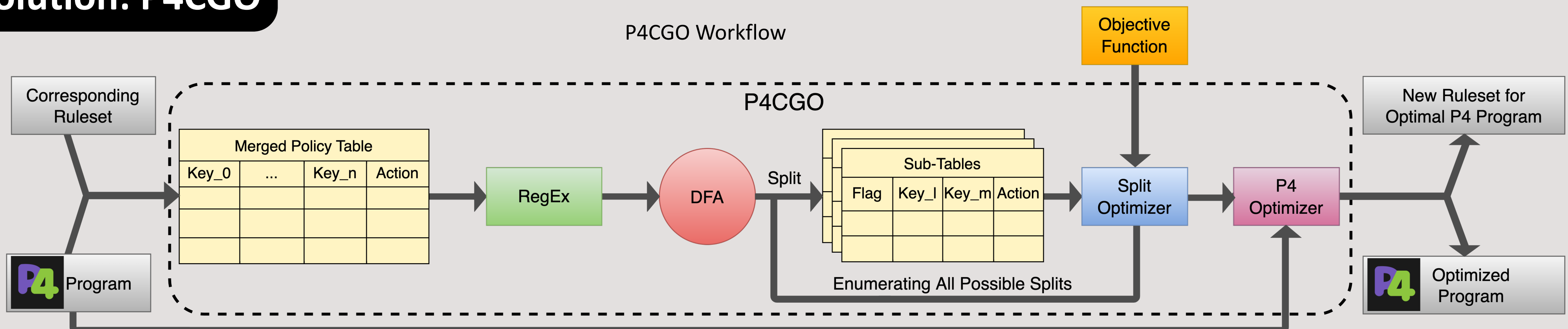**How can formal methods help achieve efficient compile-time optimizations?**

- Leveraging domain knowledge
- Enhancing generic synthesis techniques

Scientific Impact

- The project will advance formal methods and program synthesis, contributing to areas such as *syntax-guided synthesis*, *quantitative synthesis*, and *specification mining*

- Our tools will simplify data plane programming, making formal reasoning and optimization easier and tractable

- Our methods could have broader applications (e.g., many other optimization problems) and benefit users beyond the networking domain

- Preliminary results published: Wen, C., Li, Z., Jafri, S.U., Qiu, X. and Rao, S. 2024. P4CGO: Control Plane Guided P4 Program Optimization. In *2024 SIGCOMM Workshop on Formal Methods Aided Network Operation (FMANO '24)*, pp. 1-7.
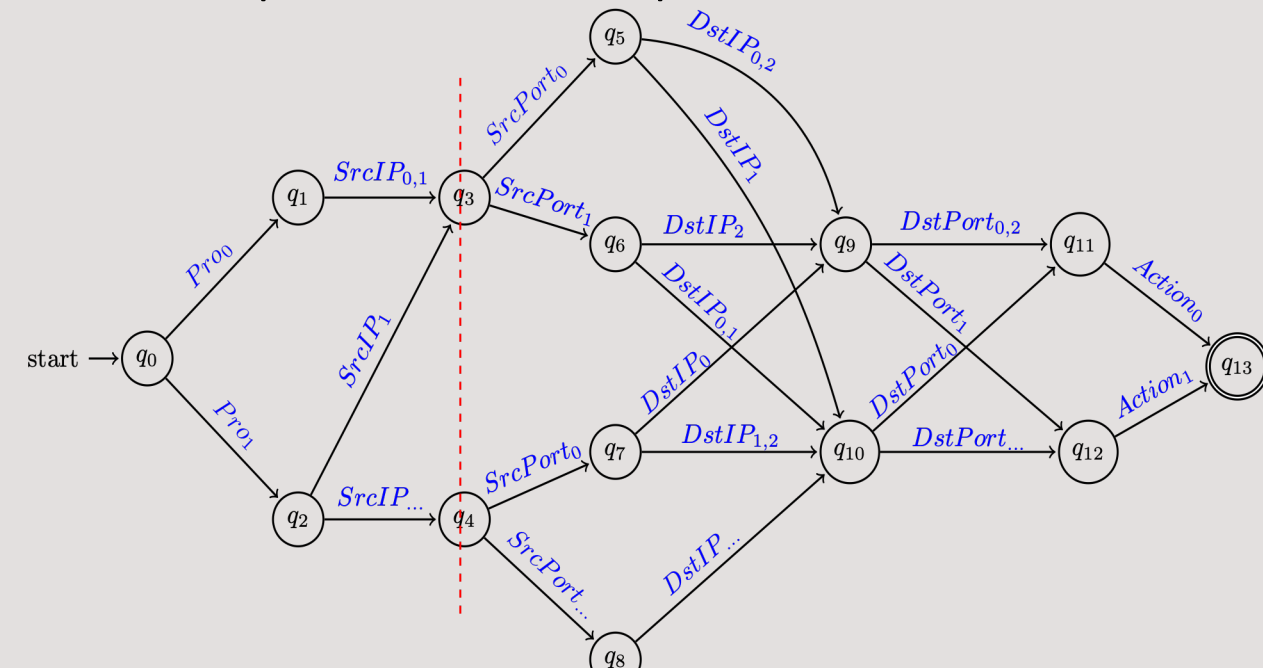
Our Solution: P4CGO

P4CGO Workflow

Take P4 program together with control plane policy and objective function as input
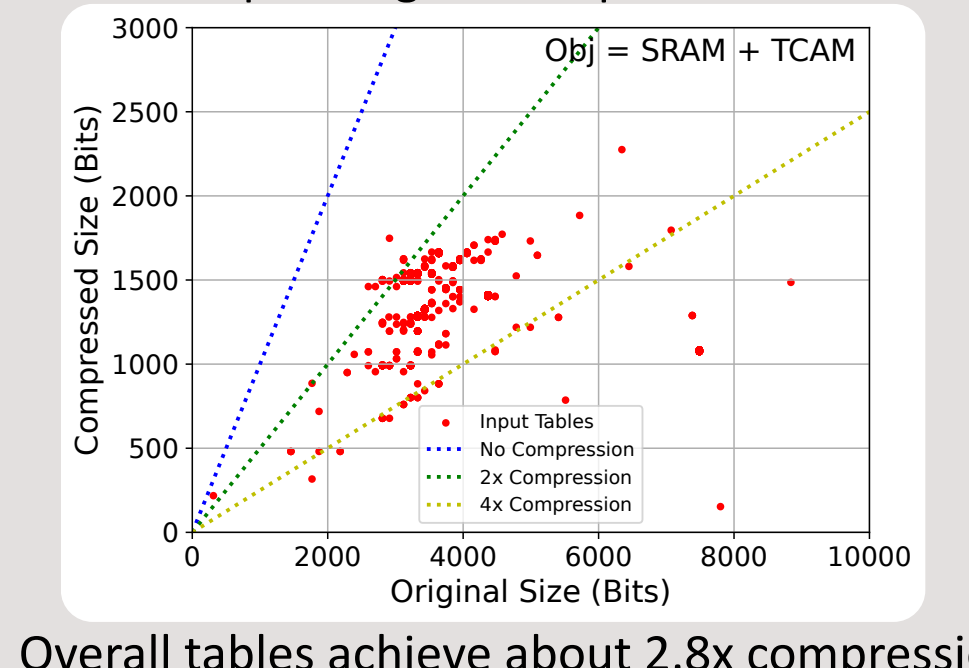
minimize (SRAM + TCAM)

Transform inputs into a DFA to perform minimization and DFA split

Generate optimized P4 program with corresponding control plane

Overall tables achieve about 2.8x compression

Impact on Society

Simplifying data plane programming will promote the broader adoption of programmable routers, benefiting the networking and IT industries.

Impact on Education

Curriculum development will include new material on programmable switches and networking for courses at Purdue.

Broader Participation

- This project has been providing valuable training for four graduate students and one undergraduate student
- We have been extensively interacting with Purdue's IT department