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Cryptographic Hashing in P4 Data Planes

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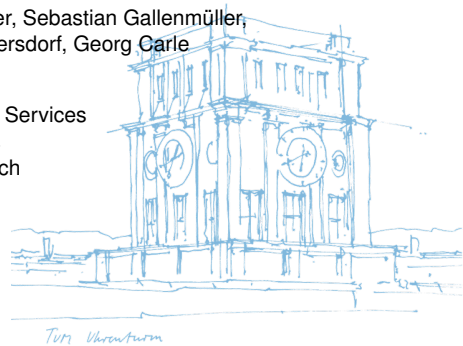
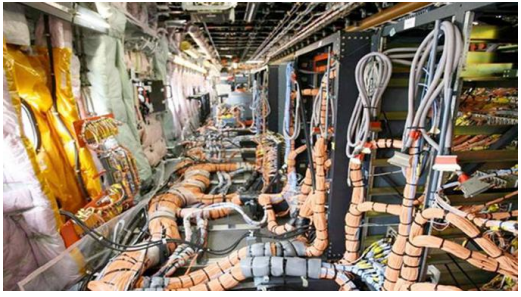


Motivation

Manifold P4 Applications and Programs

Imagine long list of P4 programs here
→ Few programs that require cryptographic functionality



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P4 is of high interest to industry, e.g. avionics

- Rapid prototyping
- Program verification
- ...

Requires guarantees: e.g. authentication of switches

Motivation

Cryptographic Properties and Functions

Cryptographic properties commonly found in network applications and protocols

- Confidentiality
- Authenticity (data/message integrity)
- Authentication (data origin authentication)

Cryptographic functions

- Encryption
- Hash functions

$\rightarrow$ in this work we focus on cryptographic hash functions

Motivation

Use cases for cryptographic hash functions

Data structures

- Hash maps
- Bloom-Filter

But: cryptographic functions not required
e.g. Bloom-Filter: linear-independent hashes suffice

Authenticity/Authentication

- Message Authentication Codes
- Client puzzles (TCP SYN cookies)

Cryptographic functions required

Outline

Problem Statement

Feasibility of cryptographic hashing in programmable data planes

- Hash with cryptographic properties
- Hash of complete packet content
- Ideally achieving 10 GbE line-rate
- Software and hardware P4 targets

Choice of Hash Function

Cryptography vs. Performance

Cryptographic (hash) functions are

- Slow $\leftrightarrow$ line-rate
- Complex $\leftrightarrow$ resource consumption on target

Pseudo-cryptographic SipHash

- Optimized for small inputs
- Optimized for performance in software

Benchmarks on software system

Hash algorithm	Cycles per B	Fixed cycles per packet	Cycles for 64 B
CRC32	0.32	0.00	10.79
Checksum	0.44	0.00	30.06
SipHash-2-4	1.06	56.40	121.10
BLAKE2b	3.14	35.85	232.77
HMAC-SHA256	5.57	959.69	1462.13

Available P4 Targets

. . . that can be extended with cryptographic hashing

- Software: t4p4s (P4ELTE), based on DPDK
- Network Processing Unit: Netronome Agilio SmartNIC (NFP-4000)
- FPGA: NetFPGA SUME (P4→NetFPGA)
- ASIC: none that we are aware of

P4 Hash Integration

t4p4s

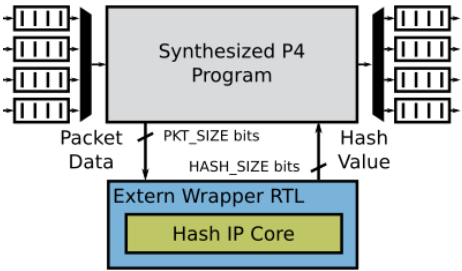
- Trivial: link library, add extern
- Added SipHash-2-4 and HMAC-SHA512 (openssl)

NFP-4000

- Crypto security accelerator (SHA1): not available on our card
- Integrated SipHash-2-4 as extern in variation of C

NetFPGA SUME

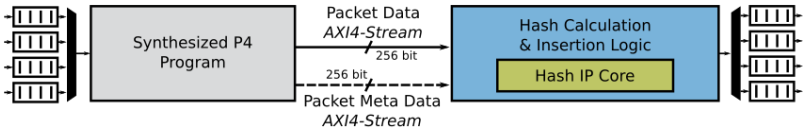
- Externs implemented in Verilog/VHDL
- Integrated SipHash-2-4 and SHA3-512
- Problem:
  - Data passed between P4 program and extern is a single data word
  - SDNet limit: 600 B input width
  - No timing closure due to resource congestion



P4 Hash Integration

NetFPGA

Alternative P4 architecture model



Limitations

- All packets are always hashed
- Hash outcome not usable in P4
- Alternatives:
  - Hashing before P4 pipeline
  - Second P4 pipeline after hashing core
  - Traffic manager
- SHA3-512 core uses 125 MHz $\rightarrow$ clock domain crossing

Measurement Results

Setup

- Load Generator
  - CBR traffic of constant packet size
  - Precise latency measurements
- Device-under-Test (DuT)
  - Intel Xeon E5-2620 with Intel X540 NIC
  - Netronome NFP-4000 SmartNIC
  - NetFPGA SUME
- P4 program
  - L2 forwarder
  - Hashes complete packets

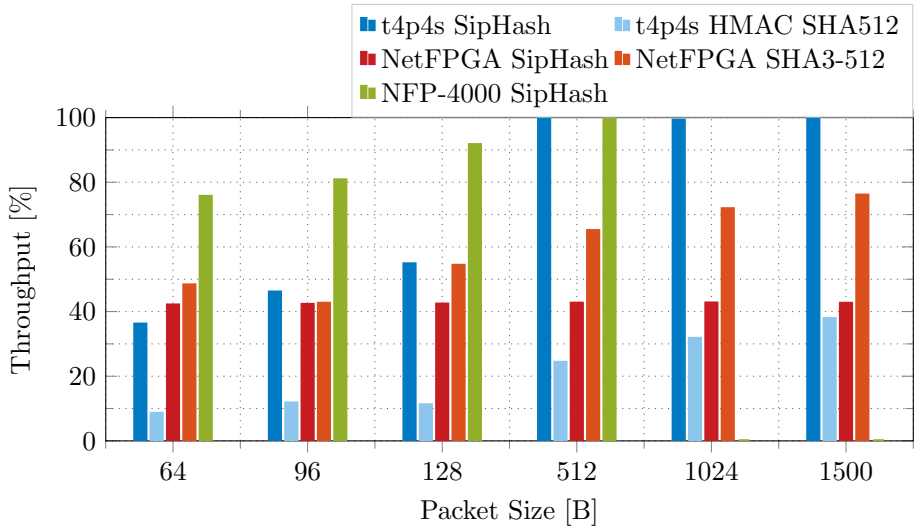
Disclaimer

- Open-source implementations
- Non-commercial IP cores
- Not optimized integration → proof-of-concept
- Take performance figures with grain of salt

→ conservative numbers

Measurement Results

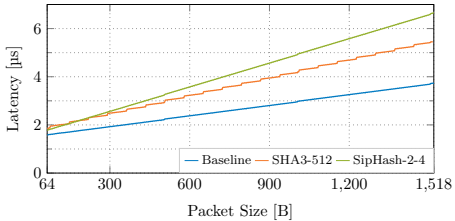
Achievable Throughput



Measurement Results

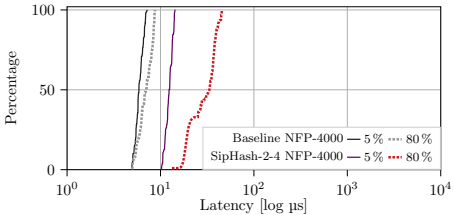
Latency

NetFPGA



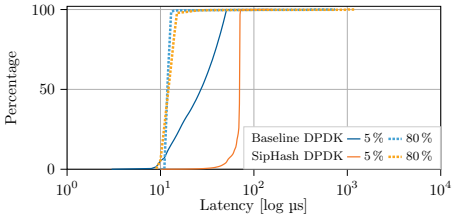
Stable latency: no long-tail

NFP-4000



t4p4s

Typical behavior of software system/DPDK: long-tail



Measurement Results

Resource Utilization

Does the program fit on the target?

- t4p4s: trivial
- NFP-4000: no restrictions enountered
- NetFPGA:

	LUTs		Registers		BRAM	
	Abs.	%	Abs.	%	Abs. [kB]	%
Baseline	64,533	14.90	109,783	12.67	16,362	30.92
SipHash-2-4	66,380	15.32	114,282	13.19	17,460	32.99
SHA3-512	73,449	16.95	118,689	13.70	17,460	32.99

Conclusion

The current use of hash functions in P4 programs

- Data structures might be vulnerable to attacks (hash collisions)
- Lack of programs/protocols requiring authentication and integrity

→ Cryptographic hash functions increase applicability of P4

Cryptographic hashing is target, algorithm and use-case dependent

- Line-rate possible on hardware targets
- Integration for instance by adjusting P4 architecture model
- Algorithms might be better on one target than another

→ no one-size-fits-all solution

→ P4 specification should recommend family of hash functions, including cryptographic ones