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XXXVI Cycle

Timely and lightweight in-network traffic stream analytics

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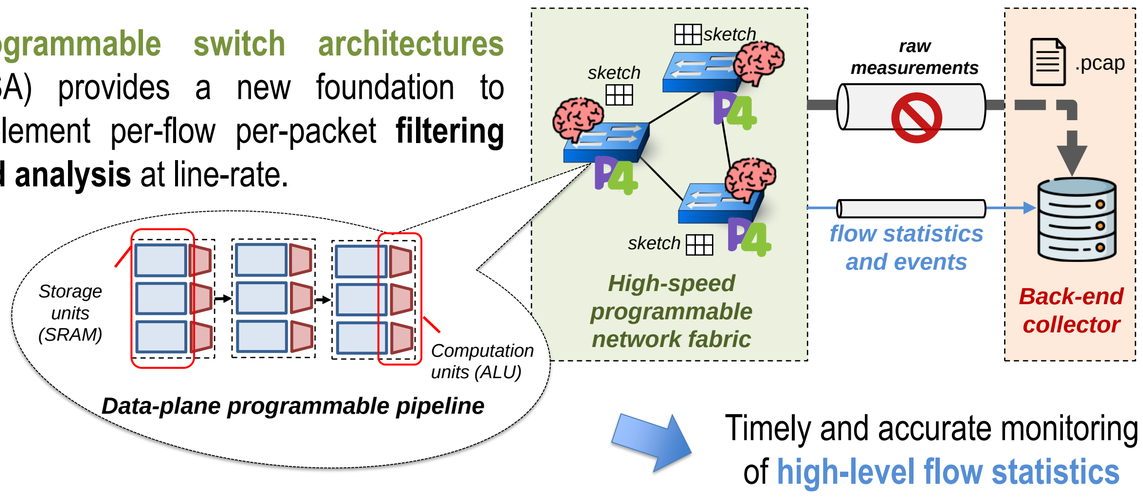
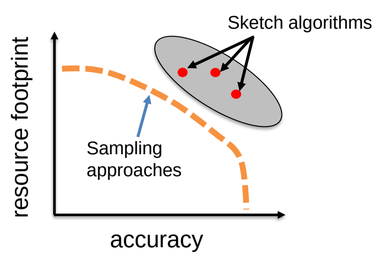
Research context and motivation

- Timely mitigation of anomalous network events is critical for modern microservices and serveless-based applications, as they are more sensitive to network performance.

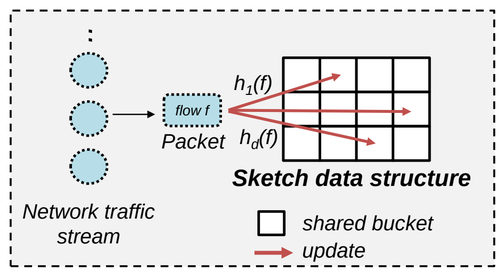
- **Programmable switch architectures** (PSA) provides a new foundation to implement per-flow per-packet **filtering and analysis** at line-rate.



- Need of novel algorithms to monitor flows without sampling.



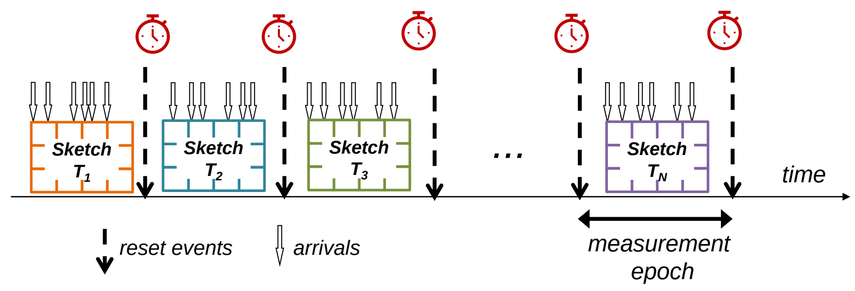
Timely and accurate monitoring of **high-level flow statistics** and **events** (e.g., heavy hitters, jitter anomalies, ..) inside the network



- **Sketch algorithms** offer a tunable **probabilistic trade-off** between memory/computation complexity and estimation accuracy.

Addressed research questions/problems

- Most state-of-the-art sketches are operated on a slotted time basis.



#1
Making sketches more ***reactive***

- **Latency overhead.** Results are representative only at the end of the measurement epochs.

How to refactor existing sketches to operate in **continuous-time**?

- **Memory is scarce.** Sketch accuracy is function of the ratio between the number of monitored flows and memory size.

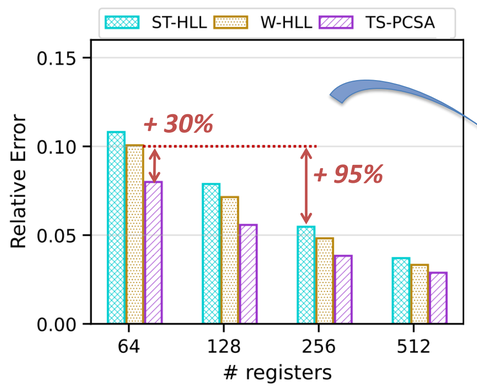
Challenging for large epochs

How to leverage the memory on multiple switches to design a **distributed sketch**?

 # 2
Making sketches more ***accurate***

Novel contributions

① Flow cardinality estimation over sliding windows



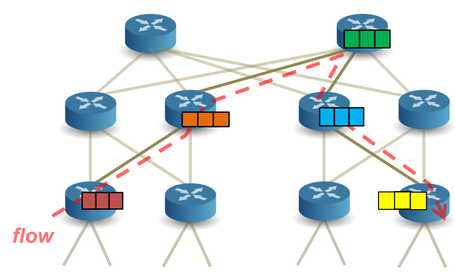
Networking use cases:

- DDoS attack detection
- Superspreaders identification
- Port scanners identification
- Network provisioning

Two novel sketch designs: ST-HLL and TS-PCSA. They are **more accurate** of state-of-the-art solutions for the same memory footprint.

② Network-disaggregated sketches (NetSketches)

- Logical sketch is disaggregated into **sketchlets** on flow path.
- Devised an optimal sketchlet **update policy** for a FatTree topology.



Adopted methodologies

Algorithm conceptualization and theoretical analysis

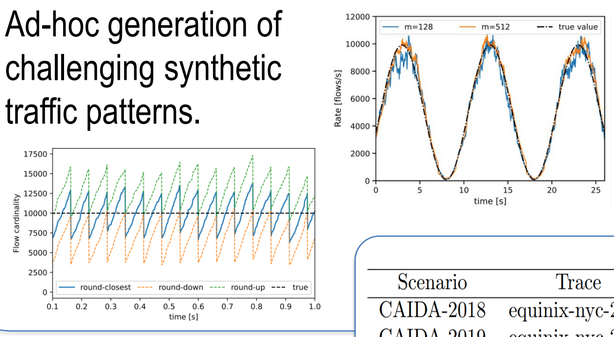
- New analytical estimators tailored to our novel ST-HLL and TS-PCSA sketches.
- Probabilistic upper bound to the accuracy of NetSketches.

$$\hat{\lambda}_i = 2^{M_i - \gamma'} \frac{m^2}{2Wi}$$

$$P(\hat{\theta}_f \geq \tau | \theta_f < \tau) \leq \prod_{\{s|\gamma_{sf}=1\}} \left(\frac{\lambda_s}{c(\tau - \theta_f)} \right)^d$$

Iterative validation through numerical simulation

- Ad-hoc generation of challenging synthetic traffic patterns.

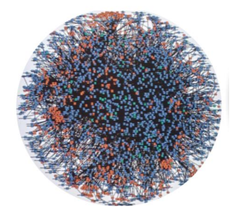


Evaluation over real traffic traces

- Performance comparison with alternative approaches on Internet traffic captured by CAIDA.

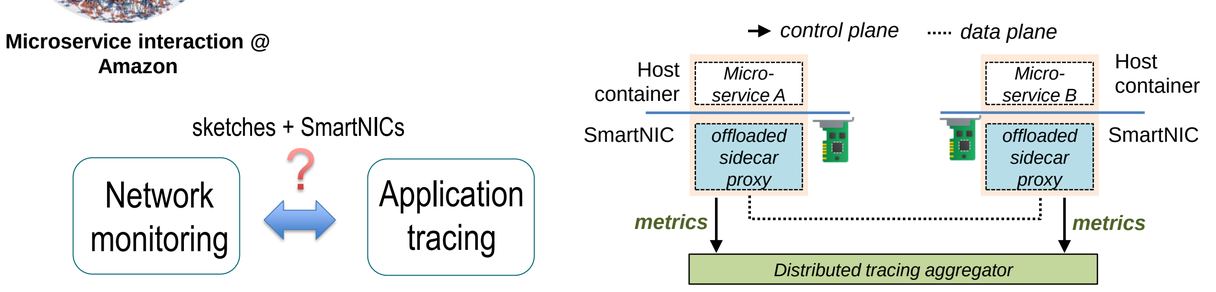
Scenario	Trace	Ave. Bitrate	Link rate	Num. Packets	Num. Flows
CAIDA-2018	equinix-nyc-2018	4.26 Gbps	10 Gbps	37.8M	1.8M
CAIDA-2019	equinix-nyc-2019	4.49 Gbps	10 Gbps	36.7M	1.2M

Future work



Microservice interaction @ Amazon

- Application tracing in serverless computing has huge overhead.
- Tracing has no visibility into network events and viceversa.
- Can sketches and SmartNICs bridge this gap?



List of attended classes

- 01UJBRV – Adversarial training of neural networks (6/2021, 3 CFU)
- 01SOVBH – Statistical learning and neural networks (23/02/2021, 6 CFU)
- 01TTJRV – The Hitchhiker's Guide to the Academic Galaxy (13/04/2021 , 3 CFU)
- 01QORRV – Writing Scientific Papers in English (23/06/2021, 6 CFU)
- 01QFFRV – Tecniche innovative per l'ottimizzazione (23/07/2021, 4 CFU)
- 01TSBRV – Scienza dei dati applicata alle reti complesse (23/07/2021, 4 CFU)
- 01NRWBG – Communication systems (08/09/2021, 6 CFU)
- 01UNWRV – Intercultural & interpersonal management (22/06/2022, 1 CFU)

Submitted and published works

- Cornacchia A., Bianchi G., Bianco A., and Giaccone P., "*Staggered HLL: near-continuous-time cardinality estimation with no overhead*", Computer Communications, vol. 193, 2022, pp. 168-175.
- Cornacchia A., Bianchi G., Bianco A., and Giaccone P., "*Designing probabilistic flow counting over sliding windows*", PEWMN, IFIP, Rome, 2022, submission accepted.
- Cornacchia A., Sviridov G., Giaccone P., and Bianco A., "*A traffic-aware perspective on network disaggregated sketches*", MedComNet, IEEE, online, 2021, pp. 1-4.

POLITECNICO DI TORINO

PhD program in
Electrical, Electronics and Communications Engineering