A Hybrid P4/NFV Architecture for Cloud Gaming Traffic Detection with Unsupervised ML

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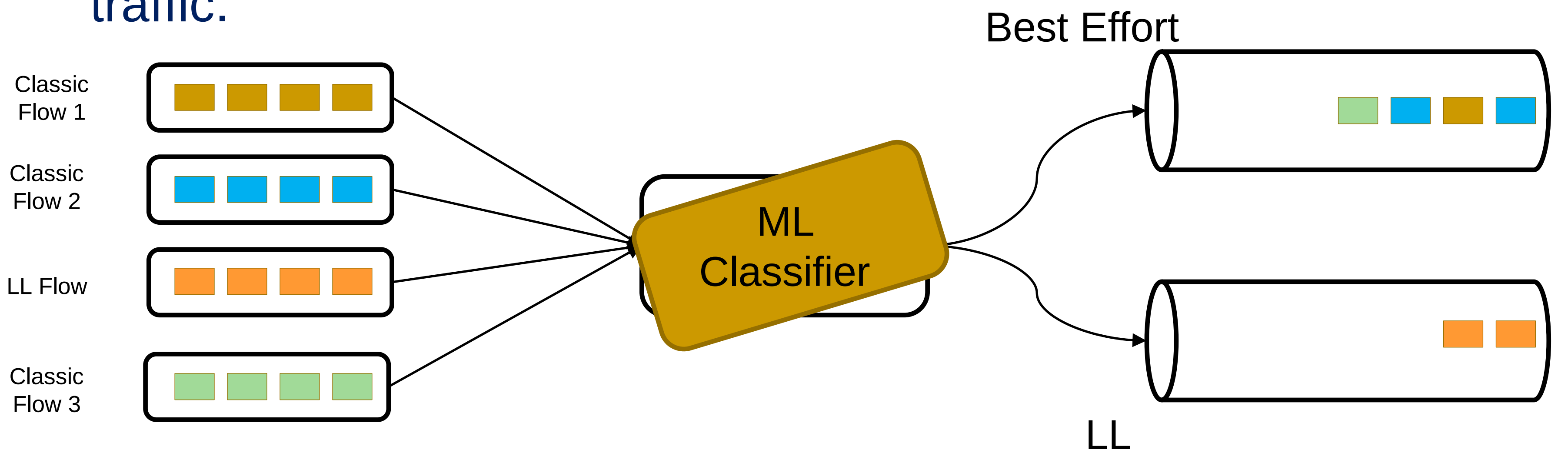
1. Context & Motivation

- Increasing pressure of Cloud Gaming (CG) traffic on current network infrastructures.
- Stringent network requirements, especially in terms of jitter and latency.
- Recent network technologies such as L4S (Low Latency Low Loss Scalable throughput) can reduce the latency of low-latency (LL) traffic.



2. Previous works

- Cloud Gaming traffic from 4 main CG platforms available in Europe (Stadia (STD), GeForceNow (GFN), Xbox Cloud (XC) and PlayStationNow (PSN)):
  - Traffic on normal conditions
  - Traffic with network constraints
- Non-Cloud Gaming Traffic: (Video conferencing (VC); Video streaming (VS); Live video streaming (LV); Facebook navigation (FN))

- Decision Tree (DT) model (supervised ML) in a set of VNF to detect CG traffic [Graff et al.].

Performance degradations with new CG traffic (« unseen » CG traffic or new CG platforms).

- New datasets: (new games and new CG platforms (Moonlight, Steam)

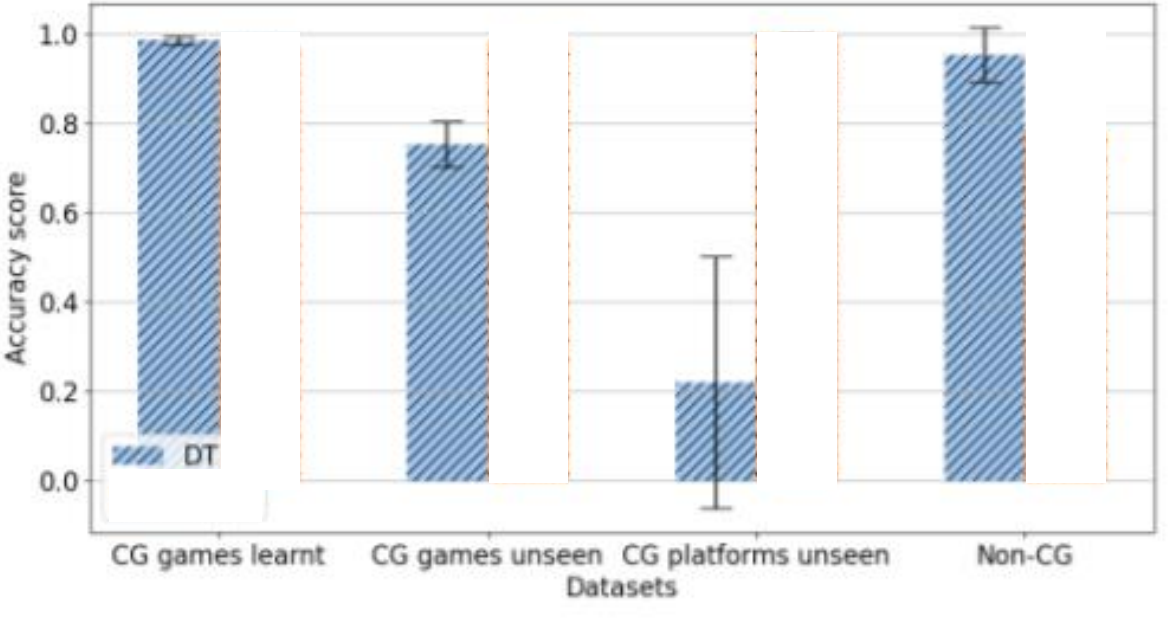
- Mean packet size
- Average Inter Arrival Times (IAT)
- Total number of packets
- Standard deviation of packet size
- Standard deviation of IATs
- Total size of application data

12 network traffic features (computed for uplink and downlink traffic) for a window traffic of 33ms

3. ML-based CG Traffic Detection

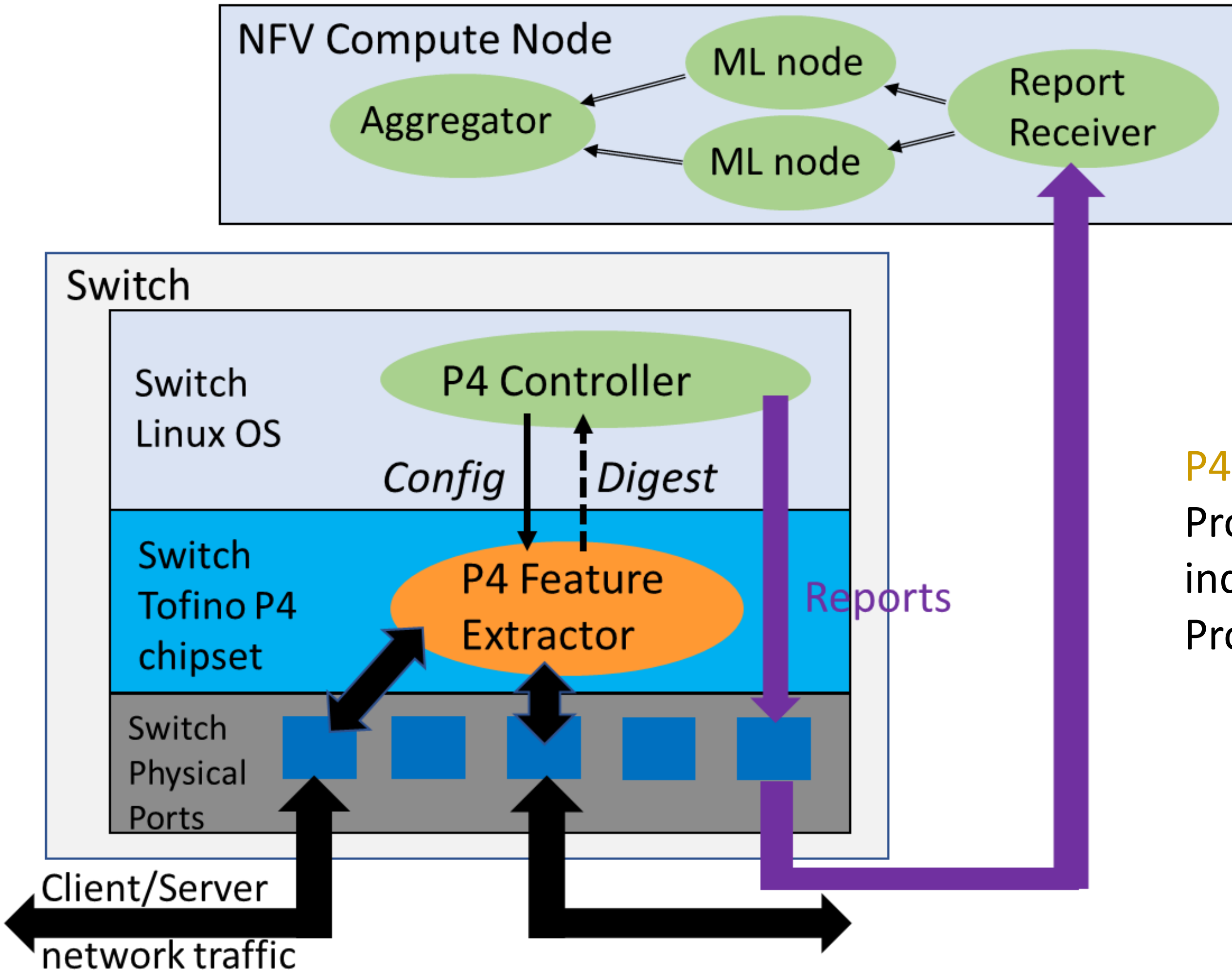
- ML models:
  - DT (Decision Tree): CG traffic on normal conditions and NCG traffic (with labels)
  - USAD (UnSupervised Anomaly Detection): CG traffic on normal conditions only (without labels) [Audibert et al.]:

- ML models Performance:



4. Hybrid P4/NFV Architecture

- 1 hardware P4 switch, 1 NFV compute node



P4: Programming Protocol-independent Packet Processors)

5. Evaluation

- Accuracy & F1-score for all traffic

Traffic	Type	Performance with P4 Accuracy	Performance with P4 F1	Performance with application Accuracy	Performance with application F1	Difference (%) Accuracy	Difference (%) F1
Normal CG	**STD**	0.965	0.983	0.984	0.992	-1.90	-0.97
	GFN	0.990	0.995	0.979	0.989	1.16	0.58
	XC	0.903	0.942	0.966	0.981	-6.35	-3.85
	PSN	0.981	0.990	0.966	0.983	1.46	0.76
	Overall	**0.958 (±0.054)**	**0.979 (±0.03)**	**0.973 (±0.021)**	**0.986 (±0.011)**	**-1.44**	**-0.74**
CG with network constraints	**STD**	0.999	0.999	1.000	1.000	-0.01	-0.01
	XC	0.954	0.977	0.992	0.996	3.33	1.55
	PSN	0.995	0.998	0.961	0.983	-3.73	-1.91
	Overall	**0.983 (±0.035)**	**0.993 (±0.019)**	**0.984 (±0.019)**	**0.992 (±0.010)**	**-0.14**	**0.05**
Non CG	**VC**	0.938	0.971	0.867	0.941	7.18	3.00
	LV	0.980	0.990	0.978	0.989	0.17	0.10
	VS	0.993	0.996	0.991	0.996	0.14	0.01
	FB	0.988	0.994	0.989	0.995	-0.10	-0.04
	Overall	**0.959 (±0.056)**	**0.983 (±0.031)**	**0.918 (±0.114)**	**0.970 (±0.066)**	**4.13**	**1.30**
New games CG learned platforms	**GFN**	0.973	0.986	0.995	0.997	-2.15	-1.10
	XC	0.969	0.984	0.979	0.989	-0.97	-0.50
	PSN	0.980	0.990	0.999	1.000	-1.97	-1.00
	Overall	**0.974 (±0.010)**	**0.987 (±0.005)**	**0.991 (±0.011)**	**0.996 (±0.006)**	**-1.70**	**-0.84**
New CG platforms	**MoonLight**	0.999	0.999	1.00	1.00	-0.01	-0.01
	Steam	0.999	0.999	1.00	1.00	-0.01	-0.01
	Overall	**0.999 (±0.00)**	**0.999 (±0.00)**	**1.00 (±0.00)**	**1.00 (±0.00)**	**-0.01**	**-0.01**

6. P4 Limitations

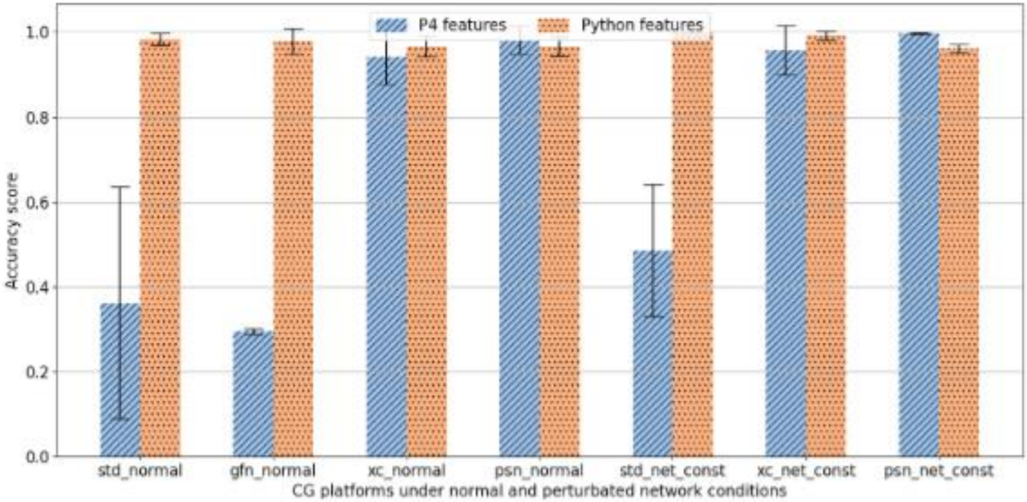
- Limited computation capabilities due to:
  - Limited number of operations
  - Variable multiplication/division limited => Standard deviation can not be computed

- Not a packet buffering/copying capability in P4
  - => Impossible to keep in memory packet features value to compute standard deviation

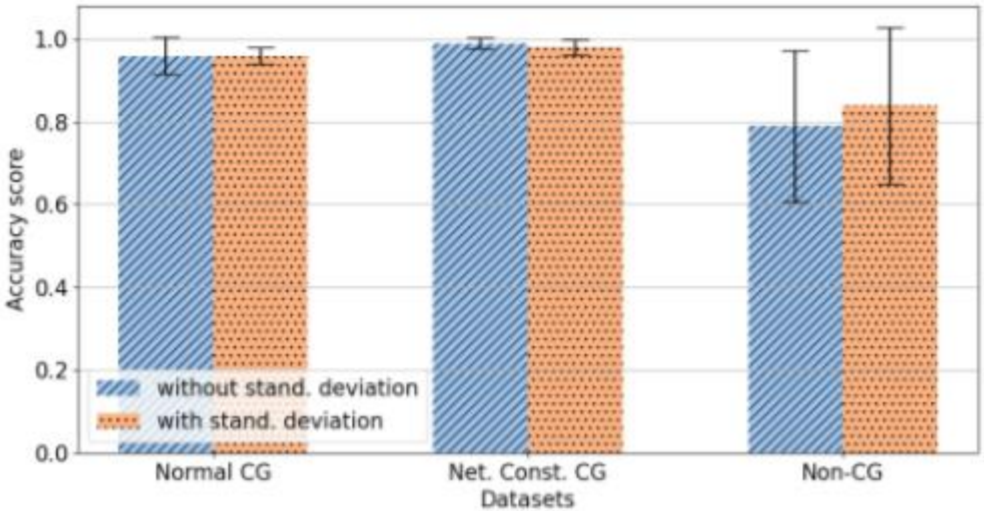
- Processing trigger upon packet arrival
  - => Reports are not sent exactly each 33ms because there is no timer
  - If sporadic traffic, empty reports need to be send to acknowledge the lack of traffic

6. P4 Limitations

- Standard deviation approximation with previous mean value.



- Remove standard deviation from ML features



7. Conclusion

- CG traffic detection implementation on P4 hardware module demonstrates excellent performance.
- Lessons learned from P4 hardware implementation:
  - P4 not suitable for handling complex computational tasks.
  - Time event-based programs are not ideal for P4.
  - Code optimization is required with P4

- Trade-off between high-speed line-rate packet processing and ease of programming.
- Hybrid P4/NFV architecture is a promising approach to efficiently split processing tasks.

- Evaluation of the solution with operational traffic from network operators will be considered in future work.

Thank you

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https://www.mosaico-project.org/

https://github.com/mosaico-anr/P4_NFV_CG_Detector

8. References

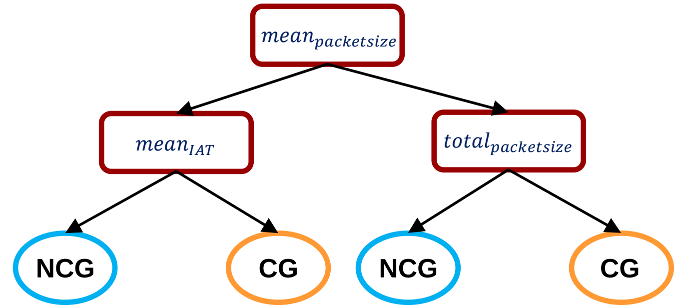
- [Graff et al.]: Philippe Graff, Xavier Marchal, Thibault Cholez, Bertrand Mathieu, Olivier Festor. Efficient Identification of Cloud Gaming Traffic at the Edge. NOMS 2023 - 36th IEEE/IFIP Network Operations and Management Symposium, May 2023, Miami, United States. pp.10.

- [Audibert et al.]: Julien Audibert, Pietro Michiardi, Frédéric Guyard, Sébastien Marti, and Maria A. Zuluaga. 2020. USAD: UnSupervised Anomaly Detection on Multivariate Time Series. In Proceedings of the 26th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD '20). Association for Computing Machinery, New York, NY, USA, 3395–3404.

Appendix

A-1. ML Models

- Decision Tree (DT):



- UnSupervised Anomaly Detection (USAD) [Audibert et al.]: