Minerva: Automated Hardware Optimization Tool

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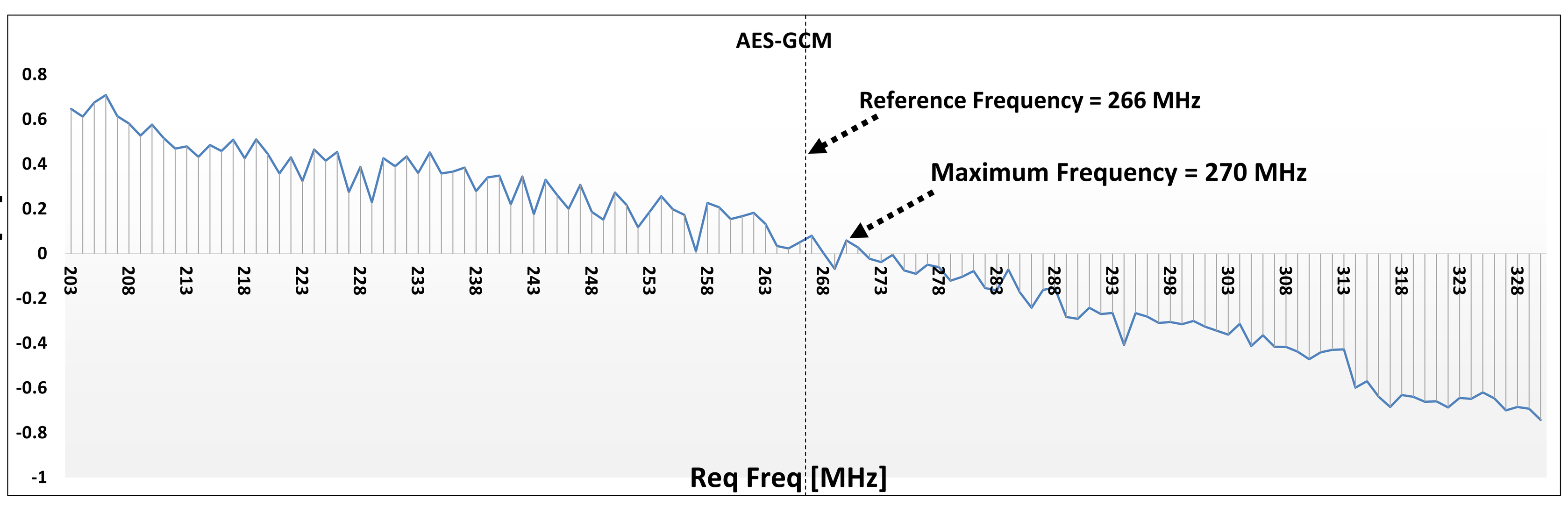
INTRODUCTION

- **Static timing analysis** provided by CAD toolsets let us determine the maximum clock frequency of the digital system.
- Finding the actual **maximum clock frequency** is difficult, especially in Xilinx Vivado, due to the multitude of tool options, and a complex dependence between the requested clock frequency and the actual clock frequency achieved by the tool.
- In this research, we introduce an **automated hardware optimization tool** that determines the close-to-optimal settings of tools, using static timing analysis and a heuristic algorithm developed by the authors.
- We evaluate RTL designs of 29 Round 2 CAESAR candidates and the current standard, AES-GCM, in terms of throughput and TPA ratio. Compared to a binary search for maximum frequency, our results **demonstrate up to 25% improvement in terms of throughput, and up to 38% improvement in terms of TPA ratio**.

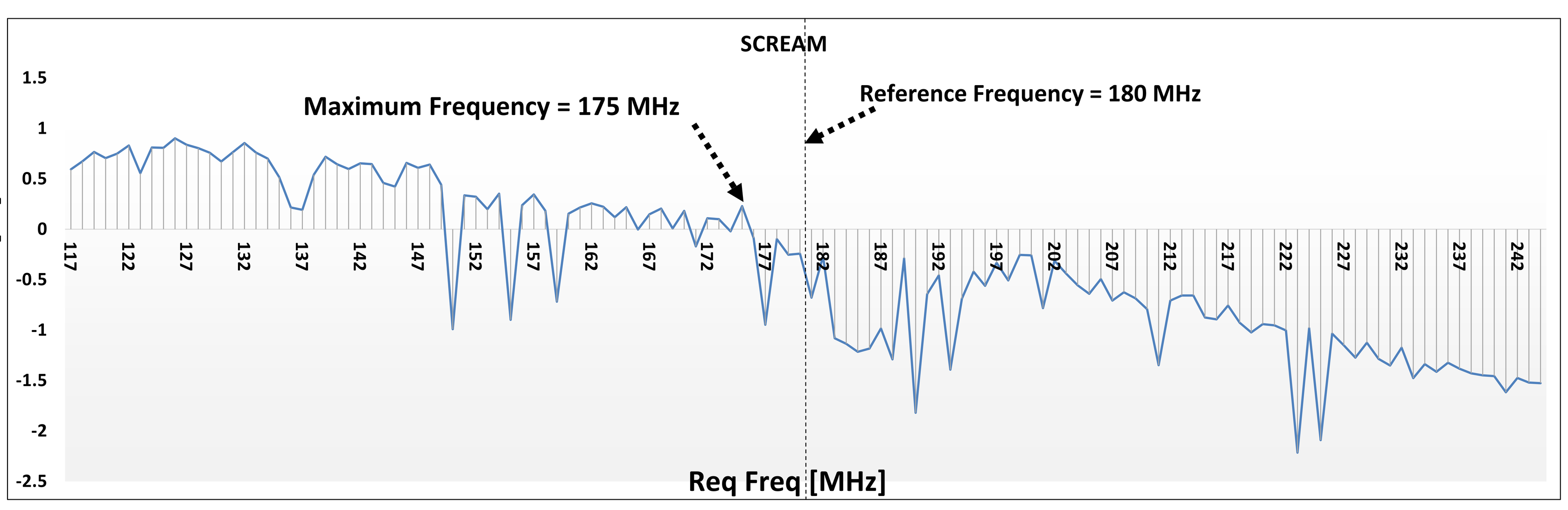
VIVADO EVALUATION: Dependence of the WNS on the Requested Clock Frequency

1. WNS: Worst Negative Slack.
2. Req Freq: Requested Clock Frequency.

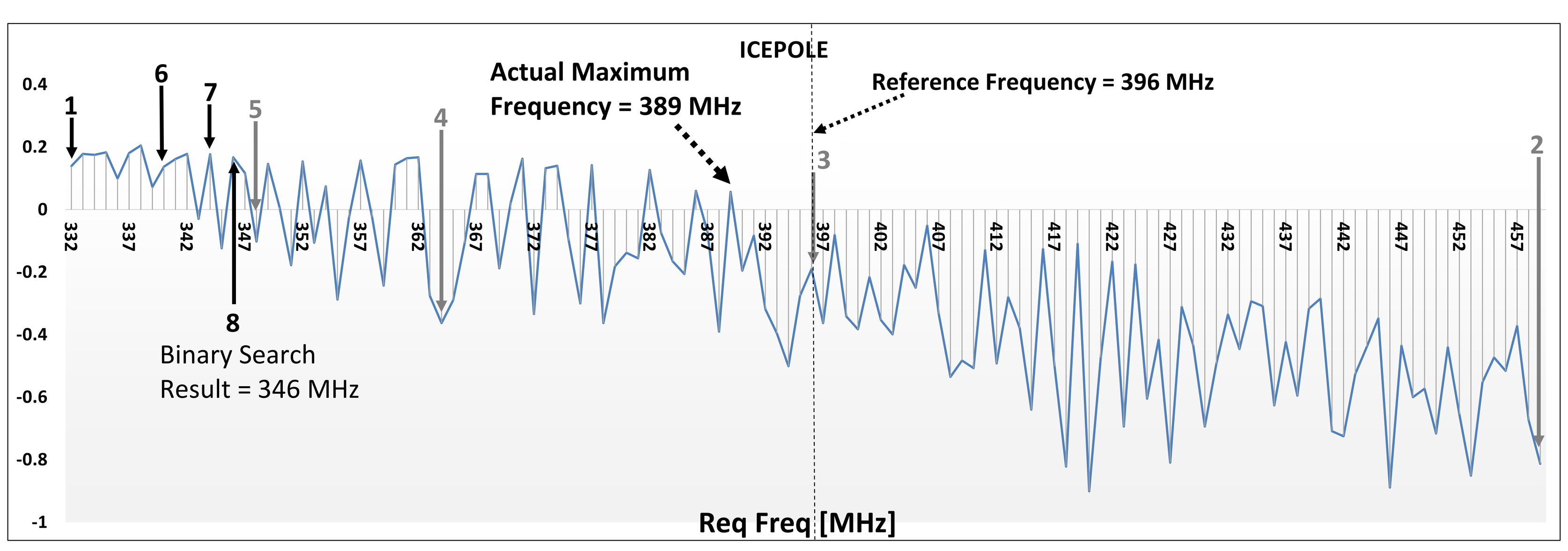
- **High-speed implementation of AES-GCM:**



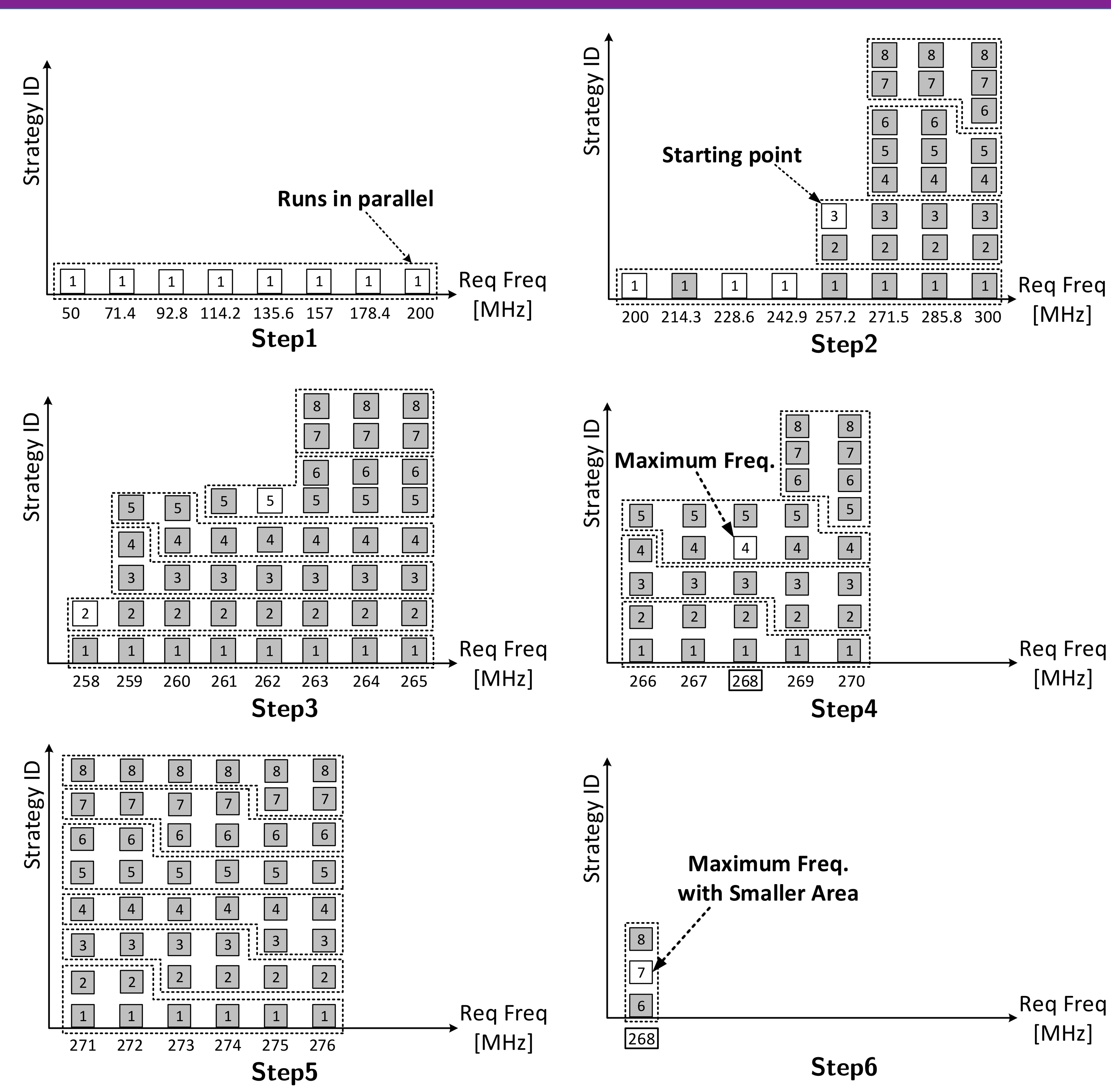
- **High-speed implementation of SCREAM:**



- **High-speed implementation of ICEPOLE:**

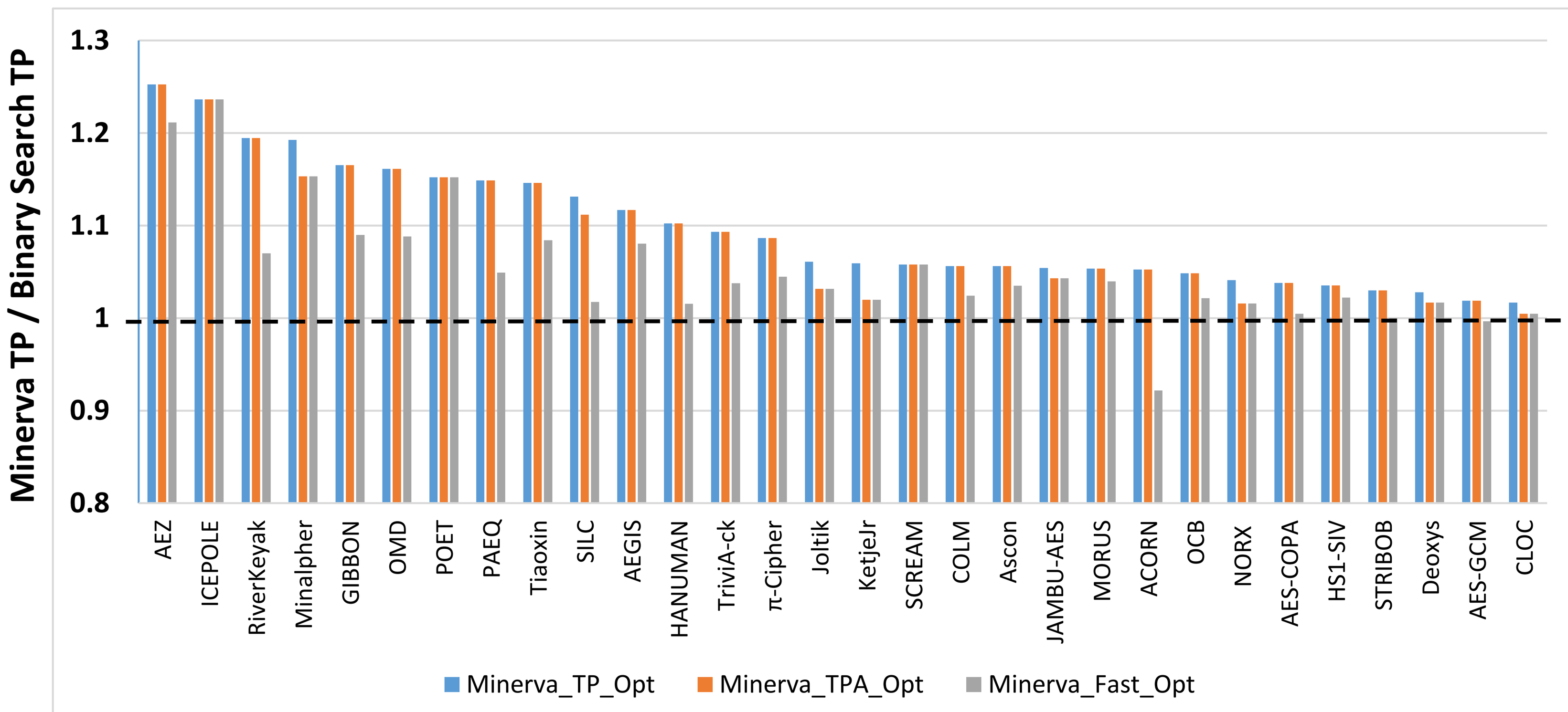


ENVIRONMENT: Graphical Representation of Minerva Frequency Search Algorithm

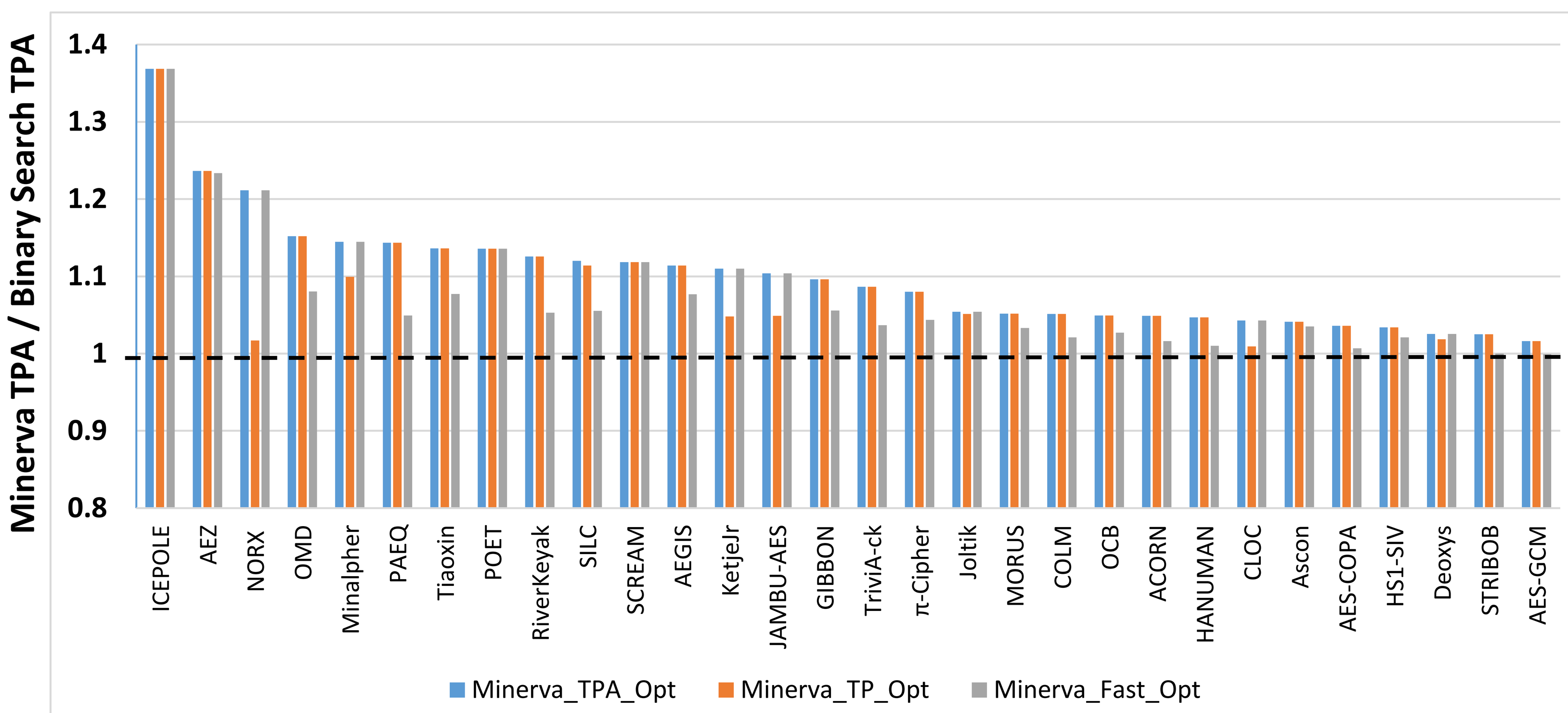


RESULTS: Minerva vs. Binary Search

- **Ratios of Minerva TP / Binary Search TP for three modes of Minerva frequency search, and 30 authenticated ciphers. Notation: TP - Throughput**

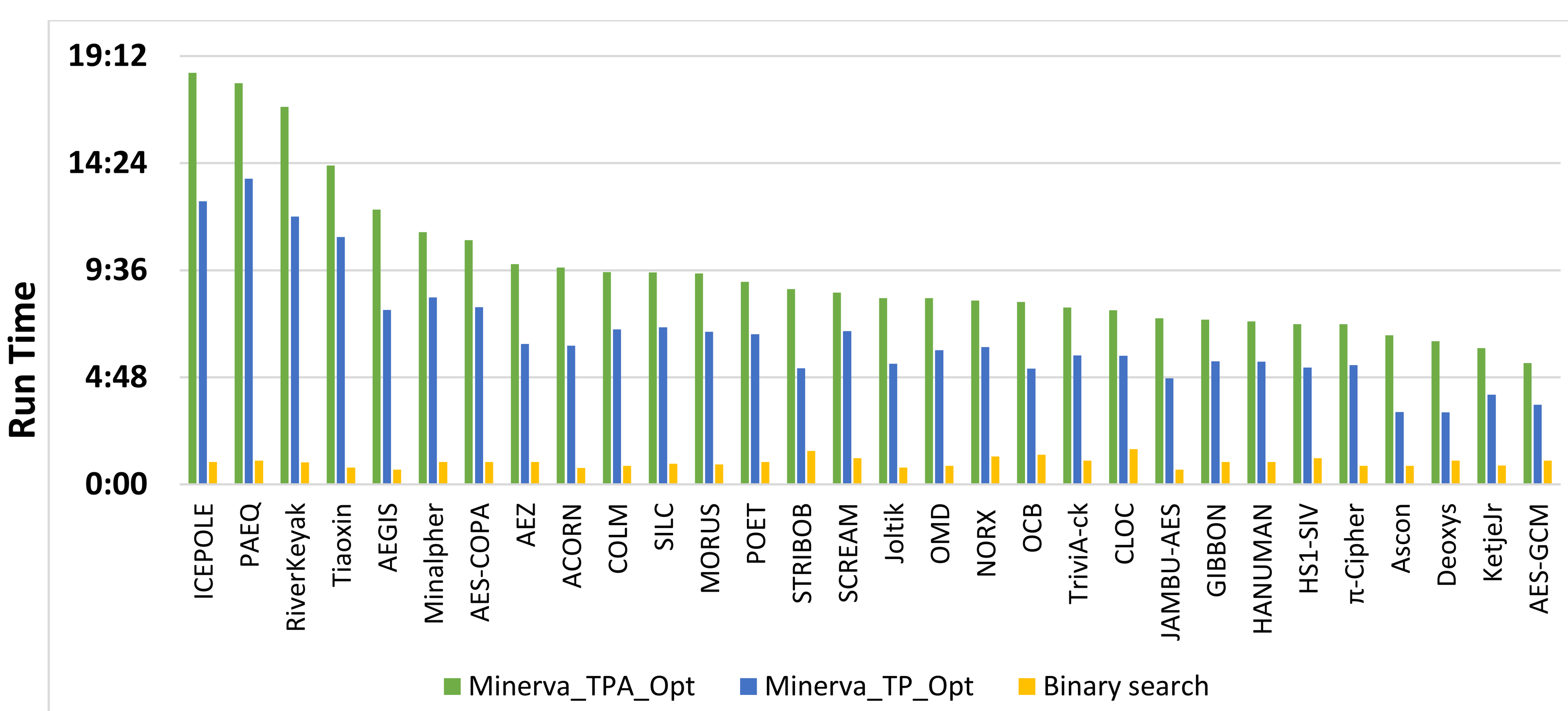


- **Ratios of Minerva TPA / Binary Search TPA for three modes of Minerva frequency search, and 30 authenticated ciphers. Notation: TPA - Throughput/Area ratio**

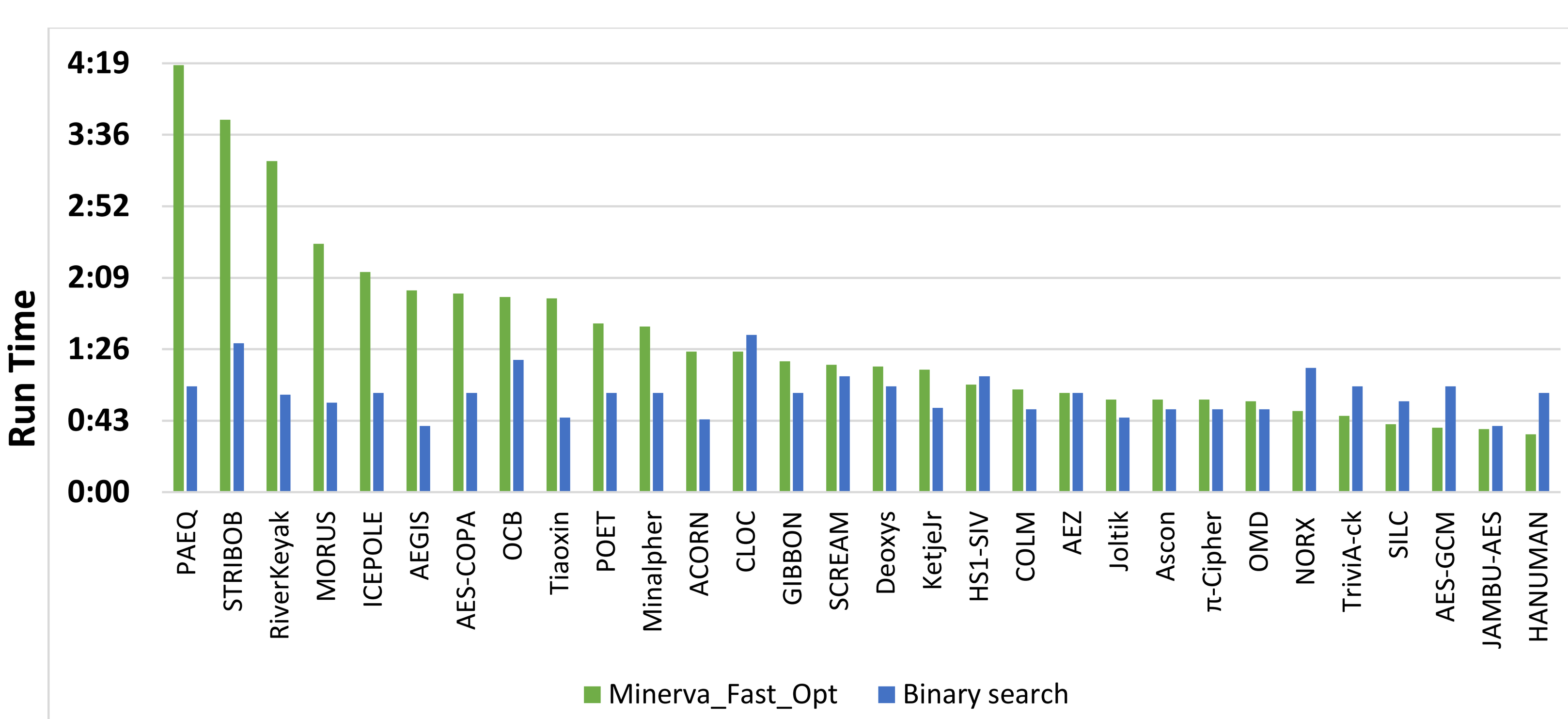


RESULTS: Run Time

- **Run time comparison of Minerva TP, Minerva TPA and binary search for 29 Round 2 CAESAR candidates and AES-GCM**



- **Run time comparison of Minerva Fast and binary search for 29 Round 2 CAESAR candidates and AES-GCM**



CONCLUSIONS

- Minerva searches for the **best requested clock frequency** and the **best set of tool options**, leading to the highest clock frequency, or the highest frequency to area ratio.
- It can apply an arbitrary number of **preselected tool option sets** and combine them with a frequency search in order to achieve the best results.
- The results for **30 authenticated ciphers** indicate that we can achieve up to **38% improvement in** terms of the **TPA ratio** in comparison to a simpler binary search.
- The average run time for the *Minerva_TP*, and *Minerva_TPA* modes is over 6 and 9 times longer than binary search, respectively. However, *Minerva_Fast* has an execution time equal to binary search, and produces acceptable results.

Minerva source code and user's manual are available for free at:
https://cryptography.gmu.edu/athena/index.php?id=Minerva

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