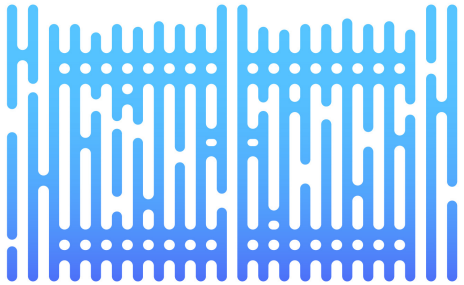

OpenFHE

OpenFHE: Open-Source Fully Homomorphic Encryption Library

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OPENFHE DESIGN PRINCIPLES

- OpenFHE, a new open-source C++17 FHE software library that incorporates selected design ideas from prior FHE projects, including **PALISADE**, **HElib**, **HEAAN**, and **FHEW**, and includes several new design concepts and ideas.
- The main new design features can be summarized as follows:
  - From the **cryptography** perspective, we assume from the very beginning that all implemented FHE schemes will support **bootstrapping** and **scheme switching**
    - Common features are used by the implementation, for example, the key switching implementation is shared by multiple SIMD schemes
  - From the **performance** perspective, OpenFHE supports multiple hardware acceleration backends using a standard **Hardware Abstraction Layer** (HAL)
  - From the **usability** perspective, OpenFHE includes both
    - **user-friendly modes**, where all maintenance operations, such as modulus switching, key switching, and bootstrapping, are automatically invoked by the library, and
    - **compiler-friendly modes**, where an external compiler makes these decisions

CRYPTOGRAPHIC CAPABILITIES

- OpenFHE includes efficient implementations of all common FHE schemes:
  - Brakerski/Fan-Vercauteren (BFV) scheme for integer arithmetic
  - Brakerski-Gentry-Vaikuntanathan (BGV) scheme for integer arithmetic
  - Cheon-Kim-Kim-Song (CKKS) scheme for real-number arithmetic
    - with approximate bootstrapping
  - Ducas-Micciancio (DM/FHEW) and Chillotti-Gama-Georgieva-Izabachene (CGGI/TFHE) schemes for Boolean circuit evaluation
    - with arbitrary-function evaluation for larger plaintext moduli
- OpenFHE also includes the following multiparty extensions of FHE:
  - Threshold FHE for BGV, BFV, and CKKS schemes
  - Proxy Re-Encryption (PRE) for BGV, BFV, and CKKS schemes

KEY FACTS ABOUT OPENFHE

- Preview release (v0.9) launched on July 19, 2022
  - A stable version (v1.0) will be available later this fall
- Designed by (some of) authors of PALISADE, HElib, HEAAN, and FHEW libraries
- Official successor of PALISADE
- Complies with the HomomorphicEncryption.org post-quantum security standards for homomorphic encryption
- We offer OpenFHE under the 2-clause BSD open-source license, making it easier to wrap and redistribute OpenFHE in products
- Generously supported by DARPA
- A community-driven open-source project developed by a diverse group of contributors from both industry and academia, including Duality, Samsung, Intel, MIT, UCSD, and others
- Google Transpiler uses the CGGI (TFHE) implementation as the FHE backend
- OpenFHE is formally affiliated with the NumFocus stable of open-source software projects

DESIGN PAPER [https://eprint.iacr.org/2022/915]

Paper 2022/915

OpenFHE: Open-Source Fully Homomorphic Encryption Library

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OpenFHE

SCHEME SUPPORT MATRIX

Library/ Scheme or Extension	BGV	BGV Bootstr.	BFV	CKKS	CKKS Bootstr.	DM	CGGI	Threshold FHE (MP)	PRE (MP)
Concrete							✓		
FHEW						✓			
HEAAN				✓	✓				
HELib	✓	✓		✓					
Lattigo			✓	✓	✓			✓	
OpenFHE	✓	*	✓	✓	✓	✓	✓	✓	✓
PALISADE	✓		✓	✓		✓	✓	✓	✓
SEAL	✓		✓	✓					
TFHE							✓		

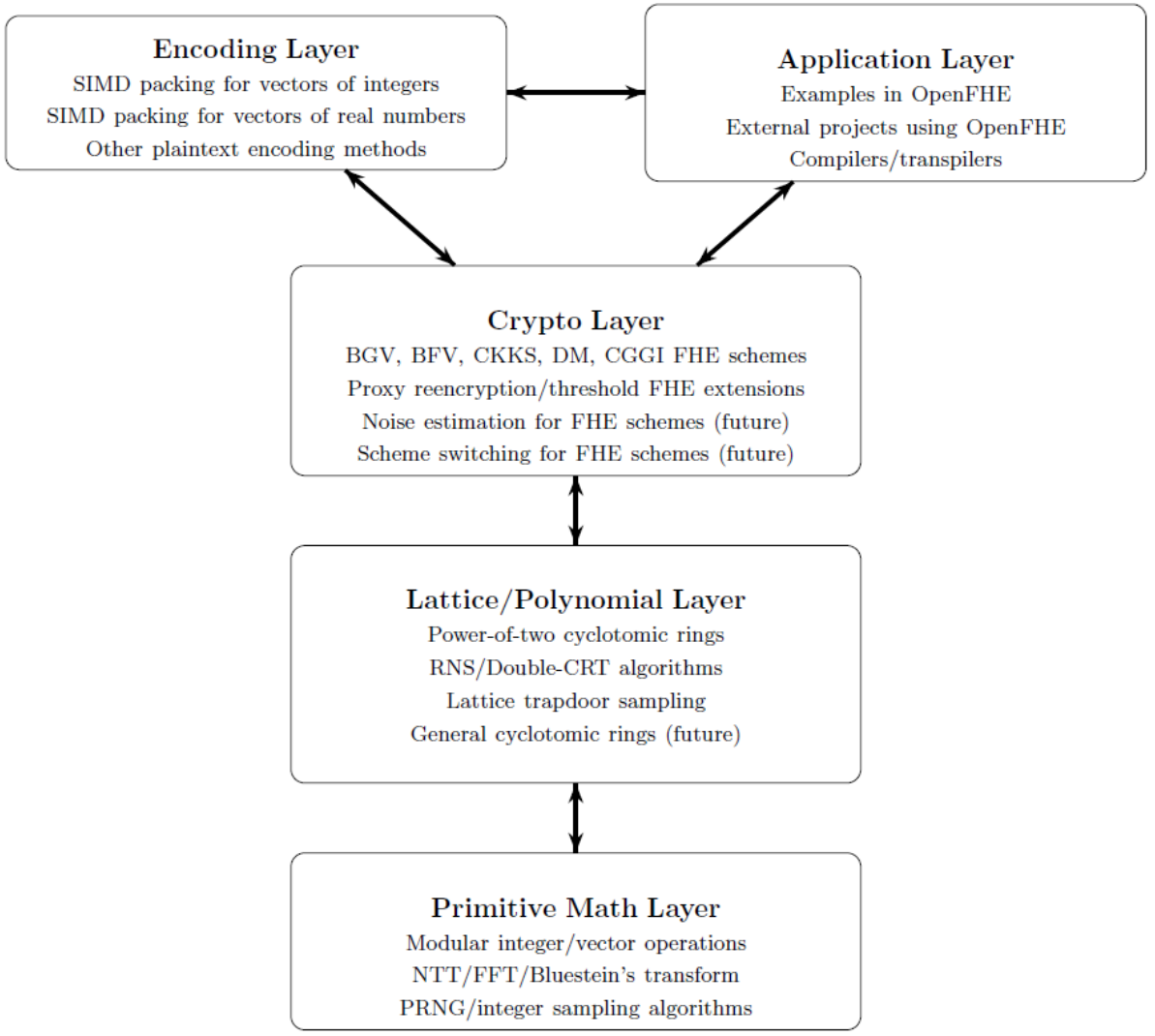
* - prototype exists, but not part of release

SUMMARY OF NEW FEATURES IN OPENFHE

Includes all prior FHE functionality of PALISADE. Also adds the following new features:

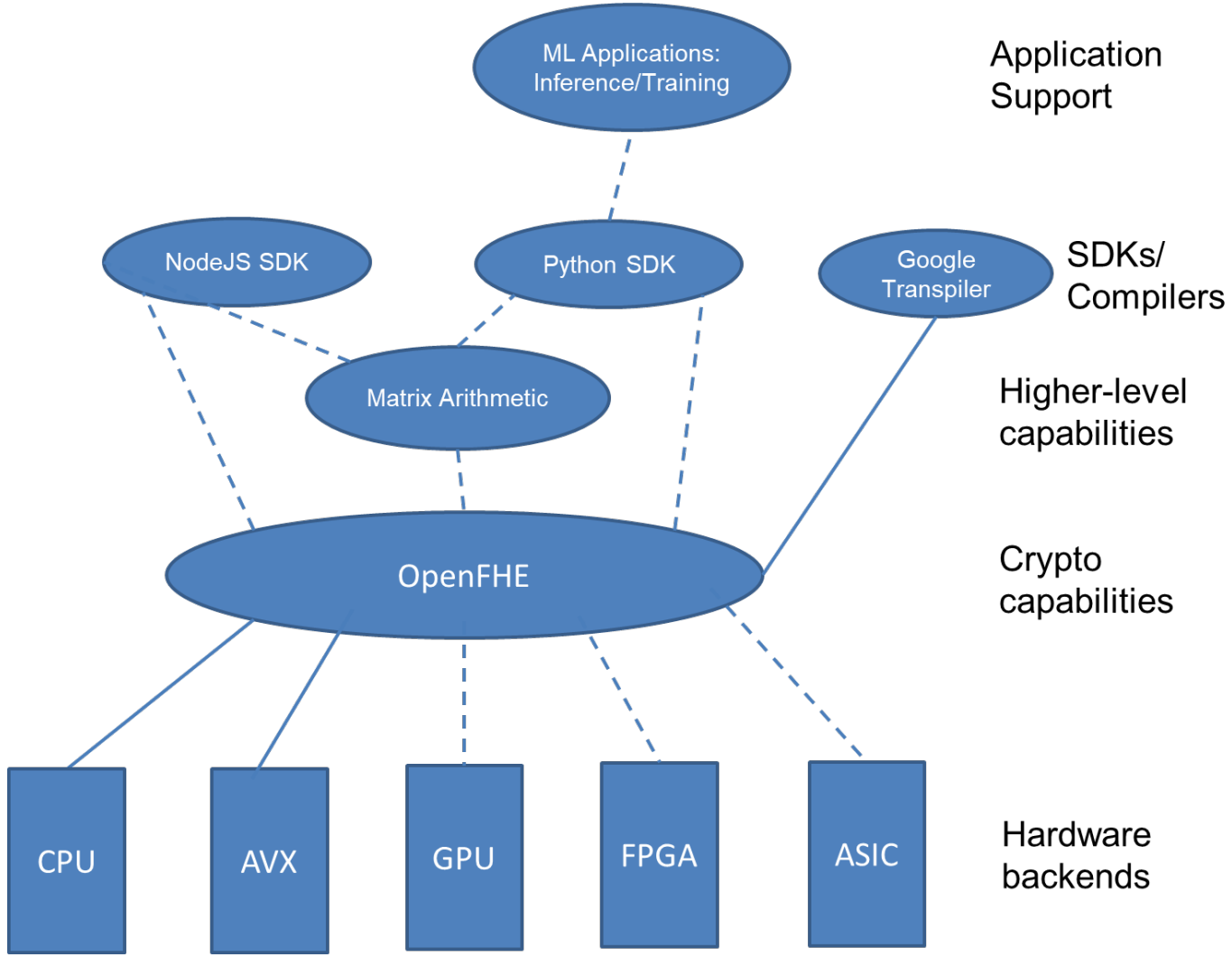
- New BGV and BFV RNS variants proposed in https://eprint.iacr.org/2021/204
- A new CKKS RNS variant proposed in https://eprint.iacr.org/2020/1118
- A full RNS implementation of CKKS bootstrapping (important for deep learning!)
- Large-precision comparison and other algorithms based on functional bootstrapping, which are proposed in https://eprint.iacr.org/2021/1337
- Adds support for multiple hardware acceleration backends using a Hardware Abstraction Layer feature
  - Intel HEXL library implemented as a backend for CPUs with AVX-512 extensions

LAYERS IN OPENFHE (CONTRIBUTOR VIEW)



OpenFHE

BROADER OPENFHE COMMUNITY (USER VIEW)



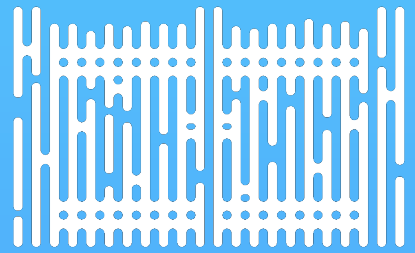
OpenFHE

OPENFHE VISION FOR MACHINE LEARNING (ML) USING FHE

- The main ML focus is on
  - Approximate method based on CKKS
  - Hybrid approximate/LUT approach based on CKKS and DM (FHEW) /CGGI (TFHE)
- Features that are already available in OpenFHE
  - CKKS bootstrapping to support deep learning
  - Large-precision comparison and small-precision LUT evaluation
- Features under development
  - A prototype of scheme switching from CKKS to/from DM/CGGI already exists, and this feature is expected to be available in OpenFHE shortly after the first stable release
  - Matrix arithmetic library
  - Python SDK
  - NodeJS SDK

MAIN RESOURCES AND LINKS FOR OPENFHE

- OpenFHE design paper: https://eprint.iacr.org/2022/915
- OpenFHE website: https://openfhe.org
- ReadTheDocs documentation for OpenFHE: https://openfhe-development.readthedocs.io/en/latest/
- OpenFHE development repository: https://github.com/openfheorg/openfhe-development
- OpenFHE github organization where various OpenFHE-dependent projects are housed: https://github.com/openfheorg
- Community Forum for OpenFHE: https://openfhe.discourse.group/



THANK YOU

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