
CORNAMI®
Intelligent Computing
Full Circuit FHE Acceleration on Cornami Fabric
Dr. Vineet Chadha
FHE Engineering, Cornami

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Agenda

- The FHE Problem Statement
- Cornami FHE Solution
- Cornami Architecture Overview
- Secure Computing Interface Framework (SCIFR API™)
- Summary and Future Directions

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Fully Homomorphic Encryption

- Fully Homomorphic Encryption (FHE) is de-facto solution to secure the in-use data in an untrusted environment
  - Data, once encrypted, need not be decrypted for processing
  - Data can be decrypted with a private key in a trusted environment for viewing

- **Problem Statement:** The challenge of FHE is that it requires 10^6 greater performance than x86 and conventional processors
  - Performance gap between encrypted data vs unencrypted data processing

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Fully Homomorphic Encryption

- Today's monolithic processors have bounded limits and **do not scale** in computational performance and/or I/O bandwidth. They also are inefficient in power use.

- A typical FHE application would require racks of computers in datacenter with the workload running for days

The Fully Homomorphic Encryption Solution

- Requires an execution platform that can:
  - Seamlessly address the multiple security guarantees for an FHE Application
  - Scale up or scale down system resources such as computational performance, I/O bandwidth, and storage
  - Scale up or scale down FHE configuration parameters
  - Process arbitrary precision arithmetic as required by FHE applications
  - Configure resources on a per application basis **on-demand**

The Fully Homomorphic Encryption Solution

- **Solution:** We propose a Novel approach of TruStream® Computing – a **Non-Von Neumann Architecture** which includes:
  - A scalable fabric made up of programmable small cores on which an application developer can map dataflow parallelism and pipelining.
  - A standardized FHE API called the **S**ecure **C**omputing **I**nterface **F**ramework **(SCIFR API™)**
  - A series of control and data producer/consumer cores chained together to process the encrypted data together in coordinated fashion. This approach maps FHE algorithms dataflow into small cores chained together.

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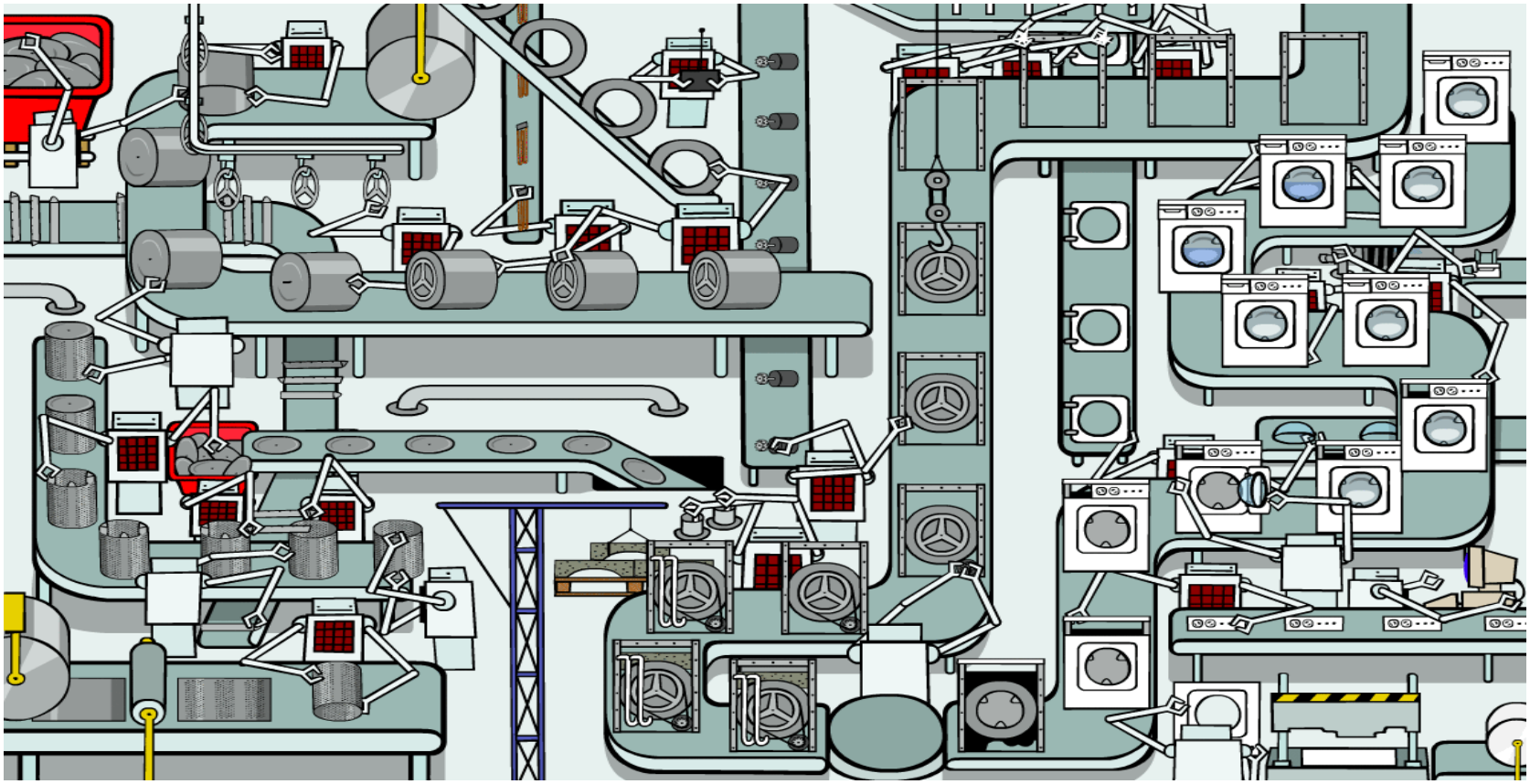
Scalable Factory for Data and Control



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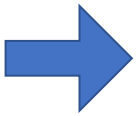
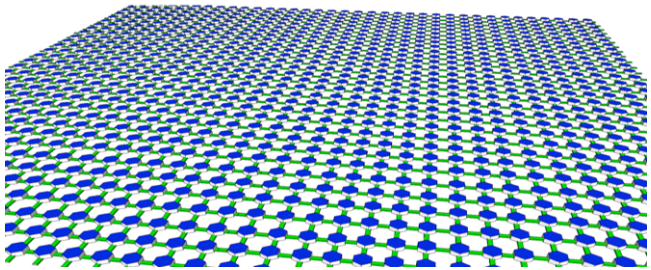
From Large Processing Units to Fabric of Small Processing Units

Today: Monolithic IC with Few Cores

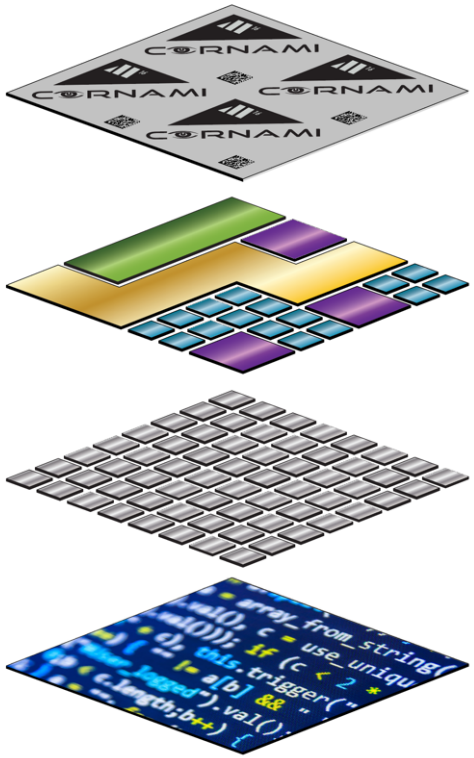




Scalable number of cores that span many ICs

- ***Why are we still limited to a single monolithic chip for workload executions ?***
  - Load, Process and Store approach is performance hog for various reasons such as context switches, multi threads, non-deterministic software stack, cache dynamics, memory bottlenecks etc.
- ***Cornami solves all these problems***
  - Deterministic, seamlessly scalable and no context switch
  - Maximize concurrency and make full use of pipelining – Scalable performance, lower latency, lower silicon footprint and lower power use

Cornami Architecture Overview



TruStream® Reconfigurable Computing Fabric

Computational Fabric

Reconfigurable cores surrounded by SRAM and all integrated by a high-speed network. Fabric is linearly scalable across multiple chips, boards and systems to increase core for performance transparent to the software model.

Software Defined Cores

Created using FracTLcores® and under software control and configured based on function, for example:

SIMD Neural Networks Signal Processing Control

FracTLcores®

Dynamically reconfigurable and independently programmable cores (each has its own scheduler) under software control to optimize performance within application programs.

TruStream®

- Software and programming environment supporting all 55 Berkeley patterns for parallelism
- Verified on numerous multi-core processors
- Large existing library of application software including Fully Homomorphic Encryption (FHE) and Privacy Preserving Machine Learning (PPML)

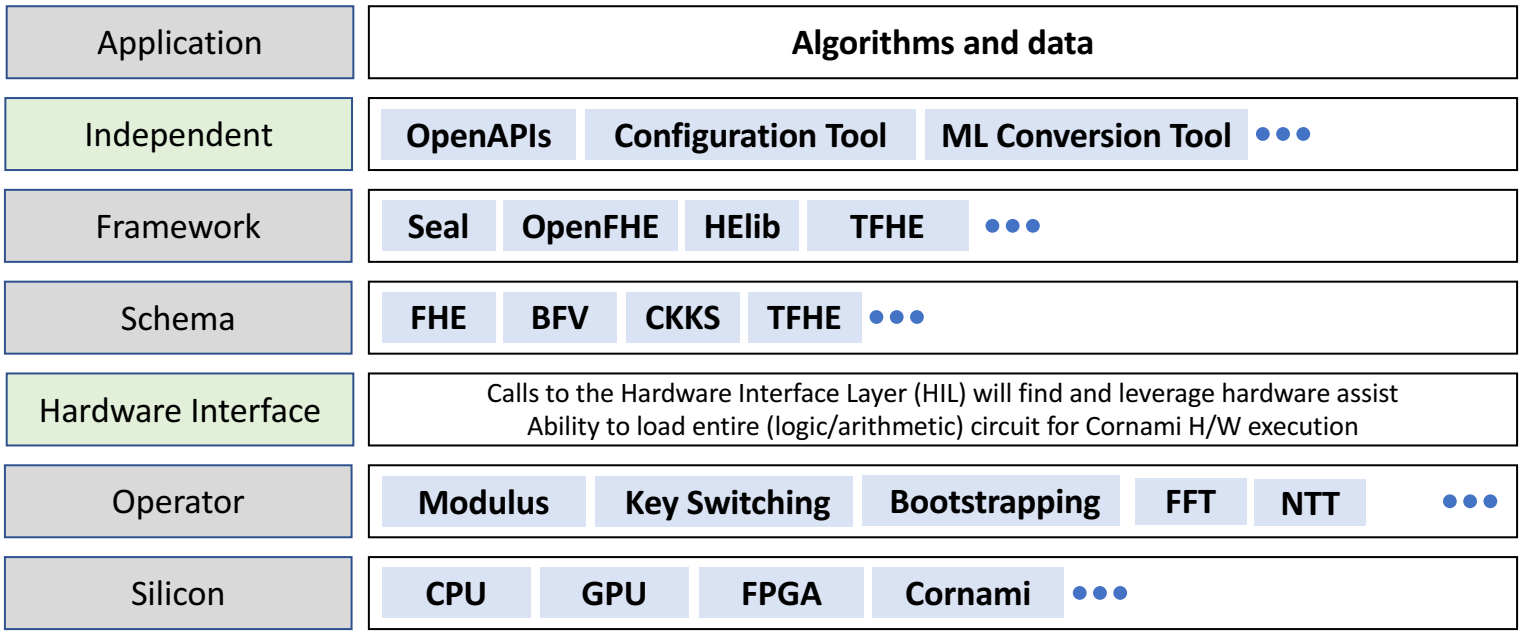
Secure Computing Interface Framework (SCIFR API™)

- To efficiently utilize and program a large number of resources in the Cornami fabric, we have developed the Secure Computing Interfacing Framework – SCIFR API™. Key features include
  - Coexist with all hardware resources such as CPU/GPU/FPGAs) including the scalable resources of a Cornami fabric.
  - Define multiple tiers of APIs for modules and operators
    - Polynomial Multiplications, Modulus, Bootstrapping, KeySwitching, NTTs, FFTs etc..
  - Enables seamless interfacing and integration with FHE Schemas and Frameworks

Secure Computing Interface Framework (SCIFR API™)

- ***Allows complete execution of FHE circuits*** on Cornami's scalable fabric.
  - Breaks free of the co-processor accelerator model by allowing an entire FHE circuit, FHE encryption, and FHE decryption to execute entirely on Cornami hardware
- Flexibility to achieve specific FHE application ***throughput, latency, footprint, and/or performance goals*** through compile time configuration
- Allows the adoption of new and emerging FHE algorithms
- Keeps FHE data movement within the Cornami scalable fabric allowing the stitching of multiple sub-topologies into a larger topology

SCIFR API™ – Abstraction Layers



Summary and Future Directions

- Cornami supports a scalable core fabric to enable FHE applications to execute at plaintext speeds.
  - Supports compile time configuration to achieve throughput, latency, footprint, and/or performance goals.
- Cornami's SCIFR API™ supports all hardware platforms and enables the execution of an entire FHE application circuit on a scalable computational fabric eliminating the need for a coprocessor approach
- Cornami's architecture is stream-based supporting a highly scalable and efficient core fabric that easily spans an arbitrary number of ICs.
- Cornami is committed to developing FHE standards and benchmarking to enable customers evaluate overall FHE circuit performance

Thank You