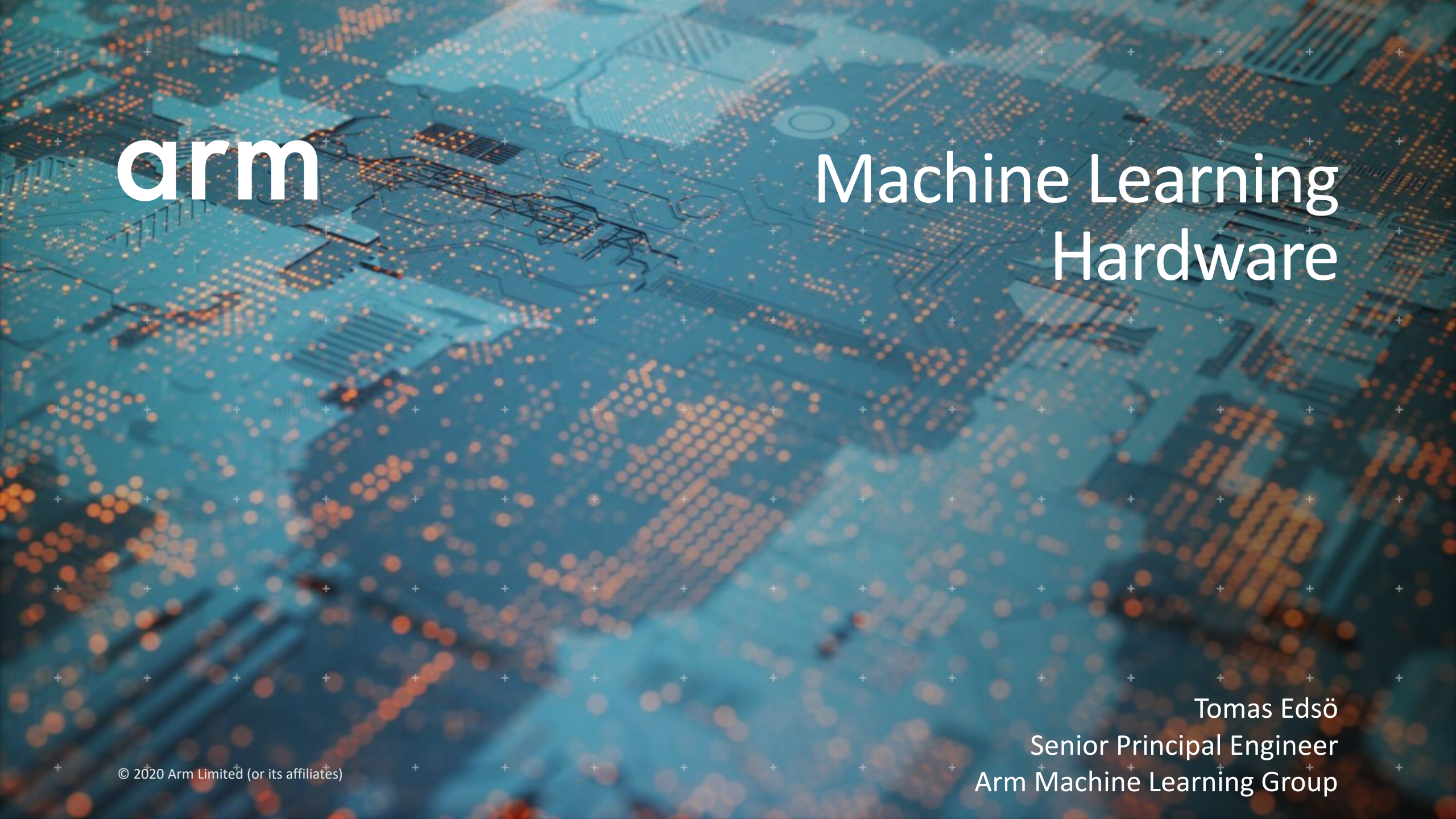

Machine Learning Hardware

Tomas Edsö
Senior Principal Engineer
Arm Machine Learning Group

What is tinyML and what is it used for?

On-device machine learning applications in the single mW and below

Vibration and motion

Any ‘signal’

Predictive maintenance, sensor fusion, accelerometer, pressure, lidar/radar, speed, shock, vibration, pollution, density, viscosity, etc.

Voice and sound

Recognition and creation

Keyword spotting, speech recognition, natural language processing, speech synthesis, sound recognition, etc.

Vision

Images and video

Object detection, face unlock, object classification etc.

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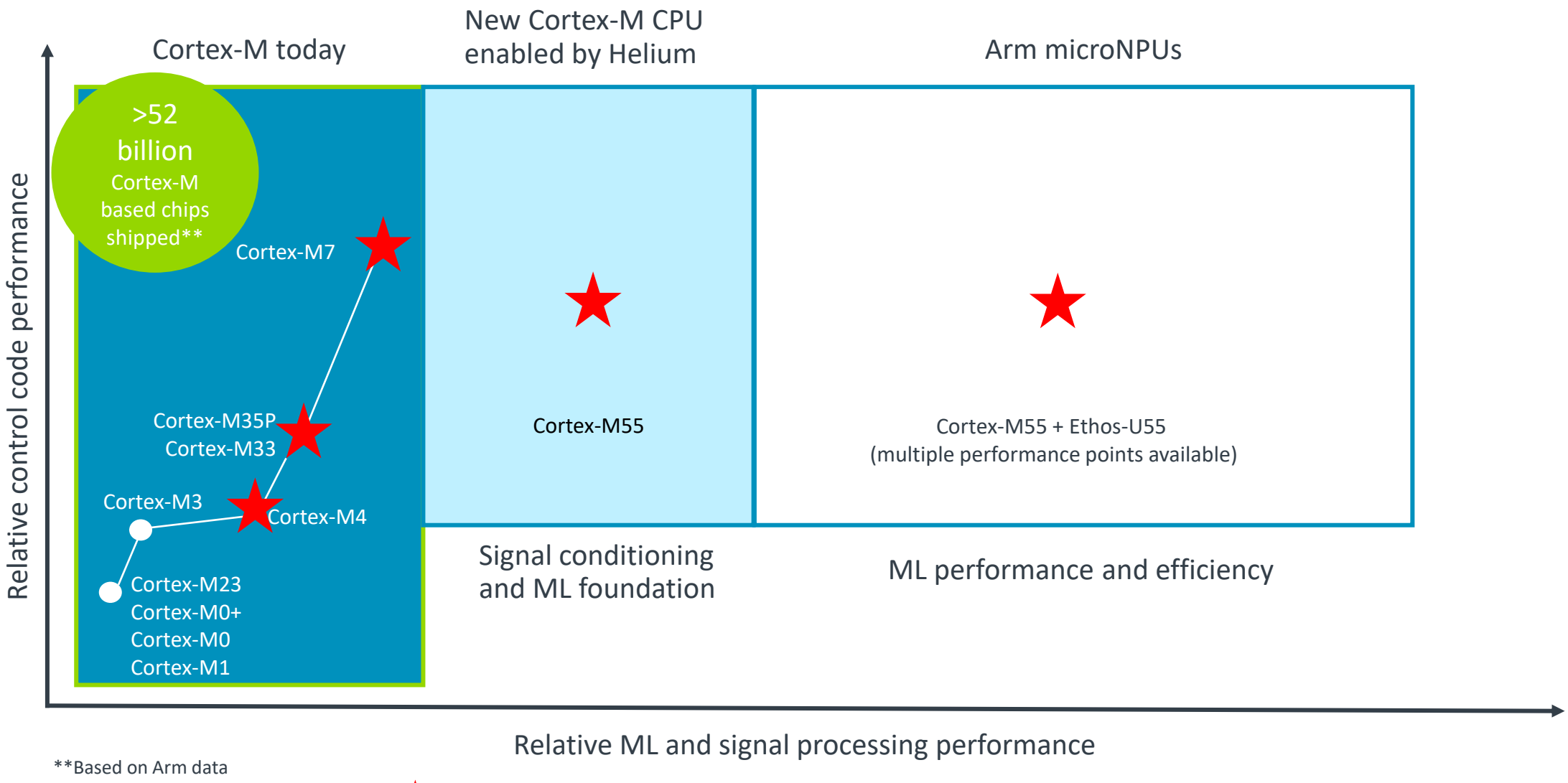
Pushing the Boundaries for Real-time On-device Processing



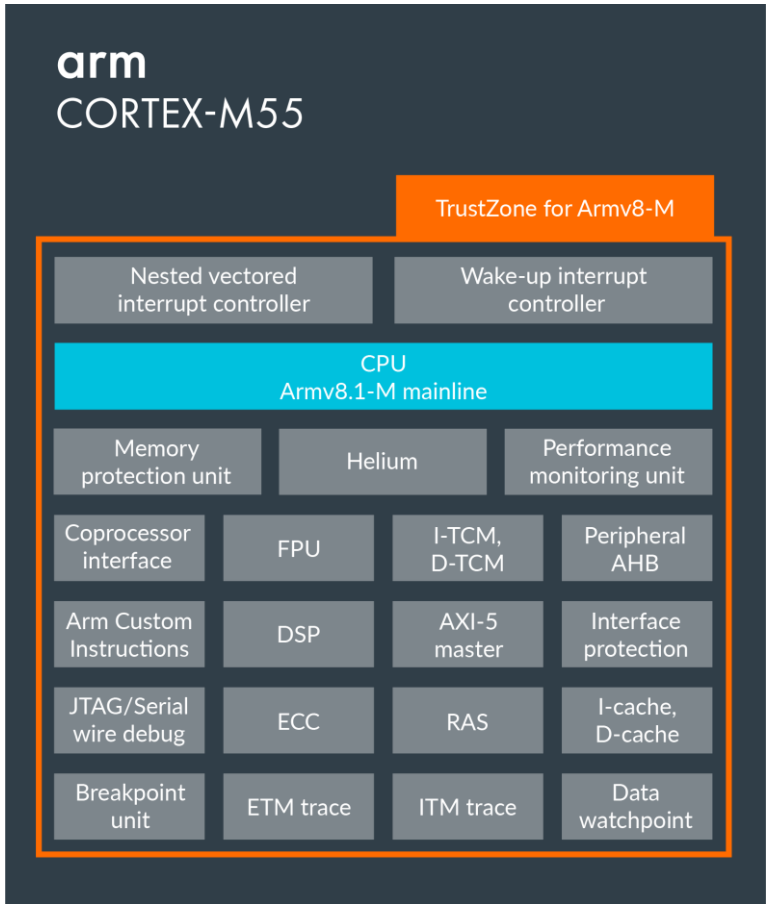
**Based on Arm data

Well suited for ML & DSP applications

Graph not to scale

Cortex-M55: The Most AI-capable Cortex-M Processor

- ✓ First CPU based on Arm Helium technology
  - Energy-efficient and configurable with vector processing capabilities
  - Delivers up to 5x DSP performance and up to 15x ML performance*
  - Versatile capability for both classical ML and NN inference
- ✓ Advanced memory interfaces for fast access to ML data and weights
- ✓ TrustZone support
- ✓ Extensive configurability



*Compared to previous Cortex-M generations

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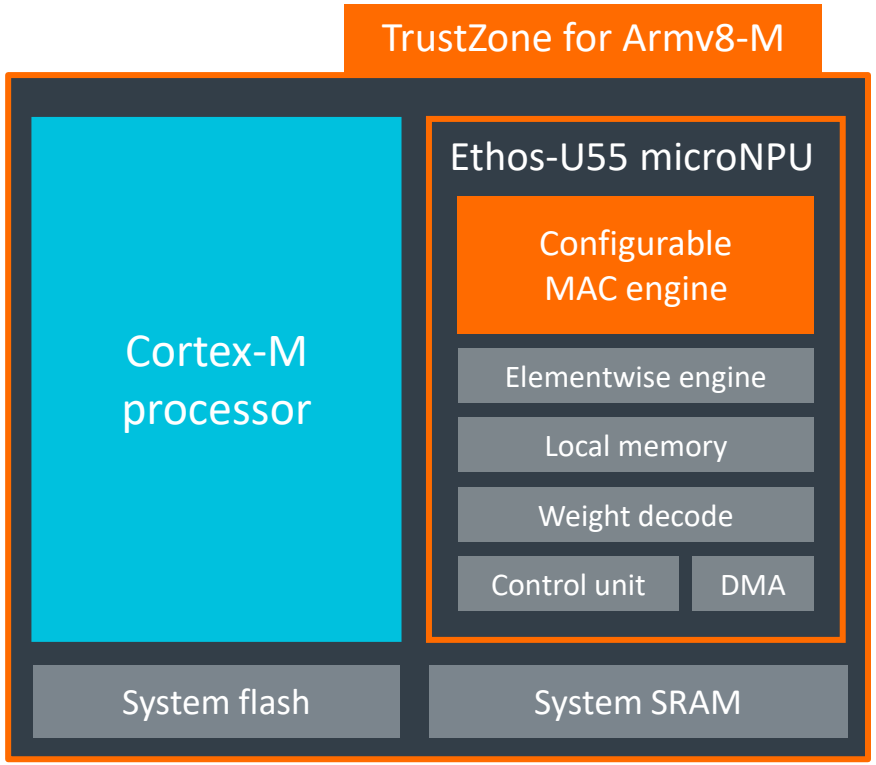
Ethos-U55: The first microNPU for Cortex-M

- ✓ Highest efficiency and small memory footprint
- ✓ 32, 64, 128, or 256 unit multiply-accumulate (MAC) engine
- ✓ Weight decoder and DMA for on-the-fly weight decompression
- ✓ Tooling available for offline optimization
- ✓ Works with a range of Cortex-M processors:
  - Cortex-M55
  - Cortex-M7
  - Cortex-M33
  - Cortex-M4



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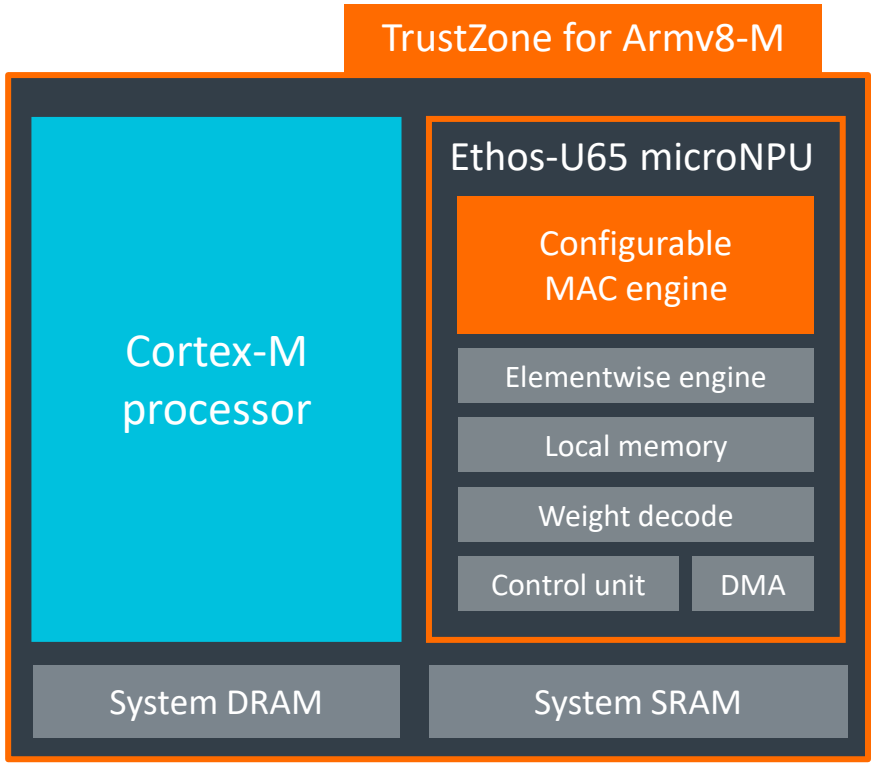
Ethos-U65: The second generation microNPU

- ✓ 256 or 512 unit multiply-accumulate (MAC) engine
- ✓ DMA update for DRAM as well as flash support
- ✓ Can be an M-class subsystem inside an A-class system



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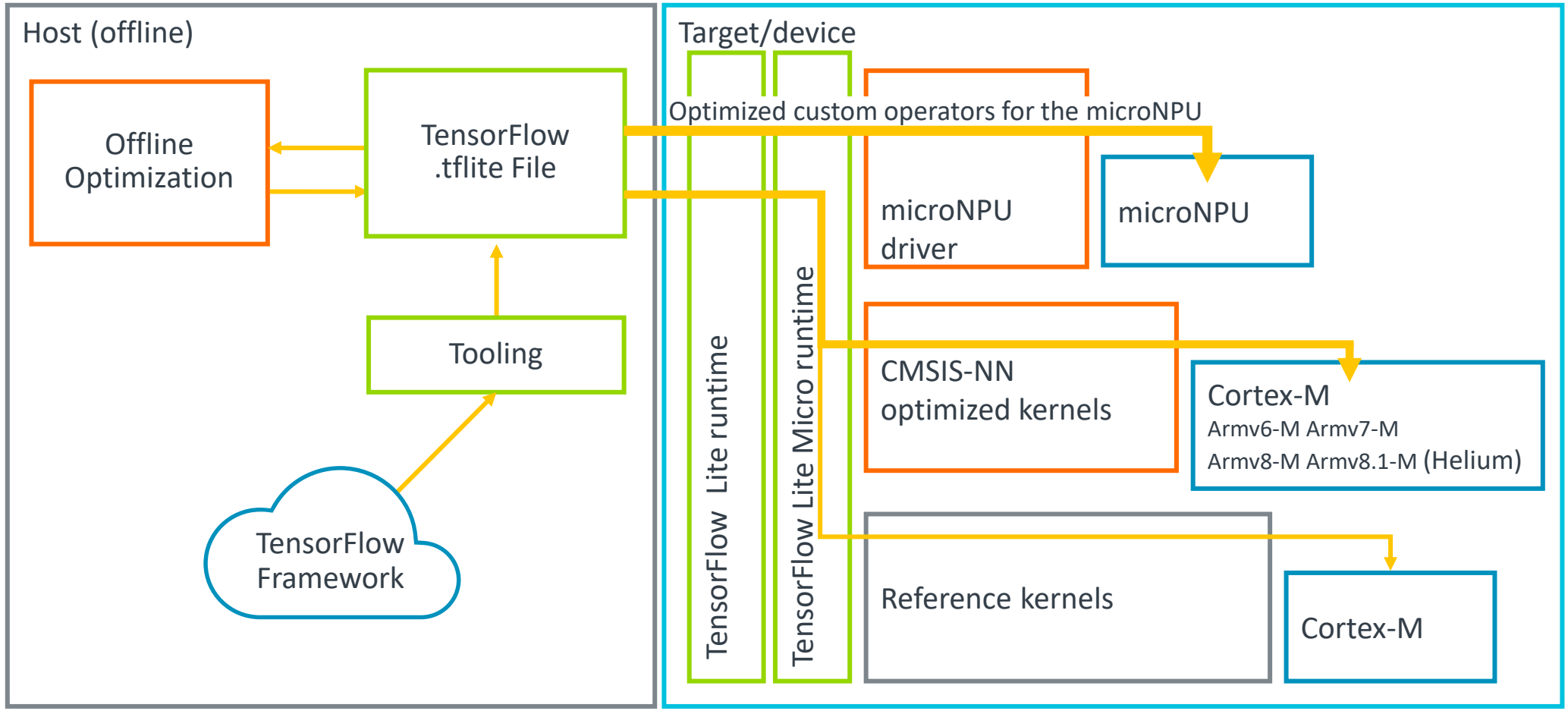
Mapping of NNs to Ethos-U using TensorFlow Lite



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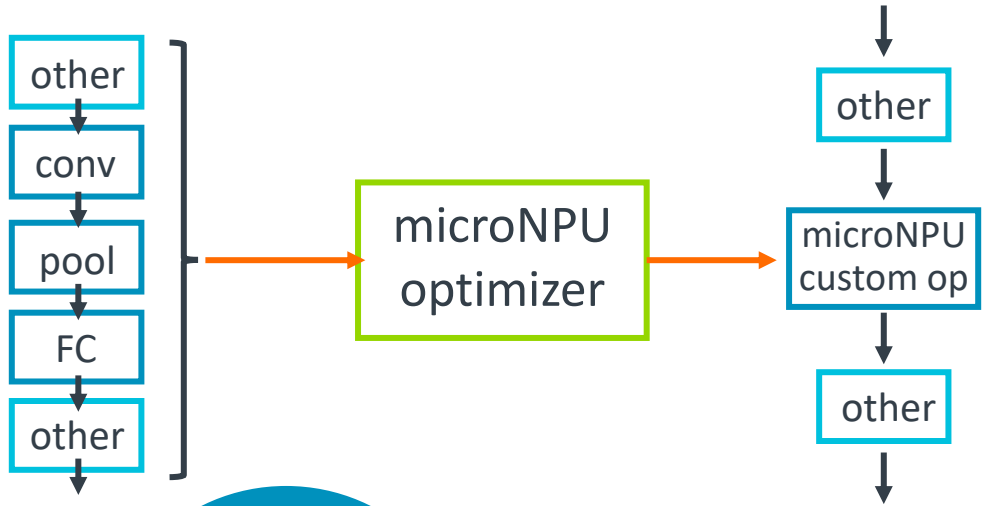
The Vela Optimizer

- Open source compiler
- Reads a tflite file and identifies subgraphs
- Optimizes scheduling of subgraphs
- Loss-less compression of weights
- Generates commands for microNPU
- Writes out a modified tflite file



Up to 90% SRAM size reduction

Up to 70% model size reduction

Enabling networks not before feasible in embedded systems

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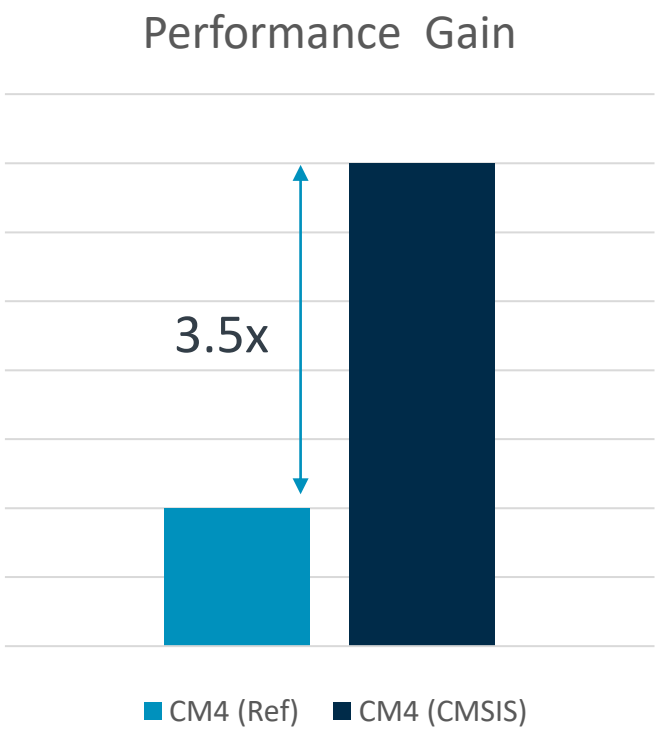
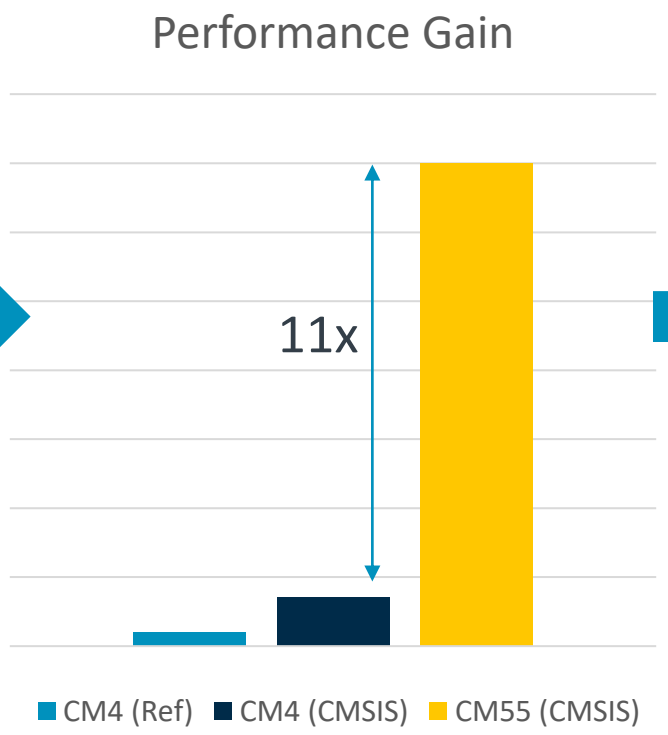
Neural Network performance Across ARM IPs

Wav2Letter

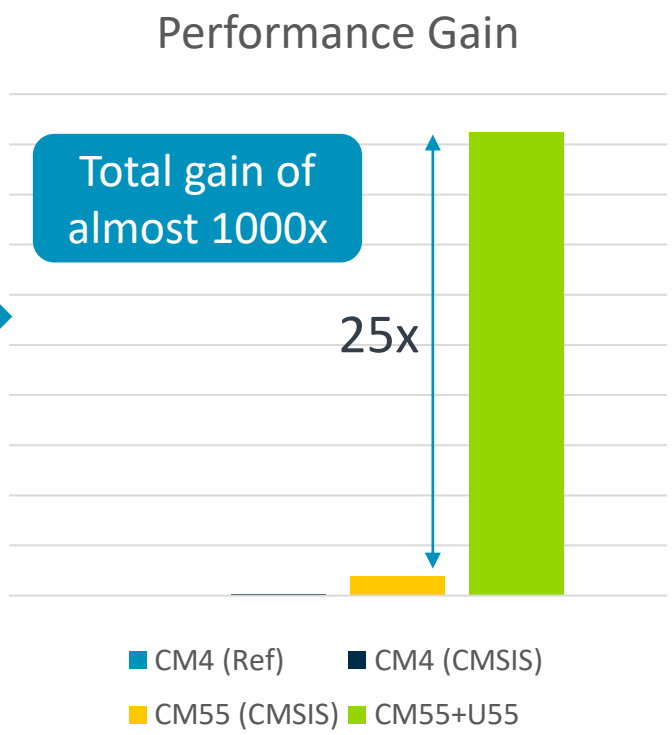
Efficient Software (CMSIS-NN)



AI Capable Cortex-M55



AI Dedicated U55 256 MAC/cycle



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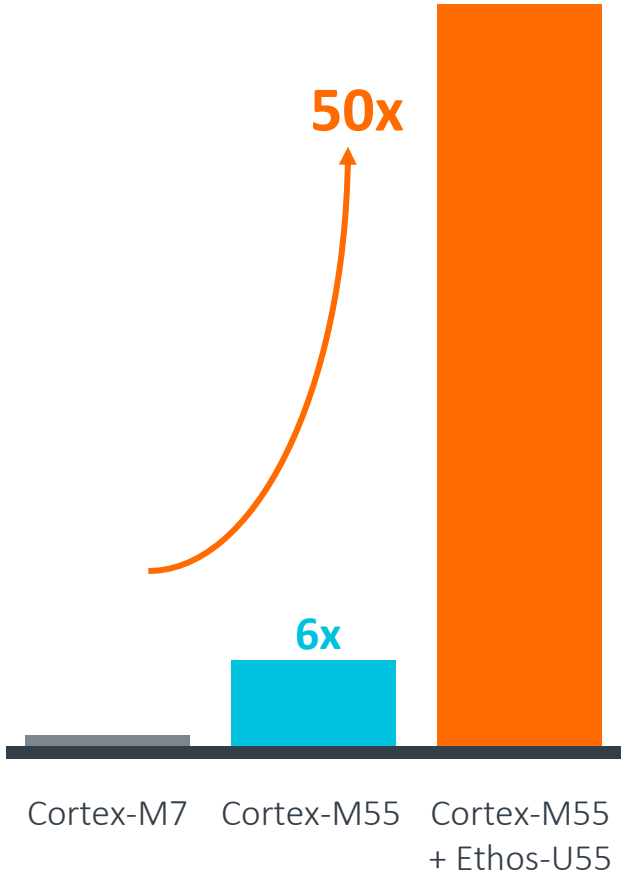
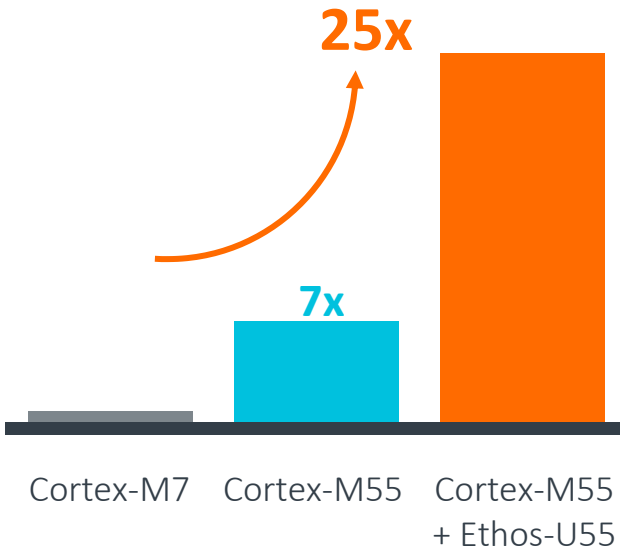
Full example: Typical ML Workload for a Voice Assistant

Speed to inference



Energy efficiency



- ✓ Faster responses
- ✓ Smaller form-factors
- ✓ Improved accuracy

Latency and energy spent for all tasks listed combined: voice activity detection, noise cancellation, two-mic beamforming, echo cancellation, equalizing, mixing, keyword spotting, OPUS decode, and automatic speech recognition.

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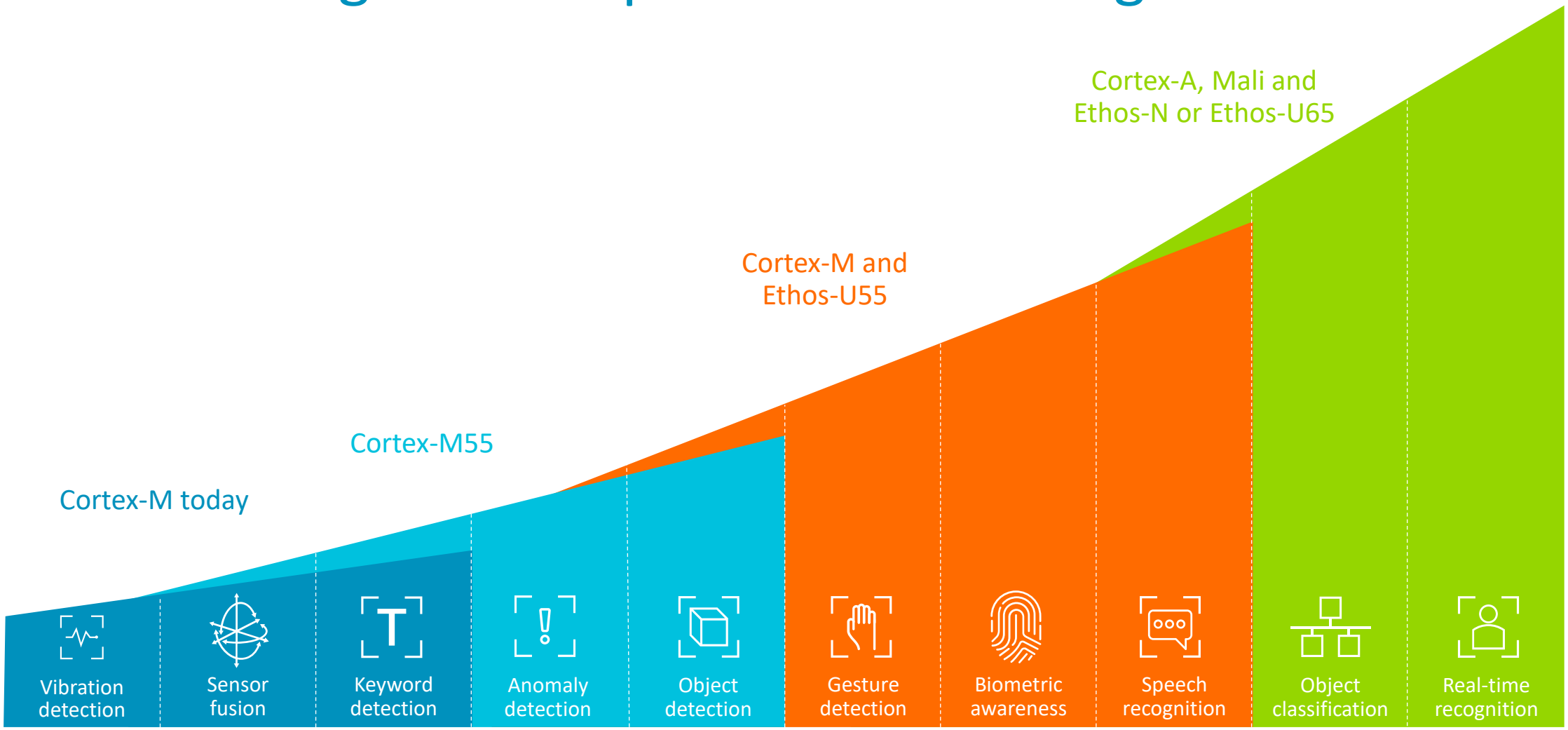
Broadest Range of ML-optimized Processing Solutions



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