

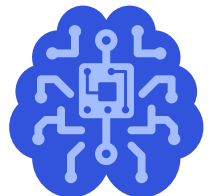
March 2018

@qualcomm_tech

Qualcomm

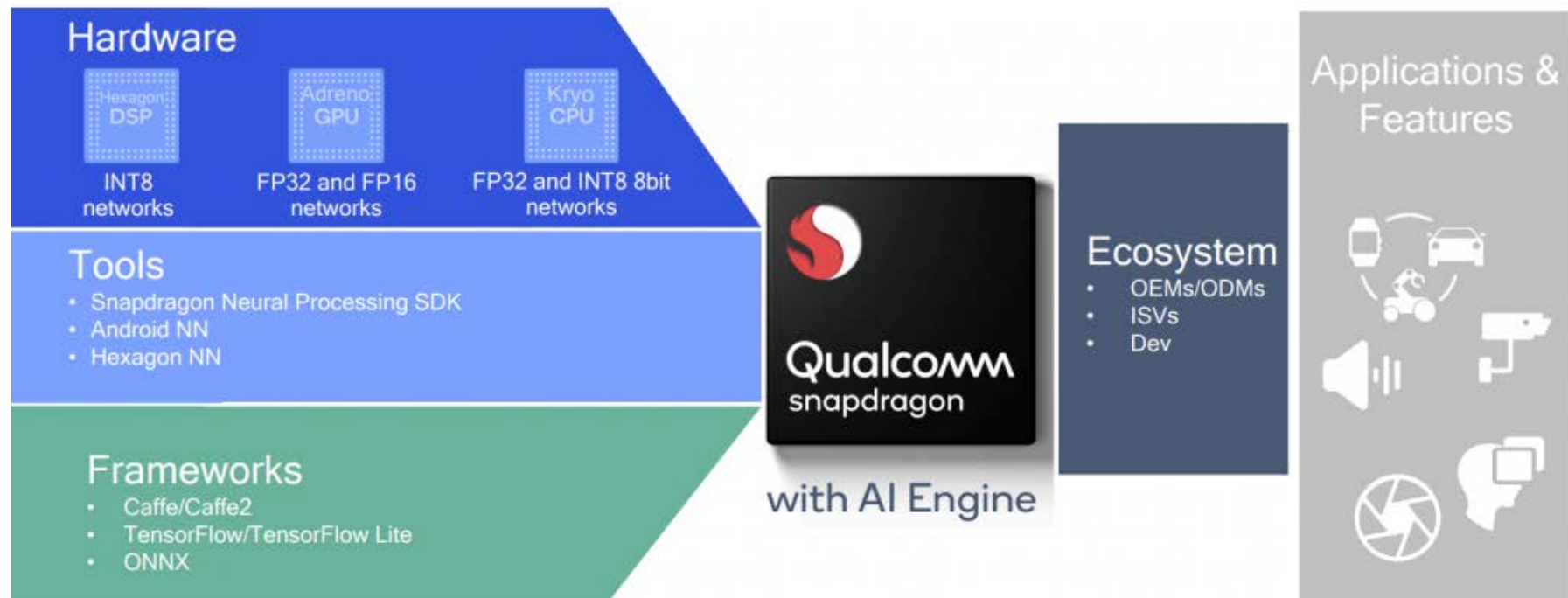
Achieving AI @Scale on Mobile Devices

Qualcomm Technologies, Inc.



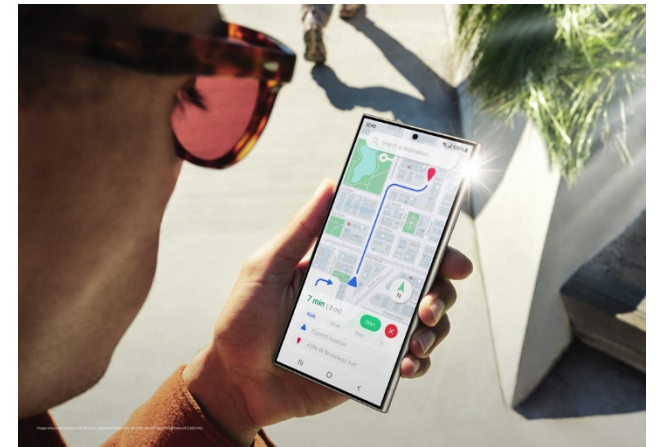
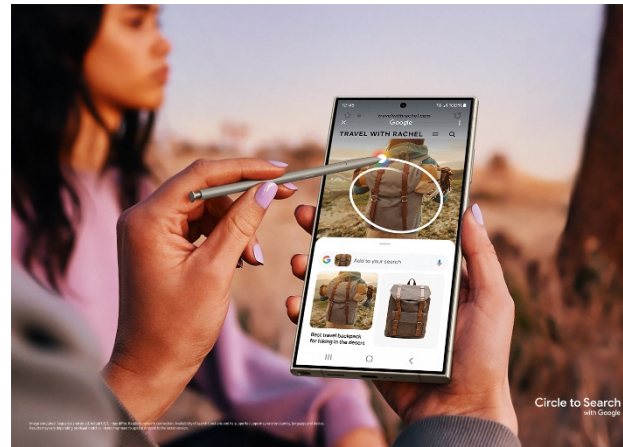
Qualcomm Artificial Intelligence Engine (AIE)

Feb. 21, 2018 – San Diego – Qualcomm Technologies, Inc., a subsidiary of Qualcomm Incorporated (NASDAQ: QCOM), today introduced its Qualcomm Artificial Intelligence (AI) Engine, which is comprised of several hardware and software components to accelerate on-device AI-enabled user experiences on select Qualcomm® Snapdragon™ mobile platforms. The AI Engine will be supported on Snapdragon 845, 835, 820 and 660 mobile platforms, with cutting-edge on-device AI processing found in the Snapdragon 845. [Source: <https://www.edge-ai-vision.com/>]



Galaxy S24 AI Smartphone

- Qualcomm Snapdragon (8 Gen 3 for Galaxy) AP SoC
- Live translate: 13 languages
- Google Gemini GenAI: 'circle to search'
- AI-assisted photo editing



Glossary

@scale = at scale: at a large enough amount to make an impact or solve a problem

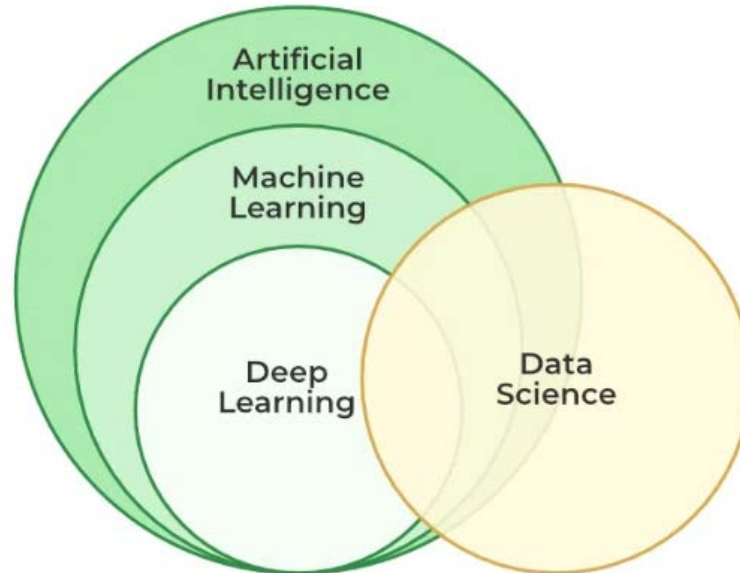
NoC (Network on Chip)

Latency: delay time that data takes to transfer across the network

Machine learning: using data and algorithms to enable AI to imitate the way that humans learn

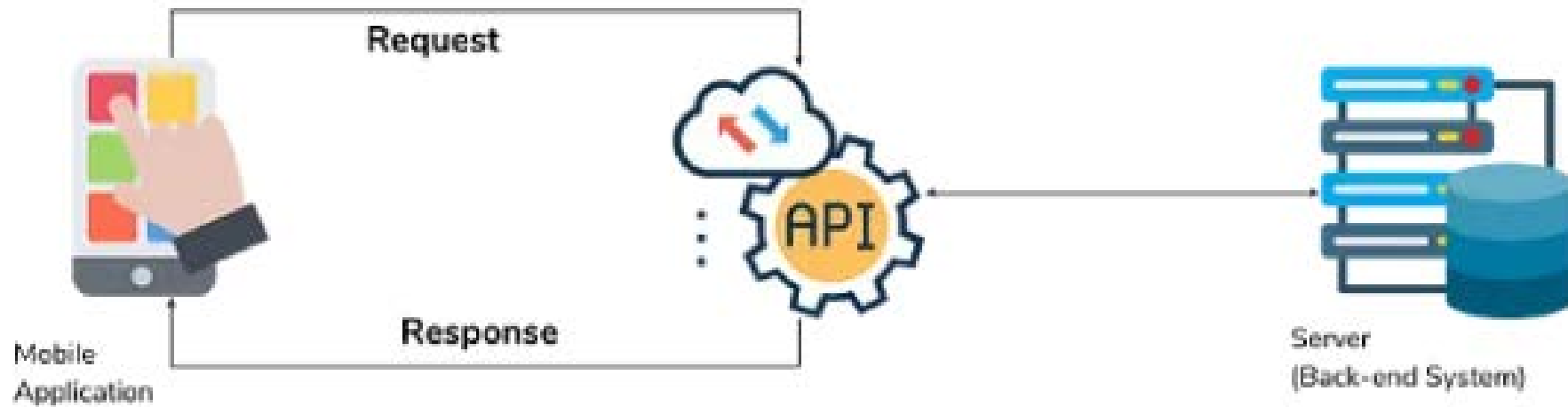
Deep learning: using multi-layered neural networks, called deep neural networks, to simulate the complex decision-making power of the human brain

NPE (Neural Processing Engine) in Qualcomm Snapdragon processors



Glossary

API (Application Programming Interface): a collection of protocols, procedures, and tools used in the development of software and applications. The means through which two or more programs may connect with one another and share data or functionality is defined by an API. In order to access services like weather data, geolocation, and others, APIs are often used to retrieve data from web-based software applications.



XR (Extended Reality): VR (Virtual Reality) + AR (Augmented Reality) + MR (Mixed Reality)

UI (User Interface)

Qualcomm Technologies' success is based on

Technology leadership

Modem

3G (CDMA, GSM)

4G/LTE

5G

Connectivity

Bluetooth Smart

Bluetooth Mesh

802.11ac/ax

802.11ad

802.11n

802.15.4

DSRC

Powerline

GNSS/Location

Peripherals (PCIe, USB.)

Connectivity



RF

Power amps

Acoustic filters

RF switches

Other

Machine learning

NoC / MemCtrl

Power management

Security

Touch

Fingerprint

Computing



Processors

CPU

GPU

DSP

Multimedia

Video

Speech

Display processing

Media processing

Camera processing

Audio processing

Computer Vision

AR / VR

A mobile processor today—Snapdragon 835

Highly integrated and complex SoC using 10nm process technology

Snapdragon X16 LTE

World's first announced
gigabit-class LTE modem

Qualcomm® Hexagon™ DSP

Snapdragon Neural Processing
Engine support

Qualcomm® Kryo™ 280 CPU

Our most power efficient
architecture to date



Qualcomm® Adreno™ Visual Processing

25% faster graphics rendering
60x more display colors*

Qualcomm Spectra™ Camera ISP

Smooth zoom | Fast-autofocus
True to life colors

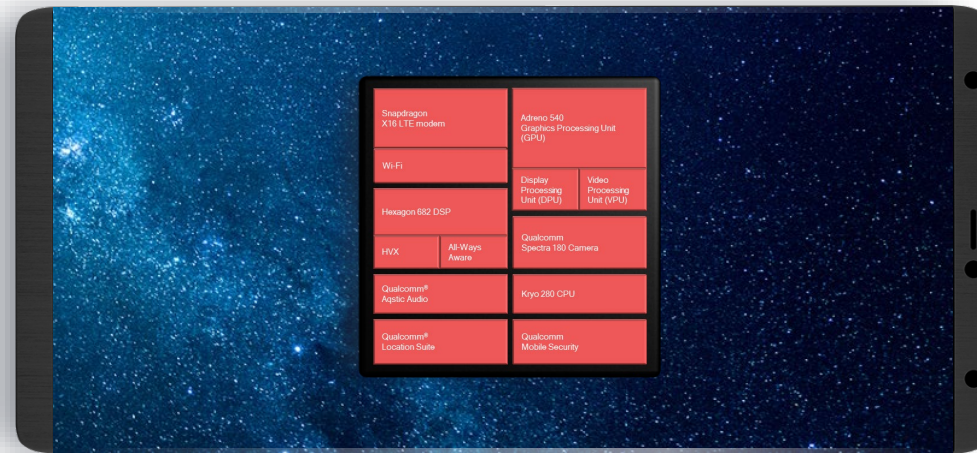
Qualcomm® Mobile Security

First to support full biometric suite

* Compared to Snapdragon 820

Qualcomm Adreno, Qualcomm Kryo, Qualcomm Hexagon, Qualcomm Spectra, Qualcomm Aqstic, Qualcomm Location Suite, Qualcomm All-Ways Aware, and Qualcomm Mobile Security are products of Qualcomm Technologies, Inc.

Mobile scale changes everything



Mobile computing



Smart homes



Industrial IoT



Wearables



Smart cities



Automotive



Healthcare



Networking



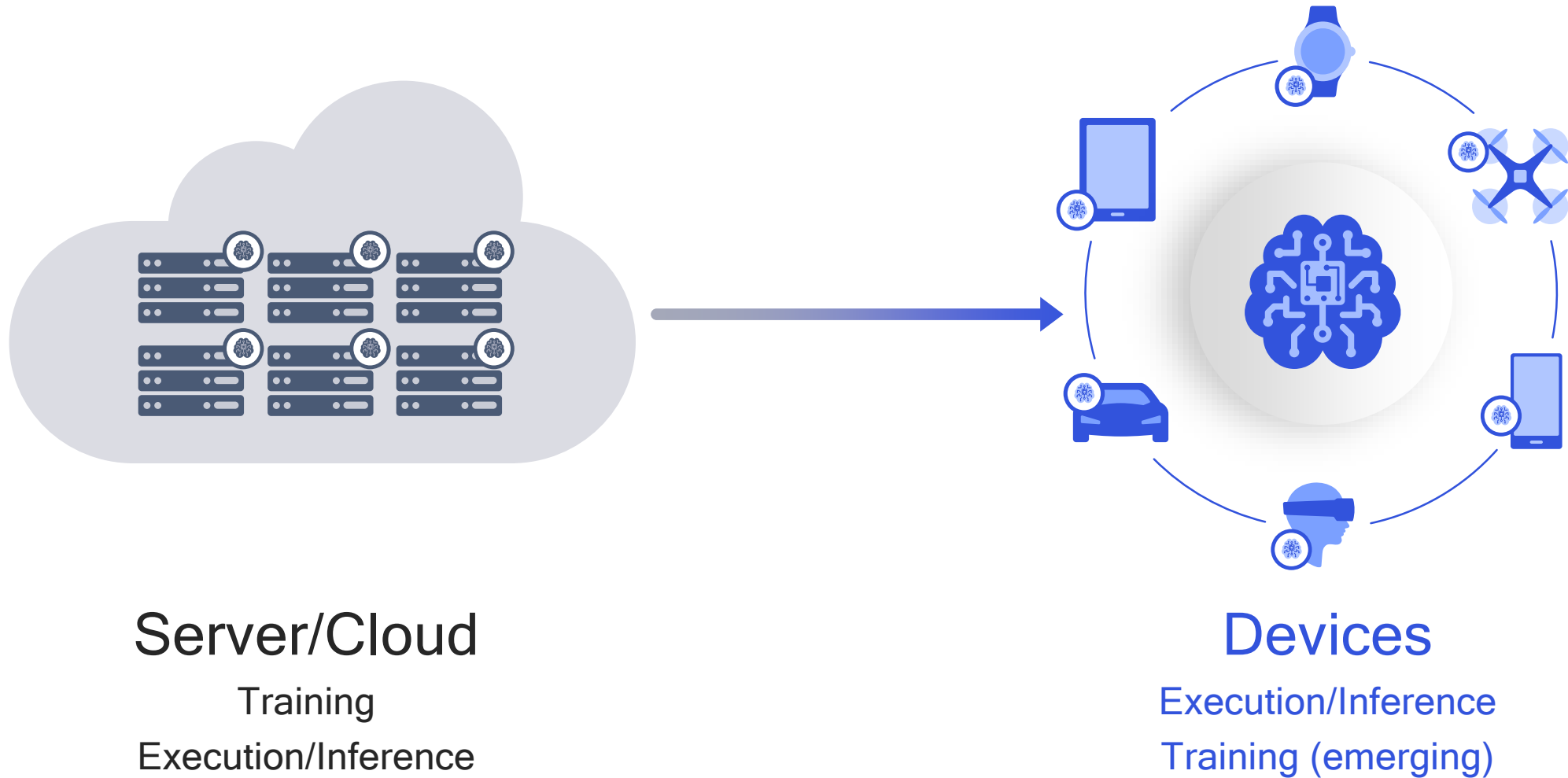
Extended reality

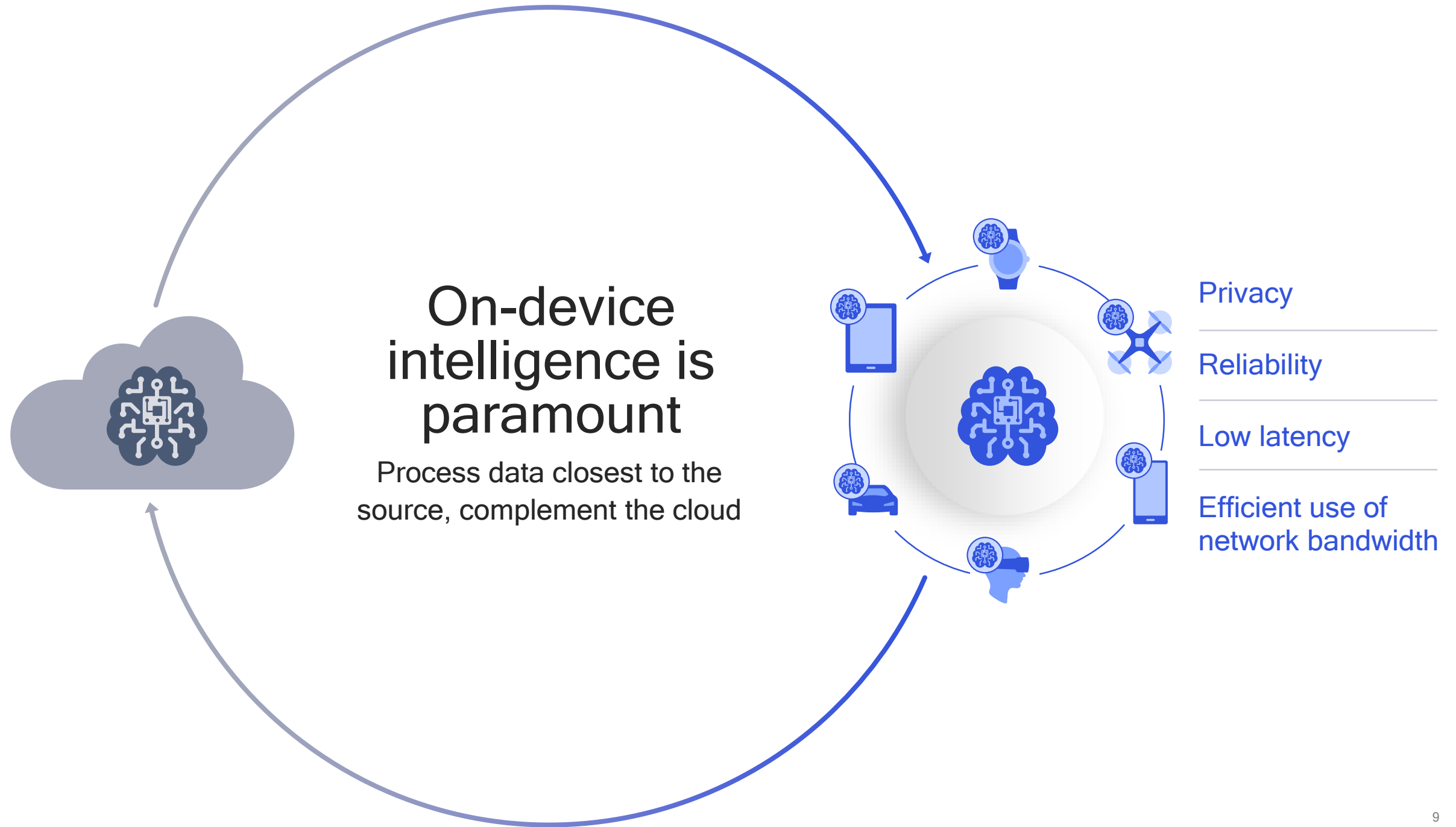
Rapid
replacement cycles

Superior scale

Integrated and
optimized technologies

Intelligence is moving to the device





Qualcomm® Artificial Intelligence Platform

The platform for efficient on-device machine learning



A high-performance platform designed to support myriad intelligent-on-device-capabilities that utilize:

- Qualcomm® Snapdragon™ mobile platform's heterogeneous compute capabilities within a highly integrated SoC
- Innovations in machine learning algorithms and enabling software
- Development frameworks to minimize the time and effort for integrating customer networks with our platform

Making on-device intelligence pervasive

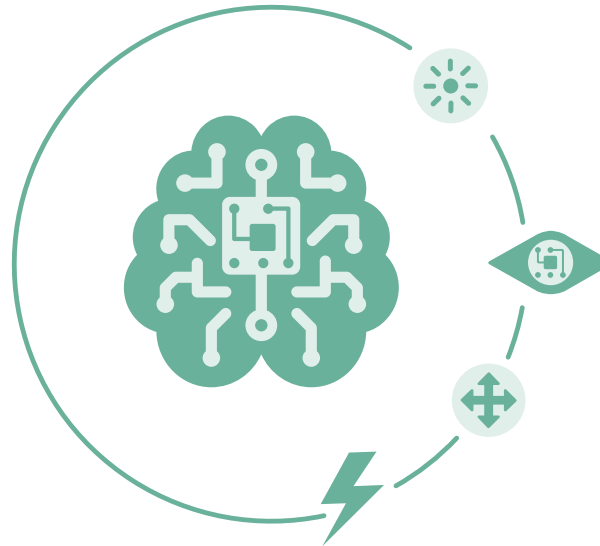
Focusing on high performance HW/SW and optimized network design



Efficient hardware

Developing heterogeneous compute to run demanding neural networks at low power and within thermal limits

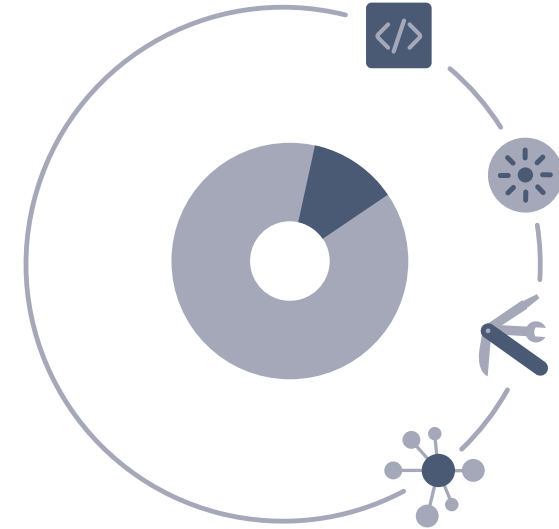
Selecting the right compute block for the right task



Algorithmic advancements

Algorithmic research that benefits from state-of-the-art deep neural networks

Optimization for space and runtime efficiency



Software tools

Software accelerated run-time for deep learning

SDK/development frameworks

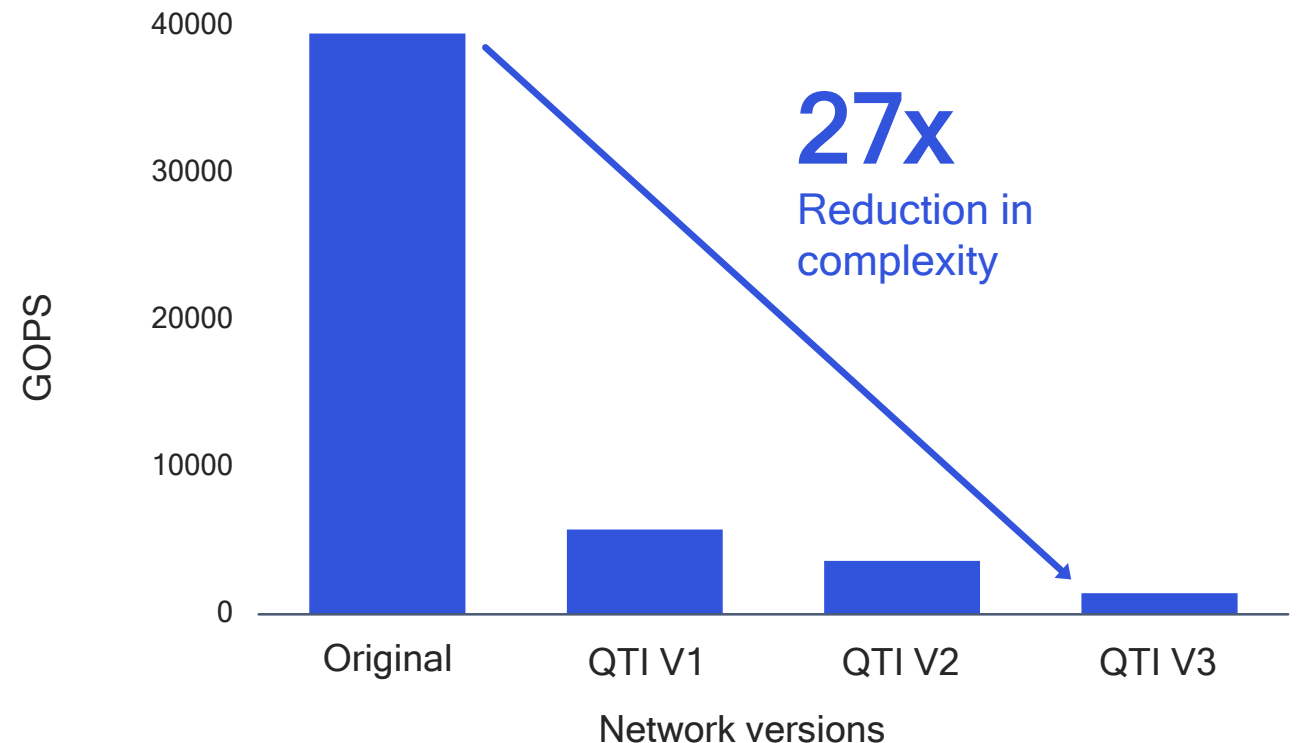
Algorithmic enhancements for space and runtime efficiency

Improve performance by addressing model complexity

Neural network optimizations for embedded

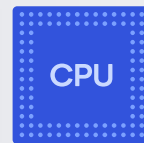
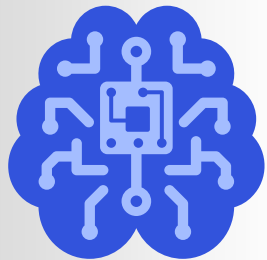
- Improved network architecture
- Focus on memory and storage
 - Reduce bit widths
 - Model compression
 - Leverage sparsity
- Architecture learning

Required operations per image

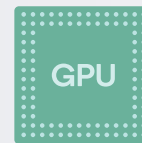


Snapdragon Neural Processing SDK

Software accelerated runtime for the execution of deep neural networks on device



Qualcomm®
Kryo™ CPU



Qualcomm®
Adreno™ GPU



Qualcomm®
Hexagon™ DSP

Efficient execution on Snapdragon

- Takes advantage of Snapdragon heterogeneous computing capabilities
- Runtime and libraries accelerate deep neural net processing on all engines: CPU, GPU, and DSP with vector extensions



Model framework/Network support

- Convolutional neural networks and LSTMs
- Support for Caffe/Caffe2, TensorFlow, and user/developer defined layers



Offline
conversion tools



Analyze
performance



Sample
code

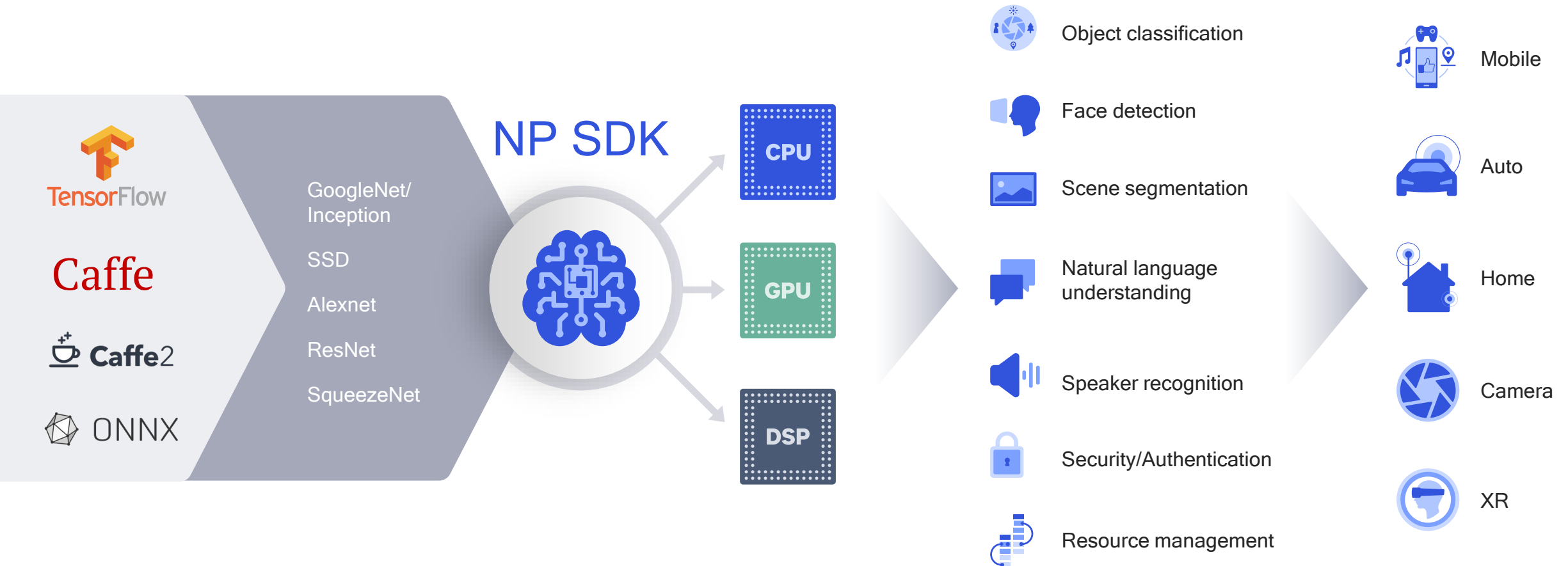


Ease of
integration

Optimization/Debugging tools

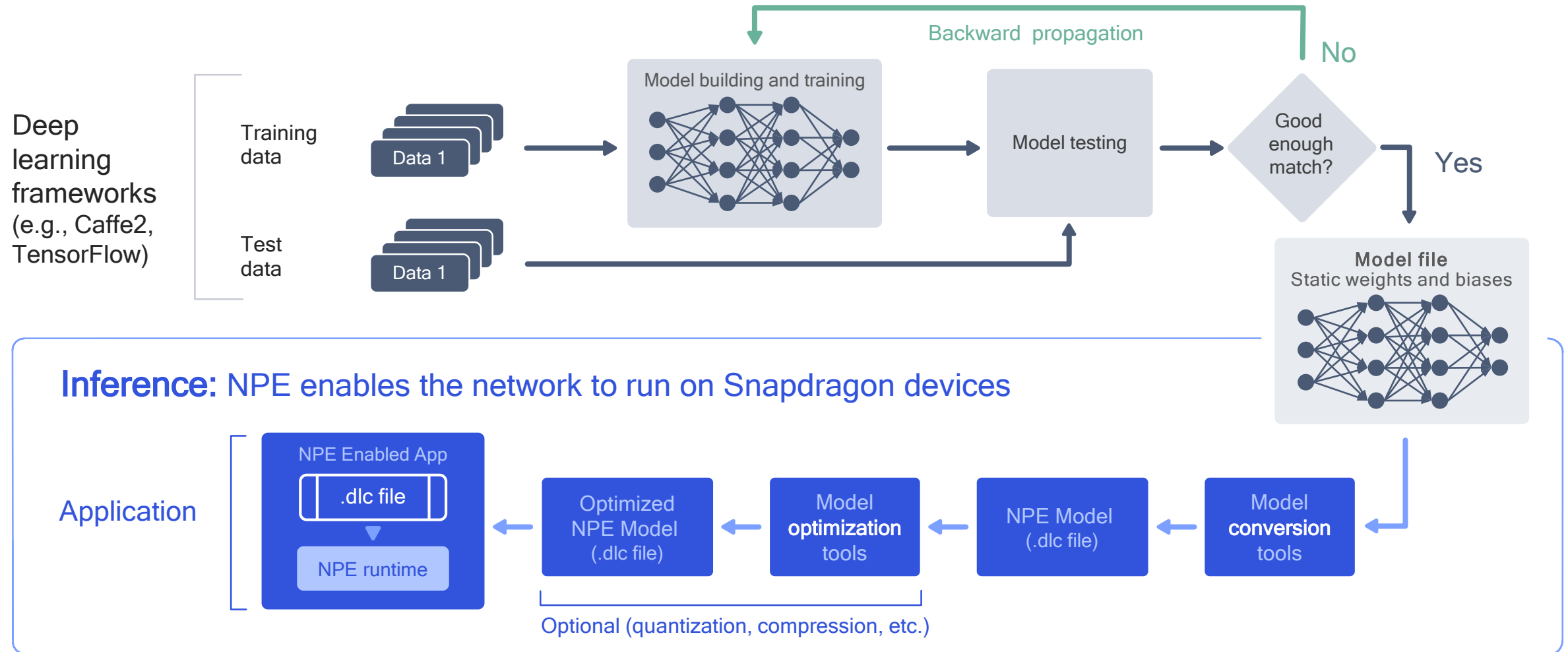
- Offline network conversion tools
- Debug and analyze network performance
- API and SDK documentation with sample code
- Ease of integration into customer applications

Robust software and tools simplify development

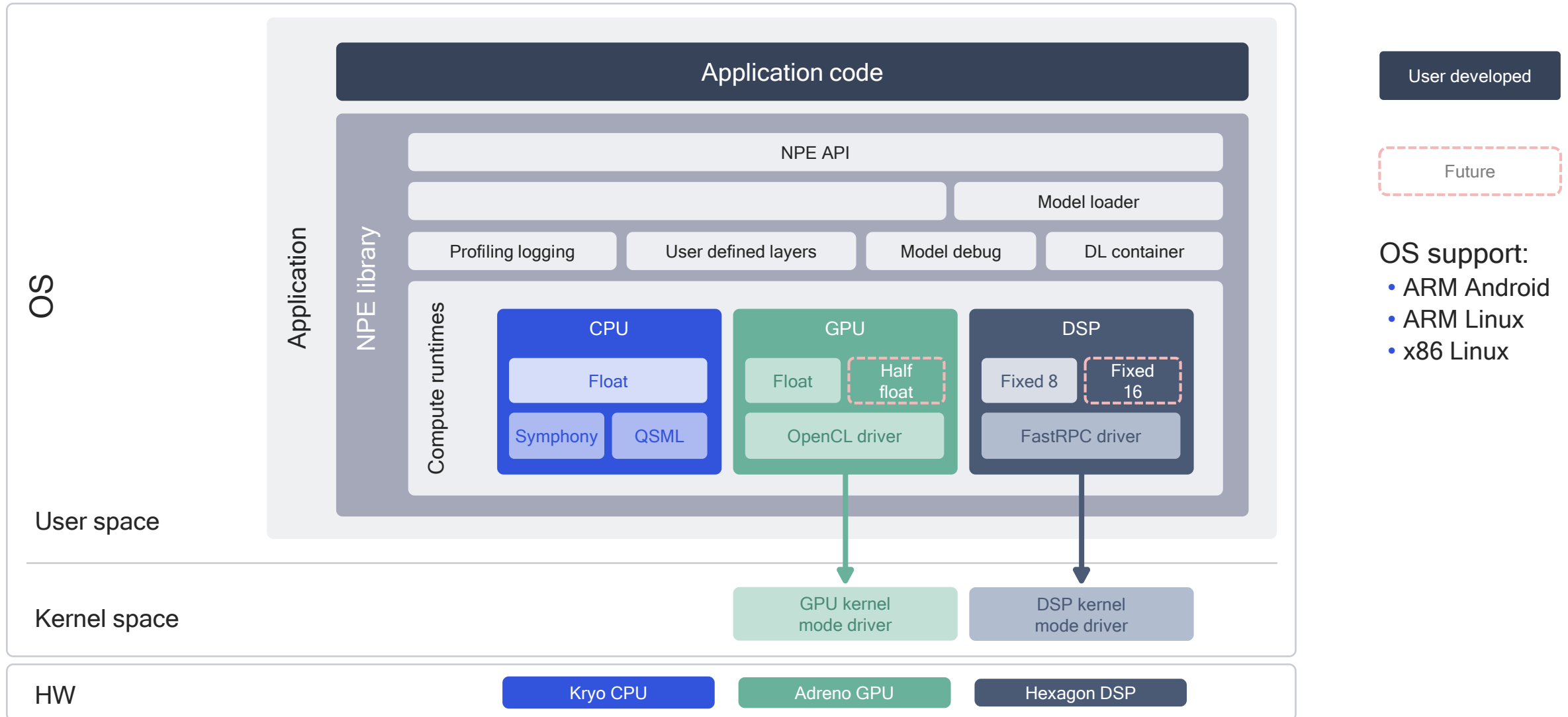


Model to runtime workflow: Training and inference

Training: Machine learning experts build and train their network to solve their particular problem



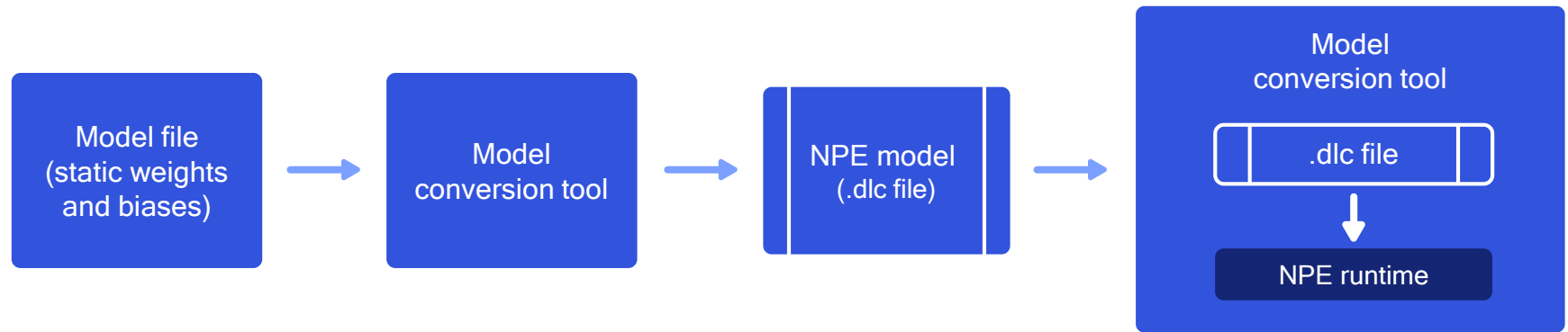
High-level software architecture for the Snapdragon NPE



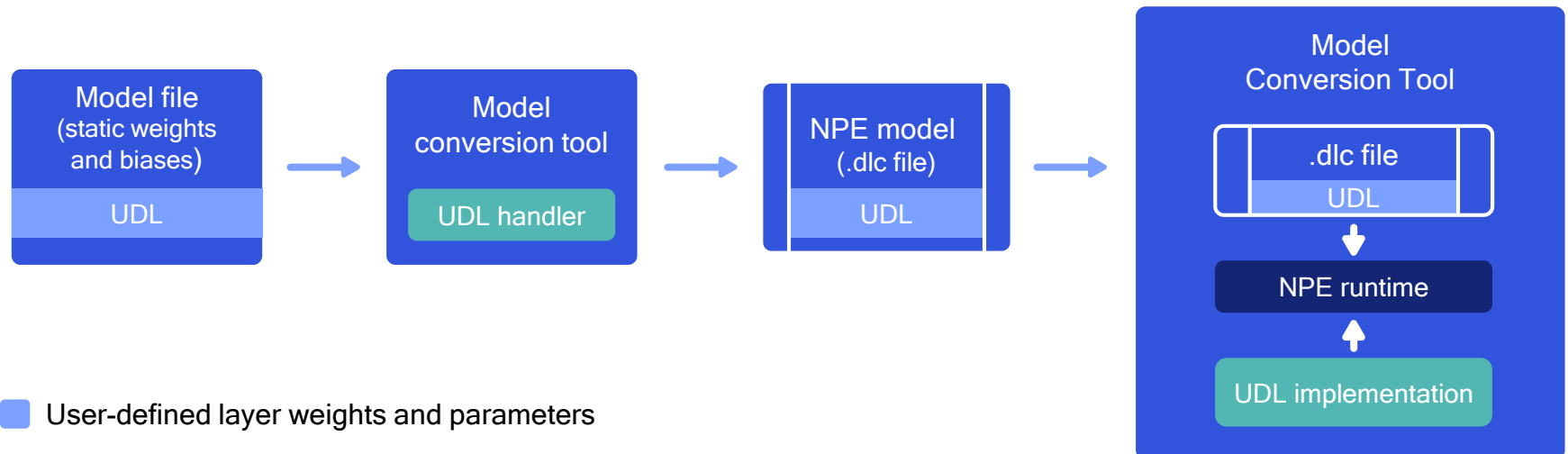
User Defined Layer (UDL) workflow

Supports prototyping of layers not yet supported by the Snapdragon NPE

NPE workflow

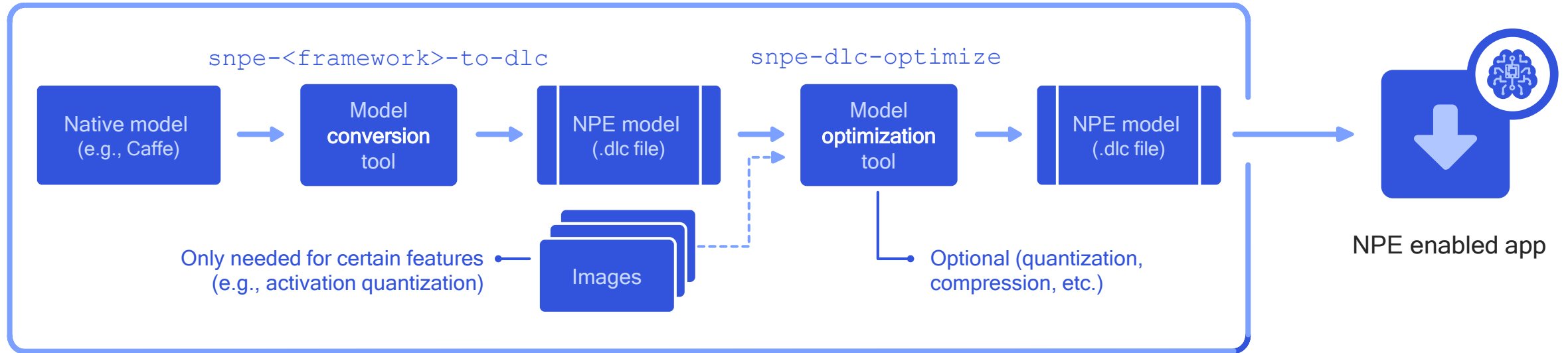


NPE workflow with UDL



■ User-provided implementation ■ User-defined layer weights and parameters

Converting and quantizing a model



`snpe-<framework>-to-dlc`

(<framework> = Caffe | Caffe2 | TensorFlow)

- Input is the model in native framework format
- Output is a converted but not optimized NPE DLC file

`snpe-dlc-optimize`

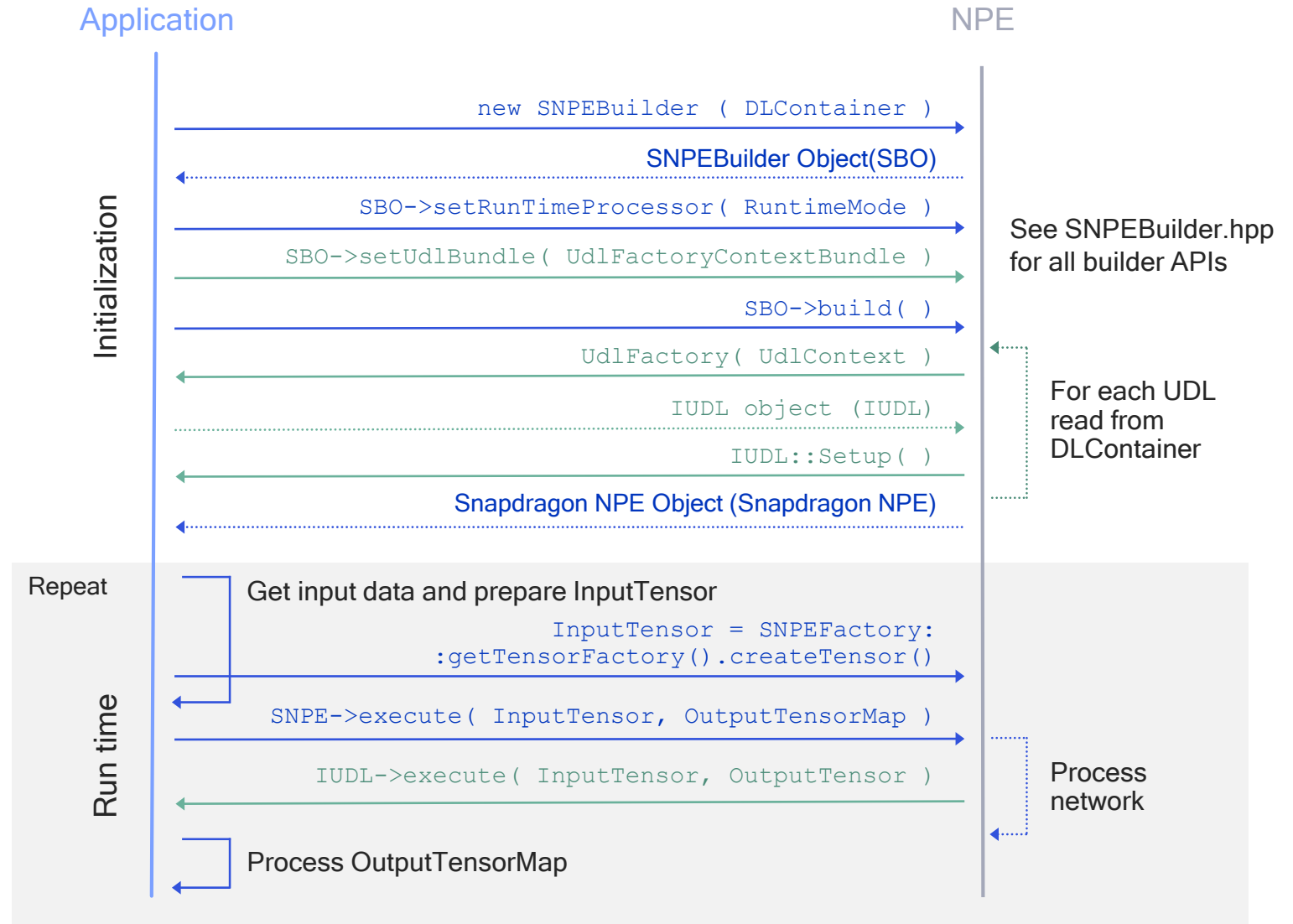
- Converts non-quantized DLC models into 8-bit quantized DLC models
 - Additionally implements further optimizations such as SVD compression
- Quantized model is necessary for fixed-point NPE runtimes (e.g. DSP)

API example usage

NPE provides a simple C++ API with the following functionality

- Load a DLC model and select the runtime
- Execute the model
- Debug support
 - Dump the output of all layers in a model
- Collect performance metrics
 - Per-layer timing

Green API calls are only required for UDLs



Facebook + Qualcomm Technologies

On-device AI with Snapdragon

Facebook and Qualcomm's Caffe2 collaboration

- Demonstrated Caffe2 acceleration with NPE at F8 2017
- 5x performance upside on GPU (compared to CPU)
- Announced commercial support of Caffe2 in July through Qualcomm Developer Network
- Facebook AML has integrated the NPE with Caffe2

Future Caffe2/NPE research and development

- Continue to work closely with Facebook to optimize key networks for maximum on-device performance
- Enhancements to Caffe2 allowing Snapdragon specific SoC optimizations
- More advanced AI-powered XR applications



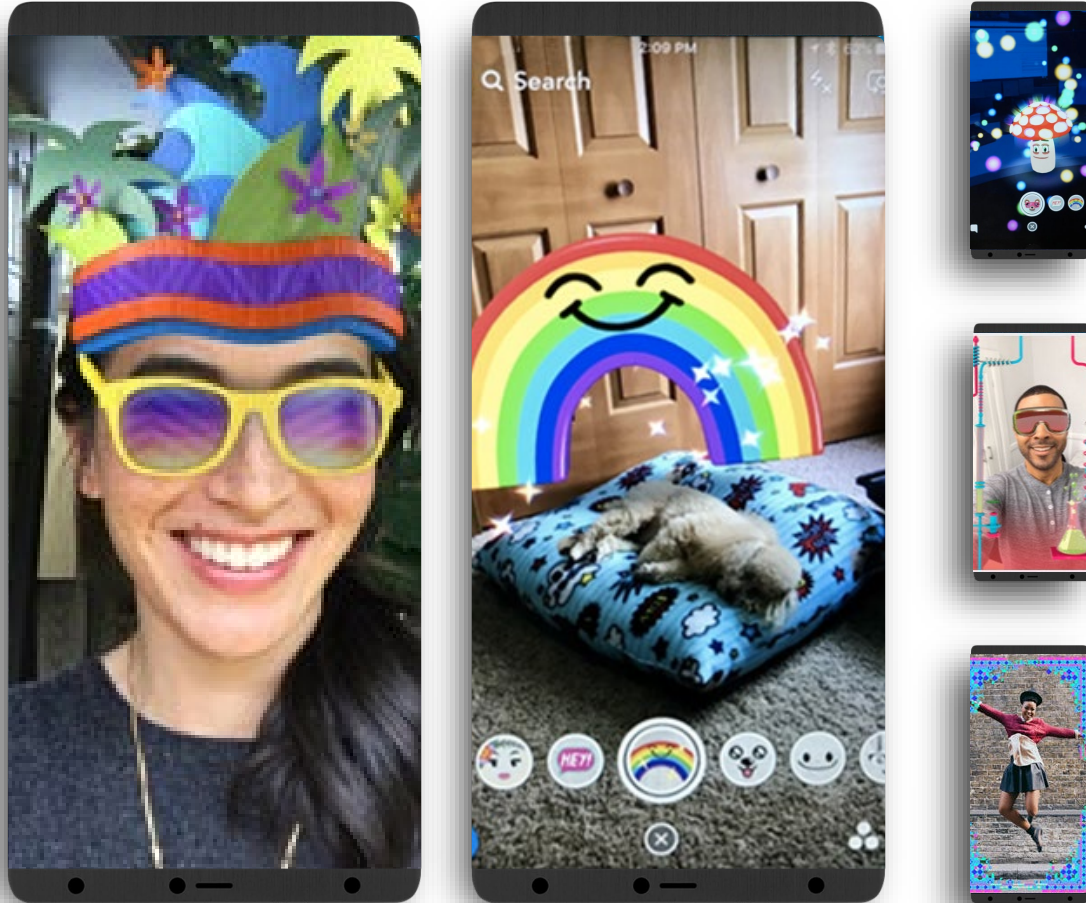
“On-device machine learning is made possible by the Qualcomm Snapdragon NPE which does the heavy lifting needed to run neural networks more efficiently on Snapdragon devices.”

Source: XDA



Enhancing the Facebook experience through on-device AI

More engaging social media with AI and AR

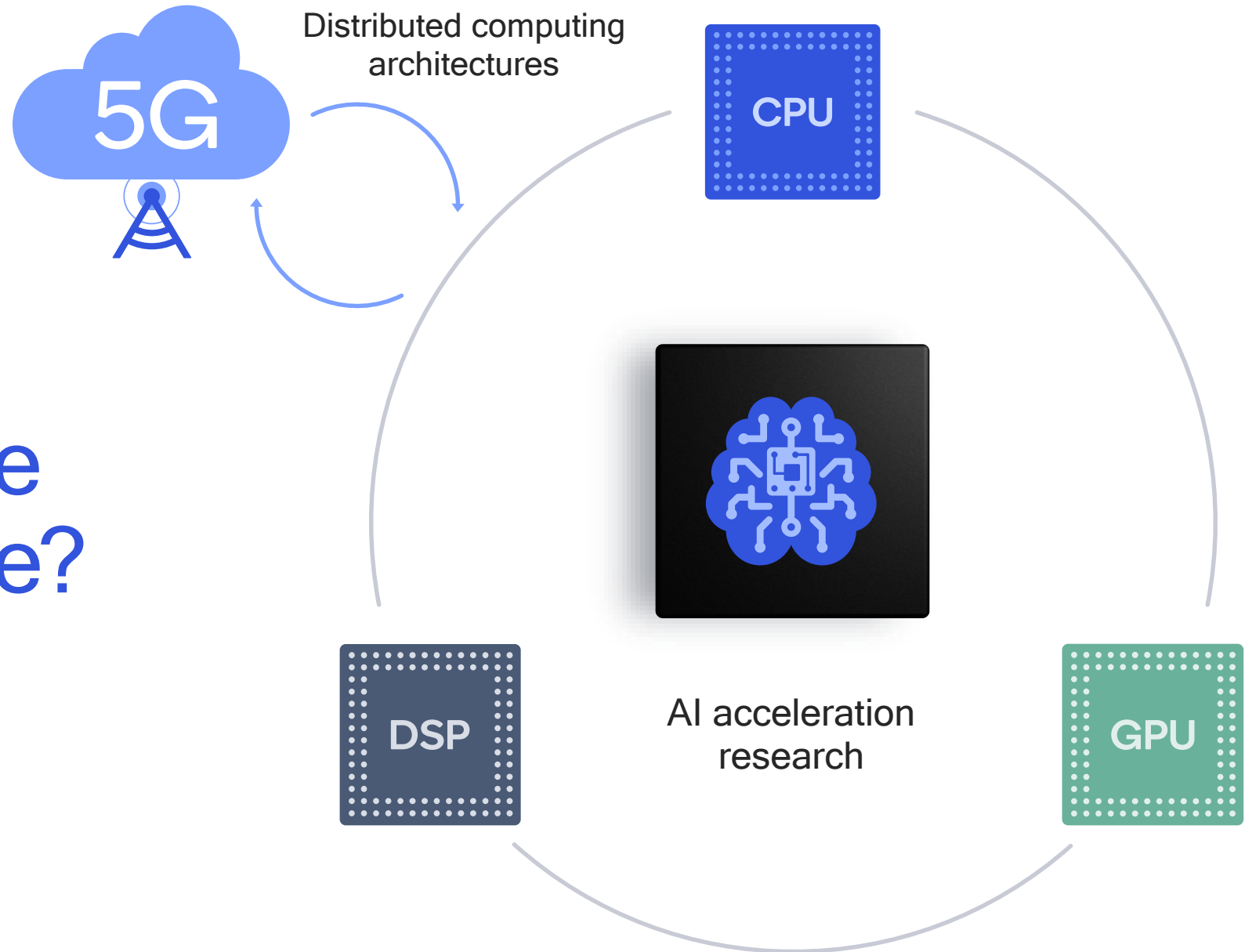


Augmented reality features potentially powered by AI

- Style transfer and filters
- Frames and masks
- Photo and live videos, including 360°
- Contextual awareness (e.g. location/sensor metadata)

On-device acceleration benefits

- Smooth UI with increased frame rate
- Increased battery life



AI hardware

What does the future look like?

AI offers enhanced experiences and new capabilities for smartphones

True personal assistance



Extended battery life



Enhanced connectivity



Qualcomm



Superior photography



Natural user interfaces



Enhanced security

A new development paradigm
where things repeatedly improve

AI will bring XR closer to the ultimate level of immersion

Creating physical presence in real or imagined worlds





AI is revolutionizing the car of the future

Redefining the in-car experience

- Natural user interfaces
- Personalization
- Driver awareness monitoring

Paving the road to autonomy

- Surround view perception
- Sensor fusion
- Path planning
- Decision making



Thank you!

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