Adaptable AI Inference with Vitis AI

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AI Product Maketing

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AI Will Transform All the Applications

Power efficient inference along with traditional software

Data Center

5G

Autonomous Driving

Security

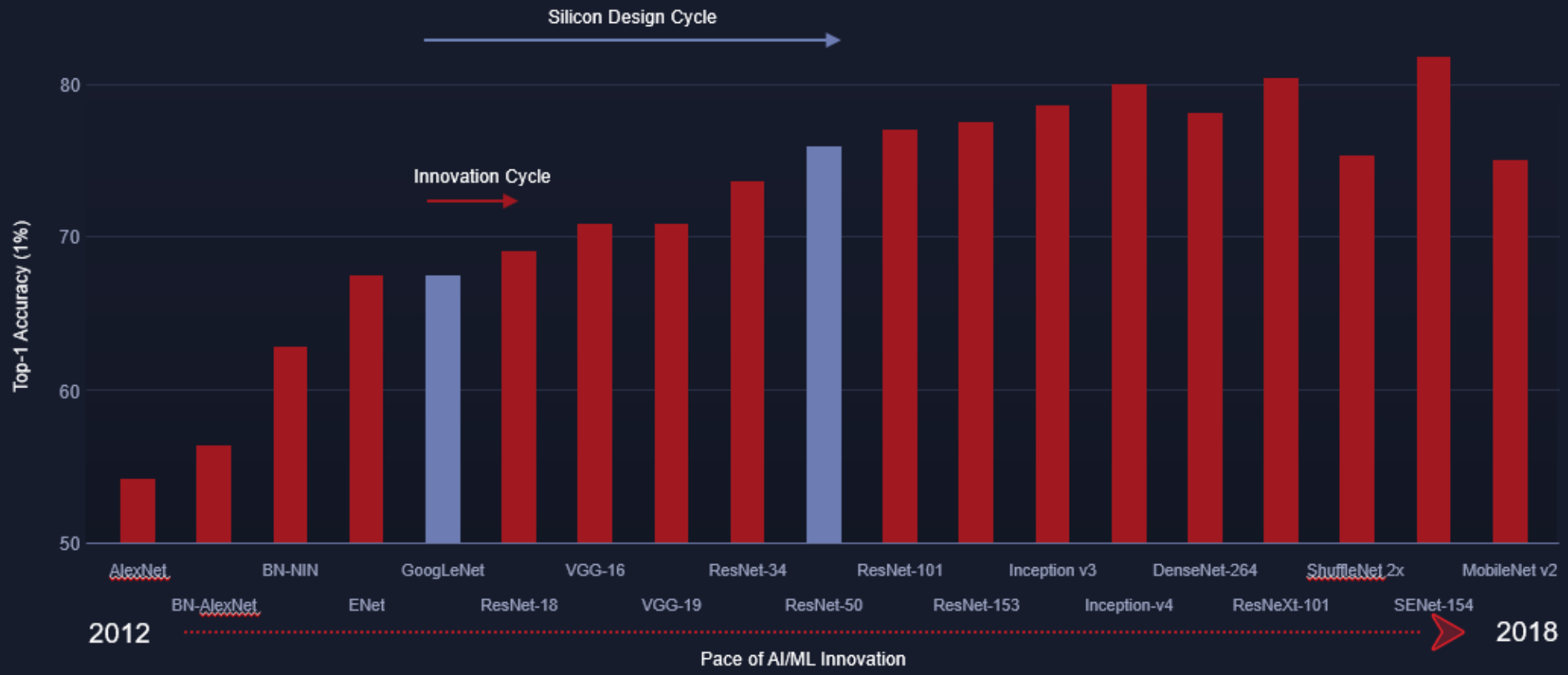
Genomics

Video Analytics

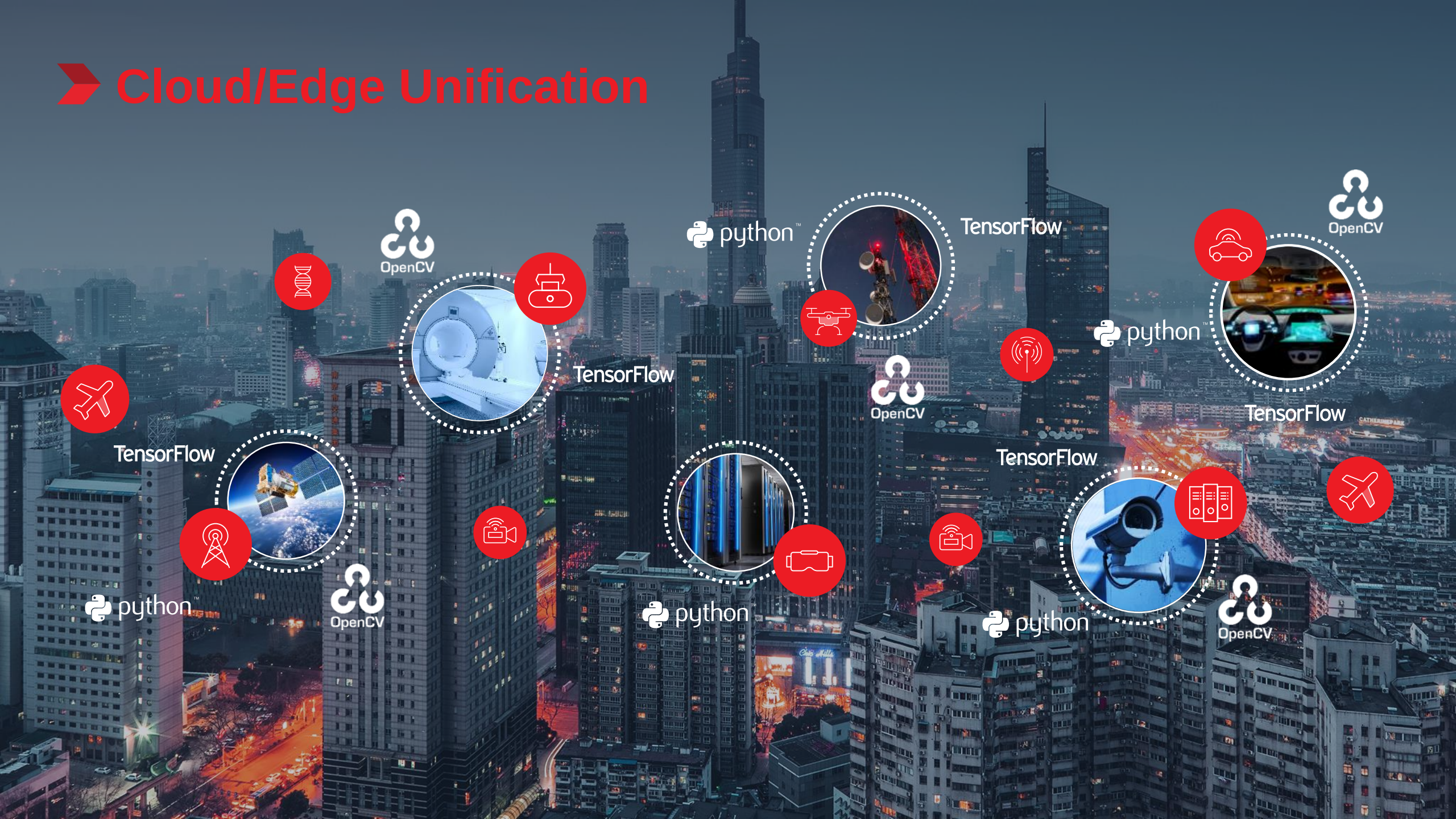
Healthcare

Finance

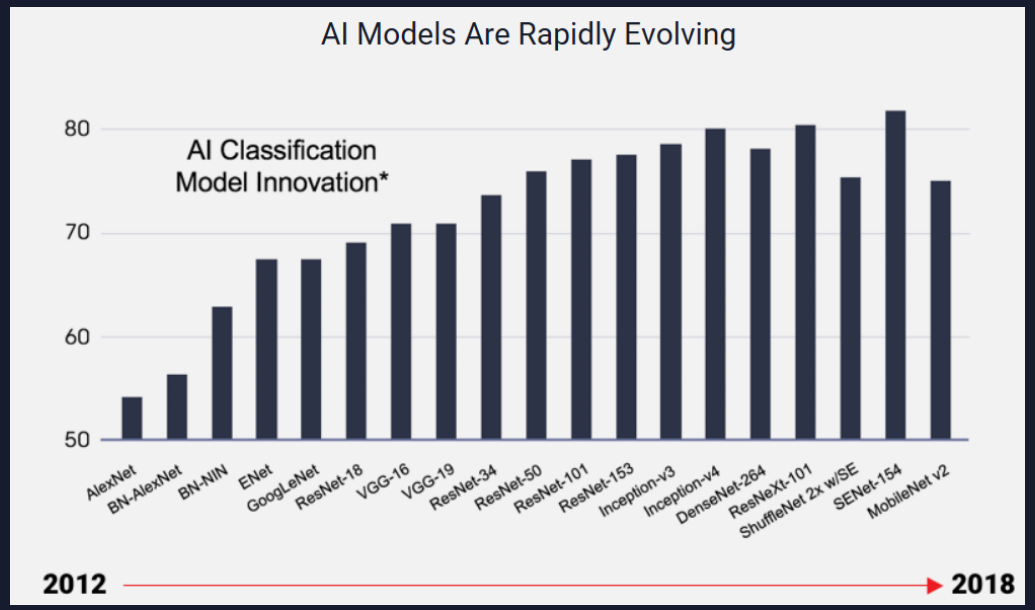
AI is Evolving Rapidly

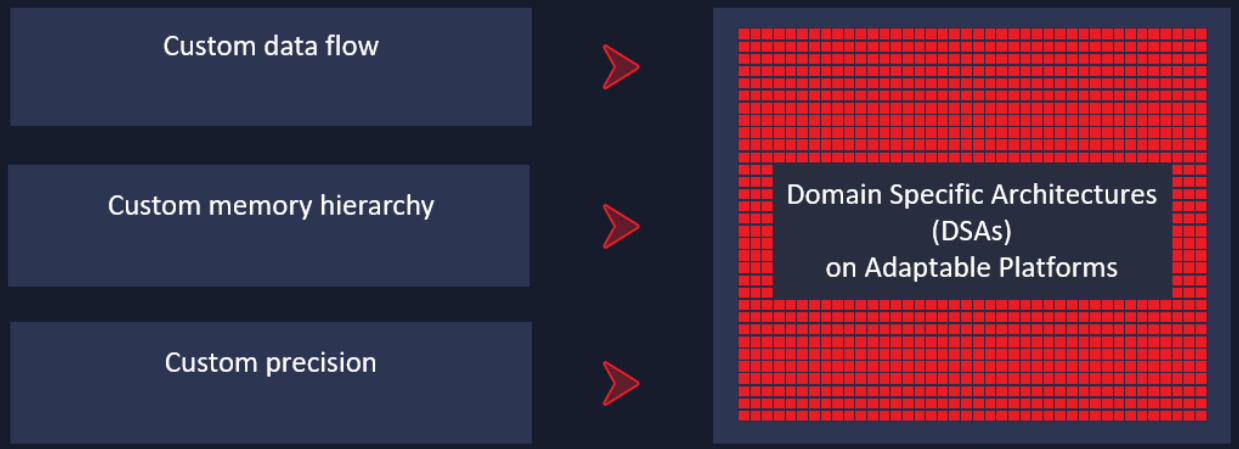


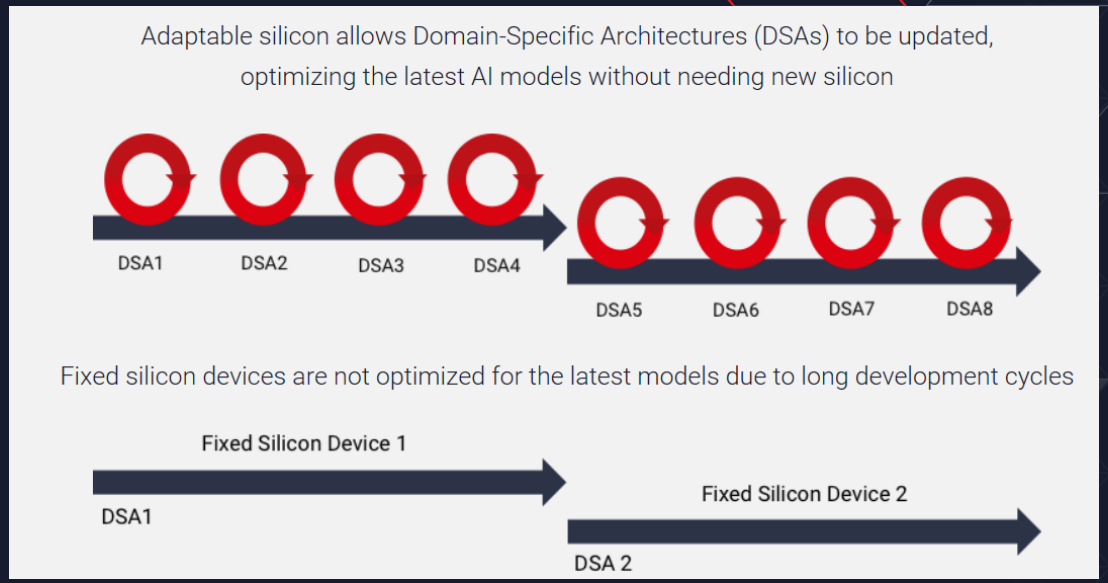
Cloud/Edge Unification



Adapt to Your AI Workloads







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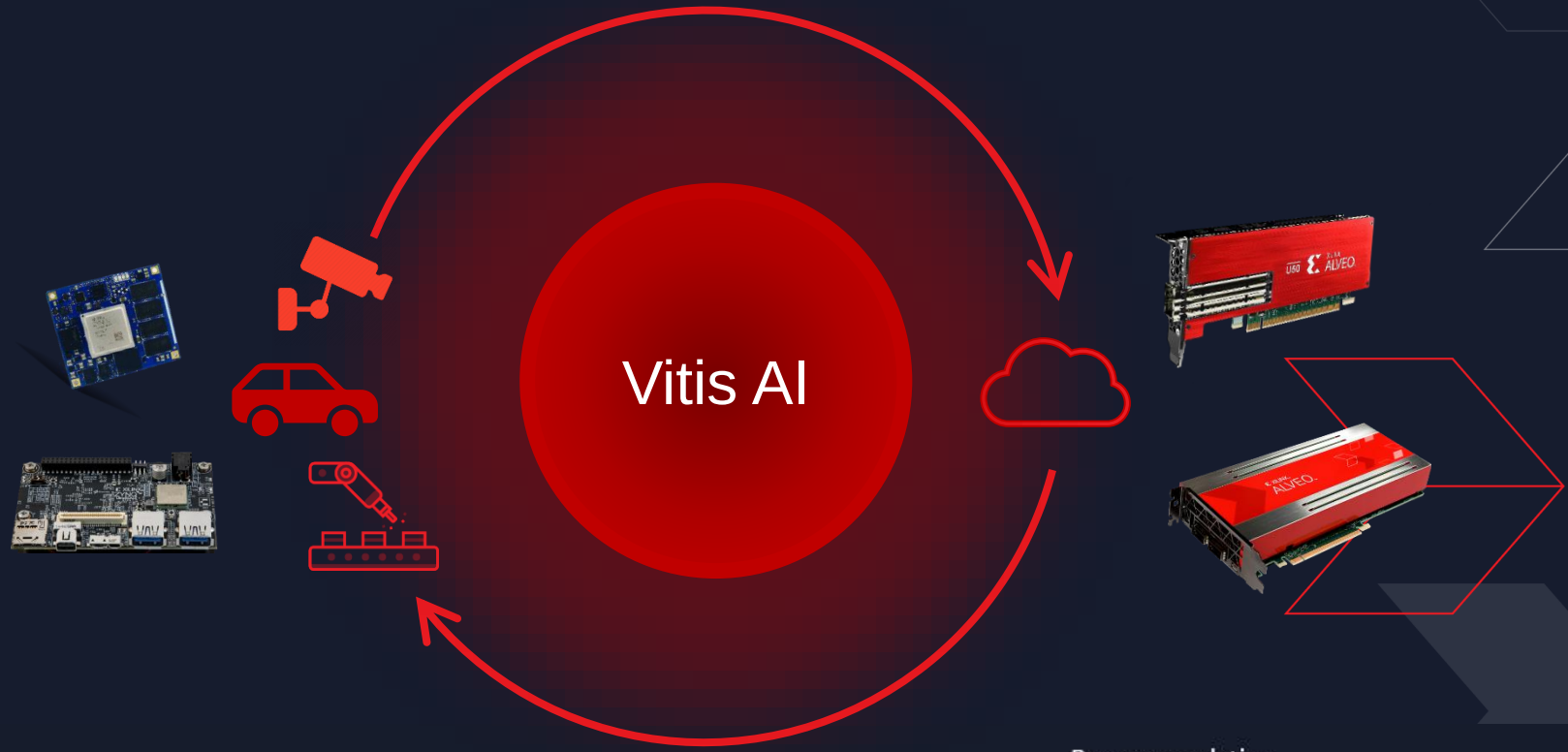
Unified Methodology Edge to Cloud



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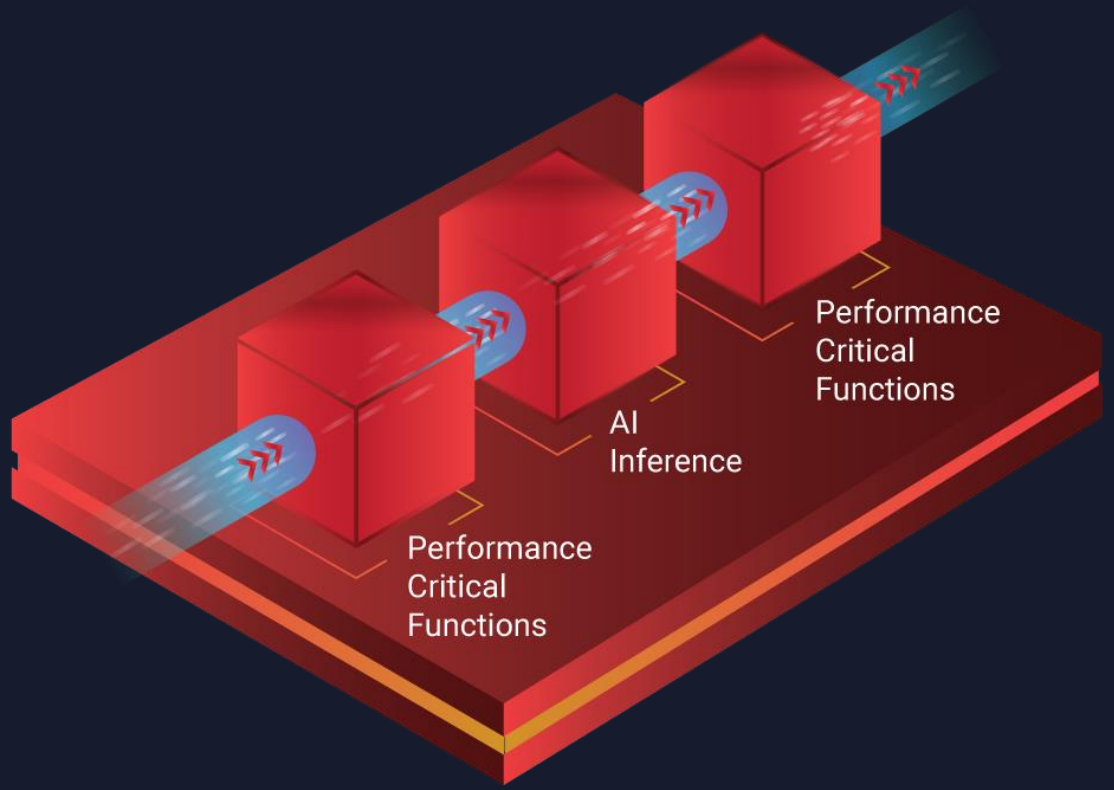
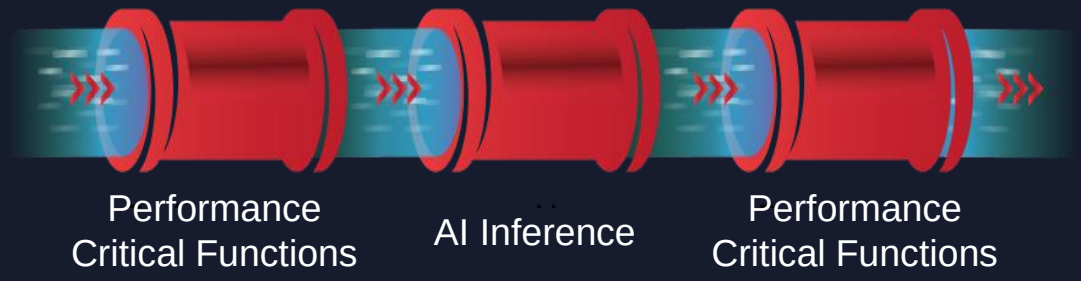
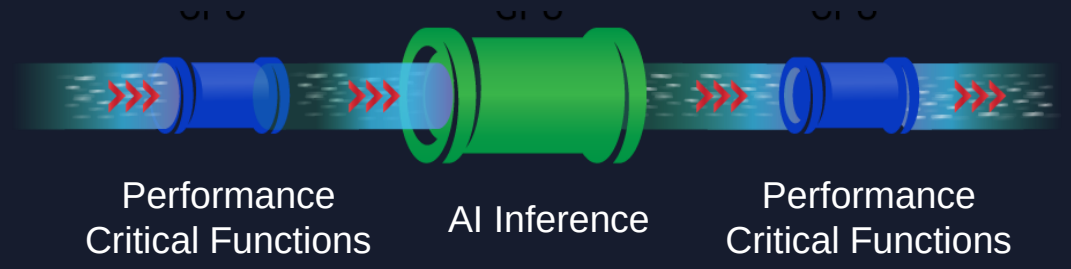
Whole Application Acceleration



Xilinx – Matched Throughput



GPU & CPU – Mismatched Throughput



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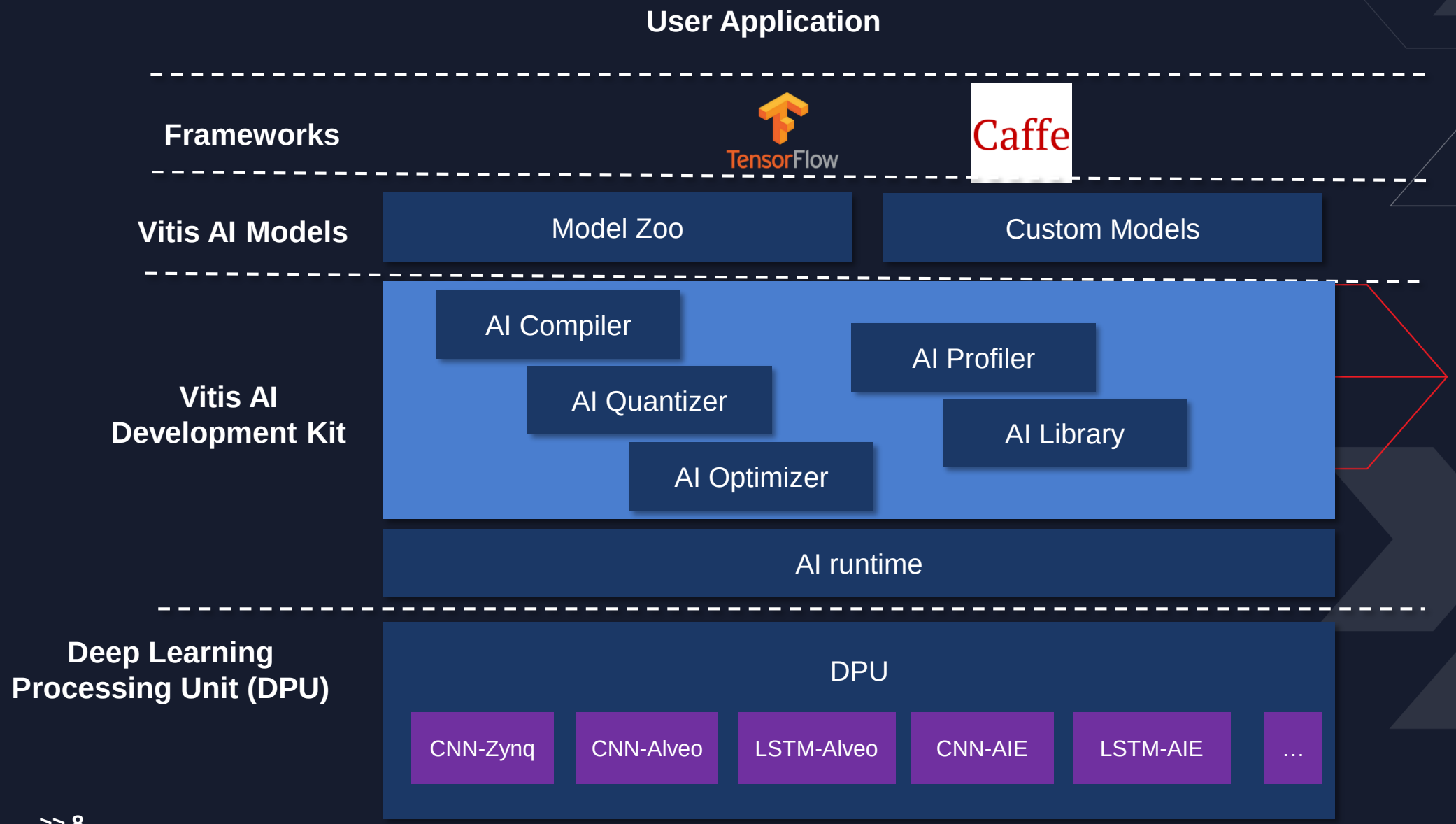
What is Vitis AI?



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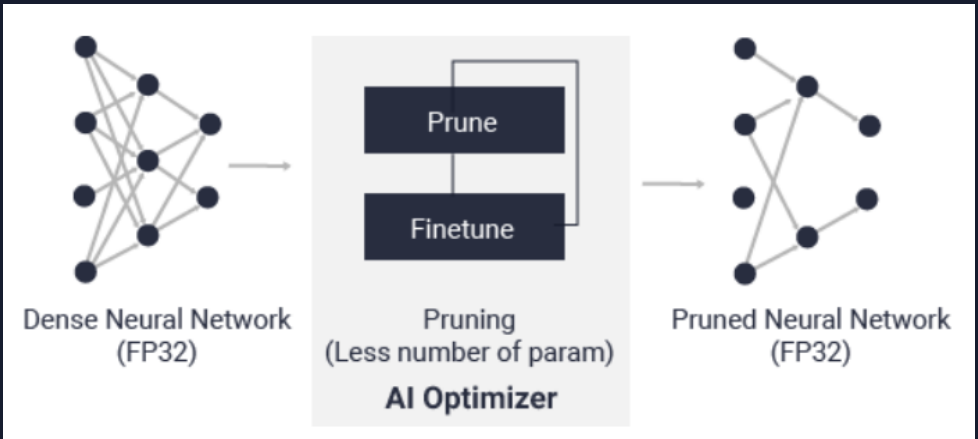
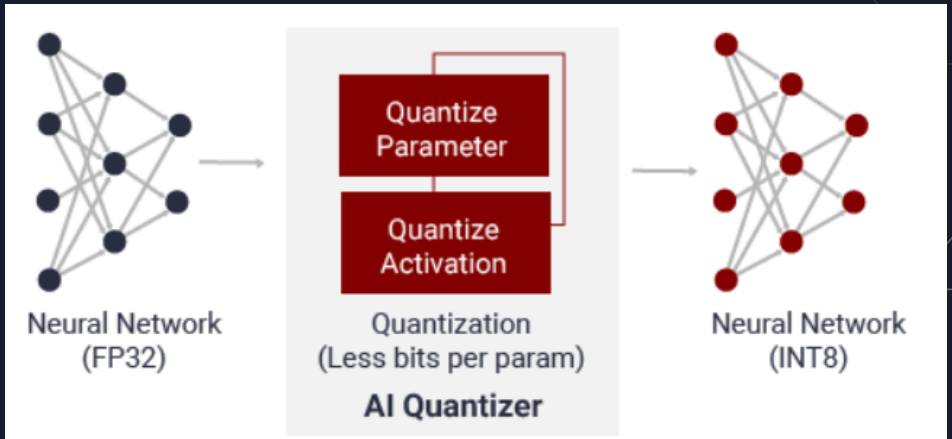
Vitis AI Model Zoo 1.0

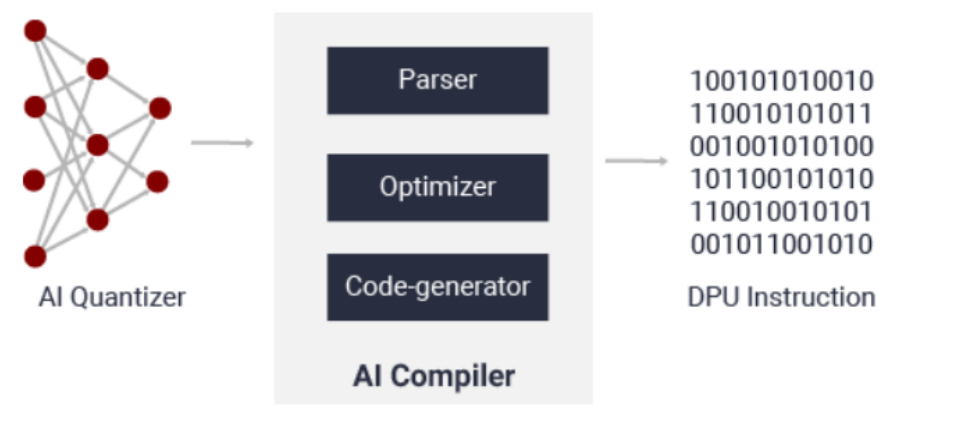
- **Shared Repository of Pre-Trained AI Models**
  - Ready to Deploy, Pre-Optimized Models
  - 50+ Models Support Broad Range of Applications
  - Open and Available on GitHub
- **Leverage Standard Frameworks, Networks, Datasets**
  - Trained Using TensorFlow and Caffe
- **Deploy As-is, Re-Train or Further Optimize**
  - Caffe_Xilinx, a custom distribution of Caffe provided to test & finetune caffe models
  - Training code, test code and train eval instructions provided

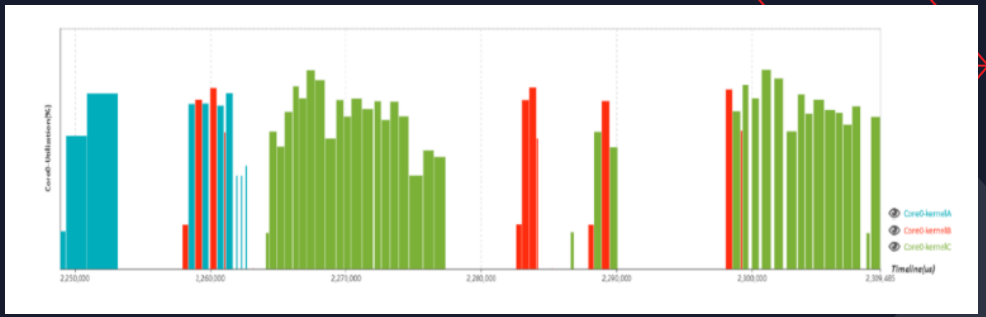
Application	Model
Face	Face detection
	Landmark Localization
	Face recognition
	Face attributes recognition
Pedestrian	Pedestrian Detection
	Pose Estimation
	Person Re-identification
Video Analytics	Object detection
	Pedestrian Attributes Recognition
	Car Attributes Recognition
	Car Logo Detection
	Car Logo Recognition
	License Plate Detection
	License Plate Recognition
ADAS/AD	Object Detection
	3D Car Detection
	Lane Detection
	Traffic Sign Detection
	Semantic Segmentation
	Drivable Space Detection

Vitis AI Development Kit

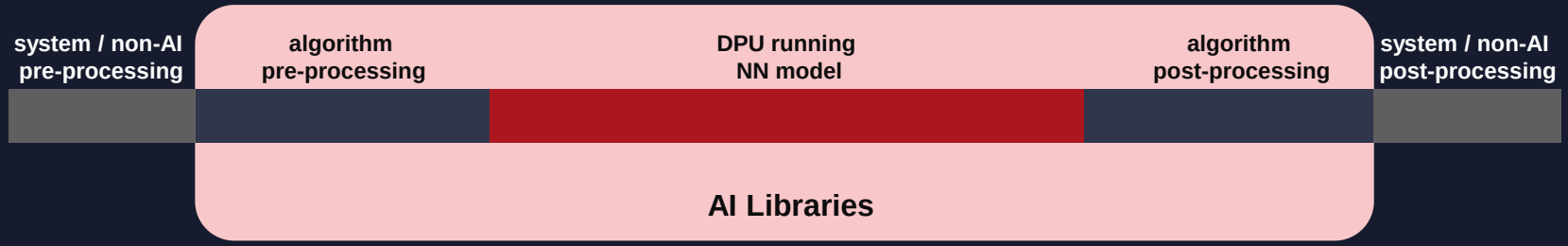








AI Profiler



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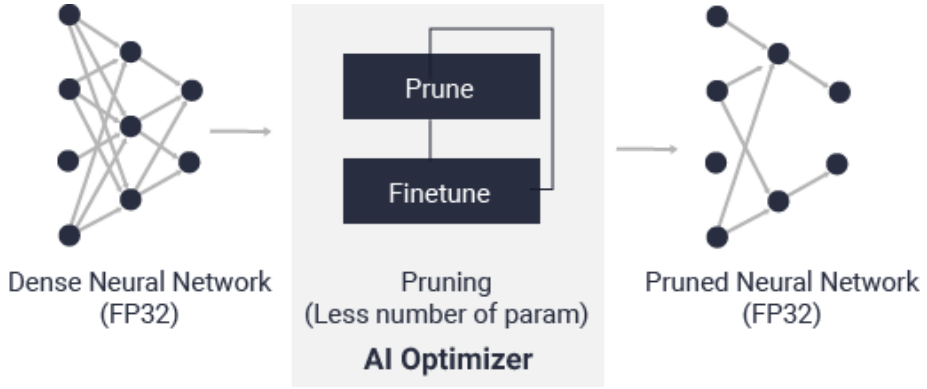
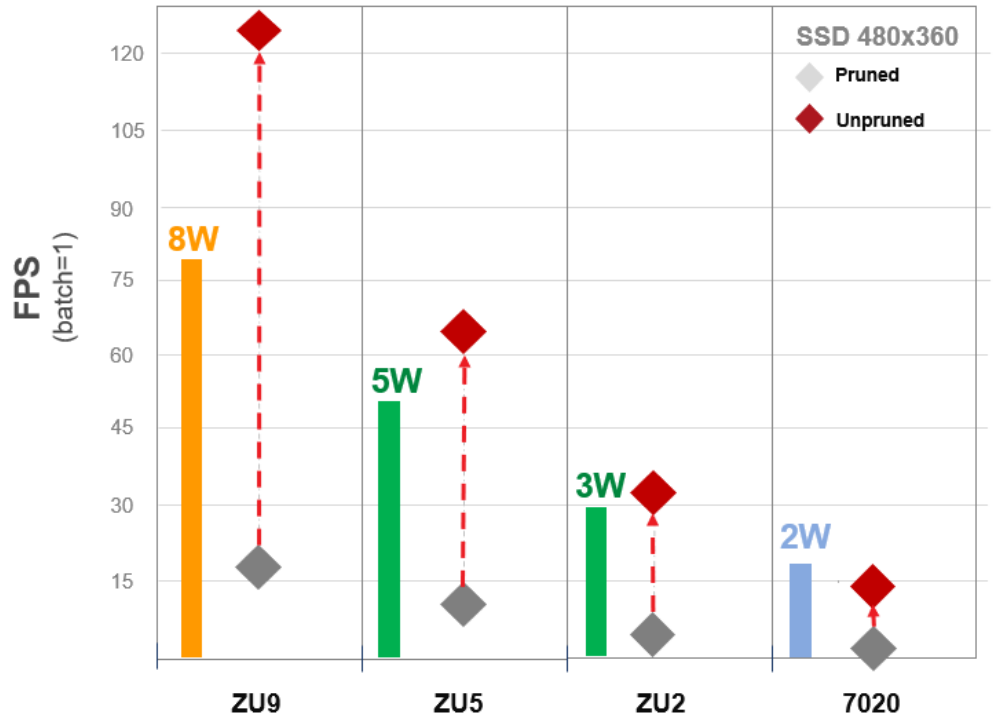
Vitis AI Optimizer





- **World's leading model compression**
  - Iterative, coarse-grained pruning
  - Reduce model size 5 – 30x
  - Increase performance 2 – 10x
  - Minimal accuracy loss, <1%
- **Supported framework**
  - Caffe, Darknet, TensorFlow
- **Commercial license available**
  - Contact Xilinx sales representative

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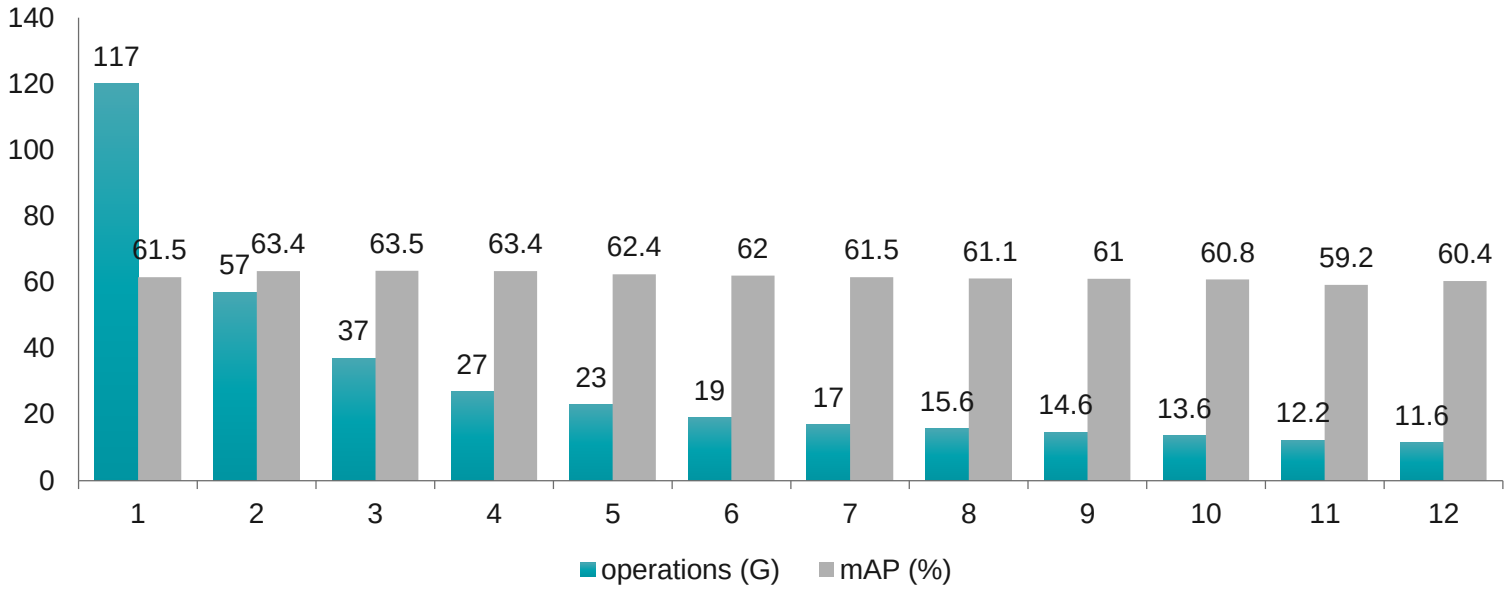
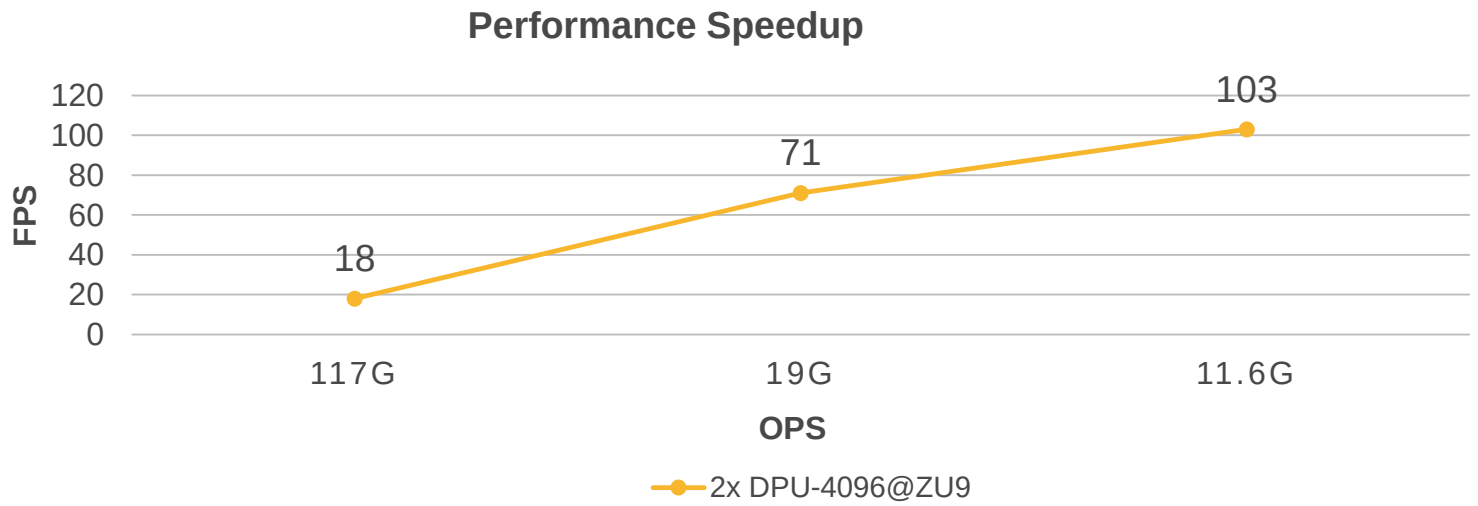
AI Optimizer Usage

- **Sensitivity analysis, searching for best pruning strategy**
- **Prune the network iteratively until the network's sparsity meets your needs**
- **Using the pruning tool**
  - Prune the network using a certain pruning ratio
  - Fine-tune the pruned network
  - Increase pruning ratio
  - Prune again
  - Loop the pruning-retraining iteration for a few times
  - Generate a final dense model

Example Using Vitis AI Optimizer





SSD+VGG @ Surveillance 4 Classes

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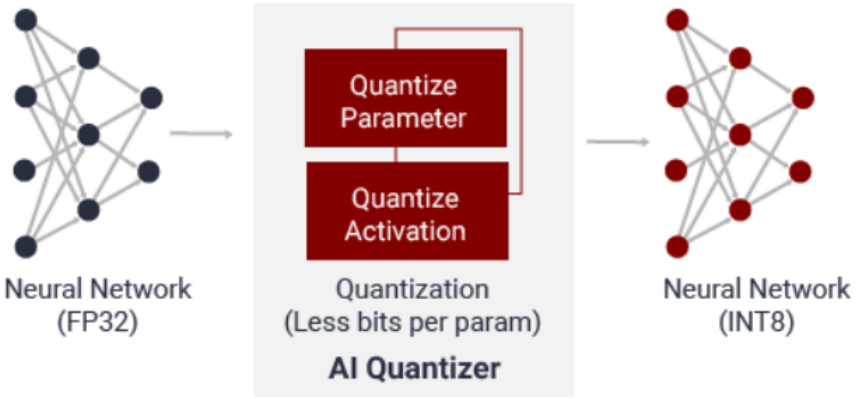
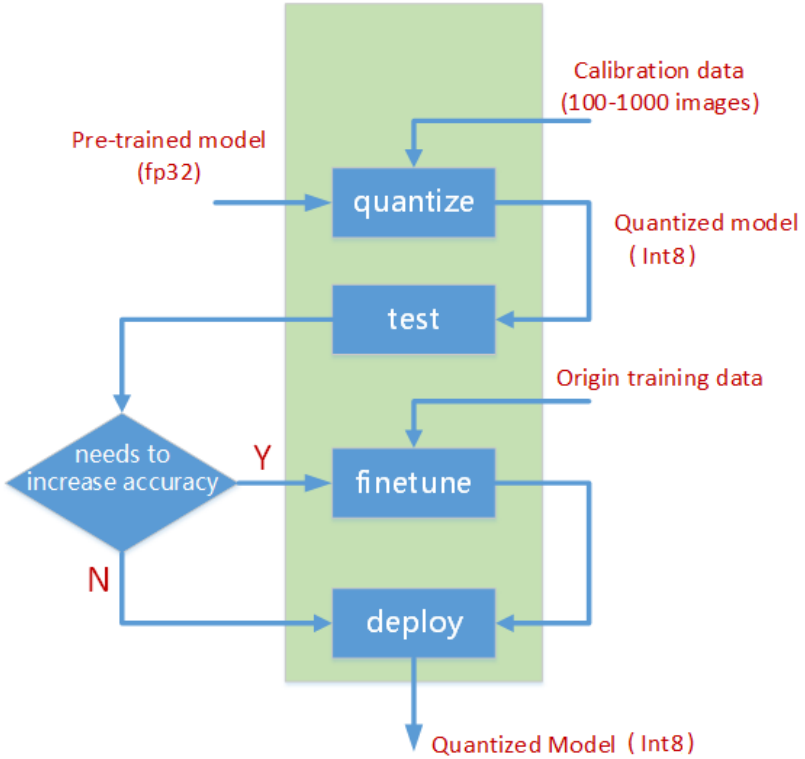
Vitis AI Quantizer





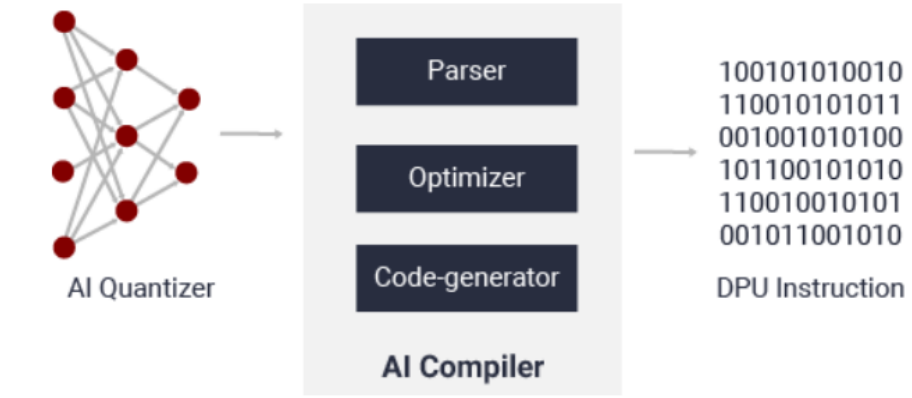
- **Uniform symmetric quantization**
  - 8bit for both weights and activation
- **Support both calibration and finetune**
  - Calibration – A small set of training data
  - Finetune – Original training data, further increase accuracy
- **Support framework**
  - Caffe, Tensorflow
  - Pytorch (Q2, 2020)
- **Have both GPU and CPU version**
  - GPU version is 10x faster than CPU version

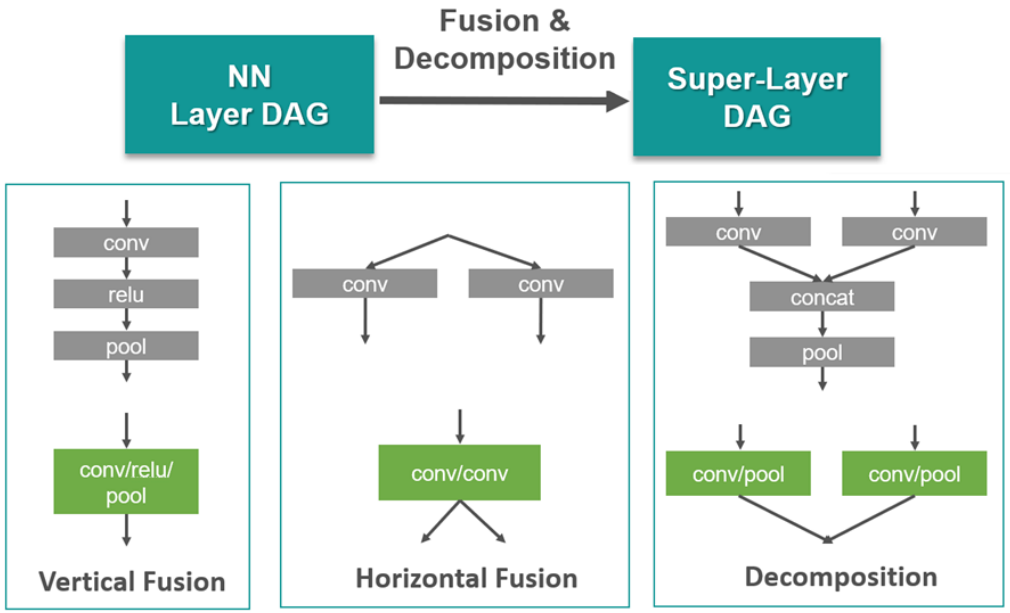
Quantization Result

Classification Networks	Float		8 bit quantized				After quantized finetune			
	Top1	Top5	Top1	ΔTop1	Top5	ΔTop5	Top1	ΔTop1	Top5	ΔTop5
Inception_v1	66.90%	87.68%	66.54%	-0.36%	87.58%	-0.10%	66.62%	-0.28%	87.58%	-0.10%
Inception_v2	72.78%	91.04%	71.93%	-0.85%	90.58%	-0.46%	72.40%	-0.38%	90.82%	-0.23%
Inception_v3	77.01%	93.29%	76.26%	-0.75%	92.85%	-0.44%	76.56%	-0.45%	93.00%	-0.29%
Inception_v4	79.74%	94.80%	79.04%	-0.70%	94.53%	-0.27%	79.42%	-0.32%	94.64%	-0.16%
ResNet-50	74.76%	92.09%	73.74%	-1.02%	91.44%	-0.65%	74.59%	-0.17%	91.95%	-0.14%
VGG16-3fc-float	70.97%	89.85%	70.67%	-0.30%	89.72%	-0.13%	70.74%	-0.23%	89.79%	-0.06%
MobileNet_v1	70.61%	89.63%	68.01%	-2.60%	88.14%	-1.49%	69.71%	-0.90%	89.06%	-0.57%

Detection Networks	Dataset	Float mAP	8 bit quantized mAP	ΔmAP
SSD_VGG	VOC 21 classes	76.47%	76.27%	-0.20%
SSD_MobileNet_v2	BDD100k 11 classes	30.80%	29.70%	-1.10%
SSDLite_MobileNet_v2	Customer's data	20.28%	20.12%	-0.16%

Vitis AI Compiler

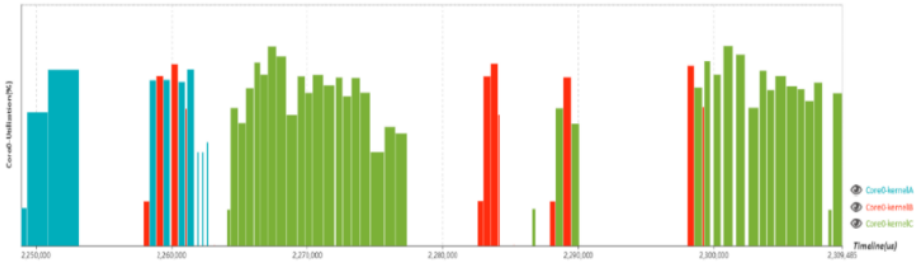




- **Maps the quantized model to instruction set and data flow**
  - High-efficient tensor-level DPU instruction set
- **Performs sophisticated optimizations**
  - Layer fusion and decomposition
  - Instruction scheduling
  - Reuses on-chip memory as much as possible
- **Support framework**
  - Caffe, Tensorflow
  - Pytorch (Q2, 2020)

Vitis AI Profiler

Layer-by-layer Profiling



ID	NodeName	Workload(MOP)	RunTime(ms)	Perf(GOPS)	Utilization	MB/S
0	conv1	236.0	5.28	44.66	19.4%	69.7
1	res2a_branch1	102.8	0.96	107.49	46.7%	1083.9
2	res2a_branch2a	25.7	0.23	111.70	48.6%	1779.4
3	res2a_branch2b	231.2	1.35	171.90	74.7%	328.7
4	res2a_branch2c	102.8	1.63	63.08	27.4%	643.8
5	res2b_branch2a	102.8	0.65	158.83	69.1%	1586.7
6	res2b_branch2b	231.2	1.34	172.03	74.8%	328.9
7	res2b_branch2c	102.8	1.64	62.74	27.3%	640.3
8	res2c_branch2a	102.8	0.65	159.07	69.2%	1589.1
9	res2c_branch2b	231.2	1.35	171.90	74.7%	328.7
...						
47	res5b_branch2a	102.8	1.00	102.35	44.5%	1180.3
48	res5b_branch2b	231.2	1.77	130.33	56.7%	1363.8
49	res5b_branch2c	102.8	1.30	78.80	34.3%	928.5
50	res5c_branch2a	102.8	1.01	101.74	44.2%	1173.3
51	res5c_branch2b	231.2	1.76	131.59	57.2%	1377.0
52	res5c_branch2c	102.8	1.27	80.66	35.1%	949.6
Total Nodes In Avg:	All	7711.9	66.43	116.10	50.5%	668.8

End-to-end Profiling

Task Name	Start Time (us)	End Time (us)	Duration (us)
xilinx::ai::yolov3_post_process	1677531	1677990	458
xilinx::ai::YOLOv3Imp::run	1678003	1804787	126783
xilinx::ai::ConfigurableDpuTaskImp::setInputImageRGB	1678012	1680140	2128
xilinx::ai::DpuTaskImp::setImageRGB_1	1678018	1680139	2120
xilinx::ai::DpuTaskImp::setImageRGB	1678025	1680137	2111
xilinx::ai::NormalizeInputDataRGB	1678036	1680121	2085
xilinx::ai::ConfigurableDpuTaskImp::run	1680145	1804366	124220
xilinx::ai::DpuTaskImp::run	1680183	1804361	124178
dpu	1740888	1804325	63436
xilinx::ai::yolov3_post_process	1804380	1804782	401
xilinx::ai::YOLOv3Imp::run	1804804	1931732	126927
xilinx::ai::ConfigurableDpuTaskImp::setInputImageRGB	1804817	1807077	2260

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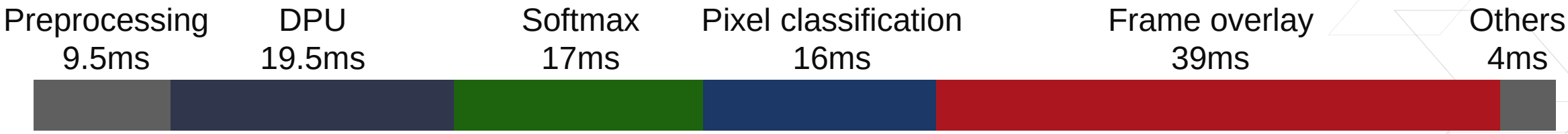
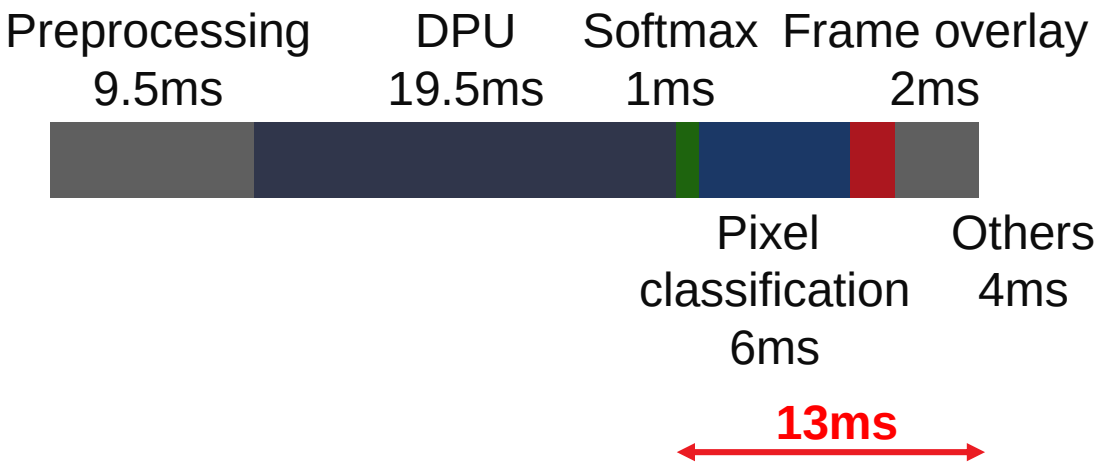
Performance Optimization with End-to-end Profiling

> **Before optimization**



76ms

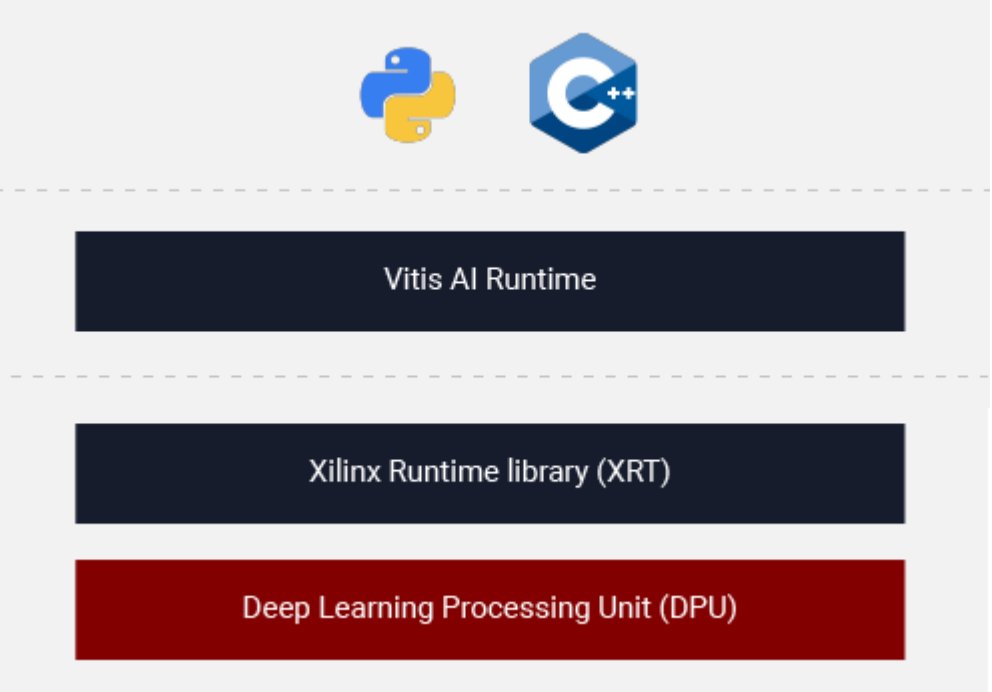
> **After optimization**



13ms

- >> Use Vitis libraries / custom hardware IPs
- >> Use NEON to accelerate the computing
- >> Use Eigen/BLAS library to perform linear superposition

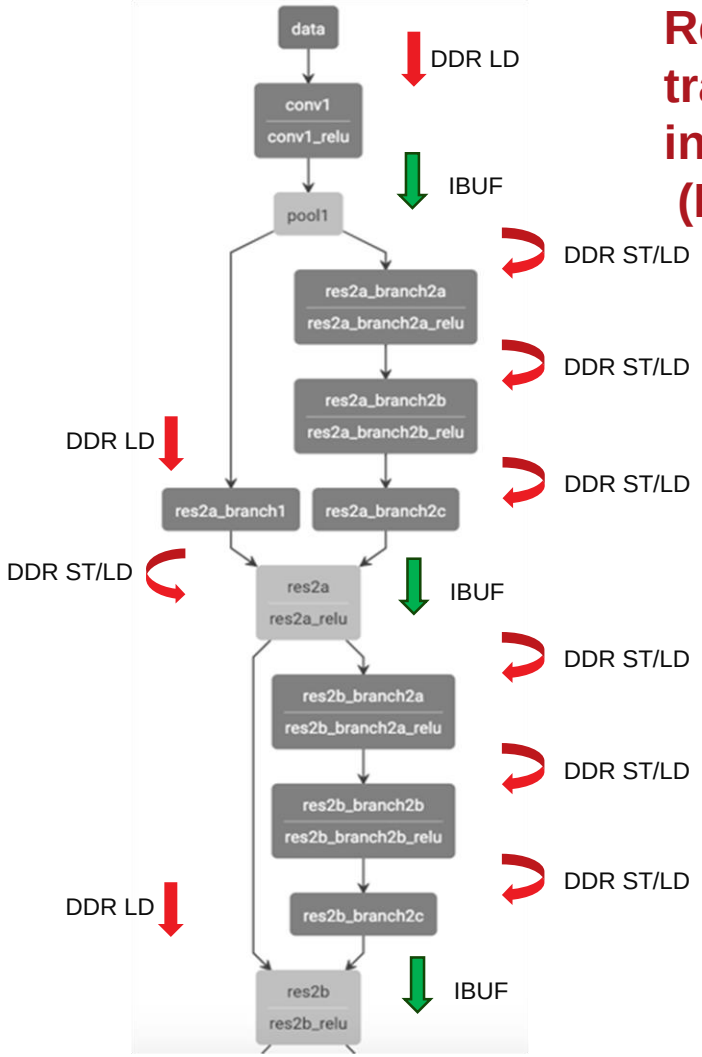
Vitis AI Runtime



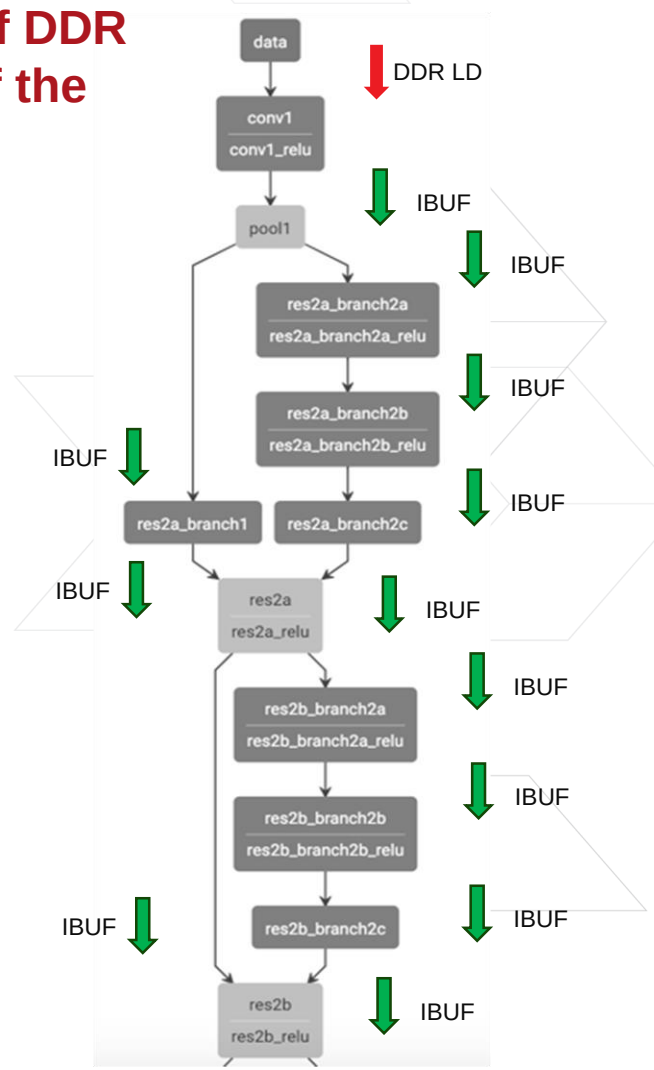
- Vitis AI Runtime
  - Efficient task scheduling
  - Memory management
  - Multi-threading
  - Interrupt handling
- Vitis AI Runtime API
  - A lightweight set of high-level C++ & Python APIs
  - Common for both embedded and Alveo/Cloud

Vitis AI Runtime Features

- Cacheable memory management
- QoS based scheduling
- IFM/OFM buffer detached from intermediate buffer
- Optimize DPU scheduling based on model topology



Reduce 80.37% of DDR traffic and 88% of the instructions! (ResNet-50)



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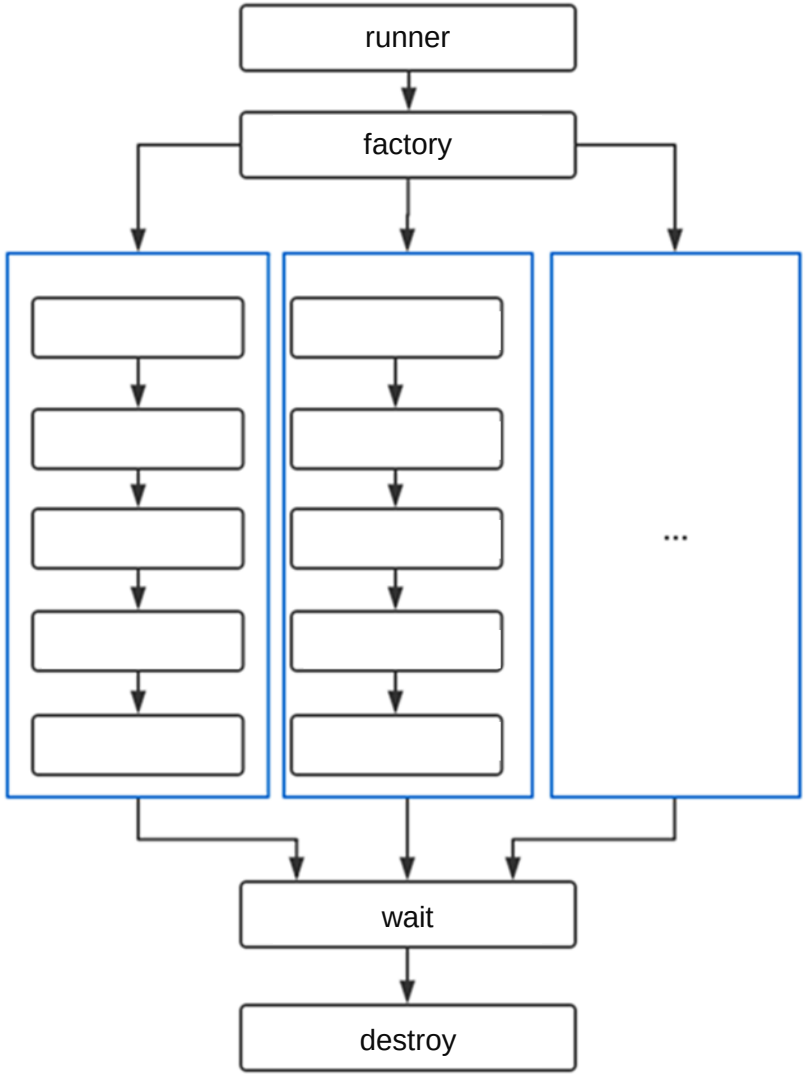
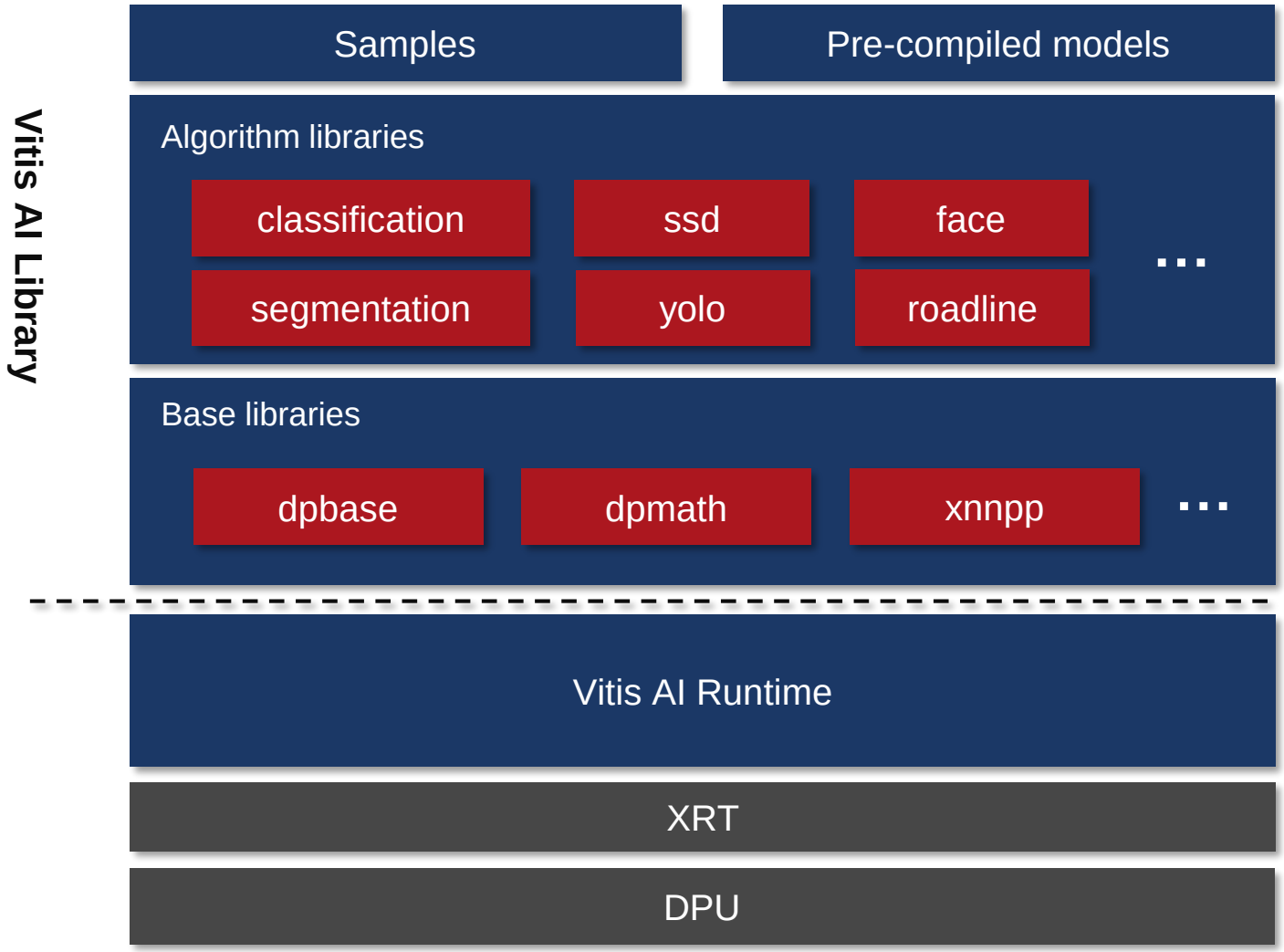
Multi-threading Support



- Multiple models with zero switching overhead
- Multiple threads for better throughput performance
- Multiple processes for multiple channel applications

Vitis AI Library



- Ease of Use
  - Quicker mode deployment
  - Easier AI application development
- Performance Optimized
  - Optimized pre & post processing
- Open
  - Open source
  - Fully sync with Vitis AI Model Zoo

Algorithm libraries: Unified API Interface

Get an instance of derived class

Get width and height for required by Algorithm

DPU run and get results

```
class YOLOv3 {
public:
  static std::unique_ptr<YOLOv3> create(const std::string &model_name,
                                        bool need_preprocess = true);
protected:
  explicit YOLOv3();
  YOLOv3(const YOLOv3 &) = delete;
public:
  virtual ~YOLOv3();
public:
  virtual int getInputWidth() const = 0;
  virtual int getInputHeight() const = 0;

  virtual YOLOv3Result run(const cv::Mat &image) = 0;

};
```

Implement YOLOv3 in AI Library

- Most important is to implement **run()** method

Pre-processing

Running DPU

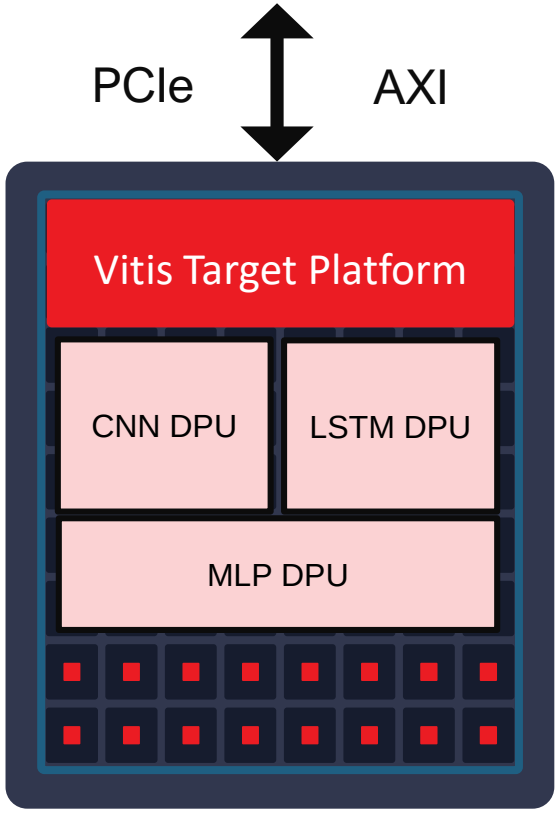
Post-processing

```
YOLOv3Result YOLOv3Imp::run(const cv::Mat &input_image) {
  cv::Mat image;
  int sWidth = getInputWidth();
  int sHeight = getInputHeight();
  auto mAP = configurable_dpu_task_->getConfig().yolo_v3_param().test_map();
  LOG_IF(INFO, false) << "tf_flag_ " << tf_flag_ << " " //
                      << "mAp " << mAP << " "           //
                      << std::endl;
  if (mAP) {
    if (!tf_flag_) {
      int channel = configurable_dpu_task_->getInputTensor()[0][0].channel;
      float scale = xilinx::ai::tensor_scale(
          configurable_dpu_task_->getInputTensor()[0][0]);
      int8_t *data =
          (int8_t *)configurable_dpu_task_->getInputTensor()[0][0].data;
      LOG_IF(INFO, false) << "scale " << scale << " "     //
                          << "sWidth " << sWidth << " "   //
                          << "sHeight " << sHeight << " " //
                          << std::endl;
      yolov3::convertInputImage(input_image, sWidth, sHeight, channel, scale, data);
    } else {
      image = yolov3::letterbox_tf(input_image, sWidth, sHeight).clone();
      configurable_dpu_task_->setInputImageRGB(image);
    }
  } else {
    auto size = cv::Size(sWidth, sHeight);
    if (size != input_image.size()) {
      cv::resize(input_image, image, size, 0, 0, cv::INTER_LINEAR);
    } else {
      image = input_image;
    }
    //  convert_RGB(image);
    __TIC__(YOLOV3_SET_IMG)
    configurable_dpu_task_->setInputImageRGB(image);
    __TOC__(YOLOV3_SET_IMG)
  }
  __TIC__(YOLOV3_DPU)
  configurable_dpu_task_->run(0);
  __TOC__(YOLOV3_DPU)

  __TIC__(YOLOV3_POST_ARM)

  auto ret = xilinx::ai::yolov3_post_process(
      configurable_dpu_task_->getInputTensor()[0],
      configurable_dpu_task_->getOutputTensor()[0],
      configurable_dpu_task_->getConfig(), input_image.cols, input_image.rows);

  __TOC__(YOLOV3_POST_ARM)
  return ret;
}
```

Deploy Yolov3 Using AI Library

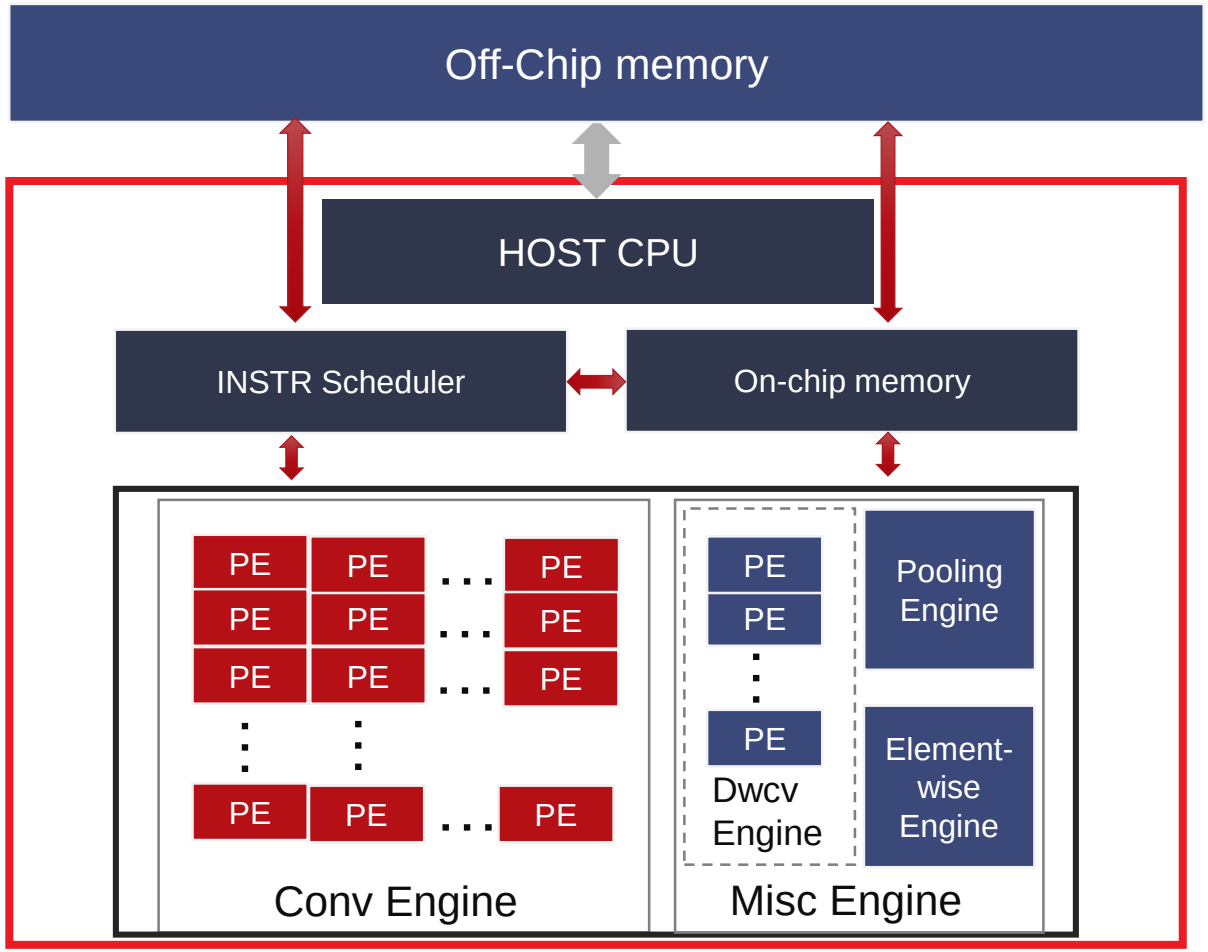
```
cv::Mat img = cv::imread(argv[2]);
auto yolo = xilinx::ai::YOLOv3::create(argv[1], true);

int width = yolo->getInputWidth();
int height = yolo->getInputHeight();
cv::Mat img_resize;
cv::resize(img, img_resize, cv::Size(width, height), 0, 0, cv::INTER_LINEAR);

auto results = yolo->run(img_resize);

for (auto &box : results.bboxes) {

  int label = box.label;
  float x = box.width * img.cols;
  float y = box.height * img.rows;
  float confidence = box.score;

  cout << "RESULT: " << label << "\t" << xmin << "\t" << ymin << "\t" << xmax
       << "\t" << ymax << "\t" << confidence << "\n";
  rectangle(img, Point(xmin, ymin), Point(xmax, ymax), Scalar(0, 255, 0), 1,
            1, 0);
}
```

Deep Learning Processing Unit (DPU)



- **Domain-Specific Architecture for AI Inference**
  - High-efficient Programmable Tensor Processor
  - Scalable across All Xilinx Platforms
- **Tailored for Different AI Workloads**
  - CNN, LSTM, MLP, …
  - Fully HW customizable and adaptable
  - Optimized for throughput, latency or utilization
- **Ease of Use**
  - Easy System Integration with Vitis or Vivado
  - Detailed Refence Design and Tutorials

CNN DPU for Zynq SoC / MPSoC



- **Flexible and Configurable DPU**
  - Configurable hardware architecture includes：Z7020 to Z7100, ZU2 to ZU11
  - Relu, Relu6, LeakyRelu
  - Max/Average pooling 2x2~8x8
  - Ram usage for higher performance or lower resource utilization
  - Core number, BRAM or URAM, More DSP or less DSP
  - Support channel augmentation to improve performance
  - Support low power consumption feature

CNN DPUs for Alveo

HIGH

THROUGHPUT

LOW

LATENCY

HIGH

Latency optimized

- Alveo U280 /U50
- Optimized for MobileNet-like models and HBM devices
- Extreme low latency with high-resolution images

Throughput optimized (DDR)

- Alveo U200 / U250
- Optimized for 100% INT8 models and ResNet/Inception Models
- Optimized for pruned models
- High Throughput at medium latency

Throughput optimized (HBM)

- Alveo U280 / U50
- Optimized for ResNet/Inception models and HBM devices
- Low-cost and high power efficiency solution

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CNN DPU for Alveo: Applications

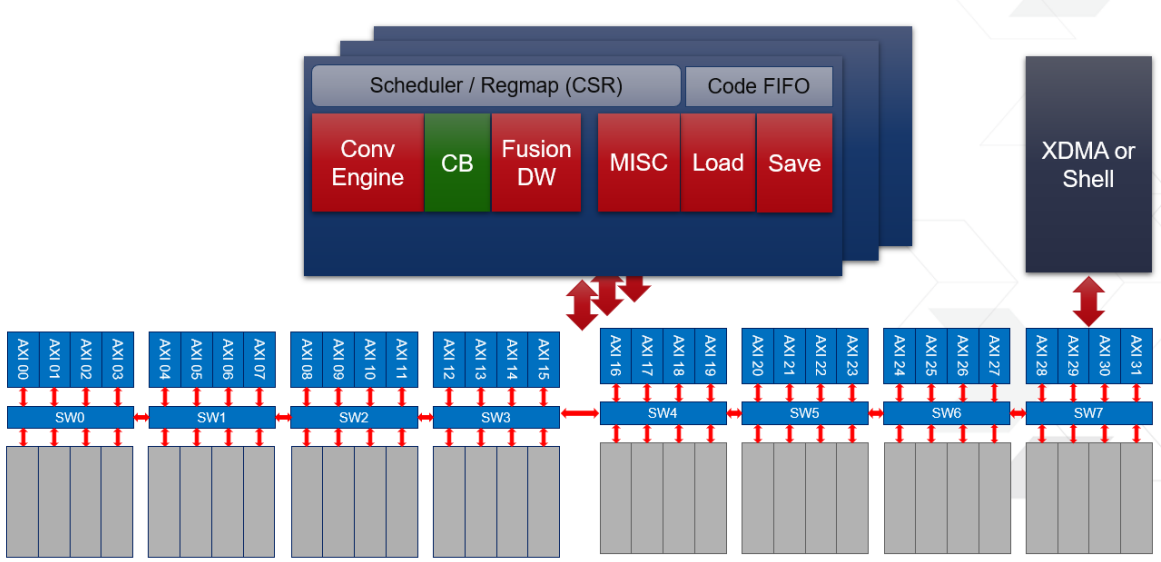
Automated Driving

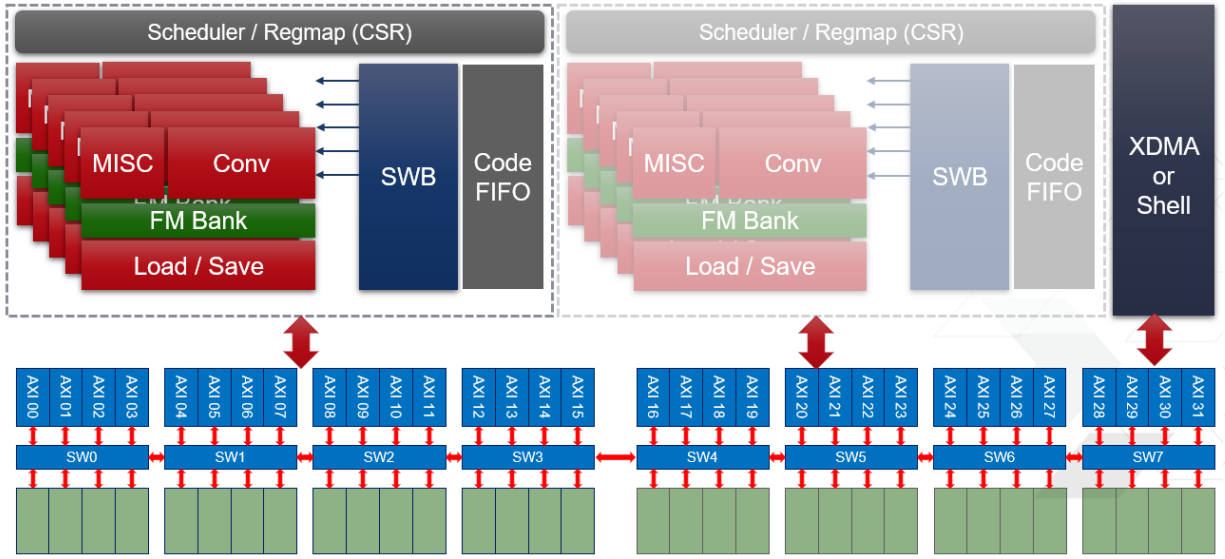
- Ultra low latency DPU
- High HW parallelism for conv & depthwise conv

Data Center

- Flexible pipeline with optimized architecture
- Multi-engine organization for SLR implementation

CNN DPU for Alveo





- **Latency Optimized**
  - Mobilenetv2 1920x1080, <13ms @ U50
- Throughput Optimized
  - Resnet50, 1100fps @ U50

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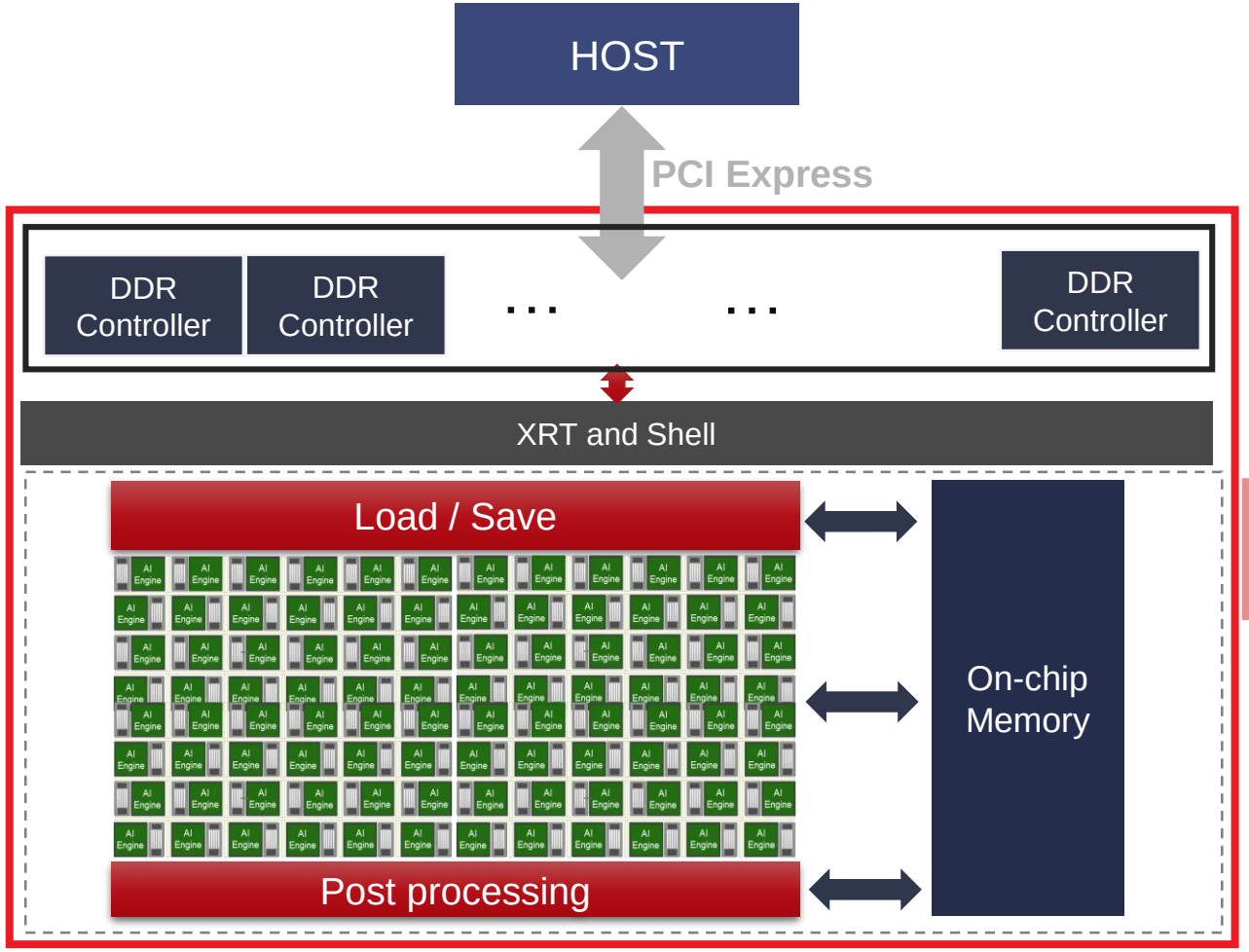
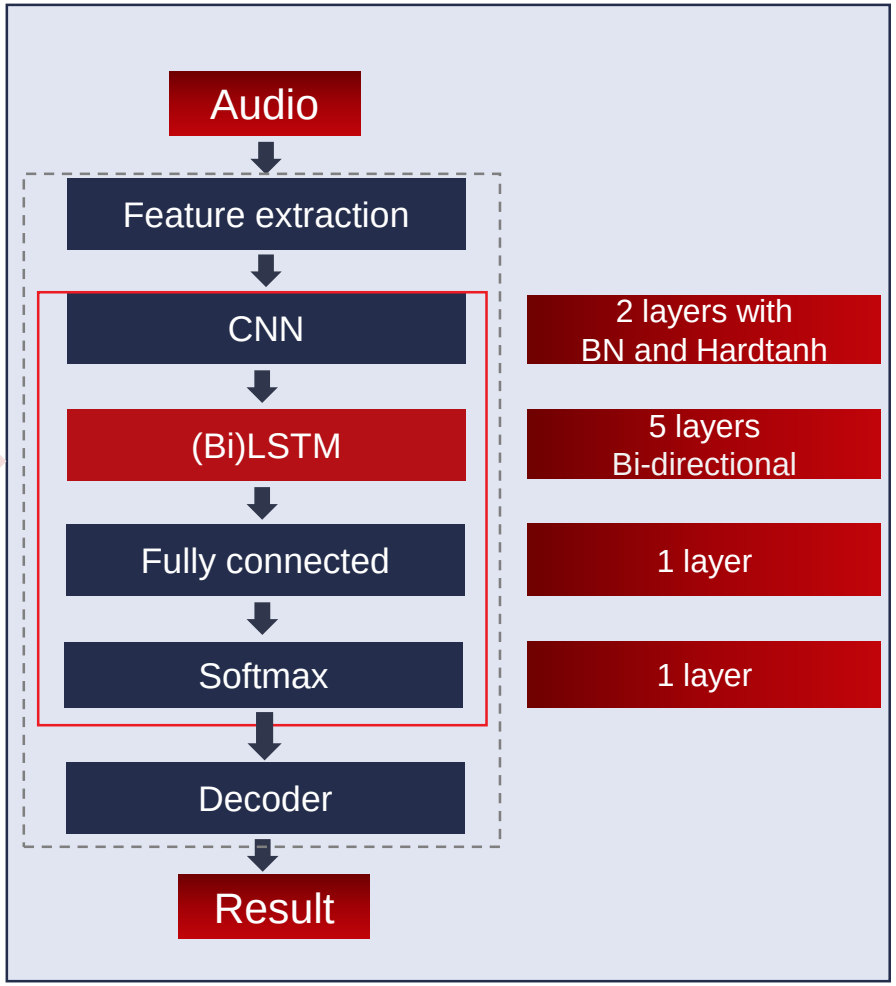
LSTM DPU for Versal ACAPs



Flow Chart



- **Low Latency LSTM Acceleration**
  - Ultra low latency
  - Matrix multiplication in AI Engine

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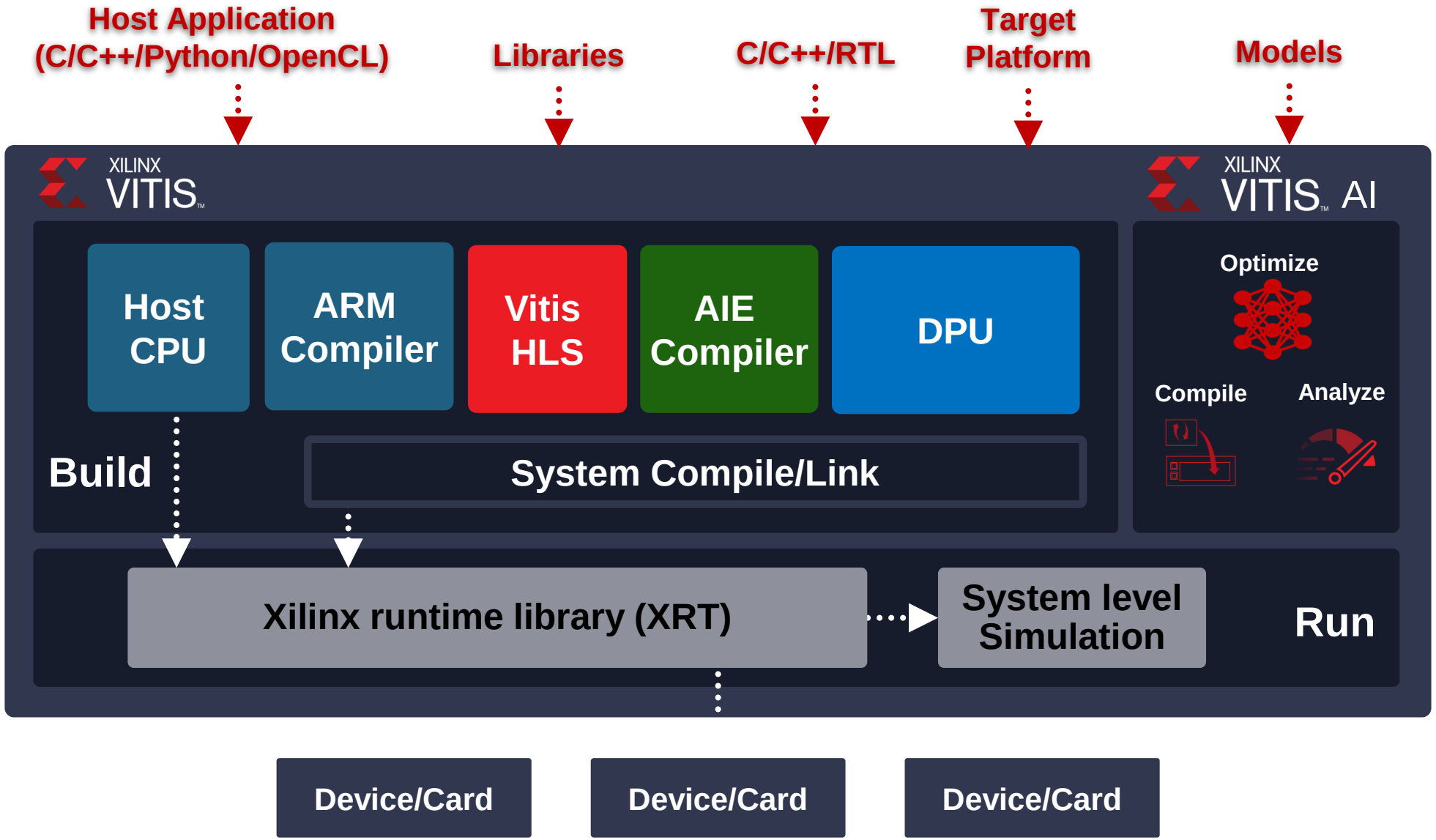
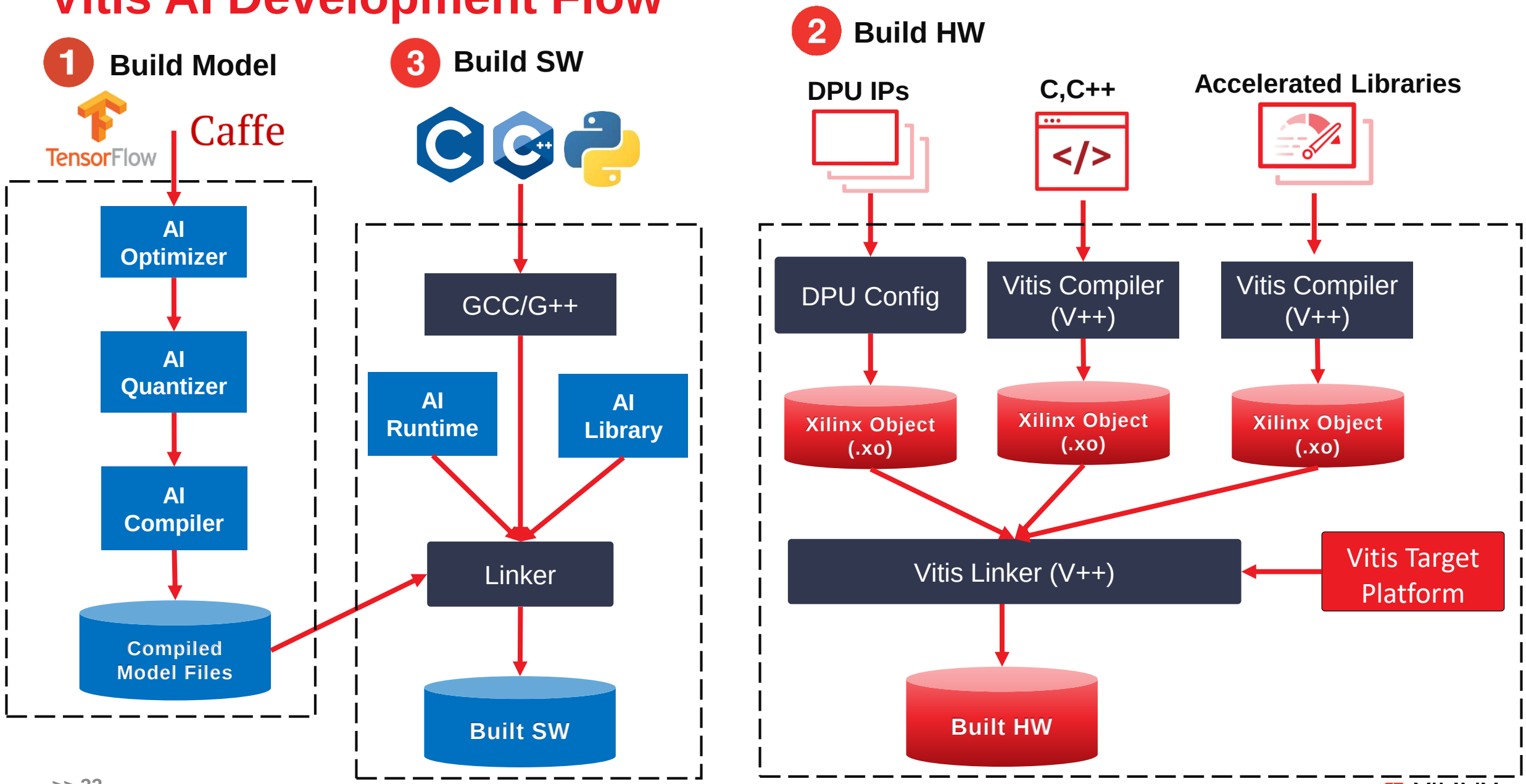
Build: Comprehensive Development Tool Suite



Vitis AI Development Flow



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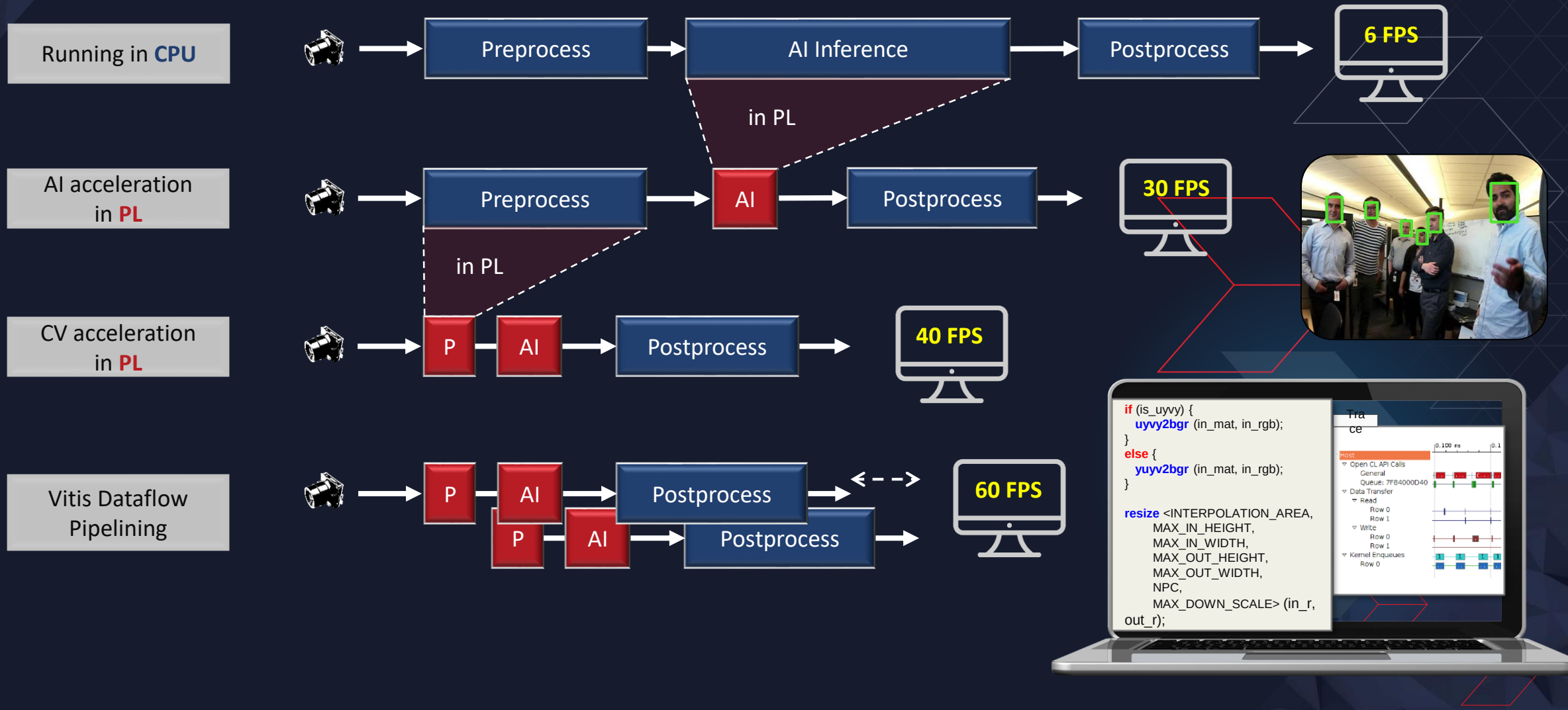
An Example of Vitis AI Development



Vitis AI Programming Interface

- Unified high-level C++/Python programming APIs
  - For all DPU
  - Will keep forward compatibility
  - Add new APIs if necessary

- Low-level C++/Python programming APIs
  - Come from legacy DNNDK and keep backward compatibility
  - For Edge DPU (DPUv2) only

Vitis AI Programming with Unified APIs

- **C++ APIs**
  - DpuRunner::create_dpu_runner()
  - DpuRunner::execute_async()
  - DpuRunner::wait()
  - DpuRunner::get_tensor_format()
  - DpuRunner::get_input_tensors()
  - DpuRunner::get_output_tensors()
- **Python APIs**
  - runner.Runner()
  - runner.execute_async()
  - runner.wait()
  - runner.get_tensor_format()
  - runner.get_input_tensors()
  - runner.get_output_tensors()

Vitis AI Samples with Unified APIs

ID	Example Name	Models	Framework	Notes
1	resnet50	ResNet50	Caffe	Image classification with Vitis AI unified C++ APIs.
2	resnet50_mt_py	ResNet50	TensorFlow	Multi-threading image classification with Vitis AI unified Python APIs.
3	inception_v1_mt_py	Inception-v1	TensorFlow	Multi-threading image classification with Vitis AI unified Python APIs.
4	pose_detection	SSD, Pose detection	Caffe	Pose detection with Vitis AI unified C++ APIs.
5	video_analysis	SSD	Caffe	Traffic detection with Vitis AI unified C++ APIs.
6	adas_detection	YOLO-v3	Caffe	ADAS detection with Vitis AI unified C++ APIs.
7	segmentation	FPN	Caffe	Semantic segmentation with Vitis AI unified C++ APIs.

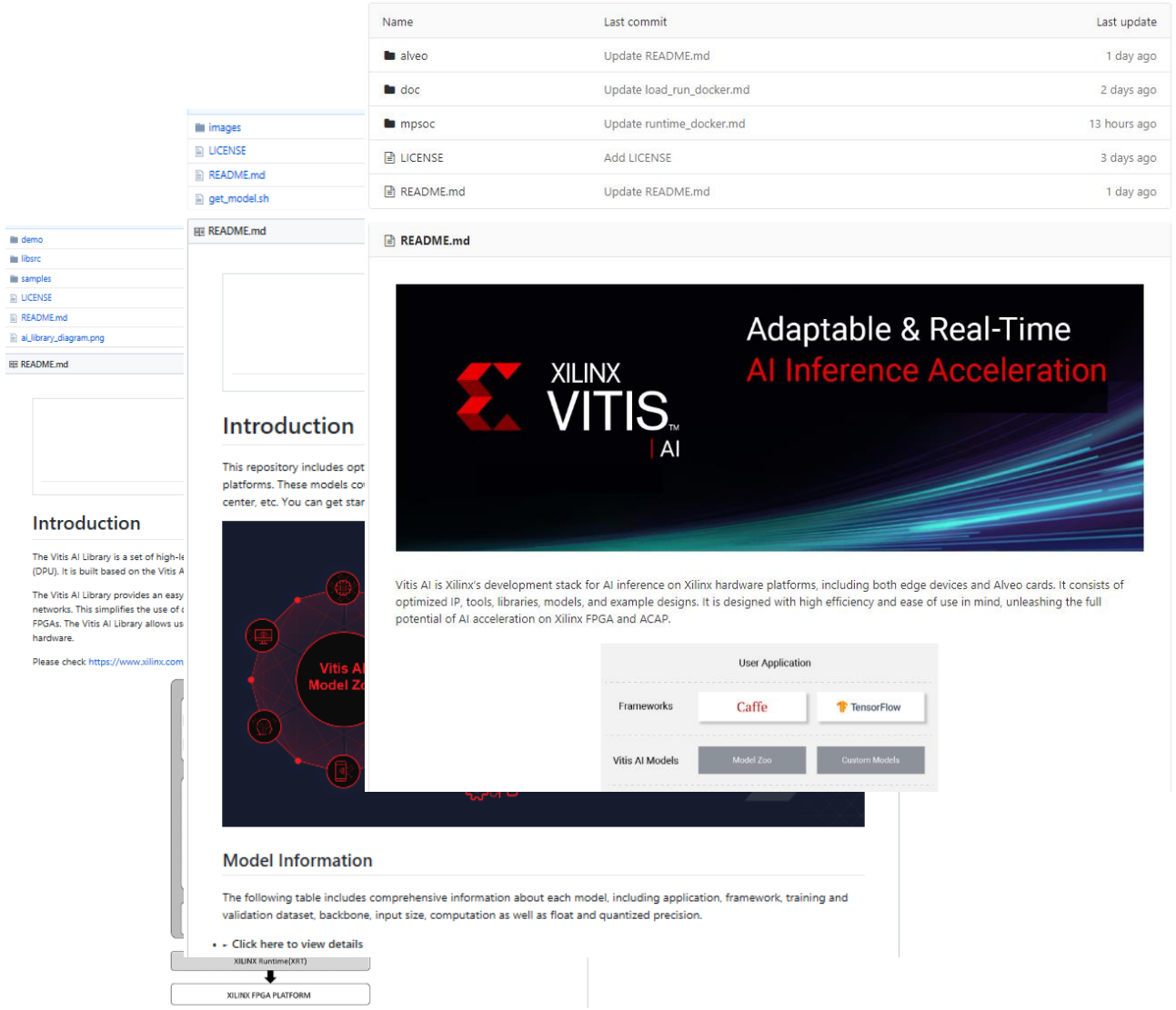
Vitis AI Programming with Unified APIs

- **Sample1 - ResNet50**
  - Caffe
  - C++ APIs
  - https://github.com/Xilinx/Vitis-AI/tree/master/mpsoc/vitis_ai_samples_zcu102/resnet50
  - https://github.com/Xilinx/Vitis-AI/tree/master/alveo/examples/vitis_ai_alveo_samples/resnet50

- **Sample2 - Inception-v1**
  - TensorFlow
  - Python APIs
  - https://github.com/Xilinx/Vitis-AI/tree/master/mpsoc/vitis_ai_samples_zcu102/inception_v1_mt_py
  - https://github.com/Xilinx/Vitis-AI/tree/master/alveo/examples/vitis_ai_alveo_samples/inception_v1_mt_py

Quick Links to Start Developing Today !

- [Getting Started from Vitis AI Github]
- [Vitis AI Model Zoo]
- [Vitis AI Optimizer Lounge*]
- [Vitis AI DPU TRD]
- [Vitis AI Library]
- [Vitis AI Tutorial]
- [Vitis AI Toolbox on SourCe]
- [Vitis AI Forum]



*** Approval required**

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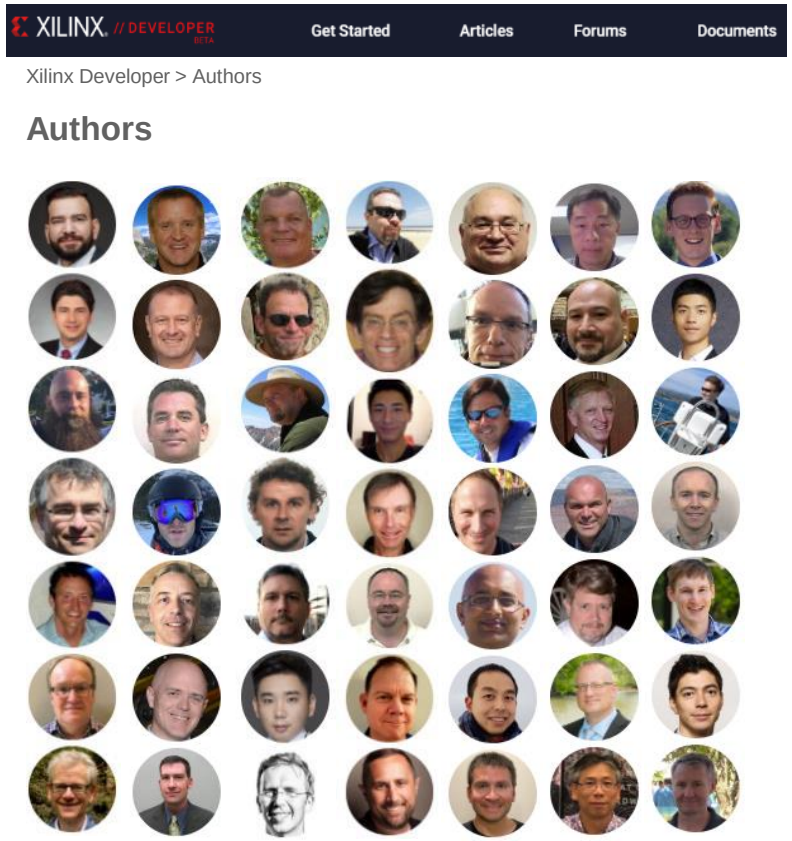

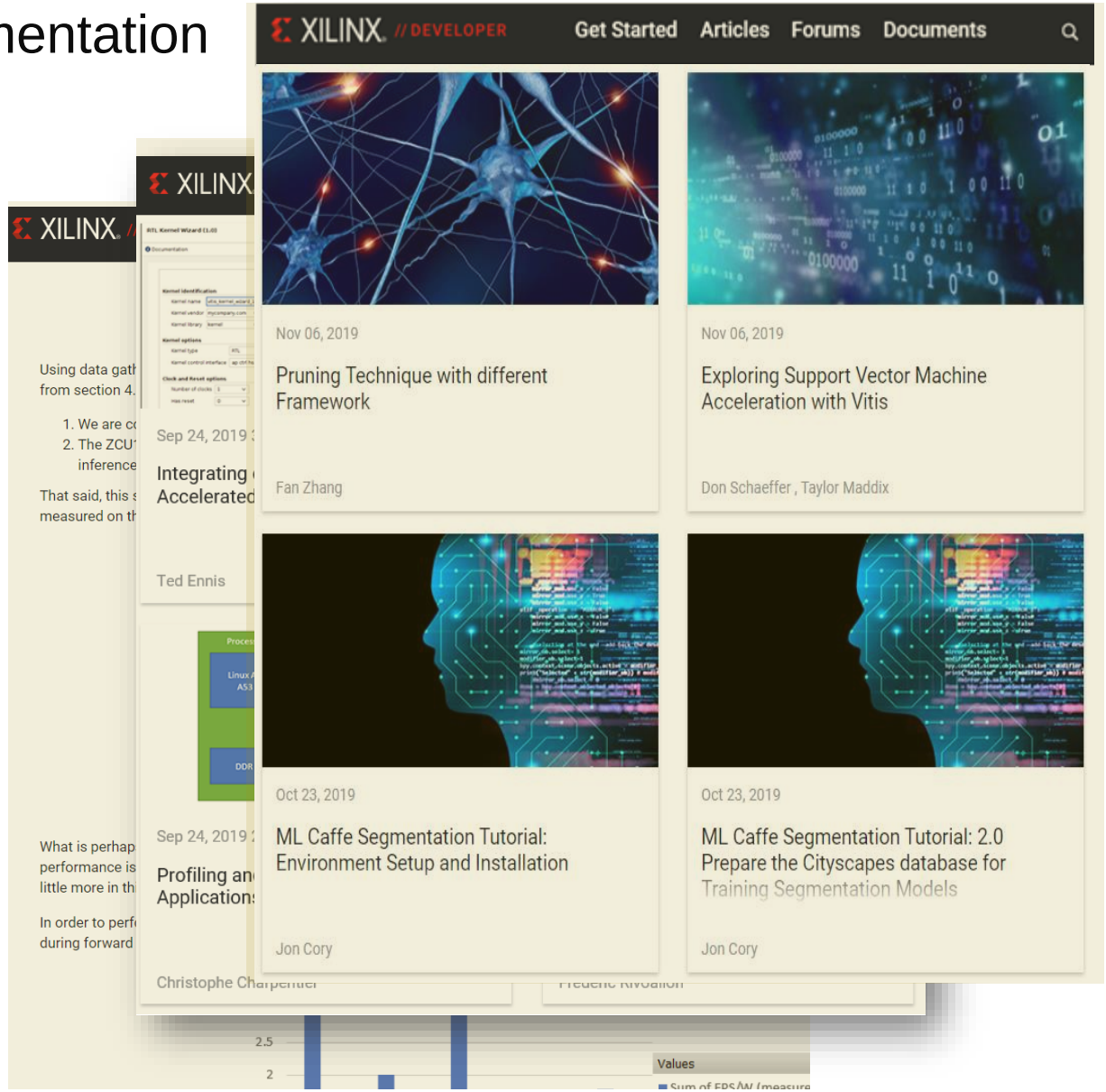

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Adaptable & Real-Time AI Inference Acceleration

- **Unified AI Platform**
  - Cloud to edge with unified environment and APIs
  - Comprehensive models and libraries
- **Work at Speed of Innovation**
  - Hardware adaptable to models & workloads
  - From model to implementation in minutes
- **Whole Application Acceleration**
  - End-to-end X + AI acceleration
  - Heterogenous integration & acceleration through Vitis

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