AI on IBM zSystems

Accelerating AI inference for high volume transactional workloads on IBM z16

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Agenda

01 The modern mainframe

02 OLTP workload Primer

03 IBM Telum

04 Software ecosystem

05 Putting it all together

IBM zSystems is at the core of the world's businesses

72% of the customer-facing applications are backed by IBM zSystems applications and data

70% of business transactions run on IBM zSystems (including 90% of all credit card transactions)

... and this means 30B transactions per day

Who runs their businesses on IBM zSystems?

67 of the Fortune 100

45 of the world's top 50 banks

8 of the top 10 insurers

4 of the top 5 airlines

7 of the top 10 global retailers

8 of the top 10 telco's

24 of the top 25 countries by GDP*

IBM zSystems - the backbone of critical business processes and the world's economy

… for unmatched reliability and security across 70%+ of Fortune 500 companies

Banking

92 of the top 100 banks

- ATM transaction processing
- Financial services transactions
- Clearing and statutory reporting
- Mobile banking apps and web payment platforms

Insurance

8 of the top 10 insurance providers

- Insurance claims processing
- Customer information management
- Billing and payments systems of record

Retail

7 of the top 10 global retailers

- Customer transaction processing with 24x7 uptime during seasonal peaks
- Secure and compliant store for customer data (GDPR, CCPA, etc.)

Healthcare

8 of the top 10 global healthcare providers

- Pervasive encryption for electronic health records systems
- Regulation compliant analytics for Protected Health Information (PHI) workloads

What is at Stake for IBM zSystems clients?

DAILY

30 billion transactions

400 million retail transactions

1 million hotel nights

ANNUALLY

29 billion ATM transactions

87% of all credit card transactions

90% of all airline reservations

The biggest customers use IBM zSystems because…

- it is reliable → The famous “7 nines” availability (99.99999%)
  - 3.2 secs of downtime per year and a Mean Time Between Failures (MTBF) measured in decades!
- it runs mixed workloads → OLTP, databases, analytics and batch on the same machine with 90%+ CPU utilization
- it is secure → With technologies like Pervasive Encryption data from the IBM zSystems remains encrypted at every point of its life cycle
- it is highly scalable → 1 – 200 computing cores, >10,000 Linux VMs on a single server
- it is cost-efficient → IBM zSystems houses > 70% of enterprise data assets but account for <10% of total IT costs
- it is modern → zSystems runs Linux, OpenShift, Python, Blockchain, talks REST APIs and makes a perfect link of the DevOps chain

Two faces of IBM zSystems

Mostly “foundational” workload…

Db2

CICS

COBOL

MQ

IMS

Java

zSystems

zOS, Linux, zVM, KVM, zTPF, zVSE

LinuxONE

Linux, KVM, zVM

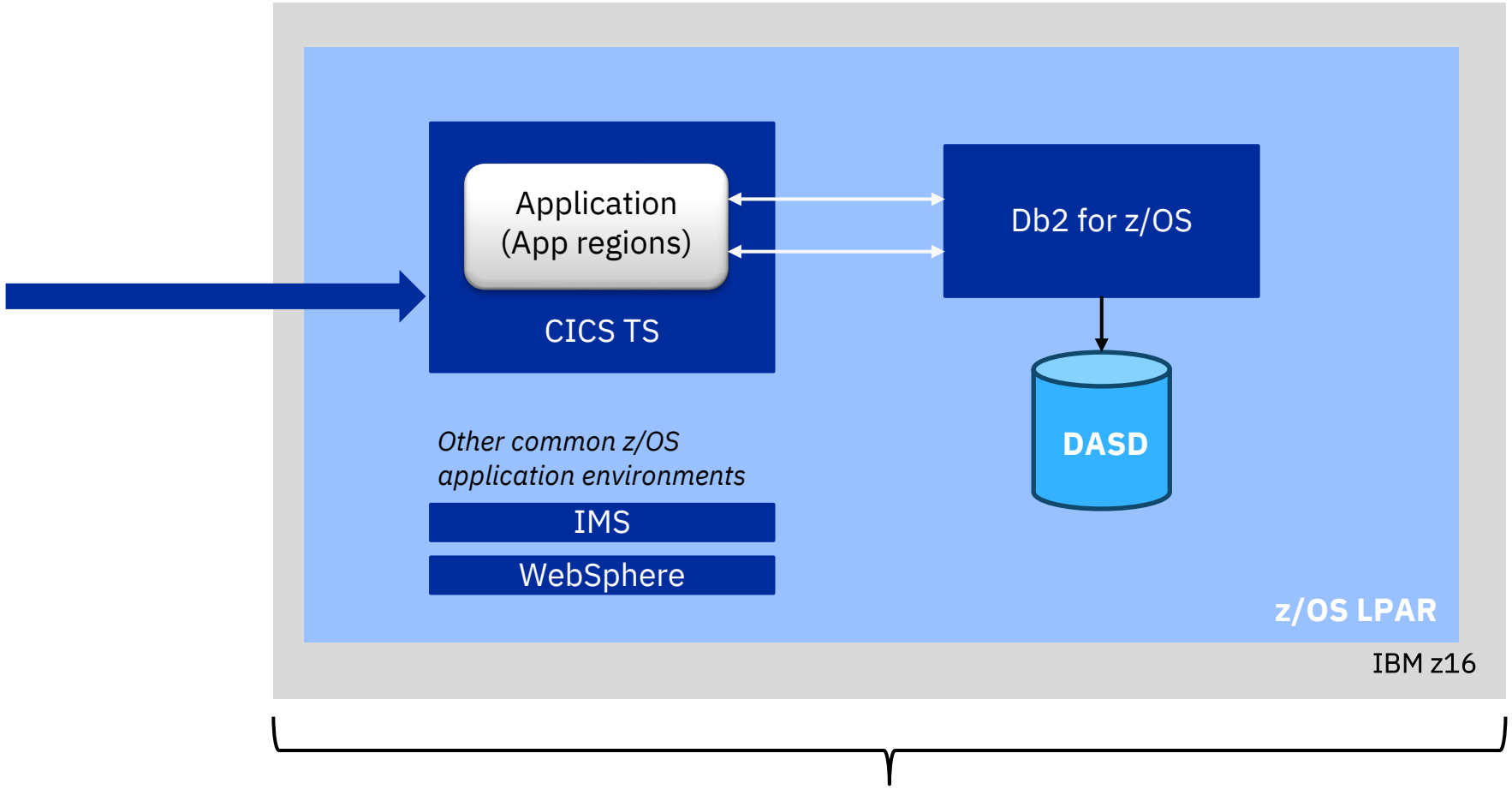
The majority of the open-source products

Anatomy of a typical z/OS transaction workload environment

Core business systems and databases co-located in a logical partition.

Reliability, availability, serviceability core considerations clients rely on.

Parallel Sysplex (not shown) provides for tightly coupled multi-system management with ongoing data consistency (not “eventual consistency”)



SLA = Service level agreement

Transaction processing workloads are often high volume, low latency workloads with tight SLA requirements.

Large credit card processor example:
- 60,000 transaction per second
- <10ms per request

Challenges to leverage AI in this environment

80%

of respondents agreed that real-time insights are important[1]

49%

getting insights where and when they are needed is a big challenge[2]

(difficulty with applying AI to business-critical workloads

without impacting SLAs)

10%

of transactions in high volume enterprise workloads go through real-time AI screening[3]

Telum Processor and IBM z16

- Telum: Next generation IBM Z processor optimized to run enterprise workloads with embedded real time AI insights
  - 7nm design with 8 cores per chip @5.2 GHz
  - 40% per socket performance growth
  - Quantum-safe cryptography
  - On-chip low latency AI acceleration
- IBM z16 is announced earlier this year with up to 32 Telum processors and 40 TB of memory

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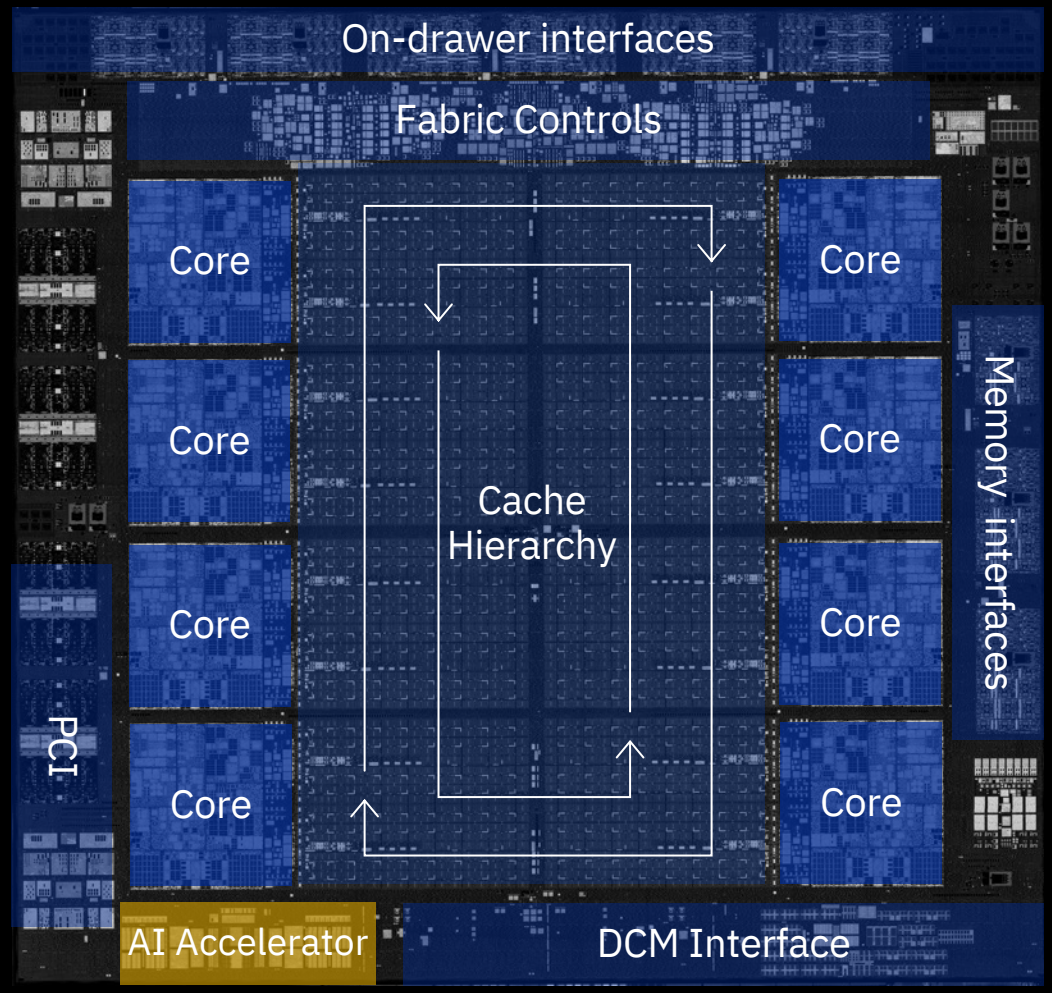


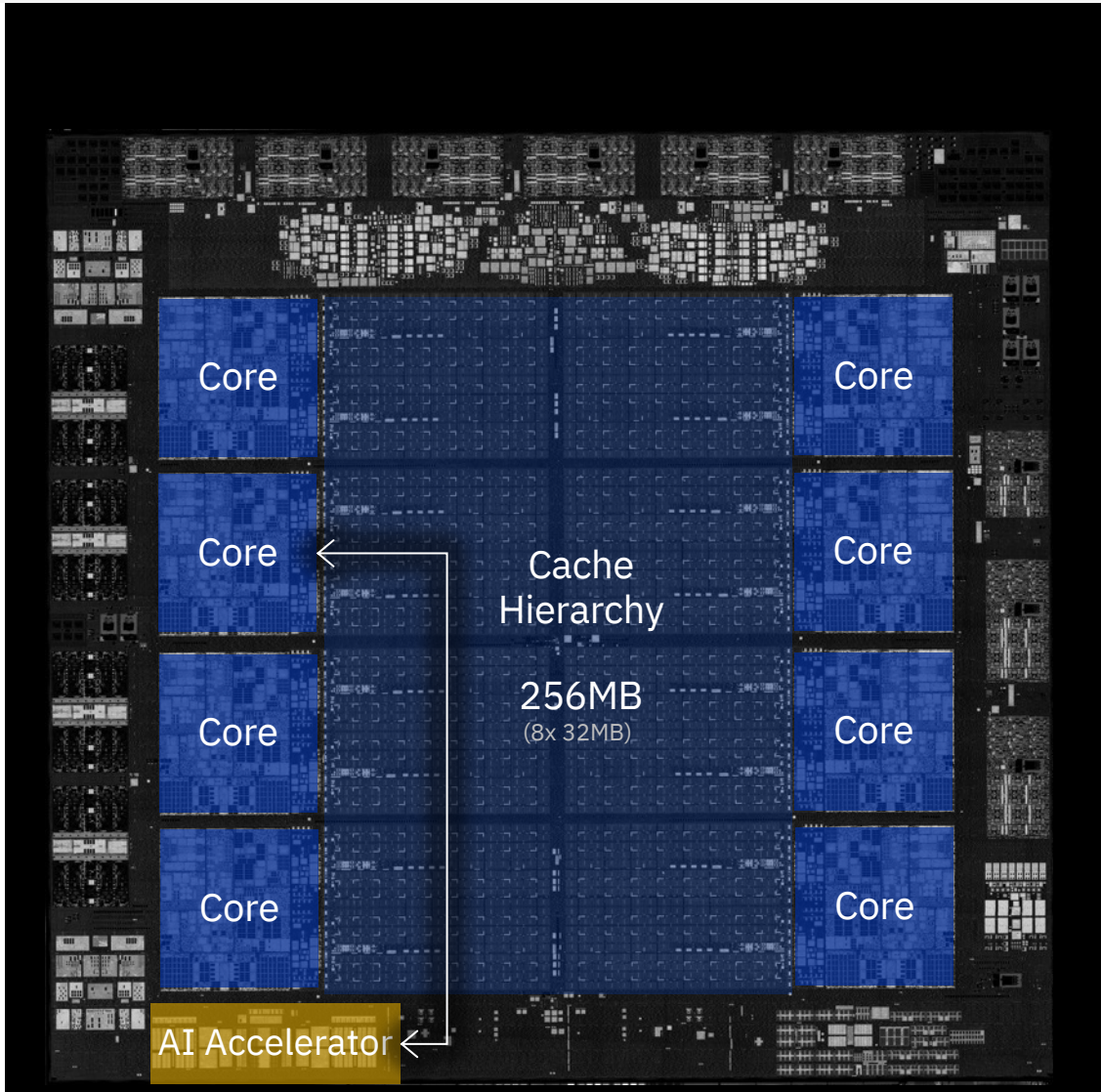
AI Inference with Central Low-latency Accelerator

Centralized On-chip accelerator shared by all cores

- Very low and consistent inference latency
- Compute capacity and bandwidth for utilization at scale
- Enterprise-grade memory virtualization and protection

Neural Network Processing Assist instruction

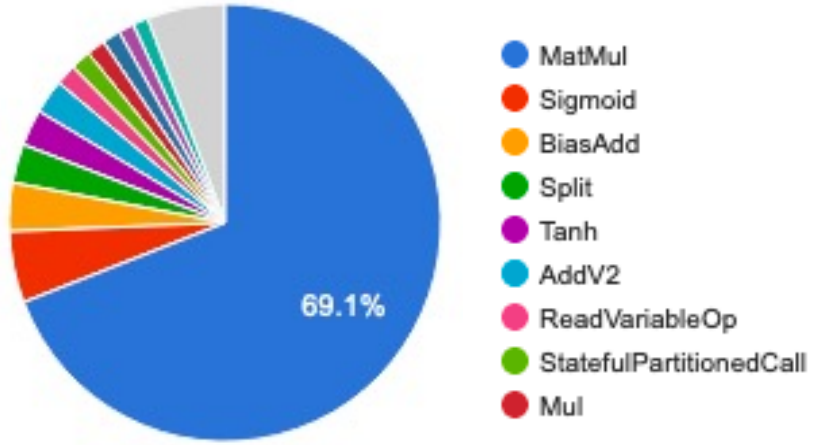
- Memory-to-memory core instruction
- Operate directly on tensors in user space
- Direct memory access with all protection mechanisms
- No data duplication and copying



AI Accelerator Supported functions

- AI Functions/Macros abstracted via NNPA instruction
  - Elementwise, Activation
  - Normalization, Pooling
  - Matrix-multiplication
  - Convolution
  - Conv+Scale+Activate
  - MatMul+Compare/Activate
  - RNN activation

Function group	#	Function support in GA1
Elementwise ops	0x10	NNPA_EL_ADD
	0x11	NNPA_EL_SUB
	0x12	NNPA_EL_MUL
	0x13	NNPA_EL_DIV
	0x14	NNPA_EL_MIN
	0x15	NNPA_EL_MAX
Activation ops	0x20	NNPA_LOG
	0x21	NNPA_EXP
	0x31	NNPA_RELU
	0x32	NNPA_TANH
	0x33	NNPA_SIGMOID
Norm op.	0x34	NNPA_SOFTMAX
	0x40	NNPA_BATCHNORM
Pooling	0x50	NNPA_AVGPOOL2D
	0x51	NNPA_MAXPOOL2D
Systolic ops	0x70	NNPA_CONVOLUTION
	0x71	NNPA_MATMUL_OP
	0x72	NNPA_MATMUL_OP_BCAST23
RNN	0x60	NNPA_LSTMACT
	0x61	NNPA_GRUACT
	0x00	NNPA_QAF



RNN model

- New functions can be added via firmware update

AI Ecosystem on zSystems

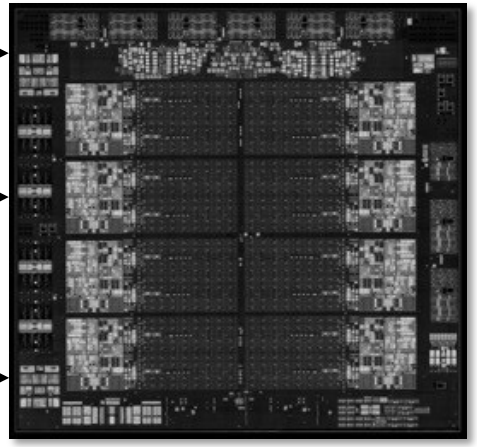
Build & Train anywhere

python
jupyter
Snap ML
dmlc XGBoost
learn
LightGBM

Keras
PyTorch
SAS
MATLAB
Chainer
TensorFlow

ONNX
ONNX

TensorFlow
Snap ML
Deep Learning Compiler



Deploy AI at scale on IBM zSystems

Applications

Banking
Finance
Insurance
Retail
Hospitality
Transport
Healthcare
Government
...

Offerings

IBM Watson

IT Operations

INSTANA an IBM Company
turbonomic
Cloud Pak for AIOps

Frameworks

Keras
PyTorch
Apache Spark
scikit learn
ANACONDA.
ONNX

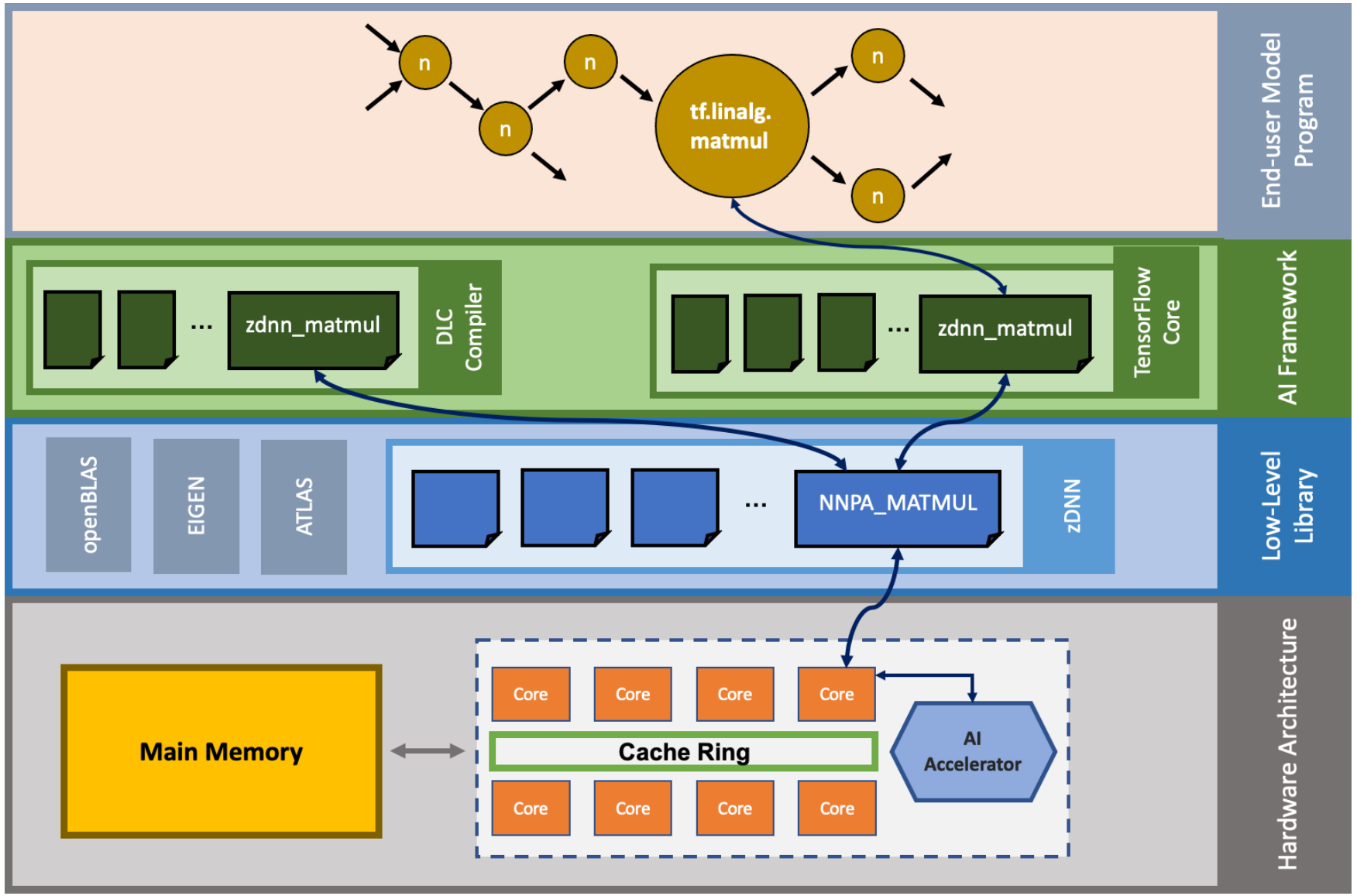
Libraries, Compilers

python
Java
GO
GCC
C++
OpenBLAS
OpenAS
Deep Learning Compiler

OS, Virtualization

z/OS
Ubuntu
SUSE
OPENSHIFT

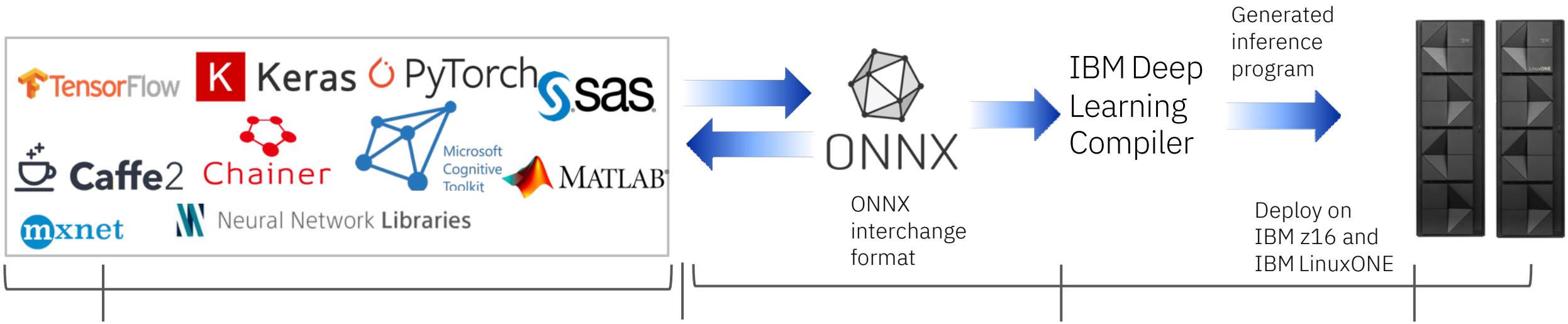
Vertical integration with IBM Telum AI accelerator



- AI models developed and trained anywhere can transparently leverage the z16 accelerator when deployed on IBM z16.
- Placement occurs via AI frameworks on zSystems instrumented to leverage IBM zDNN
- IBM zDNN is an open-source toolkit enabling developers to more simply target the z16 accelerator.

AI Ecosystem:
Seamlessly leverage AI accelerator on IBM z16

- Bring machine learning & deep learning models to IBM z16 with ONNX/DLC
- Exploit IBM Integrated Accelerator for AI for best inference performance
- Embedded within Watson Machine Learning z/OS



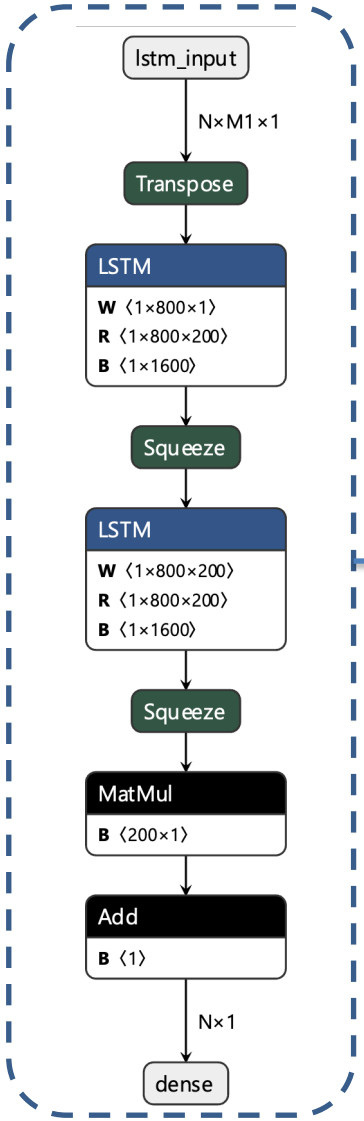
Build and train model in any popular framework on any platform of your choice

Use ONNX, an opensource tool for framework interoperability Models are converted to the ONNX interchange format Leverage zCX and run on zIIP engines

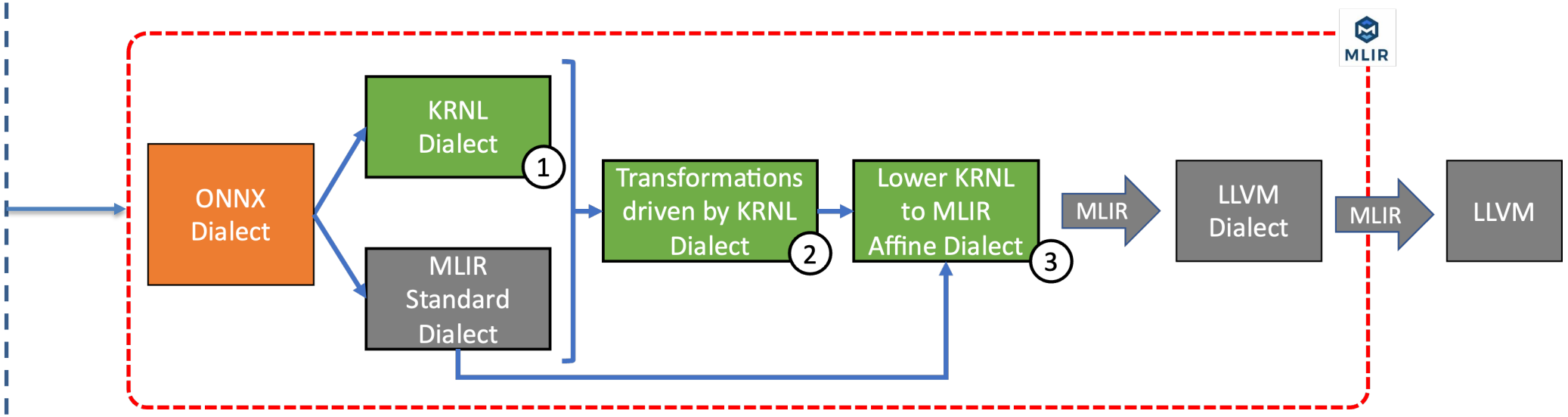
The IBM DLC (Deep Learning Compiler), optimized for performance and new libraries, generates a program from the model for execution on z/OS or Linux® on IBM z16

Deploy on IBM z16 and IBM LinuxONE and infuse model into workload application

onnx-mlir (IBM Z Deep Learning Compiler)



The ONNX model (dialect) is lowered and transformed through multiple phases of IR to a dialect that can be processed by an LLVM compiler.



The output of LLVM compilation and build is a shared library object that can be deployed

Key Features of Watson Machine Learning for z/OS v3.1 – **Enterprise Edition**

GUI Configuration

Web-based Configuration Tool for single instance and HA configuration

Model training tool

- Integrated Jupyter notebook server for model training on Z
- Leverage IBM Z Spark 3.2 and Python AI Toolkit for training and scoring

Scoring Engines

- Online scoring for SparkML, PMML, ONNX, Python and Watson Core time series models
- Leverage z16 on-chip AI accelerator for ONNX model scoring

Integrated Scoring

In-transaction scoring through native CICS and WOLA interface for CICS, IMS and BATCH COBOL applications

UI Dashboard

Web-based UI for WMLz environment and end to end model lifecycle management

Explainability

Model explainability - Integration with OpenScale on Cloud Pak for Data on IBM Z

CICS COBOL Application Calls WMLz Scoring

- The WMLz scoring service integrated in a CICS region as a program called **ALNSCORE**
- Use the CICS **LINK** command in your CICS COBOL application to call ALNSCORE for online scoring for SparkML, PMML, and ONNX models
- The call uses special containers to transfer the scoring input and output between the COBOL application and the ALNSCORE program

Container name	Type	Format
ALN_DEPLOY_ID	String	Deployment ID
ALN_INPUT_DATA	Structure	A data structure holds the input record to ALNSCORE. It is generated by the DFHJS2LS utility.
ALN_INPUT_CLASS	String	The class name is specified by the user when using the ALNJCGEN JCL to create the Java class.
ALN_OUTPUT_DATA	Structure	A data structure holds the scoring output from ALNSCORE. It is generated by the DFHJS2LS utility.
ALN_OUTPUT_CLASS	String	The class name is specified by the user when using the ALNJCGEN JCL to create the Java class.

```
IDENTIFICATION DIVISION.
PROGRAM-ID. MODELPGM.
DATA DIVISION.
WORKING-STORAGE SECTION.

01  MODELIN.
          06 COUNTRY-length              PIC S9999 COMP-5 SYNC.
          06 COUNTRY                     PIC X(255).
          06 GENDER-length               PIC S9999 COMP-5 SYNC.
          06 GENDER                      PIC X(255).
          06 AGE                         PIC S9(18) COMP-5 SYNC.
          06 MARITAL-STATUS-length       PIC S9999 COMP-5 SYNC.
          06 MARITAL-STATUS              PIC X(255).
          06 PROFESSION-length           PIC S9999 COMP-5 SYNC.
          06 PROFESSION                  PIC X(255).
          06 NATIONAL-ID-length          PIC S9999 COMP-5 SYNC.
          06 NATIONAL-ID                 PIC X(255).
          06 CUSTOMER-ID                 PIC S9(18) COMP-5 SYNC.

01  MODELOUT.
          06 PREDICTION                    COMP-2 SYNC.
          06 PROBABILITY OCCURS 2          COMP-2 SYNC.

01 I PIC 9(2) VALUE 1.

PROCEDURE DIVISION.
          MOVE 'M'       TO GENDER.
          MOVE 1         TO GENDER-length.
          MOVE 19        TO AGE.
          MOVE 'Single'  TO MARITAL-STATUS.
          MOVE 6         TO MARITAL-STATUS-length.
          MOVE 'Student' TO PROFESSION.
          MOVE 7         TO PROFESSION-length.
          MOVE 10        TO CUSTOMER-ID.
          MOVE 'USA'     TO COUNTRY.
          MOVE 4         TO COUNTRY-length.
          MOVE 'XXXX'    TO NATIONAL-ID.
          MOVE 4         TO NATIONAL-ID-length.

          DISPLAY 'GENDER         :' GENDER.
          DISPLAY 'COUNTRY        :' COUNTRY.
          DISPLAY 'MARITAL-STATUS :' MARITAL-STATUS.
          DISPLAY 'NATIONAL-ID    :' NATIONAL-ID.
          DISPLAY 'CUSTOMER-ID    :' CUSTOMER-ID.
```

```
EXEC CICS PUT CONTAINER('ALN_DEPLOY_ID') CHANNEL('CHAN')
     CHAR
     FROM('29439127-f77c-472c-a851-188ca2d4c78d')
     END-EXEC.

EXEC CICS PUT CONTAINER('ALN_INPUT_CLASS') CHANNEL('CHAN')
     CHAR FROM('ModelInWrapper')
     END-EXEC.

EXEC CICS PUT CONTAINER('ALN_INPUT_DATA') CHANNEL('CHAN')
     FROM(MODELIN) BIT END-EXEC.

EXEC CICS PUT CONTAINER('ALN_OUTPUT_CLASS') CHANNEL('CHAN')
     CHAR FROM('ModelOutWrapper')
     END-EXEC.

EXEC CICS LINK PROGRAM('ALNSCORE') CHANNEL('CHAN')
     END-EXEC.

EXEC CICS GET CONTAINER('ALN_OUTPUT_DATA') CHANNEL('CHAN')
     INTO(MODELOUT) END-EXEC.

DISPLAY 'PREDICTION     :' PREDICTION.
DISPLAY 'PROBABILITY    :'.

PERFORM UNTIL I=3
DISPLAY 'PROBABILITY-' I
DISPLAY PROBABILITY(I)
ADD 1 TO I
END-PERFORM.
EXEC CICS RETURN END-EXEC.
STOP RUN.
```

Deploy ID container

Input Class container

Input Data container

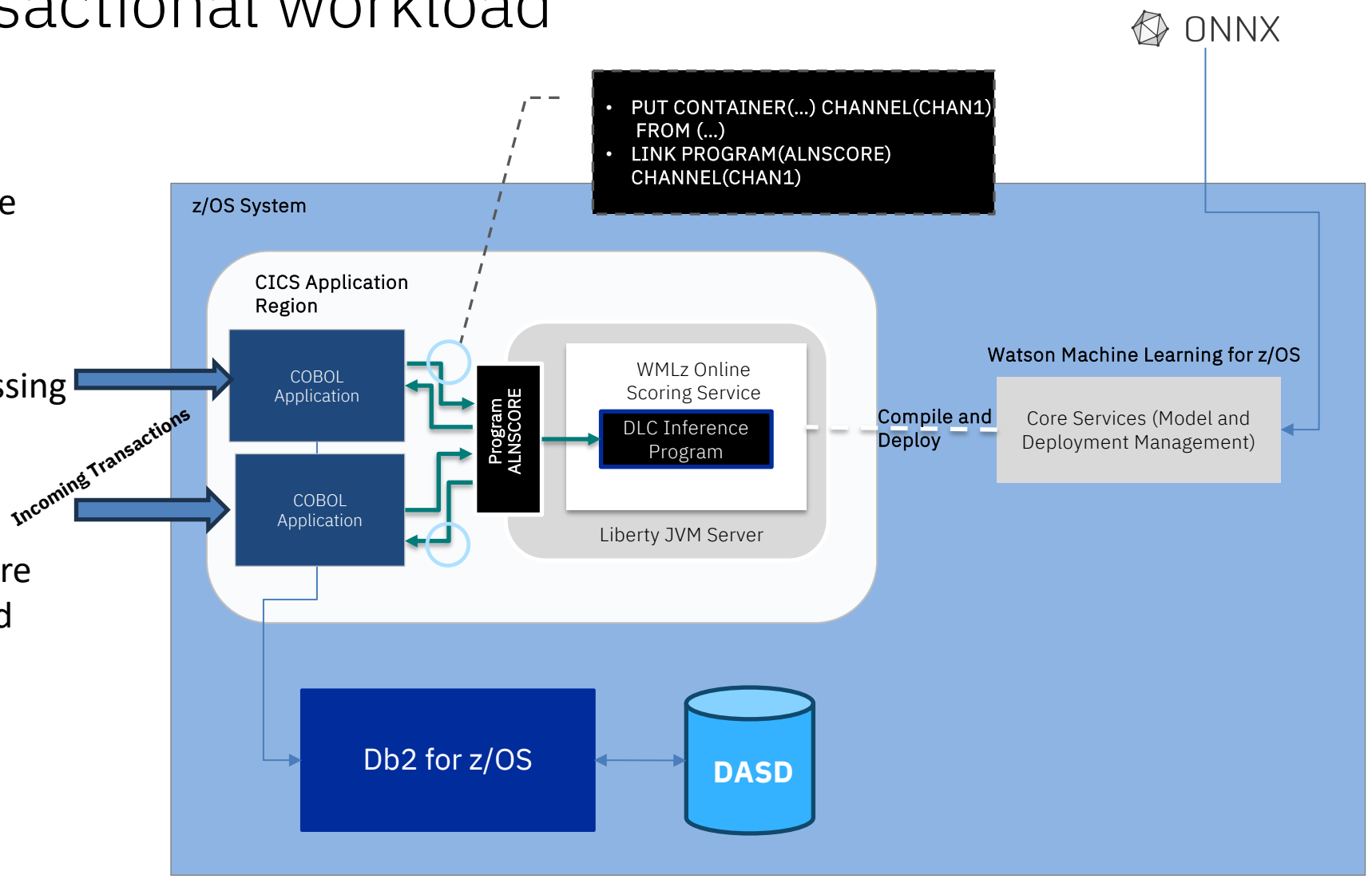
Output Class container

LINK to ALNSCORE

Output Data container

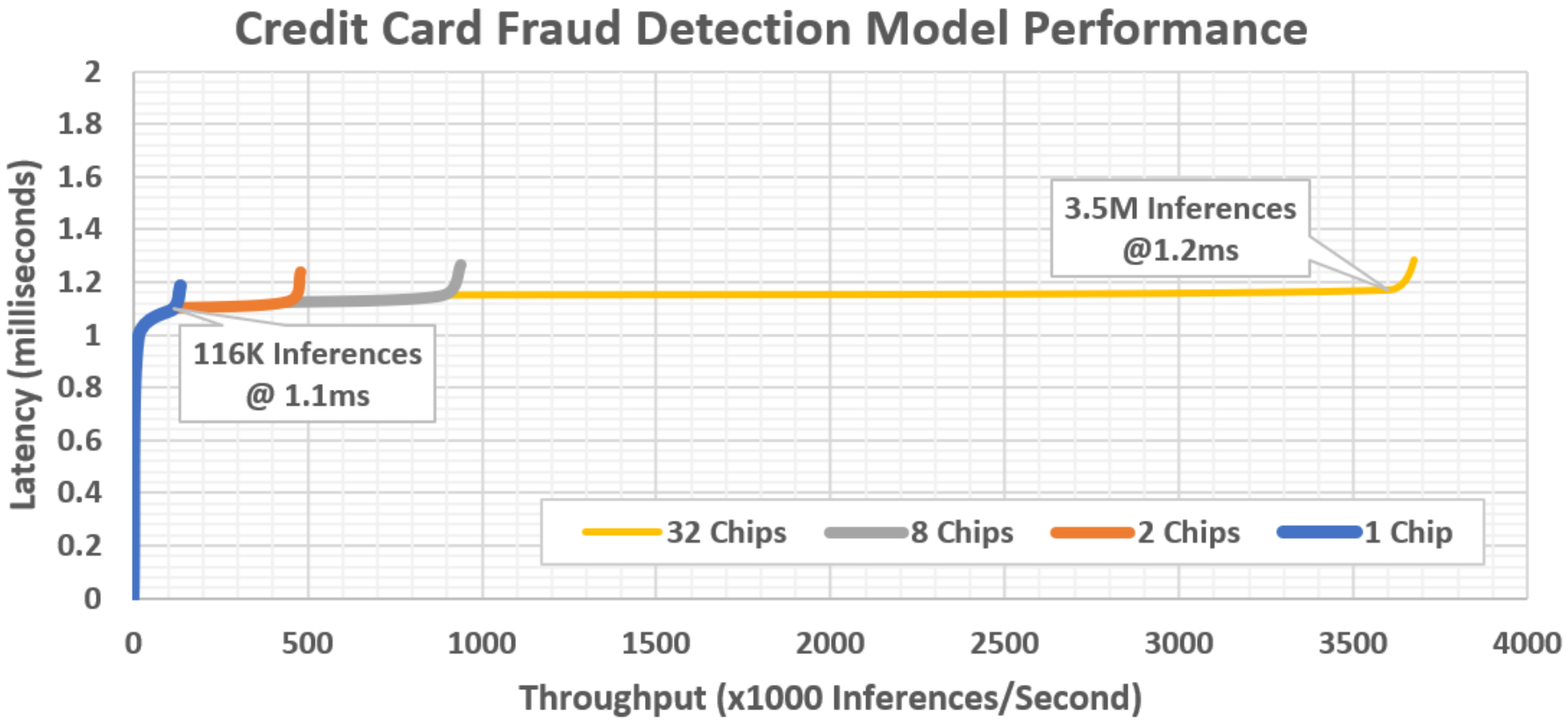
Deploying in a transactional workload

- Native language model inference library deployed in application address space.
- Utilize shared memory area, passing data in native format from/to Cobol application.
- Simplified implementation in core business applications, minimized overhead
- Transparently exploitation of hardware acceleration options



Stand-alone model execution results

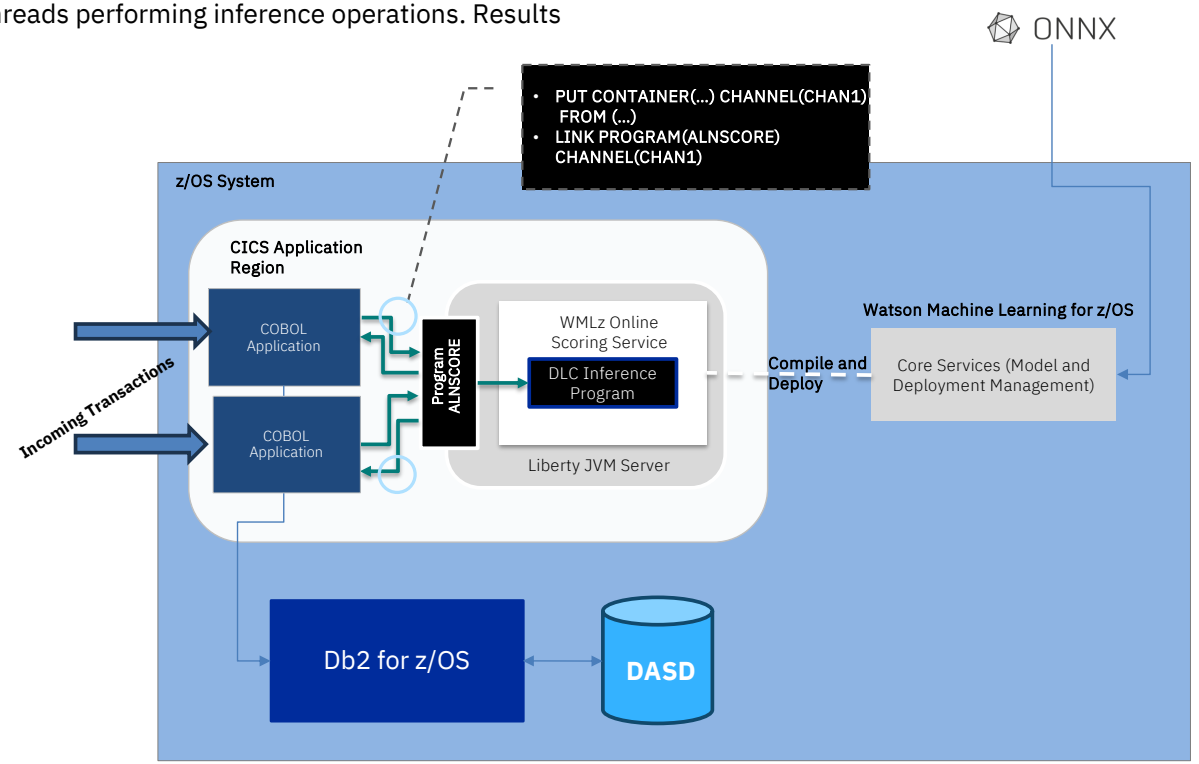
- Credit Card Fraud Detection Proxy Model
- Almost perfect scaling up to 32 chips in a system
- Input batch size of 128 (LSTM input is 7,128,204)



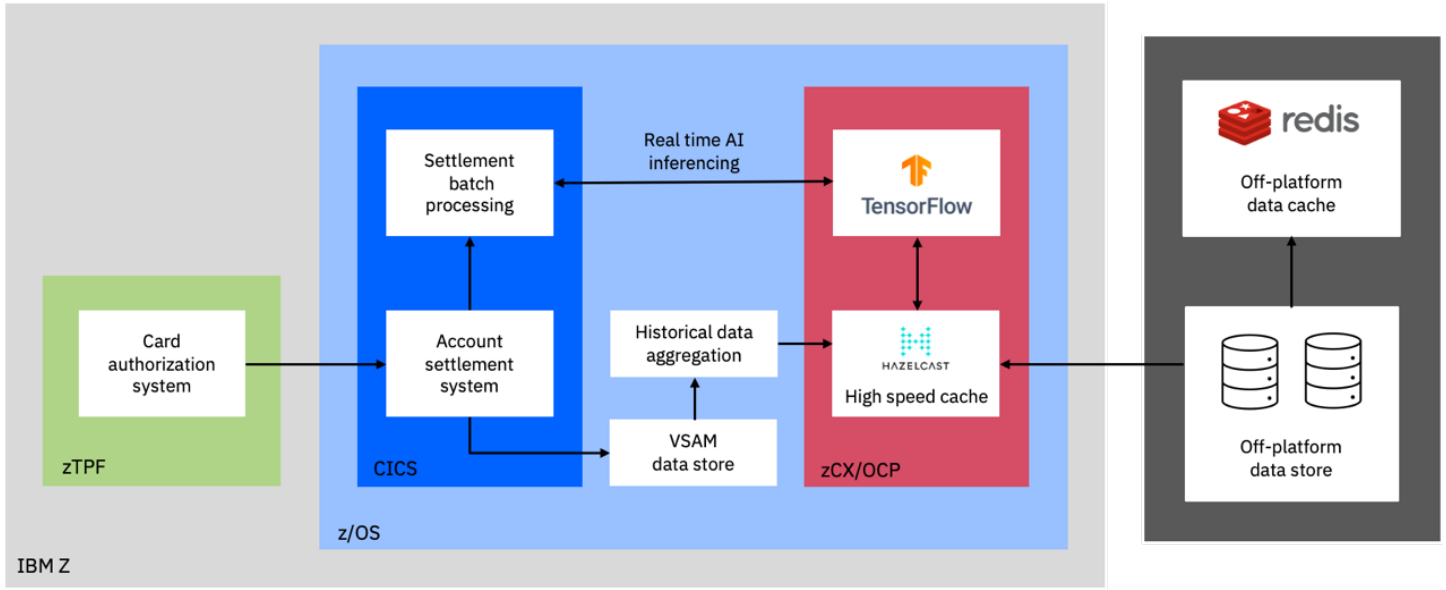
Results in transactional workload context

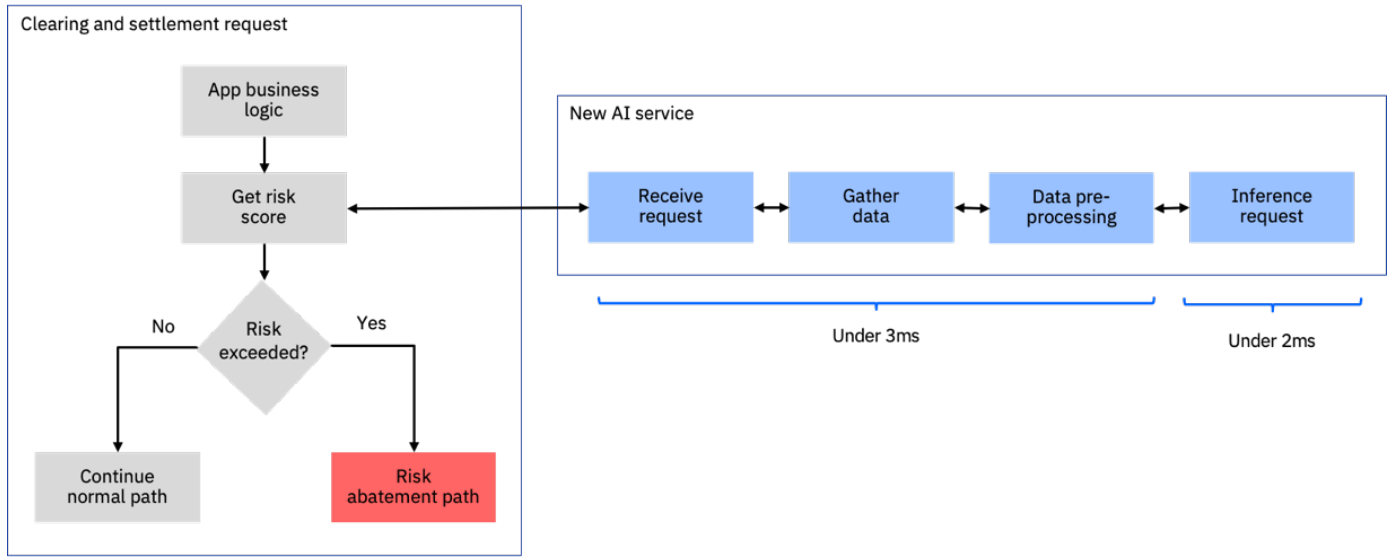
An IBM z16 system can process **up to 228K z/OS CICS credit card transactions per second with 6 ms response time**, each with an in-transaction fraud detection inference operation using a Deep Learning Model.

DISCLAIMER: Performance result is extrapolated from IBM internal tests running a CICS credit card transaction workload with inference operations on an IBM z16. A z/OS V2R4 LPAR configured with 6 CPs and 256 GB of memory was used. Inferencing was done with Watson Machine Learning for z/OS 2.4 running on Websphere Application Server Liberty 21.0.0.12, using a synthetic credit card fraud detection model (https://github.com/IBM/ai-on-z-fraud-detection) and the Integrated Accelerator for AI. Server-side batching was enabled on Watson Machine Learning for z/OS with a size of 8 inference operations. The benchmark was executed with 48 threads performing inference operations. Results represent a fully configured IBM z16 with 200 CPs and 40 TB storage. Results may vary.



Other common patterns: open-source on Linux on Z





- Co-located with z/OS workload, on Linux on Z environment**.**
- **TensorFlow Serving** used to deploy a pre-trained TensorFlow model.
- **Hazelcast** (in-memory data store) utilized as feature store.
- Full end-to-end pipeline including transport achieving < 5ms latency at scale.

Considerations + Closing

- Focused strategy was critical to enabling real-time AI in high volume transaction workloads
  - Optimize inference; training not currently a high value target for platform.
  - Minimize ecosystem impacts; critical in a non-x86 architecture environment.

- Full business application context must be considered:
  - It’s not just about model optimization and acceleration… Must also consider:
    - Serving performance and scalability
    - Overhead in invoking APIs
  - Simplified methods of invoking model server – using native language constructs.
    - Important when an update is required to the businesses most critical application(s).

Thank you!

Interested in trying it out?

Free access to a LinuxONE (IBM Z) environment is available!

Register in LinuxONE Community Cloud – hosted by Marist College
- Instructions: https://ibm.biz/BdPcL8

Engage with us:

- aionz@us.ibm.com

- AI on IBM Z and LinuxONE Community

- https://ibm.github.io/ai-on-z-101/

- Contact us directly

Sites
Journey to AI on IBM Z Content Solution link
IBM Z and Cloud Mod Center AI Page link
Real-Time analytics and AI on the IBM mainframe link

Blogs
TensorFlow blog: link
ONNX blog: link

Demos
Watson Machine Learning Demo link
Anti-Money Laundering with AI on Z link
Fraud Detection Demo link

Redbooks
Optimized Inferencing and Integration with AI on IBM Z Introduction, Methodology, and Use Cases: link
Demystifying Data with AI on IBM Z –POV: link
Art of the Possible with AI on IBM zSystems link

Paper
IDC: The business value of the transformative mainframe link
Operationalizing Fraud Prevention on IBM z16: Reducing Losses in Banking, Cards, and Payments link

Open Source
IBM Z and LinuxONE container Image Registry: link
TensorFlow on IBM Z and LinuxONE container Image Registry: link
Anaconda Partnership link

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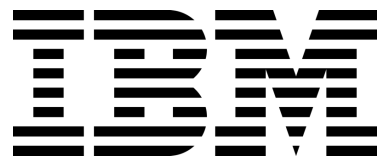
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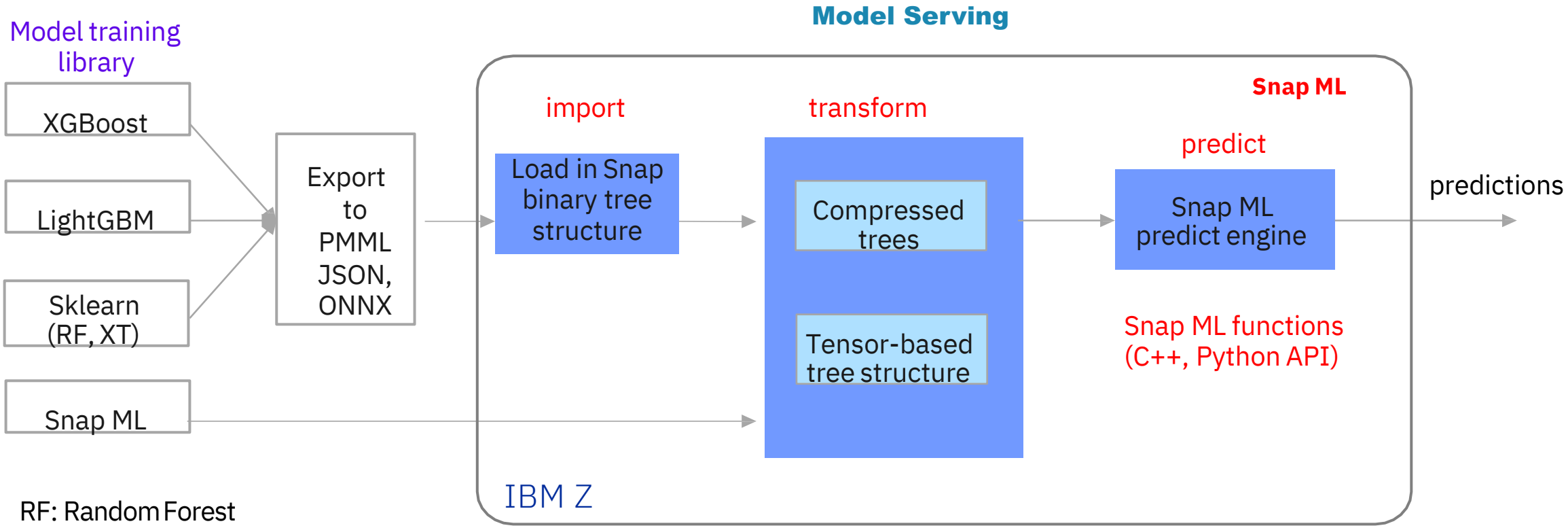
IBM Snap ML for ML model execution



RF: Random Forest
XT: Extra Trees

Transformations are tailored to inference H/W:

Compressed Trees: Runs on the IBM Z CPU

Tensor-based Trees: Runs on the Integrated Accelerator for AI

Snap ML scoring pipeline is agnostic to the framework used to train the model

1. Save a model trained with scikit-learn, XGBoost, LightGBM into PMML/JSON/ONNX format
2. Import & transform the model
3. Score with Snap ML accelerated inference engine