STORAGE DEVELOPER CONFERENCE

SD2 Fremont, CA September 12-15, 2022

BY Developers FOR Developers

# Accelerating Near Real-Time Analytics with High Performance Object Storage

A SNIA, Event

Mayank Saxena Senior Director of Engineering

Data Fabric Solutions, Memory Solutions Lab, Samsung www.samsungmsl.com Sept 14<sup>th</sup> 2022

## **HPOS with Computational SSD Acceleration**

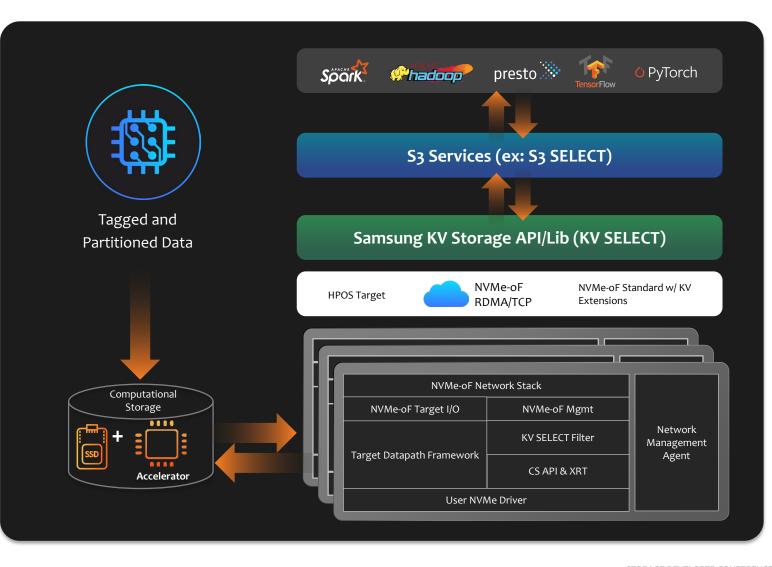
## High Performance Object Storage (HPOS)

#### **Use Cases**

Large scale real time analytics - Smart City, Smart Home, eHealth, IoT, Images, Video Analytics, Security

#### Benefits

- Faster queries
- Lesser network traffic
- Lower TCO due to reduced CPU and network traffic

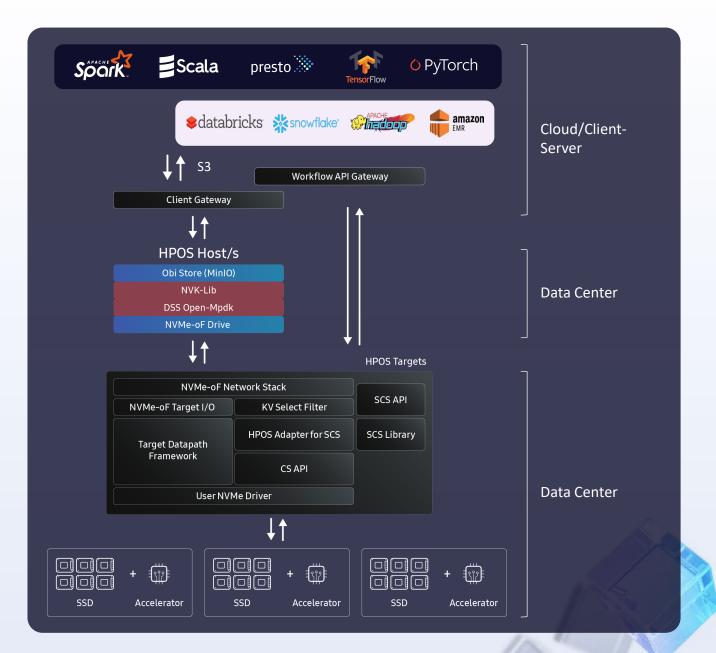




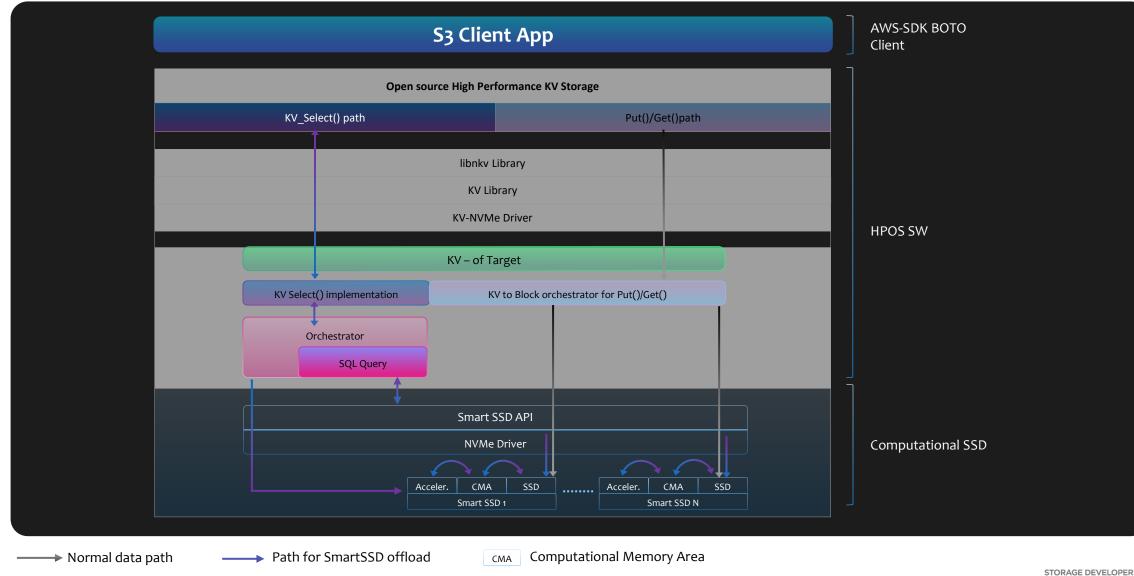


## **Efficient & Accelerated Analytics Solutions**

- Custom Functions in AI pipeline accelerated by HPOS + SmartSSD
- Client applications like (e.g. S3 Select, AI apps) talk to API Gateway for I/O and HPOS workflow definition
- Deployment efficiency HPOS Host & Target as Containers
- Scale Client Gateway and API gateway can be in the Cloud or Datacenter
- HPOS CSD based Solutions
  - S3 Select 100x more Throughput
  - Video AI 51x faster Inferencing
  - Significant Lesser TCO



## **End-to-End S3 Select with HPOS**



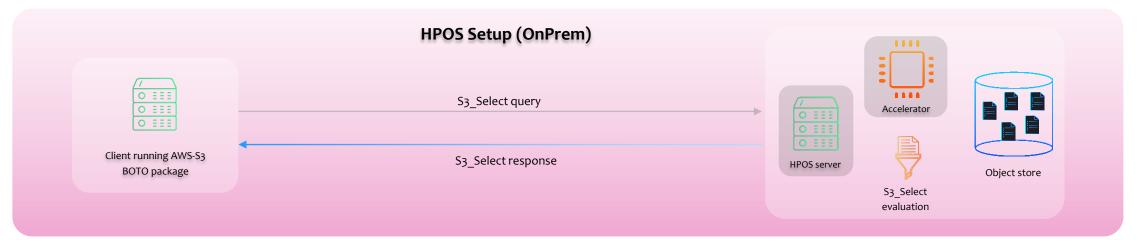


## Near data processing for S3\_Select

	AWS Baseline		
	S3_Select query		
Client running AWS-S3 BOTO package	S3_Select response	S3_Select evaluation	Object Store

	Customer's Sample Dataset								
Index	Year	DayOfYear	Precipitation	ET0	tMax	tMin	RS		
0	1	1	0	0	-26.6808	-29.7293	0		
1	1	2	0	0	-27.0202	-30.9575	0		
2	1	3	0	0	-28.0491	-31.0459	0		
3	1	4	0	0	-26.2893	-29.3781	0		
4	1	5	0	0	-25.1941	-27.9265	0		
5	1	6	0	0	-23.5173	-27.2431	0		
6	1	7	0	0	-23.8696	-29.4691	0		
7	1	8	0	0	-24.4267	-29.0663	0		

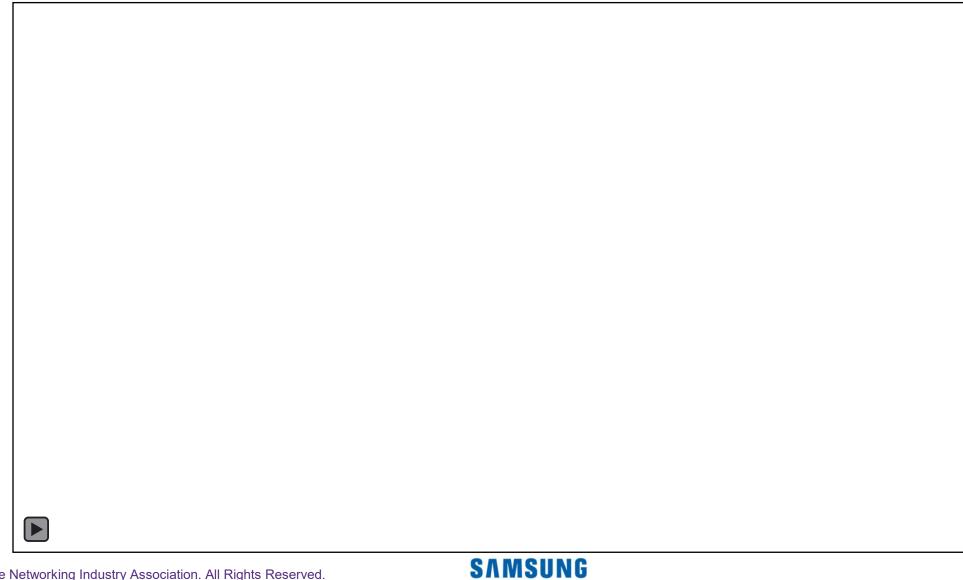
S3\_Select Query ('Select COUNT(\*) FROM S3Object s WHERE dayofyear < 55');



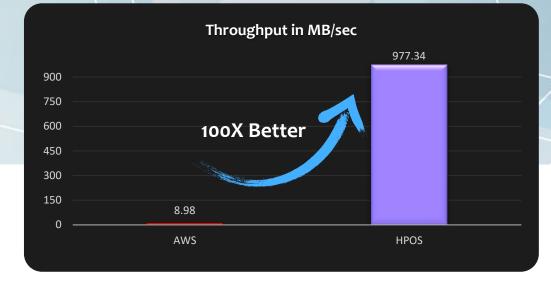


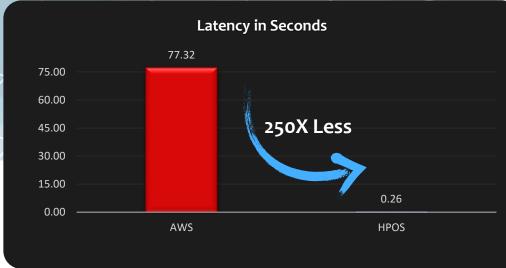
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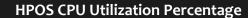
## HPOS S3\_Select Drag Race Demo

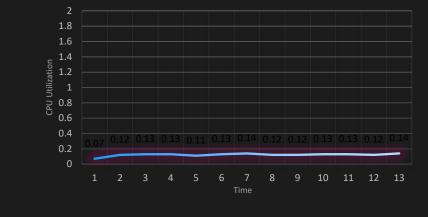


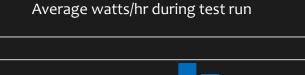
## **AWS S3 Select vs HPOS S3 Select**





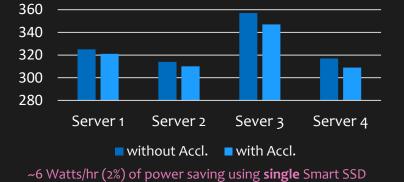






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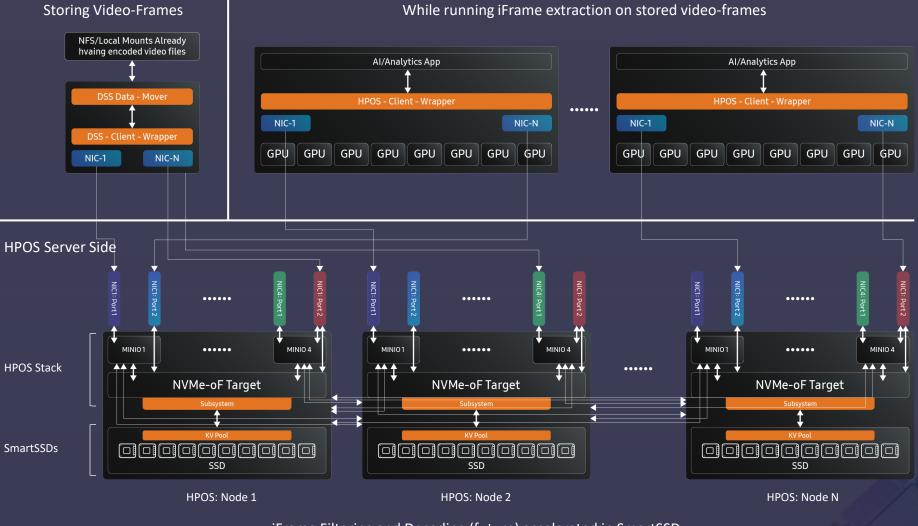




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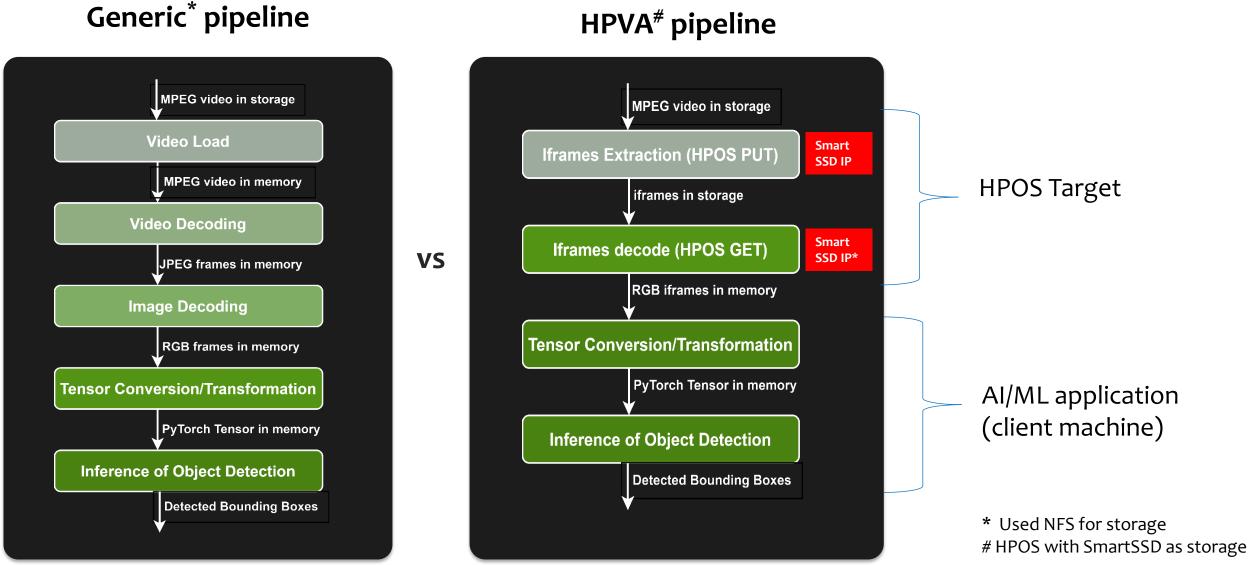
## High Performance Video Analytics – Solution Deployment

- High Performance Video
  Analytics
- TCO Disaggregation of GPUs and Storage
- Smart SSD acceleration for video decoding (future) and iFrame extraction
- Large Object Support (Video files)
- Supports SmartSSD 1.0 & Smart SSD 2.0



iFrame Filtering and Decoding (future) accelerated in SmartSSD

## **Video Analytics Pipeline Comparison**





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## **Drag Race – Generic vs HPVA**

#### **Generic Pipeline**

pplications 🛛 🗰 Terminal - root@msl 🔳 Terminal - root@msl						3 8		16:50 EN	Pengfe
Terminal - root(#msl-td-pbssd02:/opt/mike/mi-cv-vanilla/scripts	and a state of the		I	rminal - root	emsl-td-phsse	102:-			
le Edit View Terminal Tabs Help	File Edt View	Terrical							
root@msl-td-pbssd02:/opt/mik x pringtei.xu@msl-etx-cn2: -/De > pringtei.xu@msl-etx-	cn3: -/De ) root@msl-td-p	bssd02:~		pengfei.xu	@msl-etx-cni	: =/D	pengtei.xu@	imsl-etx-cn3: -	/0
iting objects: 180% (1296/1296), 38.68 MiB   26.12 MiB/s, done.	04:49:43 PM	all	33.05	8.89	0.03	0.08	9,80	66.92	
(delta 143), reused θ (delta θ)	04:49:44 PM	all	38.98	8.80	0.02	0.08	0.00	61.90	
ote: Resolving deltas: 180% (143/143), completed with 50 local objects.	04:49:45 PM	all	39.35	8.88	0.06	0.08	0.00	68.68	
git@msl-dc-gitlab.ssi.samsung.com:pengfei.xu/ml-cv-vanilla.git	04:49:46 PM	all	39.25	0.00	0.09	0.08	0.00	60.65	
f5ca60cd56c2ea main → main	04:49:47 PM	all	39.88	8.89	0.14	0.08	0.00	60.07	
nch main set up to track remote branch main from origin.	04:49:48 PM	all	39.84	0.00	0.09	0.08	0.00	60.87	
ot@msl-td-pbssd02 scripts]# bash main_ssd-resnet50_video_nfs_	04:49:49 PM	all	39.22	0.00	0.10	0.08	0.00	60.68	
n_ssd-resnet50_video_nfs_end2end.sh main_ssd-resnet50_video_nfs_preproces		all	40.25	0.00	0.06	0.00	0.00	59.69	
n_ssd-resnet50_video_nfs_inference.sh	04:49:51 PM	all	39.83	0.00	0.06	0.08	0.00	60.11	
ot@msl-td-pbssd02 scripts]≢ bash main_ssd-resnet50 video_nfs_	04:49:52 PM	all	39.91	0.00	0.02	0.00	0.00	60.06	
n_ssd-resnet50_video_nfs_end2end.sh main_ssd-resnet50_video_nfs_preproces		all	39.61	0.00	0.15	0.00	0.00	60.25	
n_ssd-resnet50_video_nfs_inference.sh	04:49:54 PM	all	39.77	8.60	0.89	0.08	0.00	59.34	
ot@msl-td-pbssd02 scripts]# bash main_ssd-resnet50 video_nfs_inference.sh	04:49:55 PM	all	40.08	0.00	0.06	0.08	8.60	59.86	
ng cache found in /root/.cache/torch/hub/WIDIA_DeepLearningExamples_torchhub		all	38.77	8.88	0.02	8.68	0.80	61.21	
ot/.cache/torch/hub/NVIDIA_DeepLearningExamples_torchhub/PyTorch/Classificati		all	32.78	8.88	0.13	0.08	0.80	67.10	
<pre>ge_classification/models/common.py:14: UserWarning: pytorch_quantization modu</pre>		all	4.53	8.88	0.18	0.08 0.08	8.60	95.29	
uantization will not be available pytorch quantization module not found, quantization will not be available"	84:49:59 PM 84:50:00 PM	all	0.00	8.80 8.80	0.00	0.00	0.00 0.00	100.00	
pycorch_quantization_module_not_found, quantization_will_not_be_available ot/.cache/torch/hub/NVIDIA_DeeplearningExamples_torchhub/PyTorch/Classificati		all	0,00	8,88	0.01	0.08	8.80	99,99	
ge_classification/models/efficientnet.py:18: UserWarning: pytorch_quantizatio	n module not 04:50:02 PM	all	0.00	8.88	0.01	0.00	0.00	99.92	
und, quantization will not be available	04:50:02 PM	all	0.02	0.00	0.00	0.00	0.80	99,99	
be available*	04:50:04 PM	all	0.00	8.88	0.00	0.00	0.00	100.00	
resnet video.py: Overall inference time tensor, it is rec		all	0.00	8,60	0.00	0.00	0.60	100.00	
sourceTensor.clone().detach() or sourceTensor.clone().detach().requires_grad		all	0.00	8.60	0.00	0.08	0.00	100.00	
than torch.tensor(sourceTensor).	04:50:07 PM	all	0.01	0.00	0.00	0.00	0.00	99,99	
ensor = torch.tensor(transformed_frame, dtyp_torch.float32)	04:50:08 PM	all	0.00	8.88	0.01	0.00	0.00	99.99	
profiling results	04:50:09 PM	all	0.00	0.00	0.00	0.08	0.00	100.00	
latency in total (preprocessing + inference): 61.18115997314453 (s)									
ot@msl-td-pbssd02 scripts]# bash main ssd-resnet50 video_nfs_preprocess.sh	04:50:09 PM	CPU	Suser	Snice	system	Siowait	<b>%steal</b>	hidle	
ng cache found in /root/.cache/torch/hub/WVIDIA_DeepLearningExamples_torchhub	04:50:10 PM	all	0.00	8.88	0.01	0.08	0.00	99.99	
ot/.cache/torch/hub/WIDIA_DeepLearningExamples_torchhub/PyTorch/Classificati		all	0.00	0.00	0.00	0.00	0.00	100.00	
ge_classification/models/common.py:14: UserWarning: pytorch_quantization modu		all	1.25	8.89	5.82	0.08	0.00	92.93	
uantization will not be available	04:50:13 PM	all	2.62	0.00	0.24	0.08	0.00	97.14	
pytorch_quantization module not found, quantization will not be available"	04:50:14 PM	all	4.88	0.00	5.05	0.08	0.00	90.16	
ot/.cache/torch/hub/WIDIA_DeepLearningExamples_torchhub/PyTorch/Classificati		all	34.71	1000				64.94	
<pre>ge_classification/models/efficientnet.py:18: UserWarning: pytorch_quantizatio</pre>		all	36.74	Prei	proces	ssing (	CPU%	63.05	
und,	04:50:17 PM	all	15.96					83.86	
pyto Preprocessing time antization will not be available"	04:50:18 PM	all	0.00	0.00 0.00	0.01	0.08	0.00	99.98	
restruct from a tensor, it is rec		att	0.00	8.66	0.00	9.99	0.80	100.00	
<pre>proprocessing time (construction act indo be abilitate sourceTensor.clone() (construct from a tensor, it is re- sourceTensor.clone().detach(), requires_grad than torch.tensor(source_isor). ensor = torch.tensor(the ined frame, dtype=torch.float32) </pre>	_(indef, rat								
ensor - torch tensor(to c read frame, diven-torch float22)									
ensure tortal tensority is they in alle, utype=tortal noticity2)									
latency for preprocessing: 2.4198296070898877 (s)									
otimsl-td-pbssd02_scripts]#	🛛 🔄 🚱 Q, 🚞								

#### **HPVA Pipeline**

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Terminal - root@m	sl-td-pbssd02:/opt/mike/mi-cv-vanilla/scripts	0.0.0.0				rminal - root	@msl-td-pbsse	992:			* - = ×
Edit View Terminal Tabs Help			File Edit Wew	Terrinal 1	Tabs Help						
pot@msl-td-pbssd02:/opt/mik x p	engtei.xu@msl-ebc-cn3: +/De · per	glol.xu§msl-etx-cn3: -/De 🤌	root@msl-td-p	bssd02:-		pengtei.xu	@msl-etx-cn	l: ~/D	pengtei.xu	(emsl-etx-cm):	/D
antization will not be availab			AL 50 33 PH	0.011							
	found, quantization will not be LearningExamples torchhub/PyTorch		04:58:23 PM 04:58:24 PM	CPU	%user 0.00	\$nice 8.80	%system 0.01	%iowait 0.08	%steal 0.00	%idle 99.99	
	entnet.py:18: UserWarning: pytorc		04:58:25 PM	all	0.00	8.60	0.01	0.00	0.00	100.00	
ind, quantization will not be a		_quancización moduce noc	04:58:26 PM	all	0.00	8.88	0.00	0.00	0.00	99.99	
	found, quantization will not be	availahle"	04:58:27 PM	all	0.00	8.88	0.01	0.00	0.00	100.00	
loader init done	feand, deancied cion arec not be	010110010	04:58:28 PM	all	0.00	8.88	0.01	0.00	0.80	99.98	
L5fpss0 0',)			04:58:29 PM	all	0.38	8.80	0.06	8.00	8.60	99.57	
(5fpss0_1',)			04:58:30 PM	all	1.33	0.00	5.96	0.08	0.00	92.71	
5fpss0_2',)			04:58:31 PM	all	6.21	0.00	0.34	0.00	0.00	93.45	
5fpss0 3',)			04:58:32 PM	all	0.73	8.88	3.25	8.08	0.00	96.02	
(5fpss8 4',)			04:58:33 PM	all	0.06	8.88	0.10	8.08	0.80	99.84	
5fpss8 5',)			04:58:34 PM	all	0.00	0.00	0.00	0.00	0.00	100.00	
Sfoss8 6' )			04:58:35 PM	all	0.02	0.00	0.03	0.00	0.80	99.94	
5fpss8 7'.)	rall inference	time	04:58:36 PM	all	0.00	8.88	0.02	0.08	0.80	99.98	
5fpss0 8',)	run interence	- chile	04:58:37 PM	all	5.42	8.68	1.23	8.08	8.60	93.35	
5fpss8_9',)	$\sim$		04:58:38 PM	all	33.36	8,68	0.81	0.01	0.00	65.82	
5fpss0_10',)			04:58:39 PM	all	0.19	0,00	0.11	0.08	0.80	99.69	
profiling results			04:58:40 PM	all	0.00	0.00	0.00	0.08	0.60	180.00	
	g + inference): 1.229686498641967		04:58:41 PM	all	0,02	8.88	0.06	0.08	8,68	99.92	
ot@msl-td-pbssd02_scripts]≠ basi	h main_ssd-resnet50_iframe_vl_blj	1_preprocess.sh	04:58:42 PM	all	0.05	0,00	0.07	0.08	0,80	99,89	
	torch/hub/NVIDIA_DeepLearningExam		04:58:43 PM	all	0.00	0.00	0.00	0.00	0.00	100.00	
	LearningExamples_torchhub/PyTorch		04:58:44 PM	all	0.02	0.00	0.05	0.00	0.00	99.93	
	.py:14: UserWarning: pytorch_quan	tization module not found	04:58:45 PM	all	0.00	0.00	0.00	0.08	0.00	180,00	
antization will not be availab			04:58:46 PM	all	0.00	0.00	0.02	0.08	0.00	99.98	
	found, quantization will not be		04:58:47 PM	all	0.02	0.00	0.05	0.08	0.00	99.93	
	LearningExamples_torchhub/PyTorch		04:58:48 PM	all	0.01	9 88	9.05	0.00	6.90	GG 0.4	
	entnet.py:18: UserWarning: pytorc	n_quantization module not	04:58:49 PM	all	0.00	Dwe				CDLL	0/
und, quantization will not be a			04:58:50 PM	all	0.01	Pre	pro	cess	Ing	CPU	70
bytorch_quantization module not a loader init done	found, quantization will not be	avartable	04:58:51 PM 04:58:52 PM	all all	1.38		-				
				all		0.00 0.00	5.77	0.00 0.00	9.00	92.86 95.56	
5fpss0_0',)			04:58:53 PM 04:58:54 PM	all	4.24 2.82	0.00	3.49	9.00	0.00 0.00	93.50	
(5fpss0_1',) (5fpss0_2',)			04:58:55 PM	all	2.02	8.60	0.00	0.00	0.00	93.69	
5fpss0_3',)			04:58:55 PM	all	0.00	0.00	0.00	0.00	0.00	100.00	
Store At			04:58:57 PM	all	0.00	8.00	0.00	0.00	0.00	100.00	
510550 5" Preproc	essing time		04:58:58 PM	all	0.00	0.00	0.00	9.08	8.80	99.99	
Sfpss0 6'	cooling time		04:58:59 PM	all	0.56	0.00	0.01	0.00	0.00	99.36	
L5fpss0 7',)			04:59:00 PM	all	0.35	8.89	0.19	0.00	0.00	99.45	
(5fpss0_8',)			n —								
(5fpss0_9',)			<u> </u>								_
L5fpss8_10',)											
profiling results		4									
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t@msl-td-pbssd02_scripts]#			U								



## **Profiling Comparison Summary**







	Generic (Baseline)	НРVА	Comment
Video IOs	video file 936 KB ( SSD to Target to Host)	11 iframes, ~20KB/frame (SSD drive to Decoder in Target) 11 decoded frames, ~220KB/decoded Frames (Target to Host)	More performance gain for video files with lesser number of iFrames
Avg CPU Utilization (preprocessing)	~29%	~2.8%	Key TCO benefit with HPOS, as preprocessing done in target (with SmartSSD) itself.
Avg CPU Utilization (overall inference)	~38%	33%	Currently after preprocessing it's the same pipeline. So, not much difference.*
Latency (preprocessing)	2.425	0.29s	Latency benefit with HPOS, as preprocessing done in target (with SmartSSD) itself
Latency (overall inference)	61.18s	1.25	After preprocessing it's the same pipeline, but less frames (only iFrames) to process for HPOS.



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## **Open Source – HPOS Foundation**

## **Open Source** <u>https://github.com/OpenMPDK/DSS</u>

• DSS – Disaggregate Storage Solution

#### **Complete Ecosystem**

- Al Benchmarking Framework supporting user preferred training and models
- Client Wrappers supporting Pytorch and Tensorflow
- Host and Target Stack

More CSD specific loadable modules & SDK coming up ...



# **Thank You**

Mayank Saxena Senior Director of Engineering <u>mayank.s4@samsung.com</u>

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