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Swiss Federal Institute of Technology Zurich

Accelerating OpenVX Applications on Embedded Many-Core Accelerators

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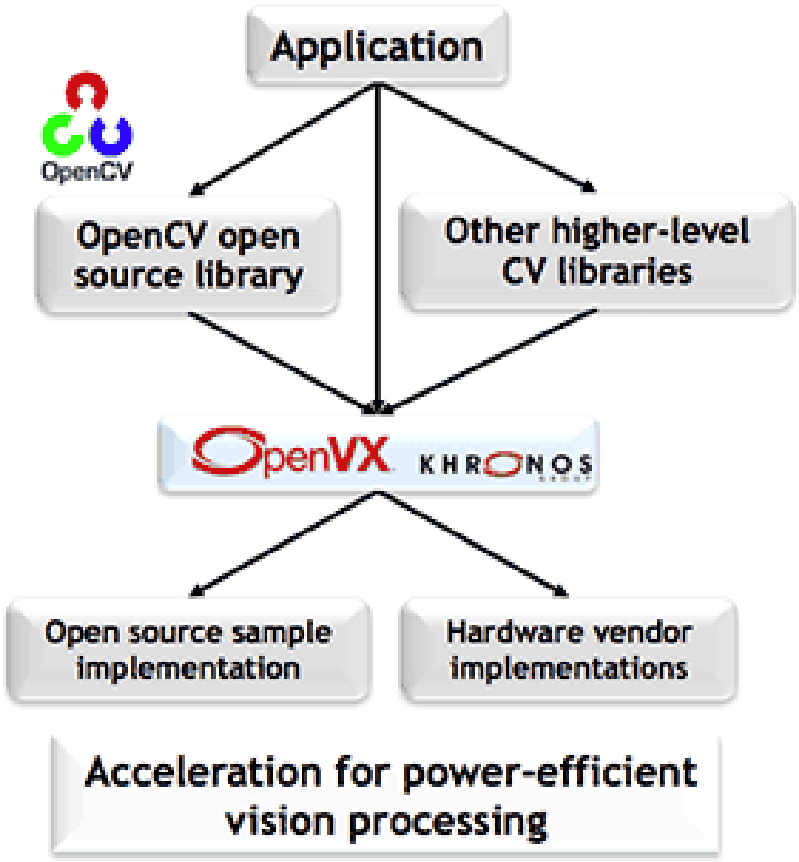
Outline

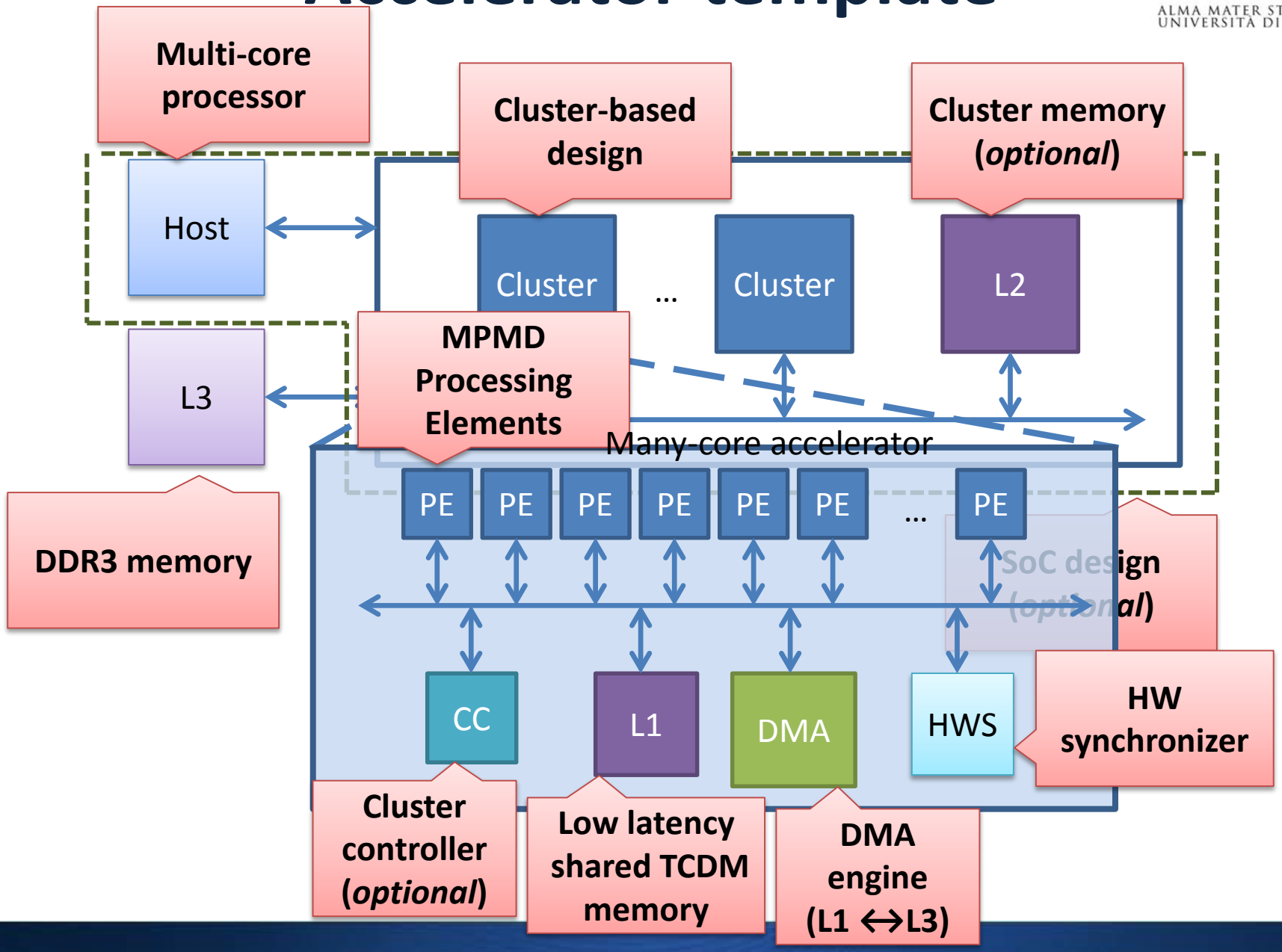
- **Introduction**
- OpenVX acceleration
- Work in progress

OpenVX overview



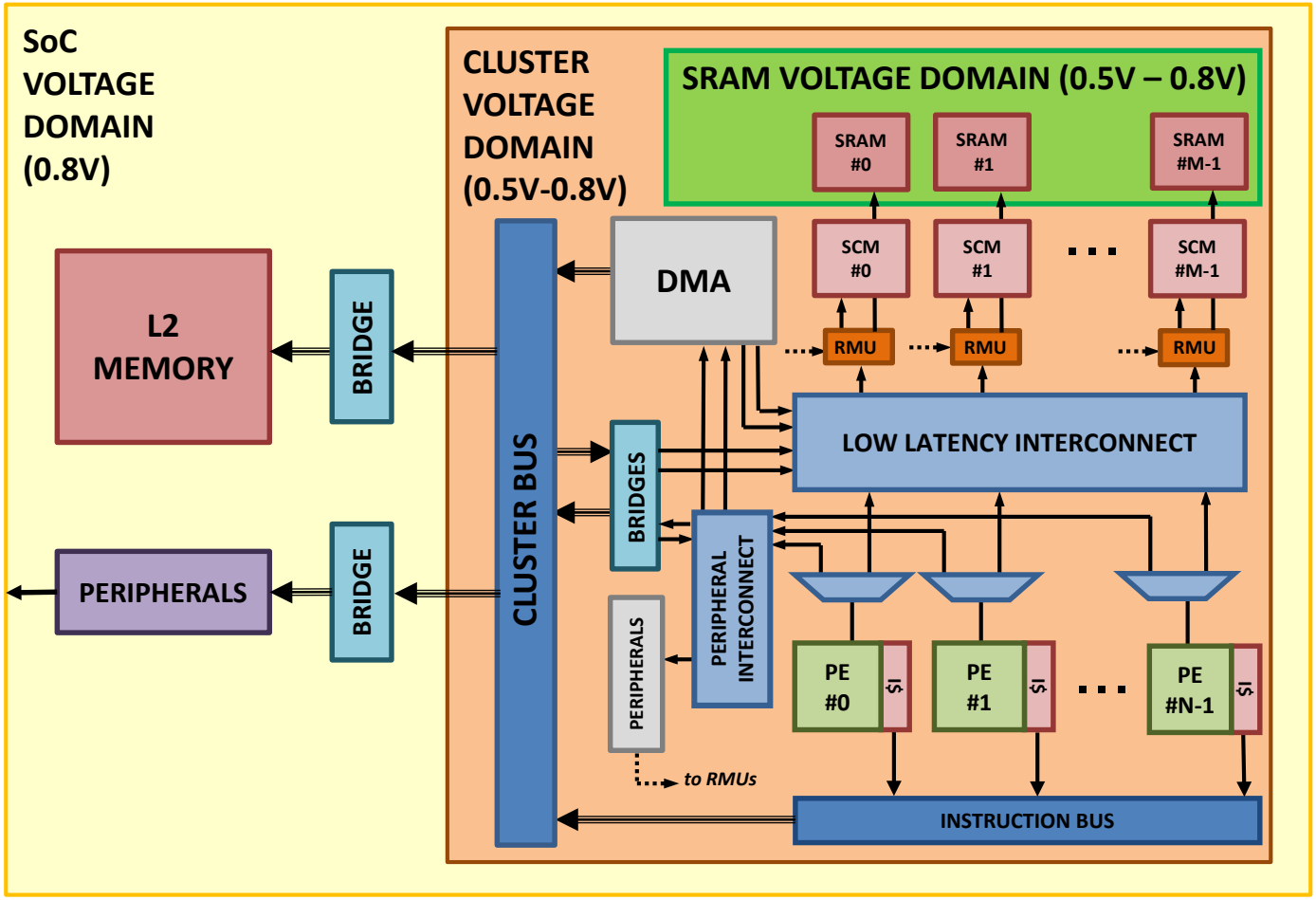
- Foundational API for vision acceleration
  - Focus on ***mobile and embedded systems***
- Stand-alone or complementary to other libraries
- Enable **efficient implementations** on different devices
  - CPUs, GPUs, DSPs, ***many-core accelerators***

Accelerator template



PULP

Parallel Ultra-Low-Power platform



OpenVX programming model

- The OpenVX model is based on a **directed acyclic graph** of nodes (***kernels***), with data (***images***) as linkage

```
vx_image imgs[] = {
  vxCreateImage(ctx, width, height, VX_DF_IMAGE_RGB),
  vxCreateVirtualImage(graph, 0, VX_DF_IMAGE_U8),
```

Virtual images are not required to actually reside in main memory
✓They define a data dependency between kernels, but they cannot be read/written

An OpenVX program must be verified to guarantee some mandatory properties:
✓Inputs and outputs compliant to the node interface
✓No cycles in the graph
✓Only a single writer node to any data object is allowed
✓Writes have higher priorities than reads.
✓Virtual image must be resolved into concrete types

```
vxVerifyGraph(graph);
vxProcessGraph(graph);
```

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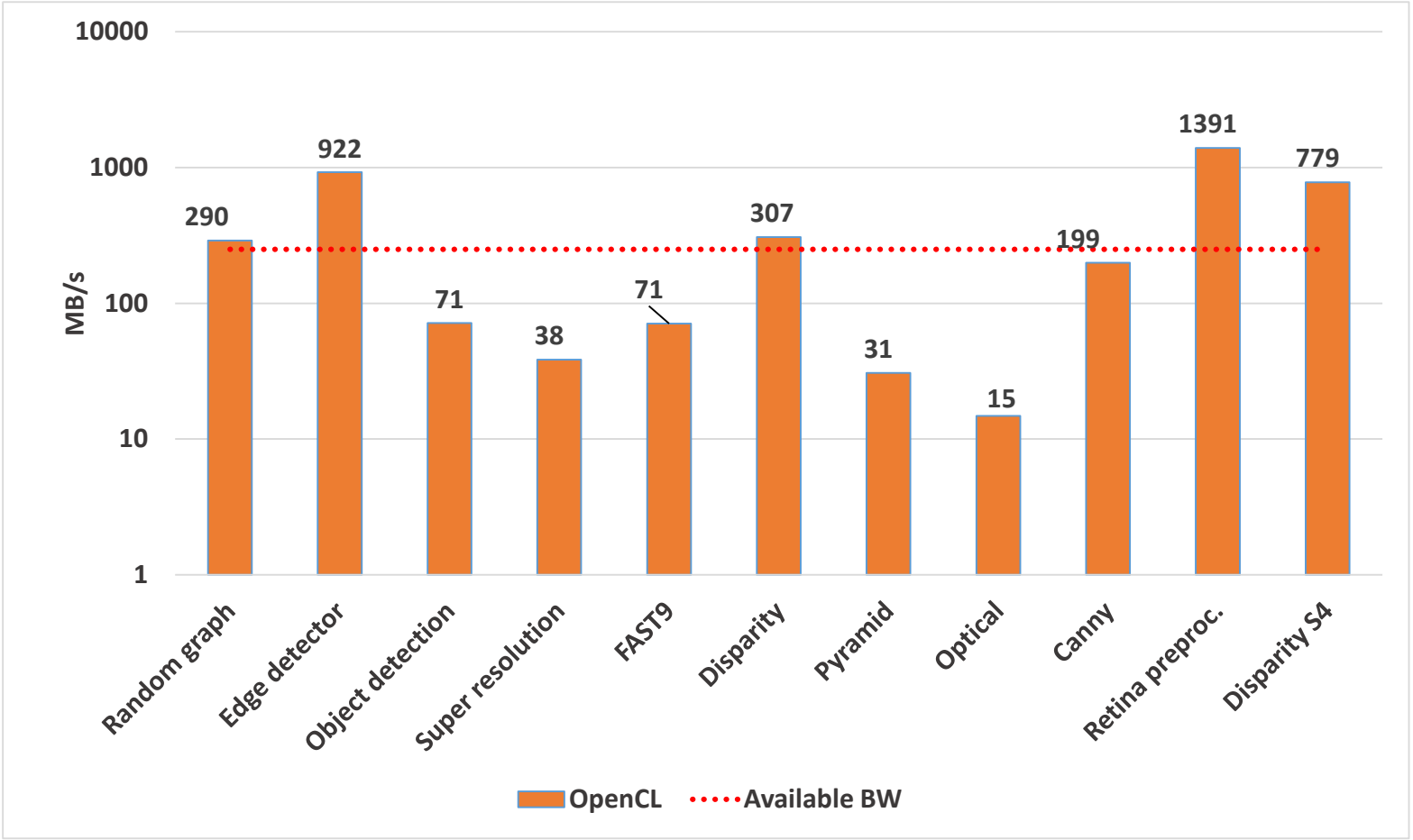
A first solution: using OpenCL to accelerate OpenVX kernels

- OpenCL is a commonly used programming model for many-core accelerators
- First solution: **OpenVX kernel == OpenCL kernel**
  - When a node is selected for execution, the related OpenCL kernel is enqueued on the device
- Main limiting factor**: memory bandwidth**

OpenCL bandwidth

- Experiments performed on the STHORM evaluation board



Our solution

- We realized an OpenVX framework for many-core accelerators coupling a **tiling approach** with algorithms for **graph partition and scheduling**
- Main goals:
  - **Reducing the memory bandwidth**
  - Maximize the accelerator efficiency
- Several steps are required:
  - **Tile size propagation**
  - **Graph partitioning**
  - **Node scheduling**
  - **Buffer allocation**
  - **Buffer sizing**

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Common access patterns for image processing kernels

(D) GLOBAL OPERATORS
Compute the value of a point in the output image using the whole input image
Support: ***Host exec / Graph partitioning***

(A) POINT OPERATORS
Compute the value of each output point from the corresponding input point

Support: ***Basic tiling***

(E) GEOMETRIC OPERATORS
Compute the value of a point in the output image using a non-rectangular input window
Support: ***Host exec / Graph partitioning***

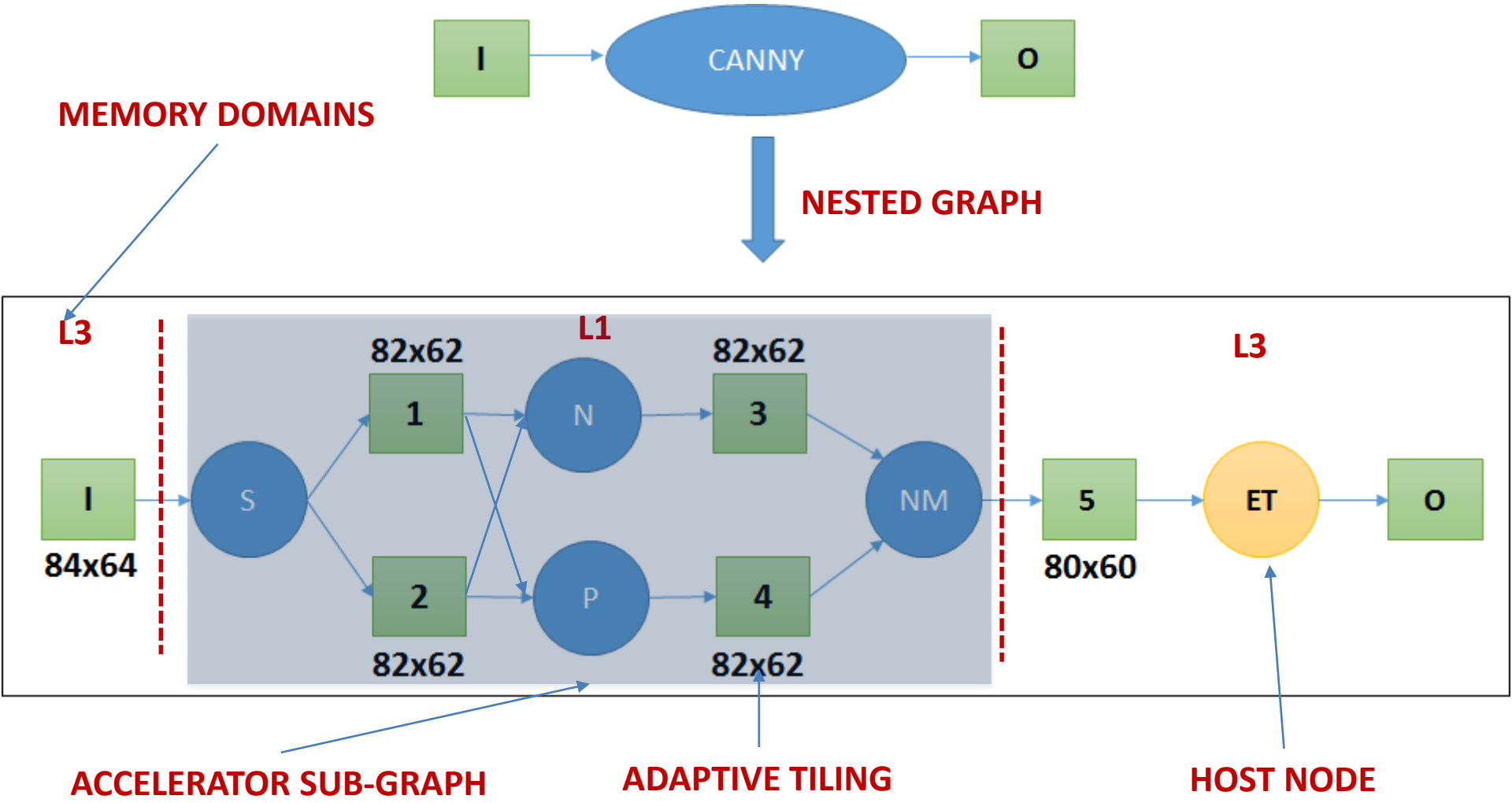
(B) LOCAL NEIGHBOR OPERATORS
Compute the value of a point in the output image that corresponds to the input window
Support: ***Tile overlapping***

(F) STATISTICAL OPERATORS
Compute any statistical functions of the image points

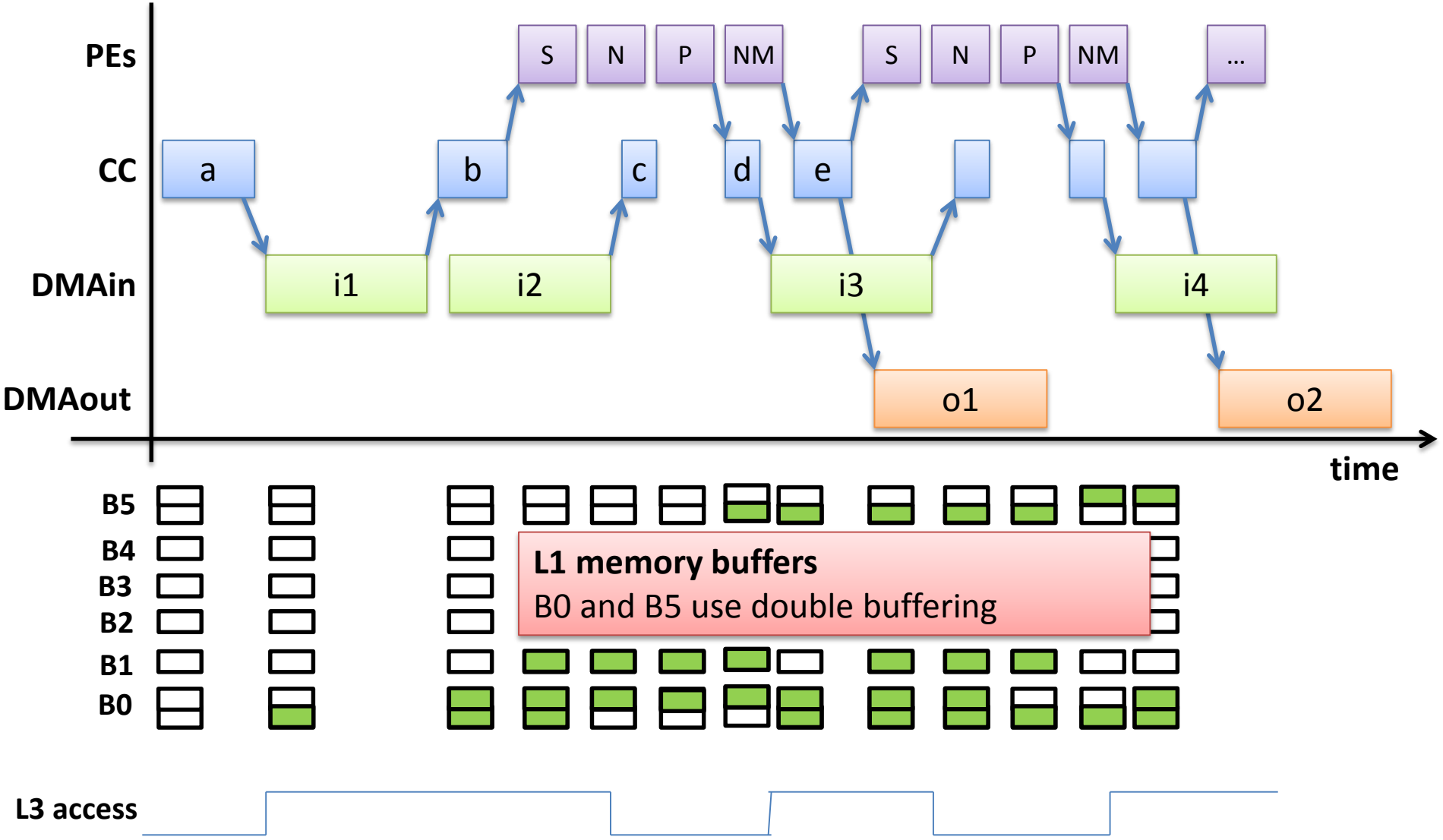
Support: ***Graph partitioning***

(C) RECURSIVE NEIGHBOR OPERATORS
Like the previous ones, but also consider the previously computed values in the output window
Support: ***Persistent buffer***

Example (1)


I
CANNY
O
MEMORY DOMAINS
NESTED GRAPH
L3
L1
L3
82x62
82x62
1
N
3
I
S
NM
5
ET
O
84x64
2
P
4
80x60
82x62
82x62
ACCELERATOR SUB-GRAPH
ADAPTIVE TILING
HOST NODE

Example (2)


PEs
CC
DMAin
DMAout
S
N
P
NM
S
N
P
NM
...
a
b
c
d
e
i1
i2
i3
i4
o1
o2
time
B5
B4
B3
B2
B1
B0
L1 memory buffers
B0 and B5 use double buffering
L3 access

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Bandwidth reduction

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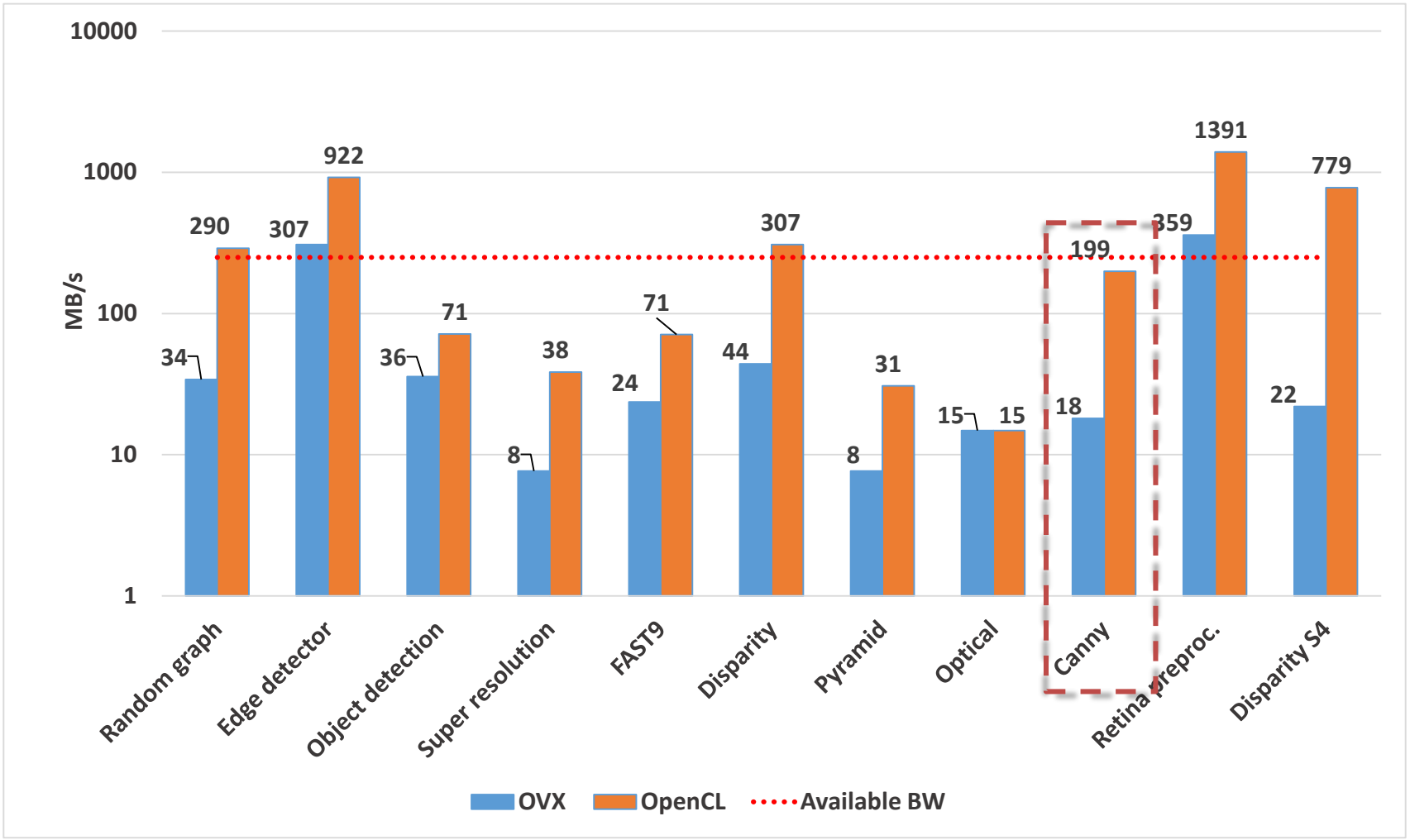
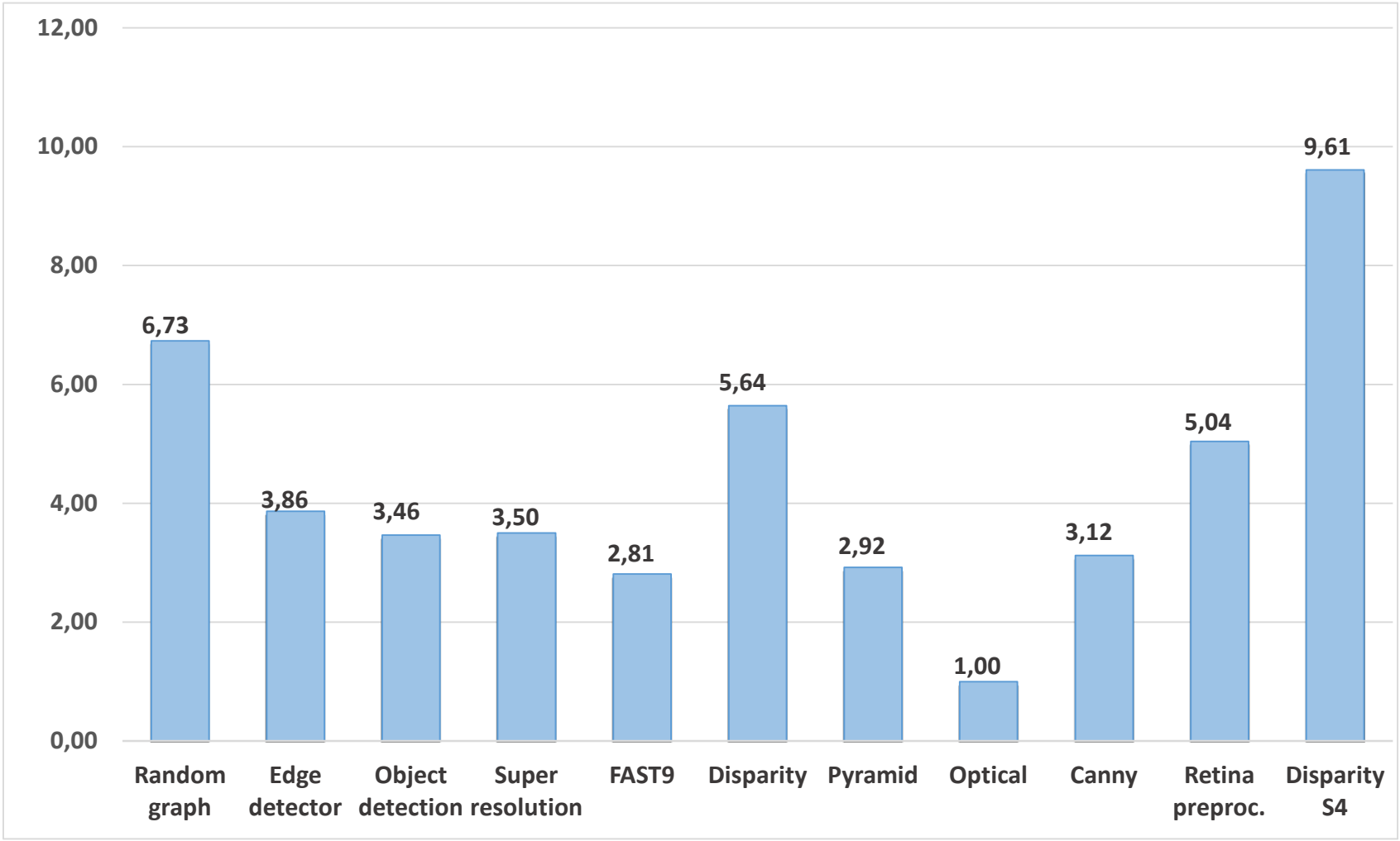


Speed-up w.r.t. OpenCL



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OpenVX + Virtual Platform

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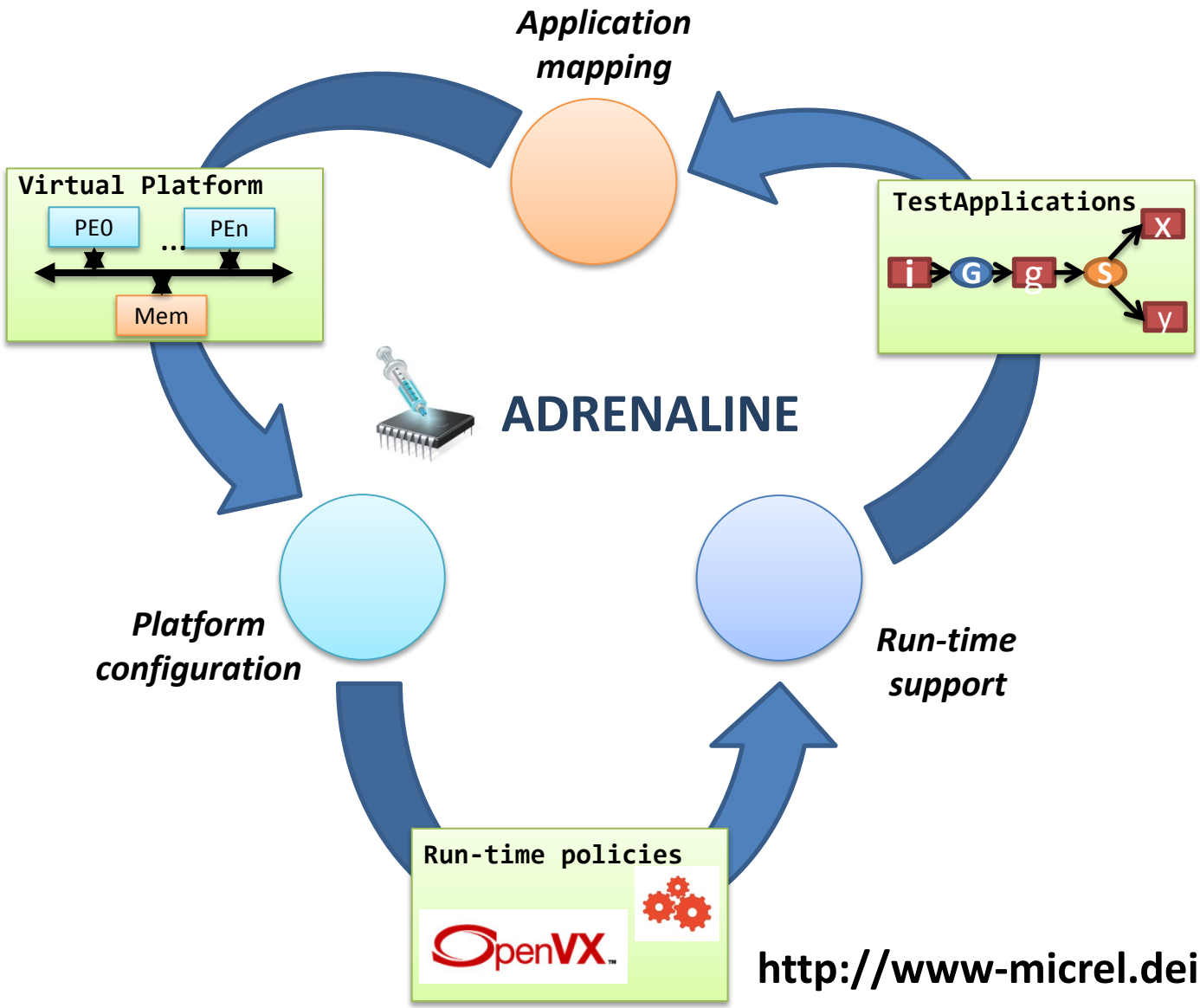

http://www-micrel.deis.unibo.it/adrenaline/

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THANKS!!!

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PHIDIAS

P-SOCRATES