EU H2020 NEURONN: 2D Oscillatory Neural Networks For Energy Efficient Neuromorphic Computing

Stefania Carapezzi, Gabriele Boschetto, Corentin Delacour, Madeleine Abernot, Thierry Gil, Aida Todri-Sanial

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EU H2020 NEURONN: Two-Dimensional Oscillatory Neural Networks For Energy Efficient Neuromorphic Computing

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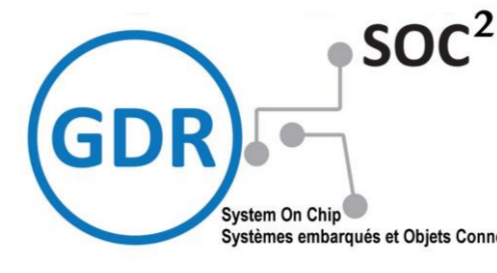
MOTIVATION AND GOALS

ARTIFICIAL INTELLIGENCE AT THE EDGE

- Bandwidth (inference/second)
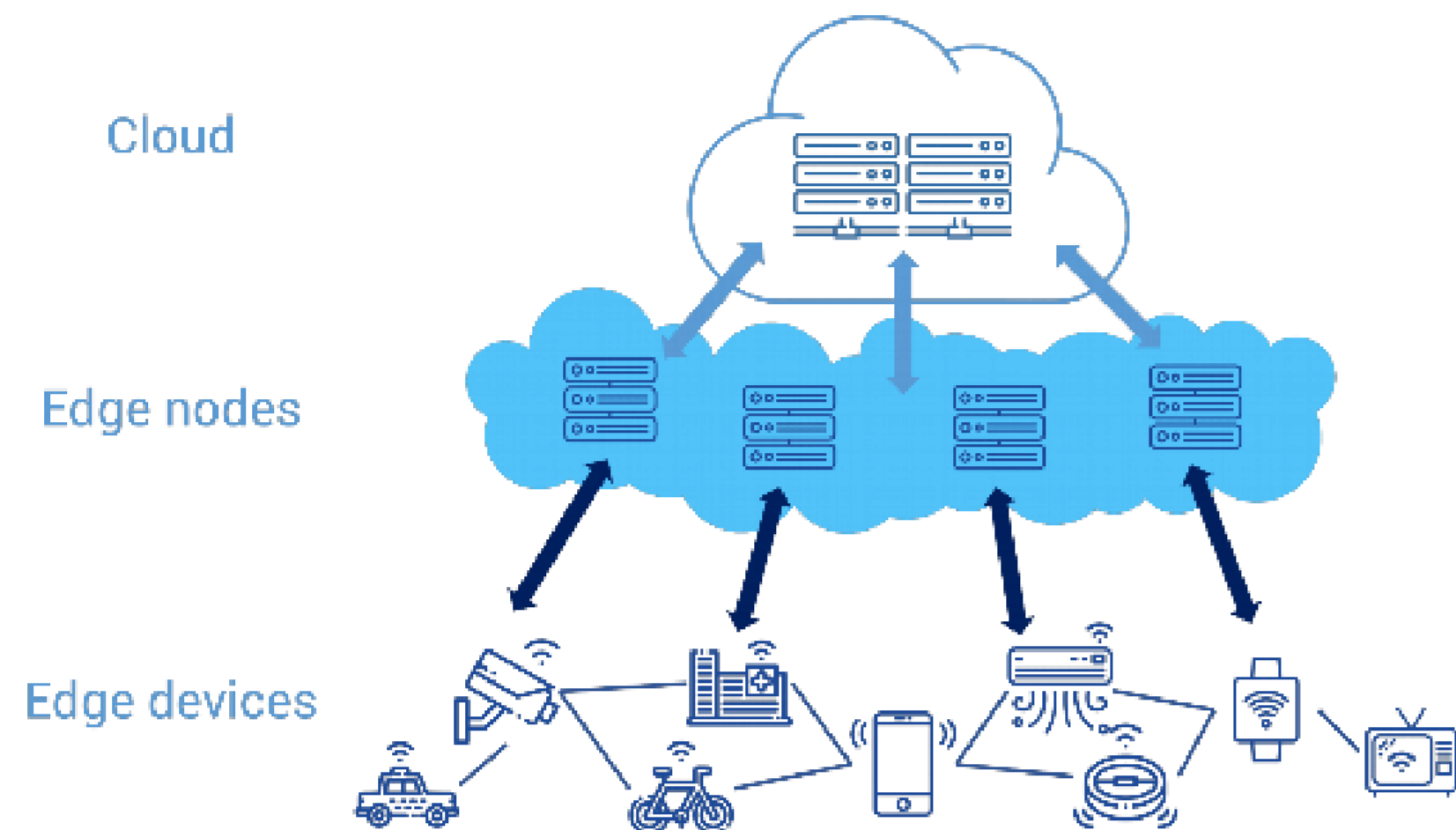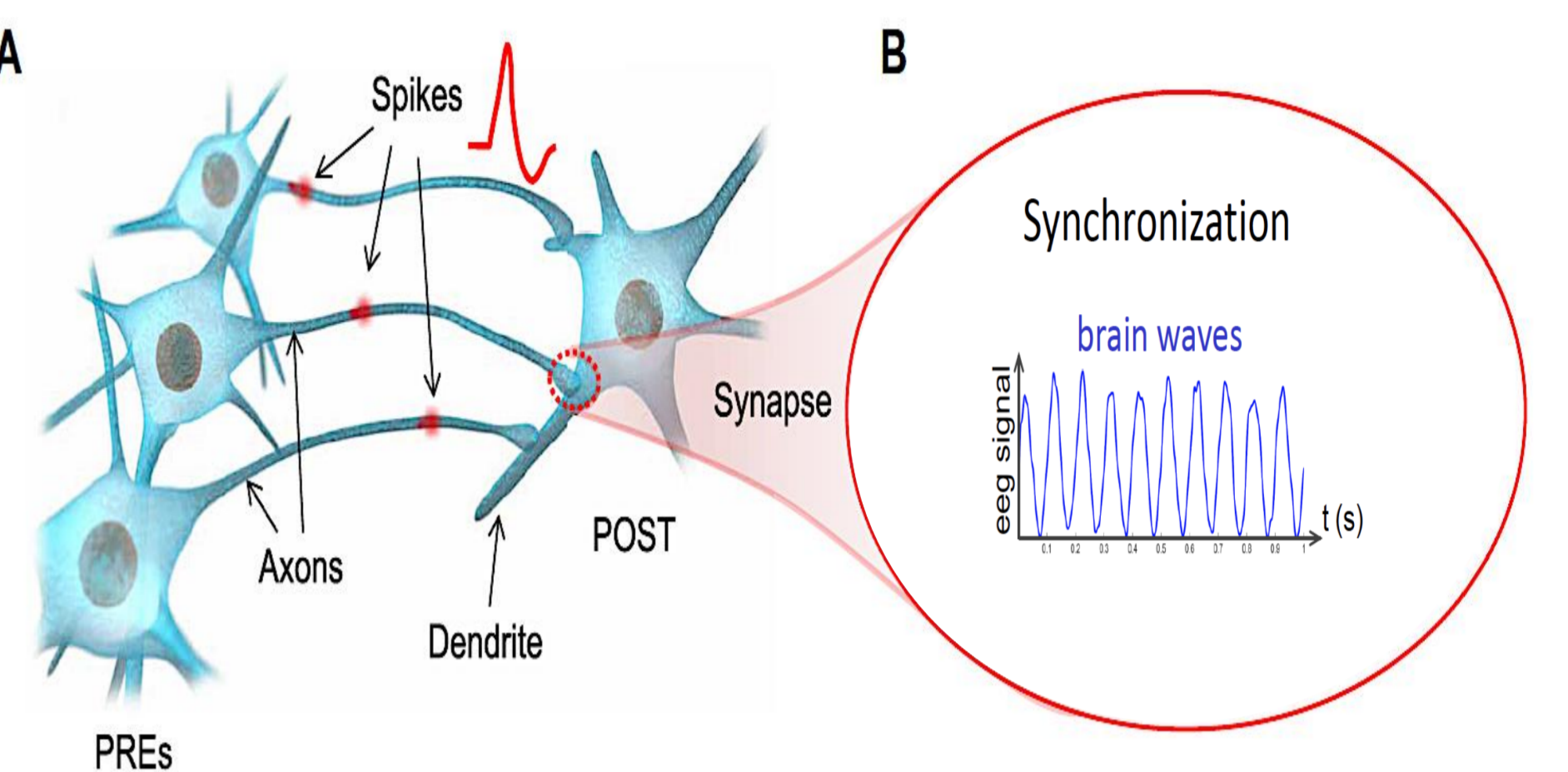- Latency (frames/second)
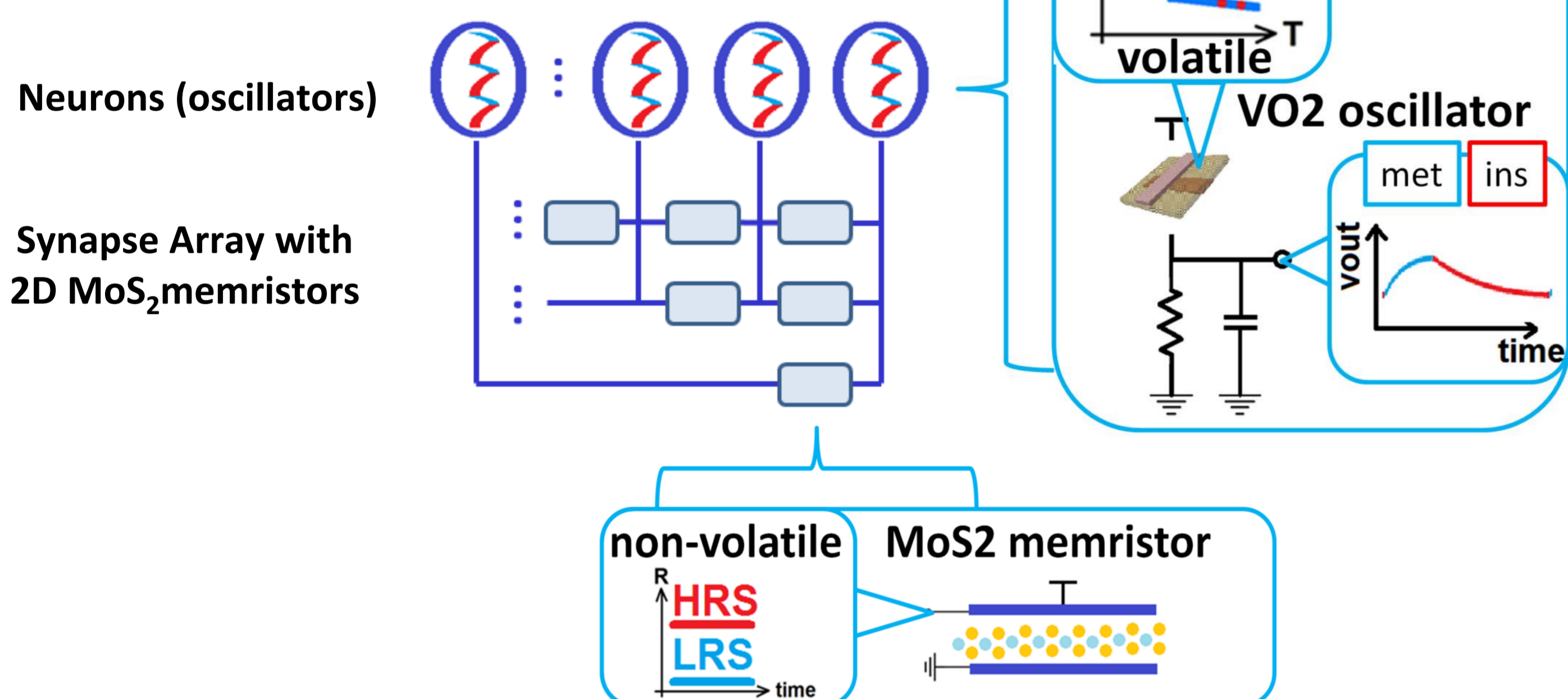- Privacy concerns
- Power consumption

Cloud

Edge nodes

Edge devices

NEUROMORPHIC COMPUTING

- Support online learning
- Excellent inference engine
- Low power consumption
- Scalable/low cost

A · Spikes · B · Synchronization · brain waves · Axons · POST · Dendrite · PREs · Synapse · eeg signal · t(s)
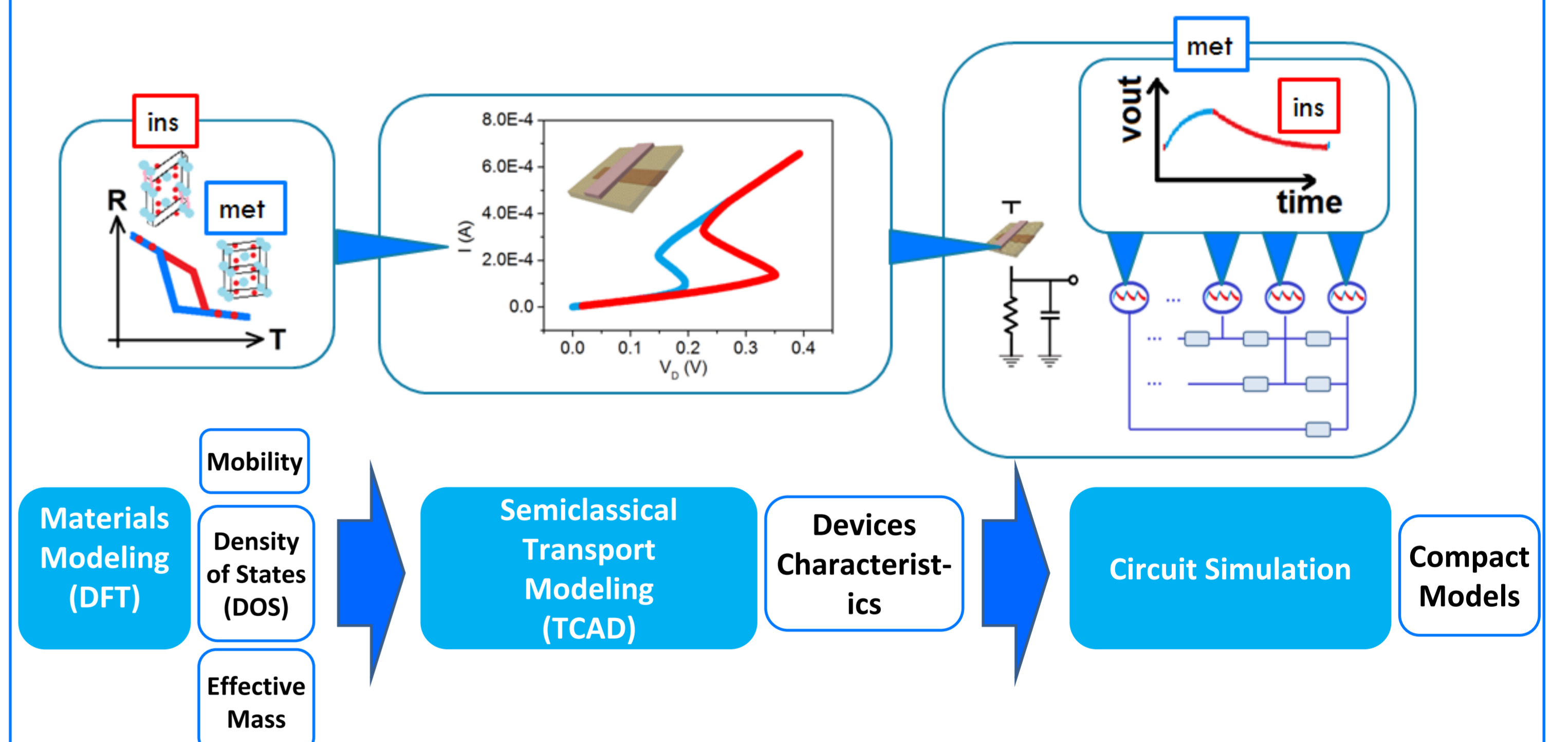
WP1: NOVEL COMPUTING DEVICES AND CIRCUITS

- VO_2 oscillator devices emulating neurons
- MoS_2 memristor devices emulating synapses
- Co-integration of VO_2 and MoS_2 devices
- ONN VO_2 MOS_2 architecture

Neurons (oscillators)

Synapse Array with 2D MoS_2 memristors

ins · met · R · T · volatile · VO2 oscillator · vout · met · ins · time

non-volatile · MoS2 memristor · R · HRS · LRS · time

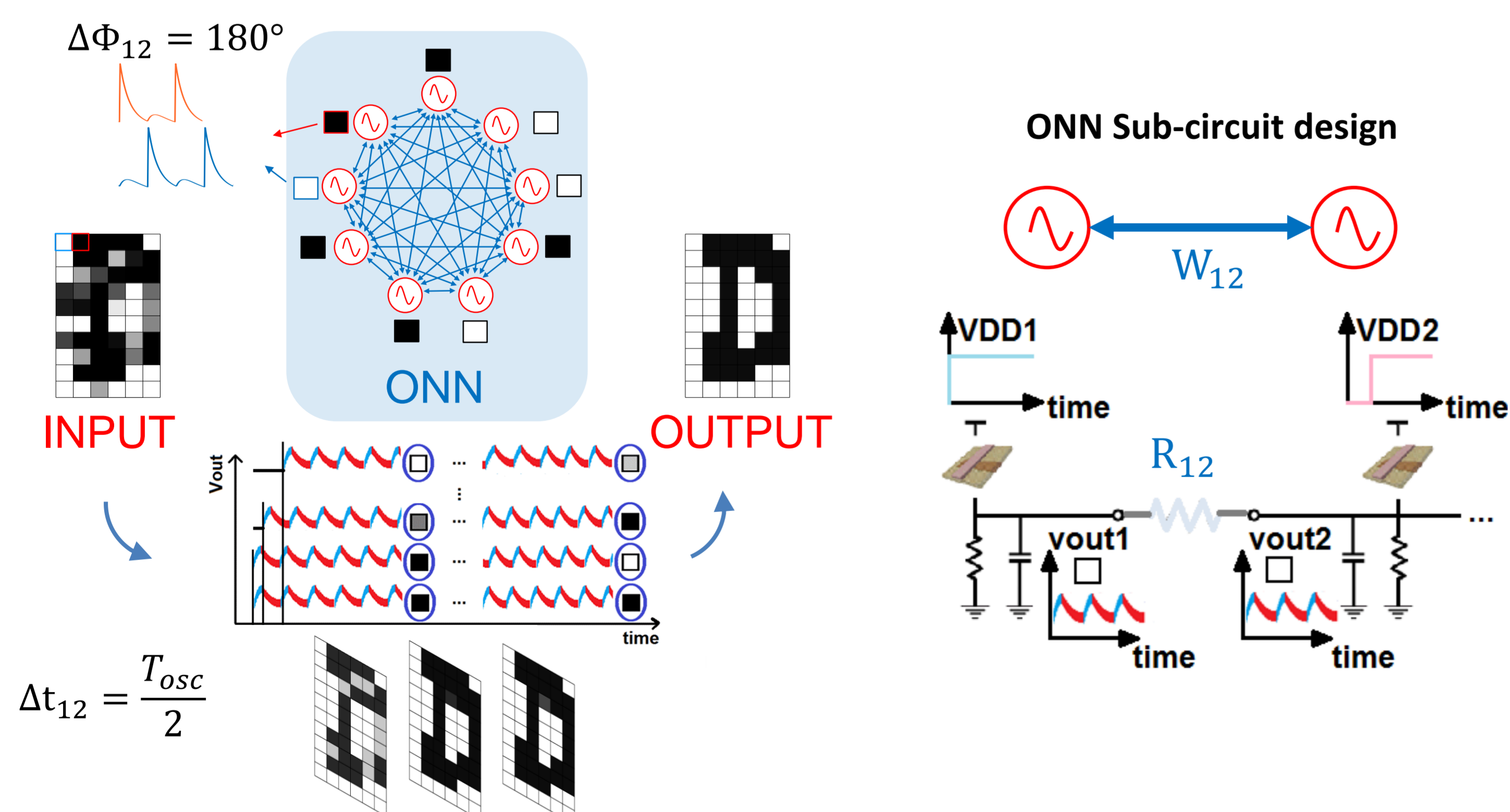## WP2: ADVANCED DESIGN METHODS

- Atomistic simulation
- TCAD device-level simulation
- Compact-models for circuit-level simulation

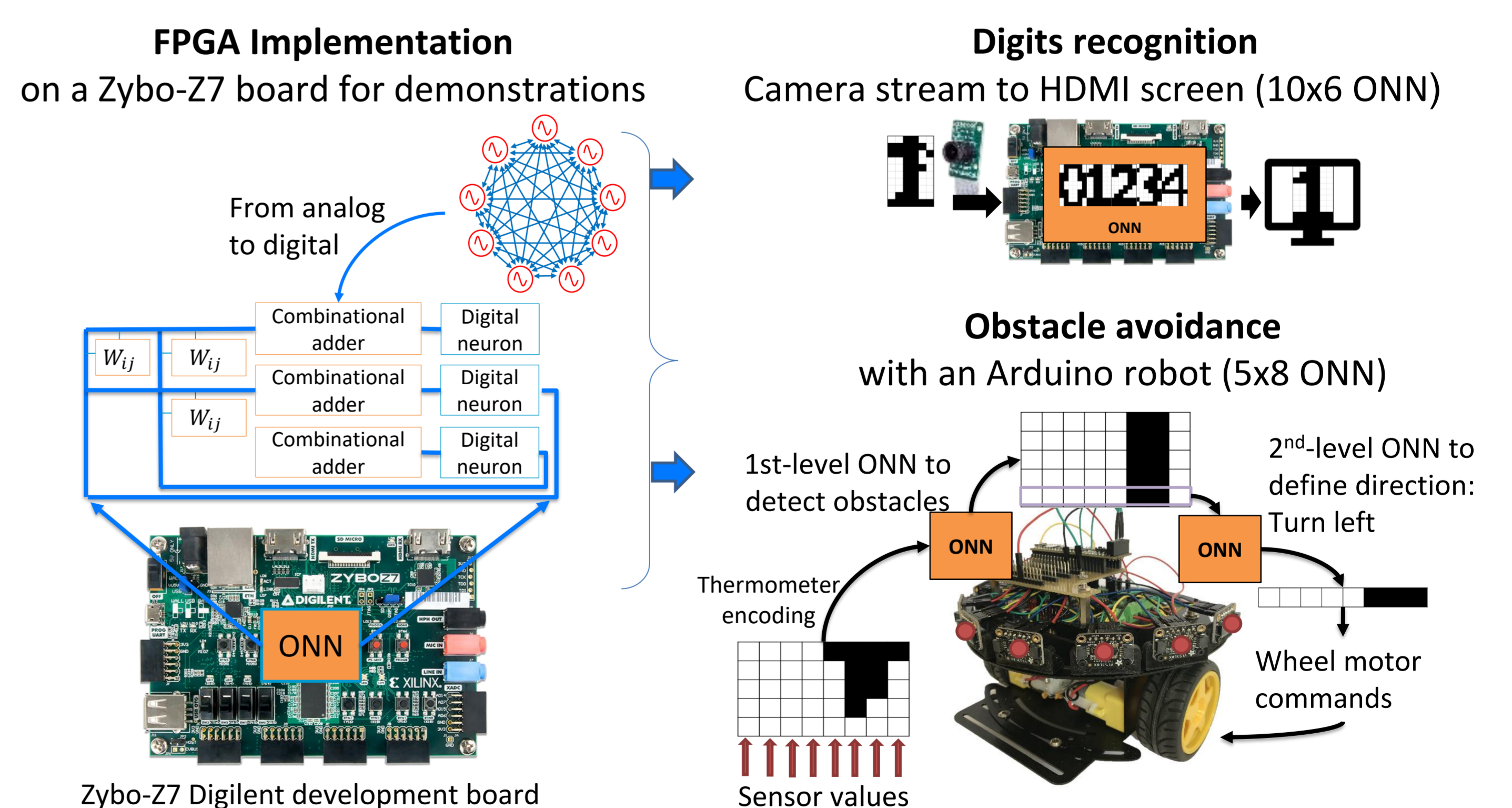ins · R · met · T · I (A) · V_D (V) · met · ins · vout · time

Materials Modeling (DFT)	Mobility		
	Density of States (DOS)	Semiclassical Transport Modeling (TCAD)	Devices Characteristics
	Effective Mass		

Circuit Simulation · Compact Models

WP3: ARCHITECTURE AND DESIGN SPACE EXPLORATION

- Energy-efficient Analog ONN Architecture Design

$\Delta\Phi_{12} = 180°$

INPUT · ONN · OUTPUT

$\Delta t_{12} = \dfrac{T_{osc}}{2}$

ONN Sub-circuit design

W_{12}

VDD1 · time · VDD2 · time · R_{12} · vout1 · vout2 · time · time

WP4: DEMONSTRATORS AND USE CASES

- Digital ONN Implementation on FPGA

FPGA Implementation on a Zybo-Z7 board for demonstrations

From analog to digital

W_{ij}	W_{ij}	Combinational adder	Digital neuron
	W_{ij}	Combinational adder	Digital neuron
		Combinational adder	Digital neuron

ONN

Zybo-Z7 Digilent development board

Digits recognition
Camera stream to HDMI screen (10x6 ONN)

0123 · ONN

Obstacle avoidance
with an Arduino robot (5x8 ONN)

1st-level ONN to detect obstacles · ONN · ONN · 2nd-level ONN to define direction: Turn left · Thermometer encoding · Wheel motor commands · Sensor values

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