European Commission

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Computation-in-Memory Architecture based on Resistive Devices

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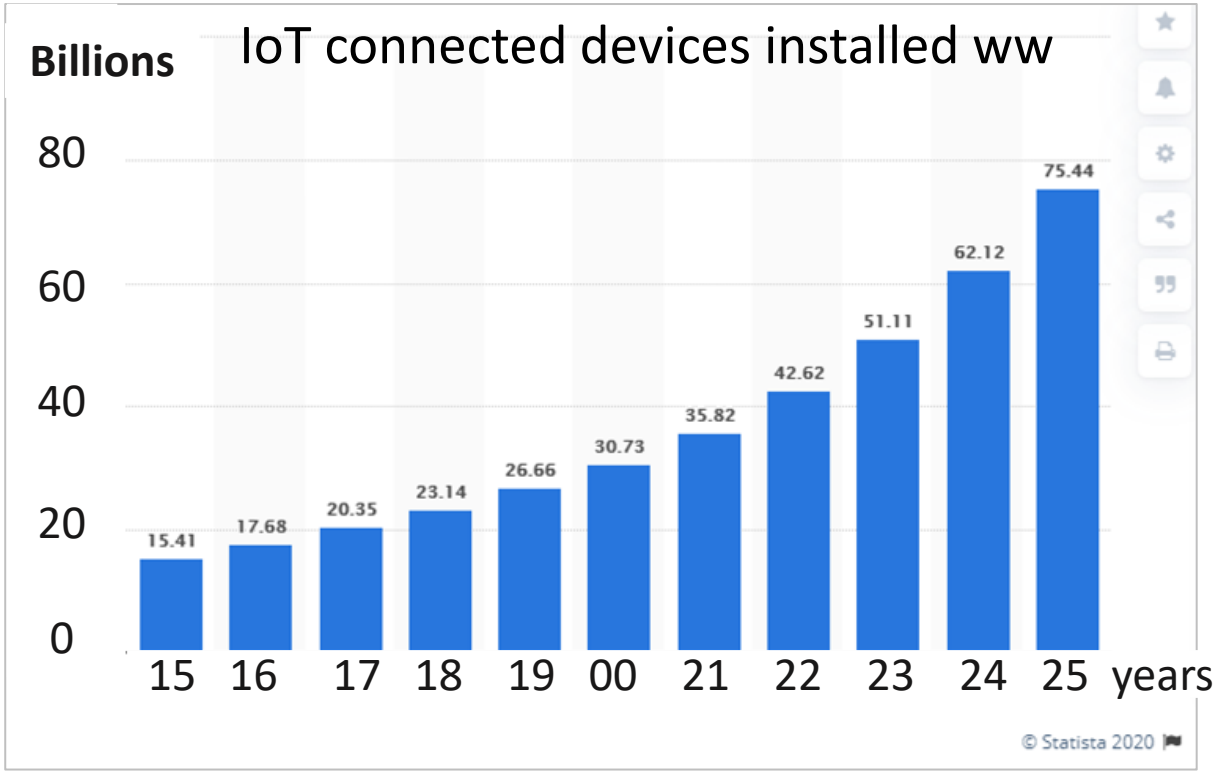
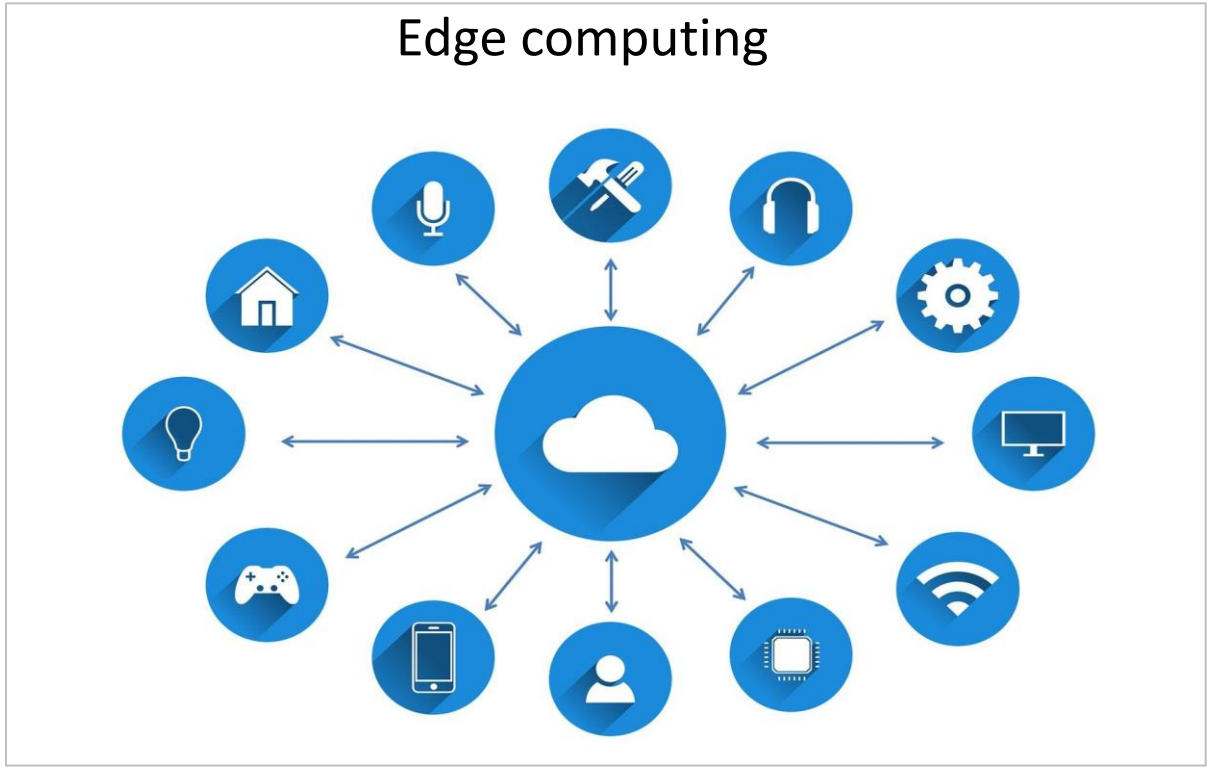
TU Delft · RWTH Aachen University · ETH zürich · IBM Research · TU/e Technische Universiteit Eindhoven University of Technology · Inria Inventeurs du monde numérique · imec · arm · intelligentsia consultants

The opportunity: IoT-edge partnership



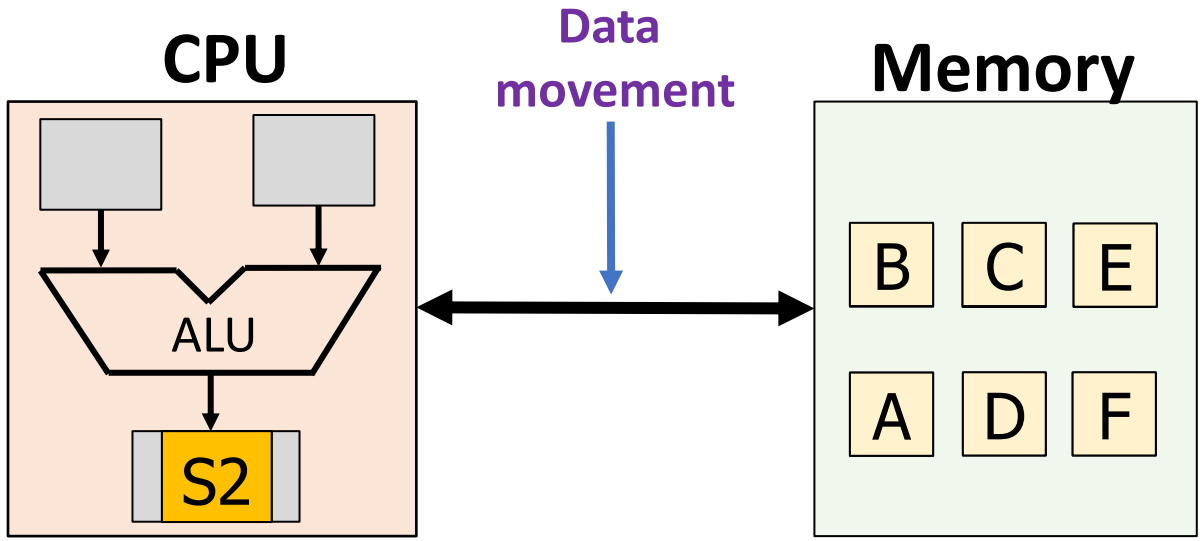


Many requirements

- **Energy constraints**
- Local computing
- More storage
- Data privacy
- Real-time decisions
- 24/7

The challenges: Data movement & static power

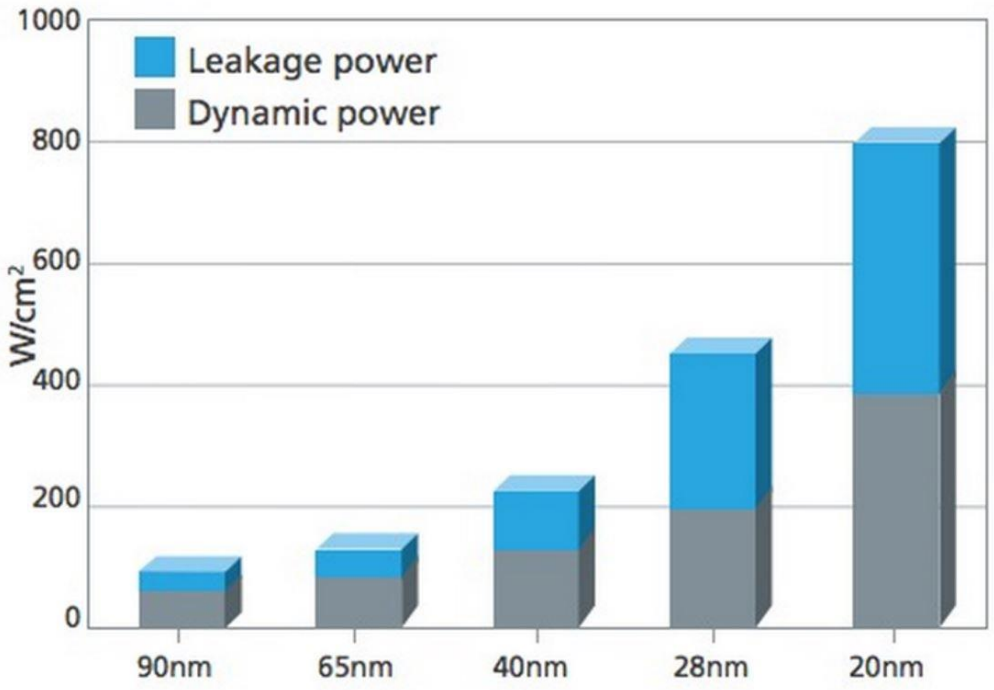
- **Energy in conventional computer**
  - S1 = A + B



Action (8 bit oper.)	**Energy** (45nm)	**Relative** (vs. ALU)
Add operation (ALU)	0.05 pJ	**1X**
Send to memory	**320 pJ**	**6.400X**

Need of new (unconventional) ***Architectures***

- **Conventional technology**



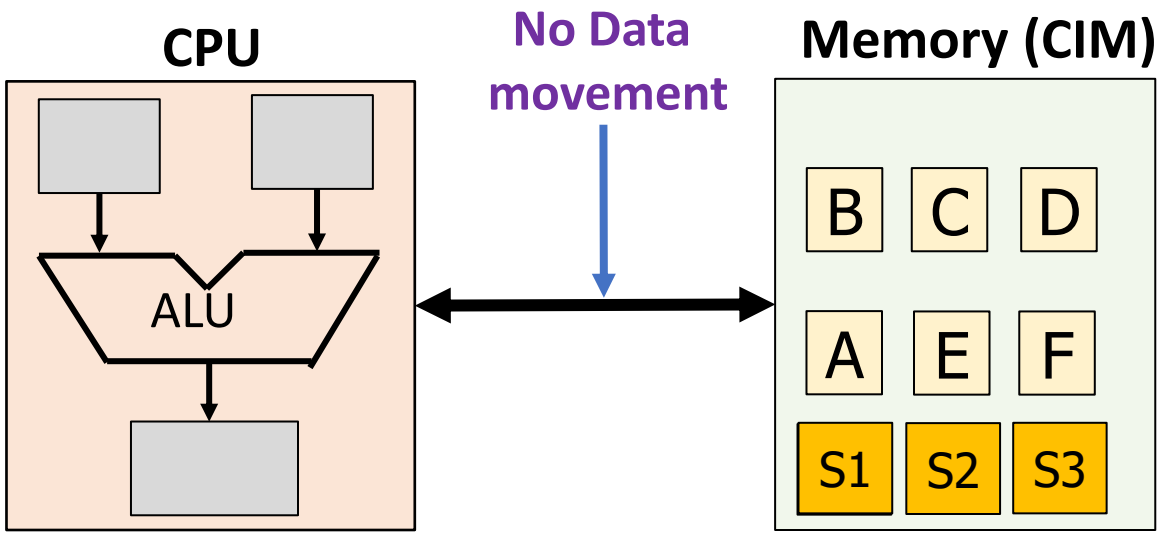
https://semiengineering.com/

Need of new (unconventional) ***Technologies***

The solution: MNEMOSENE

*Explore **alternatives architectures** in the light of emerging **non-volatile device technologies***

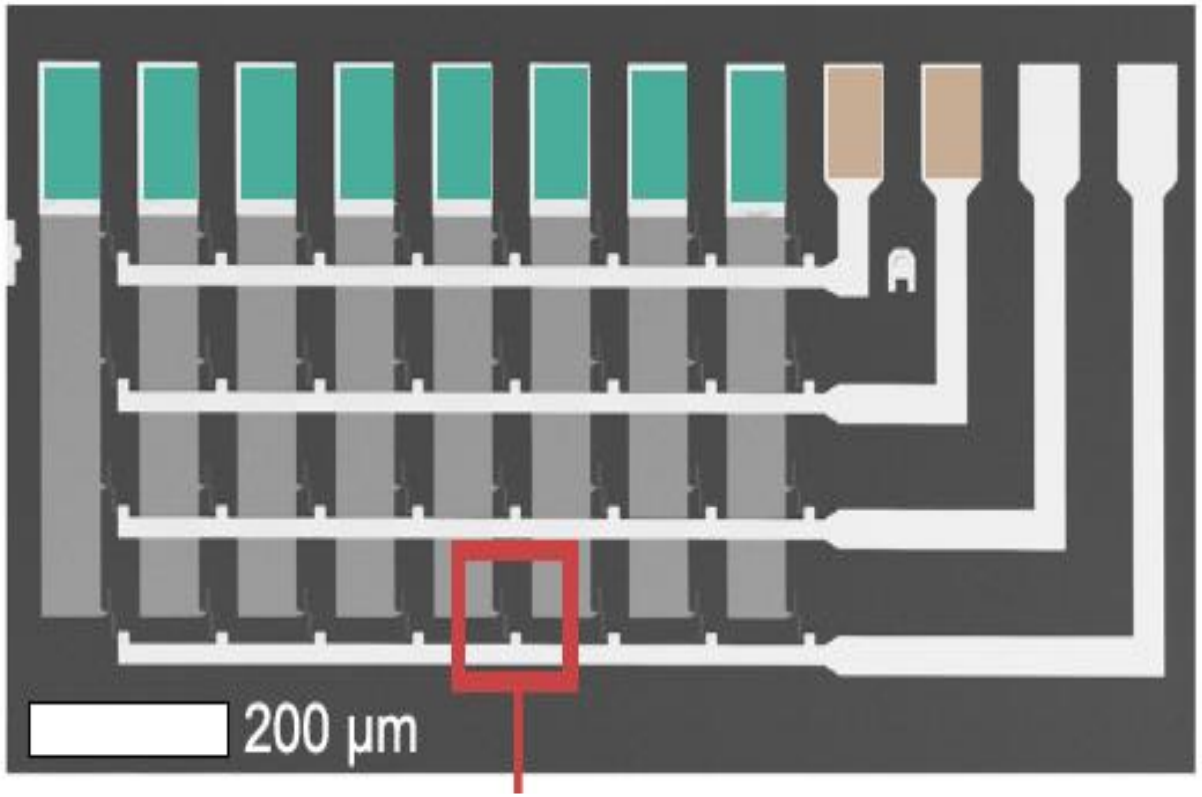
- **Computation-In Memory (CIM)**
  - Single operation: S1= A + B
  - Parallel operations
- **Use memristor devices**
  - Practically **leakage is zero**



Improve the **energy efficiency** and **performance efficiency** by a factor of **10X to 100X**

One selected highlight

Heart disease-related Database (TUD, IBM): CIM demo



[Source: Iason Giannopoulos et.al, "In-Memory Database Query", Advanced Intelligent Systems, open access, 2020]

- **11-step** query in **36 ns**

Throughput: **92.9 GOPS**

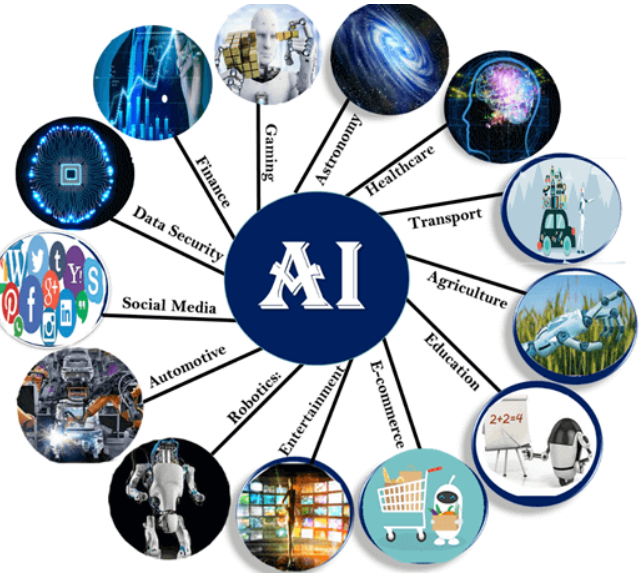
- Total energy: **20 pJ** (power: 558 µW)

Efficiency: **166 TOPS/W**

Efficiency = **< 1pJ/operation**

Potential of CIM: Enabling edge/IoT applications

Enable deployment of AI at the edge



CIM

10 TOPS/W
0.1 pj/operation

1 TOPS/W,
1 pj/operation

100,000 MOps/mW

10,000 MOps/mW

1,000 MOps/mW

100 MOps/mW

10 MOps/mW

1 MOps/mW

Better power efficiency

4G wireless

Mobile HD video

3G wireless

SODA (65 nm)

SODA (90 nm)

Imagine

IBM Cell

VIRAM

TI C6X

Pentium M

Performance (Gops)

Power (watts)

1000,00

100,00

10,000

1,000

100

10

1

0.1

1

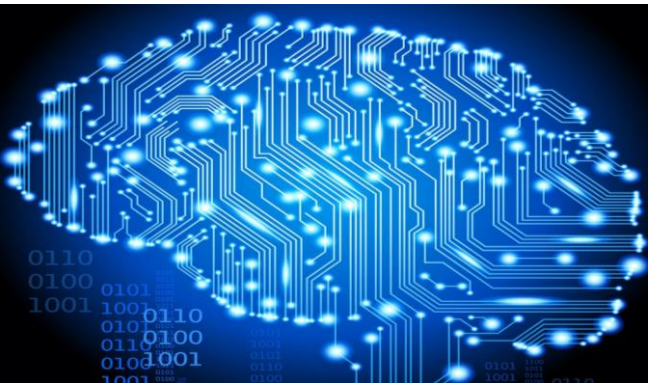
10

100

[Source: Mark Woh et al., Computer 43(1): 81-85 (2010)]

Conclusion

- Enabling cost effective computation of currently infeasible AI edge applications fueling important societal changes; e.g., personalized healthcare



- Support breakthrough development in Neuromorphic Computing

- Puts Europe in a leading position in the areas of *unconventional computer architectures* and *memristive technology*.

http://www.mnemosene.eu/

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