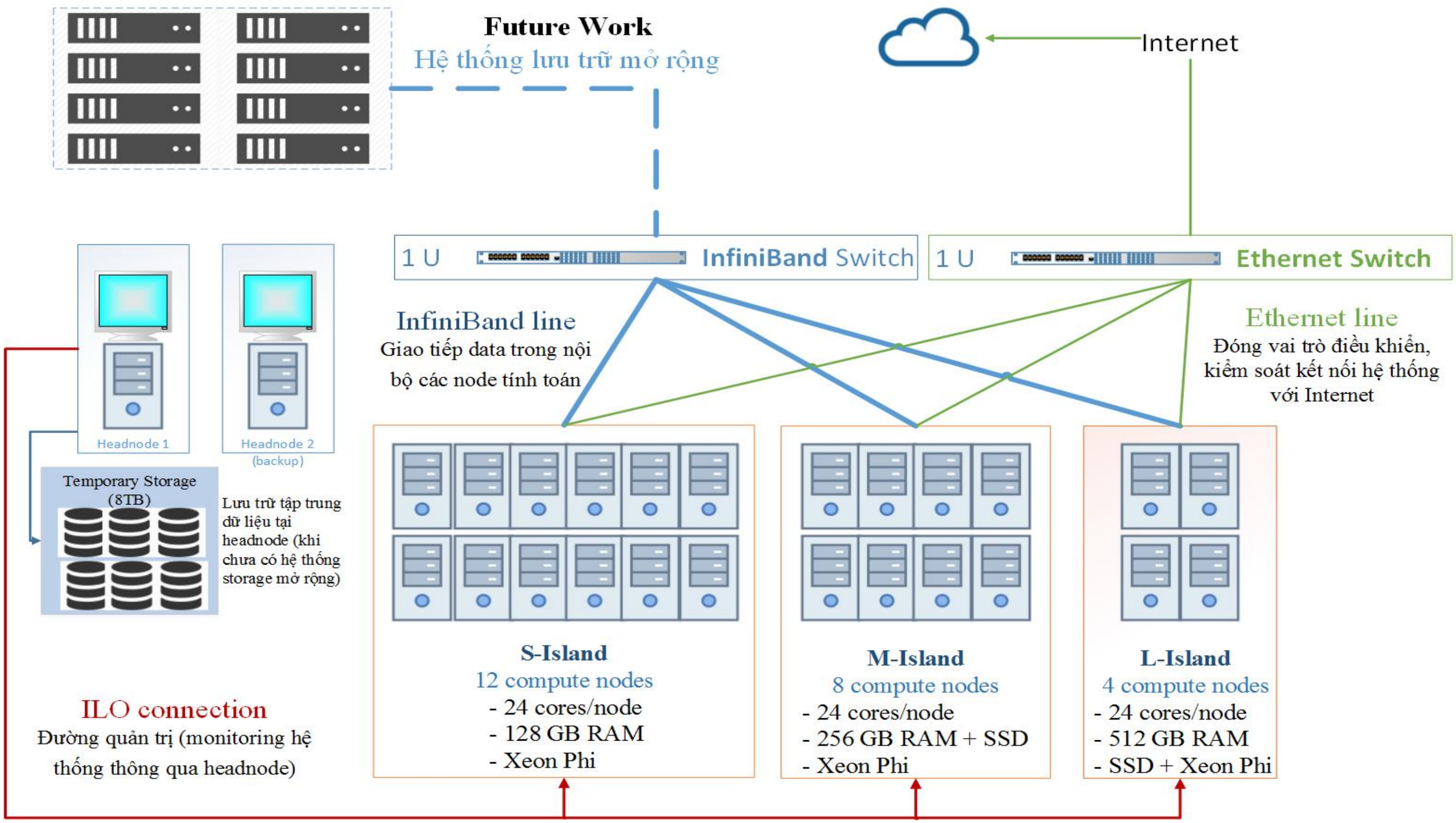
Parallel Processing

Thoai Nam

Faculty of Computer Science and Engineering

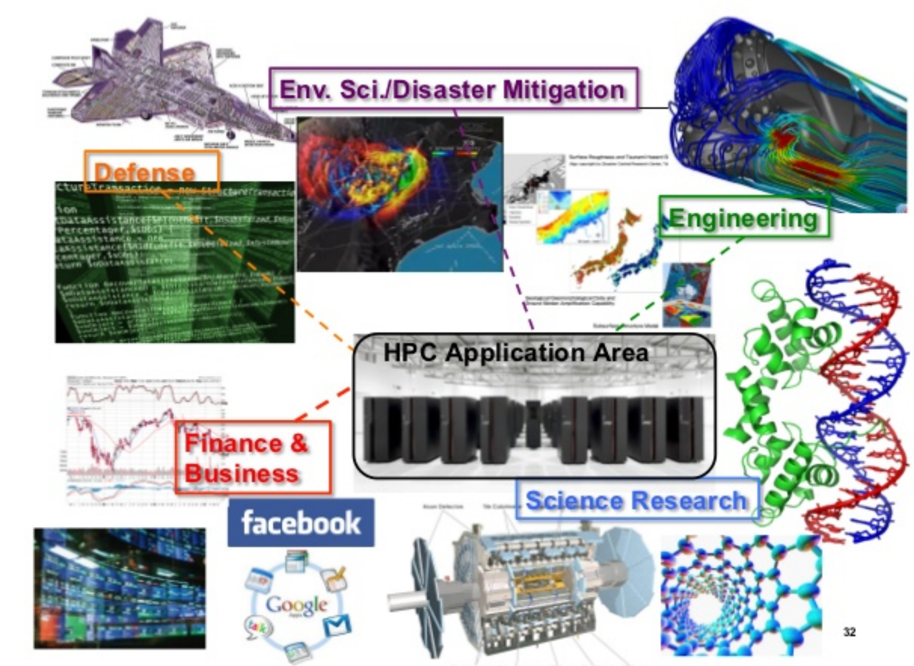
HCMC University of Technology

SuperNode-XP
50 TFlops machine

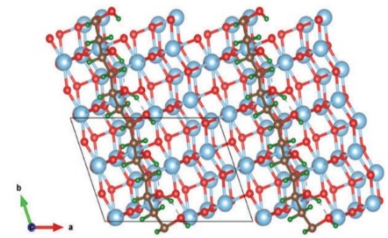


Applications on SuperNode-XP

User	Start Time	End Time	Apps	Organization/Unit
A/Prof. Nguyễn Thống	30/09/14		OpenTelemac	HCMUT – Faculty of Civil Engineering
Ms. Phạm Ngọc Thanh, Dr. Ing Jorg Franke	06/06/16		OpenFoam	Vietnam Germany University
Dr. Lê Thanh Vân	20/08/16		Hadoop	HCMUT – Faculty of Computer Science
A/Prof. Trần Văn Hoài	25/10/16		BLAS	HCMUT – Faculty of Computer Science
Mr. Quân	01/11/16		DFFT	HCMUT – Faculty of Electrical and Electronic Engineering



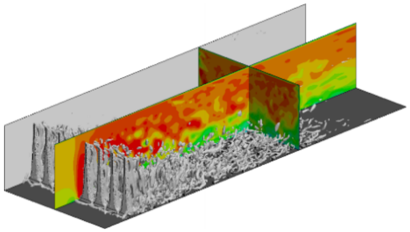
INOMAR center



VASP, Quantum Expresso Simulations

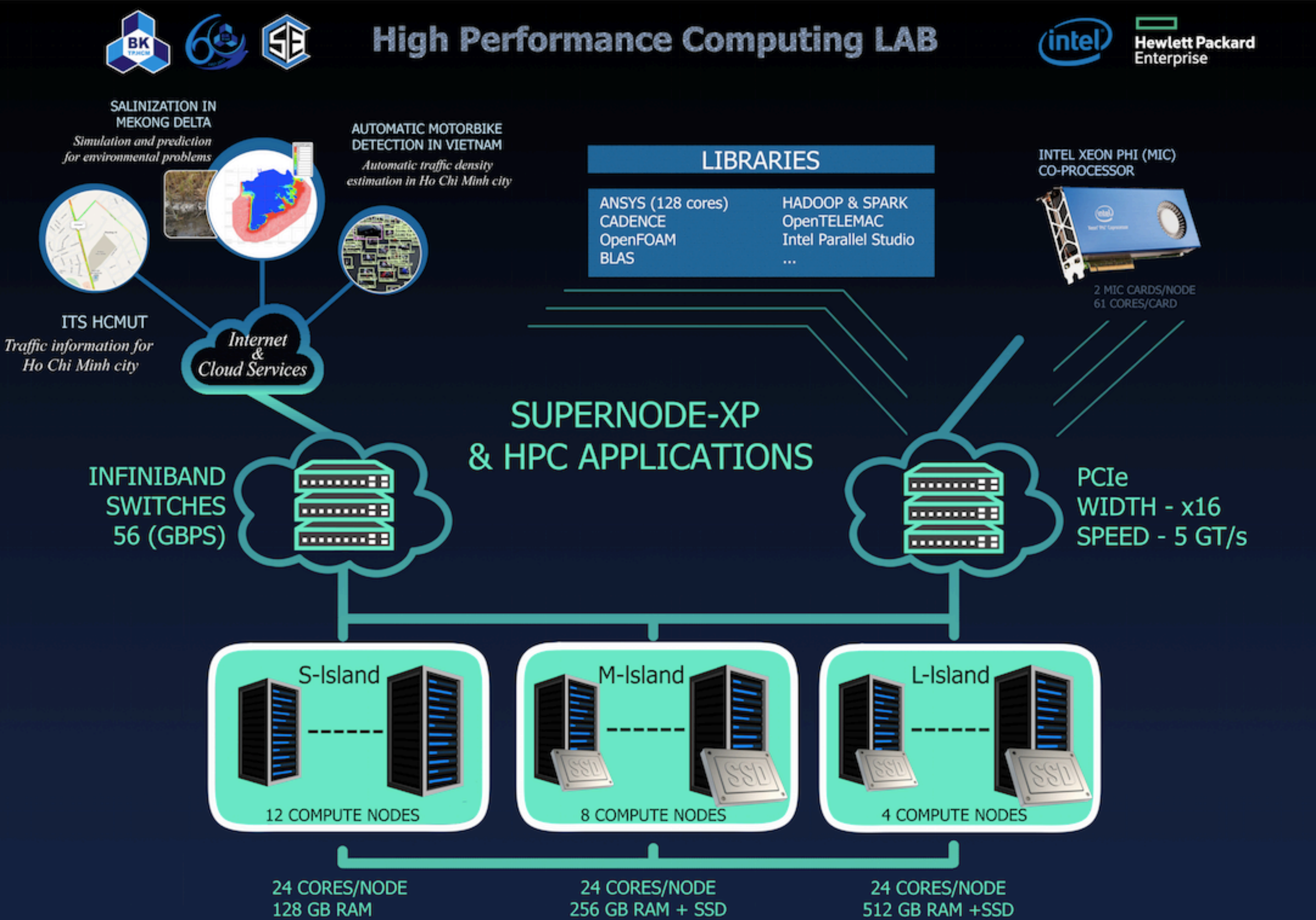
A/Prof. Dzung Hoang

Vietnam Germany University

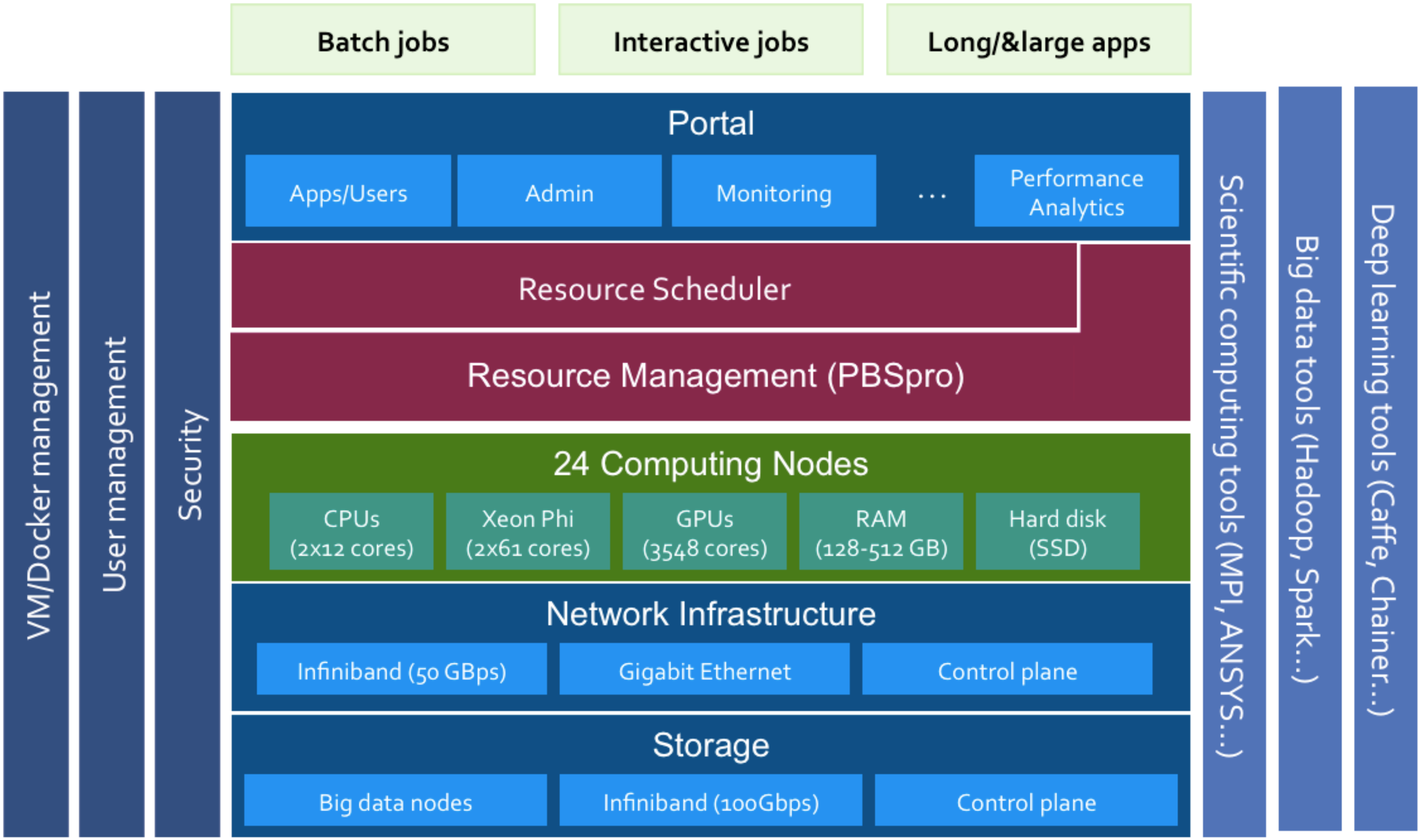


OpenFOAM sims

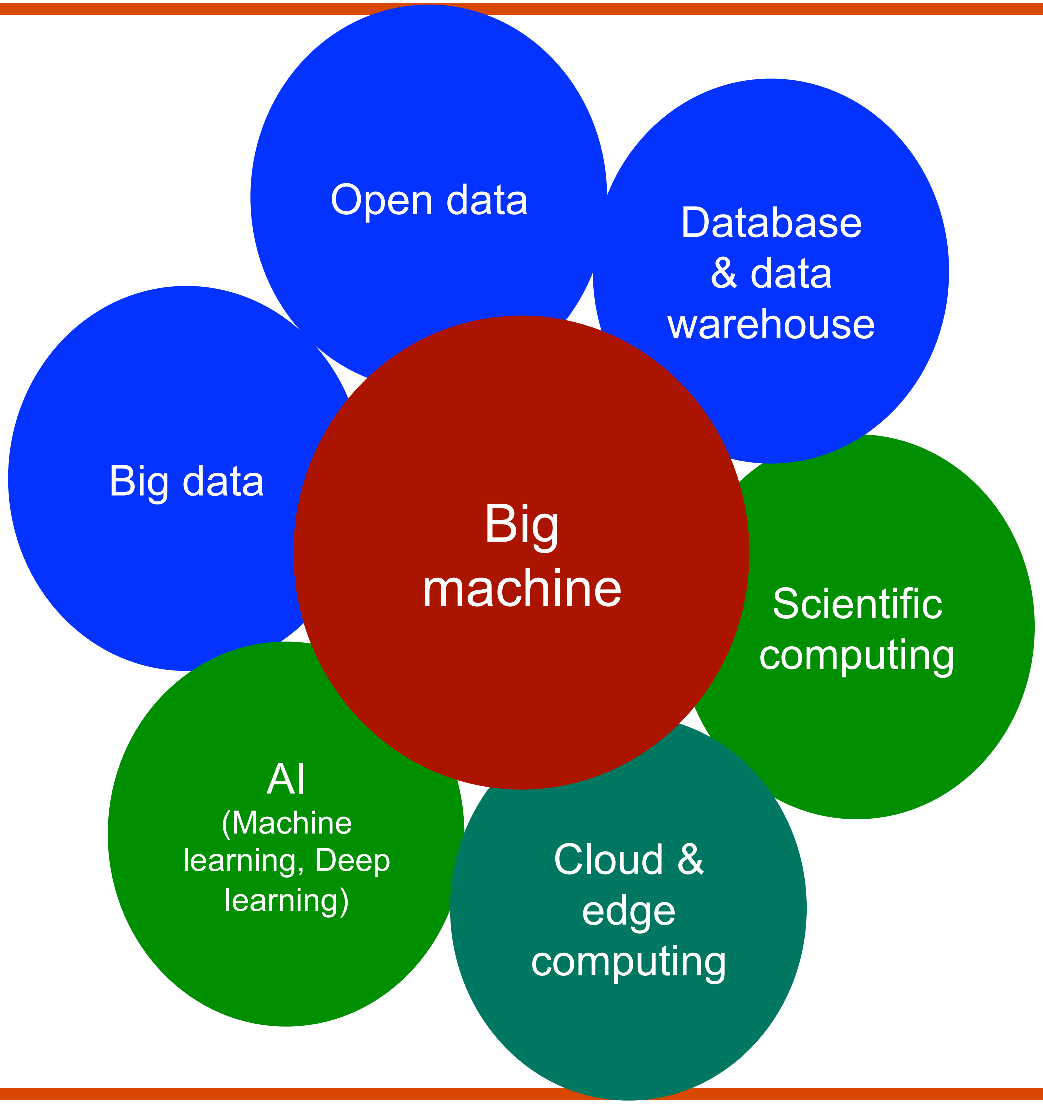
Prof. Joerg Franke


High Performance Computing LAB
BK TP.HCM
intel
Hewlett Packard Enterprise
SALINIZATION IN MEKONG DELTA
Simulation and prediction for environmental problems
AUTOMATIC MOTORBIKE DETECTION IN VIETNAM
Automatic traffic density estimation in Ho Chi Minh city
ITS HCMUT
Traffic information for Ho Chi Minh city
Internet & Cloud Services
LIBRARIES
ANSYS (128 cores)
CADENCE
OpenFOAM
BLAS
HADOOP & SPARK
OpenTELEMAC
Intel Parallel Studio
...
INTEL XEON PHI (MIC) CO-PROCESSOR
2 MIC CARDS/NODE
61 CORES/CARD
SUPERNODE-XP & HPC APPLICATIONS
INFINIBAND SWITCHES 56 (GBPS)
PCIe WIDTH - x16 SPEED - 5 GT/s
S-Island
12 COMPUTE NODES
M-Island
8 COMPUTE NODES
L-Island
4 COMPUTE NODES
24 CORES/NODE
128 GB RAM
24 CORES/NODE
256 GB RAM + SSD
24 CORES/NODE
512 GB RAM +SSD

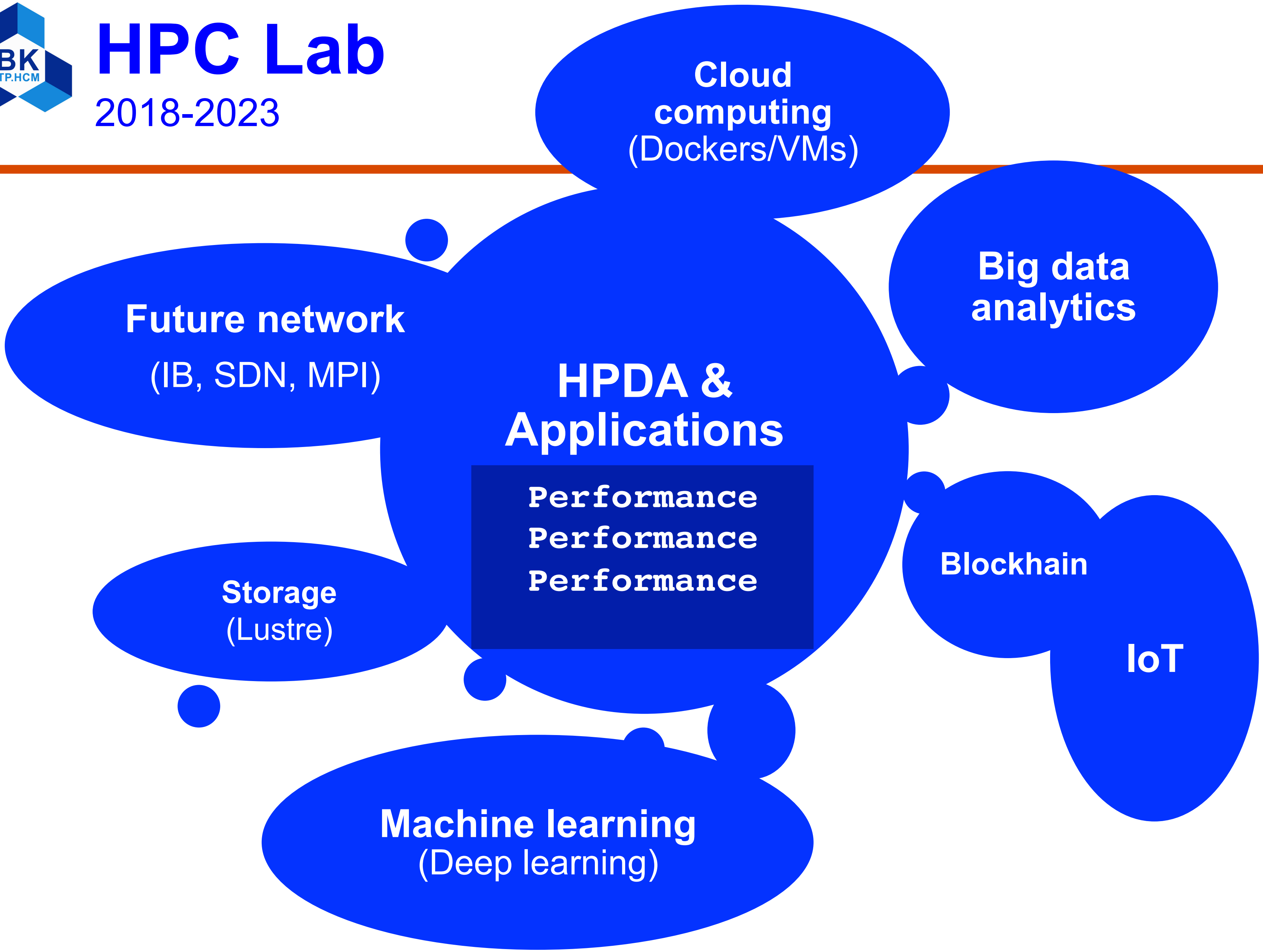
SuperNode-XP Architecture



Smart cities: Data center



HPC Lab
2018-2023



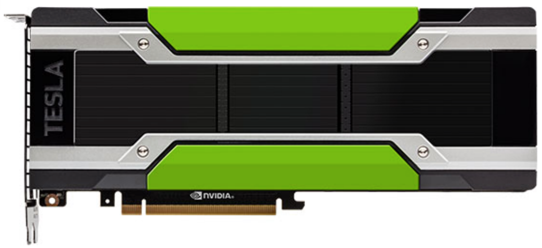
HPDA: Big data analytics
(Lrz-Germany, Intel+HPE)

- SuperNode-XP
  - Xeon + Xeon Phi, GPUs
  - IB, Lustre storage, SSD
- Technology
  - Hadoop, Spark, PBSpro
  - Edge computing, Docker/VMs
  - Intel@ Parallel Studio XE
  - Libraries: ANSYS, OpenTelemac, Gromacs…
- Applications

  (1) Data mining for large-scale data sets: Association rules, K-means, SVM…

  (2) Security analytics

  (3) Real problems in HCMC & VN on SuperNode-XP



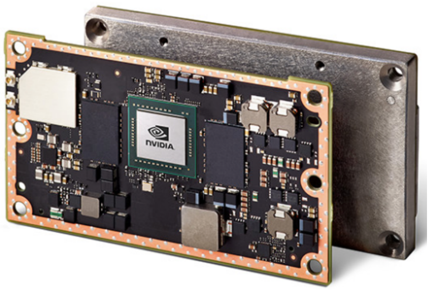
Machine Learning + IoT
(Dr. Lê Thành Sách + Nvidia)

- SuperNode-XP + GPUs
  - P100, P4, GTX 1080Ti, Jetson TX2
- ML: Deep Learning
  - TensorFlow, Torch, Theano, Caffe, Chainer…
- Applications

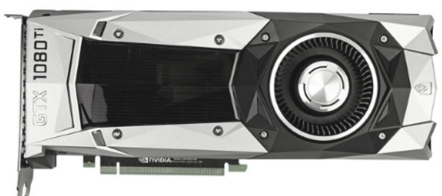
  (1) Image/data analytics

  (2) Computing box (Edge computing)

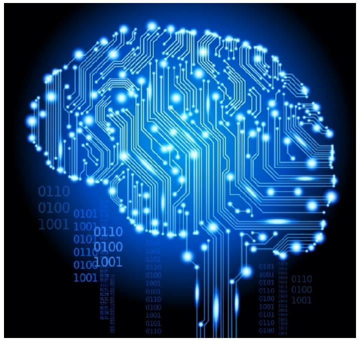
  (3) Real problems in HCMC & VN

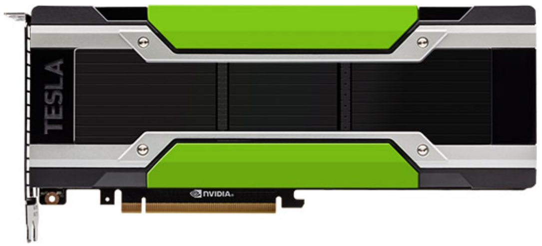


Jetson TX2



GTX 1080 Ti





P100, P4

Future Network
(Dr. Phan Trường Khoa (UCL – UK))

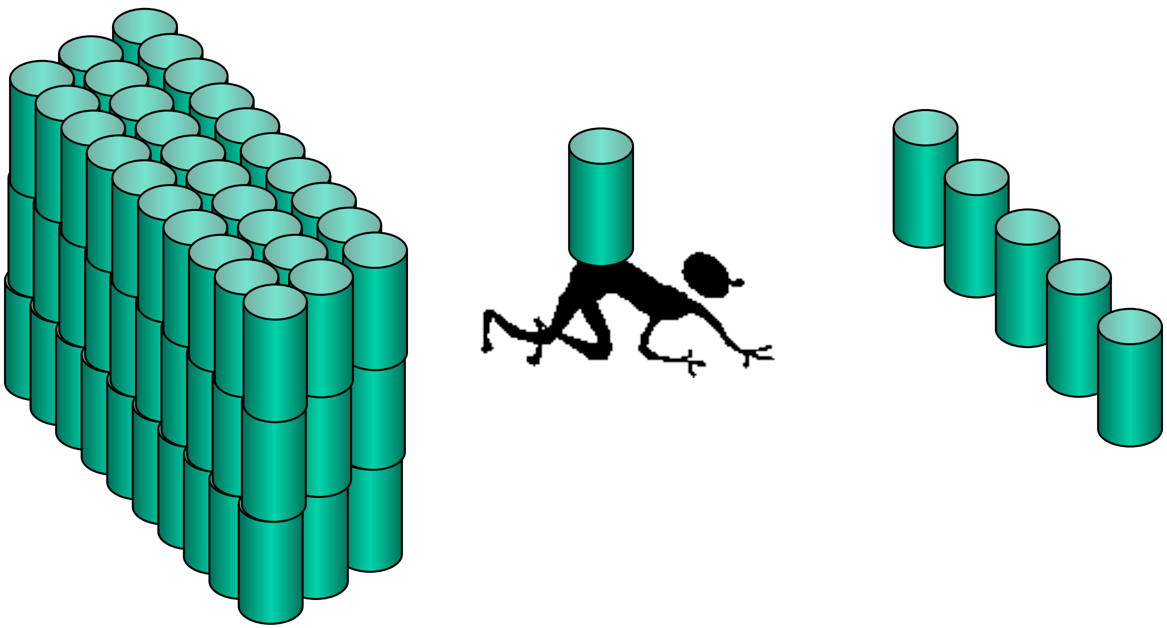
- SDN (Software-Defined Networking)
  - P4: a language for programming the data plane of network devices
  - OpenFlow, OpenDayLight
- MPI
  - MPI one-sided communication
- Applications:
  - Routing analysis
  - Security
  - Optimization for big data applications
- Ref:
  - P4: http://p4.org/
  - IEEE SDN: http://sdn.ieee.org
  - OpenFlow: http://archive.openflow.org
  - OpenDayLight: https://www.opendaylight.org

How to do

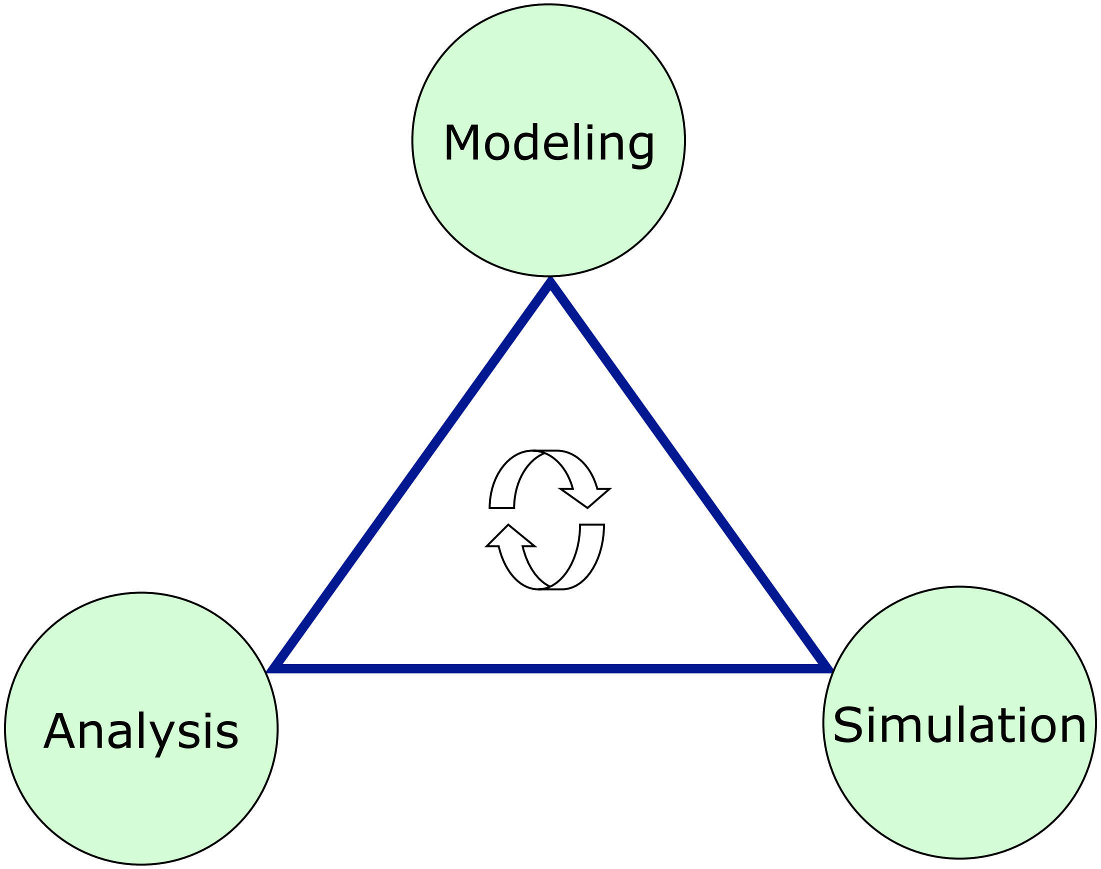
Parallel processing

Sequential Processing

- 1 CPU
- Simple
- Big problems???



New Approach

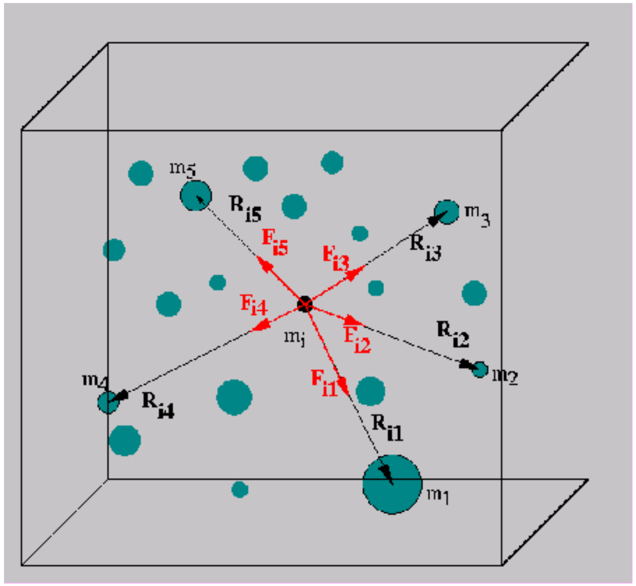


Grand Challenge Problems

- A grand challenge problem is one that cannot be solved in a reasonable amount of time with today's computers
- Ex:
  - Modeling large DNA structures
  - Global weather forecasting
  - Modeling motion of astronomical bodies

N-body

- The N^2 algorithm:
  - N bodies
  - N-1 forces to calculate for each bodies
  - N^2 calculations in total
  - After the new positions of the bodies are determined, the calculations must be repeated



Galaxy

- **10^7** stars and so **10^{14}** calculations have to be repeated
- Each calculation could be done in 1µs (10^{-6}s)
- It would take ~**3 years** for one iteration (~26800 hours)
- But it only takes **10 hours** for one iteration with **2680** processors

Solutions

- Power processor
  - 50 Hz -> 100 Hz -> 1 GHz -> 4 Ghz -> ... -> Upper bound?
- Smart worker
  - Better algorithms
- Parallel processing

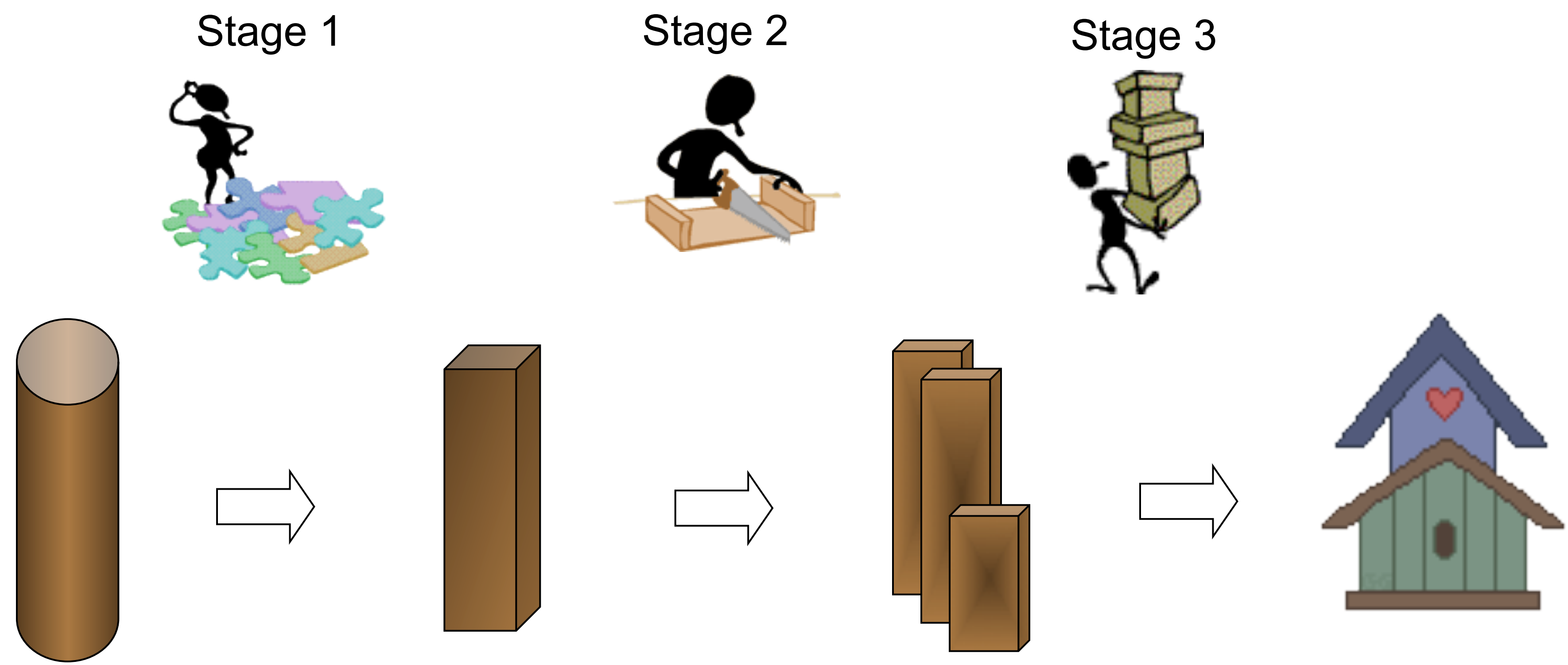
Parallel Processing Terminology

- ❑ Parallel processing
- ❑ Parallel computer
  - – Multi-processor computer capable of parallel processing
- ❑ Throughput:
  - – The throughput of a device is the number of results it produces per unit time.
- ❑ Speedup

  S = Time(the most efficient sequential algorithm)/Time(parallel algorithm)
- ❑ Parallelism:
  - – Pipeline
  - – Data parallelism
  - – Control parallelism

Pipeline

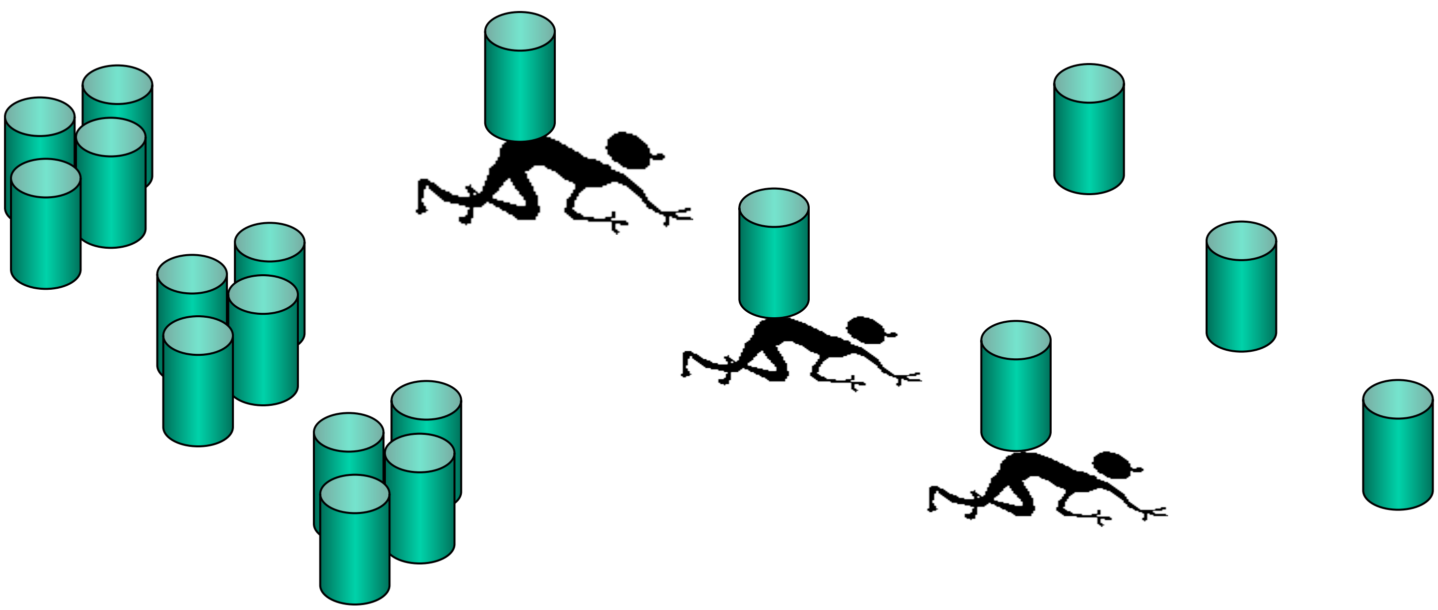
- A number of steps called **segments** or **stages**
- The output of one segment is the input of other segment



Data Parallelism

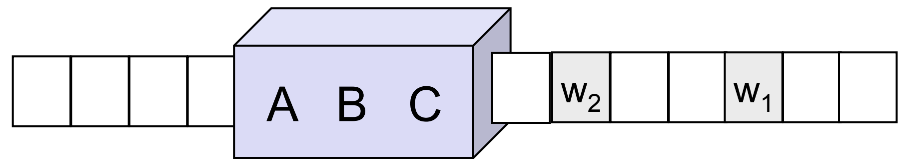
- Distributing the data across different parallel computing nodes

Applying the same operation simultaneously to elements of a data set

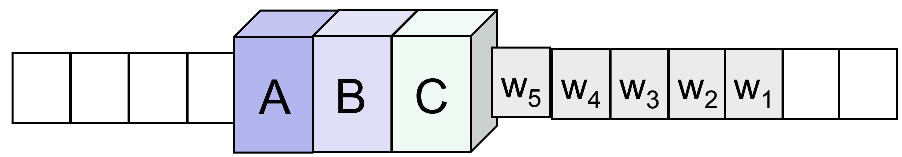


Pipeline & Data Parallelism

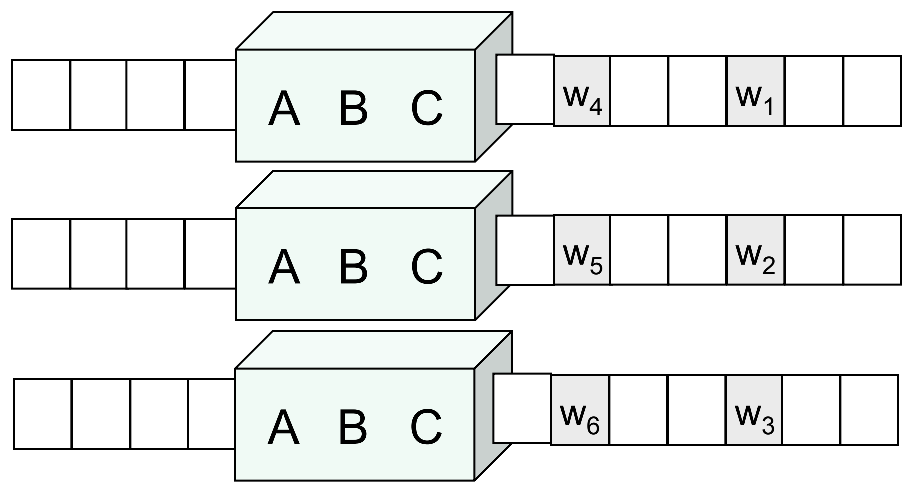
1. Sequential execution



2. Pipeline



3. Data Parallelism



Pipeline & Data Parallelism

- Pipeline is a special case of control parallelism
- T(s): Sequential execution time

  T(p): Pipeline execution time (with 3 stages)

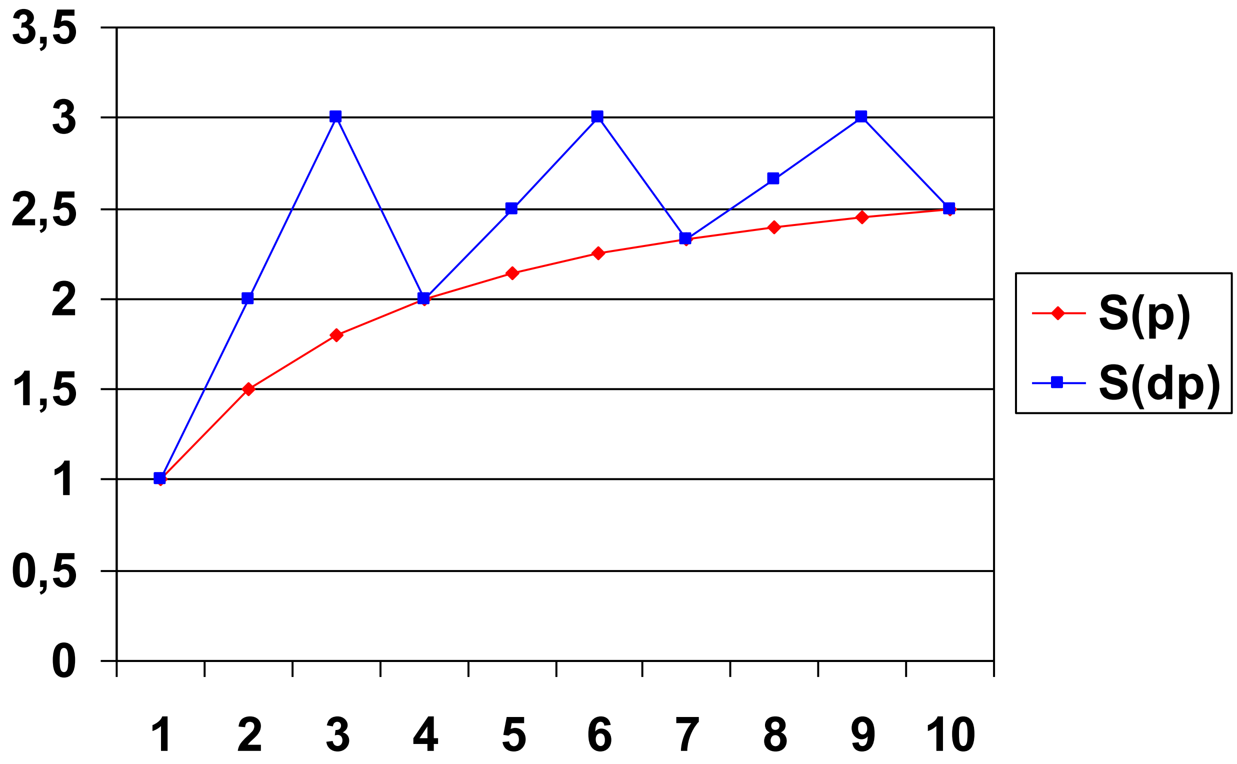
  T(dp): Data-parallelism execution time (with 3 processors)

  S(p): Speedup of pipeline

  S(dp): Speedup of data parallelism

Widget	1	2	3	4	5	6	7	8	9	10
T(s)	3	6	9	12	15	18	21	24	27	30
T(p)	3	4	5	6	7	8	9	10	11	12
T(dp)	3	3	3	6	6	6	9	9	9	12
S(p)	1	1+1/2	1+4/5	2	2+1/7	2+1/4	2+1/3	2+2/5	2+5/11	2+1/2
S(dp)	1	2	3	2	2+1/2	3	2+1/3	2+2/3	3	2+1/2

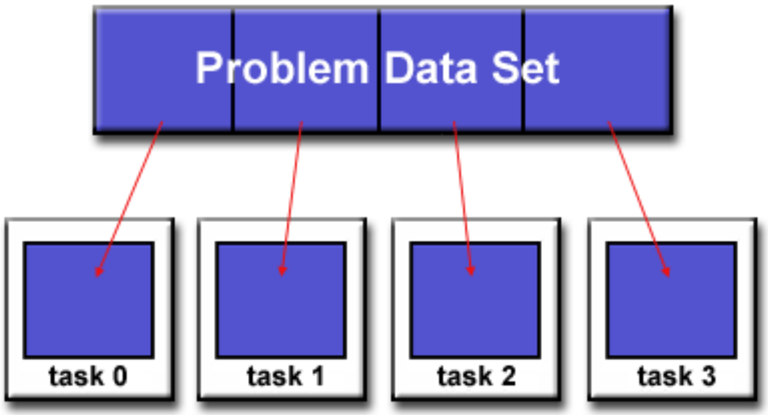
Pipeline & Data Parallelism



Control Parallelism

- Task/Function parallelism
- Distributing execution processes (threads) across different parallel computing nodes

Applying different operations to different data elements simultaneously



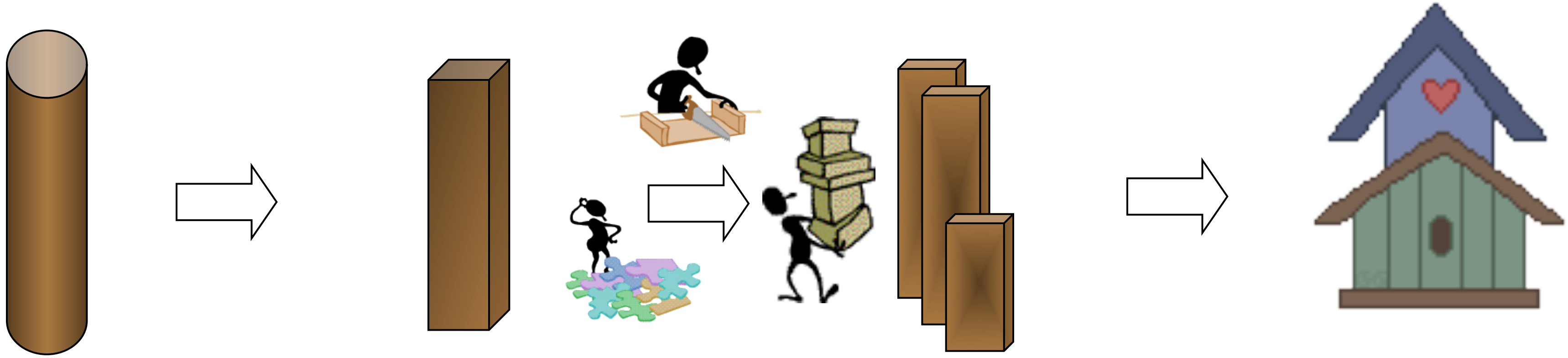
Example

{Milk, Sugar, Bread}

{Milk, Sugar, Bread, Tea}
{Bread, Milk, Coffee, Meat}
{Milk, Sugar}
{Milk, Bread, Sugar, Salt}
{Apple, Orange, Banana, Sugar, Milk}
…
{Milk, Bread, Sugar, Beer}

- Pipeline?
- Control parallelism?
- Data parallelism?

Throughput: Woodhouse problem



- 5 persons complete 1 woodhouse in 3 days
- 10 persons complete 1 woodhouse in 2 days
- How to build 2 houses with 10 persons?
  - (1) 10 persons building the 1st woodhouse and then the 2nd one later (sequentially)
  - (2) 10 persons building 2 woodhouses concurrently; it means that each group of 5 persons complete a woodhouse

Throughput

- The **throughput** of a device is the number of results it produces per unit time

- **High Performance Computing (HPC)**
  - Needing large amounts of computing power for short periods of time in order to completing the task as soon as possible
- **High Throughput Computing (HTC)**
  - How many jobs can be completed over a long period of time instead of how fast an individual job can complete

Scalability

- An algorithm is scalable if the level of parallelism increases at least linearly with the problem size.
- An architecture is scalable if it continues to yield the same performance per processor, albeit used in large problem size, as the number of processors increases.

- Data-parallelism algorithms are more scalable than control-parallelism algorithms