CS550 “Advanced Operating Systems”

Instructor: **Professor Xian-He Sun**

- Email: sun@iit.edu
- Office: SB235C
- Class time: Monday, Wed., 3:15pm-4:30pm, SB113
- Office hour: Monday, Wednesday, 4:45-5:45pm
- http://www.cs.iit.edu/~sun/cs550.html

- TA: Mr. Hua Xu, Email: hxu40@hawk.iit.edu
- Office Hour: 11am - 12pm, Tuesday
- meet.google.com/kfp-pysg-cat
- Office Hour: 12pm - 1pm, Tuesday & Thursday

  meet.google.com/bnn-eqao-htg

- Blackboard:
  - http://blackboard.iit.edu
- Substitute lecturer:
  - Anthony Kougkas, assistant research professor
  - akougkas@hawk.iit.edu

Misc. Course Details

- Grading
  - 33% -- Homework, Programming Assignment, and Participation
  - 37% -- Exam
  - 30% -- Term Project and Presentation

- Use the course blackboard
  - Announcements
  - Lecture notes
  - Assignments
  - Discussion
  - …

Term Project

- See http://www.cs.iit.edu/~sun/html/report2.html
- A two-page project proposal due by Jan. 29, 2024
- Final project report is due on April 25, 2024

- Example topics
  - Study and practice of some middleware programming-environment, software packages, applications.
  - Study and analyze some distributed environment, architectures, and network structures.
  - Study the distributed solution of certain application package, algorithm, and system software.
  - Performance metric, measurement, and benchmark.
  - Study and practice of some visualization tools.
  - Survey of certain topics.
  - Any other topics that are relevant to this course.

Will have more on the topics in Jan. 24 lecture

The Gnosis Research Center

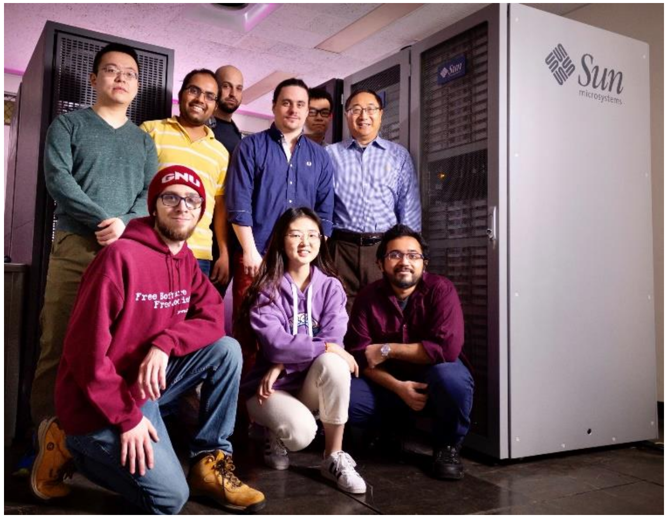
http://grc.iit.edu

Specialize in high performance software systems for big data applications

(System Group, GRC Center)

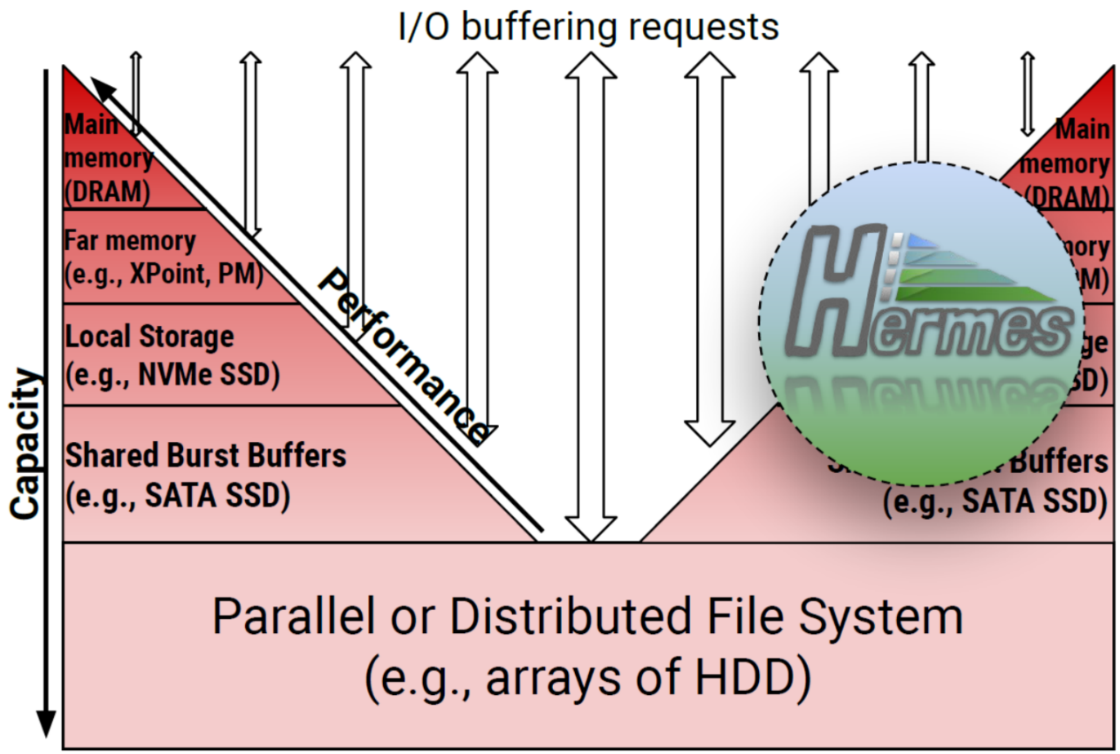
Supported by:

- NSF, DoE, NASA, and industry



Hermes: A Multi-tiered I/O Buffering System

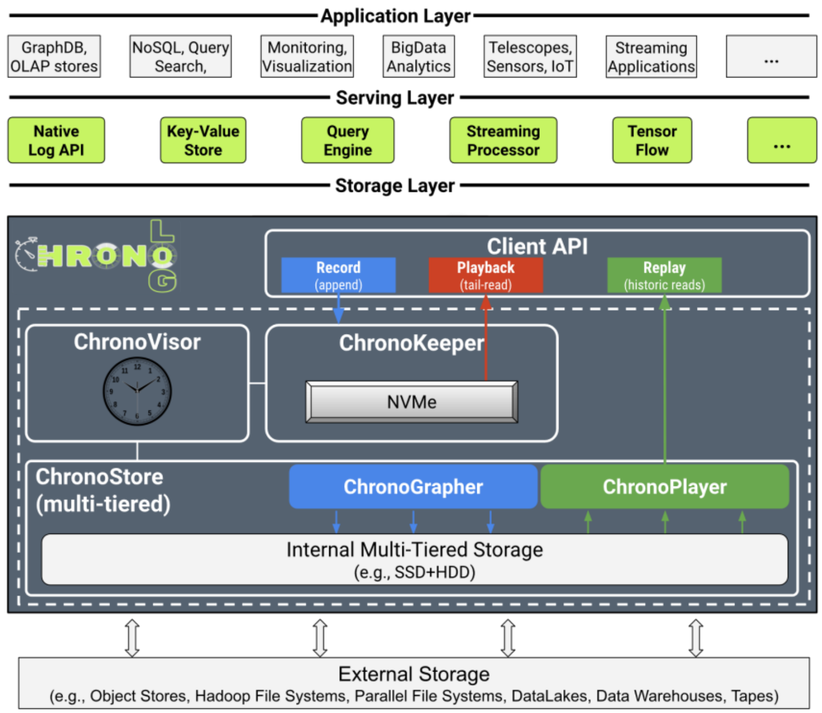
- Selective cache, concurrent, matching
- Independent management of each tier



A. Kougkas, H. Devarajan, and X.-H. Sun, "I/O Acceleration via Multi-Tiered Data Buffering and Prefetching," Journal of Computer Science and Technology, vol. 35, no. 1, pp. 92-120, Jan. 2020

ChronoLog: A High-Performance Storage Infrastructure for Activity and Log Workloads

- Unprecedented huge activity (or log) data
  - Activity data describe things that happen rather than things that are
- Unparalleled importance of activity/log data
  - traditional database systems, non-traditional data management systems, decision making, information retrieval, data mining, deep learning, etc.
- *ChronoLog* is a distributed shared log storage ecosystem
  - Supports a wide variety of applications with different requirements under a single platform
  - Offers total ordering, high concurrency, and capacity scaling
- Challenges:
  - •Imposing total ordering of distributed events
  - •Scaling under a global log order
- Key techniques:
  - A log ordering based on a physical time (i.e., a globally accessible clock)
  - A dynamic tiered data management



Proposed ecosystem: including a core library & collection of plugins

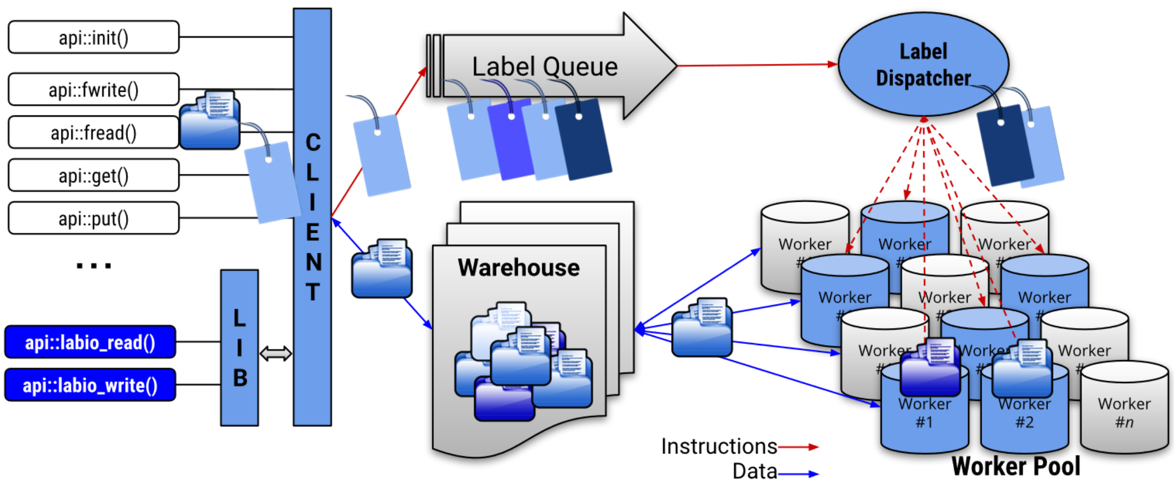
COEUS: Accelerating Scientific Insights Using Enriched Metadata

X.Sun (IIT)

Funded by the National Science Foundation under Award Number (FAIN): 2104013

dLabel: Data Operation with Label

- Data requests are transformed into (data) ***Label*** units
  - A label is a tuple of an operation and a pointer to the data
- A dispatcher distributes labels to the workers
- Workers execute labels independently (i.e., fully decoupled)



A. Kougkas, H. Devarajan, J. Lofstead, X.-H. Sun; "*LABIOS: A Distributed Label-Based I/O System*", *i*n Proceedings of ACM HPDC '19 (Best Paper Award)

Frontier: the World Fastest Computer

- 1.194 exaFLOPS (Rmax, 10^18) / 1.67982 exaFLOPS (Rpeak)
- 9,472 AMD Epyc 7453s "Trento" 64 core 2 GHz CPUs (606,208 cores)
- 37,888 Radeon Instinct MI250X GPUs (8,335,360 cores).
- 74 19-inch (48 cm) rack cabinets. Each cabinet hosts 64 blades, each consisting of 2 nodes.

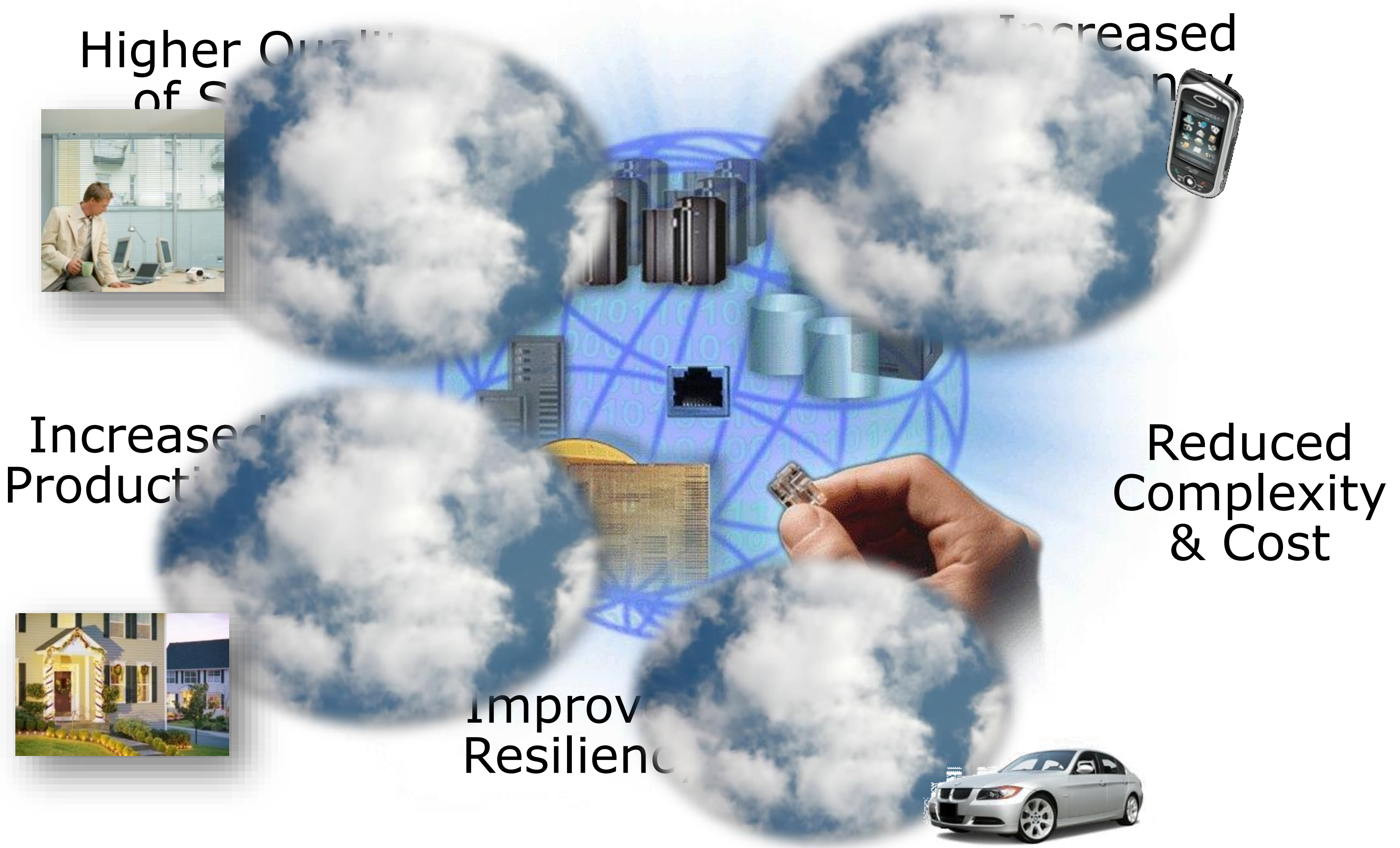
Work Opportunities

- Research opportunities for graduate students:
  - Always look for self-motivated and hard-working grad students
  - Ph.D. students: CS597 and CS691
  - MS students: CS591 “Research and Thesis for MS Degree”
  - Take CS546 & CS550, check my research projects, send me your CV
- Research opportunities for undergrad students:
  - NSF REU (Research Experiences for Undergraduates) with Prof. Xian-He Sun
    - Various project topics, including development of scheduling simulator, analysis of system logs, ….
    - If interested, contact Prof. Sun (sun@iit.edu)
- Research opportunities for both graduate & undergrad:
  - Programmer

Put it in Perspective

The Surge of Cloud & Big Data

Mimic the electrical power grid



Historical Point of View

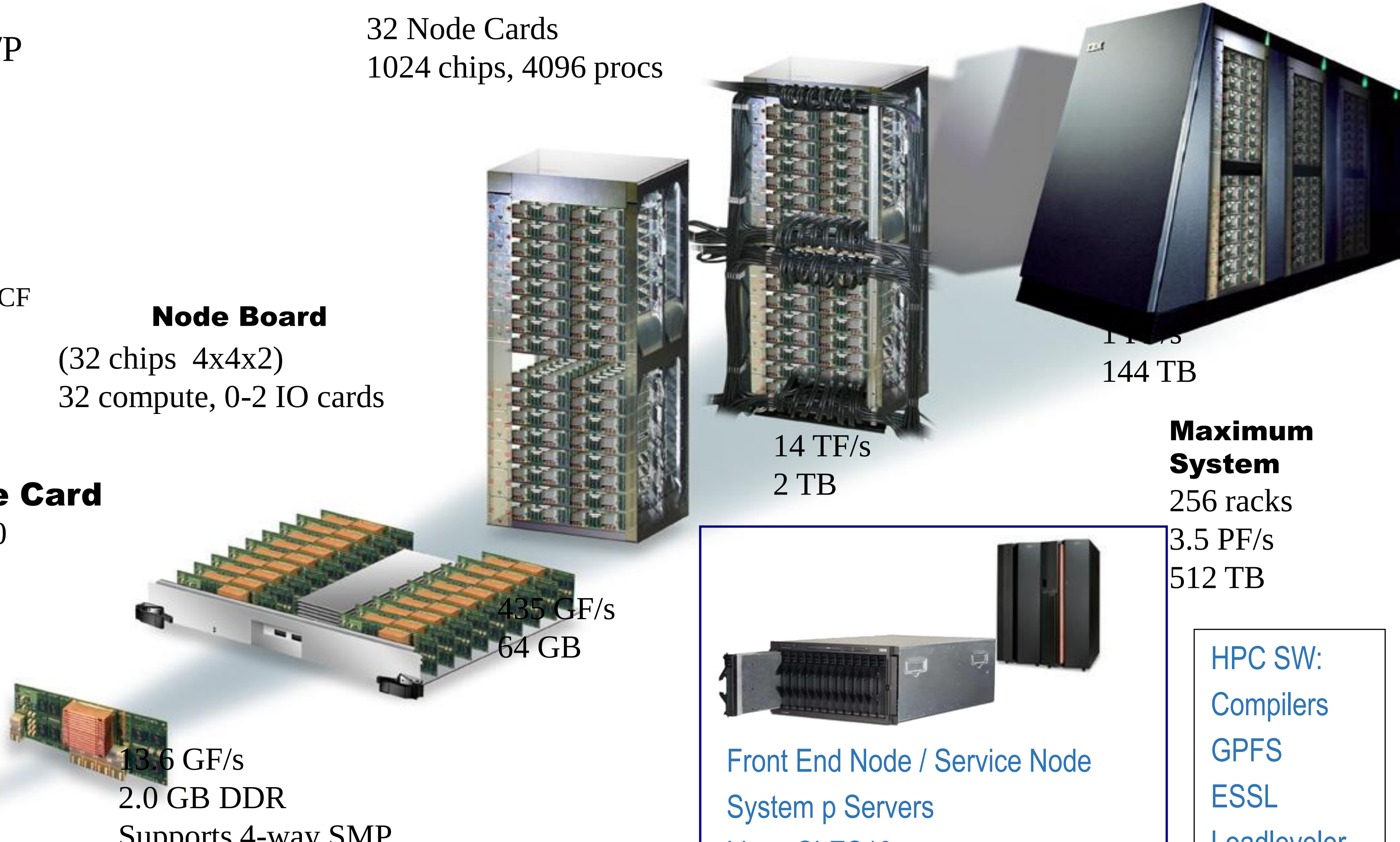
The Third Wave of Computing Revolutions

- Network, communication, and interconnectivity
- Begin in the late 90s until now
- Machine/machine, software/software, people/people
- Anytime, anywhere, WWW
- The communications landscape is shifting
  - Could Computing，Big Data, Internet of things (IoT)
  - Edge Computing, Pervasive computing
  - IoT, AIoT

Evolution of Computing:
The biggest machine becomes even bigger

IBM BG/P

Source: ANL ALCF



Chip
4 cores

850 MHz
8 MB EDRAM

13.6 GF/s
2.0 GB DDR
Supports 4-way SMP

Compute Card
1 chip, 20 DRAMs

435 GF/s
64 GB

Node Board
(32 chips 4x4x2)
32 compute, 0-2 IO cards

Rack Cabled 8x8x16

32 Node Cards
1024 chips, 4096 procs

14 TF/s
2 TB

Petaflops System
72 Racks

144 TB

Maximum System
256 racks
3.5 PF/s
512 TB

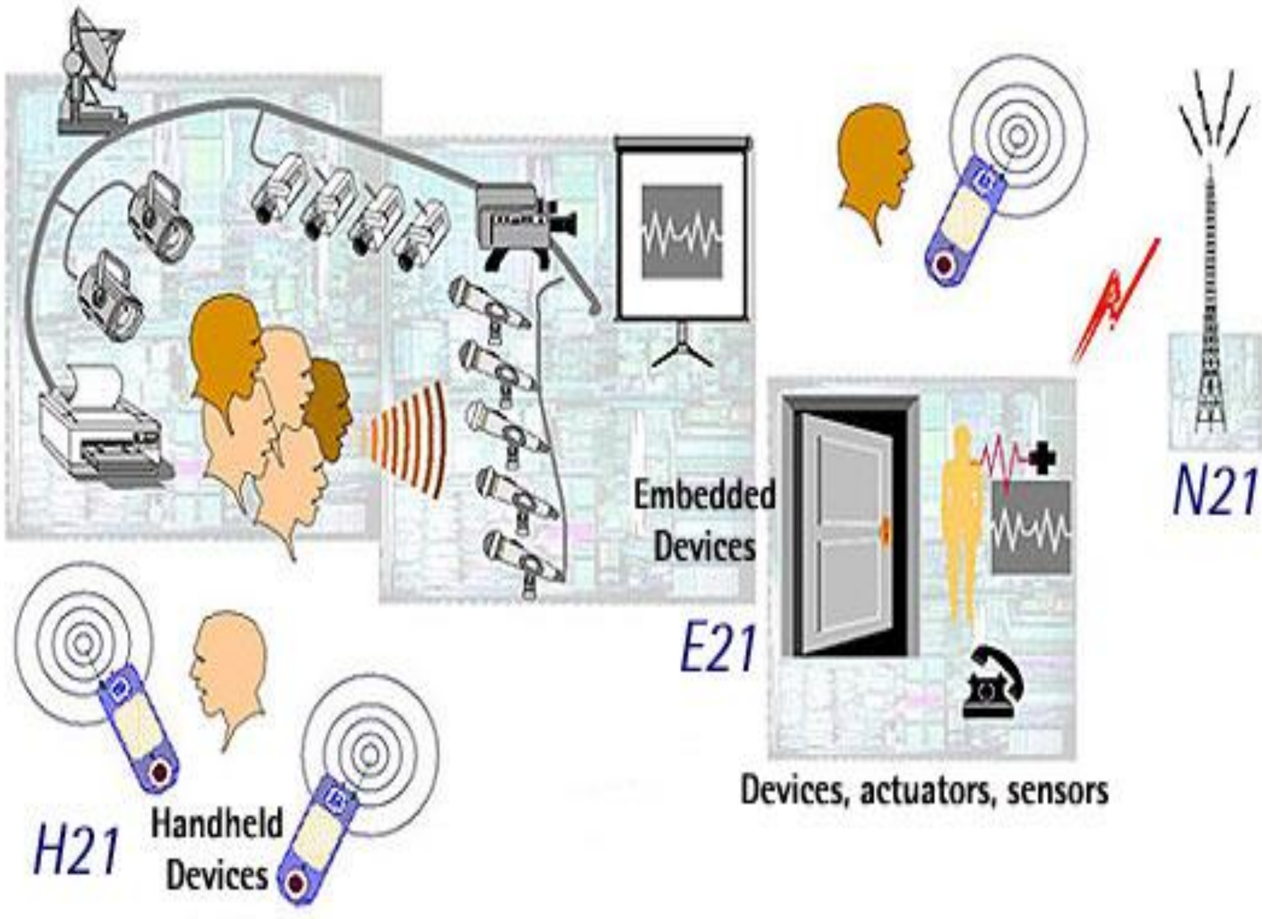
Front End Node / Service Node
System p Servers
Linux SLES10

HPC SW:
Compilers
GPFS
ESSL
Loadleveler

Evolution of Computing: The smallest machine becomes even smaller

- Devices become smaller and more powerful
- Devices are coordinated via network
- From “autonomous computing” to coordinated “human-center computing”

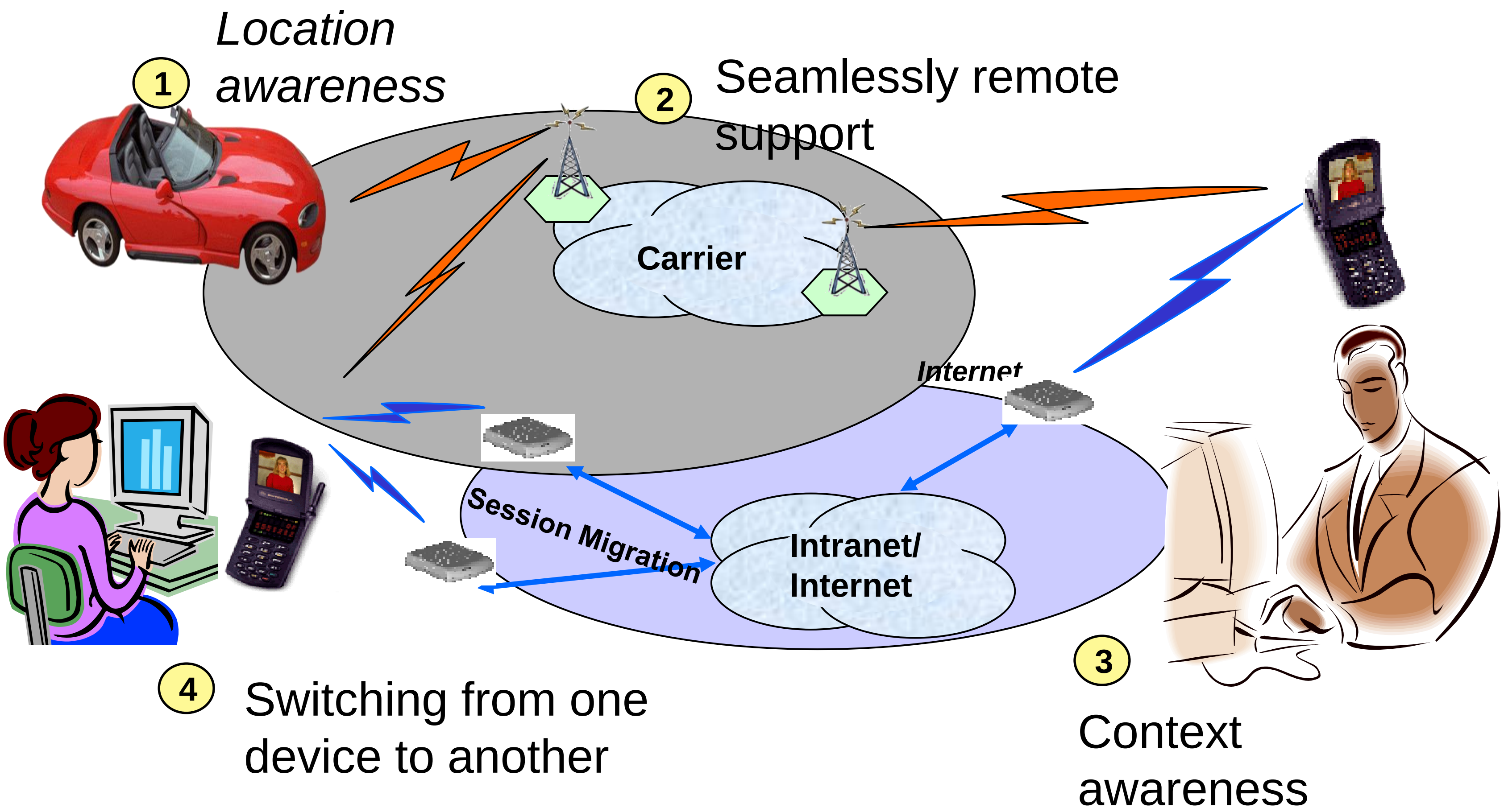
Coordinated Embedded System – Smart Space



Pervasive Computing

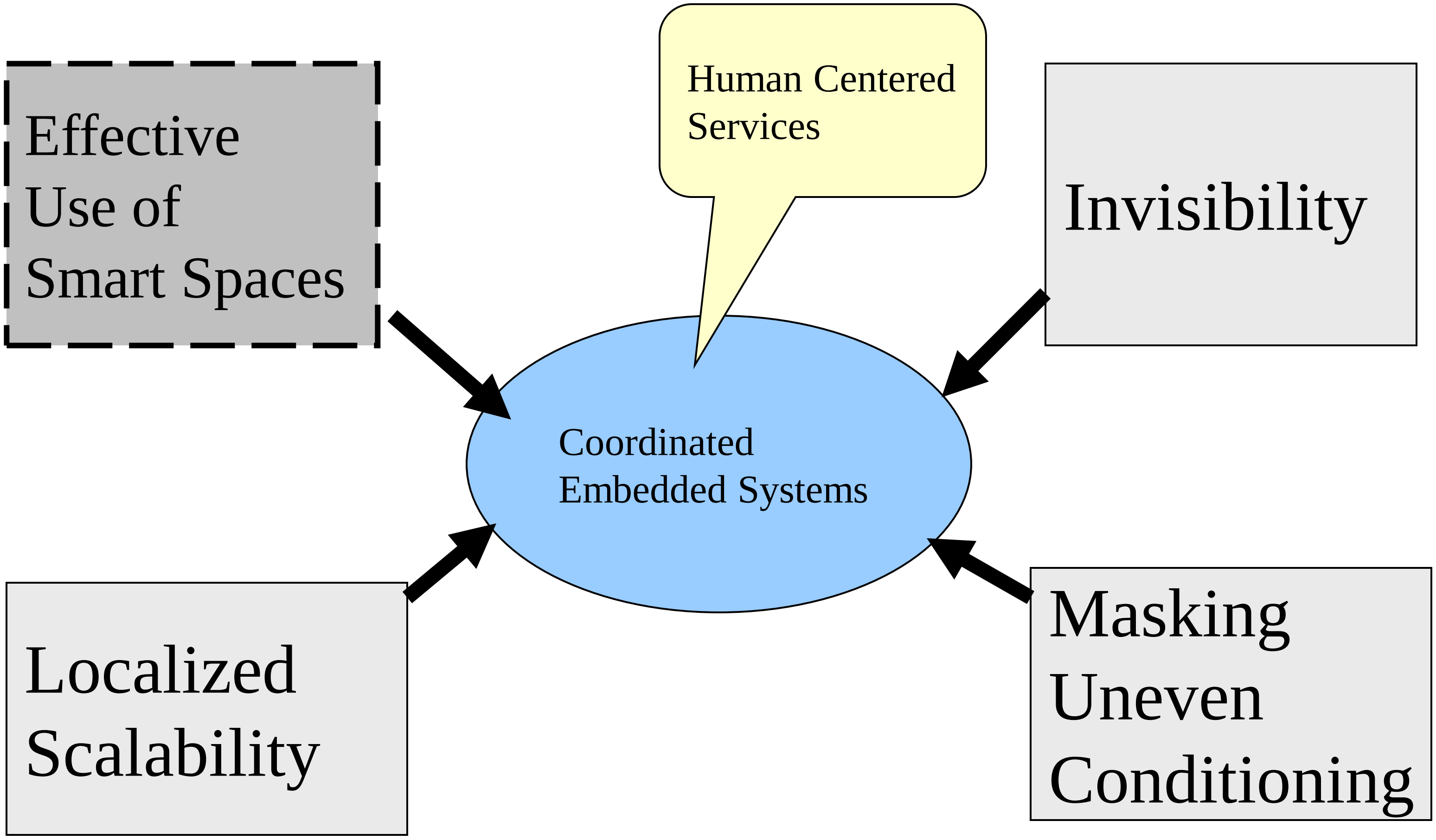
- Computers have become an embed intrinsic part of a sophisticated, networked, pervasive and ubiquitous computing environments around humans.
- Pervasive Computing: create a ubiquitous environment that combines processors and sensors with network technologies (wireless and otherwise) and intelligent software to create an immerse environment to improve life.

Pervasive Computing Applications



Design Challenges

Context awareness and Mobility



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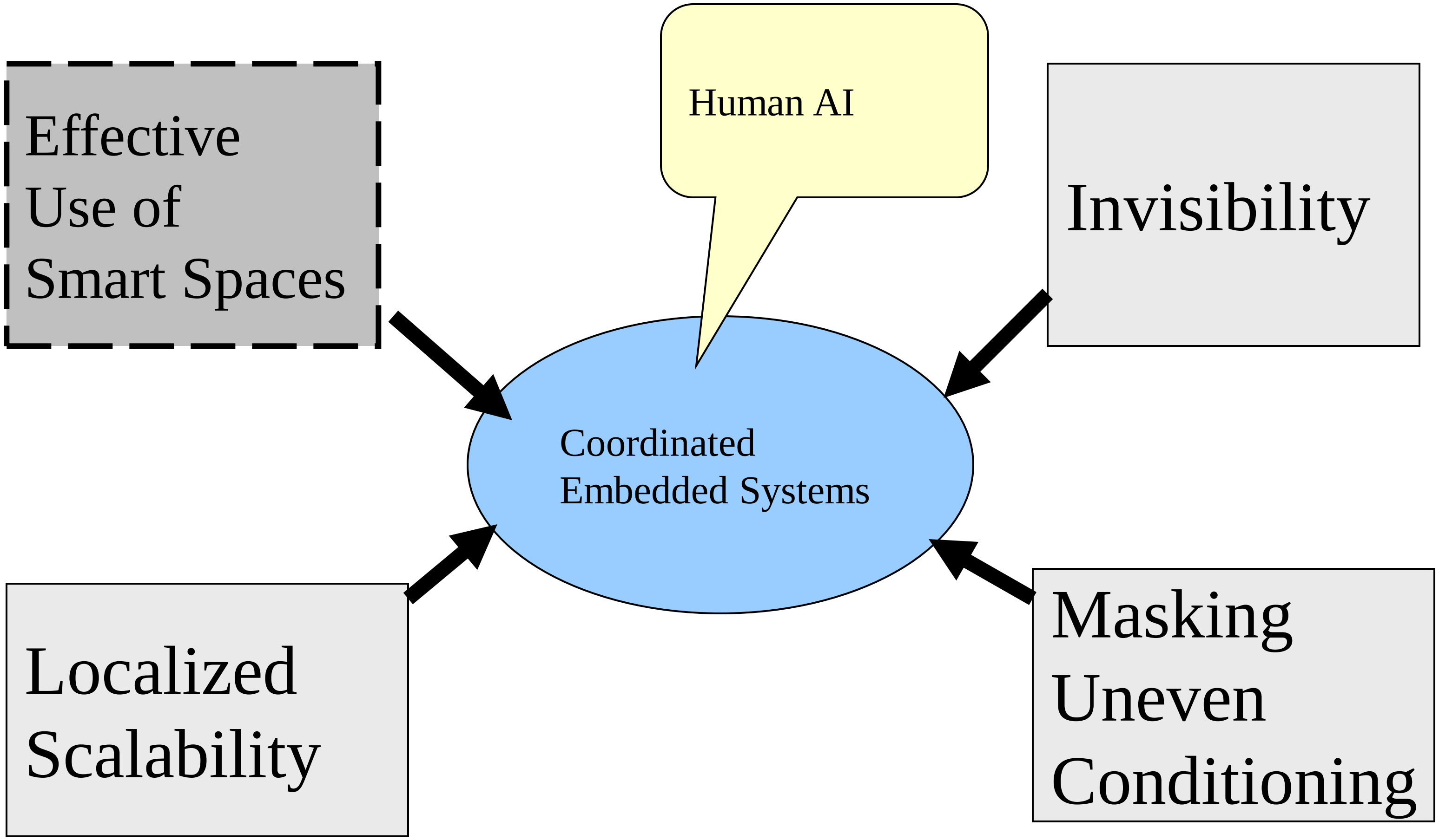
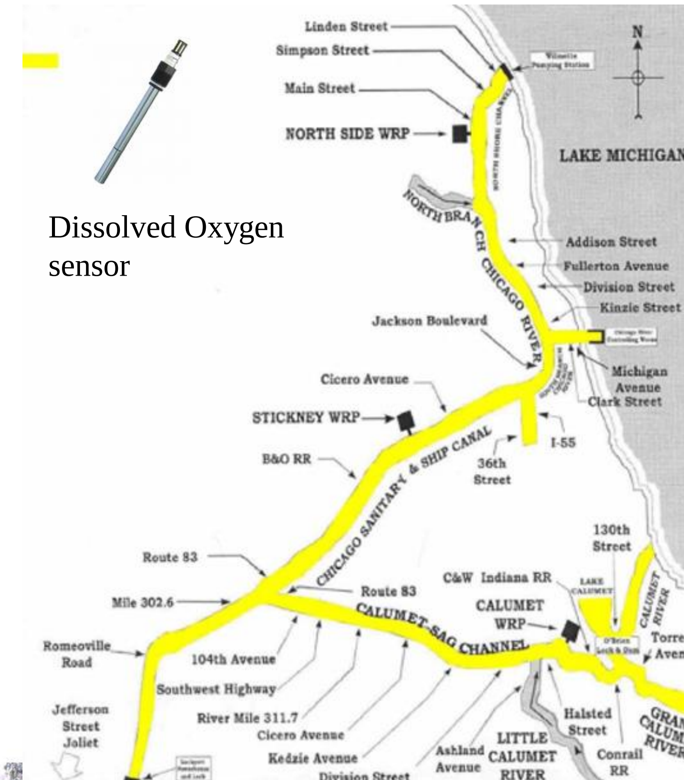
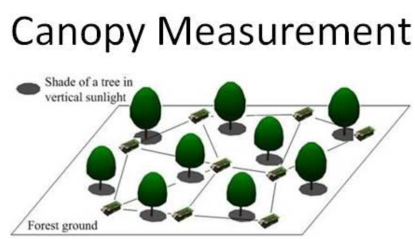


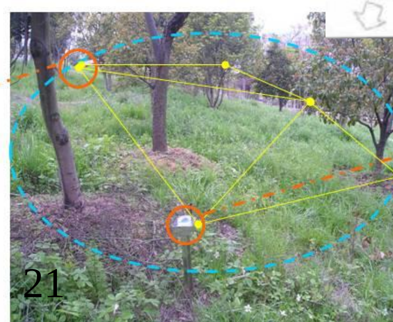
Sensor Network: *Environment monitoring*

- Environment monitoring
  - Chicago Waterway System
  - Ocean Sense
  - GreenObs
- Tracking objects: iLight

Ammonia sensor



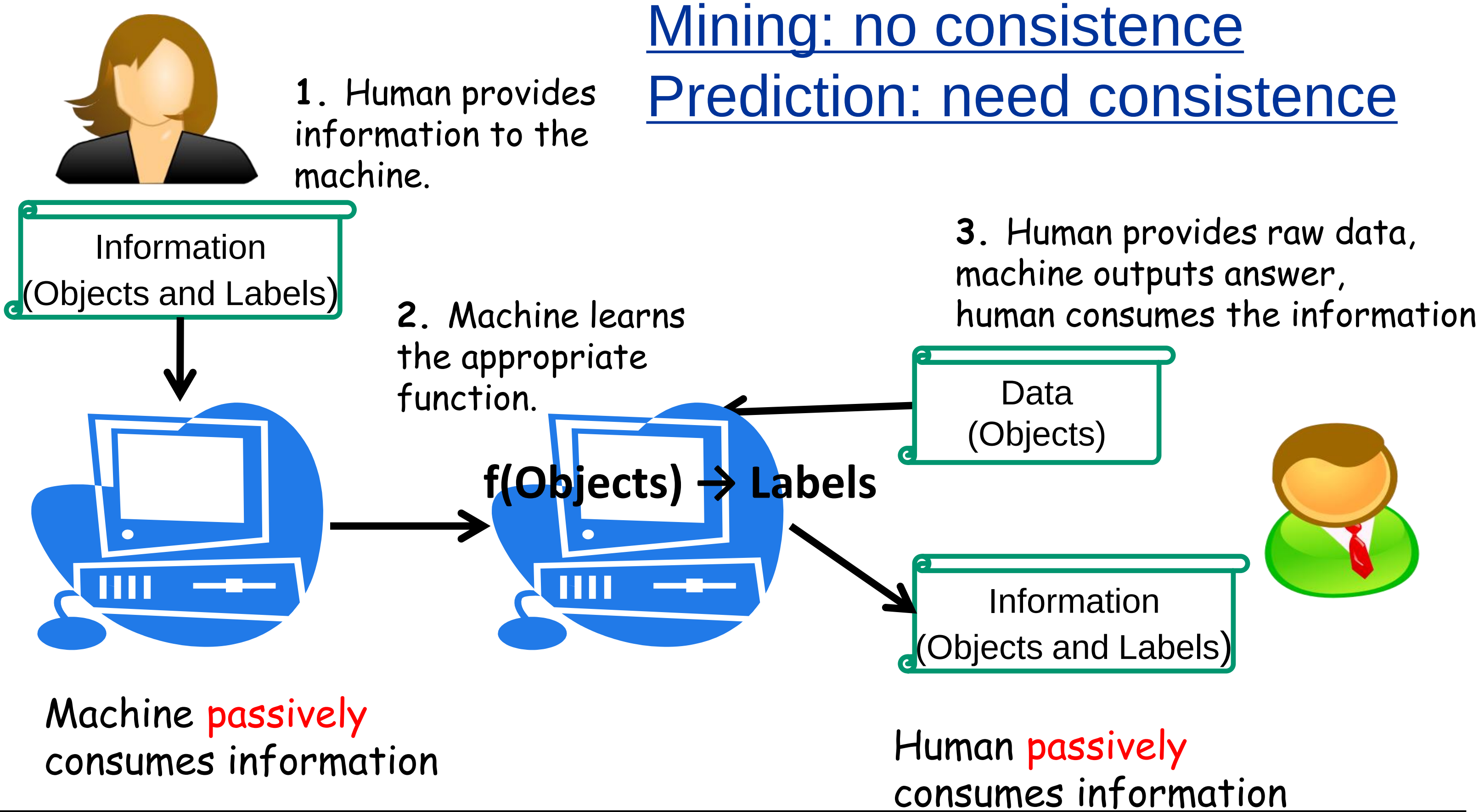




Big Data : discover information/knowledge from data

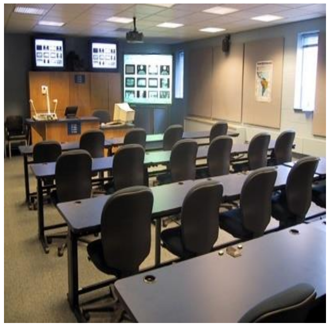
Mining: no consistence

Prediction: need consistence



The View of Future Computing

Human-centered



They are connected to form `smart space’

Devices become smaller and powerful

Cloud link `smart spaces’ to support `global smartness’

A device is an entry of the cyber world

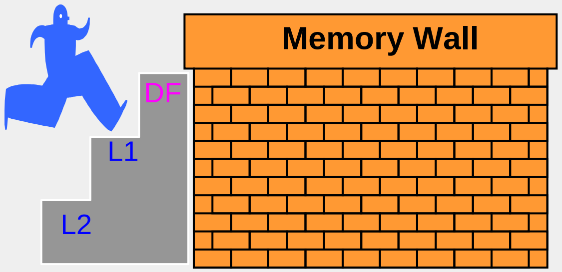
Distributed System is Everywhere

Sensor Network: Big Data
Smart Space: AI
Cyber Physics: IoT

Hot Issues

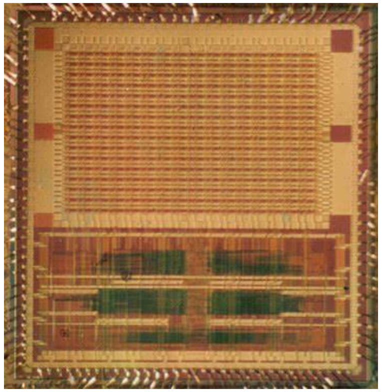
- AI and Deep Learning
- Big Data
- High Performance Computing and Cloud Computing

The Issue is Data Processing



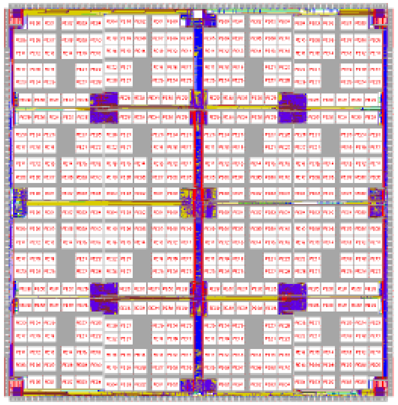
Recent Development

Many-Core Technology is Available

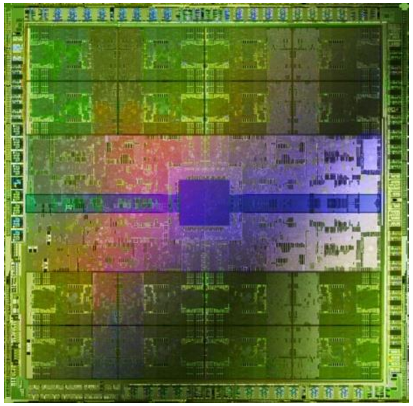


Kilocore: 256-core prototype
By Rapport Inc.

GeForce RTX 2080 SUPER:
3072 CUDA cores, by NVDIA



GRAPE-DR chip:
512-core, By Japan

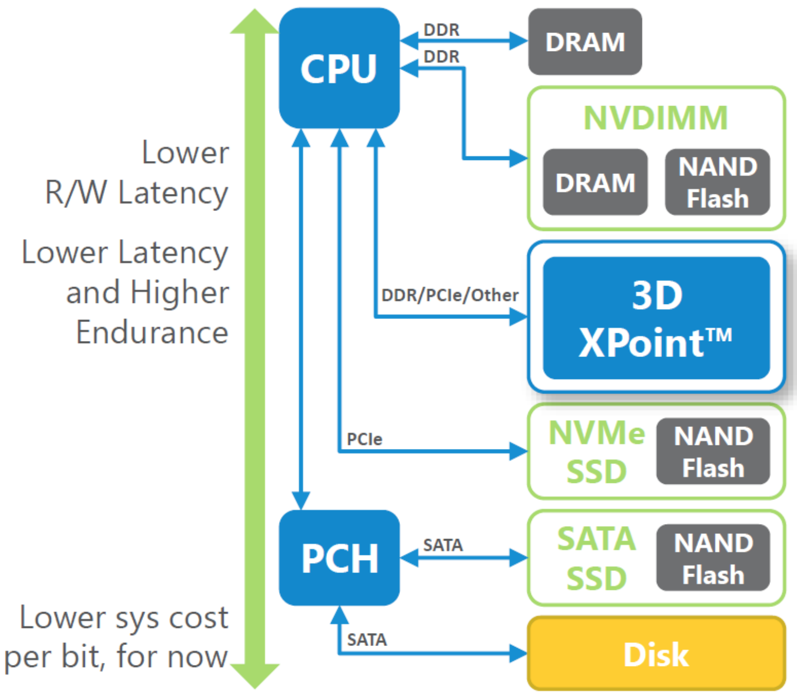


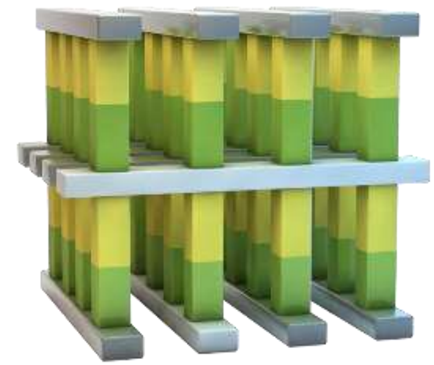
NVIDIA Fermi: 512 CUDA cores

Quadro M6000: 3,072 cores,
By NVDIA.

GRAPE-DR testboard

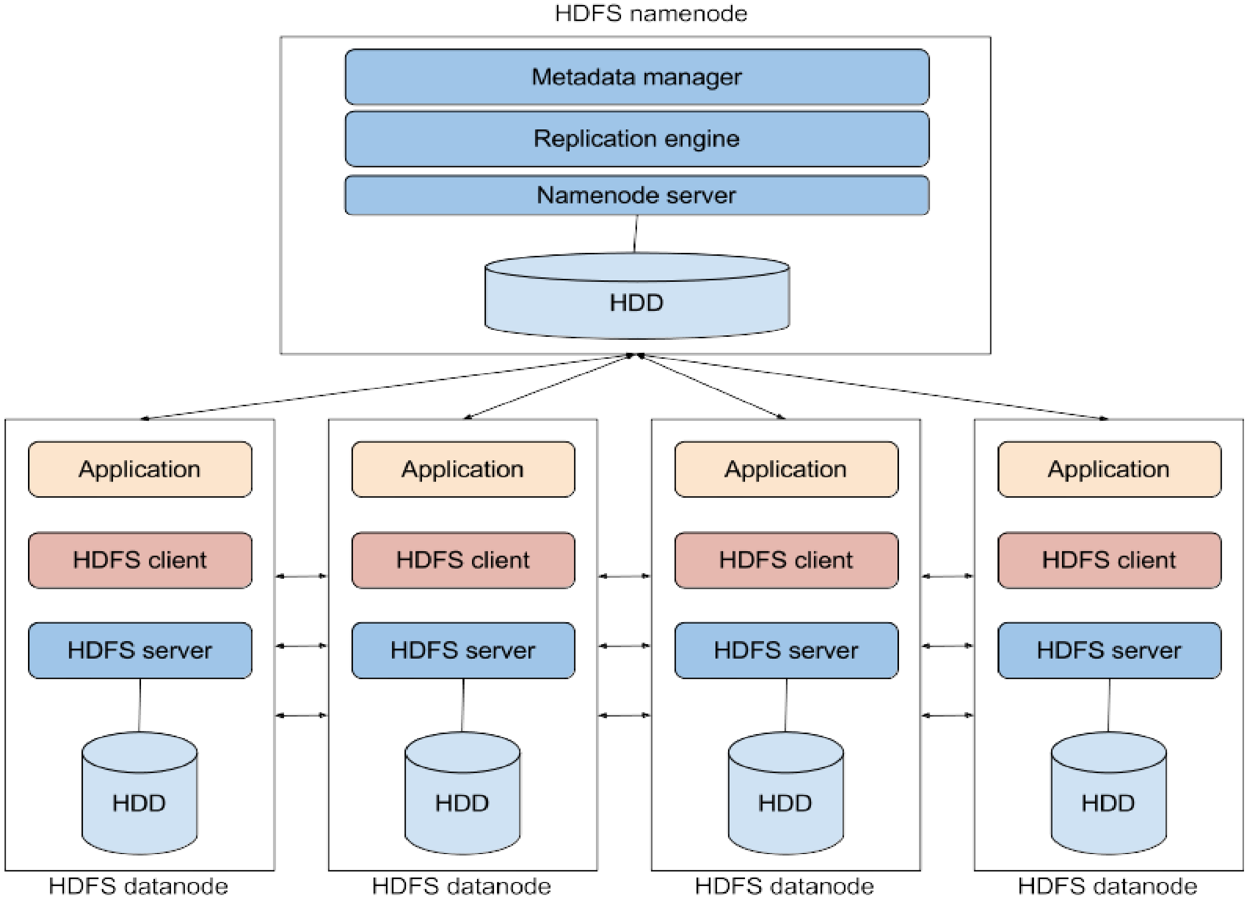
Nonvolatile Memories in Server Architectures





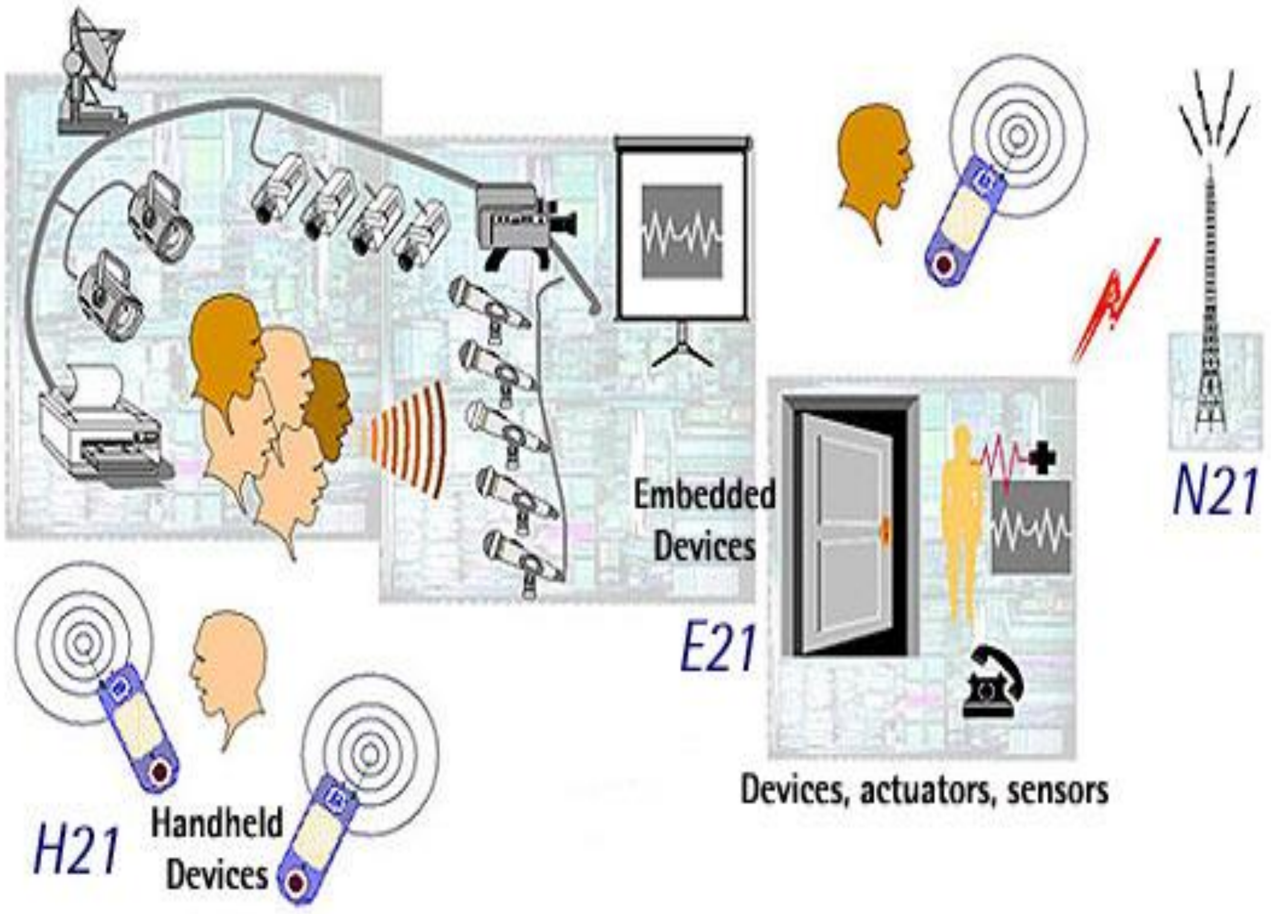
- 3D XPoint™ technology provides the benefit in the middle
- It is considerably faster than NAND Flash
- Performance can be realized on PCIe or DDR buses
- Lower cost per bit than DRAM while being considerably more dense

Industrial Solution:
Distributed I/O Systems



Architecture of a typical HDFS system

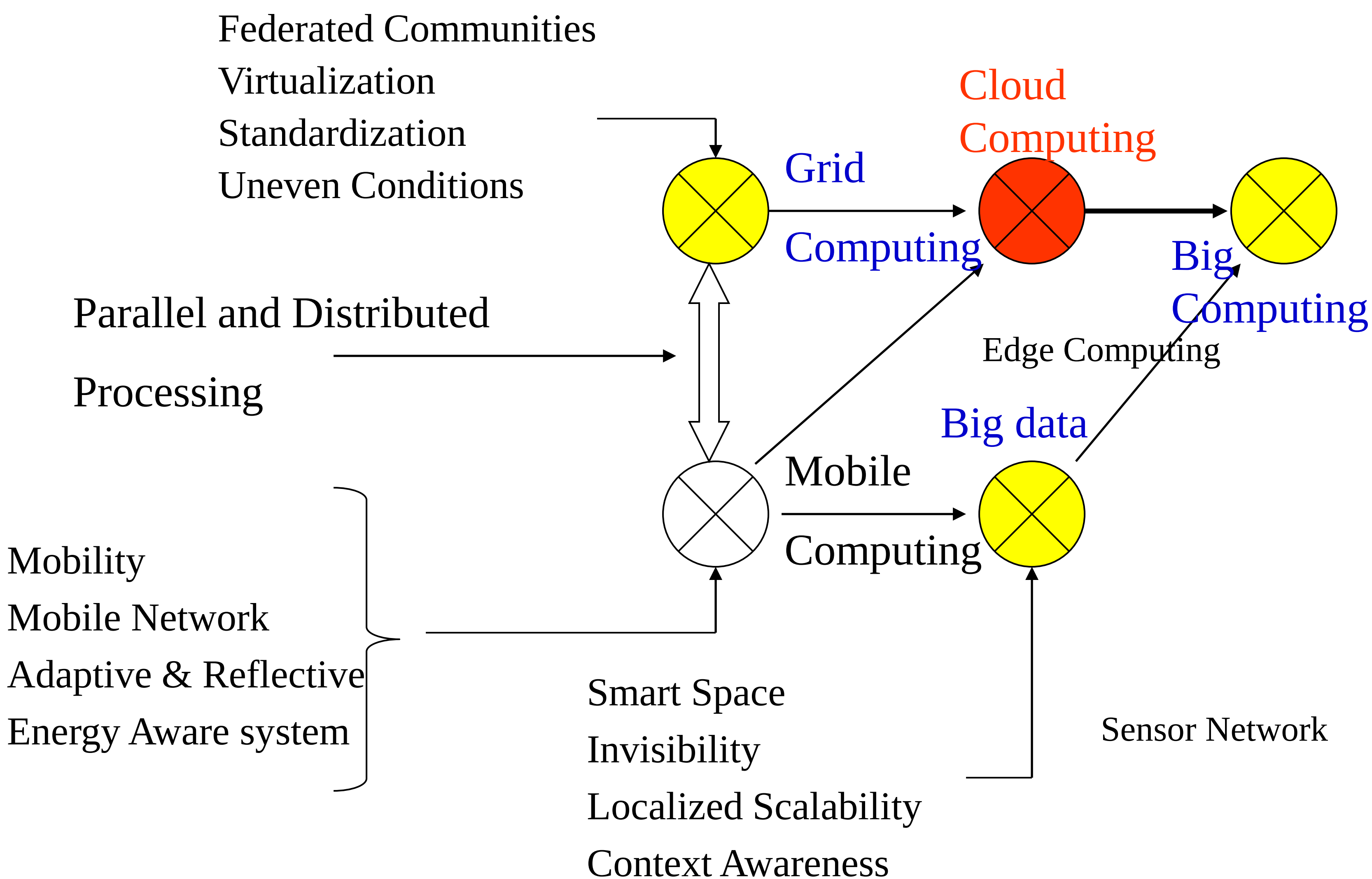
Cyber Physical System – extended Smart Space



Edge Computing

Mimic the electrical power grid

Evolution of Computing



Historical Point of View

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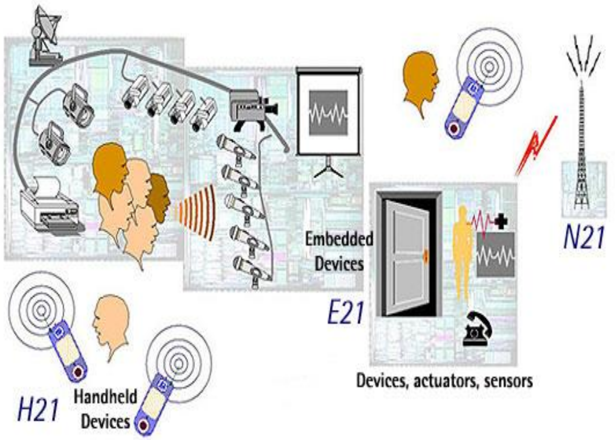
- Network, communication, and interconnectivity
- Machine/machine, software/software, but not Machine/people
- The communications landscape is shifting
  - Pervasive computing?

Pervasive Computing

- Big Computer becomes even bigger, Bigger computing power
- Small Computing becomes even smaller, Smart Space
- Smart Space, Sensor Network, bigdata
- Smart Space, IoT, Cyber Physic Systems
- Context Aware, Smartness (AI)
- AI is forward by big data and bigger computing power

  - Today (software/software connection): Cloud, CPS
  - Tomorrow (machine/human): pervasive



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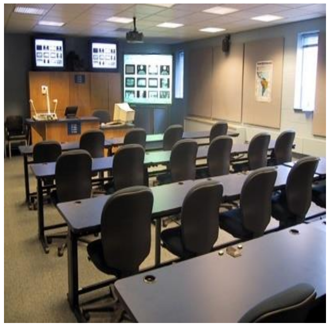

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A device is an entry of the cyber world

The Core is still Distributed Systems

Any Questions?