HPC for Smart Cities and Urban Planning

Dr. Diptendu Sinha Roy

Associate Professor
Department of Computer Science & Engineering
NIT Meghalaya

Email: diptendu.sr@nitm.ac.in

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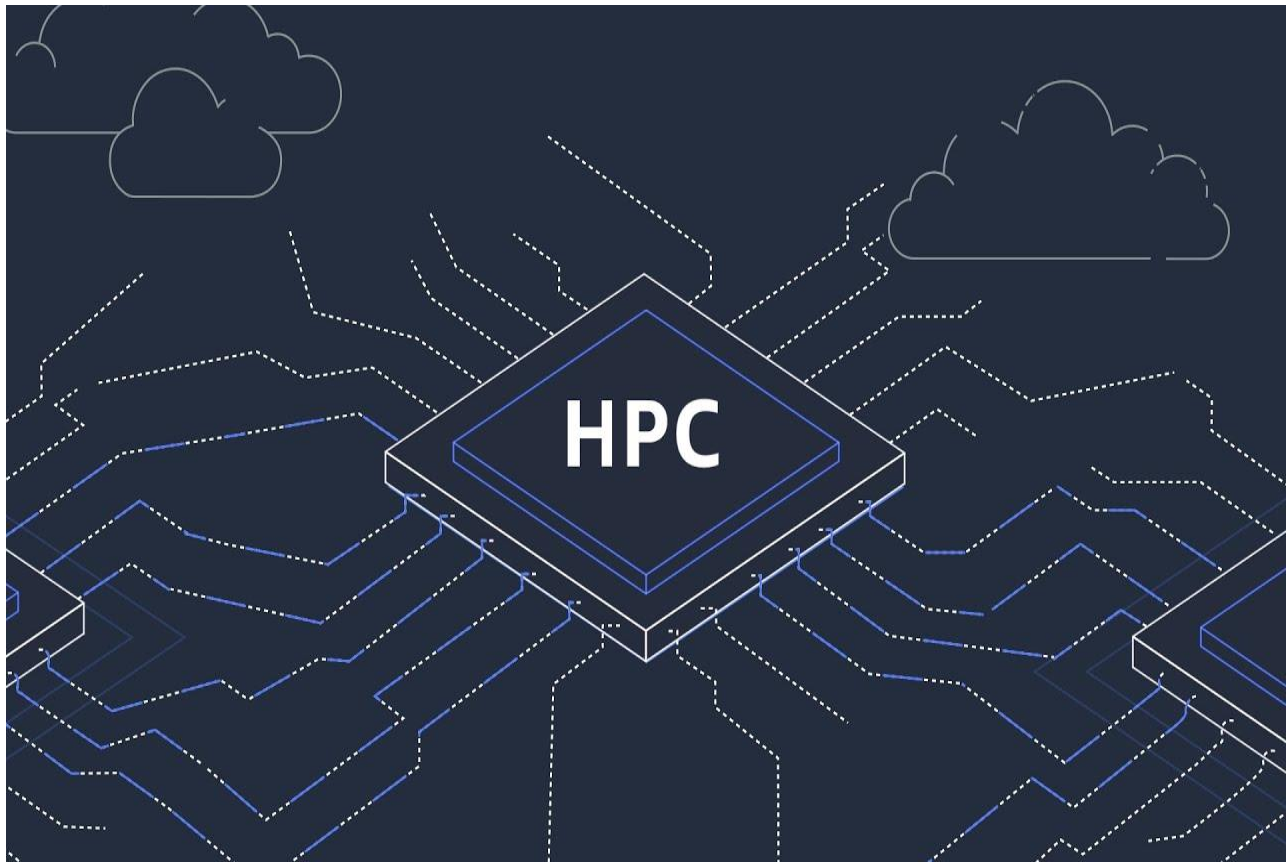
Introduction to HPC

- High-performance computing (HPC) is a technology that harnesses the power of supercomputers or computer clusters to solve complex problems requiring massive computation.
- HPC solutions can be one million times more powerful than the fastest laptop.
- Best example of HPC is the Supercomputer.
- Supercomputer contains thousands of compute node that work together to complete one or more task.



What & Why

- What is high performance computing (HPC)?
  - The use of the most efficient algorithms on computers capable of the highest performance to solve the most demanding problems.
- Why HPC?
  - Large problems – spatially/temporally
    - 10,000 x 10,000 x 10,000 grid → 10^12 grid points → 4x10^12 double variables → 32x10^12 bytes = 32 Tera-Bytes.
    - Usually need to simulate tens of millions of time steps.
    - On-demand/urgent computing; real-time computing;
  - Weather forecasting; protein folding; turbulence simulations/CFD; aerospace structures; Full-body simulation/ Digital human …

What HPC contains ?

- Hardware:

  Computer Architecture: Vector Computers, Distributed Systems, Clusters

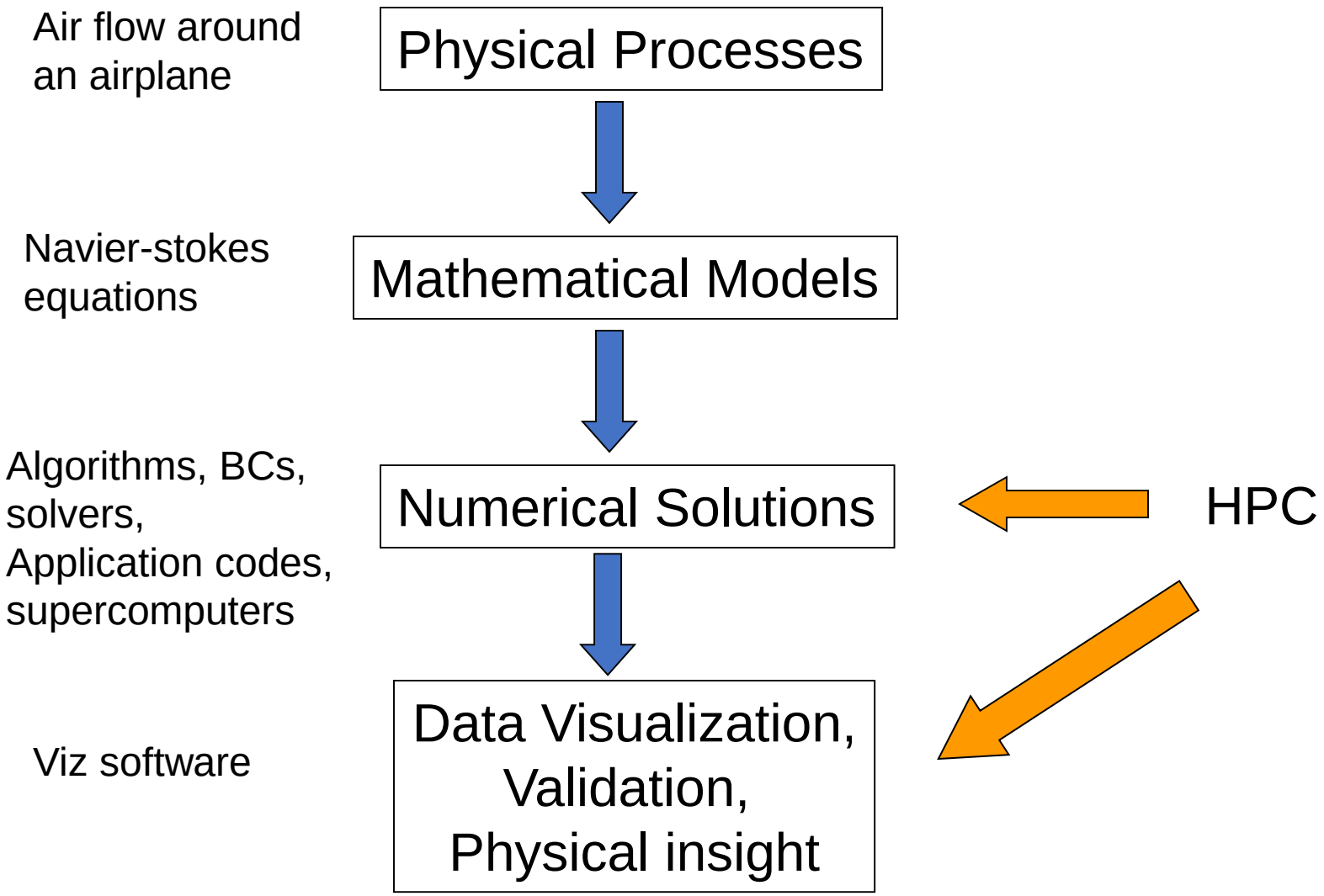
  Network Connections: InfiniBand, Ethernet, Proprietary

- Software:

  Frameworks/Platforms/Applications: Open source, Commercial

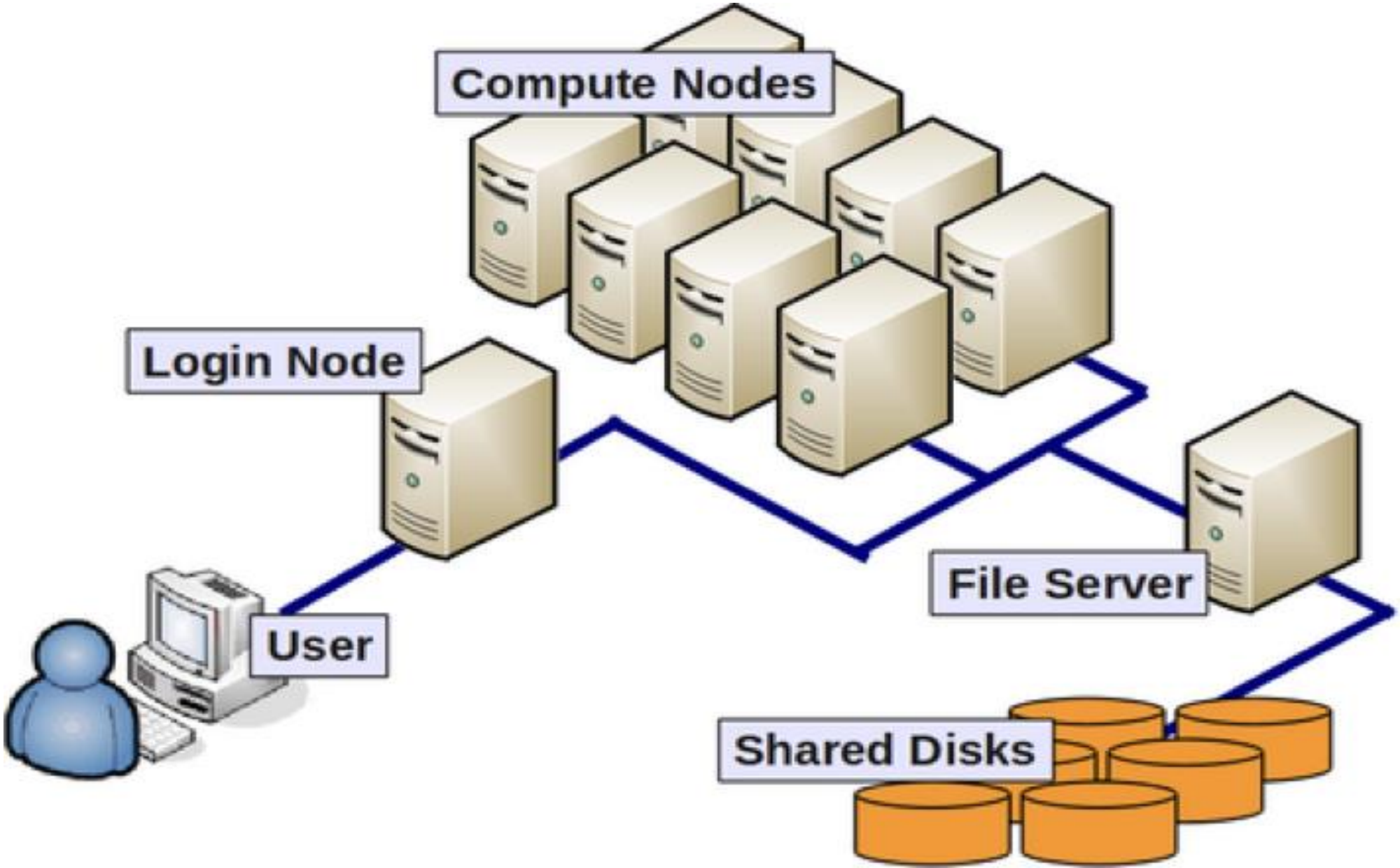
  Programming models: MPI (Message Passing Interface), SHMEM (Shared Memory) etc

How HPC fits into Scientific Computing

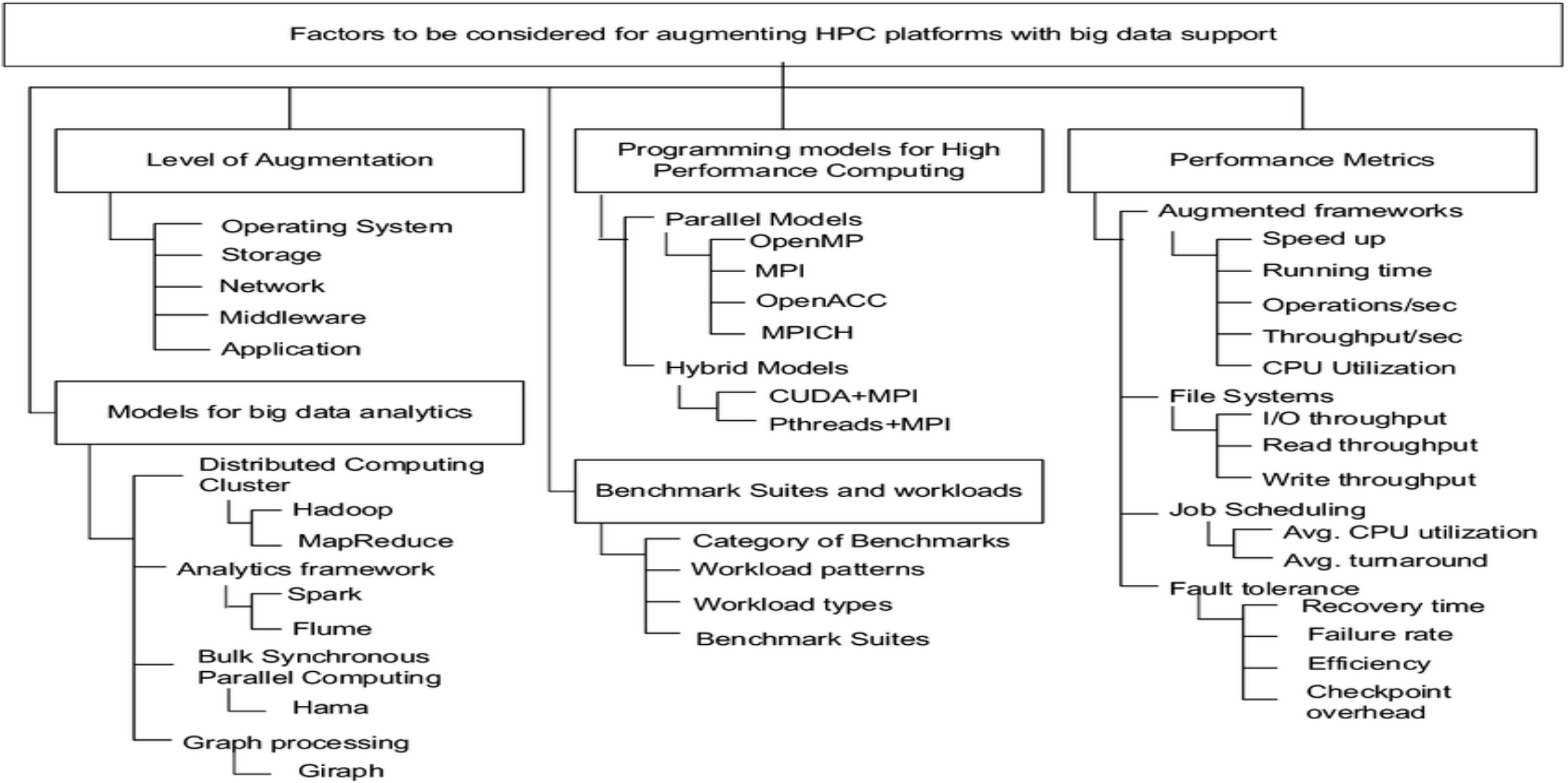


HPC solutions have three main components

- Compute
- Network
- Storage

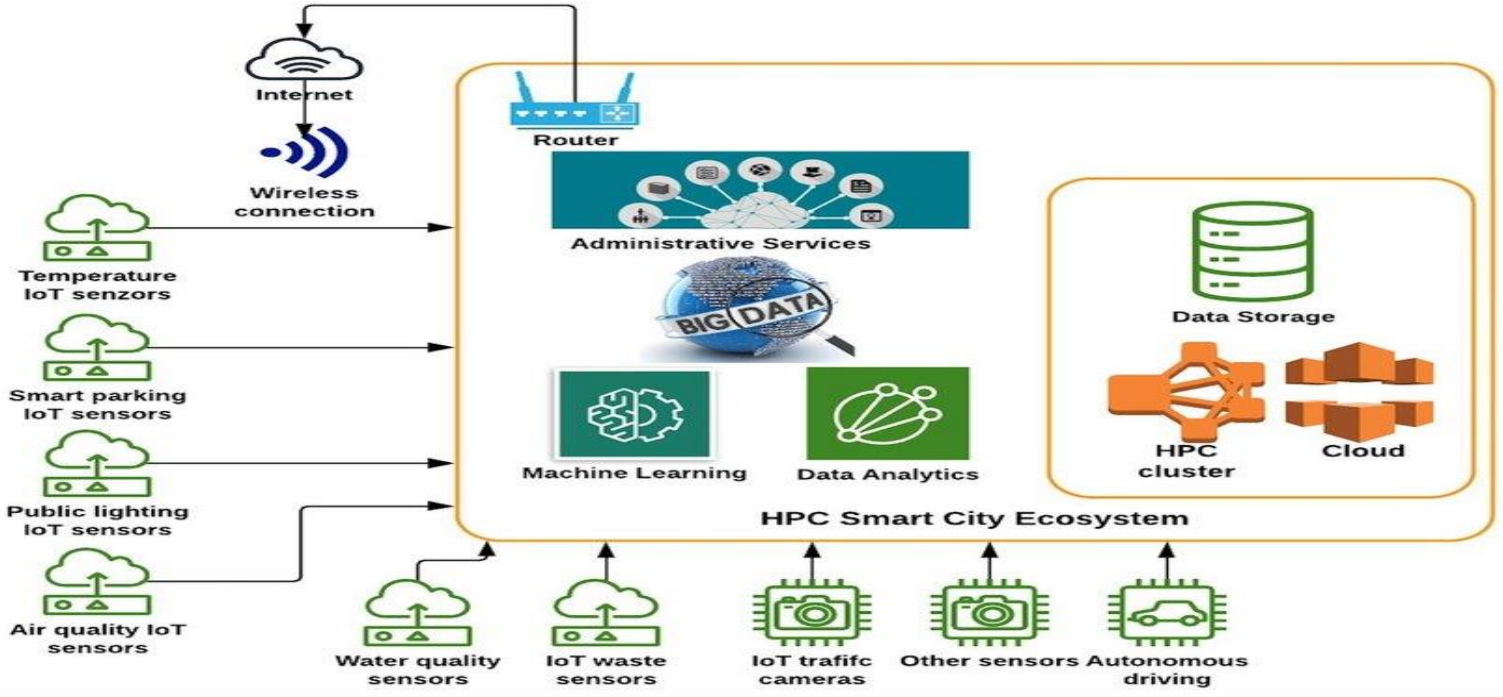


HPC with Big Data Support



Why HPC is needed in smart-city projects ?

- Smart cities leverage data from connected devices and powerful analytics tools to keep traffic flowing, protect public safety, reduce pollution, maintain public assets and improve the delivery of city services.
- Use cases for smart city technologies range from tracking the condition of roads and bridges and detecting water levels in flood-prone areas to optimizing the usage of street lights and giving citizens around-the-clock access to city services via mobile devices.



Applications and Scenarios for HPC Systems

Scientific research

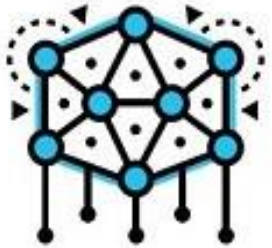
Climate simulation, hydrological simulation, astronomical science, space and various physical and chemical computations

Medical production & research

Medical imaging computation, genetic test sequence computation, precision medicine and biopharmaceutics

Computer graphics

Programming acceleration, image processing and computer animation



Data analysis and research

Data mining, data analysis, machine learning and deep learning

Aerospace application design

Fluid dynamics computation and simulation

Natural resource application

Oil and gas exploration

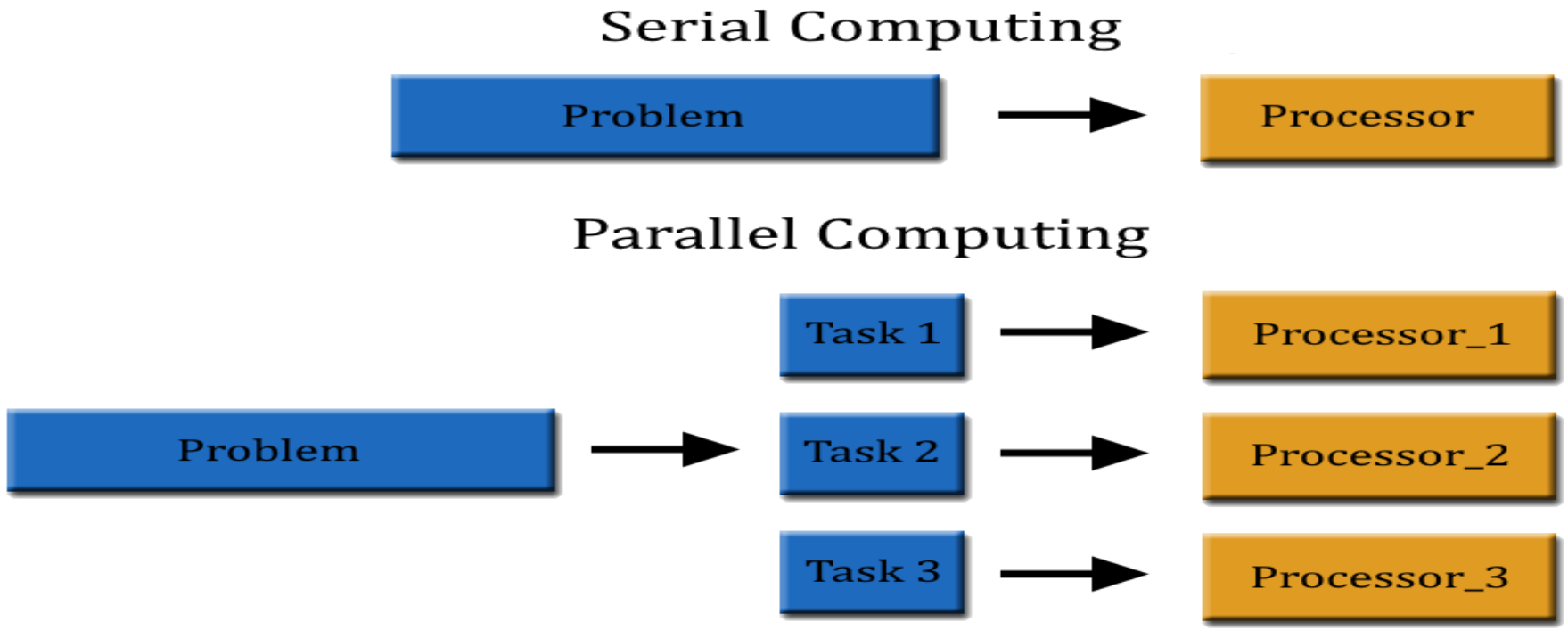
Applications and Scenarios for HPC Systems

Types

- Parallel Computing
- Distributed Computing
- Grid Computing
- Cloud Computing
- Edge Computing
- Fog Computing

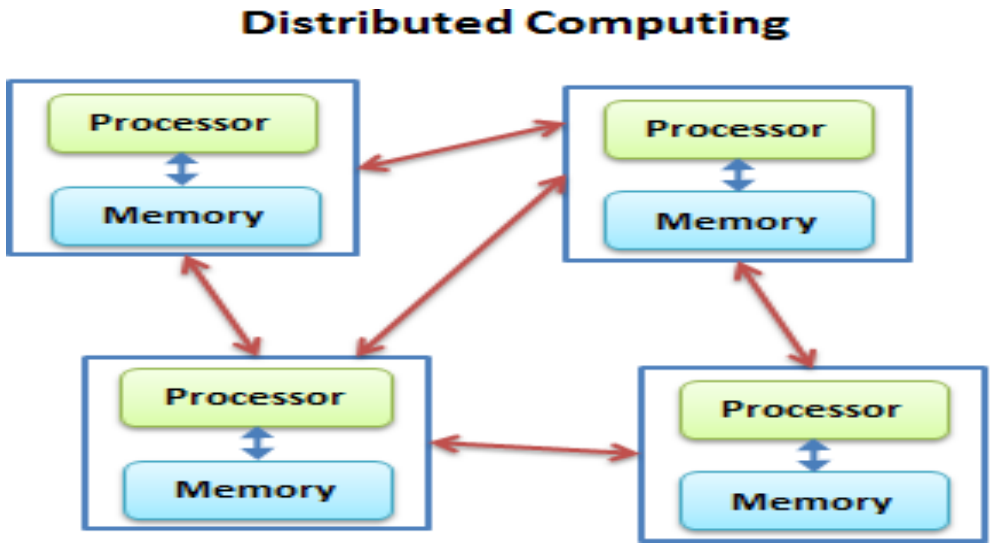
Parallel computing

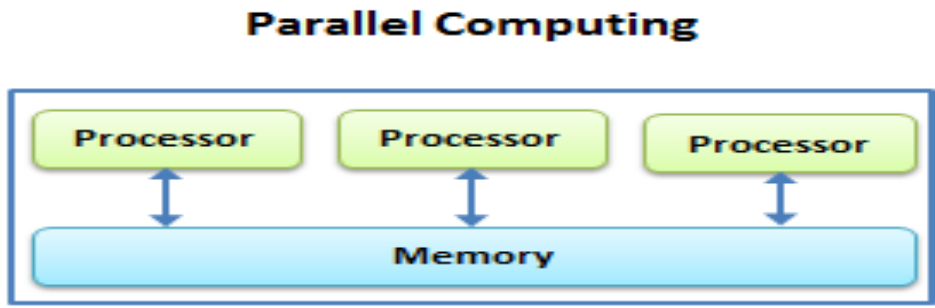
- Parallel computing refers to the process of executing several processors an application or computation simultaneously.
- Generally, it is a kind of computing architecture where the large problems break into independent, smaller, usually similar parts that can be processed in one go.
- It is done by multiple CPUs communicating via shared memory, which combines results upon completion.



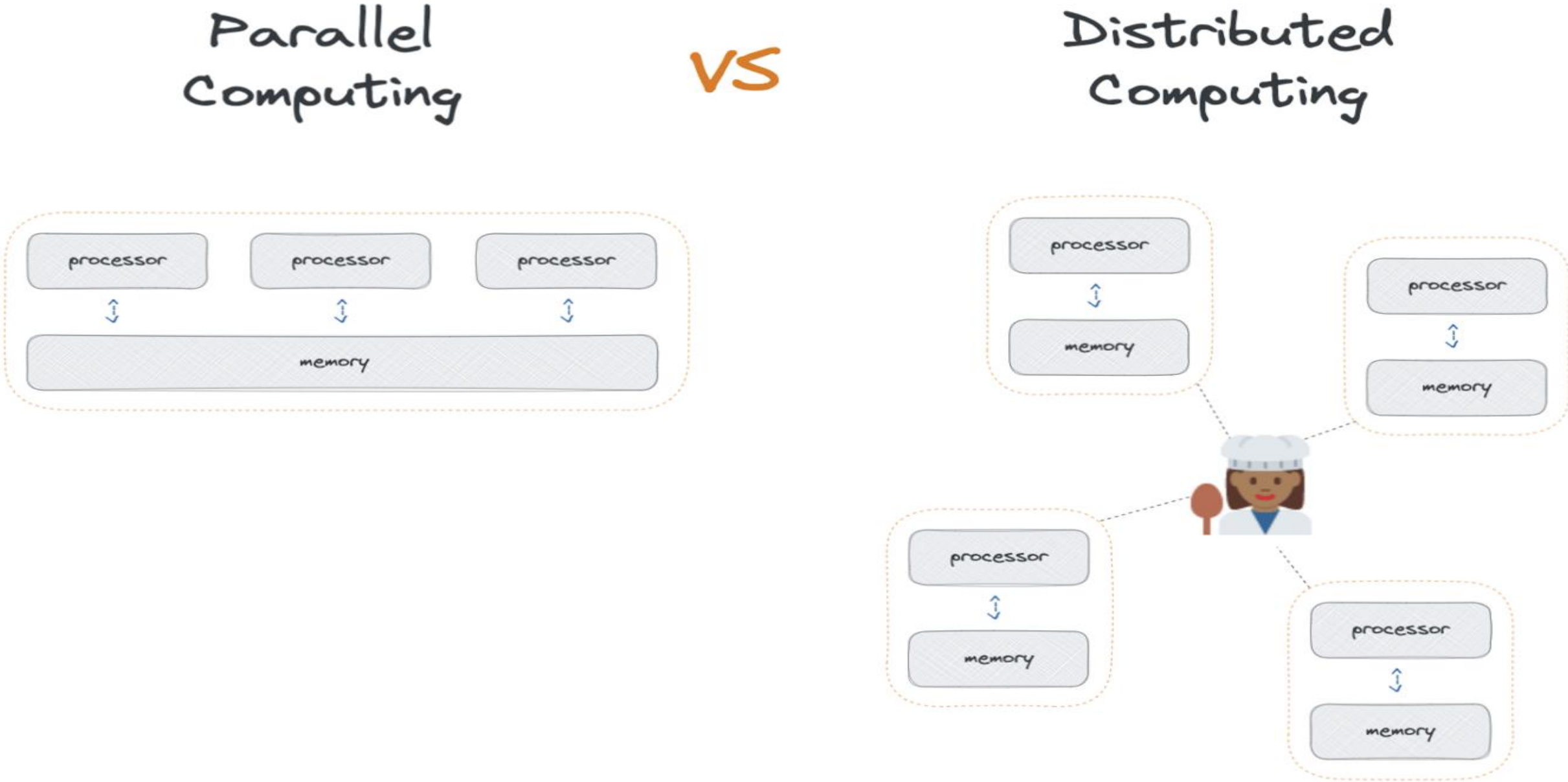
Distributed Computing

- A distributed computer system consists of multiple software components that are on multiple computers, but run as a single system.
- The computers that are in a distributed system can be physically close together and connected by a local network, or they can be geographically distant and connected by a wide area network.
- A distributed system can consist of any number of possible configurations, such as mainframes, personal computers, workstations, minicomputers, and so on. The goal of distributed computing is to make such a network work as a single computer.



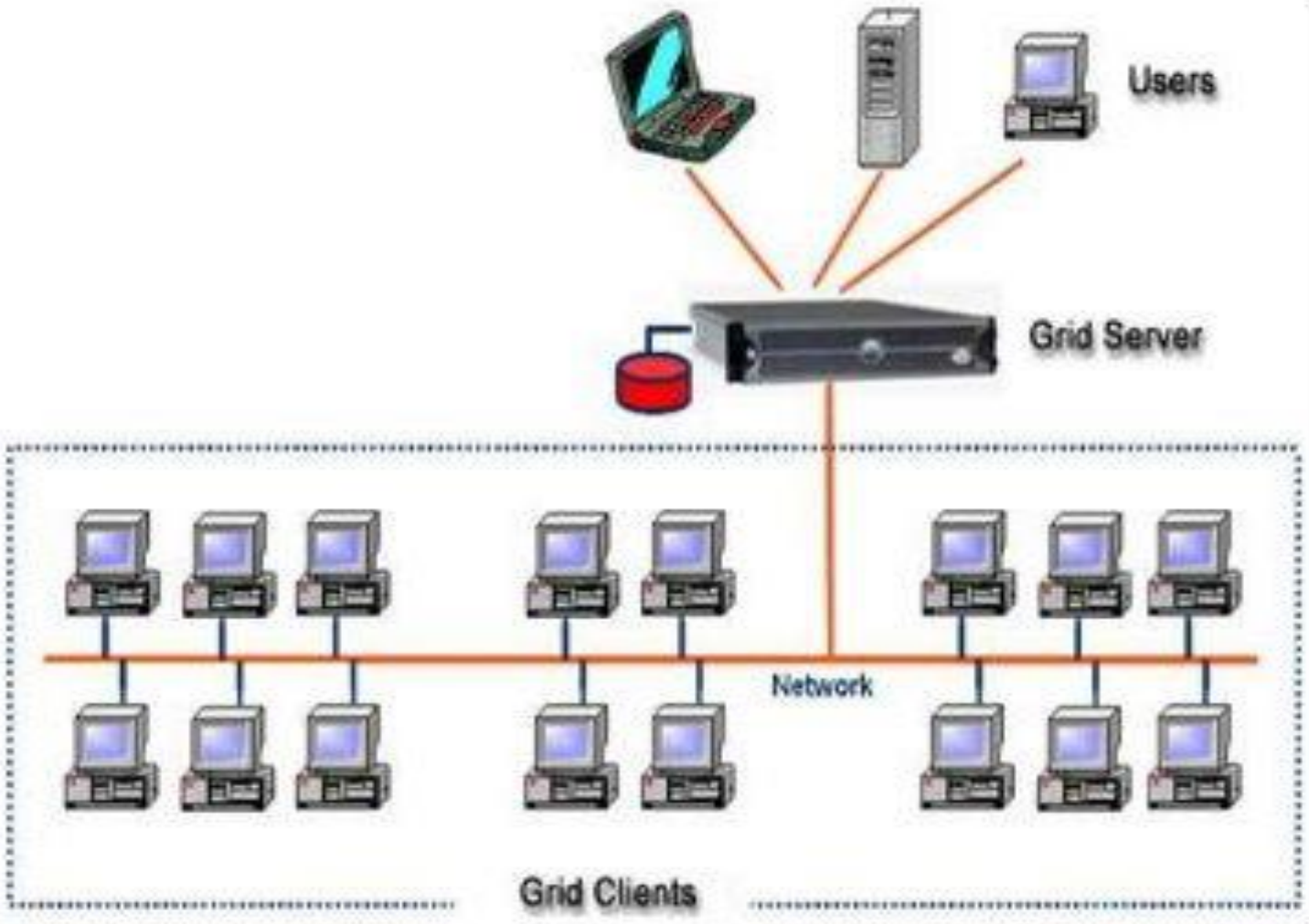


Parallel Computing vs Distributed Computing



Grid Computing

How Grid computing works ?

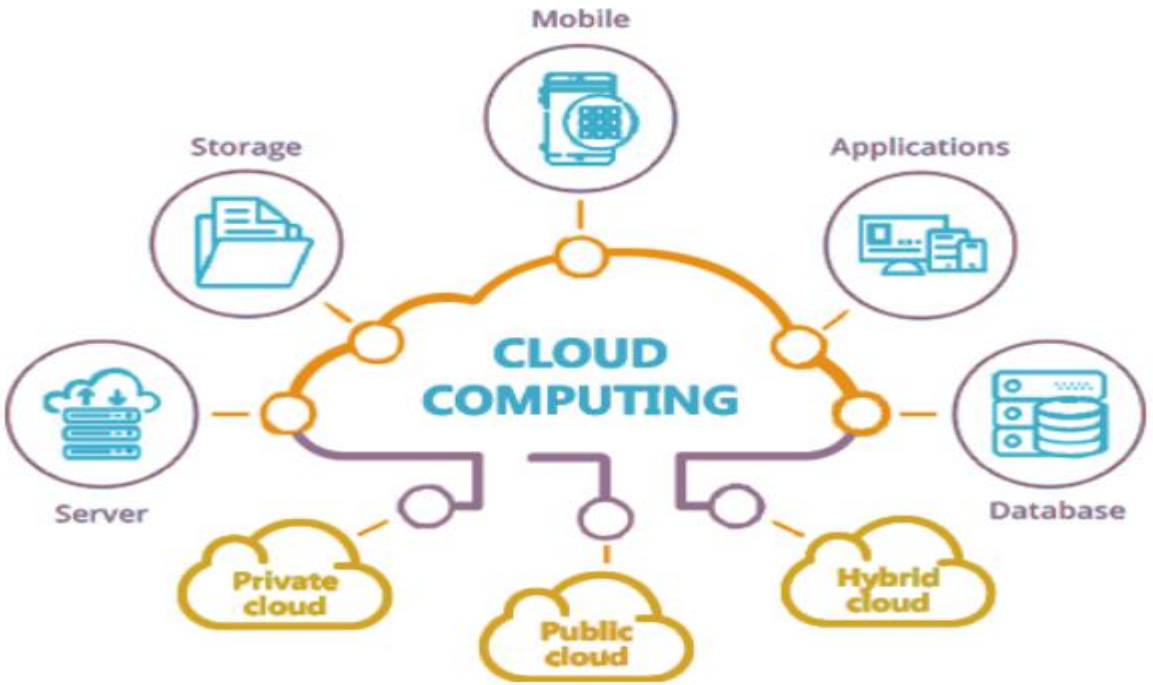


In general, a grid computing system requires:

- **At least one computer, usually a server, which handles all the administrative duties for the System**
- **A network of computers running special grid computing network software.**
- **A collection of computer software called middleware**

Cloud Computing

- Cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet (“the cloud”) to offer faster innovation, flexible resources, and economies of scale.
- You typically pay only for cloud services you use, helping lower your operating costs, run your infrastructure more efficiently and scale as your business needs change.

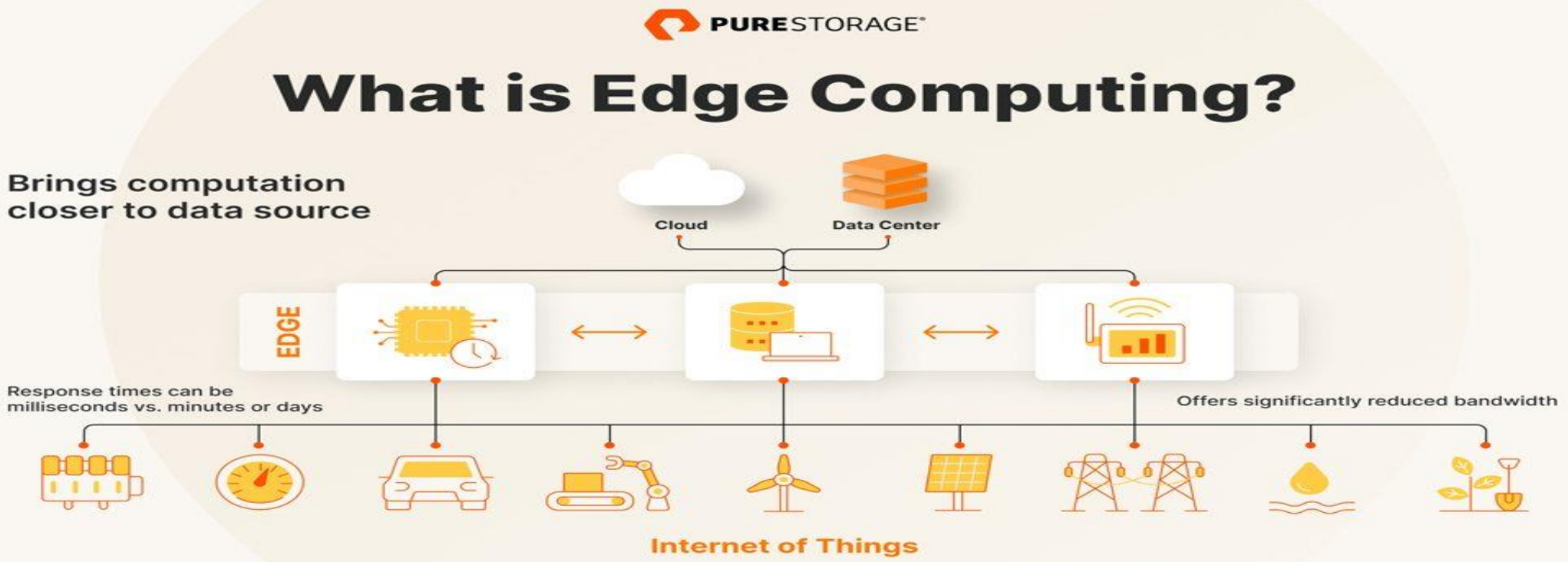


Grid Computing vs Cloud Computing

Parameter	Grid Computing	Cloud computing
Goal	Collaborative sharing of resources	Use of service (eliminates the detail)
Computational focuses	Computationally intensive	Operations Standard and high-level instances
Level of abstraction	Low (more details)	High (eliminate details)
Degree of scalability	Normal	High
Multitask	Yes	Yes
Transparency	Low	High
Time to run	Not real-time	Real-time services

Edge Computing

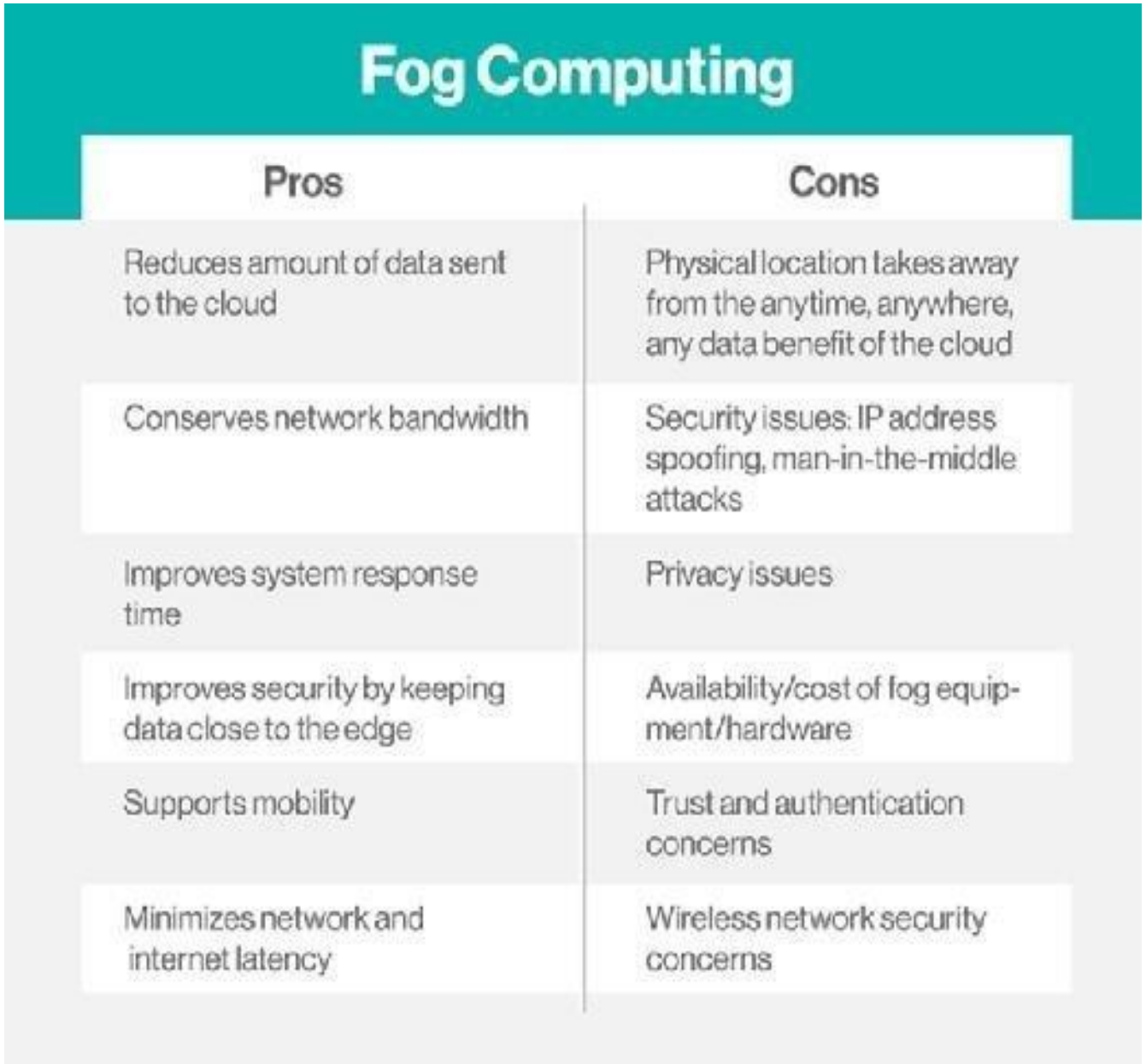
- Edge computing is a distributed computing framework that brings enterprise applications closer to data sources such as IoT devices or local edge servers.
- This proximity to data at its source can deliver strong business benefits: faster insights, improved response times and better bandwidth availability.



Fog Computing

- The term fog computing, originated by Cisco, refers to an alternative to cloud computing.
- This approach seizes upon the dual problem of the proliferation of computing devices and the opportunity presented by the data those devices generate by locating certain resources and transactions at the edge of a network.
- By locating these closer to devices, rather than establishing in-cloud channels for utilization and storage, users aggregate bandwidth at access points such as routers.
- This in turn reduces the overall need for bandwidth, as less data can be transmitted away from data centers, across cloud channels and distances.

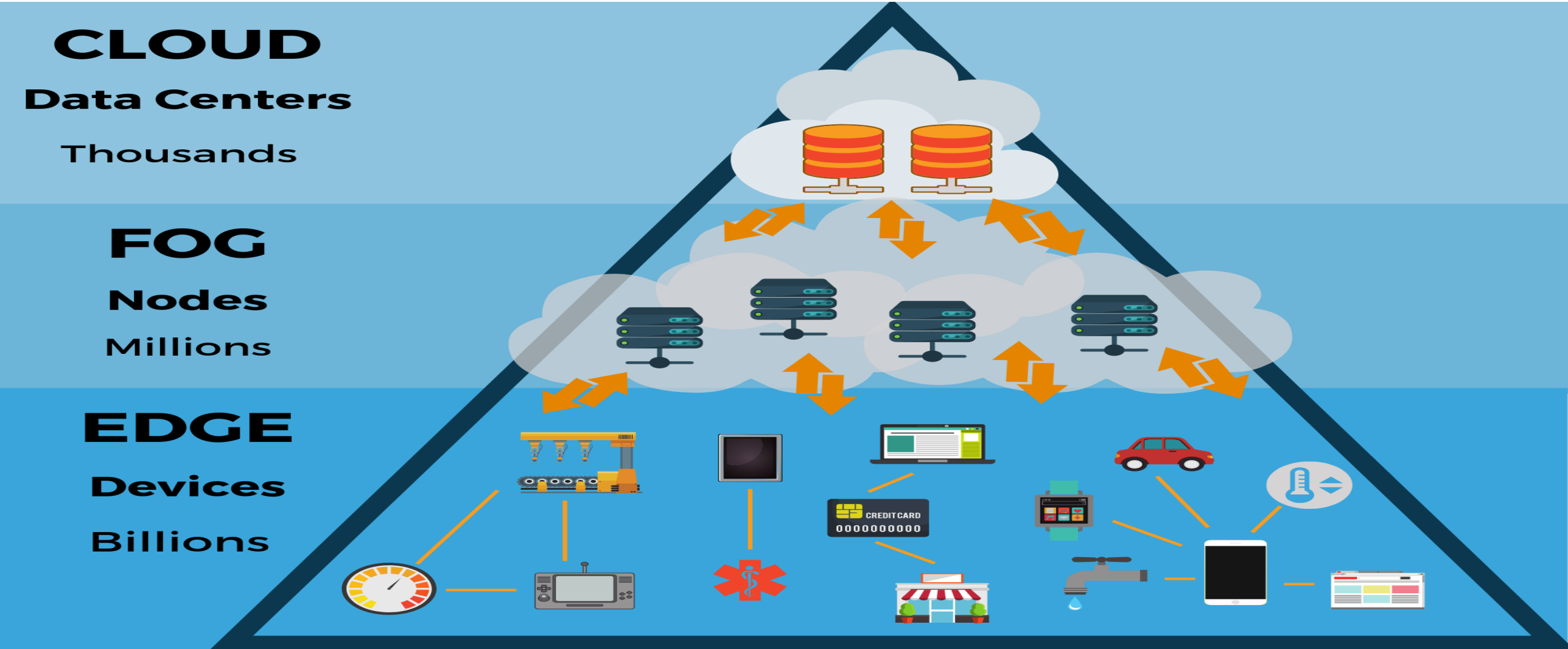
Fog Computing



Fog Computing

Pros	Cons
Reduces amount of data sent to the cloud	Physical location takes away from the anytime, anywhere, any data benefit of the cloud
Conserves network bandwidth	Security issues: IP address spoofing, man-in-the-middle attacks
Improves system response time	Privacy issues
Improves security by keeping data close to the edge	Availability/cost of fog equipment/hardware
Supports mobility	Trust and authentication concerns
Minimizes network and internet latency	Wireless network security concerns

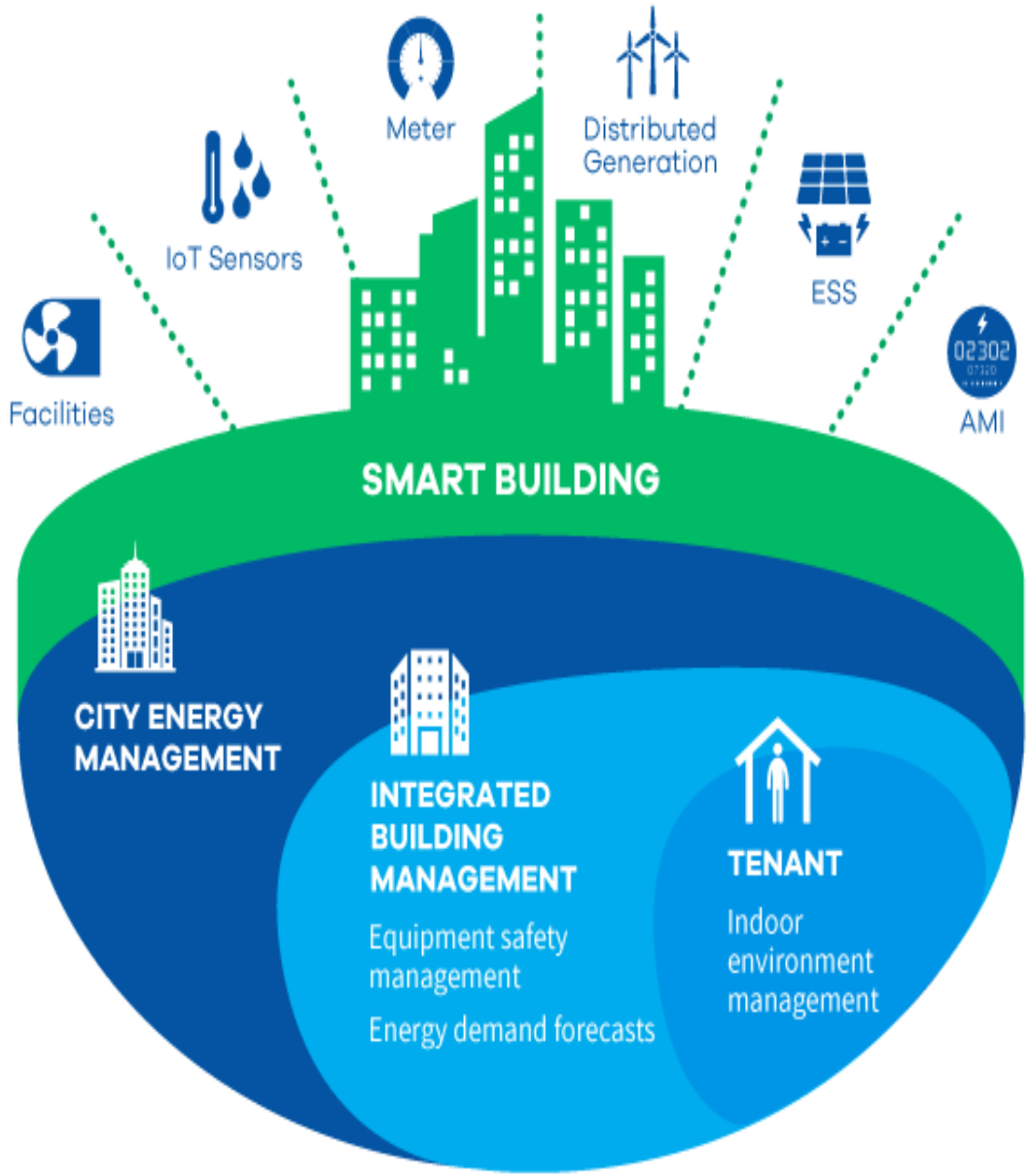
Cloud vs Fog vs Edge



HPC for IoT devices

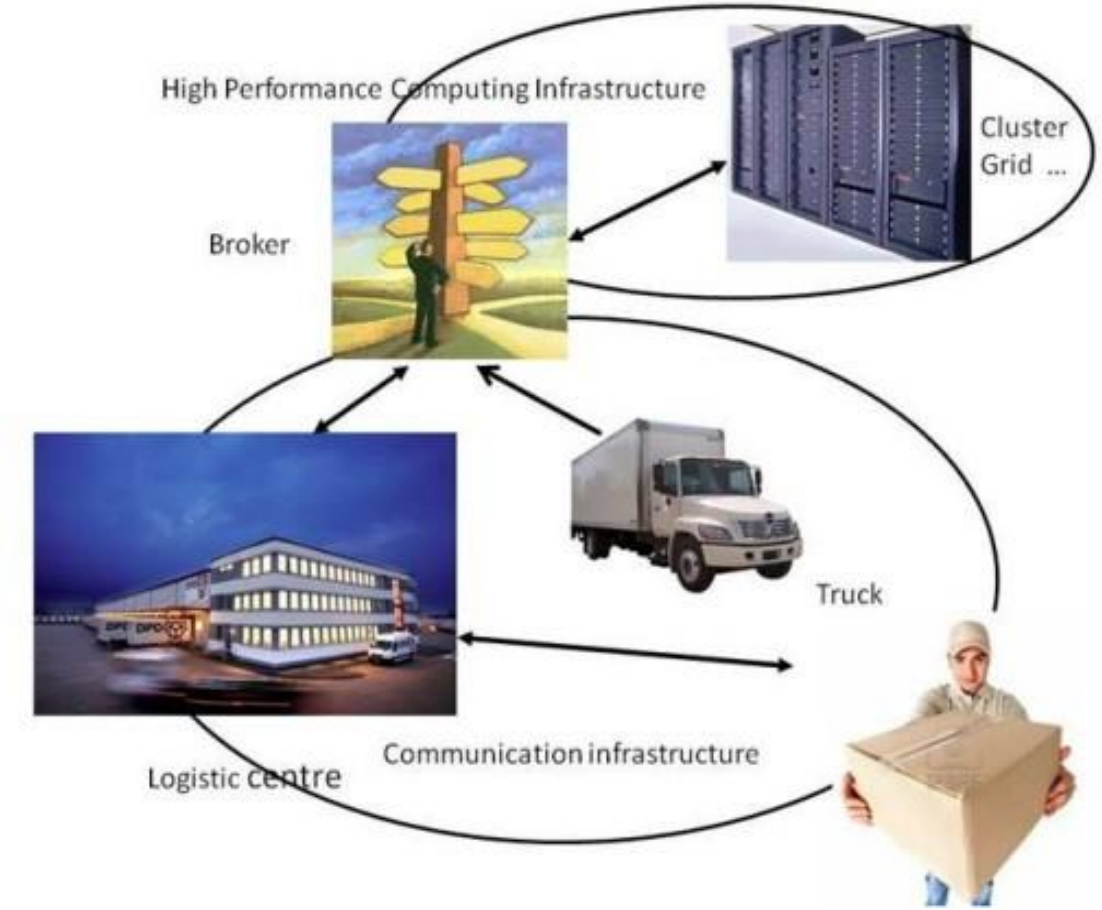
- Smart building management: The management of large number of IoT devices and collected data is hard and requires a great computational power. Use of HPC for these types of solution reduces computing time by factors from 50 up to 150 and requires less energy.
- For example, ADREAM building, which is an autonomous building in France, has 6000 sensors that measure temperature, light, motion, etc. Besides the sensors, the building has IP cameras and specialized devices like geothermal exchanger. The management of such large number of devices and collected data is hard and requires a great computational power.

Smart Building



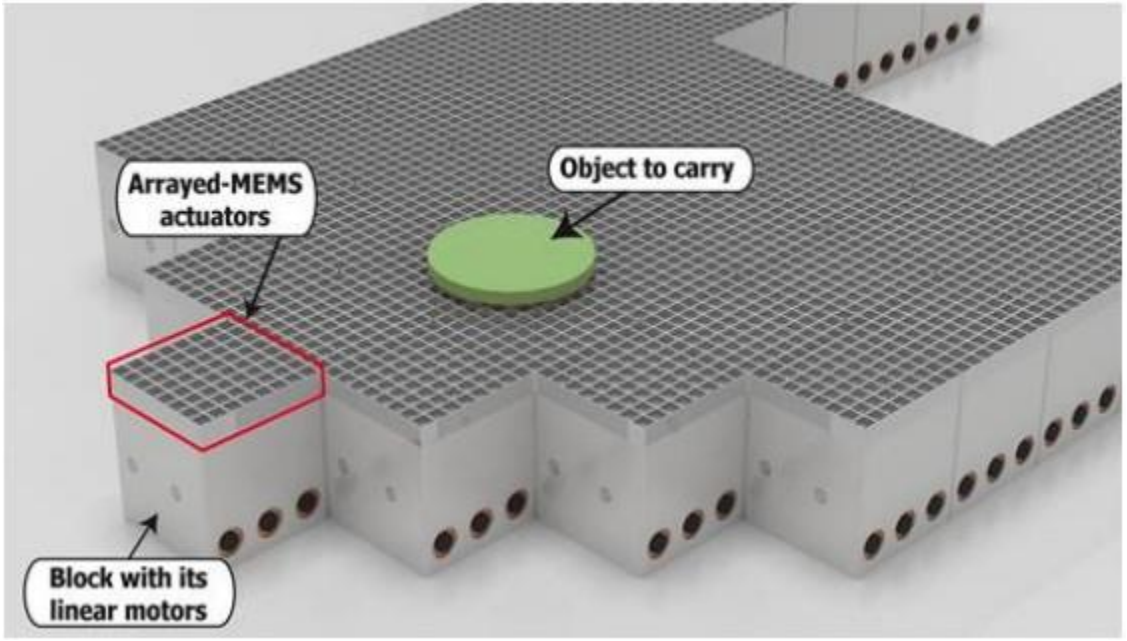
Smart logistics

- Logistic applications display also good examples where the combination of IOT and HPC is particularly fruitful. Because of the dynamics in the logistic process, difficult events may occur at any time, for example, cancellation of an order or traffic jam.

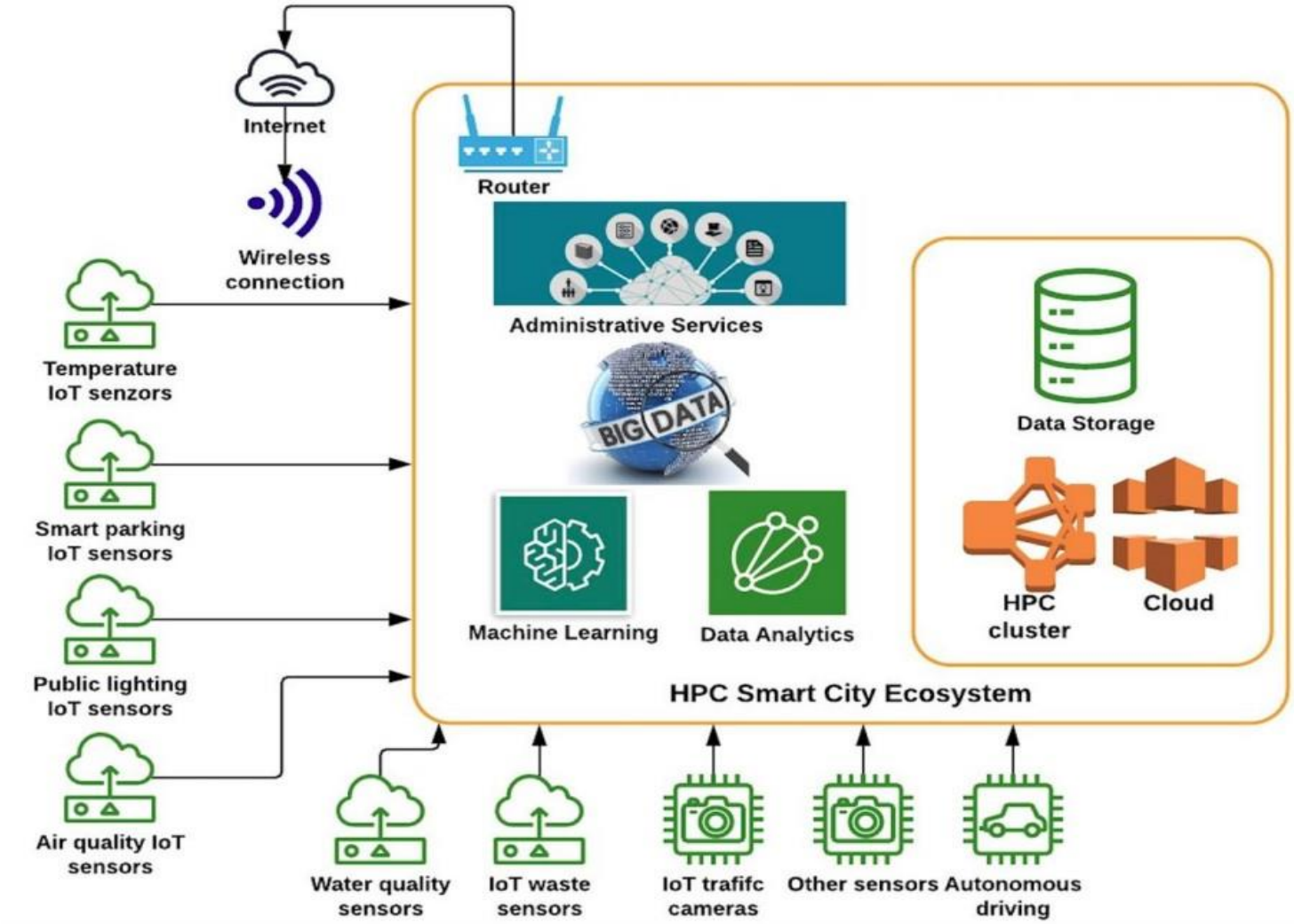


Smart Manufacturing

- Reconfigurable conveyors can easily adapt to tasks changes. They require fewer modules than a classic monolithic surface. Reconfigurable conveyors can also cope with faults.



Smart city powered by HPC architecture



ANY QUESTIONS??

THANK YOU