# Cloud Computing Overview

Instructor, Nero Chan Zhen Yu

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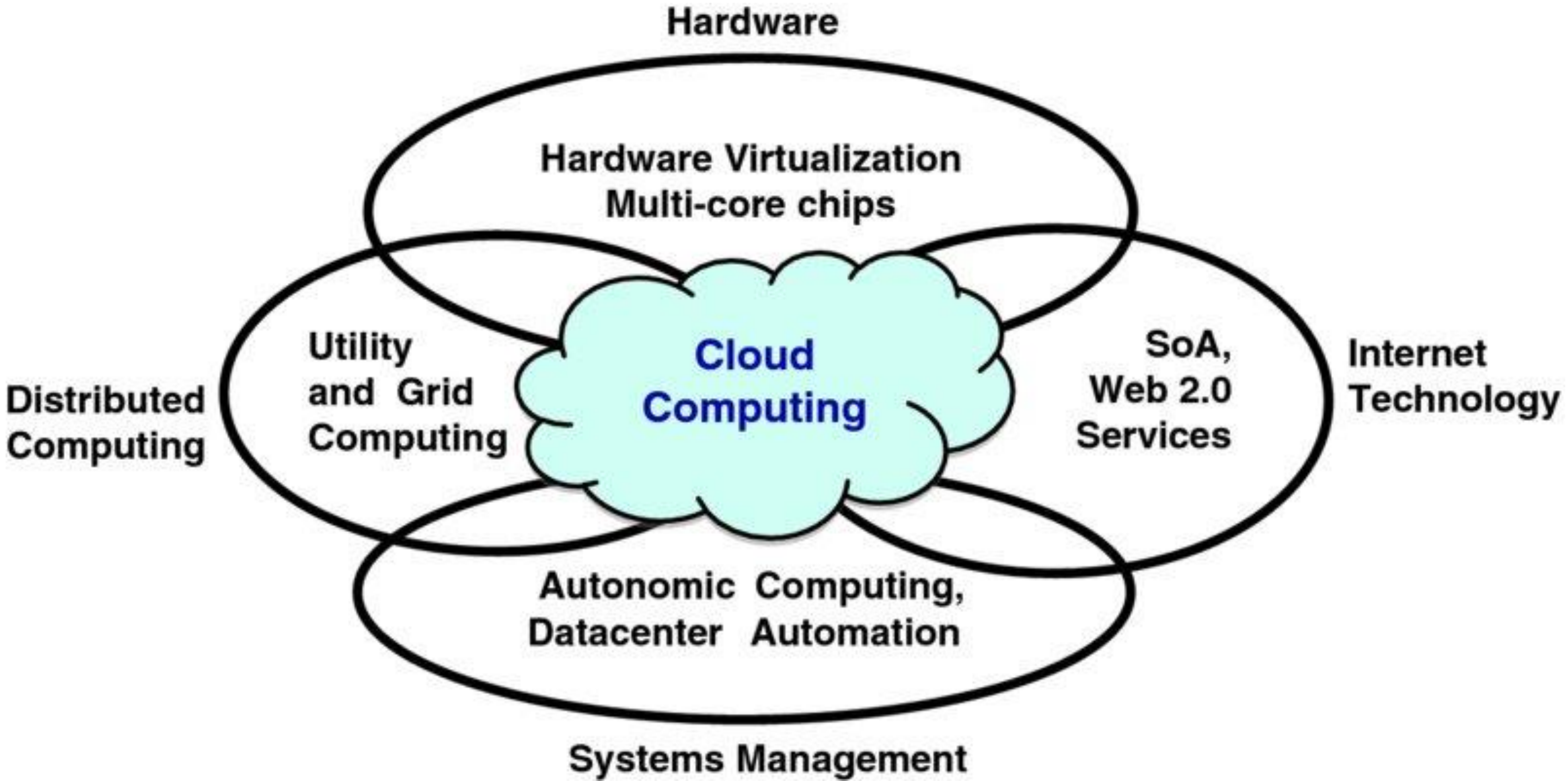
# Definition of Cloud Computing

- The U.S. National Institute of Standards and Technology (NIST) defines cloud computing as:
  - Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

# Cloud Computing

- Cloud computing is enabled by the convergence of the four technologies illustrated in the following figure:

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# Cloud Computing

- Hardware virtualization and multicore chips make it possible to have dynamic configurations in clouds.
- Utility and grid computing technologies lay the necessary foundation of computing clouds.
- Recent advances in service-oriented architecture (SOA), Web 2.0 and mashups of platforms are pushing the cloud to another forward step.
- Autonomic computing and automated data center operations have enabled cloud computing

- *The convergence of hardware, internet technology, distributed computing and systems, the vision of a data-intensive system can be realized.*

# Characteristics of Cloud Computing

# Characteristics of Cloud Computing

- On-demand self service:
  - Cloud computing resources can be provisioned on-demand by the users, without requiring interactions with the cloud service provider. The process of provisioning resources is automated.
- Broad network access:
  - Cloud computing resources can be accessed over the network using standard access mechanisms that provide platform-independent access through the use of heterogeneous client platforms such as workstations, laptops, tablets and smartphones.

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# Characteristics of Cloud Computing

- Resource pooling:
  - The computing and storage resources provided by cloud service providers are pooled to serve multiple users using multi-tenancy. Multi-tenant aspects of the cloud allow multiple users to be served by the same physical hardware.
- Rapid elasticity:
  - Cloud computing resources can be provisioned rapidly and elastically. Cloud resources can be rapidly scaled up or down based on demand.

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# Characteristics of Cloud Computing

- Measured service:
  - Cloud computing resources are provided to users on a pay-per-use model. The usage of the cloud resources is measured and the user is charged based on some specific metric.
- Performance:
  - Cloud computing provides improved performance for applications since the resources available to the applications can be scaled up or down based on the dynamic application workloads.

# Characteristics of Cloud Computing

- Reduced costs:
  - Cloud computing provides cost benefits for applications as only as much computing and storage resources as required can be provisioned dynamically, and upfront investment in purchase of computing assets to cover worst case requirements is avoid.
- Outsourced Management:
  - Cloud computing allows the users (individuals, large organizations, small and medium enterprises and governments) to outsource the IT infrastructure requirements to external cloud providers.

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# Characteristics of Cloud Computing

- Reliability:
  - Applications deployed in cloud computing environments generally have a higher reliability since the underlying IT infrastructure is professionally managed by the cloud service.
- Multi-tenancy:
  - The multi-tenanted approach of the cloud allows multiple users to make use of the same shared resources
  - In virtual multi-tenancy, computing and storage resources are shared among multiple users.
  - In organic multi-tenancy every component in the system architecture is shared among multiple tenants

# Cloud Computing versus On-Premise Computing

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# Cloud Computing versus On-Premise Computing

- Additional computing applications are primarily executed on local hosts on premises. They appear as desktops, deskside, notebooks or tablets, etc.
- On-premise computing differs from cloud computing mainly in resources control and infrastructure management
- Three common models of cloud computing
  - Infrastructure as a service (IaaS)
  - Platform as a service (PaaS)
  - Software as a service (SaaS)

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# Infrastructure as a service (IaaS)

- The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
- The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

# Advantage of cloud computing usage

- In the case of using an IaaS cloud like AWS EC2, the user only needs to worry about application software deployment. The virtual machines are jointly deployed by user and provider. The vendors are responsible for providing the remaining hardware and networks.

# Platform as a service (PaaS)

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

# Advantage of cloud computing usage

- In using the PaaS clouds, like Google AppEngine, both application codes and virtual machines are jointly deployed by user and vendor and the remaining resources are provided by the vendors.

# Software as a service (SaaS)

- The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure2.
- The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface.
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user- specific application configuration settings.

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# Advantage of cloud computing usage

- When the SaaS model is using the Saleforce cloud, everything is provided by the vendor, even including the app software.
- Office365 users do not need to install any local software and can use (slightly limited) office applications as long as they have a modern web browser.
- Video platforms – Youtube, Youke, Tudou, Netflix etc. – all through browsers!

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# Summary of Key Differences

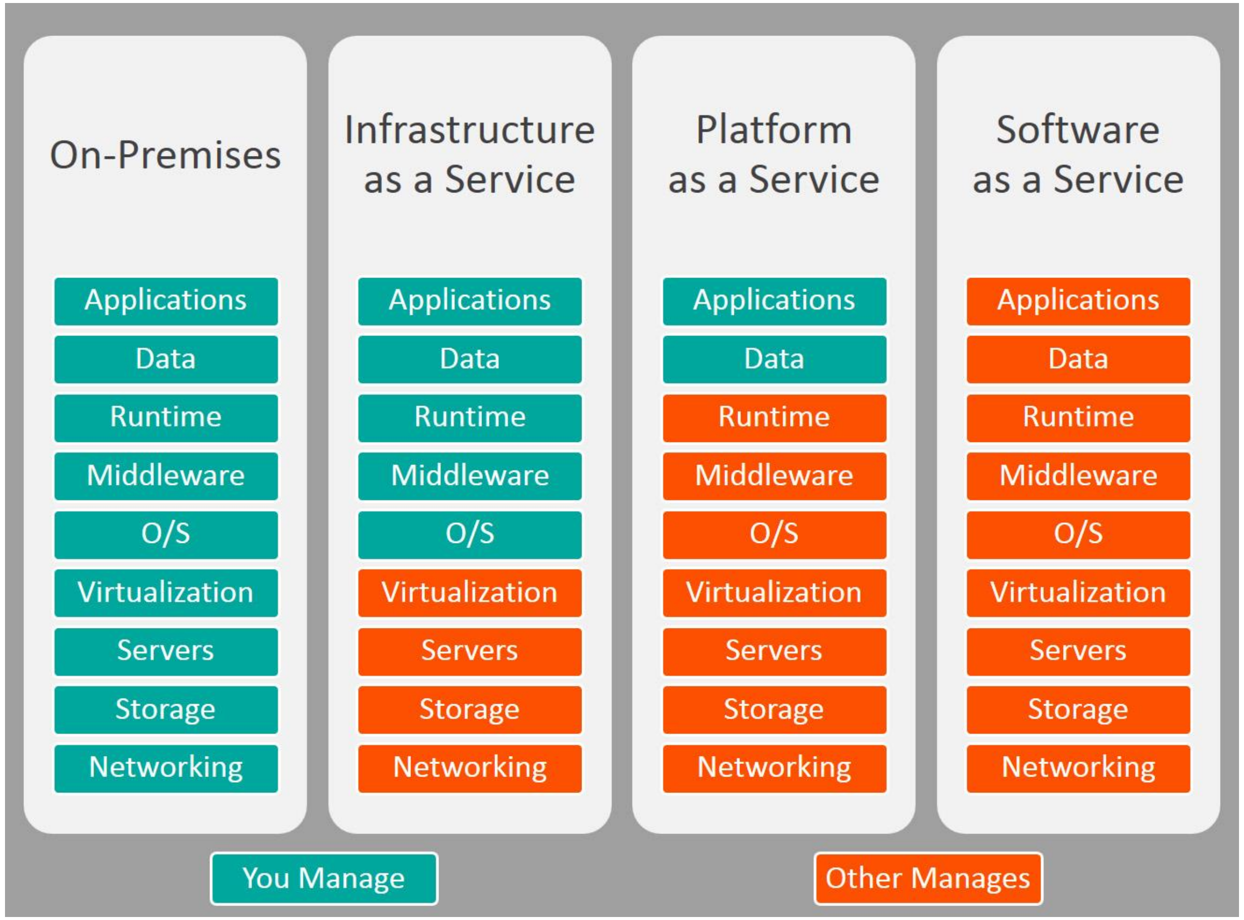


Image taken from: https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/

# Common Examples of SaaS, PaaS, & IaaS Service Providers

| Platform Type | Common Examples |
|---|---|
| **SaaS** | Google Apps, Dropbox, Salesforce, Cisco WebEx, Concur, GoToMeeting |
| **PaaS** | AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, Apache Stratos, OpenShift |
| **IaaS** | DigitalOcean, Linode, Rackspace, Amazon Web Services (AWS), Cisco Metapod, Microsoft Azure, Google Compute Engine (GCE) |

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Table taken from: https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/

# Advantage of cloud computing usage

- In conclusion, we see that cloud computing reduces users' infrastructure management burdens from two resources to none, as we move from IaaS to PaaS and SaaS services. This clearly shows the advantages for users in separating the application from resources investment and management.

# Types of cloud platforms

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# Public Clouds:

- A public cloud is built over the Internet, which can be accessed by any user who has paid for the service.
- Public clouds are owned by service providers
    - They are accessed by subscription.
- Well-known public clouds include the Google App Engine (GAE), Amazon Web Service (AWS), Microsoft Azure, IBM Blue Cloud, Salesforce Sales Clouds, etc.
- These providers offer a publicly accessible remote interface for creating and managing VM instances within the system.

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# Community Clouds

- This is a growing subclass of public clouds.
- These clouds appear as a collaborative infrastructure shared by multiple organizations with some common social or business interest, scientific discovery, high availability, etc.
- Community clouds are often built over multiple datacenters.
- In recent years, community clouds have grown rapidly in education, business enterprises and government sectors to meet the growth of big data applications.

# Private Clouds

- The private cloud is built within the domain of an intranet owned by a single organization.
- Therefore, they are client owned and managed.
- Private clouds give local users a flexible and agile private infrastructure to run service workloads within their administrative domains.
- A private cloud is supposed to deliver more efficient and convenient cloud services.
- Private clouds may wish to retain greater customization and organizational control.

# Hybrid Clouds

- A hybrid cloud is built with all cloud families.
- Private clouds support a hybrid cloud model by supplementing local infrastructure with computing capacity from an external public cloud.
- For example, the research compute cloud (RC2) is a private cloud owned by IBM.
  - The RC2 interconnects the computing resources at 8 IBM Research Centers scattered across the US, Europe and Asia.
- A hybrid cloud provides access to clients, partner networks and third parties.

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# Concepts and Enabling Technologies of cloud computing

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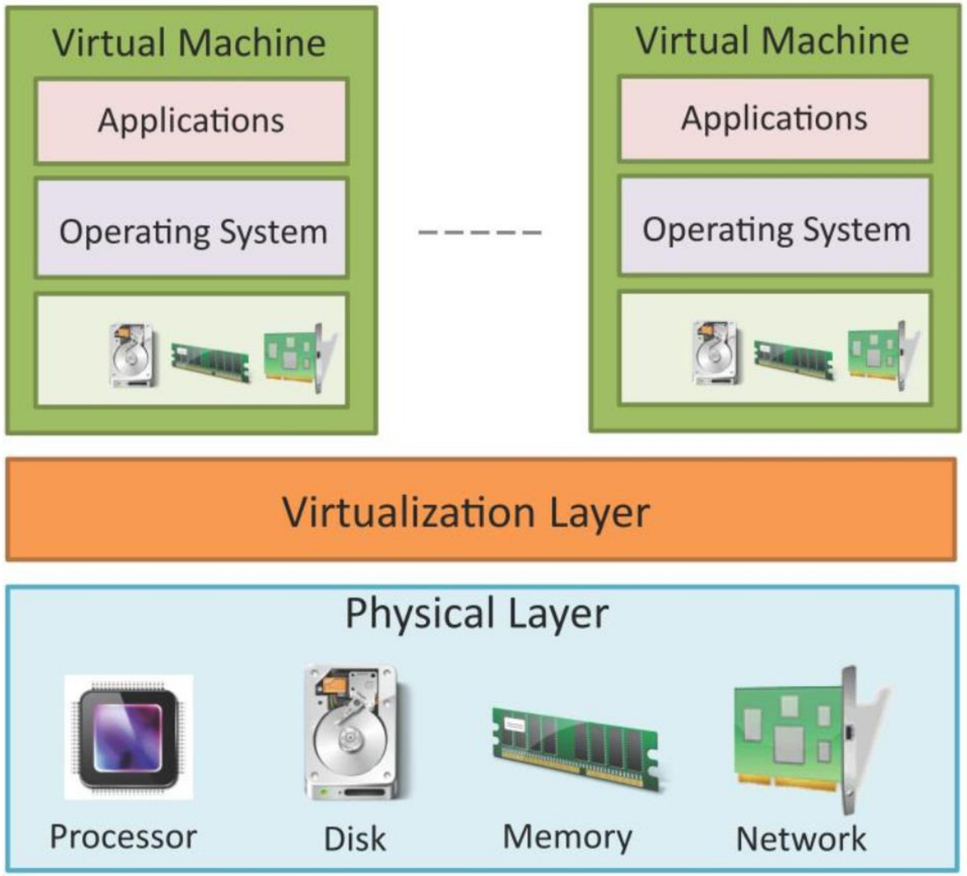
# Virtualization

- Virtualization refers to the partitioning the resources of a physical system (such as computing, storage, network and memory) into multiple virtual resources.
- Key enabling technology of cloud computing that allow pooling of resources.
- In cloud computing, resources are pooled to serve multiple users using multi-tenancy

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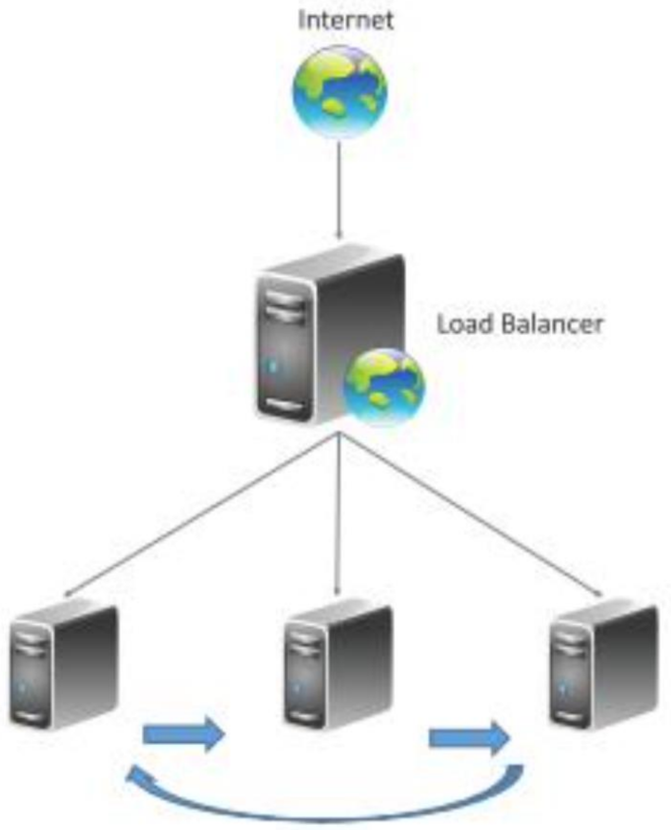
# Load Balancing

- Cloud computing resources can be scaled up on demand to meet the performance requirements of applications.
- Load balancing distributes workloads across multiple servers to meet the application workloads.
- The goals of load balancing techniques include:
  - Achieve maximum utilization of resources
  - Minimizing the response times
  - Maximizing throughput



# Load Balancing Algorithms

- Round Robin load balancing
- Weighted Round Robin load balancing
- Low Latency load balancing
- Least Connections load balancing
- Priority load balancing
- Overflow load balancing

# Load Balancing - Persistence Approaches

- Since load balancing can route successive requests from a user session to different servers, maintaining the state or the information of the session is important.
- Persistence Approaches
  - Sticky sessions
  - Session Database
  - Browser cookies
  - URL re-writing

# Scalability & Elasticity

- Multi-tier applications such as e-Commerce, social networking, business-to-business, etc. can experience rapid changes in their traffic.
- Capacity planning involves determining the right sizing of each tier of the deployment of an application in terms of the number of resources and the capacity of each resource.
- Capacity planning may be for computing, storage, memory or network resources.

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# Replication

- Replication is used to create and maintain multiple copies of the data in the cloud.
- Cloud enables rapid implementation of replication solutions for disaster recovery for organizations.
- With cloud-based data replication organizations can plan for disaster recovery without making any capital expenditures on purchasing, configuring and managing secondary site locations.
- Types:
    - Array-based Replication
    - Network-based Replication
    - Host-based Replication

# Monitoring

- Monitoring services allow cloud users to collect and analyze the data on various monitoring metrics.
- A monitoring service collects data on various system and application metrics from the cloud computing instances.
- Monitoring of cloud resources is important because it allows the users to keep track of the health of applications and services deployed in the cloud.

# Identity and Access Management

- Identity and Access Management (IDAM) for cloud describes the authentication and authorization of users to provide secure access to cloud resources.
- Organizations with multiple users can use IDAM services provided by the cloud service provider for management of user identifiers and user permissions.
- IDAM services allow organizations to centrally manage users, access permissions, security credentials and access keys.
- Organizations can enable role-based access control to cloud resources and applications using the IDAM services.
- IDAM services allow creation of user groups where all the users in a group have the same access permissions.
- Identity and Access Management is enabled by a number of technologies such as OpenAuth, Role-based Access Control (RBAC), Digital Identities, Security Tokens, Identity Providers, etc.

# Billing

- Cloud service providers offer a number of billing models described as follows:
- Elastic Pricing
  - In elastic pricing or pay-as-you-use pricing model, the customers are charged based on the usage of cloud resources.
- Fixed Pricing
  - In fixed pricing models, customers are charged a fixed amount per month for the cloud resources.
- Spot Pricing
  - Spot pricing models offer variable pricing for cloud resources which is driven by market demand.

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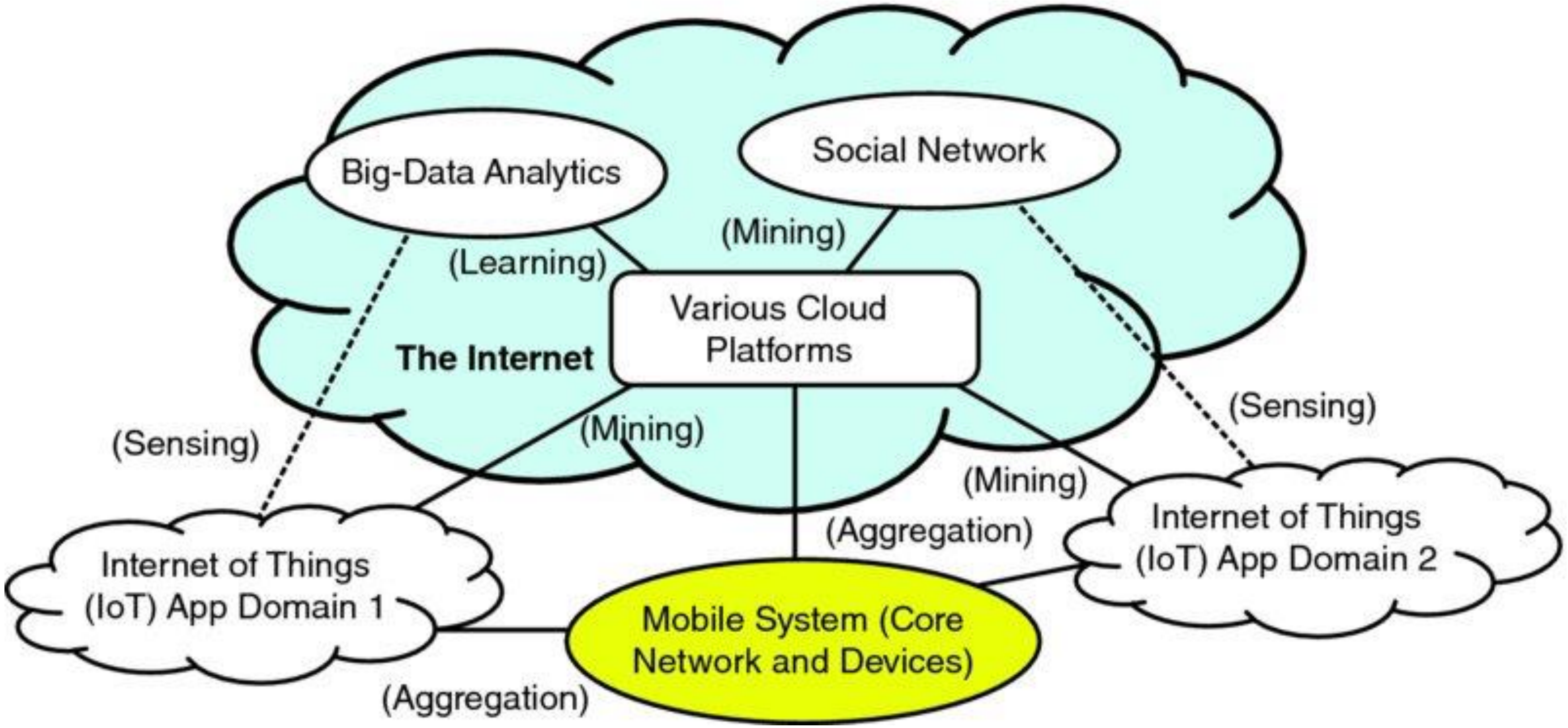
# Big Data + Cloud Computing = ??

# How does Big Data cross path with Cloud computing?

- Example of the interactions among social network, mobile systems, big data analytics and cloud platforms over various IoT domains

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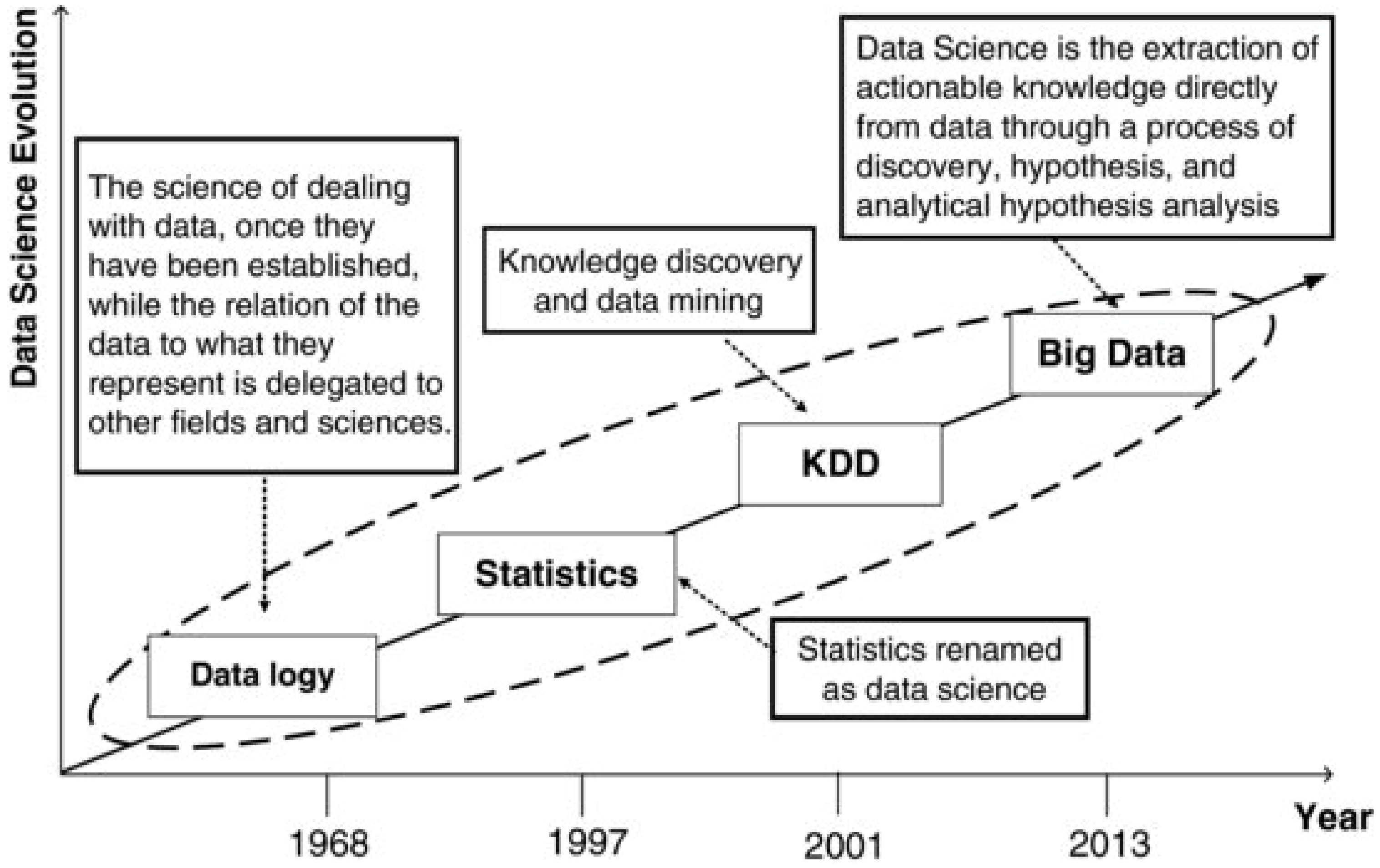
# Data Science and related disciplines

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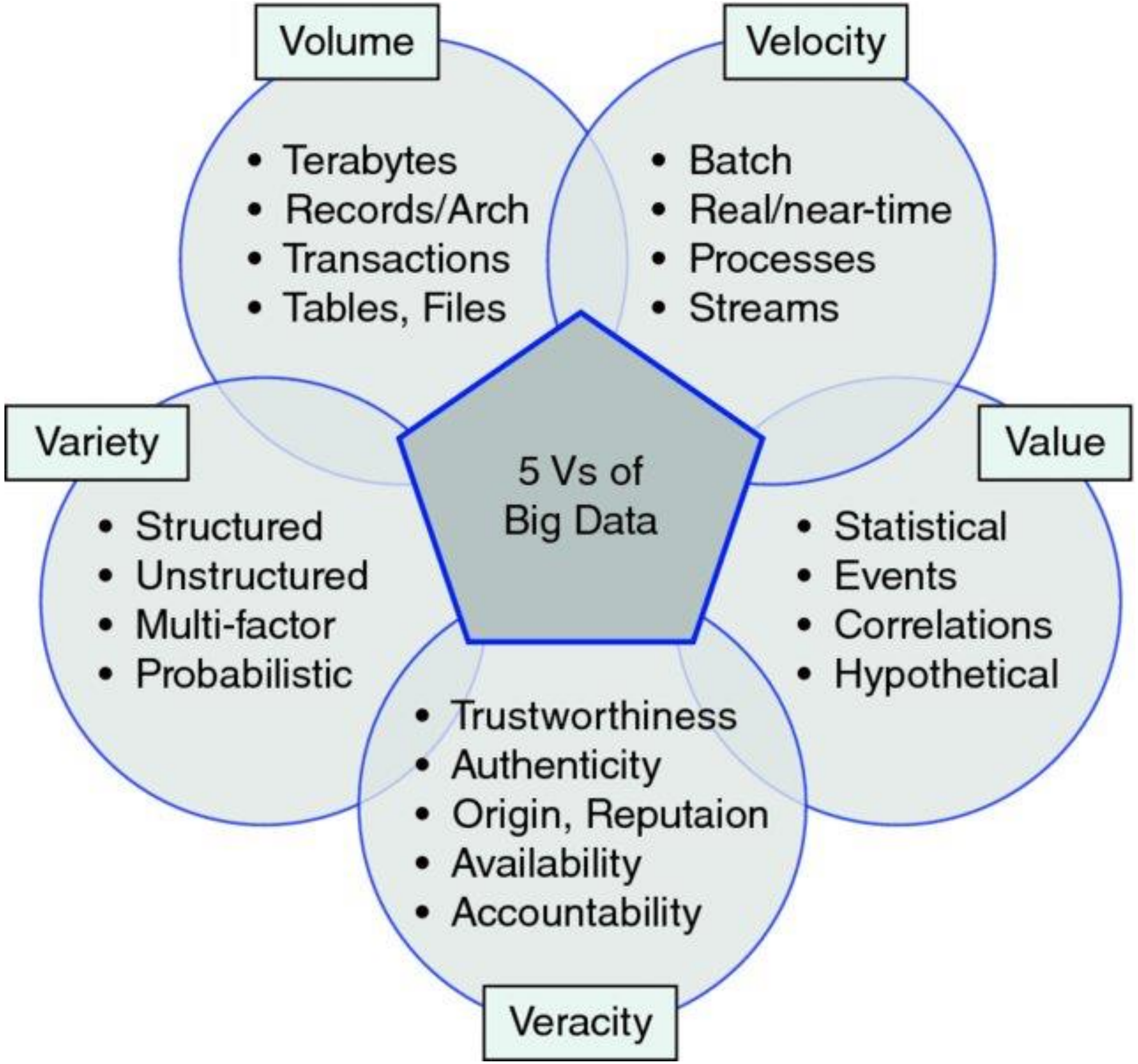
# The 5 V's

- Big data characteristics

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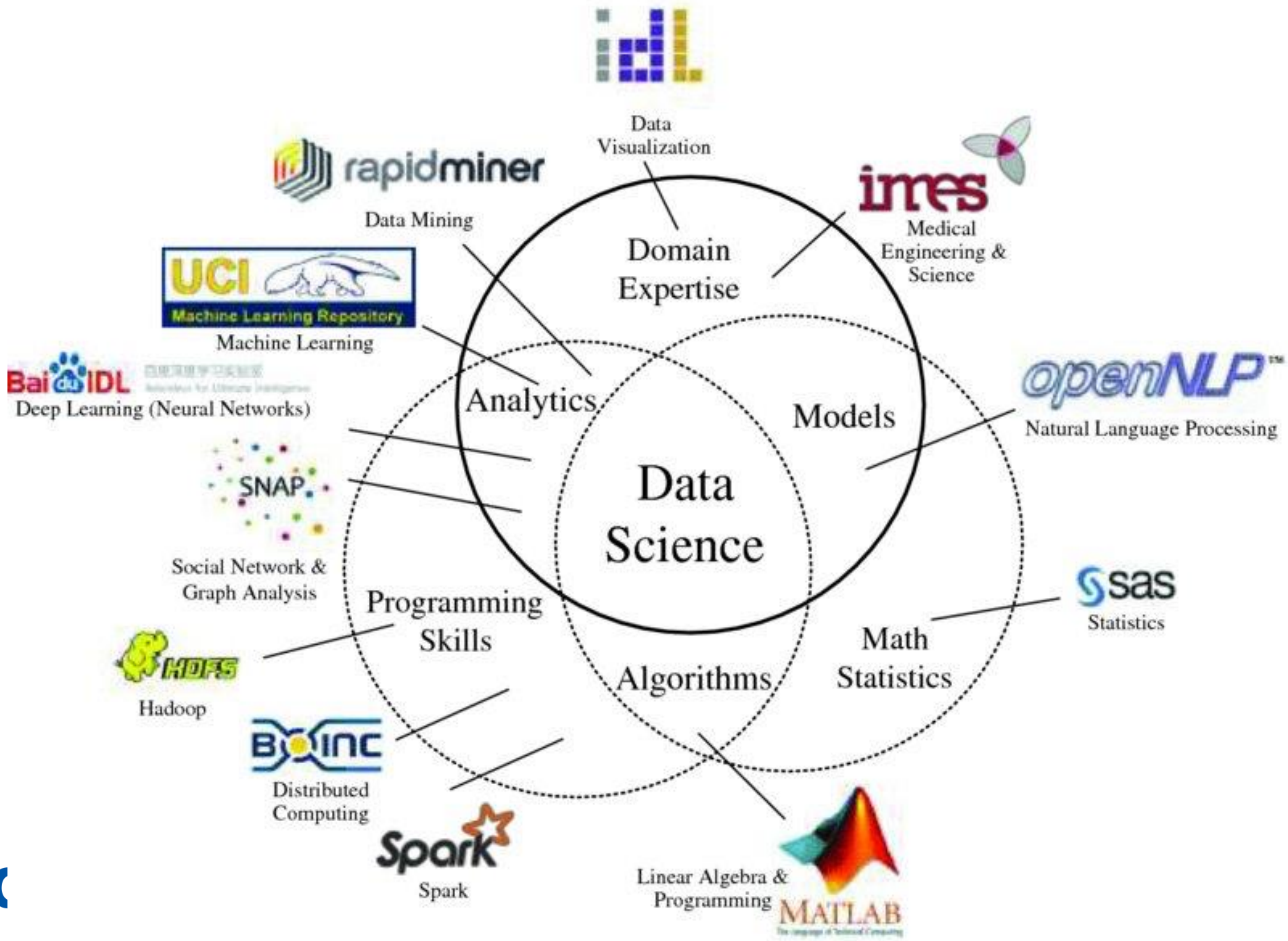

idl
Data Visualization
rapidminer
Data Mining
UCI
Machine Learning Repository
Machine Learning
Bai du IDL
Deep Learning (Neural Networks)
SNAP
Social Network & Graph Analysis
HDFS
Hadoop
BOINC
Distributed Computing
Spark
Spark
imes
Medical Engineering & Science
openNLP
Natural Language Processing
sas
Statistics
Linear Algebra & Programming
MATLAB
Domain Expertise
Analytics
Models
Data Science
Programming Skills
Algorithms
Math Statistics

# Functional components of data science

- Data science teams solve very complex data problems.
- Statistics, operations research, visualization and domain knowledge are also indispensable.
- When ever two areas overlap, they generate three important specialized fields of interest.
- The modeling field is formed by intersecting domain expertise with mathematical statistics.
  - The knowledge to be discovered is often described by abstract mathematical language.
- Another field is data analytics, which has resulted from the intersection of domain expertise and programming skills.
  - Domain experts apply special programming tools to discover knowledge by solving practical problem in their domain.
- Finally, the field of algorithms is the intersection of programming skills and mathematical statistics.

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# Open challenges in big data research, development and applications

- Structured versus unstructured data with effective indexing;
- Identification, de-identification and re-identification;
- Ontologies and semantics of big data;
- Data introspection and reduction techniques;
- Design, construction, operation and description;
- Data integration and software interoperability;
- Immutability and immortality;
- Data measurement methods;
- Data range, denominators, trending and estimation.

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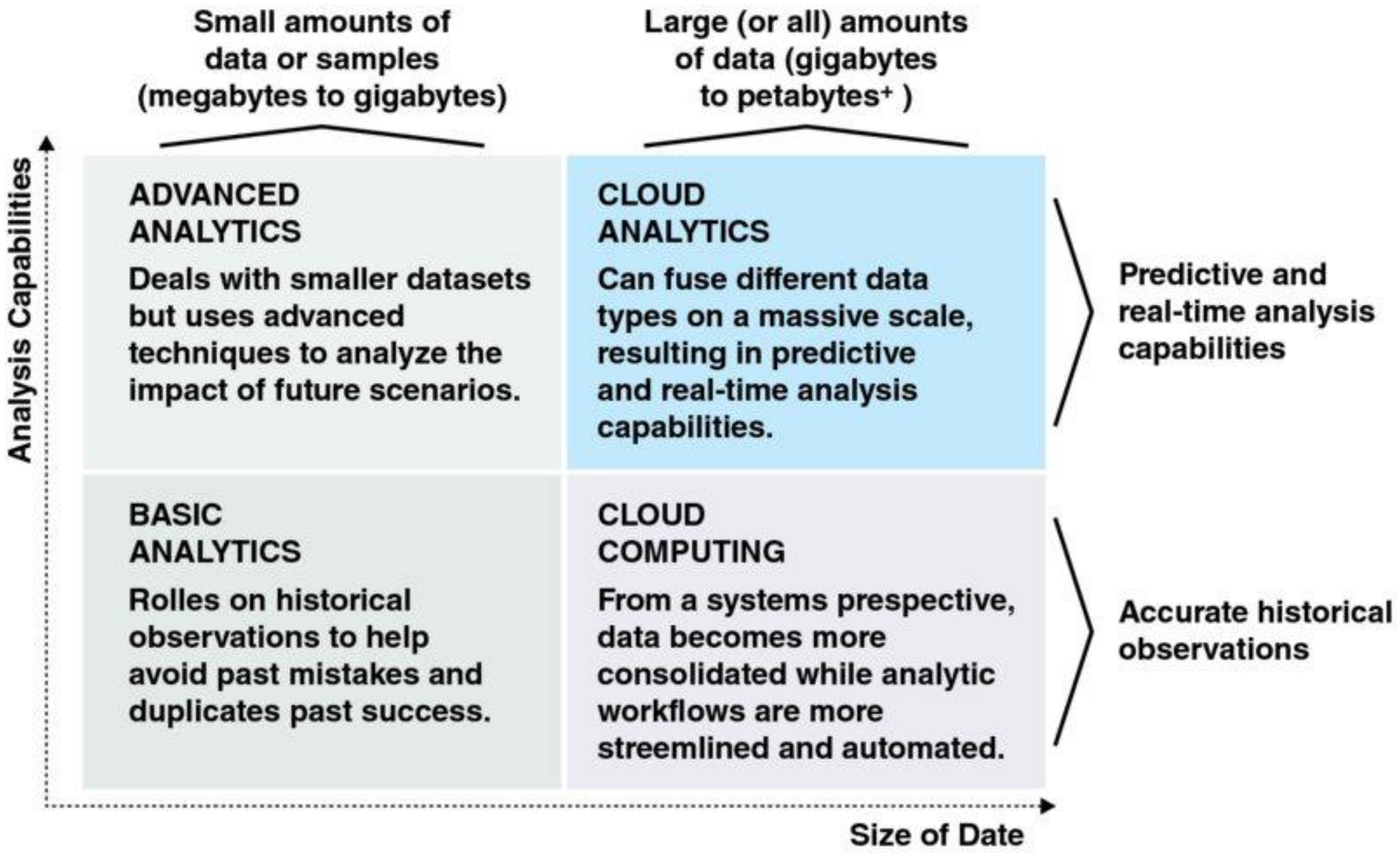
# Evolution of analytics

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# Goals and requirements of today's cloud analytics evolved from the past

- The **basic analysis** of small data relies on historical observations to help avoid past mistakes and duplicate past successes.
- The **advanced analytics** system on small data is improved from the basic capability to use advanced techniques to analyze the impact of future scenarios.
- As we move to **cloud computing**, most existing clouds provide a better coordinated analytics workflow in a streamlined and automated fashion, but still lack predictive or real-time capabilities.
- For an ideal **cloud analytics** system, we expect to handle scalable big data in streaming mode with real-time predictive capabilities.

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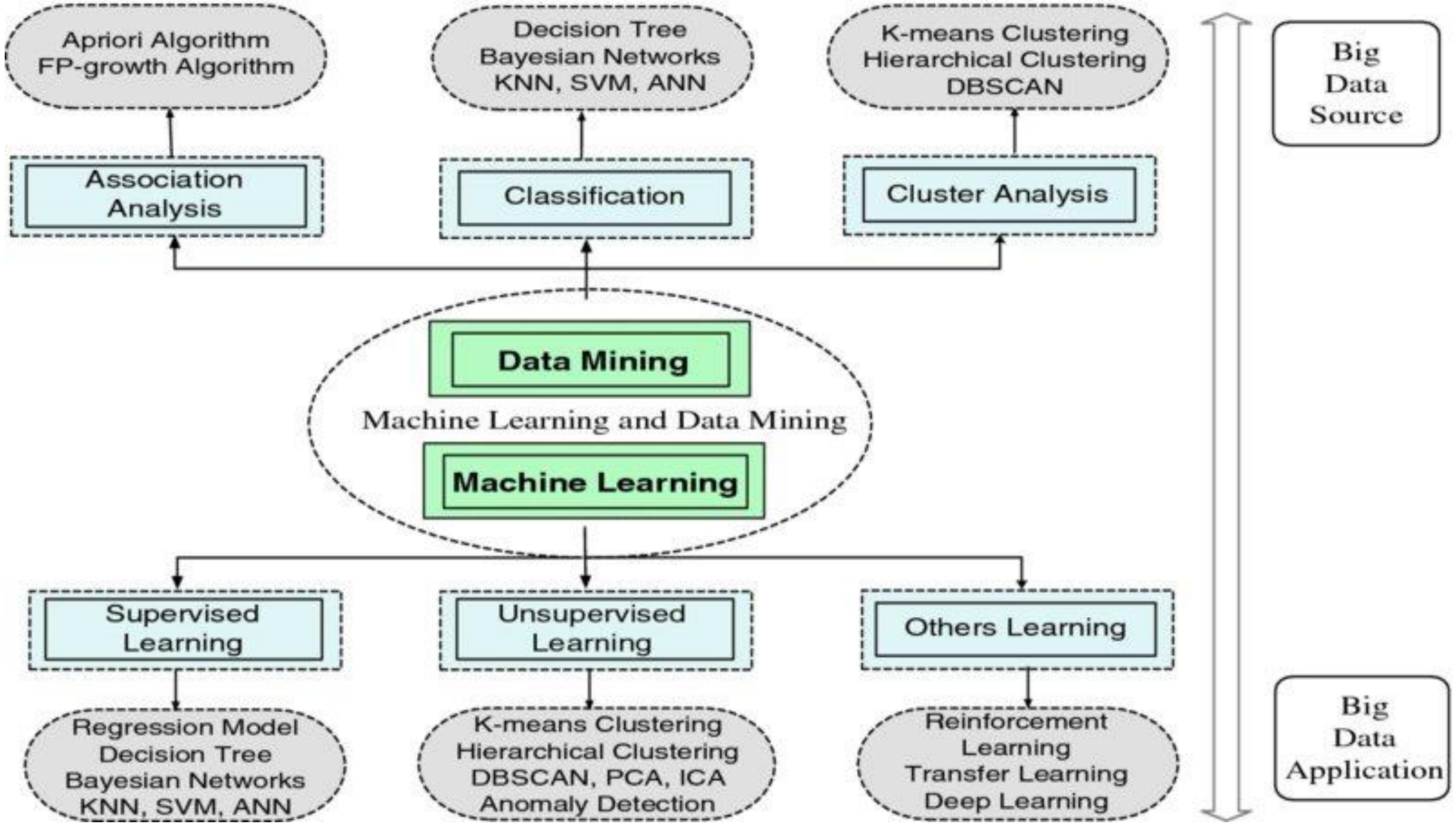
# Machine Intelligence and Big Data Applications

- **Data Mining versus Machine Learning**

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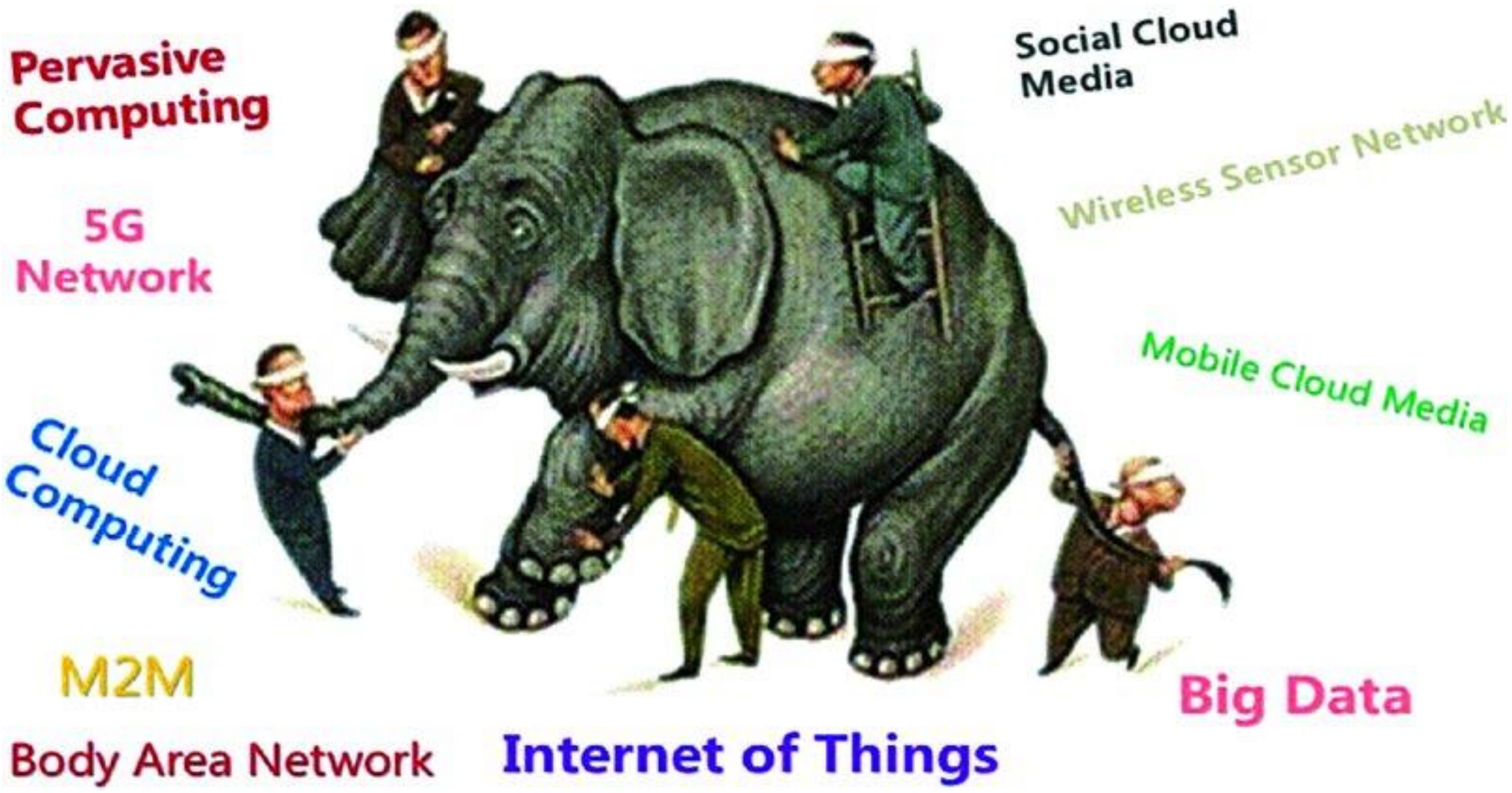
# Sensing Technology for Internet of Things

- Ultimate goal of IoT – integrating the digital world and physical world

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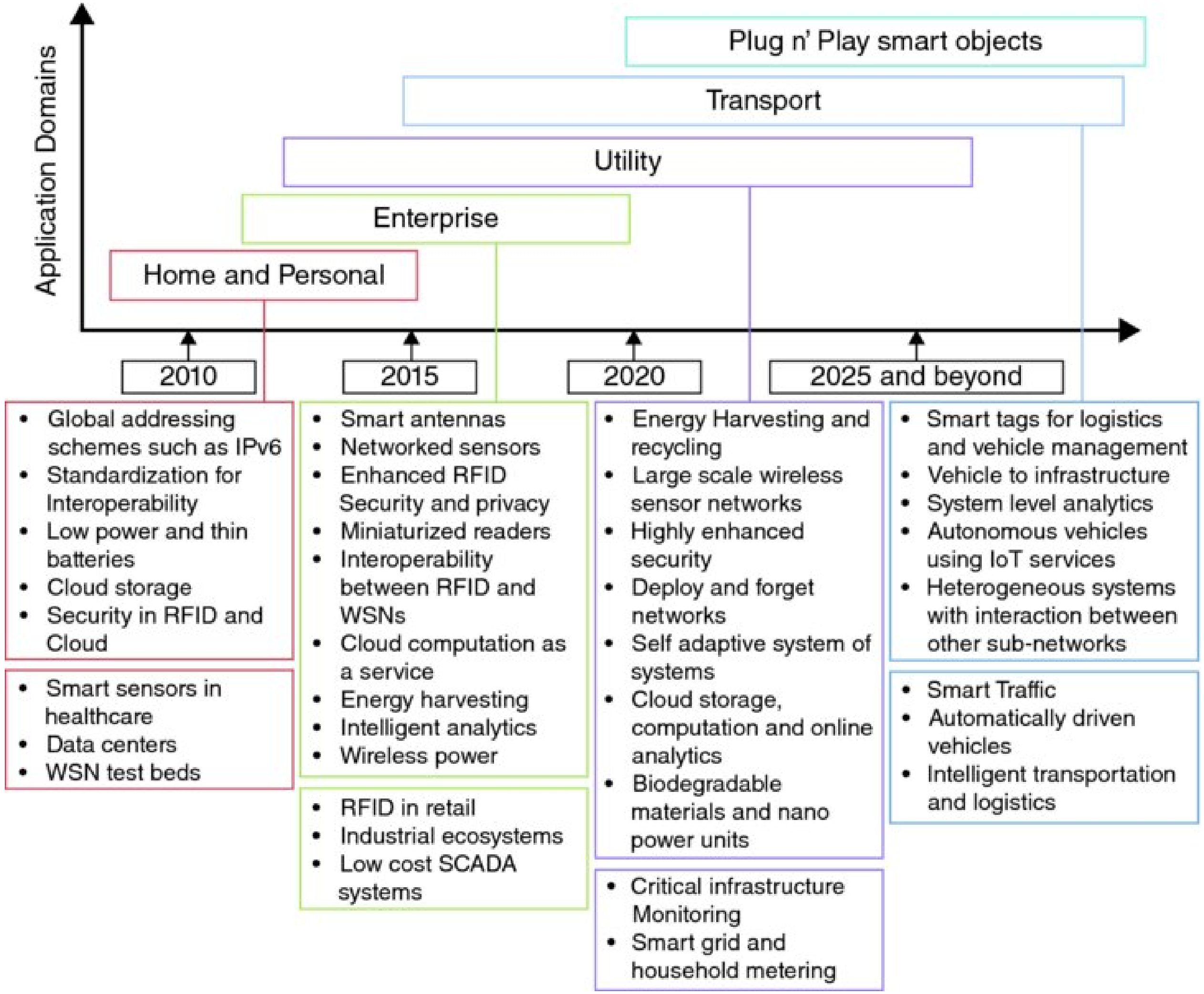
# The enabling technologies for IoT

- Enabling technologies
  - Tracking (such as RFID), Sensor networks, GPS
- Synergistic technologies
  - Supporting role via biometrics, AI, computer vision, robotics, telepresence
- Over a period of 25 years, IoT development could become mature and more sophisticated
- Connectivity will pave the way to a completely connected world
  - 5G and cloud computing will be some of the important technologies.

# Growth of five key IoT application domains from 2010 to 2025

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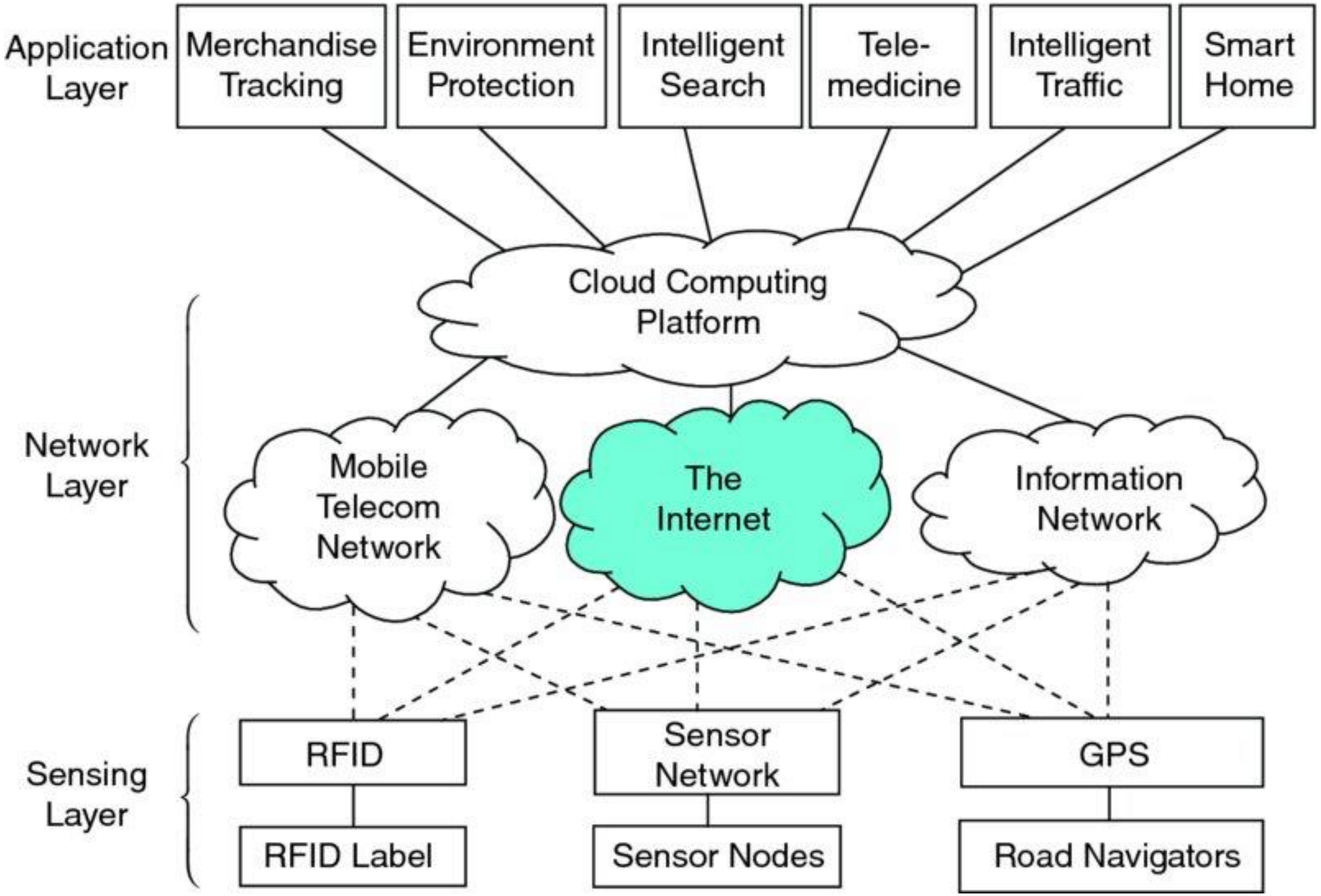
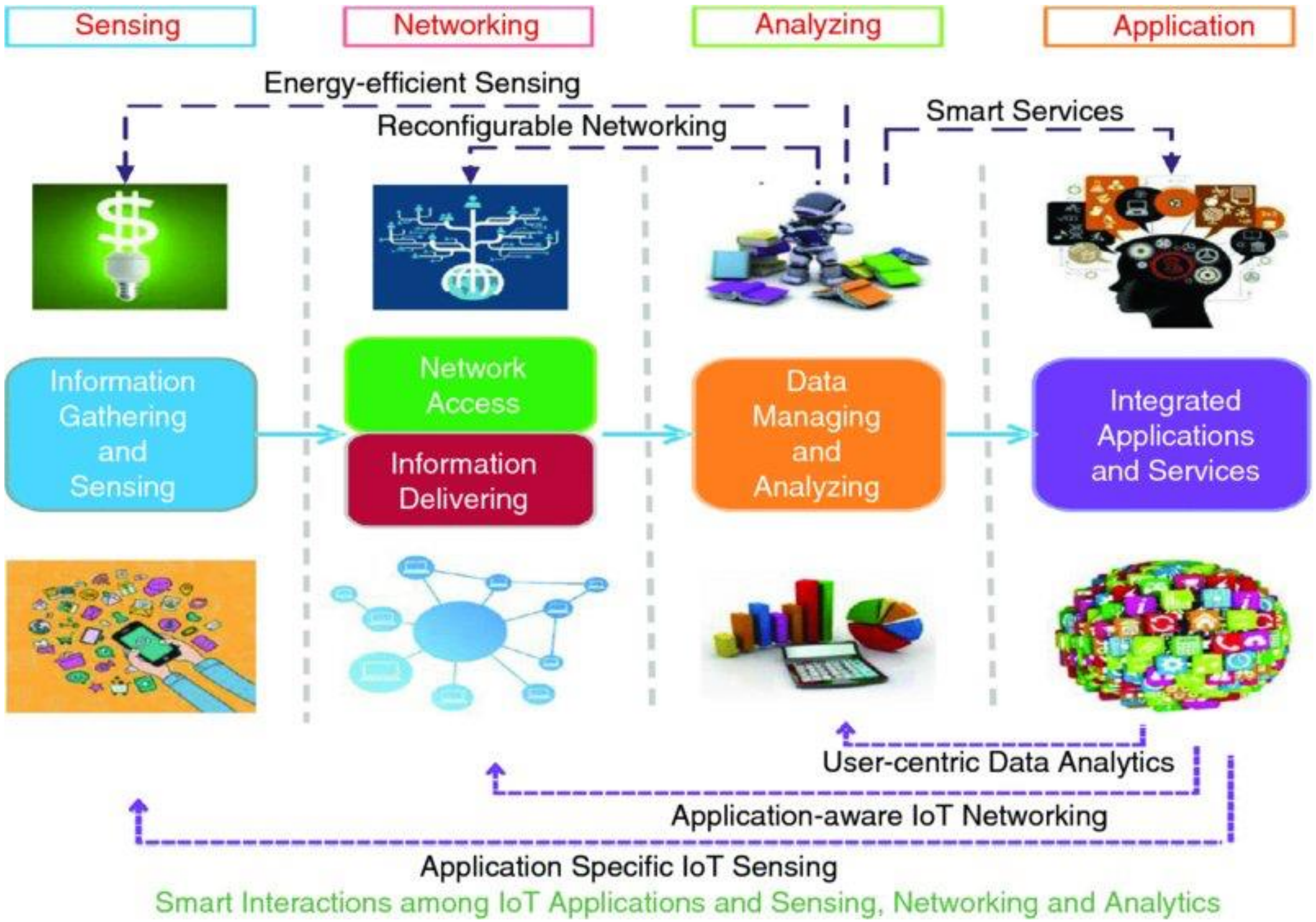
# Example Architecture of an IoT Platform/System



# Interaction between IoT sensing, mobile monitoring and cloud analytics

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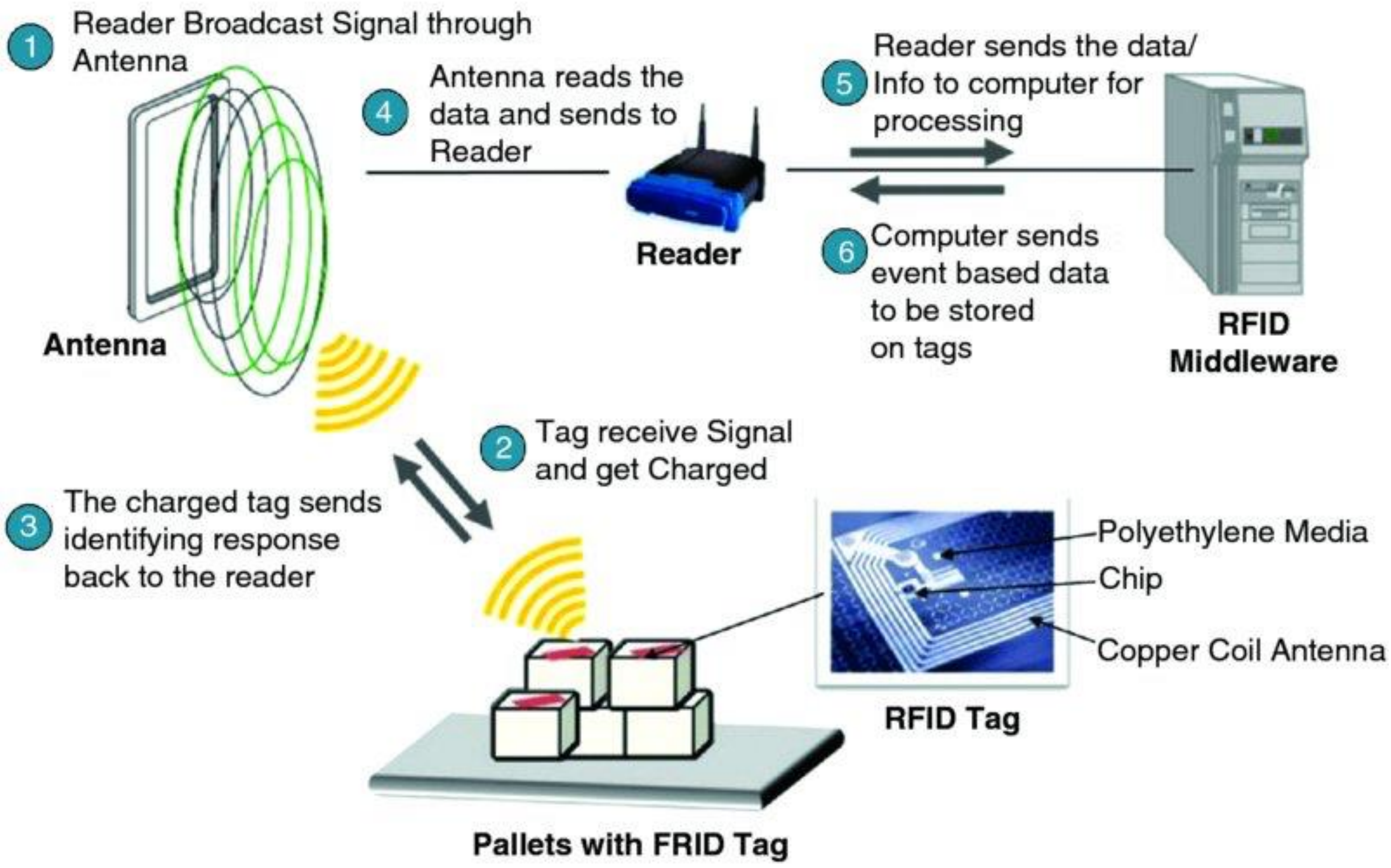
# Example: RFID-based tracking

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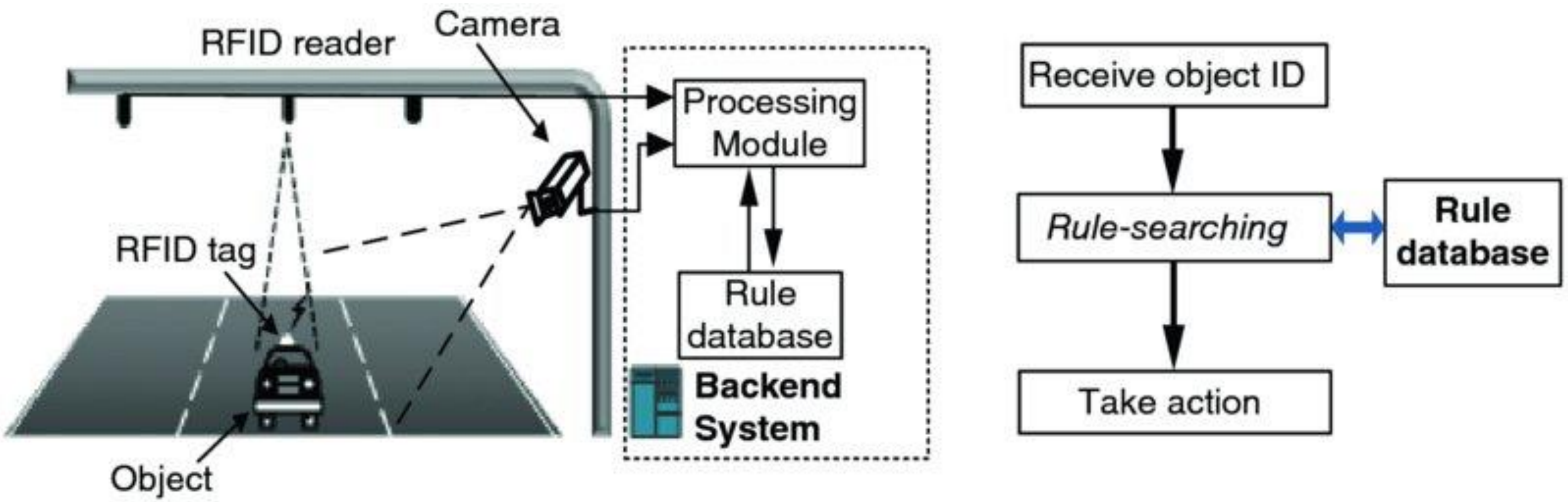
# Example: RFID system applied to automobile speeding check

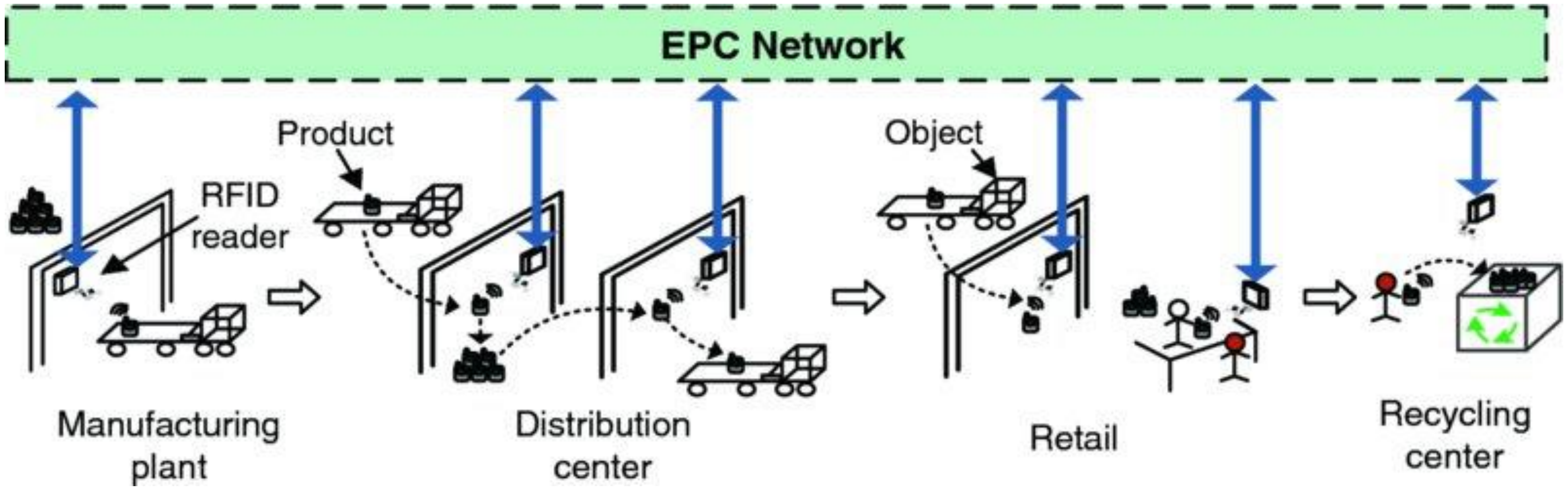



(a) Functional components in a RFID System

(b) Rule-searching process in RFID back-end system

# Example: Supply chain management

- Electronic Product Code (EPC) network enables the tracking throughout
  - **Planning and Coordination**
  - **Material and Equipment Supplies**
  - **Manufacturing and Testing**
  - **Delivery of Products**
  - **After Sale Service and Returns**

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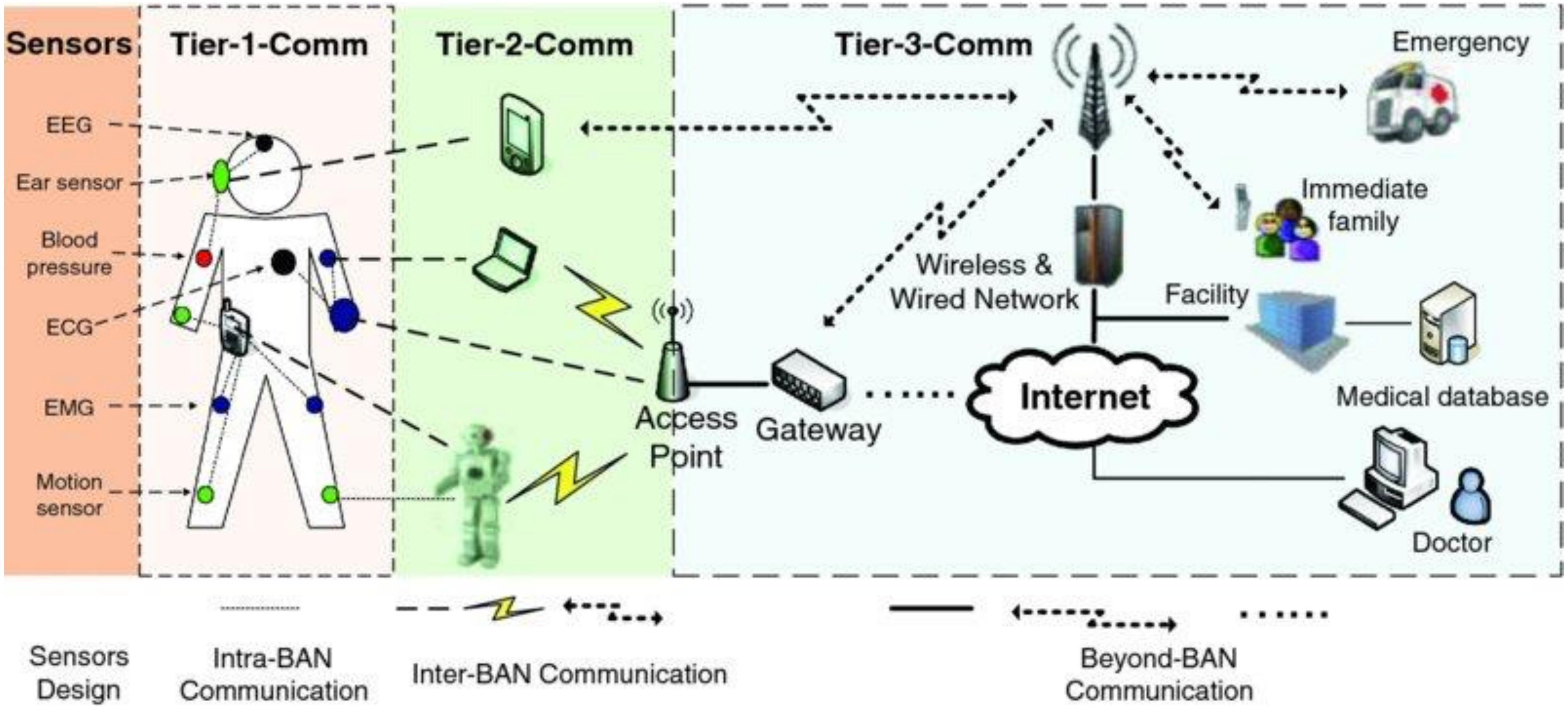
# Example: Body Area Network sensing

- A three-tier architecture based on a BAN communications system

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