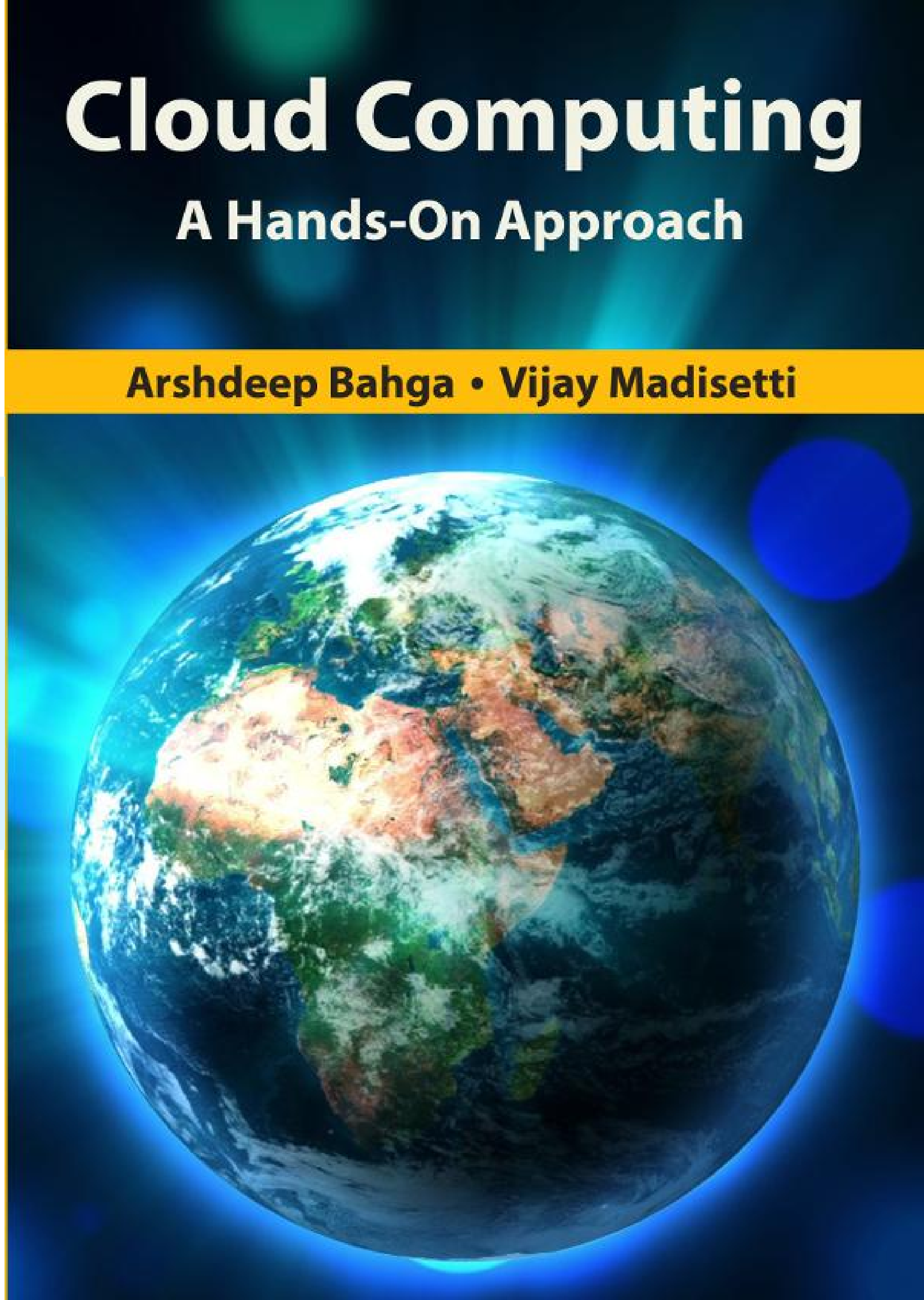
# Chapter 13

## Cloud for Industry, Healthcare & Education





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# Outline

Applications of cloud computing in:

- Healthcare
- Energy
- Industry
- Education



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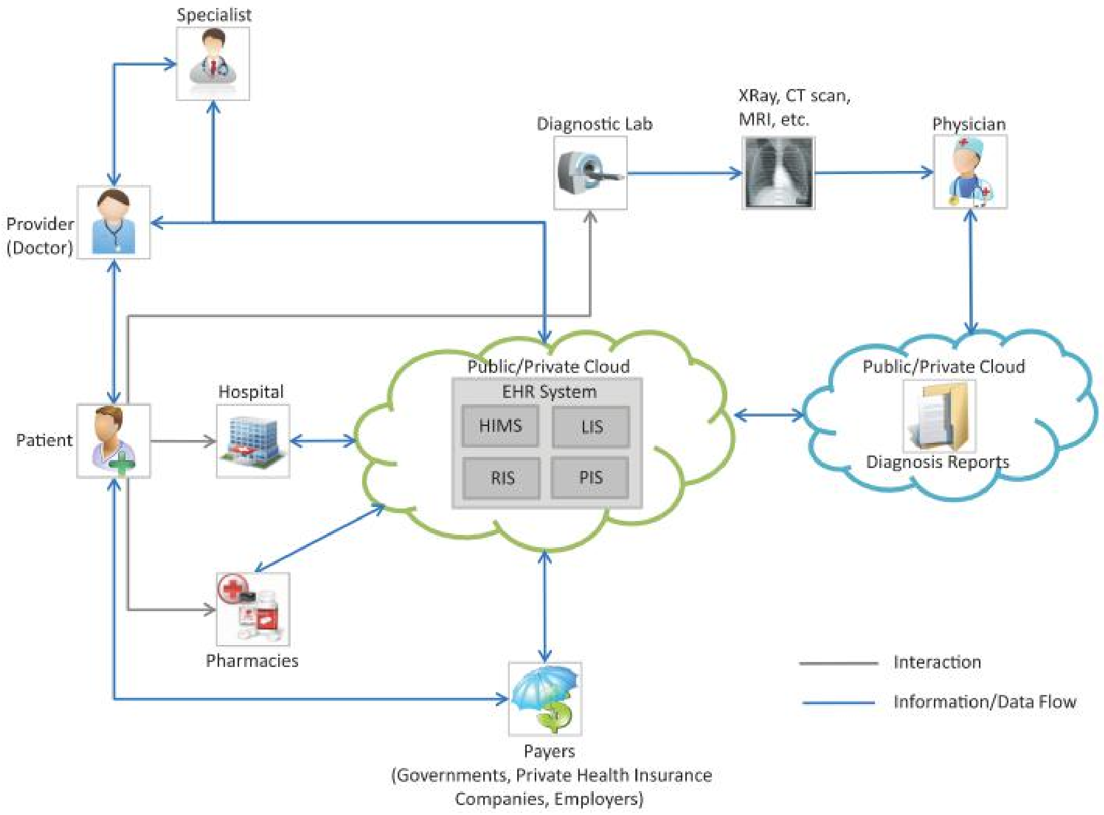
# Cloud Computing for Healthcare

- Heathcase Ecosystem
  - The healthcare ecosystem consists of numerous entities including healthcare providers (primary care physicians, specialists, hospitals, for instance), payers (government, private health insurance companies, employers), pharmaceutical, device and medical service companies, IT solutions and services firms, and patients.
- Healthcare Data
  - The process of provisioning healthcare involves massive healthcare data that exists in different forms (structured or unstructured), is stored in disparate data sources (such as relational databases, file servers, for instance) and in many different formats.
- The cloud can provide several benefits to all the stakeholders in the healthcare ecosystem through systems such as
  - Health Information Management System (HIMS), Laboratory Information System (LIS), Radiology Information System (RIS), Pharmacy Information System (PIS), for instance.



# Benefits of Cloud for Healthcare

- Providers & Hospitals
  - With public cloud based EHR systems hospitals don't need to spend a significant portion of their budgets on IT infrastructure.
  - Public cloud service providers provide on-demand provisioning of hardware resources with pay-per-use pricing models.
  - Thus hospitals using public cloud based EHR systems can save on upfront capital investments in hardware and data center infrastructure and pay only for the operating expenses of the cloud resources used.
  - Hospitals can access patient data stored in the cloud and share the data with other hospitals.
- Patients
  - Patients can provide access to their health history and information stored in the cloud (using SaaS applications) to hospitals so that the admissions, care and discharge processes can be streamlined.
  - Physicians can upload diagnosis reports (such as pathology reports) to the cloud so that they can be accessed by doctors remotely for diagnosing the illness.
  - Patients can manage their prescriptions and associated information such as dosage, amount and frequency, and provide this information to their healthcare provider.
- Payers
  - Health payers can increase the effectiveness of their care management programs by providing value added services and giving access to health information to members.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# Electronic Health Records (EHRs)

- EHRs capture and store information on patient health and provider actions including individual-level laboratory results, diagnostic, treatment, and demographic data. EHRs maintain information such as patient visits, allergies, immunizations, lab reports, prescribed medicines, vital signs, for instance.
- Though the primary use of EHRs is to maintain all medical data for an individual patient and to provide efficient access to the stored data at the point of care, EHRs can be the source for valuable aggregated information about overall patient populations.
- The EHR data can be used for advanced healthcare applications such as population-level health surveillance, disease detection, outbreak prediction, public health mapping, similarity-based clinical decision intelligence, medical prognosis, syndromic diagnosis, visual-analytics investigation, for instance.
- To exploit the potential to aggregate data for advanced healthcare applications there is a need for efficiently integrating information from distributed and heterogeneous healthcare IT systems and analyzing the integrated information.


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# Cloud EHRs

- Save Infrastructure Costs
  - Traditional client-server EHR systems with dedicated hosting require a team of IT experts to install, configure, test, run, secure and update hardware and software.
  - With cloud-based EHR systems, organizations can save on the upfront capital investments for setting up the computing infrastructure as well as the costs of managing the infrastructure.
- Data Integration & Interoperability
  - Traditional EHR systems use different and often confiicting technical and semantic standards which leads to data integration and interoperability problems.
  - To address interoperability problems, several electronic health record (EHR) standards that enable structured clinical content for the purpose of exchange are currently under development.
  - Interoperability of EHR systems will contribute to more effective and efficient patient care by facilitating the retrieval and processing of clinical information about a patient from different sites.
- Scalability and Performance
  - Traditional EHR systems are built on a client-server model with dedicated hosting that involves a server which is installed within the organization's network and multiple clients that access the server. Scaling up such systems requires additional hardware.
  - Cloud computing is a hosting abstraction in which the underlying computing infrastructure is provisioned on demand and can be scaled up or down based on the workload.
  - Scaling up cloud applications is easier as compared to client-server applications.


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# Security for Cloud EHRs

- Security Concerns for Cloud EHRs
  - Security of patient information is one of the biggest obstacles in the widespread adoption of cloud computing technology for EHR systems due to the outsourced nature of cloud computing.
- Government Regulations
  - Government regulations require privacy protection and security of patient health information.
  - In the U.S., organizations called covered entities (CE), that create, maintain, transmit, use, and disclose an individual's protected health information (PHI) are required to meet Health Insurance Portability and Accountability Act (HIPAA) requirements.
  - HIPAA requires covered entities (CE) to assure their customers that the integrity, confidentiality, and availability of PHI information they collect, maintain, use, or transmit is protected.
  - HIPAA was expanded by the Health Information Technology for Economic and Clinical Health Act (HITECH), which addresses the privacy and security concerns associated with the electronic transmission of health information.
- Securing Cloud EHRs
  - Cloud-based health IT systems require enhanced security features such as authorization services, identity management services and authentication services for providing secure access to healthcare data.


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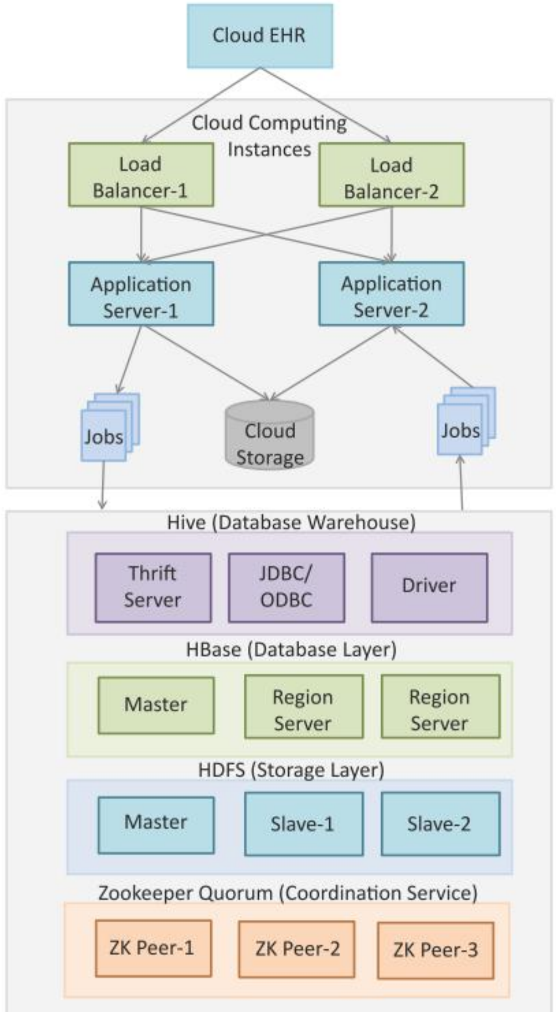
# Cloud EHR – Reference Architecture

- The reference architecture shown for a cloud-based EHR system that can support both primary and secondary use of healthcare data with healthcare data storage and analytics in the cloud.
- In this architecture, tier-1 consists of web servers and load balancers, tier-2 consists of application servers and tier-3 consists of a cloud based distributed batch processing infrastructure such as Hadoop.
- HBase is used for the database layer. HBase is a distributed non-relational column oriented database that runs on top of HDFS.
- Hive is used to provide a data warehousing infrastructure on top of Hadoop. Hive allows querying and analyzing data in HDFS/HBase using the SQL-like Hive Query Language (HQL).
- Zookeeper is used to provide a distributed coordination service for maintaining configuration information, naming, providing distributed synchronization, and providing group services.



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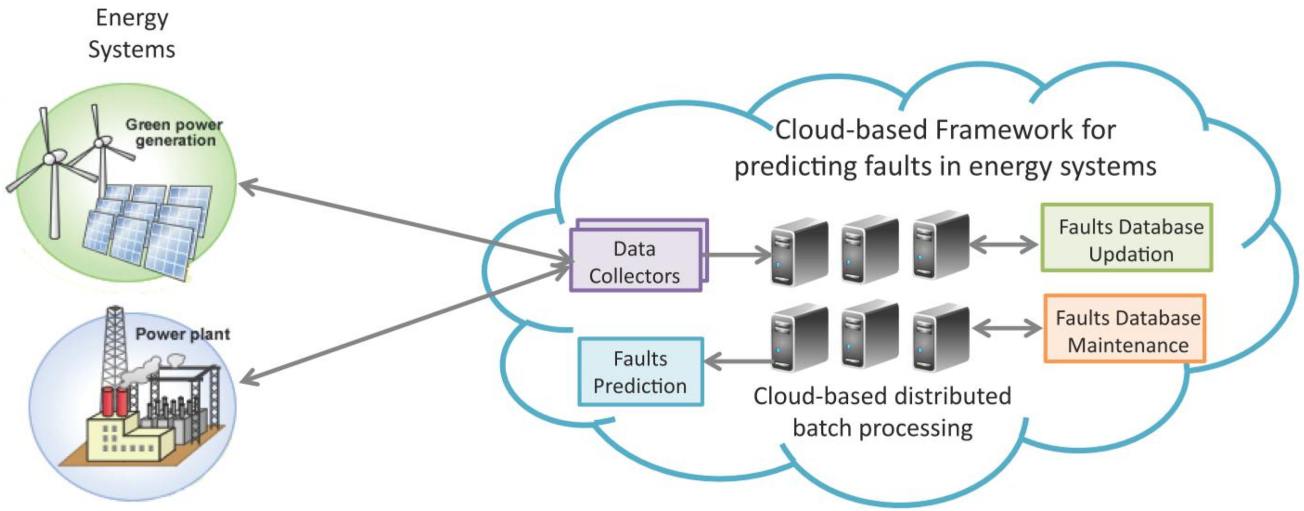
# Cloud Computing for Energy Systems

- Complex clean energy systems (such as smart grids, power plants, wind turbine farms, for instance.) have a large number of critical components that must function correctly so that the systems can perform their operations correctly.
- Energy systems have thousands of sensors that gather real-time maintenance data continuously for condition monitoring and failure prediction purposes.
- Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide predictions for the impending failures (potentially in real-time) so that their reliability and availability can be improved.





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# Energy Systems Prognostics with Cloud

- Prognostic real-time health management involves predicting system performance by analyzing the extent of deviation of a system from its normal operating profiles.
- Cloud-based big sensor data storage and analytics systems are based on distributed storage systems (such as HDFS) and distributed batch processing frameworks (such as Hadoop).
- Cloud-based distributed batch processing infrastructures process large volumes of data using inexpensive commodity computers which are connected to work in parallel.
- Such systems are designed to work on commodity hardware which has high probability of failure using techniques such as replication of file blocks on multiple machines in a cluster.


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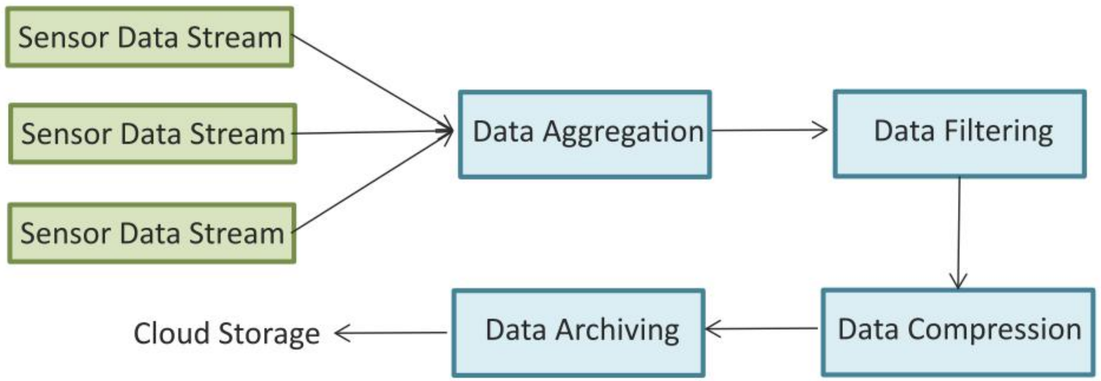
# Collecting Sensor Data in Cloud

- Workflow for aggregating sensor data in a cloud:
  - The first step in this workflow is data aggregation. Each incoming data stream is mapped to a data aggregator.
  - Since the raw sensor data comes from a large number of machines in the form of data streams, the data has to be preprocessed to make the data analysis using cloud-based parallel processing frameworks (such as Hadoop) more efficient. For example, the Hadoop MapReduce data processing model works more efficiently with a small number of large files rather than a large number of small files.
  - The data aggregators buffer the streaming data into larger chunks.
  - The next step is to filter data and remove bad records in which some sensor readings are missing.
  - The filtered data then compressed and archived to a cloud storage.





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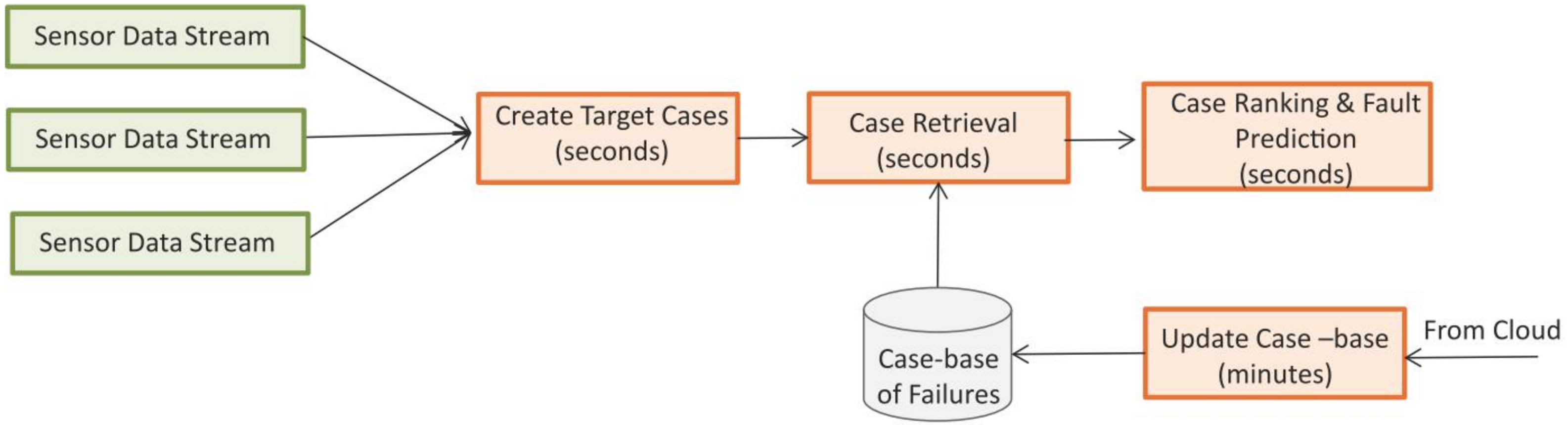
# Predicting Faults in Energy Systems

- Faults in energy systems have unique signatures such as increase in temperature, increase in vibration levels, for instance.
- Various machine learning and analysis algorithms can be implemented over the distributed processing frameworks in the cloud for analyzing the machine sensor data.
- Clustering algorithms can help in fault isolation.
- Case-based reasoning (CBR) is another popular method that has been used for fault prediction.





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# Case Based Reasoning for Fault Prediction

- Case-based reasoning (CBR) is popular method that has been used for fault prediction.
- CBR finds solutions to new problems based on past experience.
- CBR is an effective technique for problem solving in the fields in which it is hard to establish a quantitative mathematical model, such as prognostic health management.
- In CBR, the past experience is organized and represented as cases in a case-base.

- The steps involved in CBR are:
  - **Retrieve**: retrieving similar cases from case-base
  - **Reuse**: reusing the information in the retrieved cases
  - **Revise**: revising the solution
  - **Retain**: retaining a new experience into the case-base.


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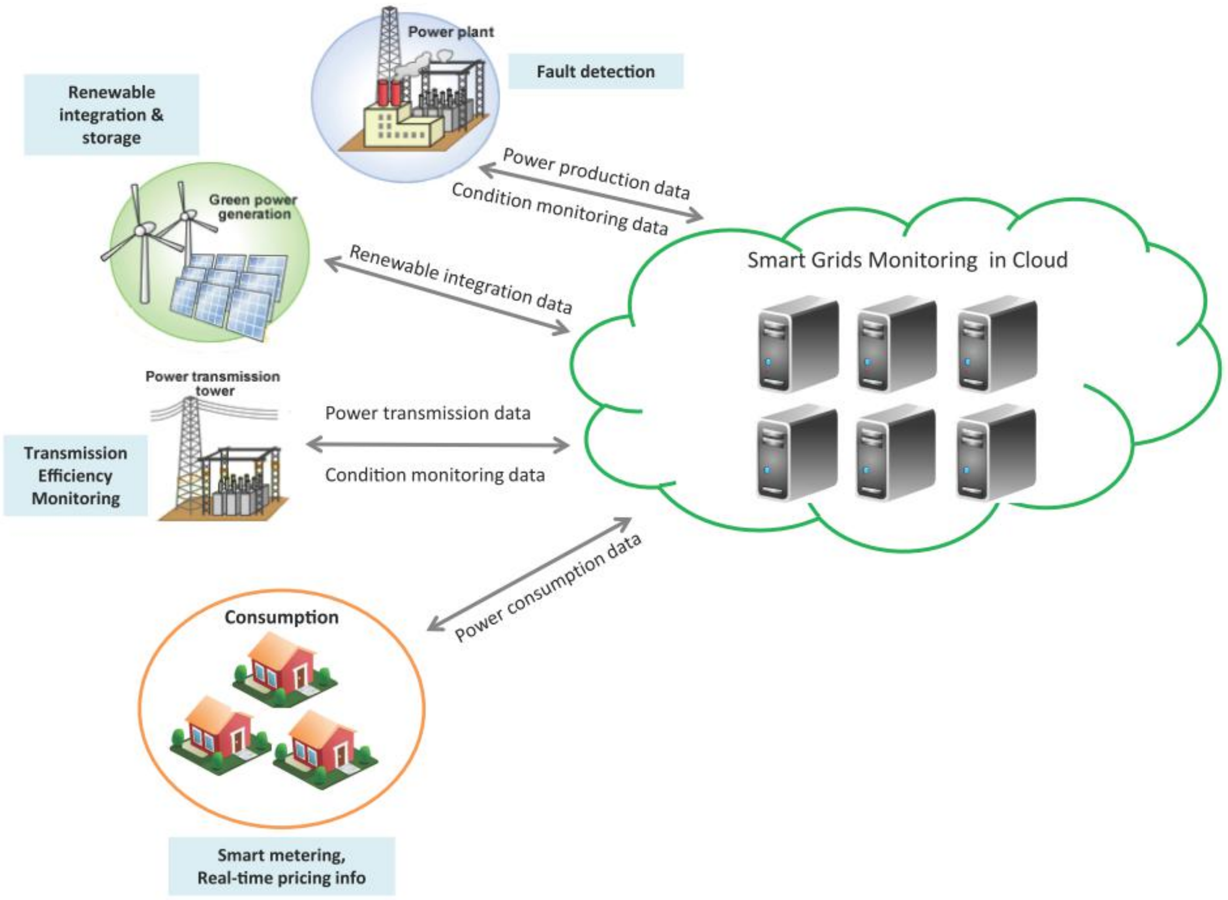
# Cloud Computing for Smart Grids

- Smart Grid is a data communications network integrated with the electrical grid that collects and analyzes data captured in near-real-time about power transmission, distribution, and consumption.
- Smart Grid technology provides predictive information and recommendations to utilities, their suppliers, and their customers on how best to manage power.
- Smart Grids collect data regarding electricity generation (centralized or distributed), consumption (instantaneous or predictive), storage (or conversion of energy into other forms), distribution and equipment health data.
- Smart grids use high-speed, fully integrated, two-way communication technologies for real-time information and power exchange.





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# Cloud Computing for Smart Grids

- Sensing and measurement technologies are used for evaluating the health of equipment and the integrity of the grid. Power thefts can be prevented using smart metering.
- By analyzing the data on power generation, transmission and consumption smart girds can improve efficiency throughout the electric system.
- Storage collection and analysis of smarts grids data in the cloud can help in dynamic optimization of system operations, maintenance, and planning.
- Cloud-based monitoring of smart grids data can improve energy usage levels via energy feedback to users coupled with real-time pricing information and from users with energy consumption status to reduce energy usage.
- Real- time demand response and management strategies can be used for lowering peak demand and overall load via appliance control and energy storage mechanisms.
- Condition monitoring data collected from power generation and transmission systems can help in detecting faults and predicting outages.



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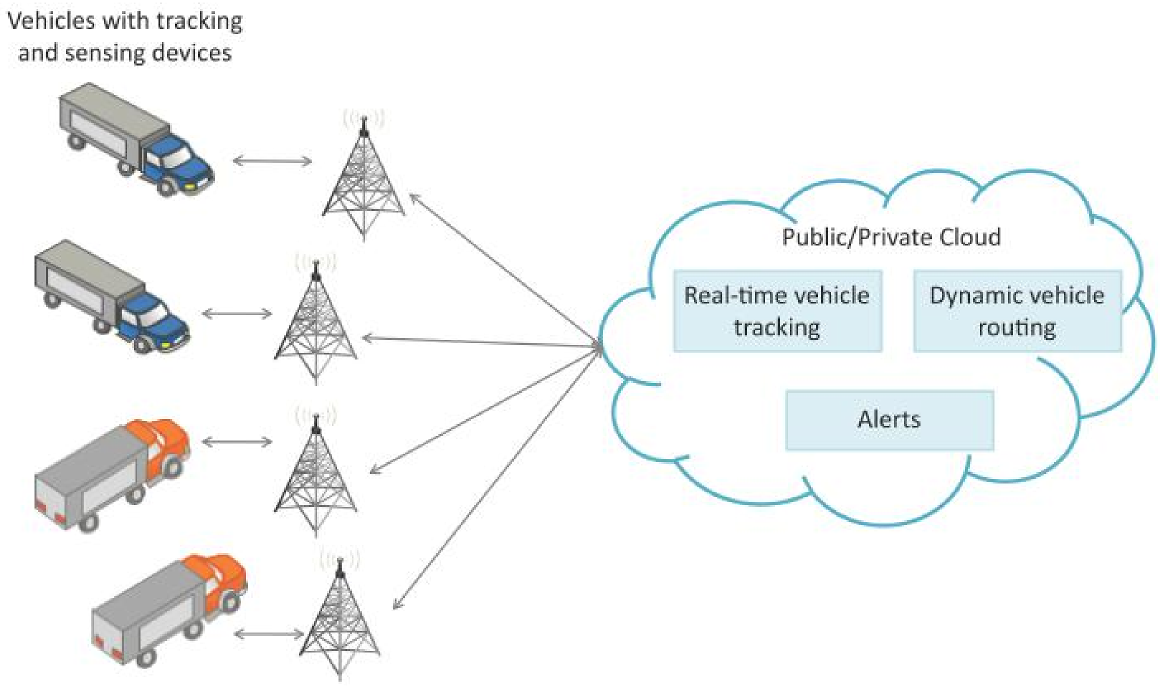
# Cloud Computing for Transportation Systems

- Modern transportation systems are driven by data collected from multiple sources which is processed to provide new services to the stakeholders.
- By collecting large amount of data from various sources and processing the data into useful information, data-driven transportation systems can provide new services such as:
  - Advanced route guidance
  - Dynamic vehicle routing
  - Anticipating customer demands for pickup and delivery problem



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# Cloud Apps for Transportation Systems

- Fleet Tracking
  - Vehicle fleet tracking systems use GPS technology to track the locations of the vehicles in real-time.
  - The vehicle locations and routes data can be aggregated and analyzed in the cloud for detecting bottlenecks in the supply chain such as traffic congestions on routes, assignments and generation of alternative routes, and supply chain optimization.
- Route Generation & Scheduling
  - Route generation and scheduling systems can generate end-to-end routes using combination of route patterns and transportation modes and feasible schedules based on the availability of vehicles.
  - As the transportation network grows in size and complexity, the number of possible route combinations increases exponentially.
  - Cloud-based route generation and scheduling systems can provide fast response to the route generation queries and can be scaled up to serve a large transportation network.
  - Condition Monitoring Condition monitoring solutions for transportation systems allow monitoring the conditions inside containers.
- Planning, Operations & Services
  - Different transportation solutions (such as fleet tracking, condition monitoring, route generation, scheduling, cargo operations, fleet maintenance, customer service, order booking, billing & collection, for instance.)  can be moved to the cloud to provide a seamless integration between order management, tactical planning & execution and customer facing processes & systems.


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# Cloud Computing for Manufacturing Industry

- There are two forms of cloud manufacturing:
  - One that uses cloud computing technologies for manufacturing
  - Other involves service-oriented manufacturing that replicates the cloud computing environment using physical manufacturing resources (like computing resources in cloud computing).

- Industrial Control Systems
  - Industrial control systems such as supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other control system configurations such as Programmable Logic Controllers (PLC) found in the manufacturing industry continuously generate monitoring and control data.
  - Real-time collection, management and analysis of data on production operations generated by ICS, in the cloud, can help in estimating the state of the systems, improve plant and personnel safety and thus take appropriate action in real-time to prevent catastrophic failures.



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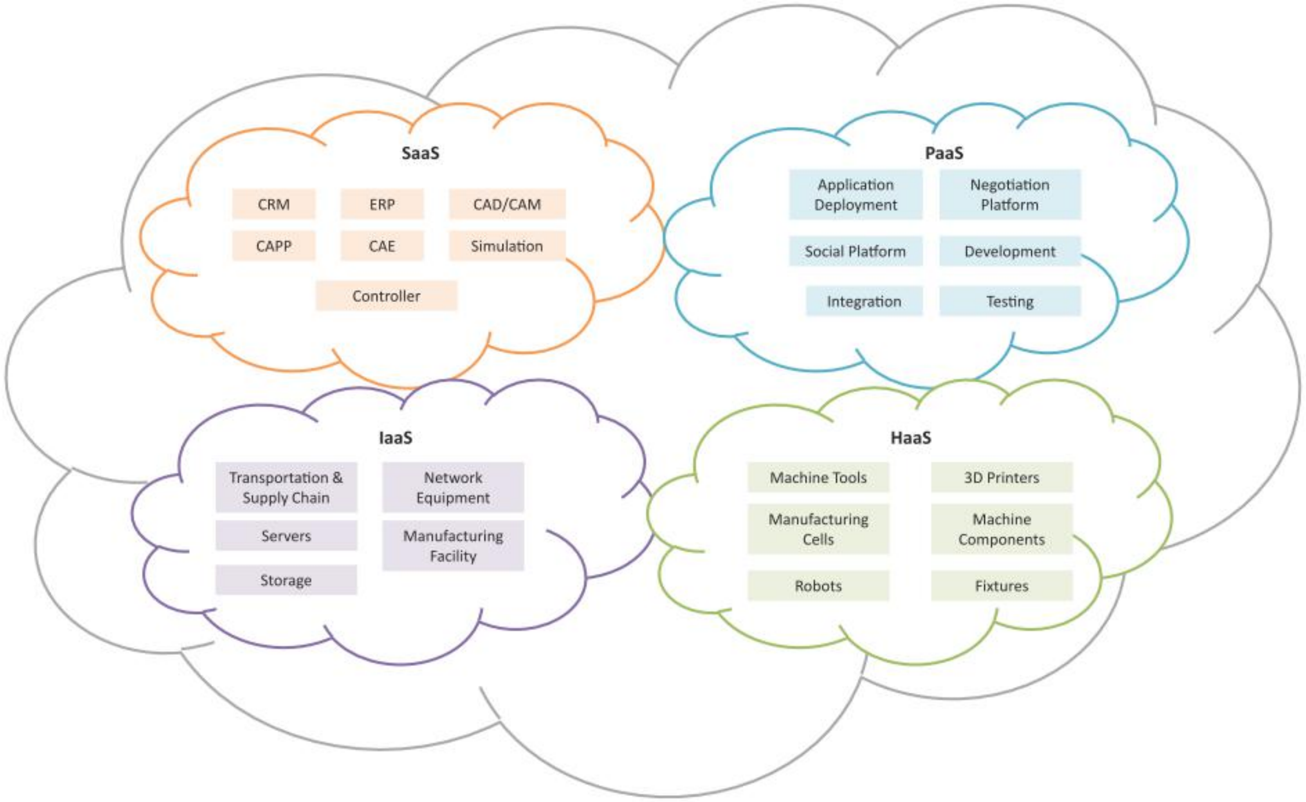
# Cloud-based Design & Manufacturing

- Software-as-a-Service (SaaS)
  - SaaS service model provides software applications such as customer relationship management (CRM), enterprise relationship management (ERP), computer aided design and manufacturing (CAD/CAM) hosted in a computing cloud, through thin clients such as web browsers.
- Platform-as-a-Service (PaaS)
  - PaaS service model allows deployment of applications without the need for buying or managing the underlying infrastructure. PaaS provides services for developing, integrating and testing applications in an integrated development environment.
- Infrastructure-as-a-Service (IaaS)
  - IaaS provides physical resources such as servers, storage that can be provisioned on demand.
- Hardware-as-a-Service (HaaS)
  - HaaS provides access to machine tools, 3D printers, manufacturing cells, industrial robots, for instance. HaaS providers can rent hardware to consumers through the CBDM environment.



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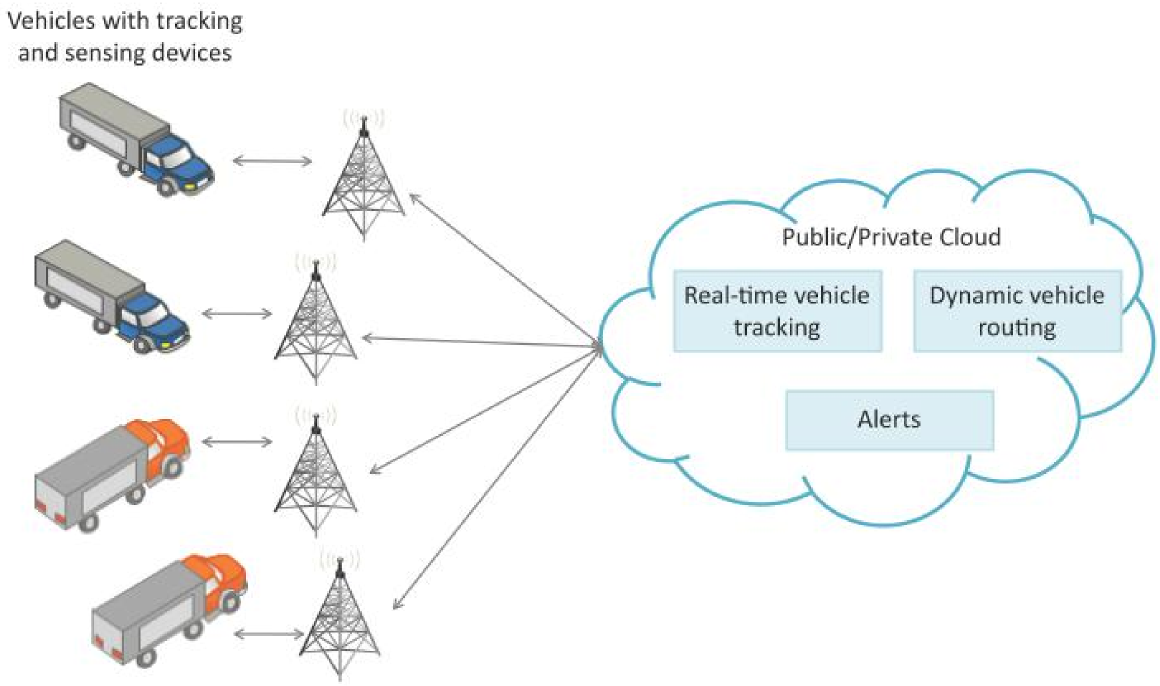



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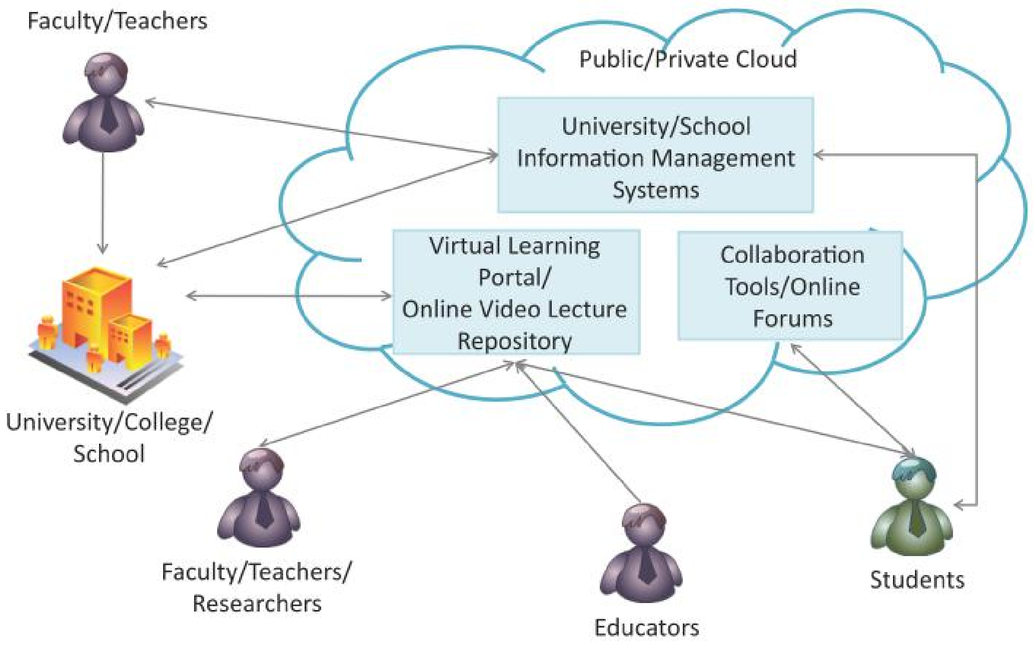
# Cloud Computing for Education

- Online Learning Platforms & Collaboration Tools
  - Cloud computing is bringing a transformative impact in the field of education by improving the reach of quality education to students through the use of online learning platforms and collaboration tools.
- MOOCs
  - MOOCs are aimed for large audiences and use cloud technologies for providing audio/video content, readings, assignment and exams.
  - Cloud-based auto-grading applications are used for grading exams and assignments. Cloud-based applications for peer grading of exams and assignments are also used in some MOOCs.
- Online Programs
  - Many universities across the world are using cloud platforms for providing online degree programs.
  - Lectures are delivered through live/recorded video using cloud based content delivery networks to students across the world.





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# Cloud Computing for Education

- Online Proctoring
    - Online proctoring for distance learning programs is also becoming popular through the use of cloud-based live video streaming technologies where online proctors observe test takers remotely through video.
- Virtual Labs
    - Access to virtual labs is provided to distance learning students through the cloud. Virtual labs provide remote access to the same software and applications that are used by students on campus.
- Course Management Platforms
    - Cloud-based course management platforms are used to for sharing reading materials, providing assignments and releasing grades, for instance.
    - Cloud-based collaboration applications such as online forums, can help student discuss common problems and seek guidance from experts.
- Information Management
    - Universities, colleges and schools can use cloud-based information management systems to improve administrative efficiency, offer online and distance education programs, online exams, track progress of students, collect feedback from students, for instance.
- Reduce Cost of Education
    - Cloud computing thus has the potential of helping in bringing down the cost of education by increasing the student-teacher ratio through the use of online learning platforms and new evaluation approaches without sacrificing quality.


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# Further Reading


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