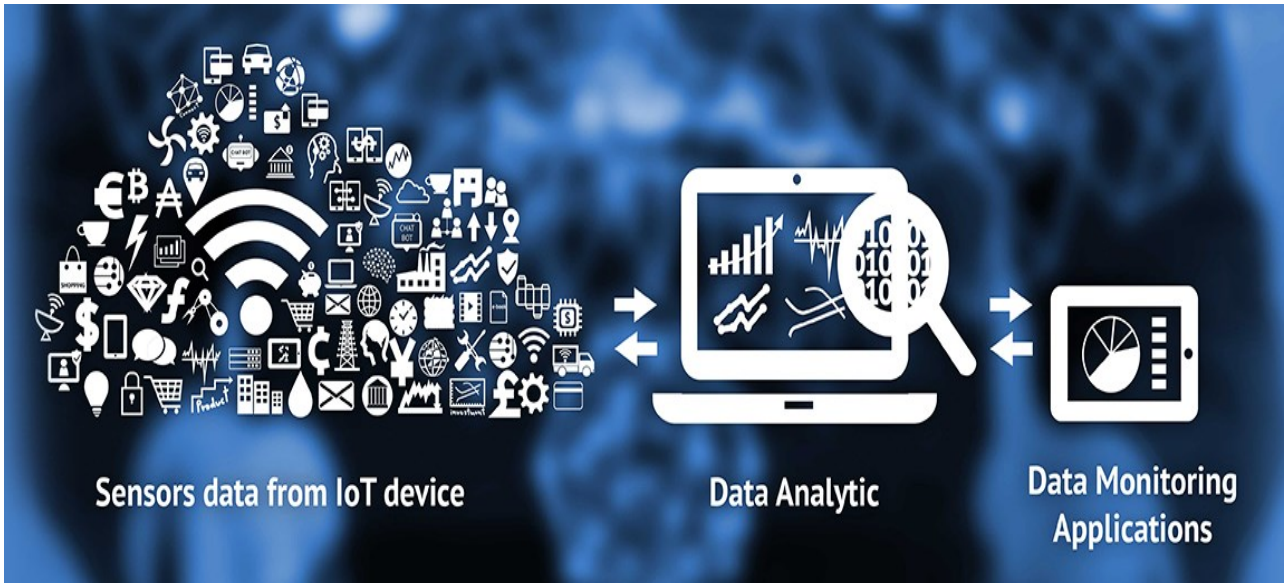
Internet of Things

Data Analytics in IoT



Thanks to Manas Khatua

Why Data Analytics in IoT ?

- One of the biggest challenges in IoT:
  - Management of massive amounts of data generated by sensors.
- Few examples
  - commercial aviation industry
  - utility industry
- Modern jet engines are fitted with thousands of sensors that generate a whopping 10GB data per second
- A twin engine commercial aircraft with these engines operating on average 8 hours a day will generate over 500TB data daily, and this is just the data from the engines!

Commercial Jet Engine

By IoT data analytics, one can identify new business opportunities, emerging business trends, customer needs, etc.

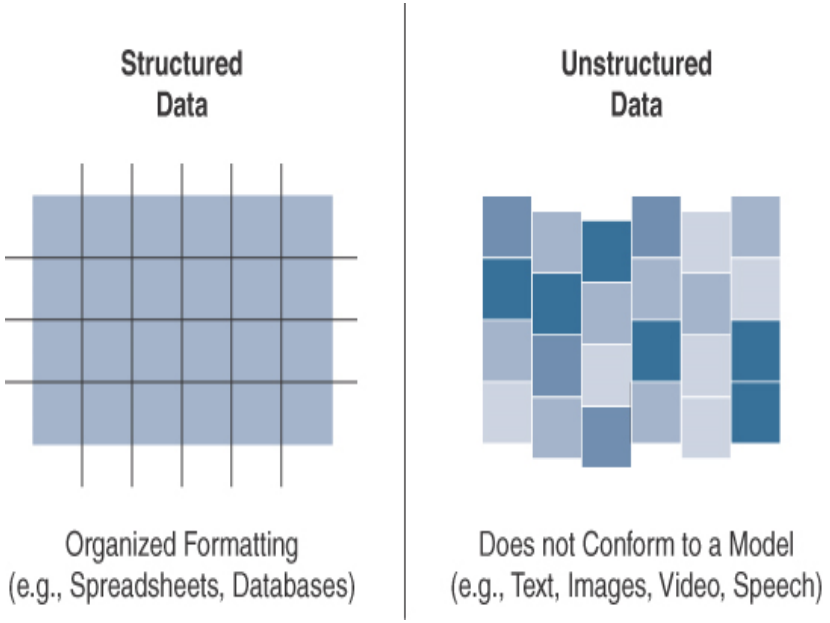
Structured v/s Unstructured Data

- Not all data is the same
- it can be categorized and thus analyzed in different ways.

- Structured data :
  - data follows a model/schema
  - defines data representation
  - easily formatted, stored, queried, and processed
  - e.g. Relational Database Model
    - has been core type of data used for business decisions
    - Wide array of data analytics tools are available

- Unstructured data:
  - lacks of logical schema
  - Doesn't fit into predefined data model
  - e.g. text, speech, images, video

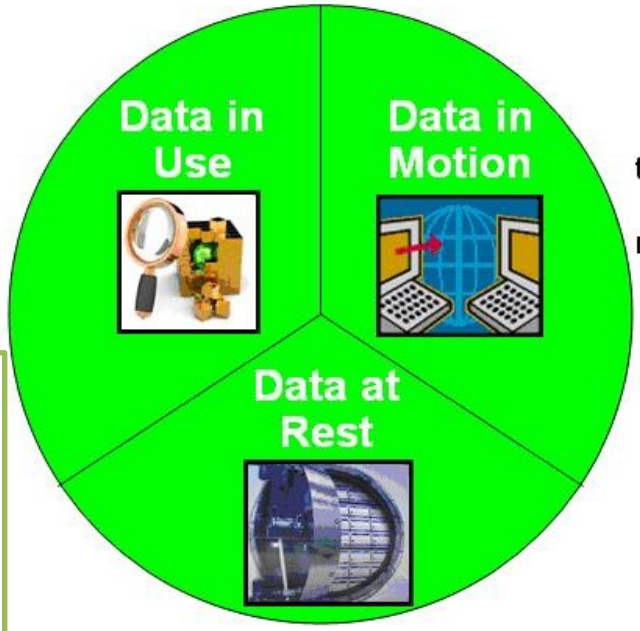
- Semi-structured data:
  - hybrid of structured and unstructured data
  - Not relational, but contains a certain schema
  - e.g. Email message: fields are well defined, but body and attachments are unstructured



Data in Motion v/s at Rest v/s in Use

- Different states of digital data can be
  - in transit (data in motion)
  - being held/stored (data at rest)
  - being processed (data in use)

- Data in motion is data that is currently travelling across a network or
- sitting in a computer's RAM ready to be read, updated, or processed.



Data in Use:
Active data under constant change stored physically in databases, data warehouses, spreadsheets etc.

Data in Motion:
Data that is traversing a network or temporarily residing in computer memory to be read or updated.

Data at Rest:
Inactive data stored physically in databases, data warehouses, spreadsheets, archives, tapes, off-site backups etc.

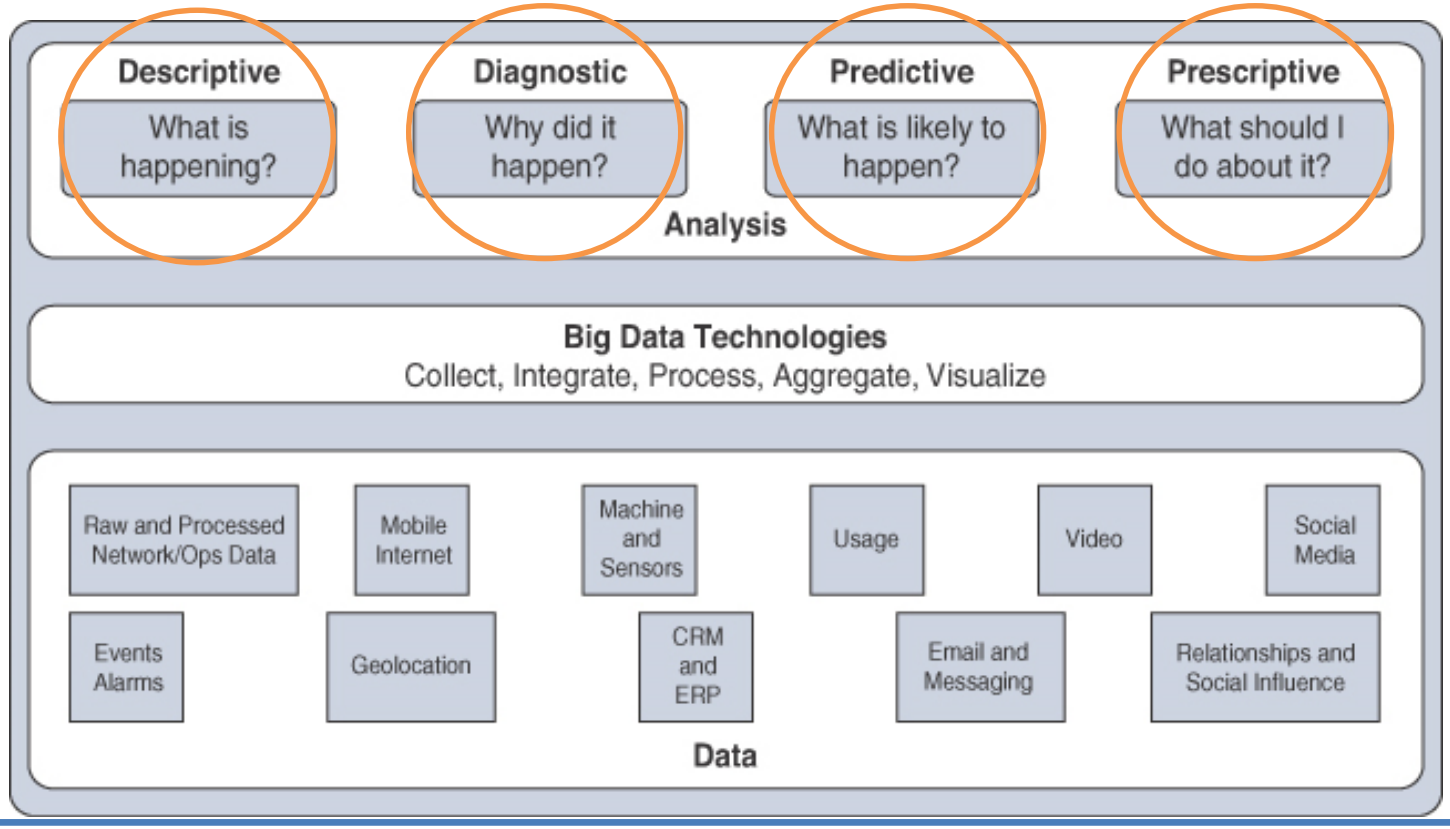
- Data being processed by one/more applications.
- data in the process of being generated, viewed, updated, appended, or erased.

- Data at rest is typically in a stable state.
- It is not travelling within the system or network, and
- it is not being acted upon by any application or the CPU.

Type of IoT Data Analytics

- The true importance of IoT data is realized only when
  - the analysis of the data leads to actionable business intelligence and insights.

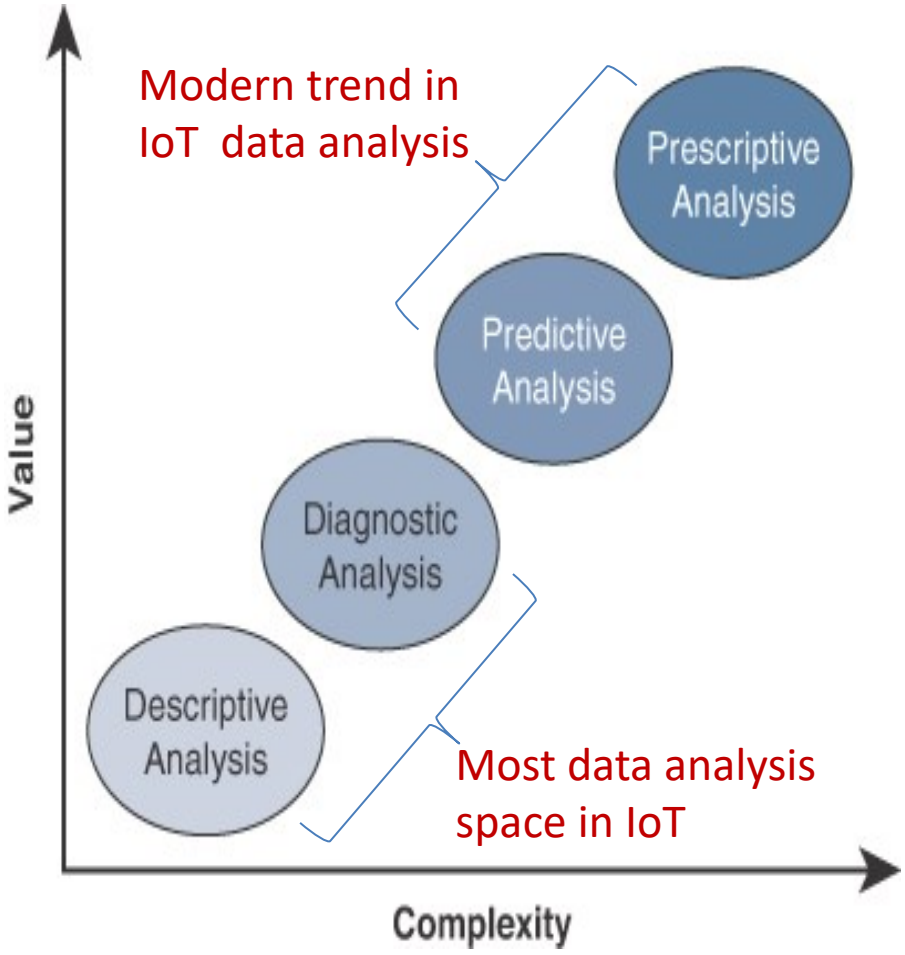
- Data analysis is typically broken down by
  - the types of results that are produced.



Cont…

- Descriptive
  - It tells you what is happening, either now or in the past.
    - e.g., thermometer in a truck engine reports temperature values every second.
- Diagnostic
  - It can provide the answer to "why" it has happened
    - e.g. why the truck engine failed
- Predictive
  - It aims to foretell problems or issues before they occur.
    - e.g., it could provide an estimate on the remaining life of the truck engine.
- Prescriptive
  - It goes a step beyond predictive and recommends solutions for upcoming problems.
    - e.g. it might calculate various alternatives to cost-effectively maintain our truck.

Application of Value and Complexity Factors to the Types of Data Analysis



IoT Data Analytics - Challenges

- Traditional solutions are not always adequate
  - It typically considers the standard RDBMS and corresponding tools

1) IoT data places two specific **challenges on relational database data**:
   - Scaling problems:
     - large number of smart objects continually send data,
     - relational databases grow incredibly large very quickly.
     - Results in performance issues which is costly to resolve
   - Volatility of data:
     - In RDBMS, schema is designed from the beginning,
     - changing the scheme later creates problem.
     - IoT data is volatile in the sense that the data model is likely to change and evolve over time.
     - A dynamic schema is often required.

- **Solution**: NoSQL database in used
  - does not use SQL to interact with the database
  - do not enforce a strict schema
  - support a complex, evolving data model
  - databases are inherently much more scalable

Cont…

2) IoT brings **challenges to streaming and network analytics**

- with the live streaming nature of its data, and
- with managing data at the network level.
  - usually of a very high volume
  - real-time analysis of streaming data
    - Google, Microsoft, IBM, etc., have streaming analytics offerings

- with the areas (or flows) of network data i.e. network analytics.
  - it can be challenging to ensure that the data flows are effectively managed, monitored, and secure.
    - Network analytics tools: Flexible NetFlow, IPFIX

Technologies Used

- Technologies used in IoT Data Analytics
  - Machine Learning
  - BigData Analytics
  - Edge Intelligence
  - Network Analytics
  - Etc.

Machine Learning

Machine Learning

- **How to make sense of the data**?
  - by Machine Learning
    - ML is used to find the data relationships that will lead to new business insights

- In more complex cases, static rules cannot be simply inserted into the program
  - because the programs require parameters that can change.
  - e.g., dictation program
    - It does not know your accent, tone, speed, and so on.
    - You need to record a set of predetermined sentences to help the tool.
    - This process is called **machine learning**.

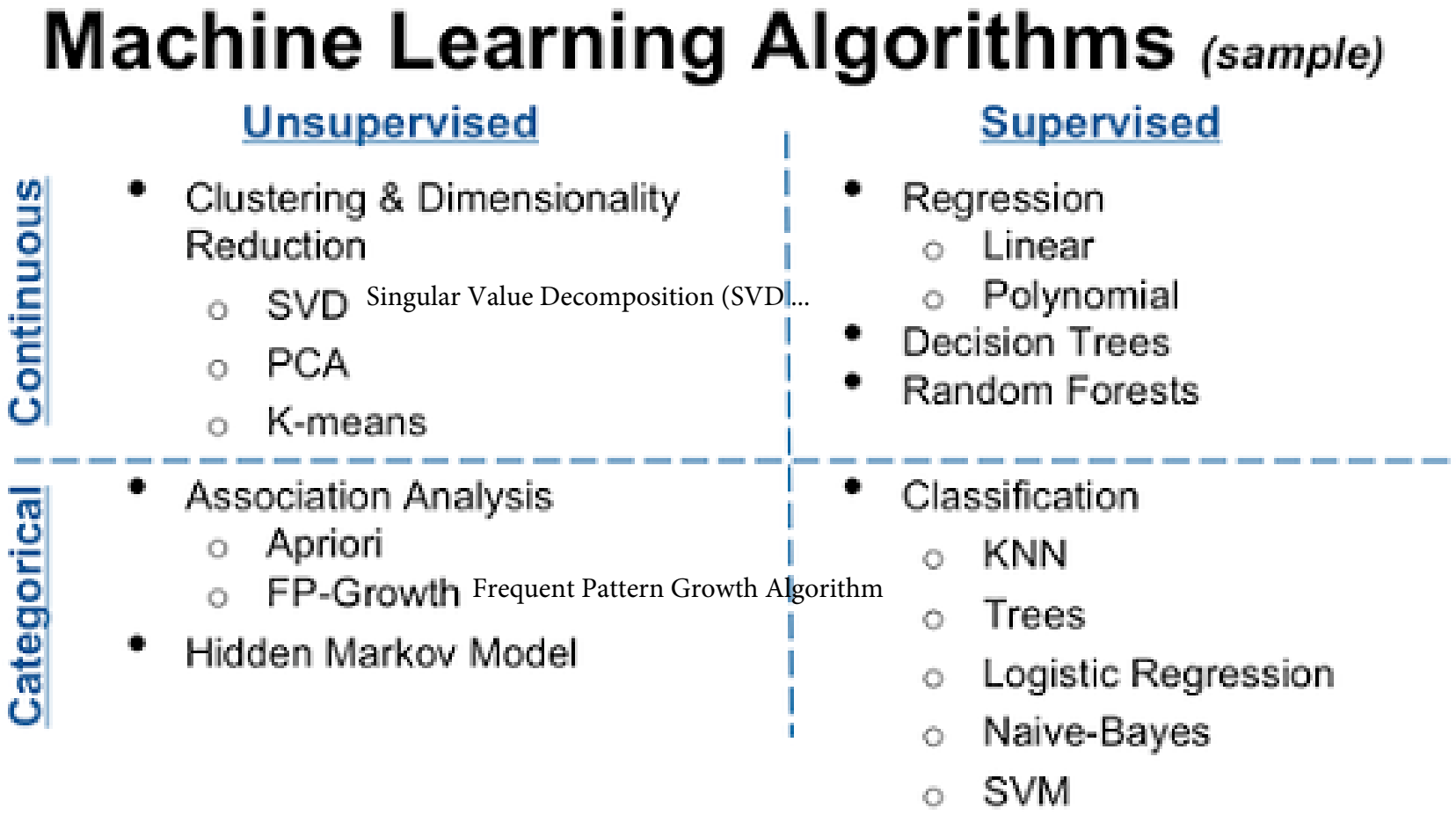
- **ML** is a part of a larger set of technologies commonly grouped under the term *artificial intelligence* (*AI*).

- **AI** includes any technology that allows a computing system to mimic human intelligence
  - e.g., an App that can help you find your parked car.
  - e.g., a GPS reading of your position at regular intervals calculates your speed.

Types of ML

Supervised	Unsupervised	Semi-Supervised	Reinforcement
• Data has **known labels** or output	• Labels or output unknown • Focus on **finding patterns and gaining insight** from the data	• Labels or output known for **a subset of** data • A blend of supervised and unsupervised learning	• Focus on **making decisions** based on previous experience • Policy-making with feedback
• Insurance underwriting • Fraud detection	• Customer clustering • Association rule mining	• Medical predictions (where tests and expert diagnoses are expensive, and only part of the population receives them)	• Game AI • Complex decision problems • Reward systems

Few ML Algorithms



Examples from IoT Application

Supervised Learning

- Suppose you are training a system to recognize when there is a human in a mine tunnel.

- Process:
  - sensor equipped with a basic camera can capture shapes
  - send them to a computing system.

  - hundreds or thousands of images are fed into the machine.
  - each image is labelled as human or nonhuman in this case

  - An algorithm is used to determine common parameters and common differences between the images.
  - This process is called *training*.

  - Each new image is compared with “good images” of human as per training model
  - This process is called *classification*.

  - the machine should be able to recognize human shapes.
  - the learning process is not about classifying in two or more categories but about finding a correct value.

  - regression predicts numeric values, whereas classification predicts categories.

Cont…

Unsupervised Learning

- Consider a factory manufacturing small engines.
- You know that about 0.1% of the produced engines on average need adjustments to prevent later defects.
- Your task is to identify them before they shipped away from the factory.

- Process:
  - you can test each engine
  - record multiple parameters, such as sound, pressure, temperature of key parts, and so on.

  - Once data is recorded, you can graph these elements in relation to one another.
  - You can then input this data into a computer and use mathematical functions to find groups.

  - A standard function to operate this grouping, *K-means clustering*
  - Grouping the engines this way can quickly reveal several types of engines that all belong to the same category.

  - There will occasionally be an engine in the group that displays unusual characteristics
  - This is the engine that you send for manual evaluation
  - This determination process is called *unsupervised learning*.

Application Domains for ML in IoT

It revolves around four major domains:

I. Monitoring
- ML can be used with monitoring to detect early failure conditions or to better evaluate the environment

II. Behaviour control
- Monitoring commonly works in conjunction with behaviour control.
- When a given set of parameters reach a target threshold, monitoring functions generate an alarm OR would trigger a corrective action

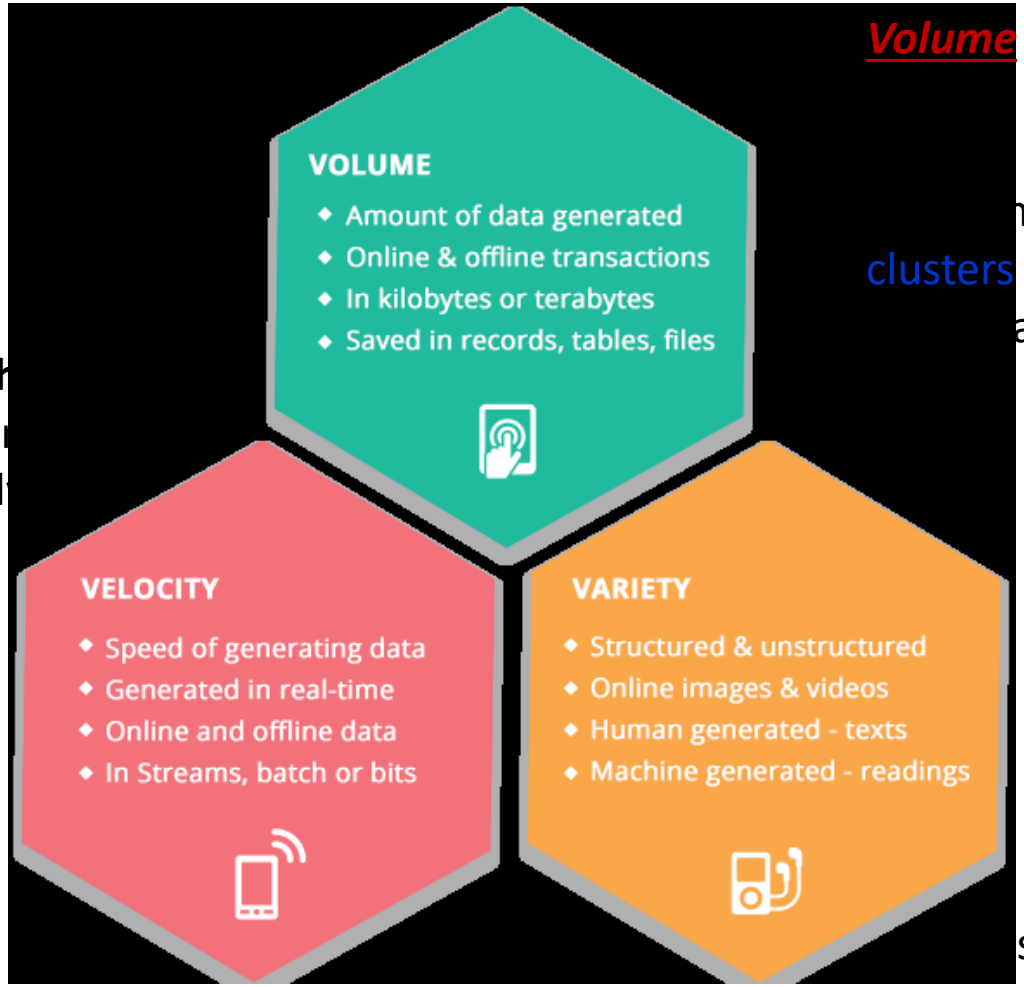
III. Operations optimization
- The objective is not merely to pilot the operations but to improve the efficiency and the result of these operations.
  - e.g., Smart system for a water purification plant in a smart city estimate the best chemical and stirring mix for a target air temperature

IV. Self-healing, self-optimizing
- The system becomes self-learning and self-optimizing.
- ML engine can be programmed to dynamically monitor and combine new parameters, and automatically deduce and implement new optimizations

BigData Analytics

What is Big Data?

- Industry looks to **three V**'s to categorize big data



Volume refers to the
the data.

mmon to see
clusters of servers for
and processing

Velocity refers to h
quickly data is bei
collected and anal

Hadoop Distributed File System is designed to process data very quickly.

Variety refers to **different types** of data.

Hadoop able to collect & store all three types – structured, unstructured, semi-structured.

Characteristics of Big Data

- Can be Categorized by the sources and types of data
  - Machine data or Sensor data
    - generated by IoT devices and is typically unstructured data.
  - Transactional data
    - from the sources that produce data from transactions on the systems, and, have high volume and structured.
  - Social data
    - which are typically high volume and structured.
  - Enterprise data
    - data that is lower in volume and very much structured.

Database Technologies

- Matured Database Technologies – Relational databases and Historians
    - Relational databases, such as Oracle and Microsoft SQL, are good for transactional or process data.
    - Historians are optimized for time-series data from systems and processes

These are not suitable for IoT Applications !

Database Technologies in IoT

- Database technologies used in an IoT context.
  - NoSQL
    - It is not a specific database technology; rather, it is an umbrella term that encompasses several different types of databases.
    - Can quickly ingest rapidly changing data
    - Can be able to query and analyse data within the database itself
    - built to scale horizontally i.e. database can span to multiple hosts (so distributed)

    - Best fit for IoT data:
      - **Document stores:** stores semi-structured data, such as **XML** or **JSON**.
        - » allowing the database schema to change quickly
      - **Key-value stores:** stores associative arrays where a key is paired with a value.
        - » capable of handling indexing and persistence.
  - Massively Parallel Processing
    - built on the concept of the relational data warehouses
    - designed to allow for fast query processing
    - often have built-in analytic functions
    - designed in a scale-out architecture such that both data and processing are distributed across multiple systems
  - Hadoop

Hadoop

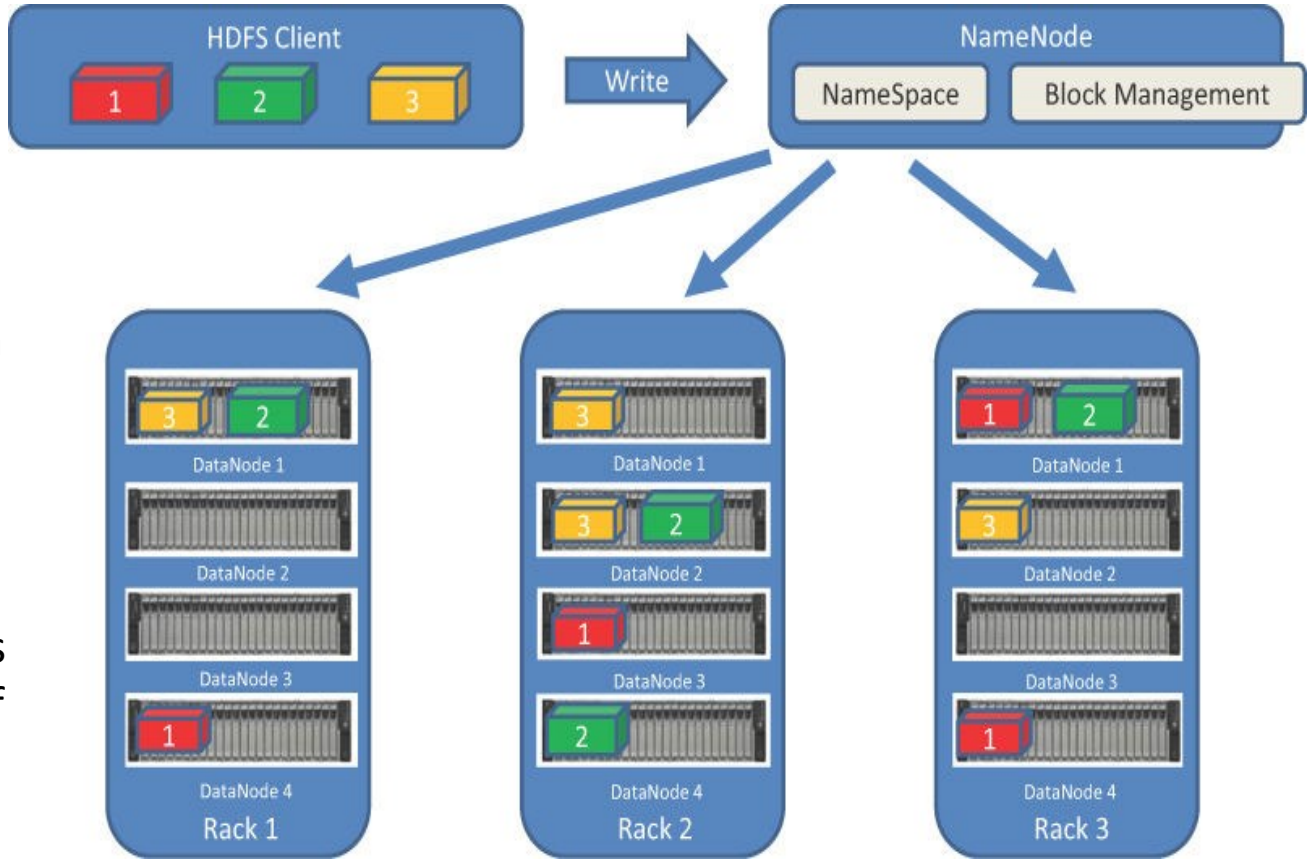
- Most popular choice as a data repository and processing engine
- Originally developed as a result of projects at Google and Yahoo!
  - original intent was to index millions of websites and quickly return search results for open source search engines.
- Initially, the project had two key elements:
  - **Hadoop Distributed File System (HDFS):** A system for storing data across multiple nodes
  - **MapReduce:** A distributed processing engine that splits a large task into smaller ones that can be run in parallel
- Hadoop relies on a scale-out architecture i.e. distributed storing and processing
- Both MapReduce and HDFS
  - take advantage of this distributed architecture to store and process massive amounts of data
  - leverages local processing, memory, and storage from all nodes in the cluster

Cont…

- For HDFS, this capability is handled by specialized nodes in the cluster – NameNode and DataNode

- NameNode coordinate where the data is stored, and maintain a map of where each block of data is stored and where it is replicated.

- DataNodes are the servers where the data is stored at the direction of the NameNode.



Hadoop Ecosystem

- Hadoop Ecosystem comprises of more than 100 software projects under the Hadoop umbrella
  - Capable of every element in the data lifecycle,
    - from data collection,
    - to storage,
    - to processing,
    - to analysis, and
    - to visualization

- Several of these packages
  - **Apache Kafka**
  - **Apache Spark**
  - **Apache Storm**
  - **Apache Flink**
  - **Lambda Architecture**

Edge Analytics

Edge Streaming Analytics

- In the world of IoT vast quantities of data are generated on the fly
  - Often they are time sensitive i.e. needs immediate attention,
  - waiting for deep analysis in the cloud simply isn't possible.
  - e.g., automobile racing industry
    - Formula One racing car has 150-200 sensors that generate more than 1000 data points per second
    - enormous insights leading to better race results can be gained by analyzing data on the fly

- Big Data tools like Hadoop and MapReduce are not suitable for real-time analysis
  - because of distance from the IoT endpoints and the network bandwidth requirement

- **Streaming analytics** allows you to continually monitor and assess data in real-time so that you can adjust or fine-tune your predictions as the race progresses.

- In IoT, streaming analytics is performed at the edge
  - either at the sensors themselves or very close to them such as gateway

- The edge isn't in just one place. The edge could be highly distributed.

Key Features of Edge Streaming Analytics

- Does the streaming analytics replaces big data analytics in the Cloud?
  - Answer: Not at all.
  - **Big data analytics** is focused on large quantities of **data at rest**,
  - **Edge analytics** continually processes streaming flows of **data in motion**.

Key Features:

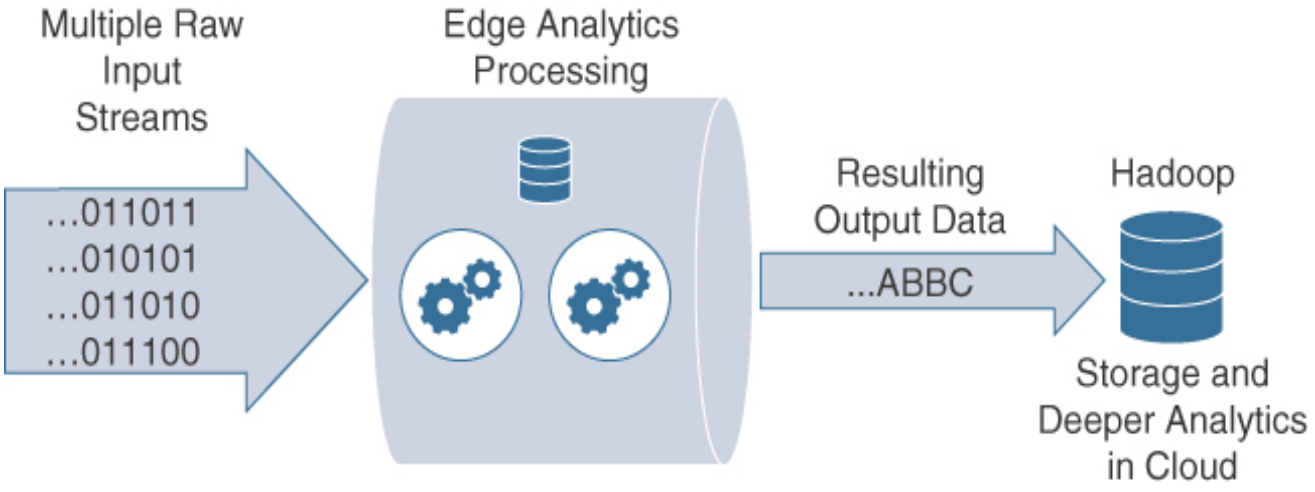
- Reducing data at the edge
  - Passing all data to the cloud is inefficient and is unnecessarily expensive in terms of bandwidth and network infrastructure.

- Analysis and Response at the edge
  - Some data is useful only at the edge and for small window of time
  - e.g., Roadway sensors combined with GPS wayfinding apps may tell a driver to avoid a certain highway due to traffic. This data is valuable for only a small window of time.

- Time sensitivity
  - When timely response to data is required, passing data to the cloud for future processing results in unacceptable latency.

Edge Analytics Core Functions

- Raw input data
  - This is the raw data coming from the sensors into the analytics processing unit.
- Analytics processing unit (APU)
  - The APU filters and combines (or separates) data streams, organizes them by time windows, and performs various analytical functions.
- Output streams
  - The data that is output is organized into insightful streams and passed on for storage and further processing in the cloud.



Network Analytics

Network Analytics

- This form of analytics extremely important in managing IoT systems
- Data analytics: concerned with finding patterns in the data generated by endpoints
- Network analytics: concerned with discovering patterns in the communication flows
  - It is network-based analytics
  - power to analyze details of communications patterns made by protocols
  - correlate this pattern across the network
  - allows to understand what should be considered normal behavior in a network

Benefits

Benefits of Network Analytics:

- Offer capabilities to cope with capacity planning for scalable IoT deployment
- Security monitoring in order to detect abnormal traffic volume and patterns
  - e.g. an unusual traffic spike for a normally quiet protocol
  - for both centralized or distributed architectures
- Network traffic monitoring and profiling
- Application traffic monitoring and profiling
- Capacity planning
- Security analysis
- Accounting
- Data warehousing and data mining

Challenges

Challenges with deploying flow analytics tools in an IoT network

- Flow analysis at the gateway is not possible with all IoT systems
  - LoRaWAN gateways simply forward MAC-layer sensor traffic to the centralized LoRaWAN network server, which means flow analysis (based on Layer 3) is not possible at this point.
  - A similar problem is encountered when using an MQTT server that sends data through an IoT broker
- Traffic flows are processed in places that might not support flow analytics, and visibility is thus lost.
- IPv4 and IPv6 native interfaces sometimes need to inspect inside VPN tunnels, which may impact the router's performance.
- Additional network management traffic is generated by analytics reporting devices

Thanks!