Big Data Architecture for Intelligent Transport Systems

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Abstract*: Day by day as the volume of data is being generated massively, storing of data and processing of data becomes a ever growing challenge in intelligent transport system (ITS). In intelligent transport system there are different areas to concentrate like smart parking systems, dynamic toll charging, smart traffic management etc. This paper is mainly focused on big data architecture for intelligent transport system for dynamic toll charging, traffic management and traffic analysis related data collection from various sources. The data collected from various sources can be in the form of structured data, semi structured data and unstructured data. Because of verity of data collected, this paper gives an idea about which data model is appropriate depending on data collected for transportation system.

Keywords—Big data architecture, Data model, ETL tool, Hadoop, Intelligent transport system, Spark.

I. INTRODUCTION

Technology is rapidly growing in the area of computers which benefit's health care systems, transportation system, banking systems, social media etc , this rapid growth in technology is leading to huge volume , veracity and velocity of data process and management . This paper is survey on intelligent transport systems (ITS) and data handling related to ITS .Intelligent transport systems is about how transportation system works with automated system. In ITS error's and performance issues which usually occur in manual process can be avoided and data collection [1] and management in ITS can be used in traffic management, theft vehicle detection, automated toll systems, vehicle monitoring etc.

Toll collection is one of the biggest area of interest in transportation system and there is lot of scope in research. currently if a vehicle has to pay toll charges at a toll gate ,the time consumption is around 1 minute and during heavy peak time traffic the vehicle has to wait for more than 1 minute ,if we calculate for 1 month , average time taken for a vehicle to pay toll charge will be around 30 minutes[2], if we extrapolate this to a min of 100 vehicles per/day there is a loss of 600 productive man hrs per year , not just man hrs but waiting time at toll means more pollution and fuel wastage, ITS plays a key role in reducing these issues .As technology is progressing the method of static toll charging system has to change and dynamically depending on the conditions toll charges has to be charged on vehicles .Intelligent transport system using methodologies in dynamic toll charging[3] depending on the traffic, path of vehicle, vehicle travelling time and size of the vehicle etc reduces most of the issues arising out of manual toll collection and automated systems can be implemented.

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A.Data Collection Sources in Intelligent transportation system (ITS)

Intelligent transportation system sources data from various sources like CCTV cameras, sensors, RFID, GPS etc. There are many advanced techniques to implement toll charges by collecting the data from available sources like CCTV cameras for number plate detection [4] using image processing which helps in collecting appropriate toll charges for the vehicle detected, CCTV cameras can also be used for footage purpose of crime identifying and misused vehicle details to be known etc.

Another source of data in ITS is through radio frequency identification (RFID)[5], With help of RFID it's possible to detect the unique RFID tags installed in the vehicles automatically .RFID tags have information about the vehicle number, details of the vehicle owner and prepaid balance. Whenever car passes through the Toll booth, RFID tag is detected and automatically toll charges are deducted. This RFID technique can also be used for security purpose to identify the authorized vehicles.

Sensor's used in ITS is major source for ITS data , by using sensors on the road the transportation data can be collected such as speed of the vehicles, position of vehicle etc . Diverse sensors such as Global positioning based sensor, magnetometer, gyroscope principled sensor etc are used to source transportation data [6]. Sensors help in effective gathering of arterial and vehicle access o highway information to record and transmit incident detection, active transportation and highway demand management. sensors are also used in adaptive signal control, ramp and freeway metering , dispatching of emergency response providers et. Traffic flow sensors when integrated with big data systems accurate and timely traffic flow information can be obtained and also by using these data sources, further analysis can be done such as identifying owner of the vehicle (owners name), vehicle details, vehicle owner details (owner address, age, insurance details, license details etc) at point of time.

B.Data Formatting and Storage of Data in ITS

As the data is collected from various sources it has to be stored in databases for analyzing the transportation data. The data collected from various sources can be in the form of structured data, semi structured data and unstructured data. Structured data is kind of data that can be organized and can be stored in tables with the help of relational databases.

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In Semi structured data, the data is in form of documents eg JSON, XML, Unstructured data talks about the data is in form of images, sound and videos .the transportation data collected is combination of these three types, the data collected from different sources has to be distributed to different systems so that dynamic decisions can be taken for ITS implementation. With volume, variety and velocity of ITS data generated concept of big data architecture is used to analyze process and store the data.

II. BIG DATA AND ITS

Why Big Data Analytics Why not Just BI for ITS [7].

Concepts of Star Schema Modeling, Data warehouse setup , data mining techniques and Analytical database have severed Industry effectively for the past 2 to 3 decades .concept of big data is comparatively new, Though IT industry has been dealing with large amounts of data in various domains for years. Big data help in Digging and analyzing semi-structured and unstructured data along with structured data in huge volume, couple of decades ago, analysis on email, sound or images was not undertaken. The concept of distributed computing was visualized long before big data (PARAM from C-DAC) but big data has provided scale and magnitude of data analysis, within controllable budgets. Similarly predictive modeling as a concept has been around for years, but predictive modeling based on variety of data that includes images and sound is something big data concepts enable us to do. To put volumes in perspective various sources point out that 90% of the data that is generated so far is only two years old. And data is growing fast at a faster rate especially in intelligent transportation systems with real time sensors data being used in a major way.

In order to serve sales and distribution and enhance logistics many enterprises have been building data warehouse and analytic platforms based on their legacy and transactional data sources but in contemporary times big data has enabled these firms managing data by itself as a new form of business opportunity for example Amazon which started off as an online e-commerce product company has now evolved to become a platform as a service, software as a service, big data as a service, and cloud data centre company. This concept in ITS may very well lead to usage of Data to enhance additional source of revenue in the form of managing user data which is collected across geography, sharing of geographic vehicle tracking , traffic data between various agencies across nations can potentially lead to new revenue generation .

Big Data for handling complex and diverse form of Transport Data.

Big data resolves three major issues wrto Transportation data: data storage, data analysis and data management. Distributed Data Architecture in Big Data system has inbuilt ability to handle expanding volume of data; Since data is stored and replicated on different nodes, Single large task is divided into no of smaller tasks and processed in parallel , here stability and fault tolerance plays a key role, massive amount of data which is very diverse in nature like structured, semi structured or unstructured[8] can he processed and stored for analysis.

Sample USE CASES for Implementing BIG Data for Transportation Systems [9]

- Planning and Demand Modeling

Big Data can be used to understand the customer demand on multiple routes. Customer movement can be mapped through multiple modes of transportation like trains, buses, airplanes etc. This data can be used to improve planning of efficient routes, schedules and frequency of transportation modes , which will help to reduce customer wait times resulting in increased ridership and productivity.

- Predictive Maintenance

Big Data helps authorities to predict optimal maintenance requirements of transportation assets .Data collected from sensors installed in transportation assets when analyzed in a Big Data context helps in understanding failure point analysis preemptively, this approach is used to predict failure points. For individual components such as brakes, wear and tear in tires, exhaust levels in buses etc. which in turn helps in maintenance of the equipment optimally.

- Big Data for efficiency in toll collection.

Congestion on the road leads to wastage of time, increases pollution, and commuter fatigue leading to drop in productivity. Commuters in Europe waste more than 50 hours a year in traffic jams; infrastructure congestion costs 1 percent of GDP. By Applying Digitization In form of Big Data, improved demand management and maintenance of Infrastructure is Possible. Analysis of historical and collective traffic data leads to better traffic forecasting and helps in congestion based toll pricing.

- Event Response Management

Big Data helps in understanding customer journeys closely like start and end points of customer commutes, different modes of commutation etc this helps concerned authorities to take effective decisions for questions like

How many number of busses need to ply on a particular route?

What is the optimum frequency busses need to ply?

What is the best approach for last mile connecting?

Which customer will be impacted in the event of traffic disruptions at a particular route, say in the event of Bad weather?

What type of alternate means of transportation needs to be deployed in the event happening?

How much capacities need to be planed?

Also helps transport planners to be better equipped for both planned and unplanned event

Communication channels to commuters can be better set with big data analytics in place like changes in service, targeted advertising, alternative routes to commuters in the event of traffic congestion etc

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III. BIG DATA ARCHITECTURE FOR ITS

A. Model Big Data Architecture for ITS

The data collected from various sources are passed through harmonizing tools which formats data in a similar format after which data is subjected to ETL process. fig1 shows below the big data architecture for ITS[10].

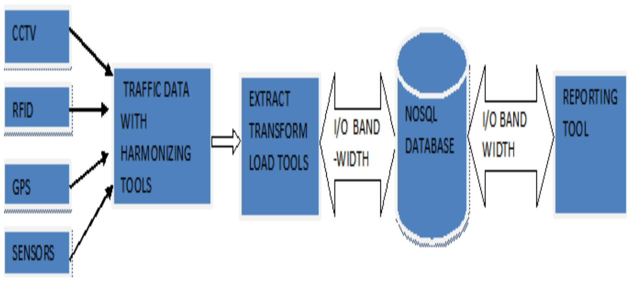

Figure 1. Big data architecture for intelligent transport system

ETL tool[11] are used to extract data and then transformation rules are applied based on functional and technical needs before loading the data in to final big data database. On the top of the final database we can run reporting tools to get business reports for analysis on transportation data which help for dynamic toll charging, I/O operations at the time of ETL operations and I/O operations at the time of Querying Reports from data Store is seen as a Major constraint in Performance during peak traffic time, here architecture modeling plays a major role in efficient use of the same.

Transportation data collected from various sources contains structured, semi structured and unstructured data, NOSQL databases [12] which supports various formats are primarily used for data storing. These databases are highly suitable for big data architecture, have high processing speed than sql data bases for read based queries and works with distributed database system. Nosql works on CAP theorem capability, availability, and partition tolerance. Nosql databases need to satisfy with at least two of these properties; it can be CA capability and availability or AP availability and partition tolerance or CP capability and partition tolerance.

NoSql databases

Basically there are four different categories in NoSql databases:

- Key value based [13]:The data stored in the tables are maintained with key value pairs for unique identification of that particular record and retrieval of data is based on that key. Hashing function is performed on key value pairs. Example for key value based are Redis, Riak.

- Document based: The data is stored in form of documents by using Xml or Json .In document based data model application logic to write in to databases is easy but reading of data is time consuming because the data is stored in form of documents or files. In document based the query engine is very powerful to facilitate queries to fetch the data while reading. The internal structure of the database has to be used for extracting the Meta data. This type is recommended when data to be stored is having major percentage of semi structured and unstructured data. Example for document based data bases are MongoDB [14], couchDB.

- Columnar Based: In this data is stored in columns and each row will have a row id to retrieve any single record from column. These data bases are highly efficient for aggregate functions, online processing websites, timestamp based data collection .the related columns store under one column family. Example for columnar database is Cassandra [15], Hbase.

- Graph based databases store the data in form of graphs with nodes and connections for better understanding and heterogeneity [16] example for graph based is Neo4J.

There are two kinds of ecosystems in big data architecture i.e. Hadoop and Spark which are available in open source community , this paper will primarily focus on these two ecosystems , commodity based big data systems are not considered for this study.

Hadoop ecosystem [17] is primarily used where batch processing and data lakes are required. Hadoop works with the data collected from different sources on which ETL methodologies are applied using tools like HIVE, PIG, SQOOP (these tools are part of Hadoop ecosystem). ETL tool are used to extract data and then transformation rules are applied based on functional and technical needs before loading the data in to final big data database. After which data is stored in HDFS (HBASE structure may be applied for SQL Analysis) . Sometimes Aggregated Data from HDFS is sent to data warehouse to store in structure format for historical analysis. Fig 2 shows below the Hadoop ecosystem.

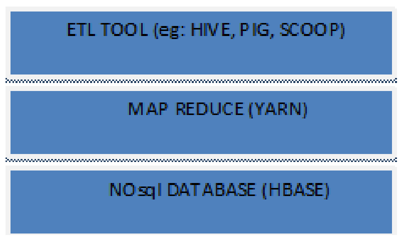

Figure 2. Hadoop ecosystem works

Spark ecosystem [18] works with stream processing and in memory computing competence along with resilience distributed dataset (RDD) for high speed execution. Spark based big data eco system is considered where processing of Streaming Data is required on a large scale for near real time in memory process . Fig 3 shows below the Spark ecosystem .

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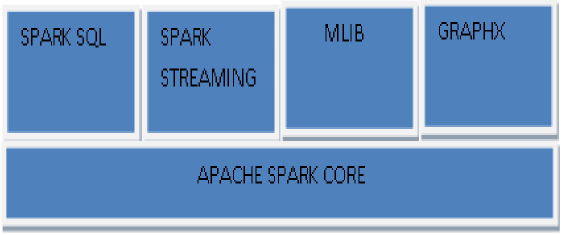

Figure 3: Spark eco system

Spark core: This Module in Spark ecosystem is responsible for basic I/O functionalities, networking with different storage systems, task dispatching, scheduling and monitoring the jobs on spark clusters, spark ecosystem memory management and fault recovery.

MLIB: Spark MLlib is a machine learning library on top of Spark-core, MLIB eases the deployment and development of machine learning pipelines, it provides algorithms that can scale over the spark cluster for regression, classification, collaborative filtering, clustering, etc.

Spark Streaming: The main characteristic of apache spark is stream processing, in this features the data is receives in data streams and it divides the data into batches. then they get processed by the Spark engine and finally stream of results in batches will be generated (micro batches).

SparkSQL : this feature in Spark supports querying data by means of SQL or hive query Language. This component uses the ability of declarative query and optimized storage by running sql like queries on spark data that is present in form of resilient distributed datasets.

GraphX: This library in spark is used for manipulating graphs and performing graph-parallel operations. It acts as a common tool for ETL, Data science analysis on graphs and iterative graph computations can be done,it comes with a library for common graph algorithms example Page Rank.

Comparison of Hadoop and Spark features :

Table 1. Comparison of Hadoop and Spark features

	Comparison of Hadoop and Spark features		
	Features	***Hadoop***	***Spark***
1	Data processing	Supports Batch processing	supports Batch processing and stream processing
2	Stream engine	supports Large data sets in batches	supports Micro batches
3	Data flow	supports Chain of stages ,one output of a stage is input for next stage	supports DAG(direct acyclic graph)
4	Performance	Performance is slow because of batch processing	Better performance because of stream processing
5	Memory management	Configurable memory management	Automating memory management
6	Line of code	More number of line of code	90% less line of code compare to hadoop
7	Machine Learning	Depends on external tools like Apache Mahout	It has own machine learning library MLIB
8	Sql support	Apache hive helps to run sql queries	Spark sql helps to run sql queries
9	Easy to use	hand code requires for each operation	Easy to program because of high level operators
10	compatibility	Compatible with spark eco system	Compatible with hadoop ecosystem

	Comparison of Hadoop and Spark features		
	Features	***Hadoop***	***Spark***
11	cost	less expensive hardware	Expensive because it requires more RAM to run in-memory
12	Processing speed	Because of map reduce processing is slow	in-memory processing is fast

To compare Spark and Hadoop on a even platform, a laboratory set up was established with a Cluster of eight virtual machines on which Hadoop and Spark are installed and deployed. Example studies based on the same algorithm and programming language were run on this cluster (Word Count—Sorted by Keys, Word Count—Sorted By Values, Page Rank), one of the key points is 3gb of memory is set in each cluster and tests are run with data size less than 3 GB.

Following are the results that were generated under laboratory conditions:

Results for 1st case: Count—Sorted by Keys for 2 GB of Data ,Hadoop took 2 mins 25 secs and Spark took 30 secs, 2nd case: Count—Sorted by Values for 2 GB of Data Hadoop took 3 mins 2 secs Spark took 30 secs, 3rd case: Page Rank for 2 GB of Data ,Hadoop took 38 mins 51 secs Spark took 2 min 30 secs. The following graph [fig 4] shows the comparison between Hadoop and Spark performance under controlled conditions [19].

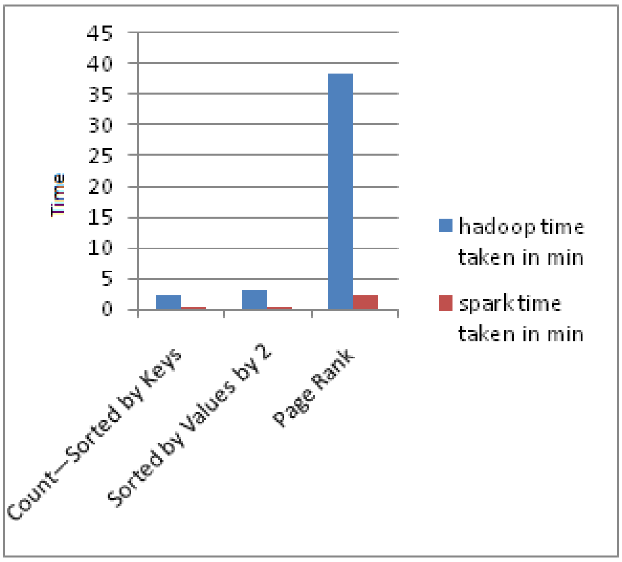

Figure 4. Comparison between Hadoop and Spark performance

Spark Scores well over Hadoop if the Processing is set well within the memory of each node because Spark is tuned for in-memory computations. Spark Also scores well over Hadoop for processing Streaming Data due to RDD approach in Spark. But Spark is memory intensive hence expensive under certain scenarios example under batch processing conditions where Ram is not a major issue Hadoop is more cost effective.

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Hadoop eco system by itself is not very ideal for transportation data management in dynamic toll charging because decision making on toll charge should happen just in time .so combination of both Hadoop and Spark can be implemented and in big data the data is very complex ,so to choose data sets for statistical analysis ,algorithms in machine learning plays a major role and processing the data accordingly is aided usage of spark Machine learning libraries .there is a good scope for research to improve algorithms which aids in the efficiency of data set selection and analysis .

Some of the gaps identified in this survey paper for big data architecture used in intelligent transportation system are I/O bandwidth defined between ETL tool and database and between database and reporting tool, the defined I/O bandwidth usually chokes during peak traffic time when more volume of data needs to be processed during ETL and also bandwidth choke occurs when more data in data lake needs to be analyzed for dynamic toll pricing. Another gap is the fitment of database model that should be adapted according to the data sources in consideration.

Analytics methodology, tools and approach used in Big Data Architecture compared with traditional BI

The analytics associated with big data is based on the following four primary characteristics are volume, velocity, variety and veracity of data that is sourced in Big data storage accordingly the analytics techniques have also evolved to accommodate these characteristics to scale up to the complex and sophisticated analytics needed. Big Data Analytical architectures along with their platforms, tools etc have evolved to meet the demands of big data. Traditional BI tools were normally installed in standalone servers and executed connected to Enterprise Data Warehouse or Operational Data Store, but for big data architecture BI tools are set in distributed processing across several nodes for parallel computing.

It is obvious that the analytics tools for traditional structured data are different from the analytical architecture for querying and processing unstructured big data. Big Data Analytics is contemporary and also comes with contemporary issues , security in traditional BI has matured with solid governance but in distributed computing same cannot be established with ease as data is spread across cluster , another issue is querying across variety of data with required level of data integrity ,Big data analytics and applications are at an early stage of development, but hope fully the advances in platforms and tools can accelerate their maturity level as desired by industry.

IV. GAPS IN BIG DATA FOR TRANSPORTATION SYSTEMS

Data: Big Data tools have handled insertion of data encompassing 4V principles very well but Meta data on the inserted data is very maturely handled in traditional BI systems since traditional systems have to handle mostly structured data not so in Big Data Systems, establishing a common semantics layer for the data stored is still a challenge more the variety of data more common should be the semantic layer for better data retrieval. Transportation industry face this challenge in a big way as variety of data like images , structured data , steaming data from sensors etc are sourced [20].

Process and Governance: Big Data is sourced from different sources which has high probability of personal information like twitter and face book text data, traditional BI systems did not face this challenge in a big way but the same is not true in Big data systems also since big data is spread in a distributed architecture establishing security rules is a much bigger challenge, which is yet to be thoroughly resolved to the satisfaction of industry standards. This is all the more true for transportation systems as vehicle tracking data is sourced in a big way.

Technology evolution: Adopting the right big data Architecture Framework for the use case in hand is one of the biggest challenges facing the industry as big data frameworks are yet to reach a stability phase. This challenge is common across industry not just to transportation systems.

V. EXPERIMENTAL RESULTS

If the number of occupants in a four wheeler can be increased, it would greatly reduce the congestion. This project works on achieving the same i.e. the toll will be charged mainly based on the seat occupancy, time stamp of the four wheeler, vehicle route. If only one person chooses to travel in a car, he will be charged higher toll rates compared to the others who travel with the appropriate load in the vehicle. The system provides the facility to detect the number of passengers within the car and the toll is dynamically calculated depending on time stamp. This helps reduce a lot of waiting time. The experimental results are done using spark architecture and Cassandra Nosql database. The architecture diagram shown below with results.

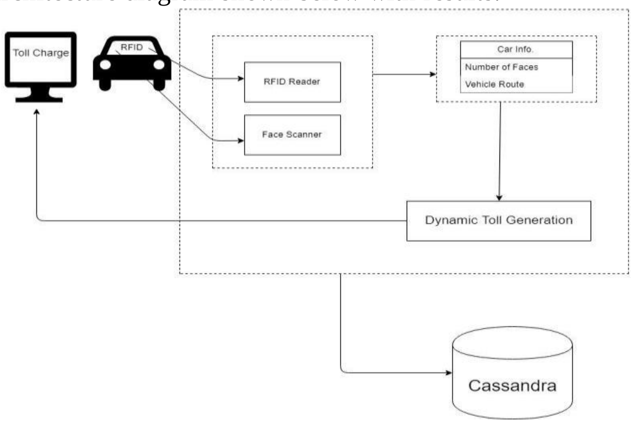

Figure 5. Architecture diagram of Dynamic toll charge generator

```
cqlsh:kscst> select * from dynamic_toll;
```

vehicle_reg_no	date	num_of_occupants	route	time	toll	toll_gate_location_address	vehicle_type
KA04JL5614	2019-04-05	1	Tumkur Road	14:11:30.000000000	170	NICE Toll Gate	Car
LEM4464A	2019-05-01	1	Mysore Road	20:21:10.000000000	99	NICE Toll Gate	Car
KA04JL7757	2019-04-05	0	Mysore Road	14:12:30.000000000	128	NICE Toll Gate	Two Wheeler

Figure 6. Results of Dynamic toll charge generator

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VI. CONCLUSION

As the data is collected from various sources for intelligent transport system, it has to be stored in databases for analyzing the transportation data .This paper gives idea about the different data sources for intelligent transport system and need for analyzing the data model to be chosen according to the source data that is collected in database for business analysis and how to fit the model for dynamic toll charging, also how database need to support for near real time results. This paper also highlights Hadoop and Spark big data ecosystem and effectiveness of using Hadoop and Spark in different scenarios .The paper also identifies research scope in the area of I/O bandwidth defined between ETL tool and database and also between database and reporting tool to increase the efficiency of I/O operations. The Paper also sees scope for research to improve algorithms which aids in the efficiency of data set selection and analysis for machine learning since sensor data is heavily sourced for transportation analytics. Scope in research is also seen for establishing a desirable framework for security in securing transportation data which gets spread across nodes in a distributed processing environment that is sourced in ITS network.

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