CONTROL AND MONITORING OF AN EFFICIENT TRAFFIC CONGESTION SYSTEM

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ABSTRACT

Through this paper, our focus was to utilize information collected from telecommunication providers related to the usage of roads by different vehicles. Complexities within collected data were a major requirement to be resolved and corrected through the definition of algorithms that provide cleansed data that can be utilized within the analysis of information. The primary focus of this paper is to identify the methodology followed in utilizing this information and benefiting from it in identifying the usage of the roads. The methodology we followed was to benefit from the current infrastructure available through mobile towers and apply certain algorithms towards cleansing the data from possible problems and issues in it. Based on those methods, we were able to generate results and beneficial analytics that provide guidance on the number of vehicles passing certain routes at different periods of time which provided intelligence in identifying which is the best route to use at a certain time.

KEYWORDS: *Tracking, transportation, Traffic jams, Mobility, Business Intelligence, mobile operators.*

I. INTRODUCTION

Transportation became one of the major activities in our daily life. It became the most affecting tradition each day. Due to the rapid increase in population and vehicles, poor readiness in the roads due to the surprising increment, traffic jams became normal within all roads, waste of time and money turned into a normal habit within our daily life. In 2007 traffic congestion resulted in 4.2 billion hours of delay and 2.9 billion gallons of wasted fuel [1]. Based on that, a solution to decrease traffic jams within all roads was mandatory, reducing the lost time and money due to traffic jams became a must [2]. Improved travel-time and congestion relief become desire. Greater reliability of the transportation system and the minimization of unpredictable delays, greater safety and security are also high on the list of user expectations [3], [4]. In order to achieve this, the adoption of Intelligent Transportation Systems (ITS) was introduced. Solving the problem in the roads may be implemented through different approaches [5]:

Vehicle Re-Identification. In this technique, a unique serial number for a device in the vehicle is detected at one location and then detected again (re-identified) further down the road. Travel times and speed are calculated by comparing the time at which a specific device is detected by pairs of sensors. Bluetooth devices, or RFID serial numbers from Electronic Toll Collection (ETC) transponders are used for this technique (also called "toll tags") [6]. GPS Based Methods. An increasing number of vehicles are equipped with in-vehicle GPS (satellite navigation) systems that have two-way communication with a traffic data provider. Position readings from these vehicles are used to compute vehicle speeds [7]. Traffic Loops and Cameras. Production of data through fixed monitoring equipment typically deployed in a discontinuous way and mostly limited to highways or main roads so not common on the underlying network [8].

Triangulation Method. In developed countries a high proportion of cars contain one or more mobile phones. The phones periodically transmit their presence information to the mobile phone network, even when no voice connection is established. By measuring and analyzing network data using triangulation, pattern matching or cell-sector statistics (in an anonymous format), the data was converted into traffic flow information. With more congestion, there are more cars, more phones, and thus, more probes. In metropolitan areas, the distance between antennas is shorter and in theory accuracy increases [9].

An advantage of this method is that no infrastructure needs to be built along the road; only the mobile phone network is leveraged. But in practice the triangulation method can be complicated, especially in areas where the same mobile phone towers serve two or more parallel routes (such as a freeway with a frontage road, a freeway and a commuter rail line, two or more parallel streets, or a street that is also a bus line) [6].

Using this method, almost all vehicles within the roads will be covered within the analysis since all vehicles utilizing the roads have passengers with mobile phones and the mobile towers are available in all roads. Although the usage of the triangulation method has decreased due to its complexity, my research was to reduce those complexities since this method has the lowest cost of implementation due to the readiness of its infrastructure. Through the research we worked on solving all complexities that prohibit the adoption of this method in order to allow the seamless implementation of it within our region ensuring that the least cost and overhead are required within those implementations.

Within the paper we will explain the mobile network structure and how we got advantage from it within the implementation of the solution at section 2. In section 3, an explanation for the problem that this paper resolves is identified and discussed. Section 4 defines the importance of information collected, methodologies of collecting it, and the needs gained from this collection. Within section 5, we have briefed previous work executed by others within the same scope. Both sections 6 and 7 explained the implemented work, activities executed, and algorithms followed in cleansing collected information. Finally, sections 8 and 9 detail the summary and conclusion of this paper.

II. MOBILE NETWORK ARCHITECTURE

Mobile network is built from a set of components that, together, make the correct function and usage of it. The components are:

2.1. The Switching System

The switching system (SS) is responsible for performing call processing and subscriber-related functions. The switching system includes functional units, which are, Home Location Register (HLR) which is a database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status [10]. Mobile Services Switching Center (MSC) that performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others [11]. Visitor Location Register (VLR) is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time [10]. Authentication Center (AUC) provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects network operators from different types of fraud found in today's cellular world. Equipment Identity Register (EIR) a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations. The AUC and EIR are implemented as stand-alone nodes or as a combined AUC/EIR node.

2.2. The Base Station System (BSS)

All radio-related functions are performed in the BSS, which consists of base station controllers (BSCs) and the base transceiver stations (BTSs) [12]. BSC provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations. A number of BSCs are served by an MSC [13]. BTS handles the radio interface to the mobile station. The BTS is the radio equipment (transceivers and antennas) needed to service each cell in the network. A group of BTSs are controlled by a BSC [11].

III. PROBLEM OF THE STUDY

Within the design of roads in each city, the consideration of vehicles inflation might not be expected accurately. This increase the chance of having more traffic jams when unexpected numbers of vehicles are served at the same time within the same road. Proper analytics on the usage of roads and the number of vehicles being served at a certain time is not available at the moment in most countries. In order to resolve such problems, lots of countries implemented and are implementing different analytics through manual approaches [14].

The research is based upon implementing an automated approach for such analysis; the collection of information available from mobile operators through the data gathering of information from their telecommunication towers shall be followed. The suggestion is to use the data from mobile operators, while the solution will be resolving the complexity in the gathered information due to unwanted information available within it and providing an automated analytics approach on this data in order to reduce traffic jams and provide proactive actions on them. Complexities that may arise are such as parallel roads that are covered through the same tower. A group of mobile phones using the same operating tower within the same vehicle. Inactive users that are utilizing the same tower but are not using the road itself such as population within a building. Walkers on the road that are not affecting the traffic through vehicles utilizing the road. And vehicles within traffic jam which are already idle for a long time and are similar in a certain extent to the walkers within the road.

IV. IMPORTANCE AND OBJECTIVES OF THE STUDY

The implemented method within this research takes advantage of an already available technique which reflects in lower start-up costs, less time in initiation and execution, reduced opportunity of loss of time and cost, and ability to take advantage of a huge amount of historical data that is already collected and not used to serve this approach.

The availability of such huge amount of information will provide the system with the instructions and methods to learn from the historical data it has and allow the experiment of the system's intelligence and recommendations prior to its actual adoption and implementation which results in real scenarios to test.

Within the research, the objective is to resolve the complexity of this approach and its usage in order to be able to notice and predict traffic jams in roads, reduce these jams and provide the ability to proactively interact with certain roads at certain period of times from the historical data analyzed. All actions and behaviors executed through this method are based on the historical data collected and are not real-time information.

The roam of error when depending on historical data shall be reduced by excluding the anomaly factors that might persist within the collected data. The analytics provided will be for the number of vehicles consuming roads at a certain period of time with the exclusion of traffic jams that occur due to accidents, fire, or any abuse of the roads.

From data collected in such systems, a Floating Car Data (FCD) market is only now growing worldwide with a wide range of applications and benefits. This would not only improve traffic management but would also help satisfy the growing demand of drivers who are willing to pay service providers as long as they have access to relevant real-time information: will there be any congestion on my usual route today? How to avoid it? If not, how long will it last? [15].

V. RELATED WORK

Erlangung "deals with cooperative traffic information systems, which support the driver of a car in selecting a route, based on traffic information collected by other cars. System participants contribute measurements of the traffic situation in their vicinity (e. g., current traffic flow speed) and use the measurements made by other drivers to find the fastest route to their destination with regard to the current conditions. Such systems help avoid traffic jams, highly congested roads, place of accidents and other unexpected deterioration" [16].

Guillaume describe their "extended data collection system, in which vehicles are able to collect data about their local environment, namely the presence of road works and traffic slowdowns, by analyzing visual data taken by a looking forward camera and data from the on-board Electronic Control Unit. Upon detection of such events, a packet is set up containing time, position, vehicle data, results of on-board elaboration, one or more images of the road ahead and an estimation of the local traffic level" [2].

McLin mentions that "traffic congestion in metropolitan areas is a major problem because of its negative effects which include increased delay, fuel consumption, and pollution. In the past, capacity expansion was identified as the solution for congestion, however, budget restrictions and other concerns now limits the growth in new infrastructure. Congestion remedies now center on traffic management solutions which better utilize the existing infrastructure. This dissertation describers the development of a regional traffic control system which is designed to provide integrated control in a large traffic network during non-recurrent congestion events" [1].

Stefano stressed on the fact that "the development of Intelligent Transportation Systems (ITS) requires high quality traffic information in real-time. For several years, under growing pressure for improving traffic management, collecting traffic data methods have been evolving considerably and the access to real-time traffic information is becoming routine worldwide" [11].

World Road Association focuses within their handbook "on the “soft” engineering approaches and tools available to the network operator to improve network operations. The handbook discusses:

The shift from the traditional building and maintaining of the road network to a service oriented policy towards the road user; The road network operator’s tasks and measures; ITS solutions for network monitoring, maintaining road serviceability and safety, traffic control, travel aid and user information and demand management; The institutional and organizational aspects of network operations; and Performance indicators for network operations" [4].

Fabian "discusses the dynamics of using vehicle probes for detecting link travel times in a large scale road networks. Data from vehicle probes that actively participate in traffic flow, also known as Floating Car Data, offers a solution to this problem. Highly distributed sensor population provides scalability as compared to traditional methods of travel time estimation. This thesis investigates Floating Car Data as a tool for acquiring traffic information. Individual components of Floating Car Data systems are examined along with various alternatives to build such components efficiently" [17].

Wahle "is to combine the contributions of some disciplines with emphasis on the methods of physics. The main objectives of this work are:

to give insights into the concepts of Intelligent Transportation Systems, to discuss potential benefits and drawbacks of providing information in traffic systems, to analyze and evaluate the usefulness of multi-agent system for modeling traffic system, to develop a general agent-based traffic model, which is capable to include the reaction of drivers to information?, to study and model the route choice behavior of road users on different time-scales, e.g., from day to day or within a day and to demonstrate the usefulness of the proposed approaches in practice, especially in combination with data provided on-line [18].

Dubai’s Road and transport authority, executed The first technique in Dubai, United Arab Emirates (UAE) through a system called “Salik”, meaning open or clear, is Dubai’s new electronic toll collection system was launched in July 2007, which emphasizes the system’s congestion management objectives as well as the choice of technology for the toll system. Salik utilizes the latest technology to achieve free flow operation with no toll booths, no toll collectors, and no impact to traffic flow, allowing vehicles to move freely through the tolling point at highway speeds. There are 4 toll points, each time you pass through a Salik tolling point, a specific amount will be deducted from your prepaid toll account using advanced Radio Frequency Identification (RFID) technology, and your vehicle will be identified to the system through communication with the small, thin Salik sticker tag affixed to your windshield [19].

VI. IMPLEMENTED SYSTEM

The main output of the solution is to get results identifying the usage of different roads at different periods of time in order to provide the intelligence on which roads to follow at different periods of times to ensure the minimal traffic jams and expenses. The solution aims towards providing this information upon request and providing recommendations on roads utilization.
Within the solution, the following steps will take action:
Data collection for raw information available at the mobile operators. Each mobile operator will provide data collected for its subscribers consuming the telecommunication services at different locations. Information is collected through the telecommunication towers installed at different locations on the roads; those towers are available to ensure the continuity of the service to those subscribers at different locations. The data includes the tower from where the data was collected, the date and time this reading was done, with subscriber number optionally identified.
Towers information. Information from each mobile operator related to their telecommunication towers installed shall be collected and defined. Information related to a tower includes the latitude and longitude of the tower. This allows the ability to know the location of each subscriber (vehicle) at a certain period of time based on defining the tower that read the subscriber's location.
Duplication of data cleansing algorithm. Within the collected information, more than one person might be within the same vehicle. The algorithm shall define those people by automatically deleting records for subscribers' that have the same readings from the same towers at the same time and date. This means that all those readings are for more than one person utilizing the same vehicle or for one person that has more than one mobile from the same mobile operator.
Inactive subscribers' data cleansing algorithm. Information for residents living beside a certain tower will be always collected and provided within the raw data. Those residents are actually not road utilizers, dot affect the usage of the roads, and don't cause traffic jam. The algorithm will automatically remove those readings by defining the repetitive information for certain subscribers that have the same readings from the same tower and different times and dates.
Group subscribers' data cleansing algorithm. Partially covered in the "duplication of data cleansing algorithm", subscribers within public transport such as bus, taxi, or service cars, shall be removed from the provided information. Those subscribers may be identified through the fact that all those subscribers have the same reading information from the same tower at the same date and time. Information such as this should be deleted from the data and ignored since the utilization of the road is from one vehicle and the number of vehicles is not based on the number of subscribers.
Non-vehicle users' data cleansing algorithm. Walking and running people are not vehicle users. Based on that, those don't cause a traffic jam within the road as they don't actually use it. Those readings are identified through having the readings with minor changes as different periods of times. Those users are not utilizing the roads and don't cause a traffic jam.
Data transformation from raw data store to staging store. Each mobile operator's data shall be stored in a separate data store. The previously explained algorithms shall be executed individually on each data store. Once those operations are executed, the transformation of data from the mobile operators' store shall be executed towards a staging store (database) which includes a collection of all data cleansed from the preliminary databases.
Data cleansing on the staging database. Algorithms previously executed on the raw data shall be executed on the staging database in order to ensure no duplication of data exists in information from different operators.
Data transformation from staging database to data warehouse. After cleansing all data and consolidating it into one location (staging database), transformation activities applied on it to move it from the staging database to the data warehouse. A data warehouse is a normal database with a de-normalized structure which allows building the structure of an analytical cube that provides the ability to analyze data and produce dynamic and intelligent reports. The process will transform the data from the staging database to the data warehouse taking into consideration that current data on the data warehouse should not be affected in order to ensure historical information is perceived and available for future reporting and analytics.
Populate data cubes. As explained earlier, data cubes provide the aggregated collection of data and information in one location. Cubes are built in a manner that allows quick and easy analytics of data

and information through the analysis of data in top-down manner. Moreover, within a cube, dimensions, which provide the analytical views are defined which provide the option of identifying on which item analytics are calculated and based as shown in Figure 1.

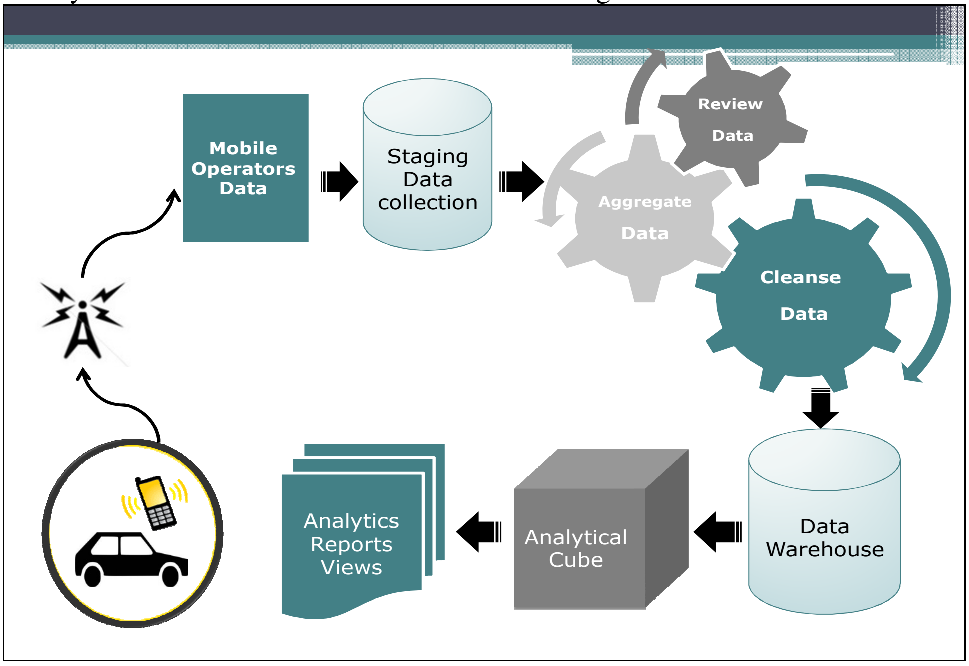

Figure 1 High-level Implementation

VII. PROPOSED SOLUTION

Upon all the above facts, and since the collection of data from the telecommunication companies was not available due to the unavailability of information at those companies, security reasons, and confidentiality requirements, it was a must to generate the data through a simulating application.
The application suggests a certain number of vehicles passing through a certain route during a certain period of time as shown in Algorithm 1. Moreover, the application uses as an input for it, the number of mobile users utilizing the same vehicle. Based on that, data generated from the application includes all available real-time options that might occur in the real life. This provides the ability to execute and run the algorithms on this data for cleansing and finalization purposes. Later on, data is grouped and analyzed. Dynamic analytics are generated and output is furnished for those items.

1. Vehicles passing within a road:
   a. **Inputs:**
      1. **Path** of the vehicle (latitude, longitude) for checkpoints
      2. Reading **time** (start and end of reading)
      3. The **Avg**(Number of mobiles within the vehicle)generate from the questioner
   b. **Outputs:**
      1. **Number of vehicles** passing the path during the reading time.
      2. **Number of mobiles** will range from 1 – 5. However, they might reach 50 in some vehicles (such as busses).
      3. **Vehicles speed** will be identified from the different readings through the formula **speed = distance / time.**

Results of the algorithm will **provide** the following information:

- Possibilities of traffic **jam** at a certain period of time.
- **Number** of vehicles and **road users** within the reading time.

Algorithm 1 Reading data from the roads (Generating data)

The algorithm 2 explains how to calculate if the road has a traffic jam or not. Jam detection algorithm is one of the main algorithms used within this research. Through this algorithm, identification of the speed of all vehicles passing two points within a road at different period of times and being able to calculate their speed provides the ability to identify whether there's a jam on the road, it's clear, or it's medium.

- From time $\mathbf{t_x}$ to time $\mathbf{t_y}$.
- Loop for all available cars.
- Distance of the road **(D) = square root((latitude$_x$)-(latitude$_y$)^2) + (longtitude$_x$)-(longtitude$_y$)^2)**
- Speed = D **(distance of the road)/(t_y – t_x).**
- If (average speed (**S**) **<Road Speed**) and (**Number of Cars**>= 100), Then there is a traffic jam.
- Key Performance Indicators (**KPIs**):
    - Low Traffic Jam: **Average Speed** is between **90%** of Road Speed to 100% of Road Speed.
    - Medium Traffic Jam: **Average Speed** is between **70%** of Road Speed to 90% of Road Speed.
    - High Traffic Jam: **Average Speed** is less than **70%** of Road Speed.

Algorithm 2 Jam Detection

VIII. RESULT AND DISCUSSION

Data cleansing algorithms were applied on collected data through different phases by applying a certain algorithm on each phase. At the end of these phases, the cleansed data was available for analysis and review.

Within the research we were able to solve the complexities in the data collected from telecommunication operators and cleansing them through the automated process of data cleansing which covered different algorithms to control data at different stages. This provided the ability to benefit from this valuable information that is available historically without using it in such scenarios.

We have analyzed the traffic load within Jamal Abdulnasser Street and Al-Dakhleya Circle for one month and collected the readings at different time periods which explain the load of vehicles utilizing this street.

IX. CONCLUSION

The research was focused on gathering information through the usage of the already available infrastructure within all roads through the telecommunication towers installed. Through the research, we were able to benefit from the algorithms we have followed in cleansing the data which made it available for review and analysis. Those algorithms showed success in resolving the problems within the data collected from those sources. Through those algorithms, unmanageable huge data that was collected became simple and available for analysis.

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Technical Biography

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