

# Fleet Management of Public Transportation using Internet of Things

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## Abstract

With the increase in the number of public and private buses in cities in recent years, managing the bus fleet across various routes in an efficient and effective manner has become cumbersome. This is resulting in suboptimal services, inability to effectively cater to existing demand, and poor quality of public transport services. Modern technological advancements have created a tremendous opportunity to improve various aspects of public transport services, to not only serve existing demand but attract increasing number of passengers to public transport from a sustainable development standpoint. One such area which is gaining momentum is intelligent fleet management using the concept of Internet of Things (IoT). This area calls for a cross-field collaboration between engineers from various disciplines to use the up and coming idea of Internet of Things (IoT) for overcoming the challenges of intelligent fleet management. This paper explores the opportunity for incorporation of IoT to manage bus fleets based on the occupancy ratio and the resulting benefits that can be achieved in terms of fleet frequency optimization.

## 1. Introduction

India is expected to surpass China as the most populous country by 2024. Increasing population, coupled with rapid urbanization and growth of private motor vehicles, is contributing to increased pollution, making India one of the most polluted countries in the world. Air pollution in particular has become a topic of grave concern with the number of motorised vehicles increasing exponentially in cities over the years. Change can be brought about only if there is a paradigm shift in the attitude of citizens, prompting them to use public transport for daily commute. However, lack of proper infrastructure and poor quality of public transport services (in particular, bus services) is discouraging people from using public transport.

One of the major issues facing public transport services in cities is the operating cost, due to issues such as old buses, improper driving practices, poor road conditions, and traffic congestion. It is important to rethink new ways to minimise bus transport running costs, in order to make our public transport economical and cost-effective. One of the solutions is to adopt a technology that helps monitor and manage the buses so as to increase the occupancy as well as the frequency of the fleet on high-demand routes at requisite times. This can be achieved by incorporating the emerging concept of Internet of Things (IoT) in our buses (Red Hat, 2016). Internet of Things is a network of physical devices (vehicles in our case) which are embedded with electronics, sensors, actuators and network connectivity which enables them to connect and receive data, and communicate with each other in real-time.

## 2. Literature Review

This section briefly describes some previous research efforts that have focused on real-time occupancy ratio optimization. Amoroso et. al (5) adopted a multi-agent objective function to evaluate the performance of bus transport with respect to the various stakeholders. For designing the bus network of a town, they aimed at developing a demand-based methodology. This approach was applied to an existing bus network serving the town of Trapani (Italy), with population of about a hundred thousand people. Strahan et. al (6) discuss the use of agent-based architecture in bus transport, wherein, the information about the location of the buses as well as their corresponding arrival times were made known to the passengers in Dublin in real-time. This was done by installing a GPS system in every bus, thereby capturing the bus location and the estimated travel time. Passengers were then notified of this information through their phones. Silva et. al (7) discuss a prototype bus service application based on mobile user location. It calculates the best route and guides the user based on the mobile user position and uses geographical database of local area. It improves the quality of service and also the user satisfaction by running a simulation on the public transport application.

## 3. Background Research

Current approaches for public transport demand assessment in the Indian context for the most part involve a manual monitoring unit that gathers all the data pertaining to the demand of the fleet, such as ticket sales on different routes, time of day, and origin-destination pairs.

This is based on the periodical study of demand over a particular bus route. However, these efforts are largely for record-keeping. Bus routes and schedules are generally kept fixed, and rarely are they demand-responsive.

However, it is very unlikely for the conditions to remain the same, particularly at different times of day, in which case it would lead to situations where buses in a particular route would ply with low occupancy rates while the demand is significantly higher but unmet on other routes (Reddy, 2015). One of the ways to solve this problem is to increase the bus frequency on the high demand routes by diverting buses from low demand routes for specific time periods. In order to accomplish this, there is a need for a modern technology that can track the location of buses as well as transmit the information regarding the occupancy of the buses to a centralised control system so as to direct the fleet based on real-time demand.

Intelligent fleet management would be a feasible approach here, as it would involve nothing more than assisting the current system with a few technological enhancements. Intelligent fleet management for the vehicles would consist of a software and hardware system to communicate across a wireless network to know the specific location of buses in the fleet. The vehicles in the fleet may or may not be connected individually, but are connected through a common network, to a control system from where the fleet manager would operate. To achieve these outcomes, certain changes need to be undertaken, which include the introduction of specific technical equipment. This equipment should be able to track the position of the vehicles and transmit the data in real-time, so that the vehicles in the fleet can be directed more effectively. Although, this may seem like an idea involving high initial investment, not to mention the fact that the entire system needs to get accustomed to the new technique, it is to be noticed that the installation of fleet management systems in bus transport will be a one-time investment with very low maintenance cost. Its effective implementation will result in a much improved operation of the fleet even from the initial stages. This endeavour can also deliver profits by reducing the fuel consumption on vain trips.

#### 4. Novelty of Approach

There are many benefits that can be reaped when machine-to-machine connection is introduced in a public transport fleet. One way of achieving this connection is by incorporating the emerging concept of Internet of Things (IoT) to manage the fleet better (Zhang, 2011). Besides an improved scheduling of buses, this would also help cut down the fuel consumption as the frequency of buses is optimized. The working of this method requires all the buses to be interconnected with each other through an intranetwork hosted by the government. The source will be the ticketing machine operated by the conductor. This device is to be embedded with a tracking system like Indian Regional Navigation Satellite System (IRNSS). Also, it must be capable of transmitting the number of tickets issued to the control system. This way, the current location and the occupancy of a particular bus can be assessed and the fleet could be managed accordingly.

The hectic task of having to analyse the prevailing demand is eliminated by this method. Also, this method efficiently tackles situations of sudden spike in the demand during peak hours in real time. This is done by the constant monitoring of the demand and increasing the frequency of the fleet when there is a surge in demand and at the same time ensuring a reasonable occupancy ratio. It also eliminates cases where two buses of the same route travel alongside (bus bunching), resulting in one of the buses travelling empty. When we have all the data regarding the bus timings and their current locations, we can also display this information at every bus stop, so that passengers don't crowd into the buses (Reddy, 2015). As the frequency of the buses is higher across the routes which have a proportionally higher demand, the fuel loss that is incurred by plying more buses in routes with

relatively lesser demand can be minimised by scheduling them based on the real-time occupancy ratios.

#### 5. Technical Details

The data pertaining to the number of occupants in a particular bus is fed into the ticketing device by the conductor while issuing the tickets. An alternative idea is to record the number of tickets issued with originating stop before the current location and destination stop after the current location (this is also representative of the current bus occupancy). This data is then transferred by the device to the control centre along with additional information that includes the current location of the vehicle and estimated time to reach the next prime point (stops with increased demand). The information regarding the current occupancy of the bus is then processed in the control centre by taking into account the remaining number of halts as well as the number of prime points. The essential feature of this device must be the real-time transfer of the data that is collected from the individual buses to the servers in the control centre without any delay. This whole process is facilitated by the concept of IoT wherein the connection and exchange of data is made easy and instantaneous. The device is also embedded with a location tracker in order to locate the vehicle along its route. After processing the information, the system arrives at an optimised fleet frequency for the particular route. If there is any other bus along the same route, the whole process has to be repeated so as to check whether it can take care of the demand or not. In case it fails to handle the demand, the nearest depot is alerted to send in a backup bus which can ease out the critical demand.

To estimate the performance of this methodology, let's consider a few cases: A bus starts from the depot, and has to cover 10 stops in its route. It reaches 80% occupancy in the 4<sup>th</sup> stop and from the data it is estimated to cross its full capacity by the 6<sup>th</sup> stop. Under a 10 minutes bus frequency scenario, people boarding at or after the 6<sup>th</sup> stop would suffer due to lack of seat availability. When the fleet frequency is optimised in real-time, however, the next bus would arrive either from the nearest depot or another route in 2 to 3 minutes, in order to accommodate the increased demand and thus the occupancy ratio is normalised. In a second case, a bus (say, Bus-1) reaches 75% occupancy ratio at 6<sup>th</sup> stop and the 7<sup>th</sup> stop is a prime point (high demand location). Another bus (Bus-2) is operating in the same route and is at the 2<sup>nd</sup> stop with 40% occupancy. The system can be designed to estimate whether Bus-2 (based on existing occupancy, demand and traffic conditions) would be able to handle the passenger demand at 8<sup>th</sup> stop and further, and if not, bus frequency would be optimised by sending a bus from nearest depot or another route to address the excess demand.

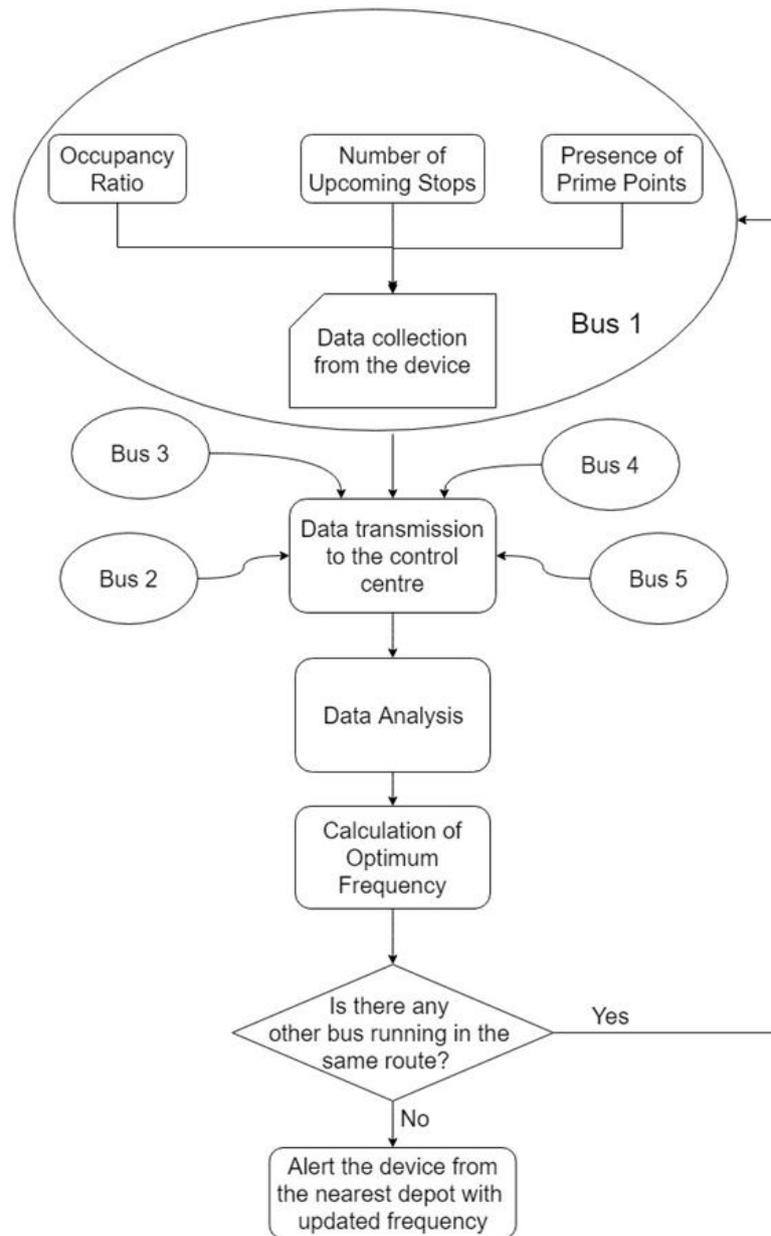
#### 6. Advantages

For the bus fleet frequency optimization system discussed above, the following would be some of the key advantages.

- The implementation of this system can increase the revenue for the Public Transport Corporation as more passengers will be inclined to use buses over their personal vehicles for commute.
- As the bus timings become more reliable, passengers need not worry about being late for work or school.
- Overcrowding of buses is eliminated as the frequency is optimized based on the real time demand. This leads to increase comfort and safety for passengers.
- The conductors need not jostle through a fully crowded bus when issuing tickets.
- The screens set up in the bus stops and depots can generate revenue by advertising.

- The possibility of people travelling without tickets is diminished to a large extent.

The following diagram shows a diagrammatic representation of the framework for bus fleet frequency optimization using IoT.



(a)

**Fig. 1:** Bus Fleet Frequency Optimization Framework

## 7. Conclusion

The adoption of the IoT based fleet management system in bus-based public transport will have a positive impact in terms of reducing the operating losses that are incurred due to the operation of vain trips. This is due to the fact that, in this method, the frequency of buses is taken as the variable, which is then optimised by increasing the occupancy ratio of the buses. This system will also contribute to other positive benefits such as enhanced revenues from increase in bus ridership, as well as reduction of negative externalities such as pollution due to shifting of demand from private vehicles to public transport.

When taking city traffic into consideration, the travel time is hard to estimate due to unpredictable traffic. However, with IRNSS, it is possible to obtain satellite imageries of the live traffic in the

area which can be used to estimate the travel time. The prime stakeholders who would benefit from the IoT based Fleet

Management System are the Bus Transport Corporations with increased revenue and decreased maintenance costs, the society or the passengers, who can rely on buses for a safe and comfortable

means of travel, and the environment, as the fuel consumption and pollution is reduced by the decline in the number of vehicles on the road. Due to poor service and lack of innovation in the field of public transport the current generation is resorting to the use of personal vehicles even for commuting to schools and colleges. It is possible to bring about a change in the attitude among the young minds by establishing a technically advanced system of public transport which also provides hope for a sustainable future.

## 8. Future Research

The IoT based fleet management system has the potential to transform the public transport sector in India by improving the passenger experience. One important step to be taken in the future is, to collaborate with the other sectors, as a way to enhance existing operations. One such collaboration would be with the other public transport corporations in the city such as the metro rail system. If the frequency and the arrival/departure times of the buses are integrated with the metro rail timings, feeder transportation will become more efficient and the waiting time of the passengers can be reduced. They no longer need to worry about the availability of buses, to catch their trains. Another important prospect of the fleet management that can enhance the passenger experience is the provision of Light Emitting Diode (LED) screens at all the bus stops and depots. After processing all the data collected from the individual buses, their location along with their estimated arrival times at different stops including metro stations can be displayed on the screens, which will be of a huge benefit for passengers. Apart from displaying this information, there is also a scope to generate additional revenue through digital advertising on these screens.

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