Demand responsive bus transit with real time planning and visualization

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Abstract

"Big data" is the buzzword of the day for many industries. However, it does carry with it the opportunity to transform public transit model and ease congestion in big cities. In this paper we try to look into the strengths and drawbacks of Demand Responsive Transit or DRT through a simulation study, to explain why big data plays a critical role to improve its usability, and to describe the solution architecture of a "real time demand responsive bus transit system" or RTDRBTS which is consisted of 3 modules: trip request and update, master plan and update, and route update. The modules are intended for use in real-time. Results from actual development and evaluation will appear in the near future.
Keywords: demand responsive transit, big data, dynamic routing and scheduling, real time trip planning.

1 Introduction

"Big data" is the buzzword of the day. However, it does carry with it the opportunity to transform business operations. In transportation sector alone, more temporal spatial data have been recorded in recent years that in all of previous human history. One key enabler behind such data explosion is the wide availability of mobile sensor networks, which has popularized the use of real time Floating Car Data generated by GPS devices or mobile phones distributed over the entire transportation network [1]. Such data has become increasingly useful to ease congestion in big cities. Use cases have been found such as to connect multi-modal journeys, to detect commuter demands via contextual based computing, to visualize request and service hot spots, to forecast traffic bottlenecks, and more [2].

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In this paper, we look into public bus transit, which as stated by a BBC news article [3], has not changed much since our grandparents' days. There are alternatives of traditional fixed route bus service available. Demand Responsive Transit or DRT for example, has been proved by previous simulations conducted in Helsinki that the health, environmental, and the like detrimental impacts of car traffic can be reduced by 50–70% [4] if implemented. Our own simulation results also showed the overall travel distance can be reduced comparing to the fixed route approach. The solution architecture to support DRT for public bus transit is therefore proposed, which is consisted of 3 modules: trip request and update, master plan and update, and route update. All modules will be used in real time. The purpose is to further close the gap between concept and practice to make DRT truly applicable in a larger scale. We are also targeting a Proof of Concept to experiment and evaluate the effectiveness together with local transit operators.

2 Strengths and drawbacks of DRT

Among all existing types of public bus transits, Demand Responsive Transit (DRT) is the most user-oriented. As the name implies, their routes are usually flexible, the bus can go off from schedule to pick up or drop off passengers. DRT is found more in rural communities where the built-up residential areas are scattered. There are also examples of DRT being applied in heavily populated cities. The red mini-bus of Hong Kong, for instance, provides flexible passenger services for local residents. The service is considered a more efficient transportation option. The drawbacks of DRT become more obvious when the size of operating area grows due to the lack of real time planning and notification capabilities. Fail of coordination, optimization and infrastructure support can easily push up operational cost and drag down the quality of service.

Stop	X	y
A	4	1
B	3	1
C	2	1
D	1	1
E	1	3
F	1	4
G	2	4
H	3	4
J	4	4
K	3	2
L	3	3
M	2	2

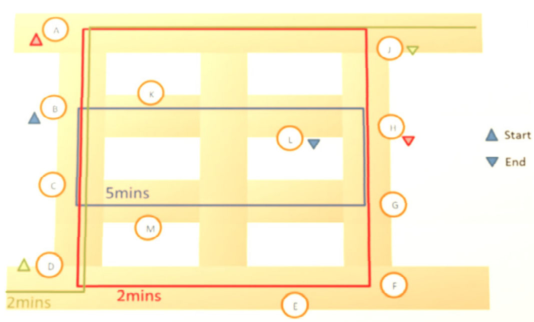

Figure 1: Example of fix route bus transit.

Traditional fix route buses are more common in large cities. The operator dispatches bus by fixed schedule and route, such as the blue line, red line and green line in Figure 1 above. Multiple services could have part of their routes overlapping each other. At certain stops, a commuter will see buses arriving but not going to his destination. In Figure 1 again, the commuter waiting at stop B for a blue line bus to alight at stop L will see more green line and red line buses passing, because green line and red line buses are being dispatched more frequently. The prolonged waiting and frequent attention to irrelevant bus arrivals will easily lead to impatience and frustration.

A first simulation has been done assuming buses were dispatched by fixed time intervals: every 2 minutes for the green line, every 2 minutes for the red line and every 5 minutes for the blue line. 100 trip requests were generated randomly including request time, starting stop and ending stop, within a 60 minutes time window. The result shows the overall travel distance of all dispatched buses are 483 units with average passenger waiting time of 2 minutes. The empty vehicle rate is 28%. In contrast, we ran the simulation again by DRT mode. Assume a bus will always go to the nearest request stop, either a pick up request or a drop off request. The shortest travel distances in between any two stops were calculated by the coordinates of stops which are also included in Figure 1. For example, the shortest distance in between stop D and stop G will be 4 units:

Distance (D to G) = Absolute value of (X coordinate (D) – X coordinate (G)) + Absolute value of (Y coordinate (D) – Y coordinate (G)) = 4

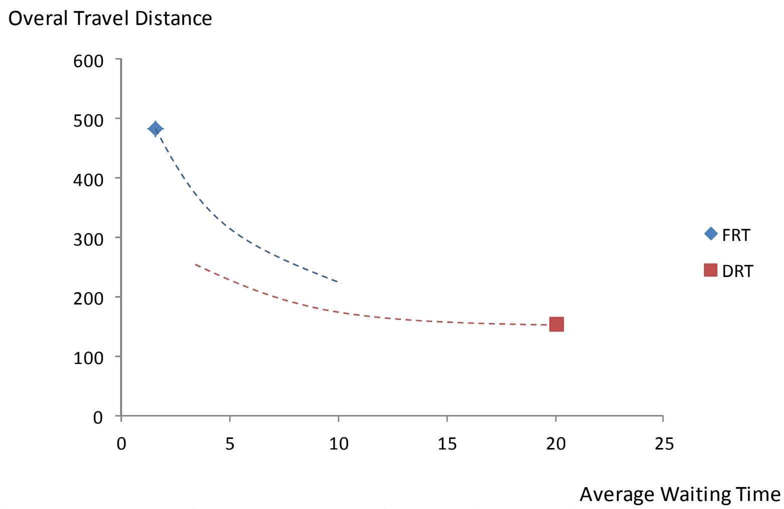

Figure 2: Comparing DRT with FRT.

The overall travel distance in the 2nd simulation for all 100 trip requests is 153 units and average waiting time becomes 20 minutes. The empty vehicle rate is 0% of course. When more buses are added to run in the DRT mode, the overall travel distance shall increase, and the average waiting time shall decrease, as the red trend line in Figure 2 suggests. The trend line shall become flatter, with sharper decrease of average waiting time, when the trip planning algorithm takes into consideration more parameters such as the number of requests in the same route and accumulated waiting time. According [5], multi-agent systems shall help in trip optimization and performance enhancement. Assuming all requests are happening randomly, we can see DRT has advantage over FRT in this simulation setting, that there shall be less travel distance with the same amount of passenger waiting time. The two approaches shall converge when the randomness of passenger request decreases, that if the majority of passengers shall travel by the same fixed route.

Note that this simulation is overly simplified, leaving out important factors such as individual bus capacity and utilization rate. Still, the simulation suggests the trip planning and optimization as the bottleneck of DRT, which causes problems in operations. Considering the constant streaming in of bus location data from the number of buses and that of passenger requests in a relatively large setting, the real time planning and optimization will be an even bigger challenge. There are hence opportunities to reduce the operational barriers of DRT via big data solutions, including storage, analytics and application.

3 RTDRBTS solution proposal

Here we propose a "real time demand responsive bus transit system" as the following: the operator is aided by a central planning system where commuters' travel requests are collected, either via a mobile application accessible through their smart phones, or touch panels installed at bus stops. When requests are collected from stops and commuters including the request time, starting stop and ending stop, the central system then suggests an adaptive dispatch plan for the next approaching bus about the exact route to take as next step. The waiting passengers shall then see the updated schedule of the upcoming bus including all details listed in Figure 3, either from their mobile phones or the panel at the bus

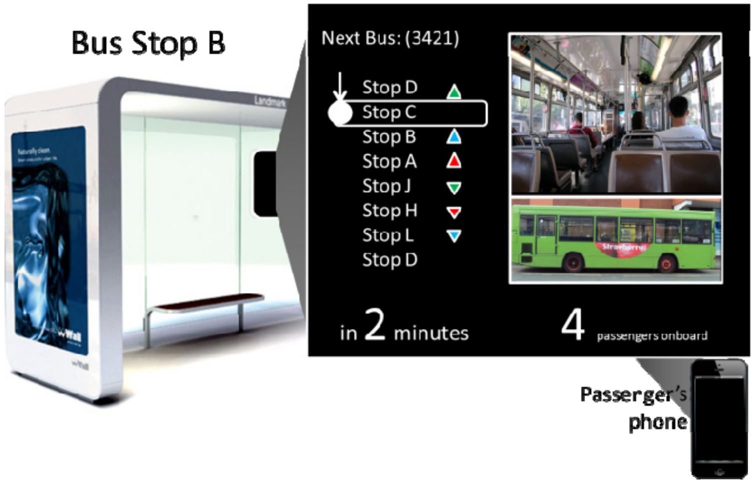

Figure 3: Dashboard panel for commuters.

stop. They will be able to tell whether the next bus is right for them with all necessary information. When the commuters on-board or alight the bus, request status shall change and update the central system. When this bus drives further on and collecting more incoming requests, its route will further change as informed by the central planning system.

By this proposed way, each individual bus will operate differently on the trip level. Hence instead of a line number or name for a fleet of buses, each one will bear just an identification number. The commuter panel will show this number together with the exterior/interior snapshots of this bus to help passengers identify it. The real time location and number of passengers on-board can be collected by telematics devices (or the like sensor systems) installed and streamed into central system via 3G network.

Actual solution architecture is copied as Figure 4 below. Note that constraints setting for individual bus could be different including the maximum number of stops in a single journey, road avoidances due to ad hoc event detections, journey types, and more. All modules are intended for use in real-time. The individual bus locations shall be updated every 10 seconds and the same for trip requests. The trip requests from commuters shall be saved for further improvement and longer term demand prediction. The bus location data streamed in shall not be saved for more than the maximum length of trip duration. Assuming the average number of daily bus rides to be around 3 million in a relatively large city, the

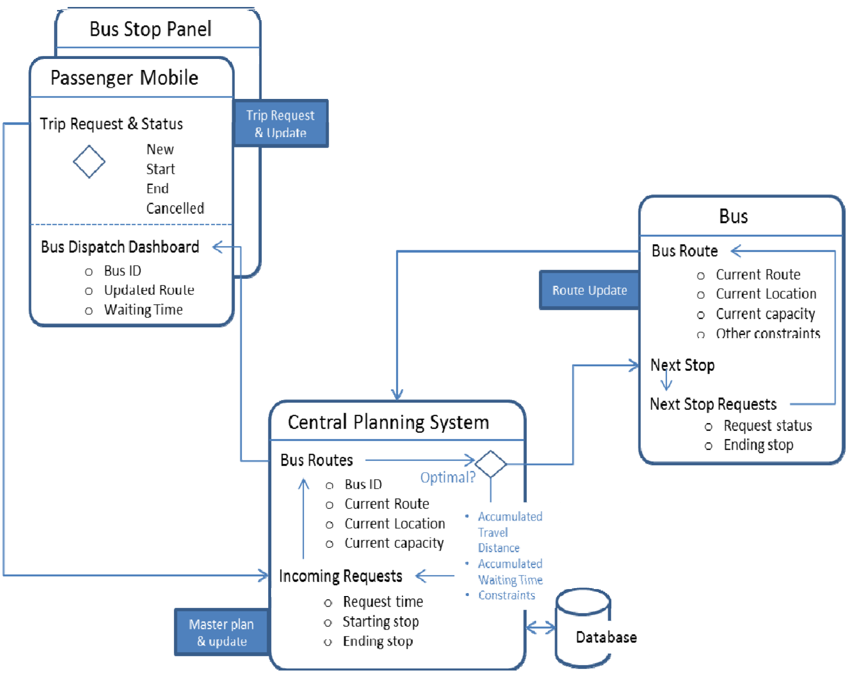

Figure 4: Solution architecture structure.

accumulated data volume is estimated to be around 30 gigabytes for a day. In-memory database will be used to reduce seek time in running the planning modules.

4 Summary

The European Commission (EBSF) has started a grand project for an intelligent, innovative and integrated bus system or short as 3iBS. Similarly the Smart City Solutions of IBM Research has the focus on the systematic improvement of end-to-end user experience and the seamless connection of existing multi-modal transportation. Apart from those big players, various transport authorities are also opening up data access to the public. Mobile applications or ideas of them have been created to better visualize and consume the available sensor data, such as the NYC Live Bus app from MTA app quest. Philips the electronics company has envisioned enabling common street lights as mini bus stops by integrating the Bluetooth technology [3]. Possibilities and opportunities are vast in this field. Previous surveys [6] and our own simulation studies have shown that DRT trip aggregation could reduce travel distance and traffic congestion. We believe DRT is a closer to optimum solution for public transportation problem. It shall lead to more innovations in sustainable urban planning and development.

A lot of academic literature for example [7–10] have laid the theoretical groundwork. Advanced modelling algorithms have been studied considering multi-modal, fleet size, bus capacity and more. Comparing to previous works, we are providing a practical framework to implement DRT, so that to further close the gap in between theory and practice. Sensor networks, real time trip planning and visualization are the key enablers in this framework. A long term demand prediction module will be added as the next step. This module will make use of recurring commuters' requests to determine fleet size and to optimize utilization rate. We are also targeting a Proof of Concept to experiment and evaluate the effectiveness together with local transit operators. It will test public bus transit as one the core playgrounds for big data solutions to showcase their value. Following research findings will be submitted when they become available.

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