Request for Research Funding for FY 2024-2025

Project Number (Research Center Use Only): PTO-25-02

Requesting Office	Transit office	**Priority**	2 of 4 (projects may not have the same ranking – no ties)
Proposed Title	Utilizing Passively Collected Internet of Things (IoT) Device Trajectories to Monitor Transit Travel Patterns		

Justification

In the past decades, there has been an increasing trend in exploiting all kinds of large-scale probe data to generate knowledge for transit applications ranging from long-term planning to real-time operations and control. A few such example applications include transit travel pattern estimation, travel pattern mining, and identification of transit improvement areas. Currently, the rapid development of smartphones and internet use provides a great opportunity to utilize Internet of Things technologies to collect public transit travel patterns data. Internet of Things (IoT) represents the interconnection of the sensors that can utilize various technologies for connection (e.g., Radio Frequency Identification (RFID), Bluetooth, Wi-Fi, LTE). IoT-enabled devices share information about their conditions with the surrounding environment. Subsequently, the information could be sent anywhere in the world through the Internet. Based on the 2021 data from Pew Research Center, 85% of U.S. adults owned a smart phone. The high percentage of smartphone ownership encourages researchers to utilize IoT-enabled devices in capturing travel patterns. As the major applications of IoT, Wi-Fi and BT technologies have the greatest potential to be reliable methods to infer the spatial and temporal trajectories of passengers, the number of passengers, along with their real-time locations.

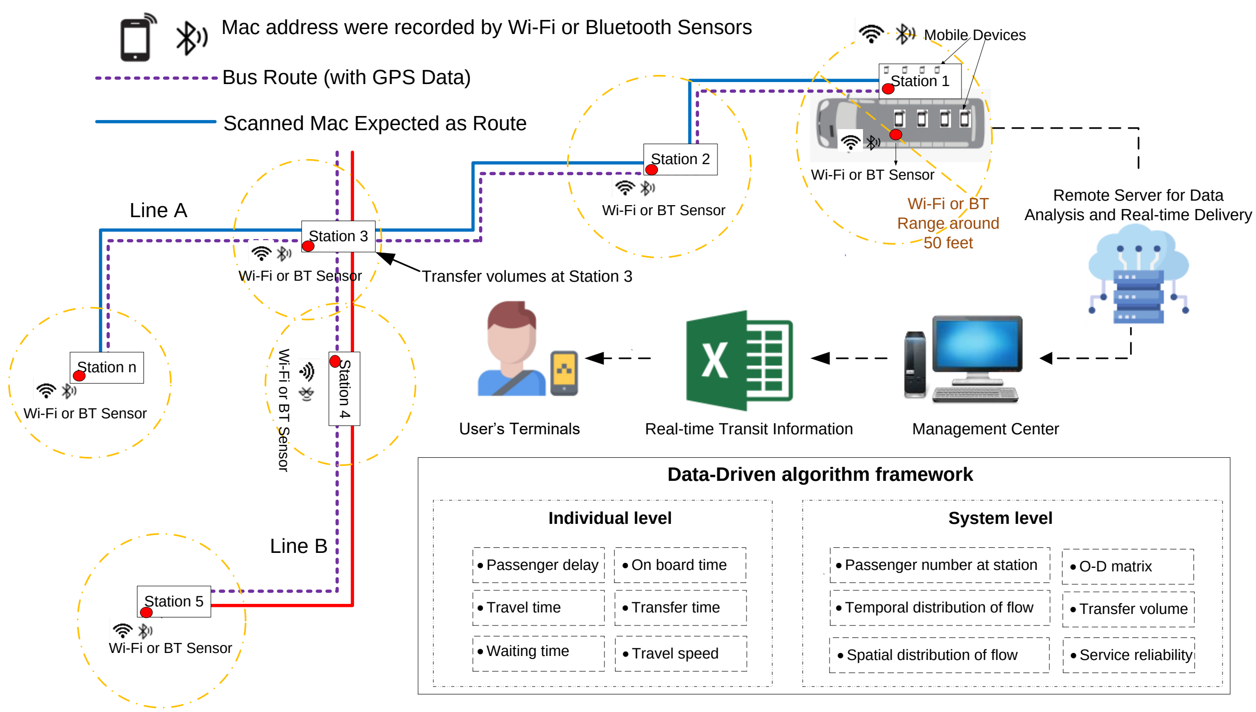

Fig. 1. Monitor System Design for Transit Travel Patterns at Individual and System Levels

System Architecture and Design

To better understand the process of travel pattern collection by utilizing Wi-Fi and BT technology, the system architecture and design are introduced in Fig.1. The basic idea is to detect smartphones by nearby sensors every second and store the unique media access control (MAC) address of each device (carried by passengers) along with the timestamp. Passengers with Wi-Fi or BT function enabled device would be detected within the detection range (around 50 ft radius) in the bus stop and transit vehicles. These unique detected MAC address data (for each passenger) also need to be merged with GPS data from AVL to identify the coordinates of each MAC address (for each passenger). The real-time data will be transmitted from sensing devices to the remote data management and analysis server through cellular networks. Data-driven algorithm framework will be developed to generate feasible spatio-temporal trajectory for each individual passenger by considering multiple data sources, i.e. transit network topology, Wi-Fi or BT probe data, vehicle schedules, and GPS data from AVL. After that, by aggregating all

	individual passenger spatio-temporal trajectory, the proposed framework can present the accurate number of passengers that board or alight at different stops, as well as travel pattern at system levels. **Advantages of Utilizing IoT Technologies** Transit travel pattern information is traditionally collected through onboard surveys, which is labor-intensive, time-consuming, and costly. As a result, the sample size is usually small, potentially resulting in large sampling errors. Since traditional survey data fail to capture the broad variation in spatiotemporal patterns of travel demand, and are only available sparsely (e.g., every quarter or year), many transit agencies start using various Automatic Data Collection (ADC) systems, including the Automatic Fare Collection (AFC), and Automatic Passenger Counters (APC). However, most of the transit smart card system only requires tap-in action, it is hard to infer alighting stops for passengers in real time. Even with both tap-in and tap-out timestamps and stations, it is still very challenging to estimate the most likely route a passenger took based on the limited AFC data. Other technologies, such as APC, can provide highly accurate counting results, but it is reported by a lot of agencies that it requires a substantial investment and maintenance, which results in the coverage area being very limited. Utilizing IoT-enable devices trajectories provides the cost-effective alternative to traditional data collection methods because of the following advantages: (1) it is easy and low-cost to install the hardware and software; (2) the passenger behavior can be observed real-time; (3) the maintenance is negligible after programming and installing; (4) data collection and retrieval is wireless and automated. **Research Objectives and Tasks** The main objective of this project is to design and conduct testing of monitoring transit travel patterns by utilizing passively collected IoT-enabled device trajectories. The proposed design tool can deal with determining boarding stops, transfer stops, and slighting stops for each passenger, but also be able to extract the MAC address for passengers to infer travel patterns at system level. The proposed research problem is not trivial because monitoring transit travel patterns by Wi-Fi or BT technologies is challenging in a real-world scenario. First, since the detection range of Wi-Fi and BT sensor is usually larger than the transit vehicle size, the mobile devices outside transit vehicles are still possible to be detected; Second, some unfavorable situations could happen that would result in the inconsistent and incomplete probe data. Therefore, a spatio-temporal location inference model is on demand to filter the non-passengers' MAC address and analysis how an individual passenger travels on different transit lines and vehicles. Pilot studies will be conducted in Miami-Dade Transit, and Star Metro Transit with different system size, service type, rider characteristic, and information technology infrastructure. By implementing the proposed system, the transit agencies can use transit travel flow information to optimize vehicle dispatching and trip schedule and improve the efficiency of identifying new service needs and evaluate quality of service for current passengers. The real-time transit flow information can be further added to its current mobile app (e.g. Go Miami-Dade Transit app) to help riders plan trips, reduce their waiting time, and improve overall user experience. During the data collection process, encryption approaches to achieve anonymous detection should be conducted to ensure maximum privacy. The information that will be collected will be encrypted at the moment of data collection so that no one will have access to any personal information other than the authorized person who holds the secure encryption key.
Impact	The proposed monitor system can show promise as an accurate and cost-effective alternative to traditional manual surveys. It can help transit agencies facilitate data collection for route optimization, trip planning tools, and traveler information systems. The results of the research would be useful for transit operators to improve the efficiency of track fleet operation, identify new service needs, and evaluate quality of service for current passengers. Furthermore, it can also help riders make travel plan based on the real-time information of transit operation from mobile app or web to reduce their waiting time and improve overall user experience.
Affected Offices/ Districts	Chris Wiglesworth and David Sherman of the Public Transit Office will be involved in the scoping of this proposed project.
Existing Work	Although transit agencies have implemented a significant number of real-time transit information systems, only a limited amount of information about them was available. After searching TRID and RIP databases, the research team found that there are some research studies conducted to obtain useful information on these systems. Reports from these studies include the following: • Guidance for Developing and Deploying Real-time Traveler Information for Transit, developed by Battelle for the Federal Transit Administration (FTA) and United States Department of Transportation (U.S. DOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO), April 30, 2003, U.S. DOT # FTA-OH-26-7017-2003.1 • TCRP Synthesis 48: Real-time Bus Arrival Information Systems, Transit Cooperative Research Program (TCRP), Transportation Research Board (TRB), 2003

	To our best knowledge, there has been little research on using IoT technologies to monitor real-time transit O-D flow data. Existing work has been mostly at utilizing smart card transaction data to infer transit OD information, and very few research can construct the real-time travel pattern for transit system by utilizing IoT technologies as the novel cost-effective methods and present the useful information to the public to improve user experience		
Keywords Used In Existing Work Search **(Cannot leave blank)**	Public Transit Travel Patterns, Wi-Fi and Bluetooth technology, Data-driven algorithm framework, Internet of Things Trajectories		
Related Contracts (Give contract numbers)	BED30 977-03, Evaluating and validating technology options for estimating transit vehicle occupancy in real time		
Funding Request	$180,000	**Anticipated Duration**	Aug. 1, 2024 – Feb. 1, 2026
Project Manager	Chris Wiglesworth	**Contracting Method**	Direct contract with university
Equipment	$ 4,000	Each Wi-Fi sensor set ($100) includes: Micro-computer board: Le Potato (AML-S950X-CC): $60/ unit Micro SD card: 32 GB SanDisk Extreme: $20/ unit Wi-Fi adapter: TP Link W722N v2/v3: $20/ unit Each transit vehicle will have 1 set of Wi-Fi sensors. 40 sets of Wi-Fi sensors are required to place in the transit network (including stations and vehicles).	
Urgency	1 (greatest likelihood of and proximity to implementing results)	Miami DTPW had mentioned the urgent need for exploring new tools for collecting passenger information. Once the proposed research is finished, the results of the research would be useful for transit operators and planners to improve the efficiency of track fleet operation, identify new service needs, and evaluate quality of service for passengers. The user experience would be greatly enhanced if the transit pattern information could be detected and open to the public via mobile app or web.	
Implementability	1 (greatest likelihood of and proximity to implementing results)	This project will develop and design a monitor system by integrating IoT technologies which can be immediately implemented in Miami-Dade Transit, Star Metro. The proposed project will yield a toolkit including promising data-driven algorithm framework, innovative implementation experiments, and comprehensive performance measurement which can advance the development of real-time transit travel pattern data collection and management.	

Project Benefits (Succinct, complete explanation)

This research can help transit agencies to improve the efficiency of track fleet operation, identify new service needs, and evaluate quality of service for passengers. The results of the research can provide some insight for transit operators to refine the current infrastructure in place by better planning and increase bus ridership through better scheduling. It can also improve the passengers' user experience by providing real-time transit travel pattern via mobile app. This project will solidate FDOT as the leader in advancing transit operations in the nation, and further increase the national and international visibility of FDOT's innovation in transit services.

Project Benefits **(Select all that apply and explain)**	**Quantifiable Benefits (units, dollars, etc…if applicable)**	**Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits**
○ Materials Enhancement		
○ Financial Impact		
○ Time Savings	○ Reduced user costs	○ With the real-time transit travel pattern open to the public, riders could better plan their trip based on the data from mobile app or web. Therefore, the proposed system can reduce riders' waiting time, and improve overall user experience.

○ Lives Saved/Injuries Prevented	○	○
○ Other (Explain)	○ Provide cost-effective method to improve the current transit operations	○ The results provided by this research would help decision-makers in FDOT, Districts, local governments, and transit agencies to better understand how IoT technologies can be utilized to monitor real-time transit travel patterns and provide the precise transit pattern information for supporting transit vehicle management and the quality-of-service enhancement.

*Comments should explain and support urgency, financial benefit, and implementability scores