

ASSISTING NEW TRANSIT RIDERS, INCLUDING THOSE WITH DISABILITIES, VIA AN APP DESIGNED FOR ALL

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FINAL REPORT

**ASSISTING NEW TRANSIT RIDERS,
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VIA AN APP DESIGNED FOR ALL**

FINAL PROJECT REPORT

by

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16. Abstract <p>Planning and riding public transportation can be particularly daunting for new transit riders, especially those with intellectual disabilities. Transit agencies are also challenged with balancing the demand for paratransit services and its rising costs. Additionally, paratransit can be limiting to riders - advance registration of 24 hours or more is often required to book trips and there are often long waiting times. Riders receiving travel training to use fixed-route transit gain the freedom to travel more frequently, attend job interviews and work, and become more involved in the community. Therefore, it is in the interest of both the transit rider and the transit agency to support technologies that can aid individuals to travel independently using fixed-route transit. However, it is often difficult to commercialize and deploy technology designed only for individuals with disabilities due to the small market size. This project enabled the large-scale deployment of technology originally created to help new transit riders, riders using a new route, and riders with intellectual disabilities by embedding it in a popular mainstream open-source real-time information transit app OneBusAway. OneBusAway has over 340,000 existing users in seven cities, and, because it is open-source, new features can be added by the universities, transit agencies, and developers that participate in the project. This project addressed several of the most difficult skills for new transit riders to master – the real-time navigation process of recognizing an upcoming stop, requesting a stop, and exiting the bus. Integrating the feature into OneBusAway avoids traditional sustainability pitfalls associated with products designed only for users with disabilities by making it relevant for all transit riders, including those with disabilities. By leveraging an existing app with a sustainable model and support of an open-source community, transit riders with disabilities will have access to a key technology that enhances their quality of life and independence.</p>			
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TABLE OF CONTENTS

1. Introduction.....	8
1.1 Limitations for large-scale TAD deployment	8
1.2 Project goals	9
2. Methodology	11
3. Destination Reminder Design	13
3.1 Setting a destination reminder.....	13
3.2 User feedback collection	15
4. Data-driven unit tests	18
5. Destination Reminder Algorithm.....	21
6. Initial Deployment and Feedback	22
7. Future Work	23
8. Conclusion	26
Appendix.....	27
References.....	28

LIST OF FIGURES

Figure 1 - The process for setting a destination reminder in OneBusAway Android.....	13
Figure 2 - Distance to destination (left), progress along the trip (center), and position on the map are shown to rider.....	14
Figure 3 - Asking the user for feedback on their experience with destination reminders	15
Figure 4 - The user can provide feedback on the destination reminder via a notification on Android N and O.....	16
Figure 5 - A flowchart describing the software that captures feedback from the user for destination reminders	17
Figure 6 - A screenshot from Android Studio showing the data-driven unit tests executing.....	19
Figure 7 - Screenshot of a destination reminder trip visualized in Google Earth.....	20
Figure 8 - The destination reminder algorithm detects the user passing the stop prior to their destination stop	21
Figure 9 - Mockup for additional prompts to the user to collect feedback.....	24

1. INTRODUCTION

Planning and riding public transportation can be particularly daunting for new transit riders, especially those with intellectual disabilities. Transit agencies are also challenged with balancing the demand for paratransit services and its rising costs. Additionally, paratransit can be limiting to riders - advance registration of 24 hours or more is often required to book trips and there are often long waiting times. Riders receiving travel training to use fixed-route transit gain the freedom to travel more frequently, attend job interviews and work, and become more involved in the community. Therefore, it is in the interest of both the transit rider and the transit agency to support technologies that can aid individuals to travel independently using fixed-route transit.

In the late 2000s, USF developed a mobile app for off-the-shelf flip phones called the “Travel Assistance Device”, or TAD. TAD was designed to help individuals with special needs (i.e. physical or mental disabilities) successfully navigate the transit system through cues that are delivered through the device. It used global positioning system (GPS) technology in the cell phone to locate the rider, therefore not requiring any additional infrastructure being deployed to transit vehicles. The wireless communication features of the device allowed positional data to be transmitted from the device to a geographic information system and to one or more interested parties to track the location of the transit rider. It facilitated the delivery of signal, cues or other communication to the transit rider to enable the rider to safely and effectively use the transit system without the immediate presence of a guide or supervisor.

1.1 LIMITATIONS FOR LARGE-SCALE TAD DEPLOYMENT

There were two key limitations to the large-scale deployment of the TAD app:

1. Commercialization - It is often difficult to commercialize and deploy technology designed only for individuals with disabilities due to the small market size. Based on a review of the literature, there has never been a mobile app designed to help travelers with disabilities navigate the public transportation system, at least not one publicly released in more than one geographic region in the United States. In late 2013, the National Center for Mobility Management (NCMM), a program of the FTA administered by Easter Seals, the Community Transportation Association of America (CTAA), and the American Public Transportation Association (APTA), reviewed the current state of publicly available mobile apps designed to help individuals with disabilities travel independently [1]. None of these apps provided real-time navigation guidance for the transit system. The primary reason for the lack of large-scale distribution of such technology is the cost associated with developing and maintaining an app designed only for individuals with disabilities. The National Science Foundation (NSF) I-Corps program helps researchers evaluate the commercial viability and potential customer base for new technologies [2]. During this intense seven-week program, researchers conduct around 100 interviews with variety of

stakeholders in a specific industry to assess current industry needs. Using this feedback researchers can evaluate what new technologies may help fulfill these needs, and if a current technology could be turned into a product as-is or modified to better serve the stakeholders. A recent NSF I-Corps project examined the Travel Assistance Device (TAD) mobile app developed by the CUTR at USF. Based on interviews with transit agencies, travel trainers, and family members of individuals with disabilities, the research team concluded that there does not appear to be a viable business model that would sustain the TAD technology as an independent app so it could be used by transit riders with disabilities.

2. Modifying the destination reminder algorithm was risky and time-intensive – TAD was a location-based application that utilized GPS data, and therefore was subject to handling the variations in GPS data quality that result from varying costs of hardware made by different manufacturers. One device may generate very different GPS data from another even when carried by the same user on the same path – one dataset may closely follow the path of the user, while another may contain various deviations from the user’s truth path, sometimes by large distances. Additionally, in different locations GPS can behave differently due to obstructions that interfere with the GPS signal. To ensure that TAD worked across a different devices and locations, the research team had to physically take the TAD to locations and ride the bus to test it. When TAD did not perform correctly on a transit trip, the research team would edit the software and try the same trip again until it was successful. However, this process could also potentially break the algorithm on a different trip where it worked successfully. The research team would not know about this problem until the user encountered it, triggering yet another change that could break other trips. A better strategy to develop a navigation application was needed.

1.2 PROJECT GOALS

This project enables the large-scale deployment of technology originally created to help new transit riders, riders using a new route, and riders with intellectual disabilities by embedding it in a popular mainstream open-source real-time information transit app OneBusAway. It also deployed a data-driven unit test methodology for the algorithm based on the collection of historical trip data to ensure that changes to the software do not break the algorithm on previously successful trips.

OneBusAway has over 340,000 existing users in seven cities [3], and, because it is open-source, new features can be added by the universities, transit agencies, and developers that participate in the project. This project addresses the most difficult skills for new transit riders to master by leveraging technology from the original USF TAD project – the real-time navigation process of recognizing an upcoming stop, requesting a stop, and exiting the bus. Integrating this “destination reminder” feature into OneBusAway avoids traditional sustainability pitfalls associated with products designed only for users with disabilities by making it relevant for all

transit riders, including those with disabilities. Adding destination reminders to OneBusAway in a way that helps all transit riders is the first steps towards building out additional features in OneBusAway that can help riders with disabilities. By leveraging an existing app with a sustainable model and support of an open-source community, transit riders with disabilities will have access to a key technology that enhances their quality of life and independence.

Additionally, the research team collected data and deployed a data-driven “unit test” approach which can simulate past trips in the lab without boarding a transit vehicle. This approach enables a far faster iterative development and testing cycle and will immediately show when a change to the algorithm “breaks” a previously successful trip. This methodology is critical to the wide deployment of the destination reminder feature in a variety of different GPS environments on a variety of mobile devices that may all have different GPS antenna quality or different pre-processing of GPS signals that would result in different quality real-time location data. A reporting mechanism allowing users to remotely submit trip data to the research team for troubleshooting problems was also created.

2. METHODOLOGY

The project aims at providing a cost-effective solution for individuals with special needs (i.e. physical or mental disabilities) by integrating one technology from the travel assistance device (TAD) app developed by USF with the OneBusAway app. OneBusAway is a popular open-source real-time transit information app that has over 300,000 users in seven cities, including Tampa, FL, Seattle, WA, San Diego, CA, and Washington, D.C..

This project followed an agile software development methodology to integrate the destination reminder TAD feature into OneBusAway. To accomplish this over 38,000 lines of code and data were added to the OneBusAway app to implement the feature and ensure the app does not have any crashes or loss of functionality due to the new feature. This software is available as open-source software on the code sharing site GitHub [4]. In order to make sure of this, an intensive testing strategy was designed and the app was rigorously tested. During this process, several issues were identified and fixed, which are further described in the Appendix A section.

A new data-driven unit testing feature was developed to enable data collection from within the OneBusAway mobile app while it was running on a real device so it could be remotely submitted to the research team for evaluation. After new data is collected, the research team adds it to the test database if the user has confirmed that the algorithm performed correctly. The collected data can then be replayed via a simulation software in the lab, and therefore reproduce field conditions when testing the algorithm without having to travel the same path repeatedly in the real world. If the user indicated that the algorithm did not perform correctly for a particular trip, the research team can step through the data from the trip within the algorithm source code to determine exactly what happened that caused the algorithm to fail. At this point, modifications can be made to the algorithm and all the previous tests executed again to ensure that changes do not break performance on previously recorded trips.

During this project the research team also worked extensively with USF's Division of Patents and Licensing to acquire permission to openly share the source code for the software that implements the two patents owned by USF for the original TAD technology: U.S. Patent # 8,169,342 "Method of Providing a Destination Alert to a Transit System Rider" and U.S. Patent # 8,138,907 "Travel Assistant Device". The portion of the source code that implements the destination reminder algorithm is now publicly available in the OneBusAway Android application under the Apache v2.0 license.

The team also completed the USF Institution Review Board official application process to determine if research performed for this project was "human-subject" research. Therefore, the team also prepared the IRB paperwork to determine if USF concludes that the work is human-subject research. This required the team to complete the "Social / Behavioral Investigators and Key Personnel" training course at <https://about.citiprogram.org/en/homepage/> and complete the

online application and supporting documents. Ultimately, after review USF determined that this research was not considered human-subject research.

3. DESTINATION REMINDER DESIGN

3.1 SETTING A DESTINATION REMINDER

As shown in Figure 1, the destination reminder can be activated within the OneBusAway app using the following steps:

1. Tap on the arrival time for the bus you plan to board (first screen)
2. Choose "Show trip status" to show the stops on that route (second screen)
3. Long press on the stop you want to receive the destination reminder for (third screen)
4. Tap "Yes" when asked if you want to set a destination reminder (fourth screen)

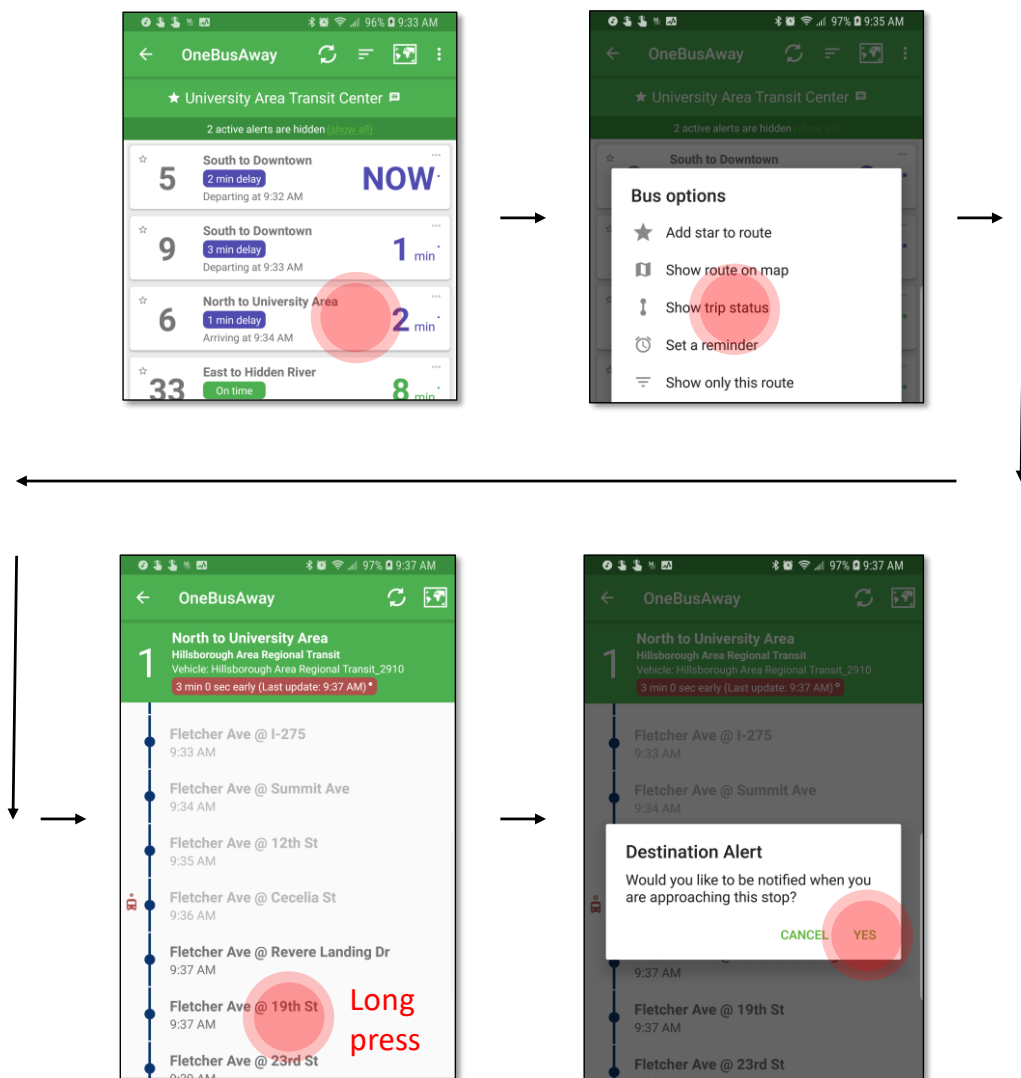


Figure 1 - The process for setting a destination reminder in OneBusAway Android

While the destination reminder is in beta testing the user is shown a warning screen indicating that they should exercise caution and always be aware of their surroundings when using the feature. As shown in Figure 2, a notification is then added to the top notification panel of the device, which can be accessed by dragging down from the top of the screen. The notification shows the distance remaining until the bus stop and will count down as the rider approaches their destination. A flag icon next to the destination stop is also added to the trip status view, which the user can compare to the icon of the bus as it continues on its progress. The user can also view the position of the bus on the map, which will also show their own location as a blue dot.

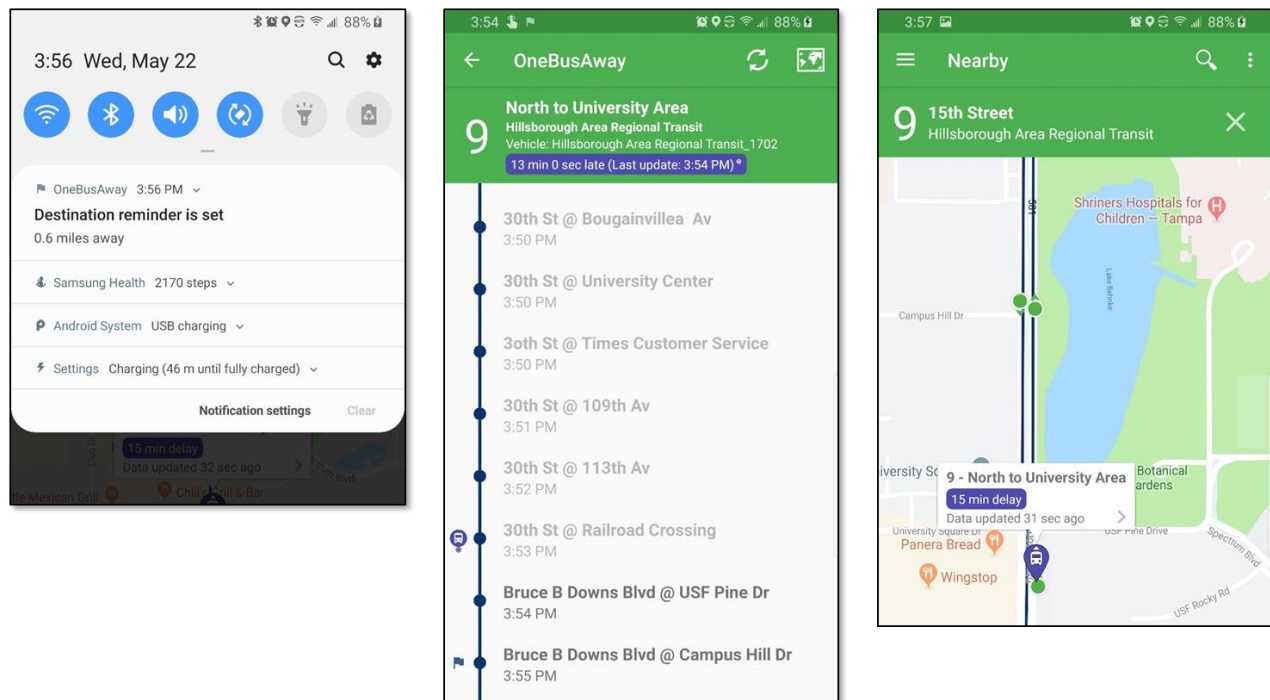


Figure 2 - Distance to destination (left), progress along the trip (center), and position on the map are shown to rider

When the rider comes within 200 meters of the stop prior to your destination, the phone will vibrate and the user hear an announcement to “Get ready” several times. A “Get ready” notification will also be shown visually on the screen. When the vehicle departs from the stop prior to the rider’s destination stop the phone will vibrate and the user will hear an announcement to “Exit at the next stop” several times, which will also be shown visually as a notification.

If the user doesn’t have location services activated on their device when they attempt to set a destination reminder, or if they have low-accuracy services activated (i.e., if satellite-based positioning is inactive), the user will be prompted to enable high accuracy satellite-based positioning in their Android system settings.

3.2 USER FEEDBACK COLLECTION

To facilitate the large-scale deployment and quality-control of the destination reminder feature, as well as the data-driven unit testing methodology, a user feedback mechanism was created.

Upon exiting the transit vehicle, the user is notified to share his experience with the destination reminder feature (Figure 3). When prompted “Were you notified at the right time?”, the user can tap on either “Yes” or “No” and add a short description of his or her experience. The user is also asked to grant permission to send a trip data file to the OneBusAway server (discussed in detail in the next section).

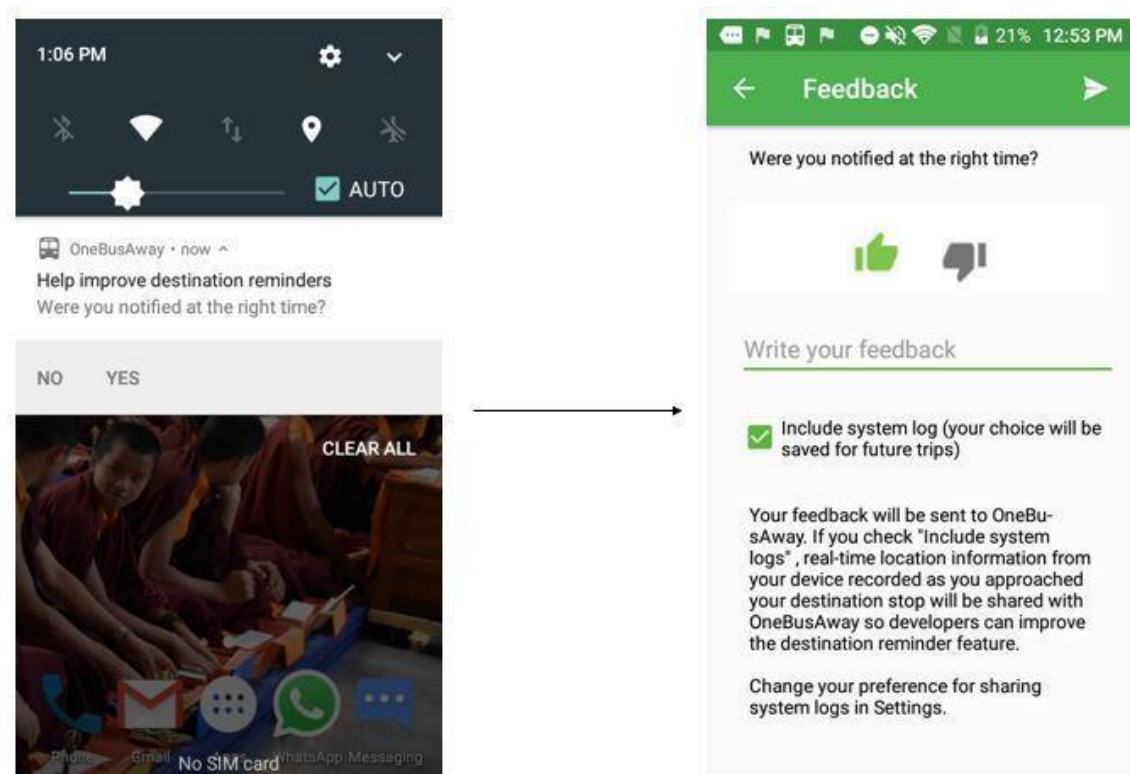


Figure 3 - Asking the user for feedback on their experience with destination reminders

Another variant of the feedback notification has been created for Android N and O that allows users to directly provide feedback from the notification itself instead of being redirected to the feedback screen (Figure 4). This allows the user to save time when submitting feedback by not having to wait for the application to open before they can submit feedback. Devices with this ability can change their preference for sharing trip data files from the app settings.

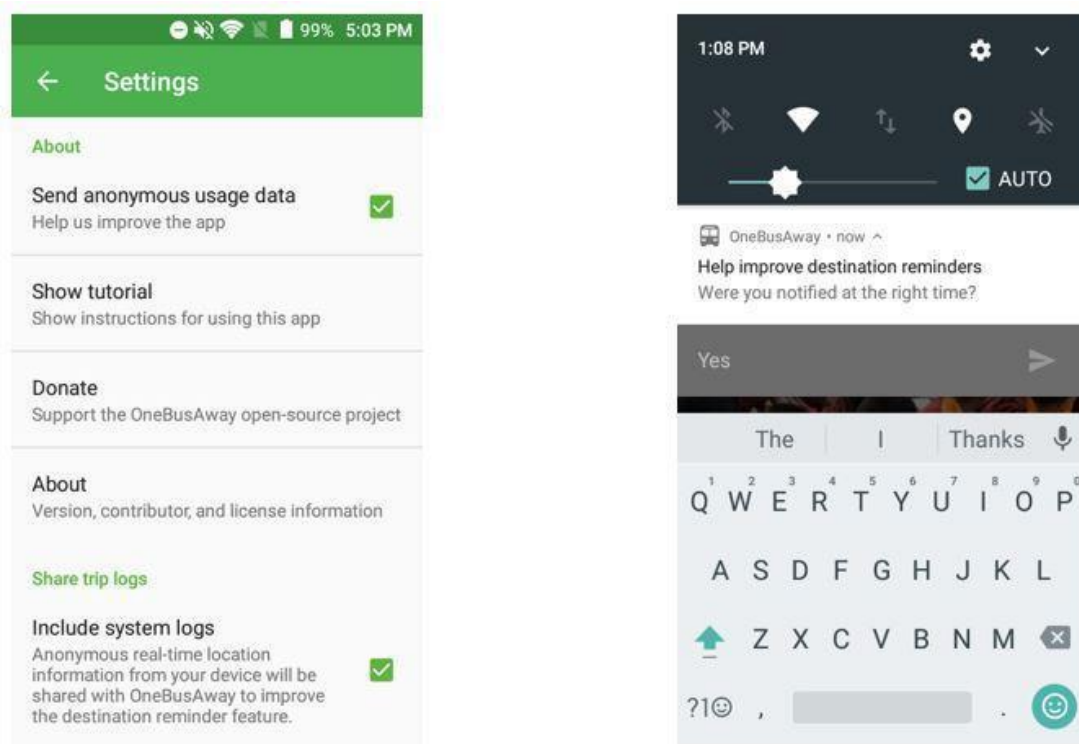


Figure 4 - The user can provide feedback on the destination reminder via a notification on Android N and O

The feedback collected by the notification is then logged using Firebase Analytics and if the user chooses to share the trip data file, the file is uploaded into Firebase Cloud Storage. These files can be used by developers to troubleshoot any issues transit riders may have encountered with the destination reminder feature and can be loaded into the data-driven unit testing framework to ensure that future changes to the algorithm don't break previously successful trips.

A complete flowchart showing the process of collecting feedback from the user within the OneBusAway app is shown in Figure 5.

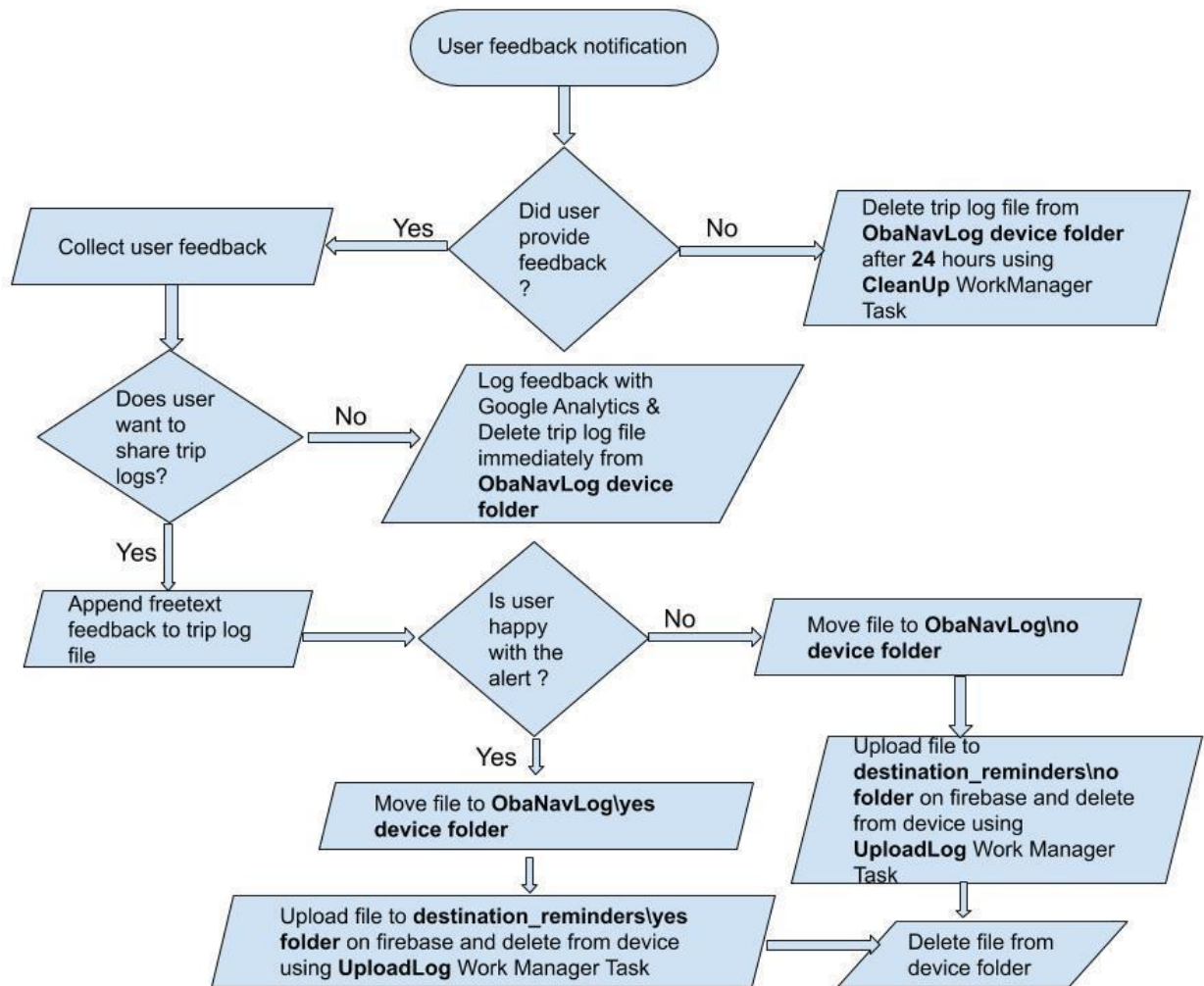


Figure 5 - A flowchart describing the software that captures feedback from the user for destination reminders

4. DATA-DRIVEN UNIT TESTS

After the user sets a destination reminder, OneBusAway will begin to monitor the device's GPS location. When the device is a predefined threshold distance away from the second to last stop (currently set to a radial distance of 300 meters), the app will start recording the location (latitude and longitude) and speed of the device along with other location metadata to a comma-separated value (CSV) trip data file. The data recording ends 30 seconds after the user is alerted to exit at the next stop. No identifying information about the user is recorded - only metadata about the transit trip, 2nd-to-last stop, destination stop, and location information is captured.

An example of the type of data that will be collected is given below:

```
Hillsborough Area Regional Transit_194232,Hillsborough Area Regional Transit_849,28.032698,-82.433939,Hillsborough Area Regional Transit_5509,28.03268,-82.432393,,,,,
```

```
0,FALSE,FALSE,35833084925236,1468797302000,28.032712,-82.39605,-1,5.37269,265.799988,3,11,gps
```

```
1,FALSE,FALSE,35833084925236,1468797302000,28.032712,-82.39605,-1,5.37269,265.799988,3,11,gps
```

```
2,FALSE,FALSE,35833084925236,1468797302000,28.032712,-82.39605,-1,5.37269,265.799988,3,11,gps
```

```
3,FALSE,FALSE,35834084896486,1468797303000,28.032715,-82.396107,-3,5.72,268.5,3,11,gps
```

```
4,FALSE,FALSE,35834084896486,1468797303000,28.032715,-82.396107,-3,5.72,268.5,3,11,gps
```

```
5,FALSE,FALSE,35835087998048,1468797304000,28.032723,-82.396179,-4,6.75003,272.299988,4,11,gps
```

```
6,FALSE,FALSE,35835087998048,1468797304000,28.032723,-82.396179,-4,6.75003,272.299988,4,11,gps
```

```
7,FALSE,FALSE,35836086698308,1468797305000,28.032726,-82.396303,-3,9.541341,271.5,3,11,gps
```

The first line of the file includes the following information in this order (delimited by commas):

1. trip ID
2. destination Stop ID
3. latitude of the destination
4. longitude of the destination
5. stop ID of the Stop before the final Stop
6. latitude of the stop before the final stop
7. longitude of the stop before the last stop

Starting from the second line, here are the columns that contain the position data:

1. coordinateID - unique ID for each location fix in the file
2. getReadyFlag - true if the "Get Ready" alert has been announced to the user, false if it has not
3. existAtTheNextStop - true if the "Exit at the next stop" alert has been announced to the user, false if it has not
4. the time in nanoseconds since the application started
5. the time in UTC
6. latitude
7. longitude

8. altitude
9. speed
10. bearing
11. horizontal accuracy
12. number of satellites used in fix
13. location provider

OneBusAway is a navigation-based app and testing any new feature requires a user to take actual trips on buses enlisted in various routes of the app. This requires a significant amount of time and it is difficult to identify the possible root cause of issues.

A data-driven unit testing framework for the OneBusAway Android app was developed, which uses AndroidJUnitRunner. Unit tests help identify any potential problems that are introduced with code changes by executing the new code against previously saved trip data from actual bus riders to ensure the “Get ready” and “Exit at the next stop” commands are still triggered at the appropriate times. In order to identify and fix issues more efficiently using Android Studio, a separate module called “NavigationTest” was implemented to simulate bus navigation by reading trip data coordinates collected in CSV formatted files (Figure 6).

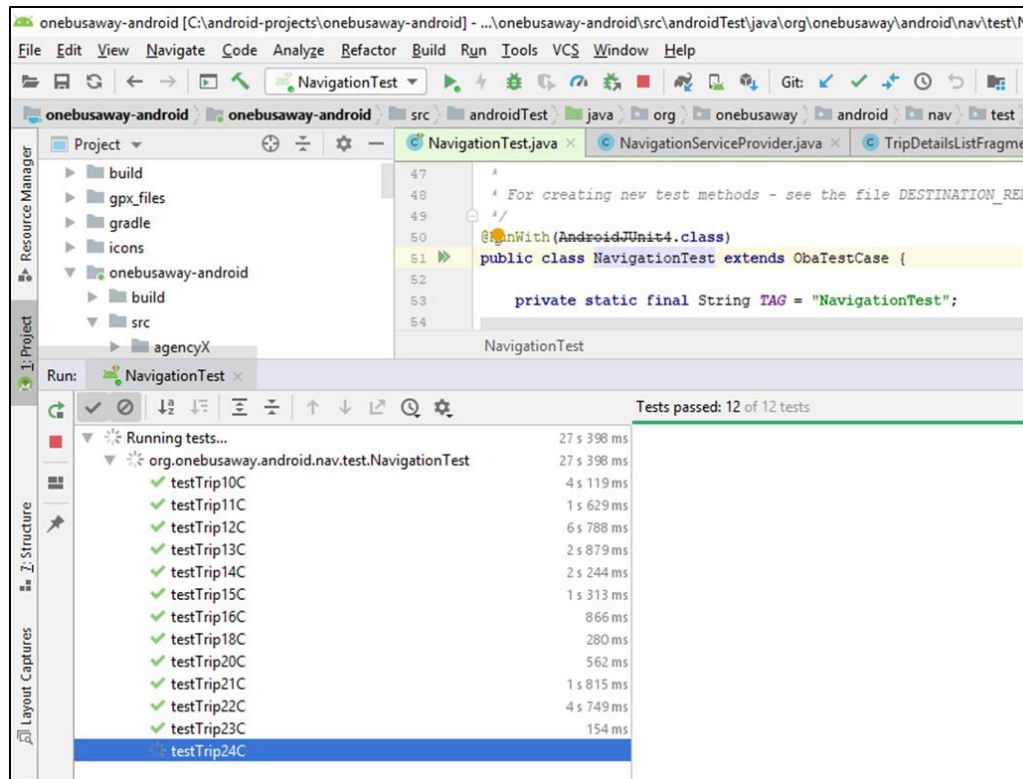


Figure 6 - A screenshot from Android Studio showing the data-driven unit tests executing

A software tool to convert CSV trip data to the Keyhole Markup Language (KML) so it can be viewed in Google Earth, available online at <https://github.com/CUTR-at-USF/onebusaway-nav-csv-to-kml>, was updated to read the most recent trip data format from the OneBusAway app. This allows each trip to quickly be visualized in Google Earth to view exactly where the user was reminded to exit the vehicle (Figure 7).

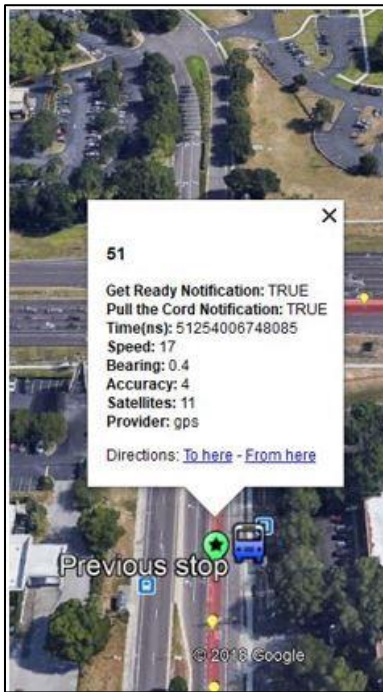


Figure 7 - Screenshot of a destination reminder trip visualized in Google Earth

Data of 55 different trips were collected and the corresponding test cases were created in the “NavigationTest” module. Then each of these trips was simulated on Android Studio and several issues were identified in the first version of the destination reminder algorithm. Several failing tests were fixed, and several additional bugs (floating point numbers written to log files with commas instead of periods, numbers written to test files in exponential notation instead of decimal form, logic when triggering navigation, etc.) were identified and fixed.

The algorithm was also modified in order to handle duplicate location data and prevent early triggering of the destination reminder. Also, changes were made in the algorithm in order to handle cases where the second to last stop and the destination stop were in close proximity to each other. With the implementation of notification channels in OneBusAway, all the test cases were executed again to figure out if the changes had caused any existing functionality to break. This process saved significant time and cost over the old method of field testing the software every time potentially breaking changes were made.

5. DESTINATION REMINDER ALGORITHM

The destination reminder algorithm calculates the change in distance from the second to last and the last stop in order to notify the rider about the arrival of their destination stop.

- Once the rider boards the bus and the bus starts approaching toward the destination the Navigation Service tracks the GPS location change of the bus.
- With every location change, the algorithm checks the proximity of the current location of the bus from the second to last stop and the destination bus.
- If the distance is less than the `DISTANCE_THRESHOLD` (currently set to a radial distance of 200 meters from the second to last stop), the “Get ready” alert is triggered to the user.
- After the bus crosses the second to last stop and is more than 50 meters away from it, the rider is notified to exit the bus at the next stop.

The algorithm is designed in a way so that it can handle the cases where the bus does not halt at the second to last stop. For this, along with tracking the distance of the bus, the speed of the bus is also recorded and checked in order to notify the rider at the appropriate time. This also helps the algorithm to handle corner cases where the bus stops are located close to each other and notify the user at the right time.

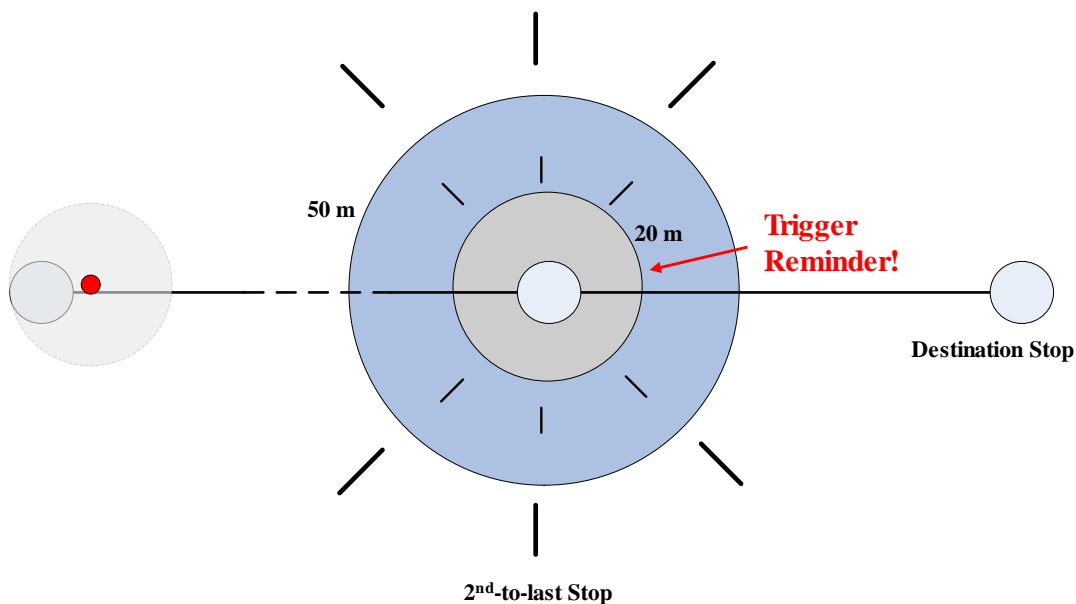


Figure 8 - The destination reminder algorithm detects the user passing the stop prior to their destination stop

6. INITIAL DEPLOYMENT AND FEEDBACK

The OneBusAway Android application with the new destination reminders feature was deployed to a beta testing group consisting of 661 users on April 15, 2019.

During testing, the research team identified that a user wasn't prompted to turn on GPS when they started a trip, in which case they were never notified to exit the bus. In order to address this issue, a new dialog system was implemented to check to see if the user has location enabled on their device, and if so, what accuracy level is enabled. Based on the various states the user is now given a customized message so they can turn location on to the correct setting. Additionally, there was a problem with the flag indicator for the destination reminder on the "trip status" screen not being removed when the user stopped the trip. The flag was fixed to be correctly removed when the user ends a trip.

During testing on a Pixel 2 device with Android 9 a user reported that the destination reminder feature of the app didn't seem to keep running – it would not trigger the reminder (vibration or notification), the destination flag icon on the trip status screen would disappear, or the notification would disappear from the top of the screen or wouldn't respond to taps. When troubleshooting this issue the research team also found that tapping on the notification would temporarily stop the navigation service from running in the background. The issue with the destination reminder service not consistently working in the background on Android 9 devices was traced to a bug in the app where the underlying Android Service that monitors the user's location in real-time wasn't configured for foreground execution. On newer Android versions, if a Service is only executing in the background (and not foreground) the Android operating system may terminate or suspend that service at any time. This may be why some users reported that the destination reminders worked fine, while a few reported these issues.

To resolve these issues, the research team configured the navigation Service to run in the foreground and also changed the configured of the notification so the Service wasn't temporarily ended when the notification was tapped. Additionally, more analytics events were added to the app so the research team can better observe the different stages at which the user activates the destination reminder feature and finishes their trip to help with usage tracking and troubleshooting problems.

A second beta version with the above improvements was released to the beta testing group on May 23, 2019.

7. FUTURE WORK

As discussed in the previous section, following the initial beta release of the destination reminders feature several enhancements were deployed in a second beta release. Future work can further monitor user feedback and destination reminder analytics in preparation for deployment to all OneBusAway Android users.

During testing of the destination reminder feature potential improvements were identified that can be explored in the future. For example, the currently implemented destination reminder feature does not provide the facility of saving a trip and repeating it every day. So, to enhance the destination reminder feature, an option for “saving a trip” or “scheduling trips” can be provided that will save the time of a rider who takes the same trip frequently or help a rider with cognitive disabilities ensure that they reminder is always easily accessible [6]. This enhancement is similar to the setting up a bus arrival reminder that is already implemented in the OneBusAway app – however, the same challenges exist in terms of needing to be able to handle changes in trip IDs when agencies update their schedule. This is particularly important for users with intellectual disabilities as they may not be able to recover quickly if they are expecting a reminder to work but it fails due to a transit agency data update. The issue of handling trip ID changes in transit agency schedule updates is discussed in detail in [6].

The OneBusAway app also notifies riders who use the plan a trip feature to find the best route to a destination in the case when the real-time status of the trip changes and the previously shared route may be running early or late. However, a drawback of the current “Plan a trip” keeps notifying the rider of a better route with the “We found a better trip plan” notifications even after the rider has already started his trip [7]. Since the destination reminder feature is tracking the rider’s device location, this data can be utilized to identify and filter or cancel the “We found a better trip plan” notifications that are no longer useful to the user. This will help to improve the usability of the app and stop generating unnecessary notifications.

The user feedback notification created to collect the user feedback after a trip has been completed can be further enhanced by adding an option of providing the feedback at a later time that is more convenient to the rider. When a notification is generated the user has an option of swiping it away. In the current implementation, if the user decides to swipe away the feedback notification, the destination reminder can no longer collect the feedback for that particular trip and use it to improve the feature. So, as an enhancement to facilitate additional feedback collection from users, a “snack bar” can be added to the bottom of the home screen of OneBusAway requesting the user to provide feedback of a previously taken trip (Figure 9). Thus, the probability of feedback collection will be increased and the data can be used for analytics and improvement of the app.

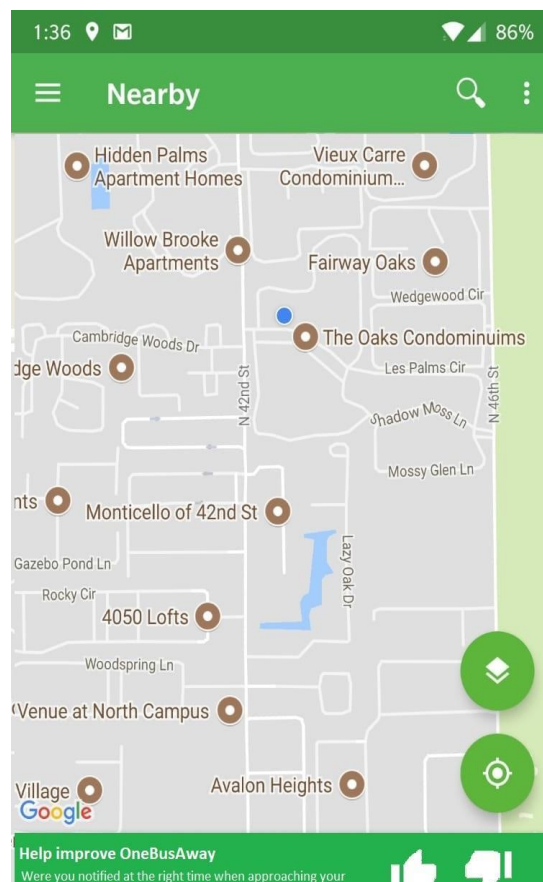


Figure 9 - Mockup for additional prompts to the user to collect feedback

After examination during this project, the research team determined that the most efficient way for a user to set up destination reminders for transfers was to integrate the destination reminder with the trip planning feature of OneBusAway. This could be accomplished in future work.

One tester requested that the research team add a way for the user to silence the reminder after it begins speaking. Currently, the “Exit the vehicle at the next stop” audio will play several

times in a row. A way to immediately silence the reminder, similar to how a user may silence a sounding alarm, could be added. Another user requested at the notification be louder – it may be helpful to provide a configurable volume option to the user. Additionally, the app could prompt the user with a large visual alert on the main screen in addition to the notification visual reminder to be more prominent. After discussion with one tester, it became clear that they were confused by the notification text with a title of “Destination reminder is set” and body text of “0.6 miles away” – they interpreted the “0.6 miles away” as the distance threshold at which the reminder would notify them, not the real-time distance between the user and their destination stop. Further discussion with other users should be conducted before modifying the text to better understand if many other users interpret the text this way as well.

Finally, the destination reminder feature is tested with the help of trip data CSV files that were collected by taking real-time trips. However, the research team identified that in case the trip data file contains empty newlines, the tests are unable to parse the coordinates and this will cause the tests to fail [5]. While empty new lines aren’t generated automatically in the current automatic user feedback process, if test data is added manually in the future this situation could potentially be encountered. Therefore, in the future the testing code base could be modified in order to successfully handle empty newlines in trip data files.

8. CONCLUSION

The implementation of the destination reminder feature within the OneBusAway Android app provides a feature originally designed for transit riders with intellectual disabilities to the public. This feature paves the way for the additional integration of features designed for users with disabilities into an app in a cost-effective way that can benefit any transit rider.

During the implementation of the feature, the development team had to review the existing code of the app and added over 38,000 new lines of code and data to support destination reminders, the feedback process, and the data-driven unit testing framework. Testing was performed by the research team to identify and fix several issues that might break the algorithm. Each of these issues required the collection of real-time trip data and debugging the code to modify the algorithm to handle corner cases. With every issue fix, automated testing of the whole app was performed using the data-driven unit testing framework to ensure none of the existing functionalities broke due to the change. The destination reminders feature was made available to 661 beta testers for further evaluation and also to identify priorities for future enhancements to this feature, including saving a recurring destination reminder, enhancing real-time trip planning updates (i.e., "we found a better trip plan"), additional feedback prompts for past destination reminders, ability to save destination reminders directly from trip plans (including transfers), and an ability to silence the reminder immediately.

APPENDIX

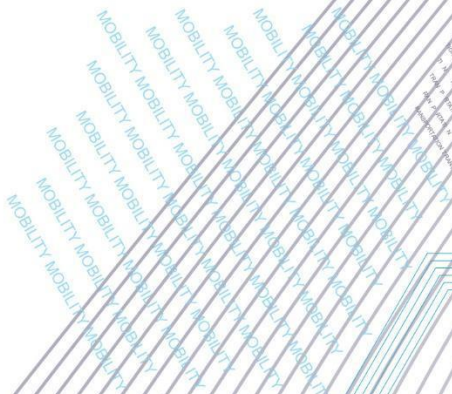
An advantage of using the OneBusAway Android app for delivery of a new feature is that a new application does not need to be developed from scratch, and a large user base already exists to which the new feature can be quickly deployed. However, using an existing app for deployment of a feature also means that various issues related to the app as a whole may be encountered that cause delays in launching the new feature. Several of these challenges encountered during this project are outlined below.

In November 2018, Google implemented a new policy that required all applications to target Android 8.0 or higher in order to distribute updates via Google Play [8]. At that time, OneBusAway was targeting Android 5.0, and therefore the app had to be updated to target Android 8.0 for the destination reminder algorithm implemented in this project to be distributed to users. Therefore, the team had to modify the OneBusAway Android app to target Android 8.0, which included the requirement for handling runtime permissions, channels for notifications, and new restrictions surrounding app background execution. The team also migrated Android support libraries to Android X and tested for any issues as part of this work. After these modifications were complete the research team was able to release an update to the app via Google Play that contained the destination reminder feature.

After Firebase Cloud Firestore was chosen as the online data store for user feedback collection, a potential conflict was identified between Microsoft Embedded Social SDK used for social features in OneBusAway Android and Firestore. A modification was proposed to Microsoft and changes had to be made in the OneBusAway Gradle build file and extensive testing had to be performed of the app to ensure it worked as intended.

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