Is Turbulence Affecting Your Network?

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Abstract – In-Flight connectivity (IFC) on commercial airplanes is in growing demand as people expect pervasive, high-performance access to the Internet. The highly unique IFC environment – with planes flying at high speed, thousands of feet midair – challenges efforts to provide a performing, reliable Internet connection. Turbulence is one of the exclusive features of the IFC context whose potential impact has been, so far, overlooked. The goal of this project is to test the potential impact of turbulence on IFC performance. To this end, we have developed an application that measures velocity of a device to detect sudden changes in speed during turbulence events, records user-validated turbulence detection, and monitors network performance during flight. Using data collected by this app, we plan to study the correlation between user-validated turbulence events, their intensity levels, and network performance.

Keywords – In-Flight Connectivity, Turbulence, Wi-Fi

I. Introduction

Internet connectivity during in-flight experience is expected to be reliable and continuous as consumers often pay for such services. Many airlines have the intent of providing In-Flight connectivity (IFC) while airborne at high altitudes traveling hundreds of miles per hour [1], which invites the challenge of maintaining a consistent link to the Internet in addition to the effects of changing distance between access points and a moving aircraft. Turbulence is distinctive to these in-flight experiences, which we propose to have an impact on network performance. In order to observe that effect, we have built an application to collect information on a device's velocity to detect sudden changes in speed of the plane if turbulence is encountered, record user experience of potential turbulence events, and document network performance statistics. The application relies on user-validated turbulence detection to determine if the user felt sudden movements or effects of turbulence on the airplane during their flight experience. Once the flight finishes, the application sends a report of the data automatically using velocity detection.

This paper is organized as follows: In the next section, the methodology of these observations within the application are described and followed by the project's current status. Afterwards, discussion of combating potential issues is presented and we conclude with possible future additions to the application.

II. Methodology

In this section, we describe how data collection is crowdsourced through the application. We focus attention to aspects of IFC performance and turbulence events from the crowdsourced data to then conduct correlation analysis.

The application gathers statistics using in-flight connection services by sending pings to www.google.com, performing DNS queries, and recording traceroute hops to observe delays in wireless network performance. In regards to turbulence, the application monitors velocity changes using the device's accelerometer to assist in quantifying turbulence. We suspect that accelerometer readings violently change as turbulence is encountered. As we see in Figure 1, the user is asked to validate turbulence detection and its intensity to establish consistency from sensor readings.

Our analysis looks for two characteristics of performance: latency in network response and packet loss from a lack of network response. If turbulence was to be detected on a flight, we compare the time of occurrence with the recorded IFC performance statistics to observe if delays and high packet loss were concurrent with the potentially long, intense turbulence.

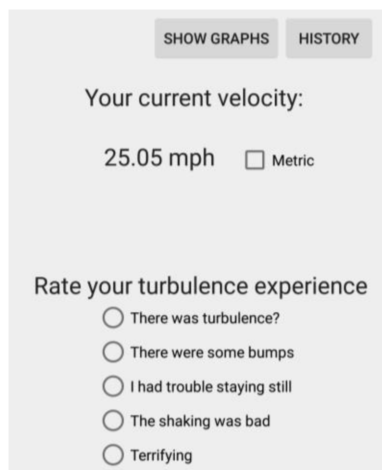

Figure 1: The active screen lets the user view their real-time velocity (in mph or m/s) and asks for user-validated turbulence detection and the experienced intensity level.

III. Project Status

Currently, data collection is ongoing. With the flights recorded so far, none have shown significant signs of turbulence. Further developments of the application will be made to add functionality, which is discussed in Section 5.

With our application, we propose means of quantifying turbulence using velocity tracking. In Figure 2, as readings from a device's accelerometer values change, the velocity graph updates in real time to track potential sudden speed changes. The user can scroll left and right to view detailed changes on the line graph. Once a flight is finished, recordings

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ISSN, ISBN: (to be inserted by LACCEI).

and statistics will be automatically submitted. This can be detected from when an airplane slows down to less than 20 mph.

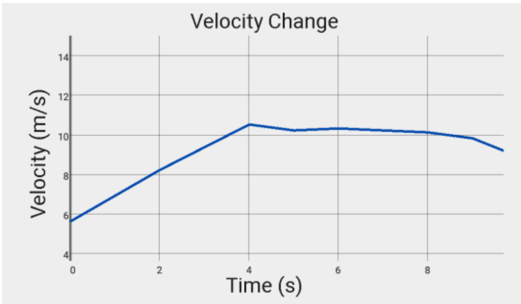

Figure 2: The "Show Graphs" screen displays changes in velocity on a scrollable graph.

IV. Discussion

Approaching this problem without access to more advanced sensors on the plane puts us at the mercy of the abilities of the user's phone. Crowdsourcing limits the number of routes that we observe and it limits the geographical area that we cover since we do not have much control over the users that download our application. Making the amount of user input from the application representative of the average user experience on a plane will require observing both user input and turbulence condition, altitude, and sky condition reports from aviation websites, specifically FlightAware.com and AviationWeather.gov. This combines qualitative and quantitative data in order to produce a more well-formed report of turbulence experience. If a user encounters turbulence during Internet usage, this app can run a service in the background, notice a major change in movement, and record the events in quantitative means using the accelerometer as before.

A couple of confounding factors that can explain packet loss in IFC environments are IFC networks are often congested and there exists sources of wireless communication interference inside an airplane. For instance, several users inside an active airplane trying to access the Internet creates the possibility of overloading the on-board router to cause major queuing delays and packet loss. In a similar situation, several devices that have high proximity can cause interference between frequencies of wireless communication (e.g. Wi-Fi, Bluetooth signals, infrared devices).

Detecting turbulence is another challenging factor for correlation analysis with IFC performance. For the analysis, the time granularity must be small, which requires turbulence detection to be almost in sync with low IFC performance. While tracking velocity, the user may drop or shake their phone to cause outliers in the dataset. Additionally, low intensity turbulence may be subtle on graphs and the user may report no turbulence as a misjudgement. As mentioned before, using weather and wind reports from aviation websites can leverage turbulence detection to reduce questioning packet loss.

V. Future Work

There is little analysis on the factors of network performance in-flight, and adding functionality to this application will play an important role of identifying those qualities.

A. Implement Aviation Website Background Readings

Aviation websites can help track altitude, weather, and sky conditions to produce consistent reports from aircrafts with user reports. These will add a qualitative measurement to correlate performance with the presence of turbulence, which may improve turbulence detection.

B. History of Flight Data

Creating an option to view device-specific history of flight performance in the application will allow users to understand in-flight connectivity quality of service in conjunction with their personal experiences. It is possible to compare different airlines and their IFC performance statistics for those who prefer a higher quality Internet service [2].

C. Possible Connection Remediation

Packet loss during a turbulence event can cause errors, but using a transfer layer protocol that handles loss recovery more strategically than TCP may result in less frequent loss for a trade off in latency. In previous work, the push for an IP based standard recognized how IFC systems can become increasingly reliable and supports higher data rates than the systems currently in place [1].

Acknowledgment

This material is based upon the work conducted by the AquaLab at Northwestern University with support from the Summer Research Opportunity Program hosted by The Graduate School at Northwestern University. We would also like to thank James Newman for data collection.

References

[1] J. P. Rula, F. E. Bustamante, and D. R. Choffnes. When IPs Fly: A Case for Redefining Airline Communication. In Proc. of HotMobile, 2016. http://dx.doi.org/10.1145/2873587.2873605

[2] J.P. Rula, J. Newman, F.E. Bustamante, A.M. Kakhkiz, and D.R. Choffnes. Mile High WiFi: A First Look At In-Flight Internet Connectivity. 2016.