Fundamental Characteristics of Wi-Fi And Wireless Local Area Network Re-Identification for Transportation

Transportation Research Board Paper 16-5776

Noah J. Goodall, Ph.D. P.E.

VTRC Virginia Transportation Research Council

VDOT Virginia Department of Transportation

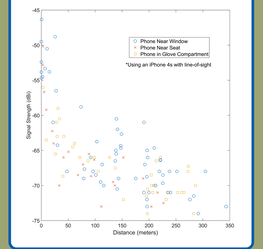
INTRODUCTION

Many transportation agencies use re-identification technologies to identify multiple vehicles along the roadway as a way to measure travel times and congestion. Recent advancements have allowed for the detection of unique media access control (MAC) addresses from Wi-Fi and wireless local area network (WLAN) enabled devices. This study represents the first attempt to measure the fundamental characteristics of Wi-Fi re-identification technology as it applies to transportation data collection.

BENCH TESTING

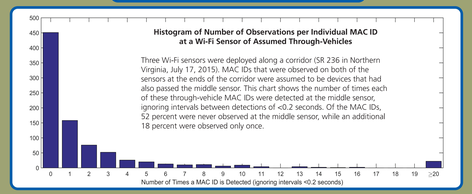
The effective range of the sensor, typical sample rates, and baseline transmission rates for Wi-Fi mobile devices were measured in controlled experiments. Signals were detected at distances of 300 meters within line of sight. Individual mobile phones were often found to go 45 seconds or more between a nearby (>1 meter) sensor receiving a MAC address. The Wi-Fi sensor used a 2.4 GHz antenna with a gain of 3 dBi, impedance of 50 Ohm, and return loss of -20 dB (min).

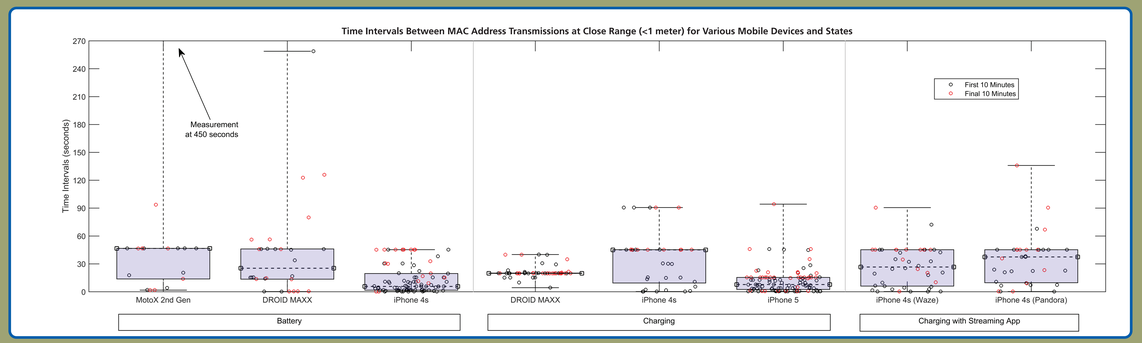
Observed Wi-Fi Signal Range



Unique MAC Addresses Detected per Vehicle in Field

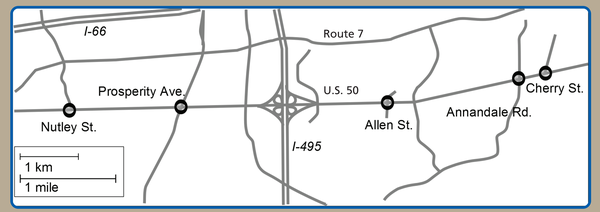
Site	Description	Sample Rate
Old Lynchburg Road, Charlottesville	Rural, 4-way stop	44 MAC IDs / 100 Vehicles
U.S. 29, Charlottesville	Arterial, 45 mph	29 MAC IDs / 100 Vehicles





FIELD TESTING

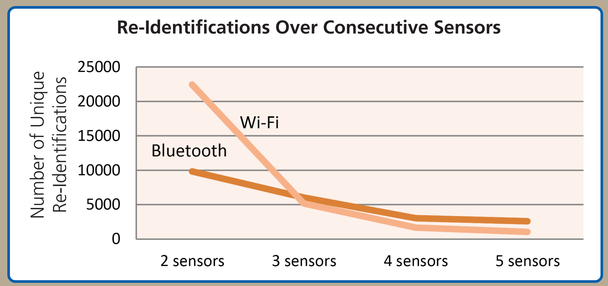
Wi-Fi sensors were placed at five intersections along a 5-mile (8km) section of U.S. 50 in Northern Virginia. Bluetooth sensors were collocated for comparison.



More MAC addresses were recorded by Wi-Fi sensors than by Bluetooth sensors at a single location. Wi-Fi devices were less likely to be re-identified when passing multiple detectors.

Device Re-Identification Rate for Likely Through-Vehicles

	Wi-Fi		Bluetooth	
Cross Street	*Discovered*	% of *n*	*Discovered*	% of *n*
At both ends	*n* = 2619	100%	*n* = 2528	100%
Prosperity Ave.	1660	63%	2049	81%
Allen St.	1454	56%	2231	88%
Annandale Rd.	950	36%	1898	75%



SIGNAL INTERFERENCE

Bluetooth and Wi-Fi sensors were located within 50 meters of each other at each of the five measurement sites on U.S. 50, which may have caused interference. This would affect the data shown in the "Field Testing" section.

The Wi-Fi sensors in this study were found to have captured 15 percent fewer matched pairs when collocated with Bluetooth as compared to a similar control day, with all but 3 percent of this difference coming from the Cherry Street sensor (36 percent decrease). Observed sampling rates should be considered a baseline of Wi-Fi's potential, given the possible interference from Bluetooth sensors.

PROBABILITY OF DISCOVERY MODEL

The probability of discovering an individual mobile device is based on the sensor range, device speed (i.e., time-in-range), baseline signal transmission rate, and transmission success rate.

Probability of Discovery Model Factors

Symbol	Description	Observed Values
$P(x)$	A Wi-Fi enabled mobile device's probability of discovery	———
r	Sensor's effective range	300 meters
v	Average speed (free flow with delay)	Not measured
$\overline{\rho}$	Average transmission success rate	14.8%
ω	Transmission frequency	0.022 Hz

$$P(x) = 1 - (1 - \overline{\rho})^{\frac{2r\omega}{v}}$$

CONCLUSIONS

- Wi-Fi devices were sampled at higher rates than Bluetooth devices.
- Wi-Fi devices are less likely to be rediscovered than Bluetooth devices. The higher number of Wi-Fi devices negates this shortcoming when tracking over two sensors.
- To improve the probability of discovery, Wi-Fi sensors should be positioned near intersections where vehicles are likely to slow or stop.
- Bluetooth sensors may generate more samples for applications that require tracking vehicles over three or more consecutive sensors.