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Investigation of Wi-Fi Sensing Technologies on Arterials

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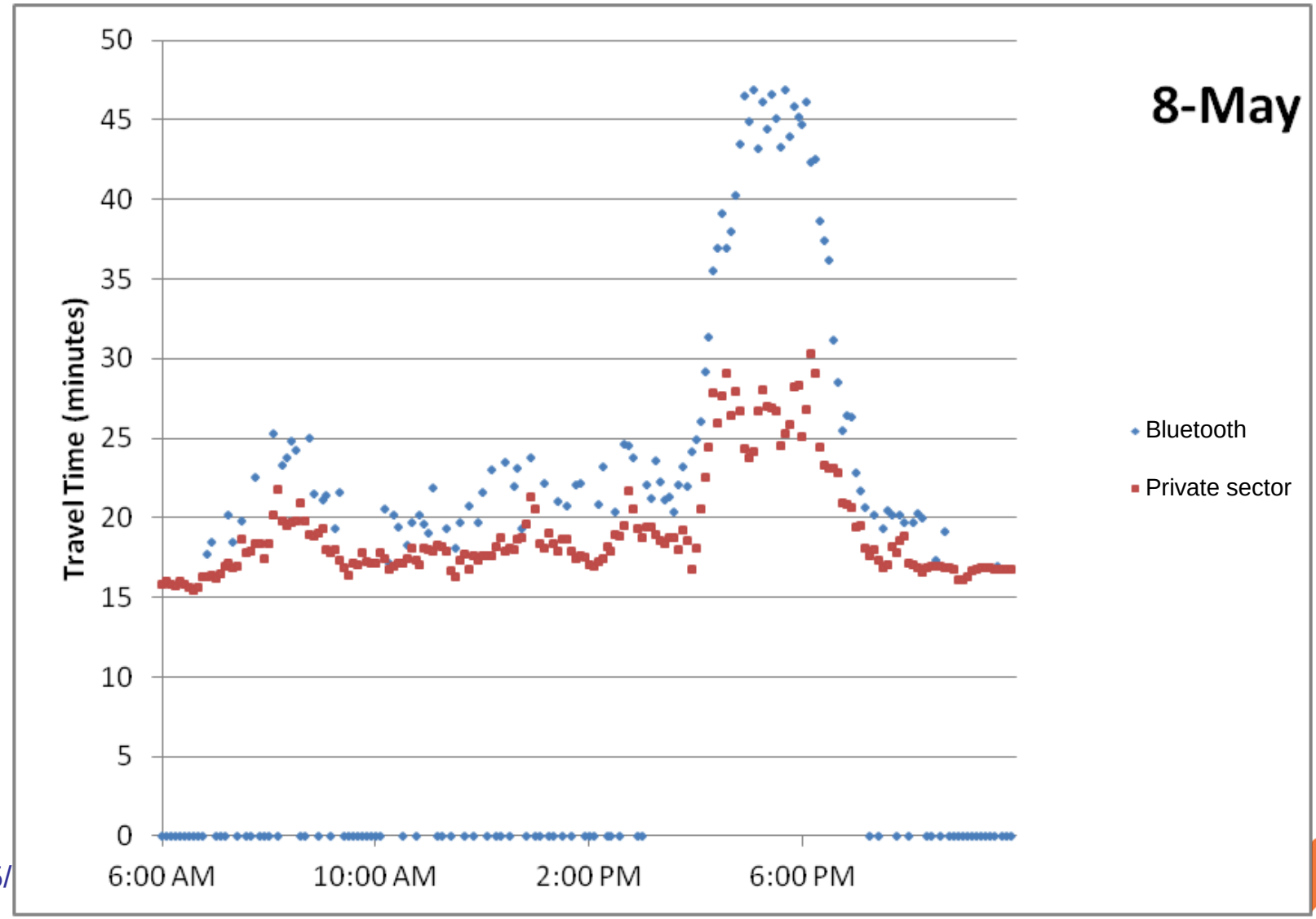
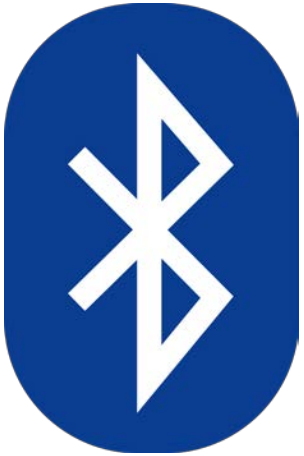
Private Sector Travel Time Data

- Uses various data sources, including GPS from vehicle fleets
- Virginia DOT maintains large signalized arterial system in urbanized counties, so quality travel time data is a priority
- Private data is very good on freeways, but found some quality issues on arterials during heavy congestion

US-50 in Fairfax, Signalized Street



Bluetooth as an Alternative



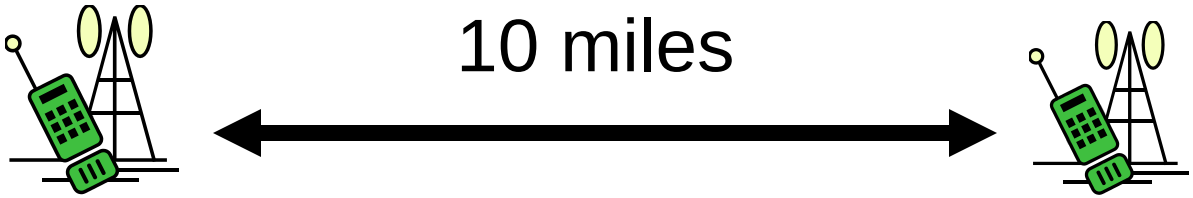
- High bandwidth, short range wireless communication
  - Phone-to-car
  - Wireless keyboards
- When your phone's Bluetooth is activated *and* in discoverable mode, it transmits a unique media access control (MAC) address

Travel Times from Bluetooth

- Use Bluetooth reidentification travel times as benchmark

MAC Address
00:1E:E2:F4:CC:4E
12:01:00 PM

MAC Address
00:1E:E2:F4:CC:4E
12:12:30 PM



10 miles
11.5 minutes
10mi/(11.5min / (60min/hr) = 52.2 mph

Limitations of Bluetooth

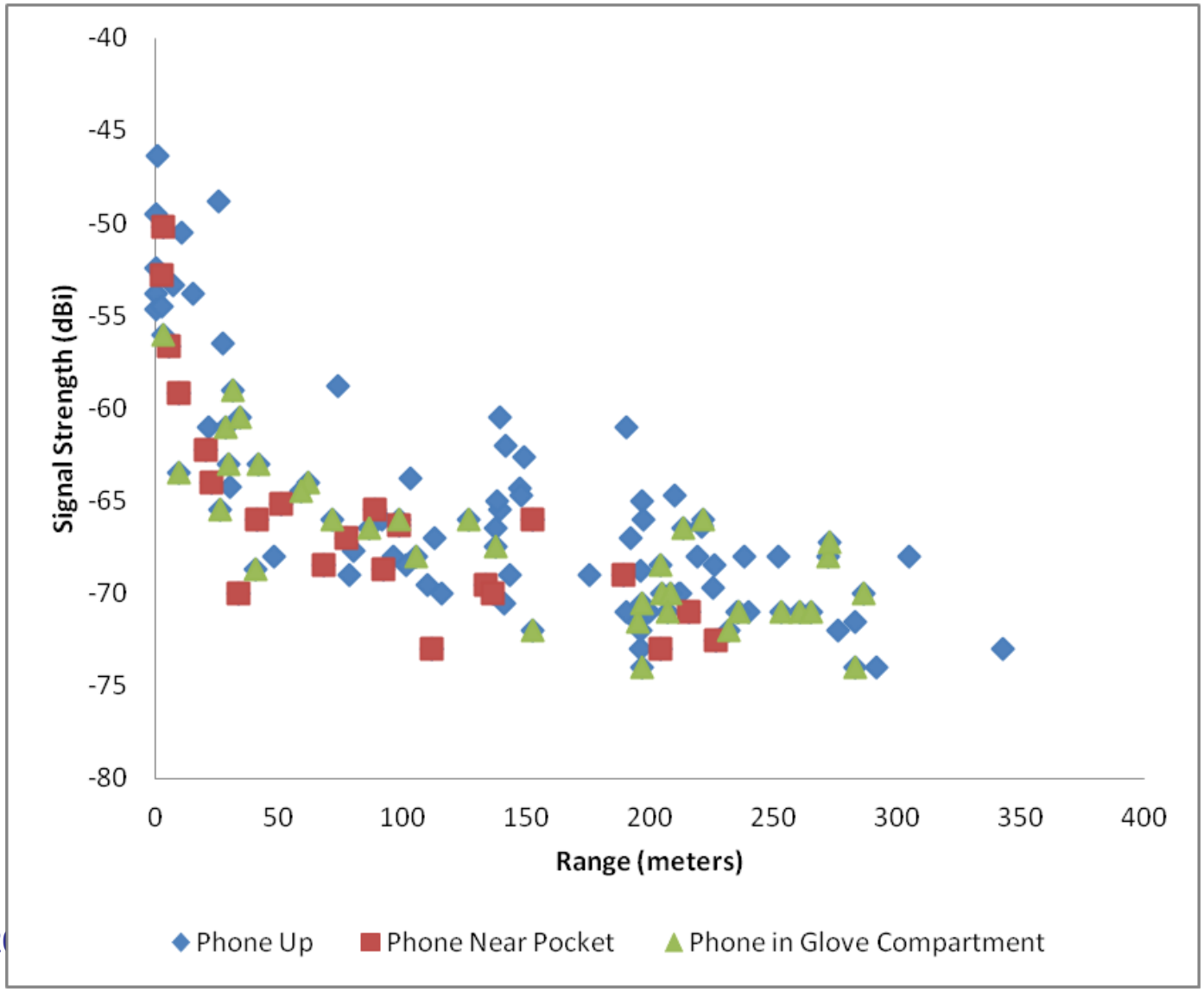
- Low sample rates are a problem
  - Few vehicles are recorded, 3-6% typically
  - Need minimum 3-5 measurements per period
  - Adequate on high-volume roads at rush hour over 15 minute interval
  - Problems at off-peak hours, 5-minute intervals, and when spacings are long
- Bluetooth broke down for real time traveler information applications on arterials

Wi-Fi Re-identification

- A phone also sends out a MAC address for Wi-Fi
- Similar technology to Bluetooth, but:
  - More phones seem to have it (Bluetooth must be in “discoverable” mode, not so for Wi-Fi)
  - Properties not well-understood

Wi-Fi Sensor Bench Testing

Range Test with Single Device



Sample Rate

Site	Description	Sample Rate
Old Lynchburg Road, Charlottesville	Rural, 4-way stop	44 MACs / 100 Vehicles
US-29, Charlottesville	Arterial, 45 mph	29 MACs / 100 Vehicles

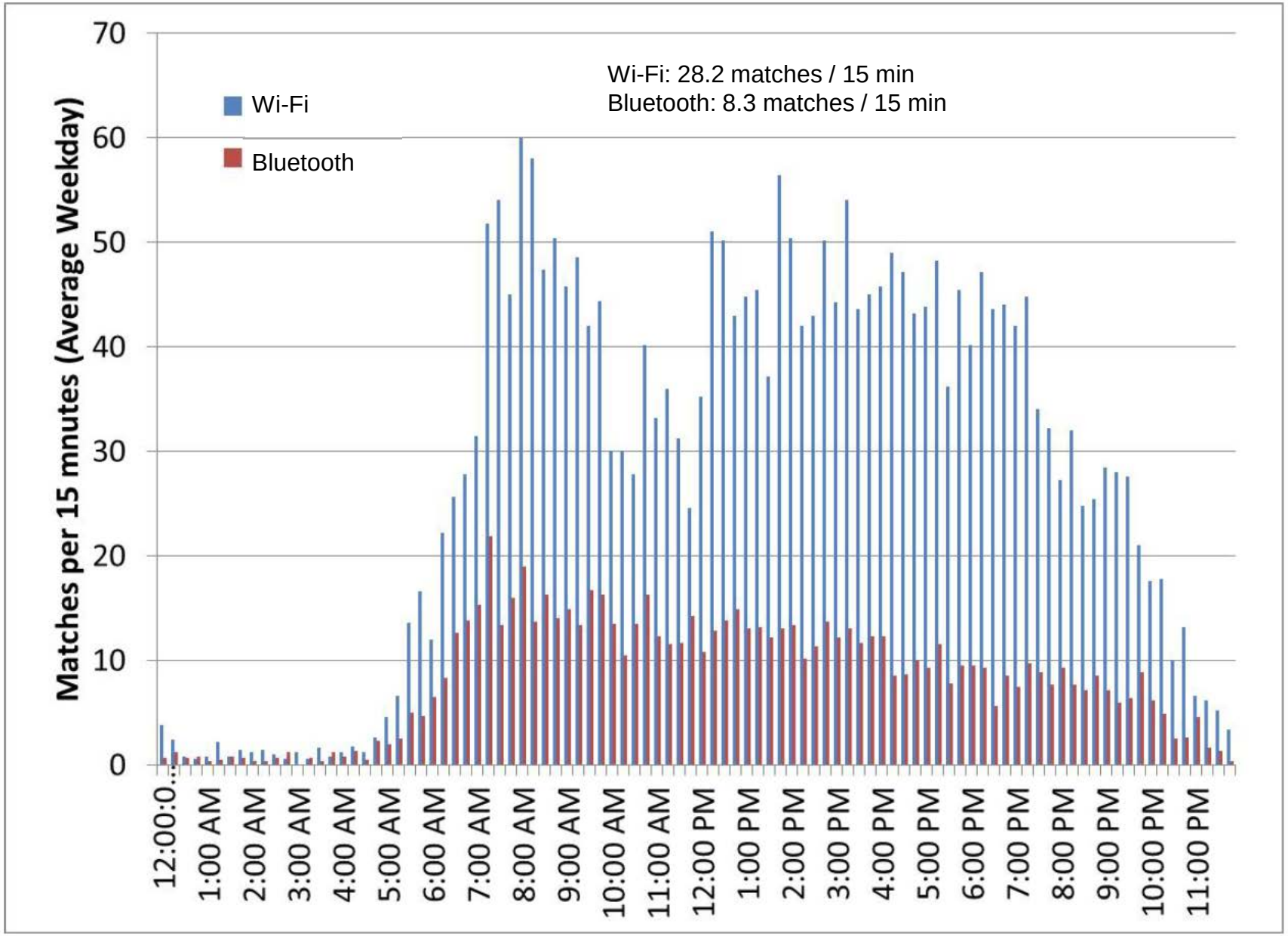


Figure 1. Little River Turnpike EB from Wakefield Chapel to Lake (0.2 miles)

Transmission Rates

- Bluetooth transmits almost continuously
- Bluetooth scanner checks every 5-10 seconds
- Wi-Fi might be transmitting *less frequently* and *irregularly*

Phone Transmission Rates

Device	Seconds Between Samples[a]				
	Average	Std. Dev.	Maximum	Average of Longest 5	Average After 10 Minute Warmup
Battery					
MotoX 2nd Generation	56.4	98.7	440.0	134.8	82.0
DROID MAXX	42.0	54.1	258.8	128.7	41.2
iPhone 4s	13.3	15.4	45.3	45.3	30.2
Charging					
DROID MAXX	21.3	6.6	40.1	38.9	22.7
iPhone 4s	35.4	29.6	90.6	90.6	53.5
iPhone 5	11.7	13.7	94.2	55.3	17.7
Charging and running apps over 3G/4G					
iPhone 4s (Waze)	27.5	21.4	90.5	54.3	39.2
iPhone 4s (Pandora)	34.1	27.9	135.9	81.3	45.3

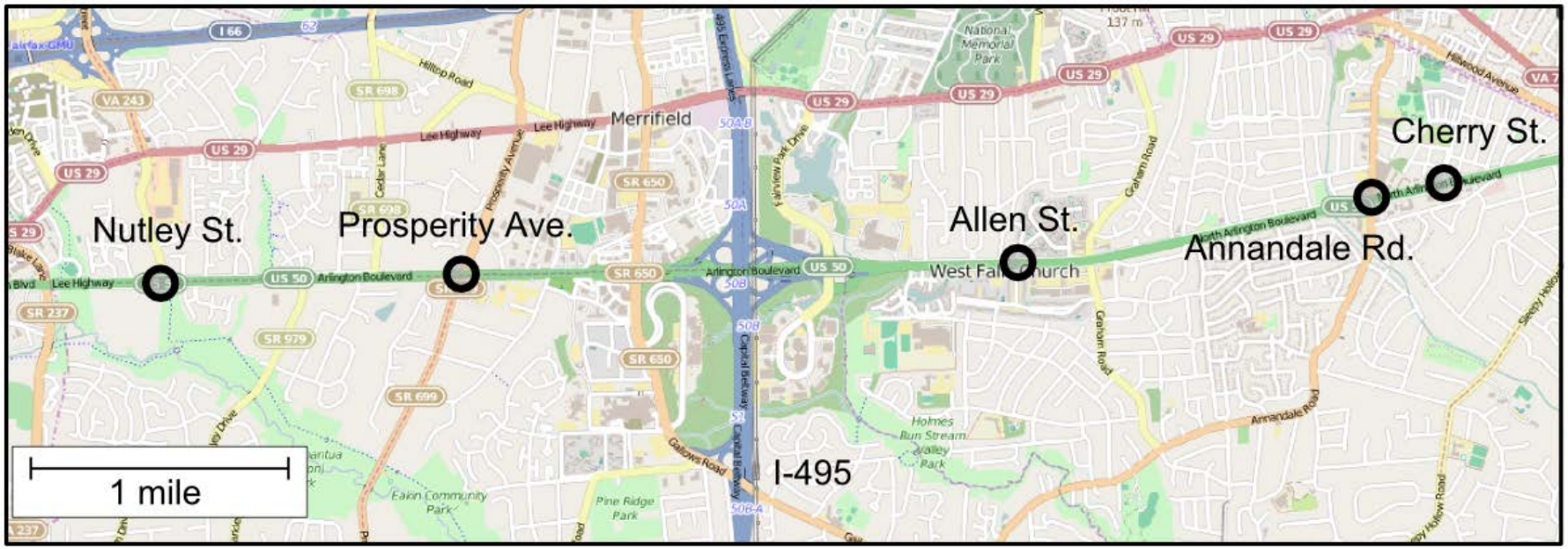
[a]Treating transmissions within 0.2 seconds of previous as single transmission, 20 minute test period

Effect on Sample Size

- Range was approximately 300 meters
- Baseline transmission approximately once every 45 seconds (irregular, varies widely)
- At 45 mph, car can travel 600 meters in 20 seconds
- Might not be enough time for sensor to catch it

Field Tests

- Phone and sensor both in our test vehicle as a baseline
- Five field sensors as backup



Comparison Between In-Vehicle and Roadside Sensors

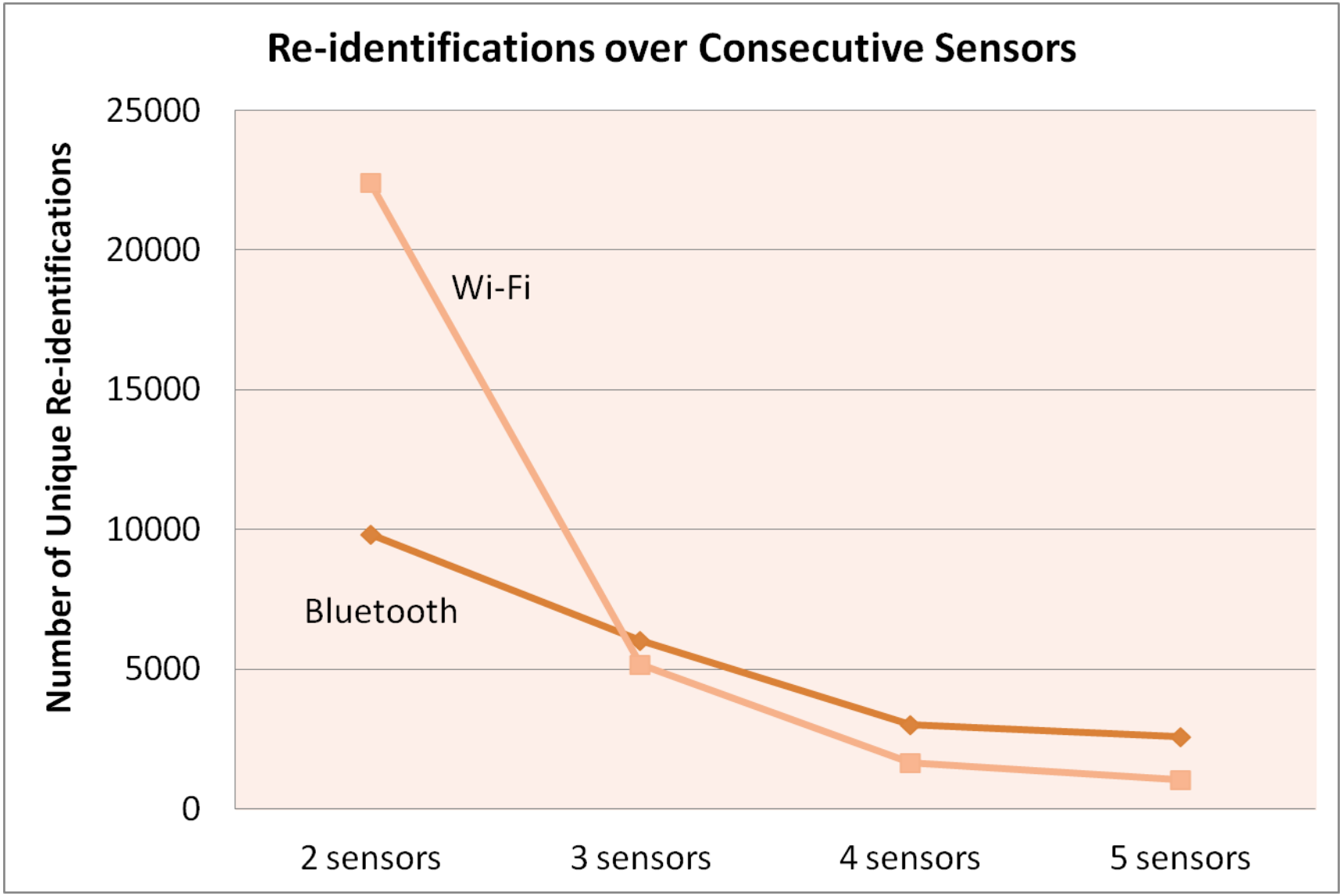
Distance (feet)	Transmission Success Rate	Transmissions Sent
0 - 100	23.6%	123
100 - 200	18.8%	101
200 - 300	13.8%	29
300 - 400	5.9%	51

Bluetooth vs. Wi-Fi Re-identification Rates

- Bluetooth catches few vehicles but with high reliability
- Wi-Fi seems to capture many vehicles, but with low reliability at an individual location
- Does field data support this?
- Compare capture rates of vehicles *known* to travel the entire corridor

For Vehicles Identified at Both Ends of Corridor

	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%


Re-identifications over Consecutive Sensors
Number of Unique Re-identifications
25000
20000
15000
10000
5000
0
Wi-Fi
Bluetooth
2 sensors
3 sensors
4 sensors
5 sensors

Conclusions

- Wi-Fi sensors may prove beneficial on low-volume roads, or during off-peak hours, or over short time intervals
- Wi-Fi offers superior sample size for individual pairs
- Wi-Fi sensors are less useful in applications that require re-identifying the same vehicle over multiple sensors

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Questions?

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