Open Spot Tracking

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Problem Statement

- Employees and visitors at Northrop Grumman spend extensive amounts of time trying to find open parking spots, and the security team has a hard time enforcing parking regulations

Mission Statement

- To develop a parking system and its connected application to shorten the amount of time employees spend parking and better enforce parking rules

Required System Specifications

The System Shall:

- Detect open spots with a minimum of 90% accuracy
- Detect parking violations with a minimum 90% accuracy
- Be private, non-invasive, secure, accurate, and easy to use

Analysis/Results

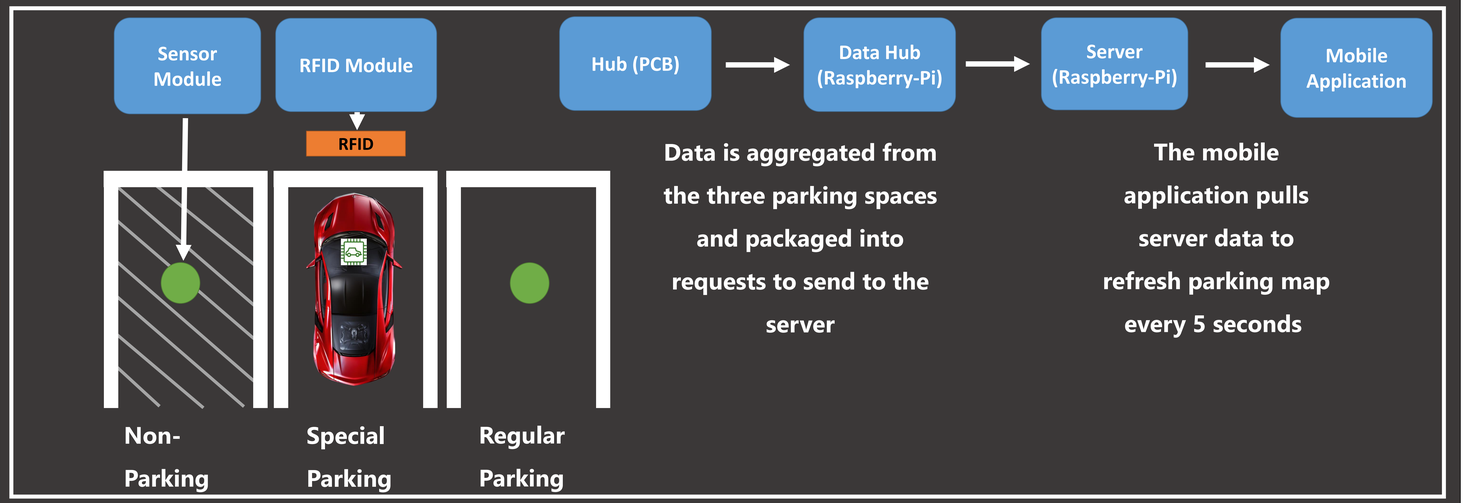
Table 1 below shows a summary of test results done with the full system as well as by each module of the system.

TABLE 1: Results Summary

Full System Tests	
8-Hour Test	98% accuracy, 100% up-time
End-to-End Latency	Average - 17.7 seconds
Sensor Module Unit Tests	
Accuracy	100%*
Battery Life	> 5 years
Weather Resistance/ Mechanical Stress	Passed - IP68, <7,500 pounds
Hub Module Unit Tests	
Range/Throughput	175ft for 100% accuracy at 50 bps
Water Resistance	Passed - IP67
RFID Module Unit Tests	
Antenna Range/Positioning	Height – 60in, 22dBm output power for ideal range
Accuracy	100%*
App/Server Unit Tests	
App Unit Tests	~80% Code Coverage
Server Throughput	250-300 requests per second

Prototype Overview:

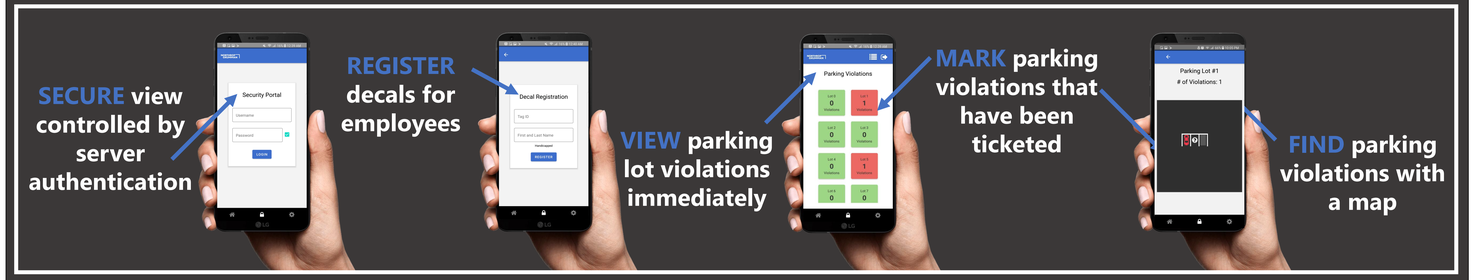
The final prototype parking system has 3 types of parking spaces: **Regular parking spaces** consist of a sensor module to determine spot occupancy. **Special parking spots** (i.e. carpool, electric vehicles) also have an RFID module and require employees to display an RFID rearview hangtag to park. **Non-parking areas** are cross-hatched, restricted areas which contain a sensor module to track violators.



Mobile Application:

Employee View

Security Team View



Business Case

- Table 2 shows the cost per parking space for the developed prototype system.

TABLE 2: Prototype Cost

3-Spot Prototype	
Module	**Cost**
Proximity Sensor (x3)	$ 491.52
Hub and Router (x1)	$ 462.54
RFID (x1)	$ 1,106.45
Server (x1)	$ 62.29
Subtotal	$ 2,122.80
Cost Per Spot	**$ 707.60**

- Table 3 shows the approximate cost per parking space if system is implemented in Northrop Grumman's site with 5,000 parking spaces

TABLE 3: Scaled System Estimate**

Estimate for 5000 Spot System	
Module	**Cost**
Proximity Sensor (x5000)	$ 819,200.00
Hub (x157)	$ 26,768.50
Router (x500)	$ 62,570.00
RFID (x300)	$ 105,500.00
Miscellaneous	$ 8,345.00
Subtotal	$ 2,122.80
Cost Per Spot	**$ 204.48**

Technical Performance Measures

- Table 4 below details the technical performance measures of the final prototype system.

TABLE 4: TPMs

TPM	Target	Actuals			
Accurately Detects Violations	90%	100%*			
Accurately Detects Open Spots	90%	100%*			
Server up-time	95%	100%			
Mobile App Updates	10 sec	Avg: 17.7 sec			
Prototype Cost per Spot	<$500	Total Cost = $2122.80 Total Cost per Spot = $707.60			
Color Codes:		Red = Unacceptable	Yellow = In Trouble	Green = Met	Blue = +10%

*Accuracy tests were conducted on 3 different vehicles. In 80 trials per car, pulling in and backing in, partially and fully, 100% accuracy was found. Further characterization is recommended for the scaled-up system to ensure >90% accuracy for all vehicles.
**Does not include non-spot costs

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