ROOTSCORE REPORT - SAN FRANCISCO
METHODOLOGY OUTLINE

INTRODUCTION

San Francisco is a very demanding environment for wireless users. The human and natural geography of the city, with steep hills, broad, empty stretches of water, and a densely built up city center, is studded with potential barriers to coverage. With one of the most wired populations in the country, peak hour congestion is a significant consideration for any wireless user. San Francisco's famous weather, which includes fog, rain, and Pacific storms, can put additional strains on the system. Finally, San Francisco has a well developed mass transit system heavily used by professionals. The RootScore Report for San Francisco provides a detailed assessment of voice, data, and text performance by the major wireless carriers in that market (AT&T, Sprint, T-Mobile, and Verizon).

Traveling by car, on foot, and via mass transit, RootMetrics's employees and contractors have traveled all over the greater San Francisco area performing a variety of tests that capture an accurate representation of the average consumer experience in this market. The resulting RootScore Report takes a detailed look at the situation of wireless coverage in this complex and challenging environment. The final goal of the report is to sum up the testing results as a series of objective, easy-to-understand scores of key performance indicators.

Traditionally, the standard industry practice for measuring network performance has been for a carrier to run its own series of drive tests. These tests are made using specially equipped vans, outfitted with dozens of phones, antennas, and control equipment that only approximate the actual consumer experience. Industry drive tests follow planned routes that cover only a small fraction of a given market. These tests are conducted one or two times per year, depending on the size of the market. While tests of this sort are useful for assessing the underlying causes of certain categories of problems, they can only make broadly generalized statements about the consumer's experience of a carrier's dependability.

RootMetrics aims to test network performance from the consumer's perspective. We test using our RootScout application running on standard consumer phones without external antennas or other non-standard equipment. The tests center on activities that consumers perform most often: making phone calls, sending and receiving text messages, and uploading and downloading files from the internet. The tests are performed at all times of day, in all weather conditions, indoors, outdoors, and around potential barriers to coverage.

Throughout the course of 2011, RootMetrics will be performing tests in the major American wireless markets and publishing RootScore Reports for each market. As time progresses, the testing

efforts will be expanded to include smaller markets, less densely populated and rural areas. High-level summaries and extracts from individual reports will be released to the consumer press and published at RootMetrics.com. However, the complete reports, with their valuable metrics, will only be available to carriers only who subscribe to the RootMetrics service.

METHODOLOGY SUMMARY

The test area centers on the San Francisco peninsula, expanding southwards to Daly City, and following the Bay Area Rapid Transit (BART) routes on both sides of the bay. The market area was been separated into three different geographic segments. Each segment was tested during the same time period using a kit made up of four popular phones, each serviced by a different carrier and running the RootScout application. The test routine measured voice performance in terms of the ability of a carrier to make and hold a connection, the upload and download speed for data transfers, and the ability of the carrier to send and receive a pre-scripted text message. The application collected a wide array of unique data points which delivered millions of data permutations. That data was sent to RootMetrics's secure servers where it was combined, analyzed, and processed into reports of carrier performance.

To assure that the tests provided an accurate picture of carrier performance in the test area, four approaches were used for data collection. Drive tests were conducted along major commuter routes and to penetrate into neighborhoods. Pedestrian tests were performed in areas where drive tests were not possible. These include locations such as tourist areas, business locations and other heavily trafficked indoor venues where wireless devices are used. Transit tests were performed by pedestrian testers along the entire one-hundred-four miles of BART, with separate tests at every station and in structural blocks such as tunnels. A set of stationary test units were placed in locations where the population varies throughout the day and week, such as business, shopping, sports, and tourist locations.

At every step along the way, careful safeguards were taken to assure that all of the phones were operating at the same level of efficiency and that no carrier was subjected to an unusual disadvantage or advantage.

ROOTSCOUT APPLICATION AND TEST EQUIPMENT

RootScout is an application that runs on standard consumer mobile devices and measures the performance of carriers in a specific market. These measurements of real-world performance are made by RootMetrics employees and contractors using a set of popular handheld devices each running the application to simultaneously conduct a group of performance tests. The test routine measures voice, data, and SMS performance continuously over a standardized test period. The San Francisco tests were performed using version 1.2.6-S3795 of the application.

The test kit uses four phones. Each phone tests a different carrier. The tests are run simultaneously on all four phones to assure exact comparability of the collected data. The test phones are configured within the kits so that they are at least eighteen inches from one-another, to avoid antenna interference, and all positioned the same way (e.g. all upright). For drive testing, the phones are enclosed in a rugged plastic box and plugged into the car's 12V outlet with a twelve hour battery back-up. Stationary kits are enclosed in a weather-proof box with a battery pack that can keep the phones running without interruption for at least one week. Pedestrian and transit testers use a wearable version of the kit consisting of a standard fisherman's vest and cargo pants with the phones stored in pockets and connectioned to portable battery packs secured on the scouter's back.

The phones used in the testing are all required to meet the same requirements. Each phone needs to have A-GPS or GPS, 3G or greater data connectivity, the ability to switch between Edge and 3G, and a processing capacity of 600MHz or greater. All phones used in the testing need to support the Android operating system. All phones chosen were popular phones having wide consumer acceptance. In the San Francisco testing. the phones used were the Droid X (to test Verizon), HTC Evo 4 (Sprint), HTC Nexus One (AT&T), and HTC Nexus One (T-Mobile). Except for battery packs, the phones were used exactly as they came off the shelf.

We utilize the following devices, but any Android device can be used.	Droid Eris	Droid X	Evo 4G	Nexus One	Nexus One
OEM	HTC	Motorola	HTC	HTC	HTC
Carrier	Verizon	Verizon	Sprint	AT&T	T-Mobile
Carrier Network	CDMA800, CDMA1900	CDMA800, CDMA1900	CDMA800, CDMA1900	GSM850, GSM900, GSM1800, GSM1900, UMTS850, UMTS1900, UMTS2100	GSM850, GSM900, GSM1800, GSM1900, UMTS900, UMTS1700, UMTS2100
Carrier Data Links	cdmaOne, CDMA2000 1xRTT, CDMA2000 1xEV-DO Rel. 0, CDMA2000 1xEV-DO Rev A	cdmaOne, CDMA2000 1xRTT, CDMA2000 1xEV-DO Rel. 0, CDMA2000 1xEV-DO Rev A	cdmaOne, CDMA2000 1xRTT, CDMA2000 1xEV-DO Rel. 0, CDMA2000 1xEV-DO Rev A	CSD, GPRS, EDGE, UMTS, HSDPA, HSUPA	CSD, GPRS, EDGE, UMTS, HSDPA, HSUPA
Release	November 2009	July 2010	April 2010	March 2010	January 2010
OS	Android 2.1	Android 2.2	Android 2.2	Android 2.2	Android 2.2
CPU	Qualcomm MSM7600	TI OMAP3630	Qualcomm Snapdragon	Qualcomm Snapdragon	Qualcomm Snapdragon
CPU Clock	528 MHz	1000 MHz	1000 MHz	998 MHz	998 MHz
RAM	288 MB	512 MB	512 MB	512 MB	512 MB
Battery Capacity	1350 mAh	1540 mAh	1500 mAh	1400 mAh	1400 mAh
MicroSD	Yes	Yes	Yes	Yes	Yes
Accelerometer	Yes	Yes	Yes	Yes	Yes
GPS	Yes	Yes	Yes	Yes	Yes

Phone specifications

The phones in the testing kit are set up identically. The phones are each provisioned by the appropriate carrier and all of the latest updates from the carrier are installed. Each phone's GPS is turned on, 3G turned on, and its data roaming enabled. Each phone has its own phone number listed in its settings. On each phone, the voicemail is disabled and wi-fi turned off. Each phone is set

to the correct time and the feature to set time to "home" network is disabled. All applications, except for RootScout, are disabled. During the test period, RootScout runs on a dedicated testing cycle for data collection only. When running, the application displays the number of samples collected, the number of samples transmitted, the GPS status, the signal quality, and the data transmission speed for upload and download.

For data verification purposes, the hardware and software are taken to a test lab to calibrate the tests and the data collected. A full series of tests are run on a test track with known network trouble spots which create a base standard across all carriers (signal attenuation). Data collected for each report is compared to the benchmarked data as verified through the test track process.

Data Collection

Data collection is performed by employees of RootMetrics or by independent contractors called scouters. Each scouter is required to meet basic health and fitness requirements such as being able to walk long distances, not have a pacemaker, or have any conditions that would limit their ability to drive. Scouters who performed driving tests need to have a working car, an up-to-date driver's license, and proof of insurance. On average, scouters spend ten days on the job, one day in training and nine days performing the test runs.

At the beginning of their shift, each scouter is given the map of their route, which has been planned in advance by RootMetrics. Before beginning their route the scouters fill out a pre-test checklist. The scouter inspects the test kit to make sure that all of the equipment is present and configured correctly. Each phone is powered up and the scouter checks that the phones are operating correctly, That each phone is set to the correct carrier, that disallowed features and software are turned off, that all four clocks are set to the same, correct time, and that the correct version of RootScout is installed and running on each phone.

When the RootScout application starts up, it performs a client handshake with the Root Mobile servers. This automatic procedure establishes the connection between the phone running the RootScout application and the servers. A handshake is completed with the server each time a phone running the application comes out of a hard reset. Once communication is established; the device ID, carrier name, client version, and OS platform are captured and sent to the server. The application then makes a request to the server to return its own phone number via SMS. The server sends back the session token (expiration in 10 years) and the test configuration file, which communicates which tests to run.

During data collection, the scouters perform regular checks of the equipment, keep an online log of their progress, and make note of equipment problems and deviations from their route or schedule. Each scouter is provided with a Troubleshooting Guide to deal with minor problems in the field without stopping their data collection run. Multiple alarms are set up within the software and hardware to alert the scouter and the server of any issues that need attention. In their log, the scouters record the time that the devices are turned on, the time that they begin their route, beginning time and end time for each sub-route, the mileage of each sub-route, the time that they

complete their full route, and the time that the hardware is turned off. In addition they log all unscheduled incidents, such as installing carrier specific updates, alarms that may occur during kit placement, any unexpected status codes. Every hour, testers make sure that at least 500 samples have been collected per device. At the end of each day, the scouters are responsible for plugging in and charging all phones.

San Francisco, like all markets to be scouted by RootMetrics, was separated into three different segments. Within each segment, data was collected using all four methods of collection at once. Drive test routes had their beginning and end points within the active segment. All stationary test units were set up in the active segment. Walk and transit routes were selected that covered the active segment. The time for collecting data in each segment was chosen to take advantage of public events that would create extreme conditions.

Drive Tests

Drive tests aim to cover as broad a geographic area as possible, focusing on freeways, major arterials, and areas of high street density. Routes for drive tests are planned in advance by RootMetrics managers in order to assure complete penetration of the test market. The final map covers not only commuter routes; it also covers the locations areas where the most people live, work, shop, and play and duplicates the routes used by wireless carriers during their own drive tests. In all, over 3,100 miles were driven in San Francisco. This amount will vary in other markets.

Data collection requires a minimum of three drivers to cover each segment. Multiple routes cross each segment. The routes are planned so as to represent realistic and efficient paths through the segment. Whenever possible, the end point of one route and the start point of the next are within one to three miles of each other. The drivers spend five hours a day collecting data. In San Francisco, each driver covered approximately 104 miles per day. The typical drive time was from 8 am to 1 pm covering the morning and lunch rush hours.

Stationary Tests

For stationary tests, the test kits are placed in weather-proof boxes and located in areas of high wireless use where the population density fluctuates dramatically over the course the day and week. Stationary tests provide a statistical view over time and identify congestion patterns. Two timeframes are used to collect data in stationary testing. For the longer series, called fixed location testing, the test kit remains in one location for a full week (Sunday to Sunday). Data is collected around the clock during the testing week. These locations include many of the same areas that are covered by pedestrian tests, such as business, tourist, retail, and entertainment destinations both indoors and out. For the shorter series, called mobile location tests, the test kits are placed for twelve to twenty-four hours along drive routes. The driving scouters are tasked with placing and retrieving the units. The stationary test kits include a thermal monitor to check for battery overheating.

Pedestrian Tests

Pedestrian tests are aimed at penetrating into areas where people congregate but cars cannot go. These are the highly populated and dense locations focused on leisure activities, such as tourist destinations, malls, theaters, and sports venues. Pedestrian tests give a higher level of resolution within densely used geographic spaces. These tests reach areas that traditional testing has never reached.

Walking tests are conducted at different times of day depending on the nature of the location. Pedestrian scouters are trained to walk at pace slow enough to run a full, six minute test routine in each location before moving on to the next location. A San Francisco Giants baseball game at AT&T Park was chosen to be one of the first pedestrian tests as the ebb and flow of the crowds provided an ideal opportunity to measure changes in network behavior against micro events occurring during game play.

Transit Tests

Transit tests are a new method of capturing data, not used in standard industry practice. Pedestrian testers rode the entire 104 miles of the Bay Area Rapid Transit (BART) system carrying the test equipment in a box identical to the one used in drive tests. The test boxes were placed on the seat next to the scouter. Tests were run along the route capturing coverage data for open spaces and in and around structural features that can create blank spots, such as tunnels and bridges. The transit tests were run both during commuting times and off hours. The scouters detrained at every stop and collected data in the stations. In other markets, those parts of the mass transit system that are most heavily trafficked will be tested.

At the end of the test period, the scouters make sure all test data has been transmitted. Any data that has not been automatically sent is sent through a force data transmit. Once data is collected from a market area and sent to the servers, a series of algorithms are run to clean the data and to remove data anomalies and bad data. Data anomalies and bad data are compared against the benchmarked data points calibrated during the earlier test track process.

The Tests

RootMetrics performs the same three tests, during every test run, on all four types of data collection. The tests run automatically at pre-determined intervals, requiring no action from the tester. Each test routine measures performance in terms of the ability of each carrier to make and hold a connection, the upload and download speed for data transfers, and the ability of the carrier to send and receive a pre-scripted text message. TheRootScout application repeates the test routine automatically every six minutes with no variation and no pause between test cycles. Additional network performance metrics are collected every five seconds during testing. At the completion of each test, the test is declared a success or a failure and the results are sent to RootMetrics's servers. Airplane mode is used to reset the network in order to reduce device anomalies.

Voice

During the voice test, all four phones dial a US-based landline that connects to a RootMetrics server specifically configured for the voice test. The goal of the test is to measure the ability of the carrier to connect to the target number and to maintain that connection.

During the test, the RootScout application on each phone calls the target number and verifies the phone state, specifically checking for call blocking. The application then measures off-hook time while waiting for the server to return its call. Upon receiving the test call, the test server proceedes to wait 100 seconds before initiating a return call to the test phone. The application logs the time that it receives the incoming call. The test server ends the return call after fifteen seconds at which time the application also hangs up. If the application receives an idle state before it receives the incoming call, the test is marked as a call dropped. The application was set to airplane mode in order to free hang-up should the application fail to hang up after 130 seconds.

The results of voice testing are reported using five metrics. These are:

- Call Accessibility – the number of successful connects divided by the number of attempts.
- Call Retainability – the number of completed calls divided by the number of successful connects.
- Call Reliability – the number of completed calls (those that stayed connected for the expected test time) divided by the number of attempts.
- Incoming Call Success Rate – the total number of successfully received incoming calls.
- Average Call Connect/Release Time – Total time of all successful calls (the length of successful cal defined as the time from first connect to final release length minus 100 seconds) calls divided by the number of successfully completed voice tests.

DATA

During the Data test, all four phones dial a virtual server configured by RootMetrics specifically for testing purposes. The goal of the test is to measure the ability of the carrier to connect to the target server and stay connected while downloading a 64k file and uploading a similar file.

The data test first measures accessibility by pinging a well-known, geographically load-balanced IP address. If no response is received, the test is logged as a failure. If the ping time is greater than the established default, the test is logged as a failure. Once accessibility has been established, the application attempts to download the test packet from the RootMetrics test server. The time to download the packet is measured. If the download is not completed within thirty seconds, the test is logged as a failure. Finally, the application attempts to upload the test packet back to the test server. If the upload is not completed within thirty seconds, the test is logged as a failure.

The results of data testing are reported using five metrics. These are:

- Average Download Speed – the average number of seconds required to download the test file from the server.

- Average Upload Speed – the average number of seconds required to upload the test file to the server.
- Network Accessibility – the number of successful connects divided by the number of attempts.

TEXT

During the texting test, all four handsets perform a scripted circular test, whereby an SMS message is sent from each handset and directed back to the same handset, that is, the handset sends a message to itself. The goal of the texting test is to measure the ability of the carrier to send and receive SMS messages.

For each test, the application diald the test number which redirects the call back the same phone. The application verifiesthe network connection and logs the time. The application then sends the test message and logs the time that it is received back in its inbox. If the message has not completed the round trip in sixty seconds, the test is logged as a failure.

The results of data testing are reported using two metrics. These are:

- Success Rate – the number of messages received divided by the number.
- Average Time – the average number of seconds required to send and receive the messages.

ROOTSCORE AWARDS

At the end of the testing period, when all of the data has been collected, analyzed, and reported, a final set of awards are presented to carriers based on metrics covering the entire test market over the entire test period. Four awards are given for speed: the Fastest Network, the Fastest 2G Network, the Fastest 3G Network, and the Fastest 4G Network. Four awards are given for reliability: the overall Most Reliable Network, the Most Reliable Voice Network, the Most Reliable Data Network, and the Most Reliable Texting Network. Four awards are given for coverage: the Best Overall Coverage, the Best Voice Coverage, the Best Data Coverage, and the Best Texting Coverage. Finally, a set of all encompassing awards are given: the Best Overall Network, the Best Overall Voice Network, the Best Overall Data Network, and the Best Overall Texting Network.

Coming as they do from an objective rating group, all of the awards are valuable from a marketing perspective. However, when combined with the detailed metrics in the complete RootScore Report, the awards are useful to carriers in measuring their place among their competitors and in singling out aspects of their local performance that need to be addressed, such as highly trafficked areas with weak coverage. Wireless service is a highly competitive and rapidly expanding industry. No serious player can afford to be without timely, accurate information about the performance of their network and those of their competitors. RootMetrics provides that data.