E911 Location Test Bed

Dispatchable Location Summary Report

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2 EXECUTIVE SUMMARY

Dispatchable Location (DL) testing in the E9-1-1 Location Technologies Test Bed was conducted during the second half of 2018 to assess the state of this emerging location technology during this early stage of National Emergency Address Database (NEAD) provisioning. Testing occurred in two regions of the country – in and around Atlanta and San Francisco – in 25 buildings within four morphologies, from 230 test points, following the guidelines established in the ATIS-0500035 standard. 30,090 simulated 911 calls were made from 24 test devices. Outcomes were captured for each call, then compared to truth, to quantify Dispatchable Location performance. This document summarizes and explains the results observed in this campaign.

This Dispatchable Location test campaign was preliminary, and it is important to acknowledge certain key limitations:

1. Only five Google Android (Android) mobile device models were tested, as only these devices so far support the necessary reporting and signaling needed to enable Dispatchable Location. Apple iOS (iOS) devices do not support the necessary functionality, and thus could not be used in this testing.
2. The National Emergency Address Database (NEAD) – the 'Reference Point' database that associates WiFi Access Point and Bluetooth Beacon identities with validated civic address information, and that provides a secure system for database access and maintenance – is in an early stage of provisioning. For testing to yield the necessary insights into wireless network performance, test buildings were intentionally chosen with at least some, even if limited, NEAD database coverage. Consequently, results of this campaign tend to skew towards an optimistic assessment of database completeness.
3. ATIS-0500035 defines a complete set of 20 test buildings of diverse types and sizes in each test region. Due to the limitations in the provisioning of the NEAD, only a subset of 25 buildings – 13 in San Francisco and 12 in Atlanta – were feasible to acquire. The test buildings were sufficiently diverse to provide a good indicative Dispatchable Location performance in the test areas, but the results in some morphologies are somewhat limited and influenced by the specific buildings used.

Given these limitations, these results reflect the capabilities of an emerging technology, rather than the capabilities of a complete, ready-to-deploy system.

This campaign demonstrated the fundamental ability of Dispatchable Location technology to deliver accurate civic addresses. It also identified the current limitations of this technology at this early stage. The following metrics capture the bottom-line Dispatchable Location performance observed:

- 82.6% of valid test calls resulted in some kind of Civic Address delivered (be it correct or incorrect.) This metric is somewhat analogous to yield in geodetic positioning systems. Inversely, 17.4% of valid test calls produced no Civic Address.
- 74.0% of valid test calls produced a correct street address and 8.6% of valid test calls produced an incorrect street address (an address of a neighboring building.)
- 38.7% of valid test calls produced an accurate DL2 or DL1 result – a result that meets the requirements for actionable Dispatchable Location as defined in the ATIS-0500035 and ATIS-0700028v1.1 standards.

An important conclusion of this testing is that reference point density in the NEAD database is not yet at sufficient levels to assure optimum performance. Low reference point density was found to cause instances where erroneous civic address details were reported, incorrect street addresses of neighboring buildings were reported, or no civic addresses were reported at all, which are reflected in the metrics above.

However, this testing also shows that higher NEAD database density can be expected to significantly improve performance. Analysis based on the data gathered in this campaign suggests that a NEAD database Provisioning Density[1] higher than 50%, possibly in the 50% to 75% range, would likely translate into significantly improved overall performance in medium and large structures. A target Provisioning Density[1] of 100% would be more appropriate for single family homes and stand-alone structures, unless Assisted-GPS (A-GPS) geodetic fixes (not hybrid fixes relying on WiFi) can be used as an effective cross-check to avoid Dispatchable Location results with erroneous civic addresses.

Note that the sources used to increase Reference Point density in the NEAD should encompass a broad diversity of building and use types, so that the resulting performance improvements apply broadly in high-density multi-unit commercial and residential structures, as well as in suburban and rural stand-alone structures. While content is added to the NEAD, eSMLC logic improvements can be implemented to mitigate the most harmful effects of low Reference Point density.

If support for Dispatchable Location is added to iOS devices (which is unlikely), and when substantial more Reference Point data is added to the NEAD, and Dispatchable Location processing logic is refined in wireless networks, a subsequent campaign of testing would be an appropriate step to undertake prior to launching Dispatchable Location capabilities into operational 9-1-1 settings.

[1] Provisioning Density is defined in Section 5.4.

3 BACKGROUND & TEST METHODOLOGY

To characterize the performance of each wireless operator's emerging Dispatchable Location system, 30,090 test calls were placed in aggregate on the wireless networks of the three national wireless carriers – Verizon, T-Mobile, and AT&T – participating in the Dispatchable Location test campaign. Approximately one third of the test calls were placed using each operator's wireless network and Dispatchable Location system. The calls were placed from 230 test points in 12 buildings in the Atlanta area and 13 buildings in the San Francisco Bay Area, between 4 September 2018 and 2 November 2018. Buildings were chosen in dense urban, urban, suburban, and rural morphologies, consistent with the ATIS-developed consensus test methodology defined in ATIS-0500035.

3.1 Mobile Devices Used

Five models of Android mobile devices were used in this testing. Due to a lack of support for the signaling needed to report Reference Point identities observed by the mobile device to the eSMLC, iOS handsets could not be used in this testing.

3.2 Building Selection

Test buildings were selected from within the ATIS-specified test areas defined in the ATIS-0500031 specification, with the addition of a new rural polygon in southern Santa Clara County (south of San Francisco) as defined in ATIS-0500035, to address current Reference Point geographic limitations.

Within the target test areas, test building selection was based on a number of factors including accessibility and permission of building management, meeting the required characteristics defined in ATIS-0500035 (building types, number of required test points per building, presence of segmented & addressable spaces, etc.), availability of building floor plans (needed for ground truth assessment), and adequate Reference Point density.

As discussed in Section 7.4 of ATIS-0500035, smaller buildings were chosen to generally have one or two provisioned reference points, noting that two reference points often correspond to one single WiFi access point operating in both the 2.4 and 5 GHz bands. At least one single family home was chosen not to have any provisioned reference points to examine this important scenario where the influence of neighboring buildings dominates. Mid-size buildings had a wider range of provisioning density, representative of the current and still limited level of NEAD provisioning, with several such buildings – especially commercial – actually having very few provisioned reference points. The larger test buildings selected had Reference Point densities generally representative of the broad area in which they were located, although truly large buildings with very few provisioned reference points were not selected, since obtaining predominantly null Dispatchable Location results was considered to be wasteful of precious test

resources in very expensive-to-test large buildings. Note that testing relied on existing Reference Points in the NEAD; no Reference Points were added for purposes of the Test Bed.

Table 3-1 and Table 3-2 show the buildings selected for Atlanta and San Francisco, respectively. The tables show for each building the morphology, use category (residential vs. commercial), building type as defined in ATIS-0500035, and number of test points used within each structure. Every effort was made to achieve the mix of building types called for in ATIS-0500035, though this was not always possible given Reference Point availability and other logistical factors. Indeed, given the growing list of building selection criteria, site selection became an increasingly difficult task.

Table 3-1 Atlanta Building Morphology and Characteristics for Dispatchable Location Testing

Region	Building ID	Morphology	Use Category	# TPs	Building Type
Atlanta	ATLDBC103	Dense Urban	Residential	15	Apartment/Condo high rise.
Atlanta	ATLRBC108	Rural	Residential	4	Residential 2 story
Atlanta	ATLSBC08	Suburban	Commercial	10	Mall/commercial center
Atlanta	ATLSBC101	Suburban	Residential	10	Apt/condo complex 3-4 story, larger foot print
Atlanta	ATLSBC104	Suburban	Residential	11	Residential mid or high rise
Atlanta	ATLSBC106	Suburban	Commercial	6	Hotel/Motel standalone 2-3 story
Atlanta	ATLSBC109	Suburban	Residential	4	Individual home next to larger apartment complex
Atlanta	ATLSBC110	Suburban	Commercial	12	Commercial mid or high rise
Atlanta	ATLSBC99	Suburban	Residential	4	Individual home in middle of single-family homes
Atlanta	ATLUBC102	Urban	Residential	15	Residential - Mid or High rise
Atlanta	ATLUBC107	Urban	Commercial	10	Museum/Exhibition hall
Atlanta	ATLUBC111	Urban	Residential	10	Residential low rise (3-4 story)

Table 3-2 San Francisco Building Morphology and Characteristics for Dispatchable Location Testing

Region	Building ID	Morphology	Use Category	# TPs	Building Type
SF	SFDBC101	Dense Urban	Commercial	10	Commercial High-rise - concrete
SF	SFDBC103	Dense Urban	Commercial	7	Commercial Low/Mid-rise surrounded by high rise
SF	SFDBC104	Dense Urban	Commercial	15	Commercial Mid/High-rise
SF	SFRBC107	Rural	Commercial	4	Public or retail 2-story (or equivalent)
SF	SFRBC108	Rural	Residential	4	Residential 1-2 story
SF	SFSBC102	Suburban	Residential	12	Residential Mid or high rise
SF	SFSBC105	Suburban	Commercial	12	Commercial mid or high rise

SF	SFSBC109	Suburban	Commercial	7	Hotel/Motel standalone 2-4 story
SF	SFSBC110	Suburban	Residential	4	Individual home in middle of single-family homes
SF	SFUBC100	Urban	Residential	10	Residential Low rise (3-4 Story)
SF	SFUBC106	Urban	Residential	15	Apartment/Condo high rise
SF	SFUBC111	Urban	Commercial	8	Museum/Exhibition hall
SF	SFUBC112	Urban	Commercial	11	Commercial mid/high rise

Since Reference Point density was taken into account when selecting test buildings to avoid the situations where no civic addresses at all were produced, yielding very little insight in to Dispatchable Location system performance, the NEAD database encountered during testing was equivalently better than would have been encountered with truly random building selection – by how much it is not possible to say. Likewise, Dispatchable Location performance was likely better than would otherwise have been expected – again, it is not possible to say by how much. Therefore, these results provide insight into the capabilities of an emerging technology, rather than express the performance of a system ready to be activated in 9-1-1 operational scenarios. Indeed, one important insight from this testing is that Reference Point density is not yet at needed levels, as discussed in Sections 4 and 5.

3.3 Call Processing

The test methodology used followed the requirements defined in ATIS-0500035. Calls were placed from 12 test mobile devices simultaneously in each market, four provided by each wireless operator. Logs from the eSMLCs and test mobiles were collected and associated, and used to determine the Dispatchable Location civic address produced by the three operators' systems for each test call. Note that the Dispatchable Location system was not able to produce a civic address for every call.

Further Enterprise Solutions (FES), the testing vendor, compared the civic address and Class of Service (CoS) produced for each test call (if any) to the known true test point location at the time of call, using manual and automated means, and these determinations were used to produce a variety of Dispatchable Location performance metrics.

3.4 Class of Service Assessment

Three 'levels' or Class of Service (CoS) indicators are output by the eSMLC with each Dispatchable Location civic address reported, with the following interpretations:

- Dispatchable Location Level 2 (DL2) – the highest level of performance. DL2 indicates that the reported Dispatchable Location is known to the specific unit number.

- Dispatchable Location Level 1 (DL1) – medium-level performance. DL1 indicates that the reported Dispatchable Location is known to the quadrant or zone of the building on the correct floor or on the floor immediately above or below the correct floor.
- Civic Address (CVC) – the lowest level of performance. CVC indicates that the reported street address is known, but no further information including a unit number is available, or if a unit number is available it does not meet the DL1 requirements. For multi-unit buildings, CVC is not considered actionable Dispatchable Location by public safety (see the note regarding single-family homes below.)

The Class of Service reported by the eSMLC with each output civic address is the 'reported CoS'.

To determine what the 'true CoS' should have been for each result, FES engineers applied the following criteria:

- Truly DL2 if: the reported street address and unit number are correct.
- Truly DL1 if: the reported CoS is not DL2, the reported street address is correct, and the reported unit number is present and fell within the same 'quadrant' on the correct floor or +/-1 floor. Note that unit numbers immediately outside the quadrant or clearly in site of true position were considered valid. (Note also that civic addresses with floor numbers, but without unit numbers, where not present in the NEAD for any of the buildings tested). DL1 assessment requires building quadrants to be manually defined, as discussed below.
- Truly CVC if: the reported CoS is not DL1 or DL2, and the reported street address is correct.
- Note that for a single-family home, reported CVC or DL1 are considered equivalent to DL2. This assumes public safety has access to a high-quality CAD map display, which is a reasonable assumption for many PSAPs.

Comparing reported CoS to the true CoS for each test call is the basis for the Dispatchable Location metrics defined in Section 4.1.

3.4.1 Quadrant Definition

Quadrant boundaries are necessary in order to make the DL1 assessments. Thus, quadrant boundaries were created by FES based on principles driven by how first responders would naturally orient themselves when entering a floor of the building, including the following:

- Aligned with building orientation
- Aligned symmetrically
- Areas roughly equivalent
- Avoided dividing units
- Intuitive and naturally clear.

4 Summary of Results

This section presents the key summary results from this Dispatchable Location test campaign.

4.1 Core Dispatchable Location Performance Metrics

Dispatchable Location performance cannot be quantified using the same metrics so familiar from geodetic location systems. The geodetic numerical quantification of accuracy, which is essentially an *analog* measure of quality, has no equivalent in Dispatchable Location. The outputs of a Dispatchable Location system when compared to truth are inherently *binary* – for example, the street address produced is accurate or not. Therefore, Dispatchable Location quality metrics must quantify the extent each binary outcome is produced in a given sample set. The following metrics have been found to best quantify overall, bottom-line, end-to-end Dispatchable Location performance:

- ***Civic Address Delivered Percentage***:
  The percentage of valid test calls which resulted in some kind of Civic Address delivered (be it correct or incorrect.) This metric is somewhat analogous to yield in geodetic positioning systems. In this campaign, **82.6%** of valid calls delivered a civic address.
- ***Civic Address Correct Percentage***:
  The percentage of valid test calls which produced a correct street address. This inverse of this metric, the percentage of valid test calls which produced an *incorrect* street address, is also of interest, as it quantifies a particularly problematic failure condition – the reporting of neighboring street addresses. In this campaign, **74.0%** of valid calls produced the correct street address, while **8.6%** of valid calls produced an incorrect address. Note how the sum of these two numbers totals to the Civic Address Delivered Percentage.
- ***DL2/DL1 Accurate Percentage***:
  The percentage of valid test calls that produced successful DL2 or DL1 civic addresses and thus met the Dispatchable Location success criteria defined in ATIS-0500035. Such fixes are considered 'actionable' or 'usable' for dispatch purposes. The definition of this metric was arrived at through extensive deliberations within ATIS between public safety, wireless carriers, and other entities involved in the 9-1-1 ecosystem and was embodied in ATIS-0500035 and 0700028v1.1. This metric is calculated by dividing the number of test calls where the reported CoS is either DL2 or DL1, and true CoS is either DL2 or DL1, (including calls where a true DL2 is reported as DL1, and vice versa) by the total number of valid calls. Note that calls from within single family homes or other small stand-alone structures reported as CVC are considered DL2, and are thus included in this definition, as long as the returned civic address is in fact correct.

Of the 30,090 test calls placed in this campaign, 28,583 were considered 'valid', and it is this number that is the denominator for the percentage calculations listed above. A valid call is one

where the call completed, it did not drop prematurely, and the eSMLC log existed and could be associated with the mobile log.

Table 4-1 shows a visual interpretation of these new Dispatchable Location metrics in the context of a grid juxtaposing reported CoS (along rows) versus true CoS and some other truth conditions (along columns). Each cell of the grid contains a percentage, which is the ratio of the number of calls meeting the conditions noted in the row and in the column, relative to the total number of valid fixes. The sum of all these percentages totals to 100%, thus this grid visually conveys the distribution of all valid test calls.

Table 4-1 Core Metrics Visualized in the Context of Reported CoS versus True CoS

	True Class of Service (Other Truth Conditions):					**No DL Reported**
Reported Class of Service:	**DL2**	**DL1**	**CVC (considered DL2)** (street address correct & from a single-family home – considered DL2)	**CVC** (street address correct)	**CVC** (street address INCORRECT)	
Reported DL2:	9.6%	4.7%	0.5%	2.1%	1.9%	17.4%
Reported DL1:	4.2%	15.2%	1.0%	5.9%	0.3%	
Reported CVC:	1.0%	14.0%	3.6%	12.2%	6.4%	

Metrics Key:

- (dashed grey box) *Civic Address Delivered Percentage*: **82.6%** of valid calls resulted in some kind of Civic Address delivered (be it correct or incorrect.)
- (green box) *Civic Address Correct Percentage*: **74.0%** of valid calls delivered a civic address and it was correct.
- (red box) *Civic Address Incorrect Percentage*: **8.6%** of valid calls delivered a civic address but it was *incorrect* (from a neighboring building).
- (blue shading) *DL2/DL1 Accurate Percentage*: **38.7%** of valid calls produced successful DL2 or DL1 civic addresses.

As an example, the percentage of valid calls where the reported CoS was DL2 and the true CoS was DL2 can be seen to be 9.6%. Similarly, the percentage of valid calls where the reported CoS was DL1 but in truth DL2 should have been reported was 4.2%. In both these cases, the correct unit address of the "door" is identified in the result, but when DL2 is indicated the network is more confident of that outcome. The opposite situation occurred in 4.7% of the calls (DL2 reported when it should have been DL1), thus the specific unit address reported would be found to be close to where the emergency actually is (same corner of the building and possibly +/- 1 floor). Groups of cells also have meaning – for example, the total percentage of valid calls where DL2 was reported can be calculated to be 18.7% (the sum of the percentages along the 'Reported DL2' row.) On the far right of the grid, it can be seen that the percentage of valid calls where no Dispatchable Location civic address or CoS was reported at all is 17.4%.

All the metrics defined above are various combinations of grids, as shown in the key. For example, the *Civic Address Delivered Percentage* can be seen to be the cells within the dashed black oval, totaling 82.6%. Likewise, the *DL2/DL1 Accurate Percentage* is shown in blue shading and totals 38.7%.

4.2 Performance by Building

Figure 4-1 shows the *Civic Address Correct Percentage* (in **green bars**) and the *Civic Address Incorrect Percentage* (in **red bars**) for each building. Note that the sum of these two quantities – the total height of the bar for each building – also represents the *Civic Address Delivered Percentage*. From this figure, two observations are apparent:

- In every building, at least some calls reported no civic address, and in a few buildings, including ATLRBC108, ATLUBC107, and SFSBC109, most calls did not report a civic address. This phenomenon is widespread, and does not correlate to test region or morphology.
- Incorrect neighboring civic addresses occur in most buildings, and in one building (ATLSBC109) every reported address was incorrect. Again, this phenomenon is widespread but its extent varies.

In both cases, low reference point density is a key factor, as will be shown below and described in detail in Section 5.

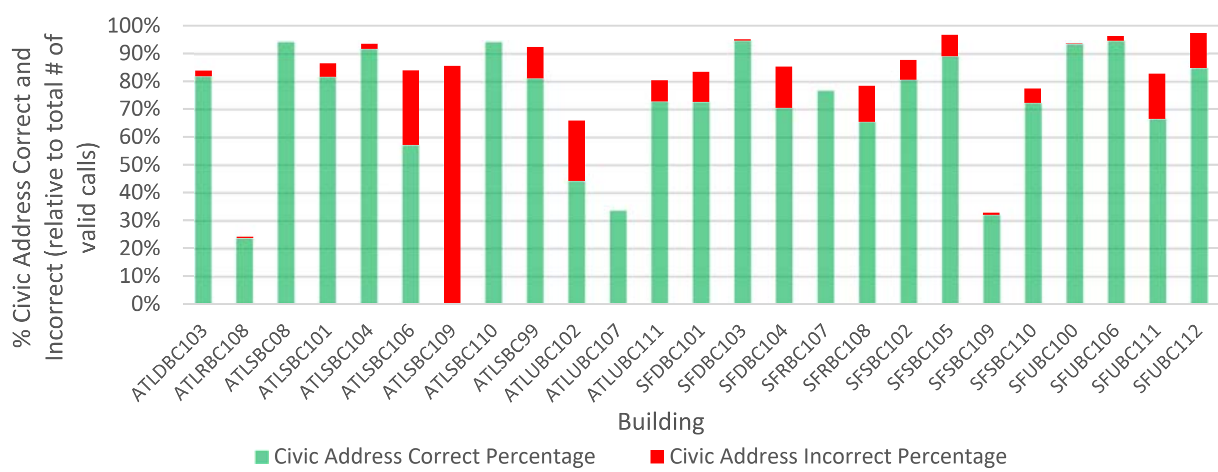

Figure 4-1 Civic Address Correct and Incorrect by Building

Figure 4-2 shows the *DL2/DL1 Accurate Percentage* by building. From this figure it is apparent that DL2/DL1 performance is quite varied across morphologies and buildings, with several buildings producing no DL2/DL1 results at all and the best building achieving 81%. By examining Figure 4-1 and Figure 4-2, it is apparent that low *Civic Address Delivered* and *Civic Address Correct* percentages play a role in a low *DL2/DL1 Accurate Percentage*. Low reference point density contributes strongly to a low *DL2/DL1 Accurate Percentage*, as will be addressed in more detail in Section 5.

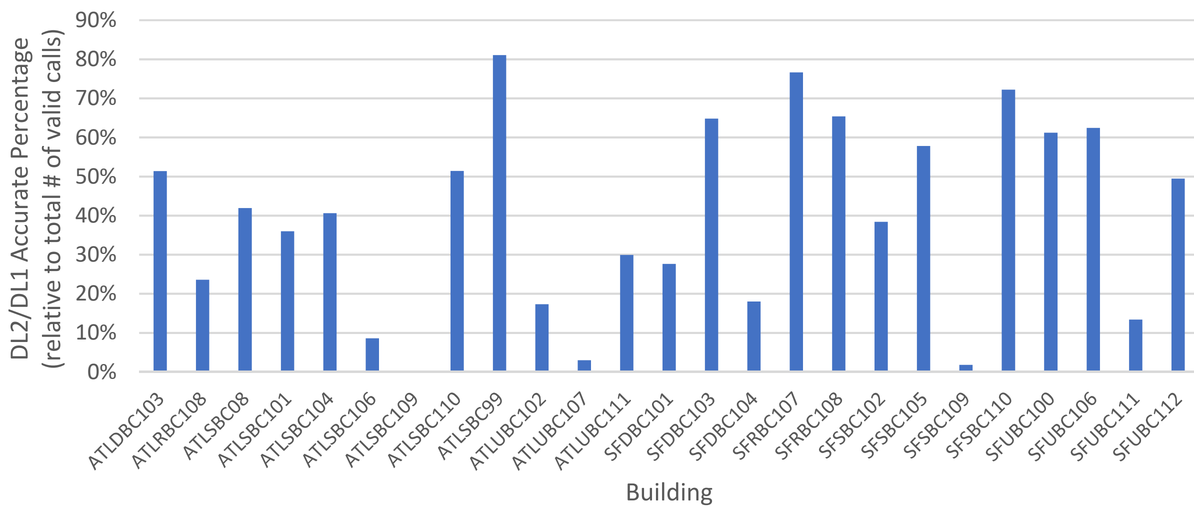

Figure 4-2 DL2/DL1 Accurate Percentage by Building

4.3 Performance by Morphology

Figure 4-3 shows the *DL2/DL1 Accurate Percentage* by morphology. This percentage increases somewhat for suburban, then significantly for rural, due to the greater number of single-family home stand alone structures, which are included in this metric as long as the delivered civic address is accurate, as described in Section 4.1.

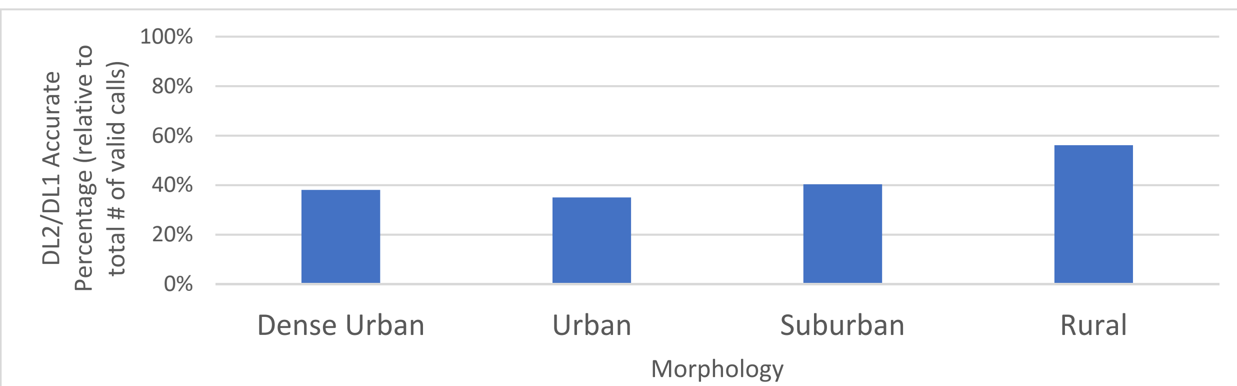

Figure 4-3 DL2/DL1 Accurate Percentage by Morphology

4.4 Performance by Test Region

Table 3-1 shows the core Dispatchable Location metrics broken out by test region. From the table, it can be seen that performance in the Atlanta area is somewhat lower than that observed in the San Francisco Bay Area. This is caused by the somewhat lower RP densities in the selection of test buildings and the particularly poor performance at the ATLSBC109 house, which did not have any provisioned reference points, as discussed in Section 5.1.

Table 4-2 Core Dispatchable Location Metrics by Test Region

Test Area	Civic Address Delivered Percentage	Civic Address Correct Percentage	Civic Address Incorrect Percentage	DL2/DL1 Accurate Percentage
Atlanta Area	78.1%	68.4%	9.7%	32.8%
San Francisco Bay Area	86.8%	79.2%	7.5%	44.1%

5 KEY FINDINGS

Low Reference Point density in the NEAD database is causing instances where erroneous civic address details are reported, an incorrect street address of a neighboring building is reported, or no civic address is reported at all. This problem typically plays out as follows:

- A mobile device receives the WiFi signals – on average about 45 unique MAC addresses – and transmits these identities to the eSMLC. Typically, in all but the most rural and isolated suburban buildings, the number of MAC addresses observed by the handset is substantial.
- The eSMLC may filter these identities further, then queries the NEAD. On average, ~38 identities are queried.
- The NEAD finds on average only about 3.5 of these MAC addresses – about a tenth of those queried – and returns their civic information to the eSMLC. This is a key problem – low reference point density in the NEAD results in a low number of the queried identities being found.
- The eSMLC reconciles the NEAD information, along with other information available, to produce a civic address, where possible. Factors such as WiFi measured signal strength are taken in to consideration, as well as geodetic information and possibly other factors.

With so few of the queried WiFi MAC addresses present in the NEAD, the critical Reference Point(s) – those that are very close to the mobile device – may not be returned, and therefore cannot be associated to a civic address by the eSMLC. The following harmful effects can ensue:

1. The eSMLC may choose inappropriate Reference Point(s), specifically those associated with neighboring building(s), causing it to report the address of a neighboring building.
2. The eSMLC may only find less ideal Reference Point(s) within the correct structure, often those more distant, reducing the quality of the returned Dispatchable Location.
3. The eSMLC may not find a suitable Reference Point at all, resulting in no civic address being returned and no Dispatchable Location.

Note that with greater NEAD Reference Point density, these effects can be substantially mitigated, thus improving overall performance, as described in Section 5.4.

The following sections quantify the extent of each of these effects, and provides some specific examples.

5.1 Address of Neighboring Building Reported

One undesirable and potentially dangerous effect (in 9-1-1 scenarios) is when the address of a neighboring building is returned. Of the 28,583 valid test calls, 2,456, or 8.6%, reported the address of a neighboring or nearby building. Figure 5-1 shows the percentage of valid calls reporting an incorrect address, broken out by building and by the reported Class of Service.

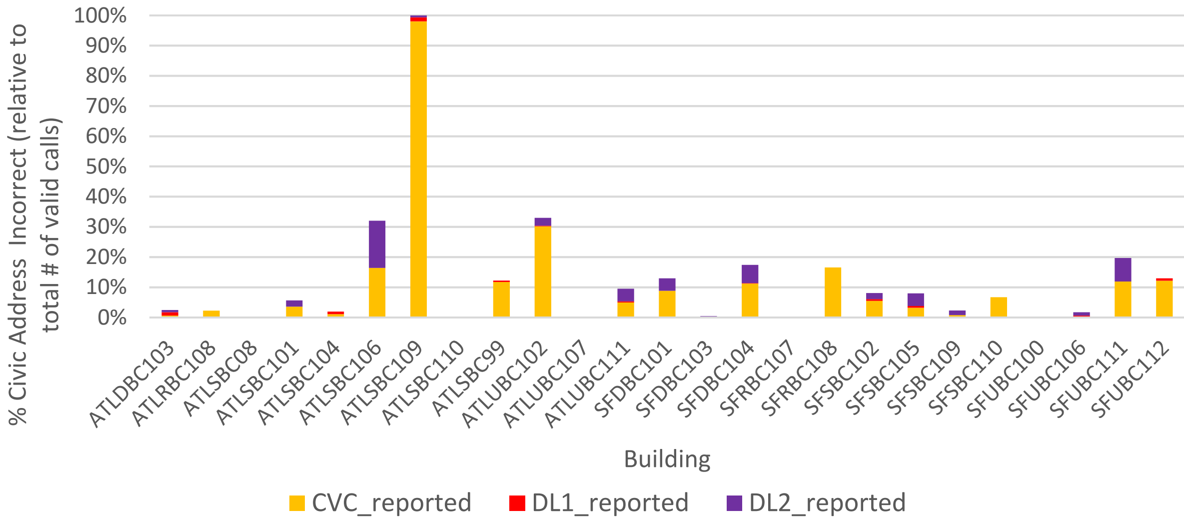

Figure 5-1 Percentage of Incorrect Civic Addresses by Building and Reported Class of Service

For most buildings, the NEAD returned at least some neighboring building addresses, thus this effect is widespread, it is not limited to only a few problem areas, and it occurs in all morphologies and building types. While the CVC Class of Service is most commonly reported in this situation, DL2 and DL1 are also sometimes reported, as indicated by the color in Figure 5-1. Reporting DL2 or DL1 is problematic, as these Classes of Service imply higher confidence in the result.

ATLSBC109, a single-family suburban residence in Atlanta, illustrates this effect. This two-story stand-alone structure had one Reference Point provisioned in the NEAD, but this MAC address was never observed by any mobile during testing, and thus it is believed to be no longer physically present or active at this location. This NEAD record was likely stale.

Because this building lacked a current reference point in the NEAD, the eSMLC chose Reference Points from neighboring structures for 449 of 525 test calls placed from this structure, as shown in Figure 5-2 – mostly to the building across the street but also to buildings as far as four houses away. The remaining calls reported no address at all. This example highlights the risks of attempting to use Dispatchable Location where there are no valid Reference Points nearby.

At the same time, Geodetic X/Y positioning performance for ATLSBC109 was strong. Figure 5-2 shows the Assisted-GPS (A-GPS) geodetic fixes in **blue** and hybrid solution types fixes in **red**. A-GPS fixes were generally quite accurate, with commensurate uncertainties, suggesting that they could be used to cross-check and help validate Dispatchable Location results, particularly in suburban conditions. Note, however, that there is evidence that some hybrid geodetic fixes containing WiFi content biased towards the dominant WiFi Access Point across the street, suggesting that Dispatchable Location and WiFi-based geodetic fixes may share a common bias since they are based on the same WiFi signal observations. Thus, caution should be exercised when performing Dispatchable Location cross-checking using WiFi-based geodetic fixes.

Requiring higher WiFi signal strength thresholds, particularly for the CVC class of service, is another approach that can help reduce inaccurate address reporting. Such a change can be implemented in the logic of the eSMLCs now, in parallel with efforts to increase Reference Point density.

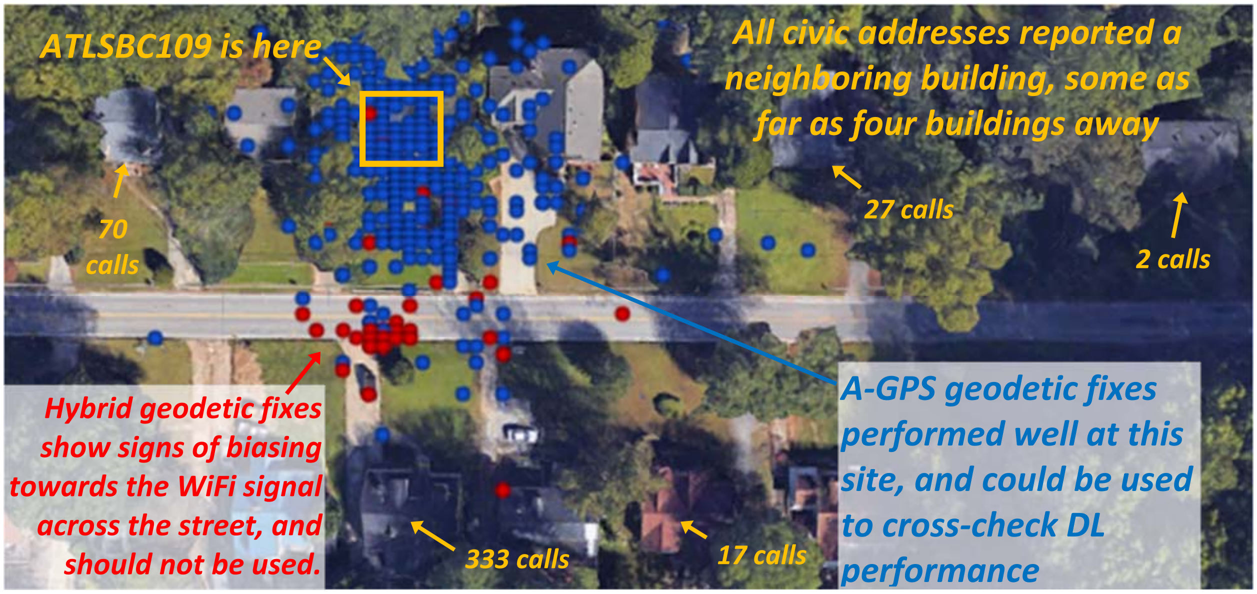

Figure 5-2 ATLSBC109 Example of Neighboring Addresses Being Reported, and the Potential to Use A-GPS Geodetic Fixes to Cross-check DL Results

5.2 Reduced Dispatchable Location Quality

Building SFDBC104 illustrates how low NEAD Reference Point density results in reduced Dispatchable Location quality in a large commercial structure. Building SFDBC104 is a historic 16-floor steel-frame commercial structure in San Francisco's Financial District. At the time of test planning, a total of 19 Reference Point records were present in the NEAD for this large structure, from only 14 unique identifiable units (suites). Several floors have no Reference Points at all. Furthermore, there is evidence that several records in the NEAD database for this building were out of date.

In addition to having a significant number of calls where a neighboring building address was reported, numerous calls were reported as DL1 or DL2, but should have been reported as CVC, caused by a lack of NEAD Reference Points close to the test points. Test Points 6 illustrates this effect and is used as an example here.

Figure 5-3 shows Test Point 6 in Suite 600 on the sixth floor, and the locations of the Reference Points in Suites 635, 612, and 609, which were the basis for the reported Dispatchable Location results. All of these Reference Points were in a different quadrant of the building; thus, the Class of Service should have been CVC, but DL1 was reported. In fact, there were no Reference Points in the Southwest quadrant of the sixth floor where Test Point 6 is positioned, or in this

quadrant in the adjoining fifth and seventh floors, thus neither a DL1 nor a DL2 Class of Service was possible with the population of NEAD Reference Points present during testing. Had a NEAD record existed in Suite 600, or in this quadrant, it would very likely have been stronger than the more distant Access Points, and a correct DL2 or DL1 civic address would likely have occurred.

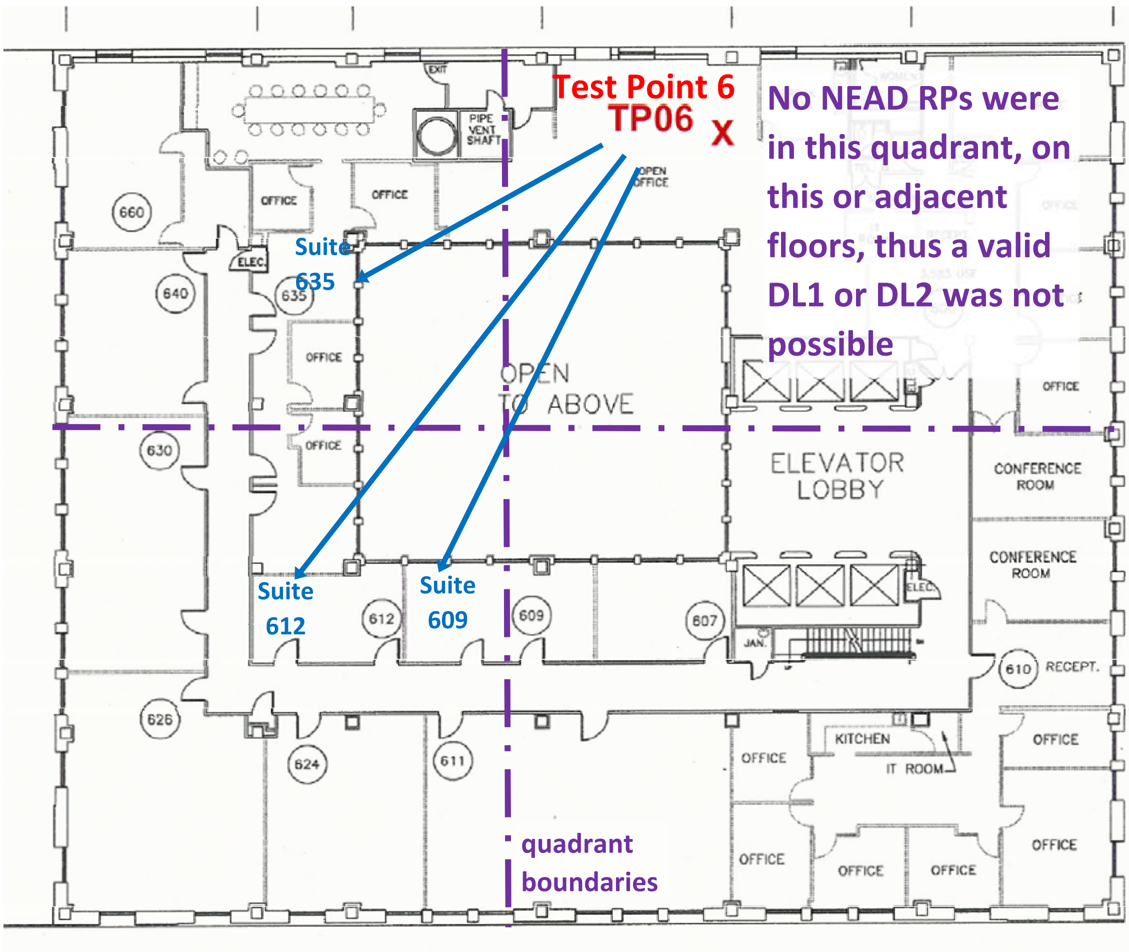

Figure 5-3 SFDBC104 Example of Reduced Dispatchable Location Quality Caused by Low Reference Point Density

5.3 No Civic Address Returned

Figure 4-1 showed that in nearly every building there are at least some calls where no civic address was returned at all, and in quite a few buildings a significant portion of calls did not report a civic address. To understand the role of NEAD database incompleteness in this, it is instructive to examine the relationship between the average number of MAC Addresses returned by the NEAD and the Civic Address Delivered Percentage. In Figure 5-4, for each building, the average number of MAC addresses found per call is scatter-plotted against the Civic Address Delivered Percentage to illustrate the correlation. The buildings with the lowest average number of MAC Addresses returned by the NEAD – ATLRBC108, SFSBC109, and ATLUBC107 – all have some of the lowest percentages of calls where a civic address is returned.

Then in general, as the number of MAC addresses found in the NEAD increases, the percentage of civic addresses returned also increases.

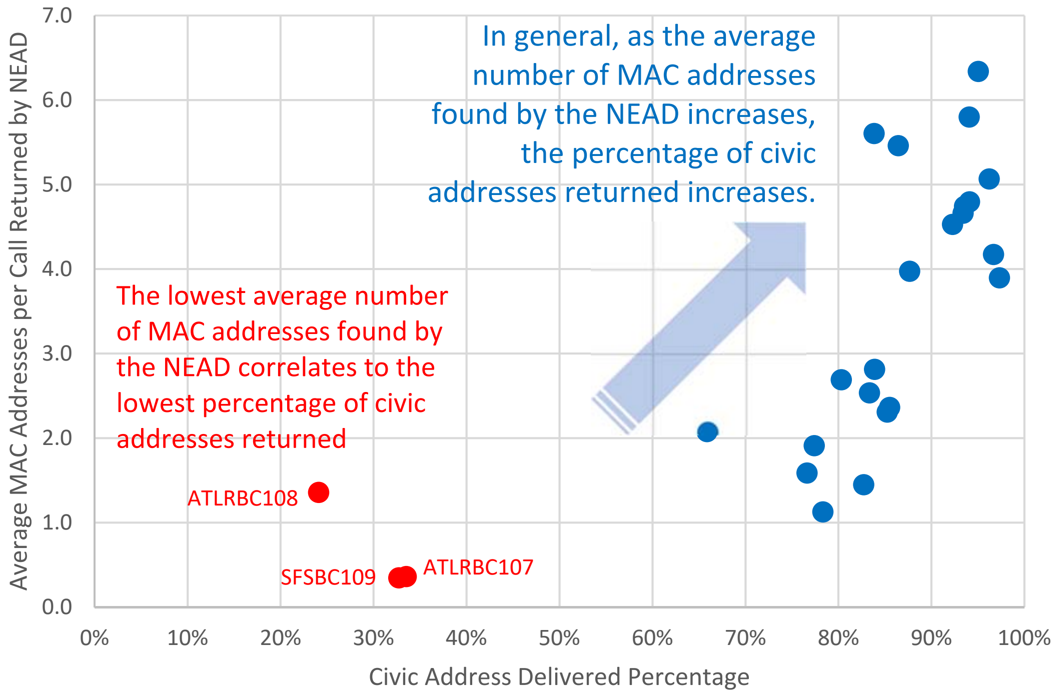

Figure 5-4 Correlation Between Database Incompleteness and Civic Address Delivered Percentage

Correlation does not assure causality, of course, but it is intuitive that increasing the number of valid MAC addresses contained in the NEAD, and thus increasing the average number of MAC addresses returned for each call, will significantly increase the number of calls where a civic address is returned, thus improving overall Dispatchable Location performance.

Note that by design, both the geodetic position and civic address are delivered to the PSAP, thus if the civic address is not present, the geodetic position will likely still be available. Never the less, the goal is to maximize the availability of Dispatchable Location. When both a geodetic position and civic address are present, the PSAP operator has the opportunity to leverage both.

5.4 Relationship Between Provisioning Density and Dispatchable Location Performance

Sections 5.1, 5.2, and 5.3 described how low Reference Point density in the NEAD database is causing a variety of Dispatchable Location performance issues. The logical next question is: how much Reference Point density is needed to improve performance? Figure 5-5 offers some intriguing clues that begin to answer this question.

In Figure 5-5, the *DL2/DL1 Accurate Percentage* for each building – the ultimate bottom-line Dispatchable Location performance measure – is scatter-plotted against the 'Provisioning Density' for that building to illustrate the correlation. 'Provisioning Density' is an analytical

assessment of the completeness of the NEAD database for a given structure; it is defined as the fraction of units (apartments, suites, separate rooms or partitions) in a building in which one or more reference points are provisioned in the NEAD.

Again, correlation does not assure causality, but it is intuitive that increasing NEAD database completeness will translate in to improved bottom-line Dispatchable Location performance. By extrapolating from the buildings in this test campaign – none of which achieved 100% *DL2/DL1 Accurate Percentage* – a trend emerges that suggests an acceptable Provisioning Density could be somewhere in the 50% to 75% range for medium and large commercial and residential structures.

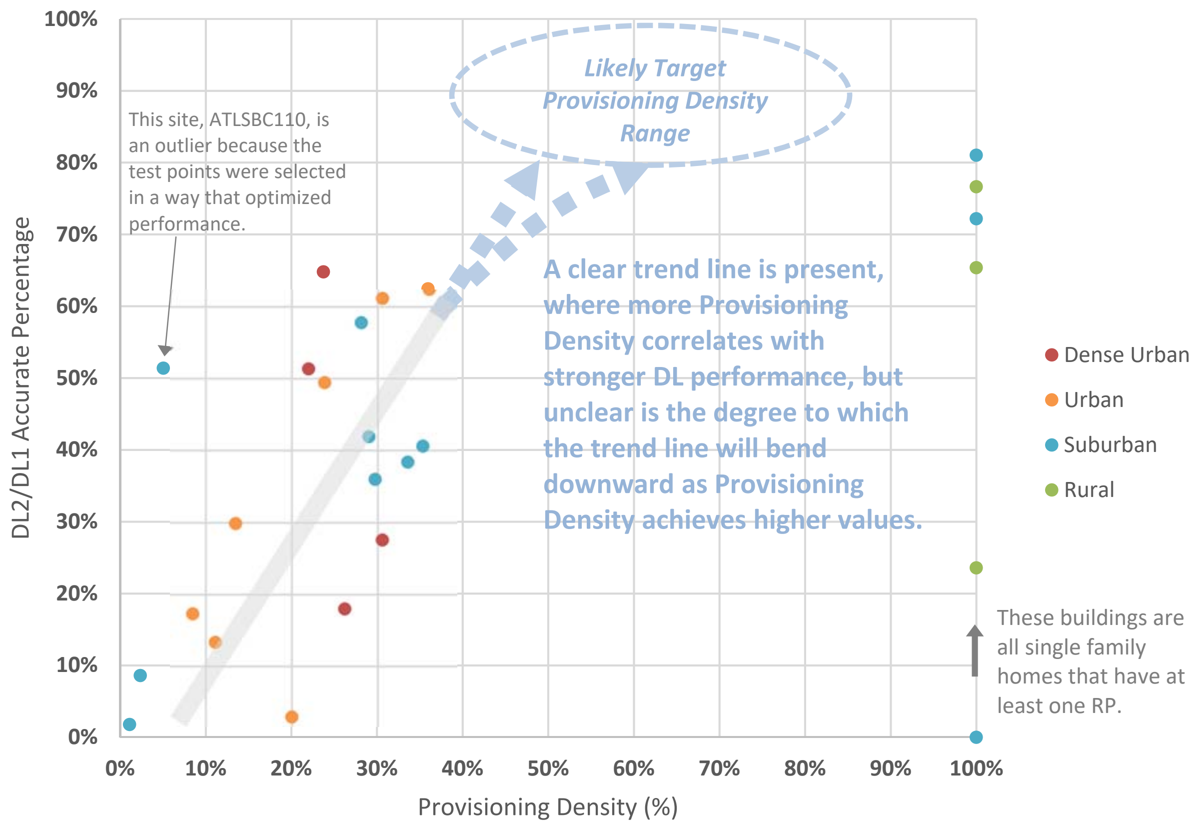

Figure 5-5 Dispatchable Location Performance by Building as a Function of Reference Point Density

Single-family and other small stand-alone structures however may need 100% Provisioning Density, to avoid reporting neighboring buildings or reporting no address at all, as discussed in Sections 5.1 and 5.3.

When testing occurred, the number of Reference Points in the test areas corresponded roughly to 14% of the population in San Francisco and 19% in Atlanta. While the exact relationship between Provisioning Density and Reference Point count relative to population has not yet been characterized, given the findings of this testing, a NEAD Reference Point count relative to population greater than 30% will likely be needed to achieve reliable Dispatchable Location

across a wide cross section of buildings. Note that the sources used to increase Reference Point density in the NEAD should encompass a broad diversity of building and use types, so that the resulting performance improvements apply broadly in high-density multi-unit commercial and residential structures, as well as in suburban and rural stand-alone structures.

6 RECOMMENDATIONS

This section describes recommendations emerging from performing Dispatchable Location testing in the Test Bed.

6.1 Database Expansion Recommendations

Expanding the size and quality of the NEAD database is a critical next step to improve Dispatchable Location performance. The following steps are recommended:

1. Continue to pursue other sources of NEAD Reference Points. Pay close attention to commercial and civic buildings, such as hotels, stadiums, museums, and mid/high-rise commercial structures, as these may benefit less from the next likely source: cable-company-provided Reference Points.
2. Add Bluetooth Reference Points to the NEAD and take steps to enable complete transmission of Bluetooth identities from the mobiles to the eSMLCs. This would provide additional higher-accuracy Reference Points and higher quality Dispatchable Location outcomes.

6.2 eSMLC Measures to Mitigate Harmful Effects of Low Reference Point Density

Low NEAD reference point density was found in some cases to cause erroneous Dispatchable Location details to be reported, incorrect addresses of neighboring buildings to be reported, or no civic address to be reported at all, as discussed in Section 5. While the size (and quality) of the NEAD database increases, steps can be taken now within the eSMLC to mitigate some of these harmful effects, including:

1. Require stronger WiFi signal strengths at the eSMLC when deciding if a NEAD record can be used for CVC Class of Service result. This can help avoid the most harmful effect, erroneous street addresses, though at the cost of some reduction in CVC results.
2. Optimize the RSSI thresholds used in determining DL2 versus DL1 and implement more sophisticated processing logic, including for example clustering and majority logic-based Dispatchable Location decisions.
3. Leverage external information available at the eSMLC where possible, including high-quality, high-accuracy A-GPS geodetic location fixes, to cross check Dispatchable Location choices, to help filter out erroneous results. Care should be taken, however, when the geodetic location method for a given call relies heavily on crowd sourced WiFi, since it could, in some circumstances, reinforce biases in the civic result, which also tends to be based on dominant WiFi signals.

6.3 Public Safety Community Recommendations

The following are recommendations for the public safety community:

1. In the CAD systems, visualize Dispatchable Locations in conjunction with reported geodetic positions, so that PSAP operators have the full context of the solutions provided.
2. Carry out a public safety educational campaign to explain the expected strengths and near-term limitations of Dispatchable Location as a function of the stage of maturity of the NEAD. Utilize the insights gained from both this Dispatchable Location test campaign and the end-to-end Dispatchable Location testing to the PSAP recently performed.

6.4 Retest Once Database Expanded & New eSMLC Features Available

If significant more Reference Point data is added to the NEAD, Dispatchable Location processing logic is refined in wireless networks, and both Android and iOS devices support the NEAD, a subsequent campaign of testing would be an appropriate step to undertake.