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Location-Based Routing for Wireless 9-1-1 Calls

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Executive Summary

The transition to location-based routing is an important step in improving our nation's 9-1-1 system, and much of the technology for a successful transition is available today. While a key focus of the FCC's Notice of Inquiry (NOI) is to understand the capabilities of location-finding and routing technologies, the Commission must also consider the importance of a national tapestry of PSAP service areas. This underlying nationwide dataset is needed so Emergency Services IP Networks (ESInets) can verify PSAP ownership for a 9-1-1 caller's location against an authoritative geographic information system (GIS) database.

Creating a national tapestry will not be easy. PSAP standard operating procedures across the country are broadly heterogeneous, accounting for local differences in population and geography. At any given PSAP, service areas may differ between Fire, EMS, or Law Enforcement personnel. These variances are based on PSAP-to-PSAP agreements with nearby jurisdictions or on higher municipal agreements between neighbors.[1]

PSAP service area agreements are made for a variety of reasons. For example, a subdivision in an administrative area may be separated from the area's own firehouse by a river (or other geographic feature), enabling a neighboring firehouse to respond faster. Other municipalities may simply be looking to take advantage of leveraging a county PSAP at scale.[2] In addition, in rural areas, secondary PSAPs often take over from the primary PSAP during non-peak hours, which means they are then responsible for broader service areas.[3]

The complexity of the scenarios mentioned above is magnified further by the need for 3D awareness of caller locations in urban areas—a requirement the Commission has already established for the not-so-distant future.[4] Due to these complexities, the current approach to 9-1-1 PSAP service area approximation, as well as any use of a primary-only PSAP service area tapestry that is now a decade old, will not suffice.

To properly collect, assemble, validate, refine, and package a PSAP service area tapestry for the entire country that provides both 2D and 3D awareness, the Commission should consider the use of an advanced GIS. Fortunately, the Commission already owns advanced GIS tools that the Public Safety and Homeland Security Bureau (PSHSB) can use to evolve and modernize the current (point only) Master PSAP Registry process. This can be accomplished by the Commission or through a public-private partnership with a PSAP industry association such as the National Emergency Number Association (NENA).

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[1] *See* https://geoplatform.maps.arcgis.com/home/item.html?id=d47bd3b0796f48d488d63c9917d25100.
[2] *Dekalb County Communications (DCCC) PSAP Report*, Section 1.1.1: http://dekalbcounty.org/PDF_INTERNET/DeKalb%20County%20PSAP%20Study%20-%20Final%20Feb%2020%202014.pdf.
[3] *South Dakota Department of Public Safety Compliance Review Checklist, PSAPs*: https://transition.fcc.gov/pshs/911/Net 911/8th-Report/SouthDakota_Compliance_Checklist.pdf.
[4] 47 CFR 20.18(i)(2)(ii)

This ex-parte filing will comment on how tower-based delays are exacerbated by geography in a way location-based routing could solve, as well as on considerations for each of the CSRIC recommendations with respect to a PSAP service area reference tapestry. It will also discuss examples of other federal agencies that are producing similar national-level information products using commercial-off-the-shelf (COTS) technology. This COTS approach would similarly limit cost to the Commission, if it were to create a PSAP service area tapestry for the nation.

1.0 State of Location-Based Routing Technologies

In the current generation of 9-1-1 call routing, a caller's location is determined by the proximity of PSAP locations to cell sector centroids. As noted in the footnotes of this Notice of Inquiry, the Commission's rules[5] require wireless 9-1-1 providers to provide (p-)Automatic Numbering Information and Automatic Location Information to the PSAPs. The notice goes on to say: "The p-ANI is used to route wireless 9-1-1 calls to a geographically appropriate PSAP by identifying the cell sector in which the caller is located, even if the caller has a wireless telephone number not associated with his or her location."

Today, cell sectors can be dynamically adjusted through adaptive arrays and beam tilting.[6] As a result, the "perfect sector coverage" ideals (shown in Figures 1 and 3) do not always represent the true sector coverage for each base station, leading to gaps and overlaps. These gaps and overlaps make sector centroid routing problematic, especially when geographic features like rivers and nature preserves disrupt ideal distribution. As PSAPs centralize, as new communities emerge, and as cellular providers modernize their networks, this environment will only become more complex.

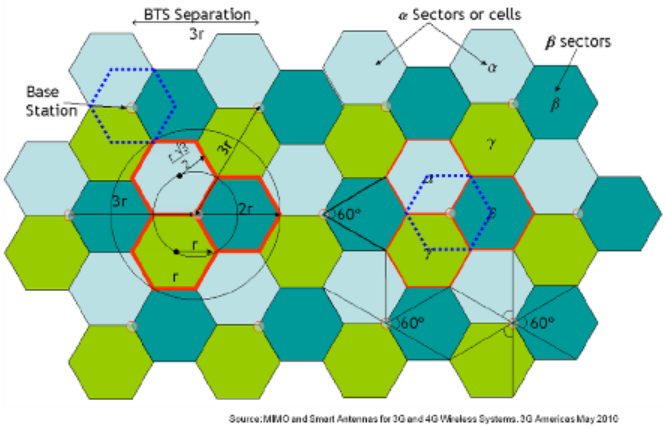

Figure 1 shows how a base station can cover sections from 3 sectors in blue and one sector or multiple sectors in red using directional arrays.[6]

[5] *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Report and Order and Further Notice of Proposed Rulemaking, 11 FCC Rcd 18676 (1996) (E911 R&O and FNPRM) at 18683-64, para. 10.

[6] James Donovan, Cells, Sectors and Antenna Beamforming, Commscope (May 28, 2014), https://www.commscope.com/Blog/Cells--Sectors-and-Antenna-Beamforming/.

Figure 2: The purple star represents a hypothetical cell sector center point, whereas the black, blue, and orange dots represent hypothetical caller locations each in different states.

The map displayed in Figure 2 shows how three hypothetical callers in different PSAP service areas could be routed to the same PSAP using the cell sector centroid and a directional array facing the DC/MD/VA border. Many veteran dispatchers would be familiar with areas like these, but dispatcher turnover rates are high,[7,8,9] which could result in a new dispatcher not being familiar with such a scenario despite their extensive training. This level of unfamiliarity would result in delay, and potentially lost life like that of Kevin Vroom, Shannell Anderson, and others.

Even with a modern six-sector configuration, there can be gaps or overlaps in the hexagons. With hexagons that are too large, gaps can exist in reliable coverage. When hexagons are too small, overlaps are introduced both within the hexagon and in neighboring hexagons. These gaps and overlaps can result in misrouting if the overlapping or gapped sectors belong to different PSAPs.

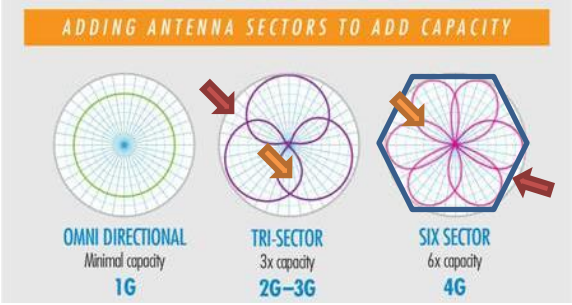

Figure 3 shows the different types of antenna sectors in an ideal equal distribution scenario—an ideal that is often unmet.[6] Red arrows identify gaps, and orange arrows identify overlaps.

Location-based routing will help modernize 9-1-1 call routing by establishing true locations—not locations approximated from the cell tower—and by assigning responsibility for those locations to specific PSAPs. These assignments will be based on area designations captured in the nationwide PSAP service area tapestry described and advocated for in this filing.

As outlined in the NOI, a precise caller location may need to be matched to a PSAP service area in less than 6 seconds. However, the California NG9-1-1 study cited by the CSRIC V LBR Report[10] found that almost 20% of calls were changed from one Emergency Service Number (ESN) to another. This significantly slows down the process of matching callers to PSAPs. With

[7] Adam Timm, A Better Way to Measure Your PSAP's Performance, The Healthy Dispatcher (Apr. 2, 2016), http://www.thehealthydispatcher.com/a-better-way-to-measure-your-psaps-performance/.
[8] Matt Bruce, Volusia, Flagler emergency dispatchers cope with long hours, low pay, high turnover, The Daytona Beach News-Journal (Updated Nov. 20, 2017), http://www.news-journalonline.com/news/20171119/volusia-flagler-emergency-dispatchers-cope-with-long-hours-low-pay-high-turnover.
[9] Stephen Williams, Schenectady County seeks to address dispatcher turnover, The Daily Gazette (Jan. 10, 2018), https://dailygazette.com/article/2018/01/10/schenectady-county-seeks-to-address-dispatcher-turnover.
[10] *CSRIC V LBR Report*, https://transition.fcc.gov/bureaus/pshs/advisory/csric5/WG1_Task2_FinalReport_092016.docx.

a location-based approach, these delays can be avoided as PSAPs are matched more accurately to calls based on their location.

The study also noted potential changes needed by WSPs and dependencies on chipsets that continue to improve. While we can't comment on the level of effort for those potential enhancements, current GIS server technology provides the location-based routing capabilities needed to calculate a caller's location and corresponding PSAP, then deliver the results to the Mobile Positioning Center (MPC)—all within 5 seconds. This technology can be embedded as a location server component of a Gateway Mobile Location Center (GMLC), of an Automatic Location Identification (ALI) server, or of a more central system component (such as an MPC for a service provider or the public safety community).

The report also noted concerns around location spoofing. One solution to spoofing could be to pair a proximity analysis check to the originating tower (or against phase 1 information) with the caller's location. This could help PSAPs flag locations as potentially spoofed, or force call routing from the receiving tower's ESN.

Another chief concern is accuracy. Current GIS technology supports GPS data from many different devices for geocoding in both 2D and 3D—including the internal GPS on smartphones as well as high-accuracy (sub-centimeter accuracy) external receivers.[11] This means GIS software is able to accurately plot locations using on-device location data and relate them to a PSAP's service area. GIS technology can also produce accurate 3D city models from available lidar, radar, and other source datasets.[12] This 3D content can work with a National Emergency Address Database (NEAD) to enable 3D dispatching.

2.0 Implementation of Location-Based Routing Technologies

In this Notice of Inquiry, the Commission is requesting input on the CSRIC V LBR's reported options for location based routing. Of the various options, there are four methods we view as favorable, and one we view as possible but potentially problematic when determining caller positions. These methods are addressed below, along with the relevancy of a PSAP service area tapestry to each method.

Two methods identified by the report—the Device-Based Hybrid (DBH) Location method and the Interim or Quick Fix method—would require a PSAP service area tapestry, since cell sectors aren't involved. As noted in section 7.1 of CSRIC V LBR's report, however, such a tapestry

[11] Erik Gakstatter, Esri introduces high-precision GNSS mobile GIS software, Geospatial Solutions (May 19, 2016), http://geospatial-solutions.com/esri-introduces-first-high-precision-gnss-mobile-gis-software/.
[12] Madeline Schueren, Import Terrain, Imagery, & OSM data into CityEngine, ArcGIS Blog (Oct. 3, 2017), https://www.esri.com/arcgis-blog/products/apps/3d-gis/import-terrain-imagery-osm-data-into-cityengine/.

would need to be accurate and constantly maintained. GIS technology today provides tools[13] that allow PSAPs and State 9-1-1 Administrators to collectively contribute to the tapestry and take ownership to keep their service areas current.

CSRIC also goes on to note in Section 7.2 that a geospatial shapefile containing PSAP polygonal jurisdictional boundaries would be needed to support this method. However, the report does not discuss the complexity of that shapefile given considerations already identified in this filing including backup PSAP relationships and special agreements. These schema complexities would need to be considered and matched with data that NG9-1-1 transition activities and State 9-1-1 Directors may already be collecting. The Commission could leverage its existing GIS holdings, available through the CIO's office, to review the data layer and assure its quality. Alternatively, the Commission could work with an industry partner like NENA who understands the necessary components for accuracy and maintenance.

The CSRIC report also discussed Geo-code Registered/Provisioned Civic Addresses as a possible method. This method will rely either on commercial geocoding technology or on the completion of a National Emergency Address Database (NEAD). GIS servers can perform the geocodes and reverse geocodes required by this method in less than 6 seconds. Since a NEAD does not presently exist, the process of compiling, maintaining, and updating the necessary geocoding databases to support this method may be cost-prohibitive. This option could introduce challenges with locating a caller in an area without an address, an area outside of range of one of these devices (such as a national park, a fishing boat on a river, or a bike trail), or a high-density area where proximity to said device may not be sufficient (like concert venues, stadiums, race tracks, and dense urban areas). Other complicating factors include different addressing methods inside areas like Native American reservations, as well as alternate locations introduced by Virtual Private Networks (VPNs).

DBH would be the preferred alternative to the geocoding method. With the DBH method, locations can be calculated through a hybrid of both caller location geocoding and a proximity check to fixed assets that are part of known infrastructure. This helps detect spoofing—spoofed locations would fail to meet the proximity check at a certain distance, and individual assets could even be tracked at registry to monitor future discrepancies. In addition, any devices that support call routing that are installed along or in close proximity to a PSAP service area boundary can be flagged for weighting purposes based on caller location.

The Notice of Inquiry also asks whether there have been developments in technology or public expectations that influence whether location-based routing should be pursued. ArcGIS, the leading commercialized GIS product, has evolved over the past 2 years to support increased parallel processing in the cloud. This capability can be deployed as part of the Emergency Services IP-Network (ESInet) to provide NG9-1-1 Core Services at a massive scale that could

[13] Web AppBuilder for ArcGIS (see https://developers.arcgis.com/web-appbuilder/) is a tool the FCC could configure to accept inputs.

support the call volumes typically received during peak 9-1-1 periods. This level of capability was not available nor possible during the advent of 9-1-1.

As GIS has continued to evolve in the consumer space, the technology has become ubiquitous in everyday life—a phenomenon known as the "democratization of GIS." A prime example of this ubiquity is the commercial use of geofencing and geotriggering. Geofencing involves identifying a location with a polygon, then triggering alerts (like shopping offers) when a mobile device enters that polygon.[14] These everyday interactions reinforce consumers' beliefs that their phones are tracking their location and should be able to provide accurate locations to 9-1-1.

The Notice also asks about the challenges 9-1-1 stakeholders will face if they are required to adopt location-based routing solutions. As discussed earlier, without a PSAP service area tapestry that accurately reflects secondary and backup PSAP arrangements (along with other special agreements that may affect the tapestry), any location-based routing solution will have limitations and gaps. A delay in the creation of this tapestry may impede the adoption and rollout of location-based routing for 9-1-1. Fortunately, the tapestry can support other groups beyond PSAPs, so the investment in a foundational dataset will benefit all 9-1-1 stakeholders. A nationwide tapestry would not only assist with call routing, but also provide an extra mechanism for CMRS providers, device manufacturers, and others to compare existing geographic layers to the PSAP service area tapestry for additional quality and verification checks, such as the spoofing checks discussed earlier.

3.0 Means to Advance 9-1-1 Location-Based Routing

To implement location-based routing, the FCC (or an industry partner of its choosing, such as NENA) should start by conducting a sampling of the data schemas used by State 9-1-1 Directors and NG9-1-1 contracts who are already collecting this information. After assessing what data is already being collected, the FCC or its partner should decide on a common national schema to use as a standard for the PSAP community.

Next, the FCC (or its selected industry partner) should provide a tool to PSAPs that would let them contribute their service area information to a national layer. At the time of release, this tool should also include automated quality control checks, as well as automation for certain processing tasks to reduce the workload for service area boundary ingestion and for future updates. Boundary data will need to be submitted in a vendor-agnostic format to achieve the maximum level of participation possible from the PSAPs, NG9-1-1 contractors, and State 9-1-1 Directors.

[14] Esri Geotrigger Service, Geospatial World (Jan. 22, 2014), https://www.geospatialworld.net/article/esri-geotrigger-service/.

Finally, the FCC should look to other major federal organizations—like the FAA, Census, USGS, HUD, and NOAA—to understand more about their enterprise dataset production for the country. This will help identify best practices when assembling layers of this magnitude and importance. For example, NOAA is using commercial GIS technology to provide navigation charts in our inland waterways and littoral environments.[15] In addition, the FAA produces flight charts,[16,17] and the USGS creates The National Map.[18] There are many other examples of commercial GIS technology being used by federal agencies to create national-level datasets that incorporate data from local entities which the FCC could further review.

4.0 Other Costs and Benefits

As an initial matter, the FCC is seeking to "know who is bearing the operational costs under the current practice." The FCC is also looking to answer the question, "Would it be reasonable to expect that developments such as NG9-1-1 would reduce or eliminate the problem in the reasonably near future?"

While Esri does not have information to contribute on the current costs, we do not believe creation of a PSAP service area tapestry is inevitable as states transition to NG9-1-1. Many states—including New York, Texas, and Ohio—have State 9-1-1 Directors that are moving them toward creating tapestries for their own states. Meanwhile, other states that lack this leadership and are behind on NG9-1-1 implementation have no evident plans to create these layers. Since each state is undertaking the process differently, there is no consistent schema—nor any guarantee of interoperability or capability parity at a national level. These stovepiped data creation efforts can have dangerous consequences, particularly during major national-scale disasters like earthquakes, hurricanes, flash floods, terrorist attacks, or wildfires, since consistent data is needed but not available.

For less than $500,000, the FCC could collect schema input and design an automated workflow for data ingestion and quality control for PSAP service areas for the entire country.[19] This workflow would cover police, fire, and EMS areas of responsibility, along with secondary and backup PSAPs. The service area dataset could then be shared publicly with limited data, or as a static, periodically updated database for computer aided dispatch (CAD) systems. The schema

[15] NOAA Modernizes Nautical Chart Production, *ArcNews* Online (Summer 2007), http://www.esri.com/news/arcnews/summer07articles/noaa-modernizes.html.
[16] FAA Rolls out Online Map system (ArcGIS) – Provides UAV Pilots with UAS Facility Maps for Airports, Geojobe (May 2, 2017), http://www.geo-jobe.com/drones-uav/faa-rolls-online-map-system-arcgis-provides-uav-pilots-uas-facility-maps-airports/.
[17] ArcGIS for Aviation Improves Aeronautical Data Management and Chart Production, *ArcNews* (Winter 2012/2013), http://www.esri.com/esri-news/arcnews/winter1213articles/arcgis-for-aviation-improves-aeronautical-data-management-and-chart-production.
[18] Caitlin Dempsey, USGS Map Services for The National Map, GIS Lounge (May 17, 2013), https://www.gislounge.com/usgs-map-services-for-the-national-map/.
[19] Estimate numbers based on our experience as a company providing services and software in the federal market.

and design could also be implemented at a central level by the FCC or an industry partner like NENA, as well as at a state level by a 9-1-1 Director who would find it useful. System architecture and testing could also be completed for less than $200,000 and represent another one-time or infrequent cost.

In terms of recurring costs, for less than $600,000 annually the FCC could also provide a live dynamic mapping interface to all of the roughly 102,000 PSAP dispatchers in the country to complement or integrate with their CAD systems. Through this interface, dispatchers can access and consume a PSAP service area tapestry as well as auxiliary information, including landmark search capability, live notifications (outages, weather, or traffic), and other useful information.

The FCC (or a chosen industry partner like NENA) would also need to consider annual hosting costs for the necessary software to support the above-mentioned activities with their IT departments or cloud providers. While both the FCC and NENA already maintain GIS software, any additional software needed could be obtained for less than $100,000 annually.

Associated costs respective to using GIS technology in support of ESInet and NextGen 9-1-1 Core Services could be estimated. However, further scoping discussions would be needed to provide accurate figures for consideration.

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