

Case Study

Cost Study for 4G LTE Unserved Areas in the U.S.

Understanding the costs to deploy and serve unserved areas across the U.S. with 4G LTE mobile broadband

DEVELOPED FOR UNITED STATES CELLULAR CORP

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COST STUDY FOR 4G UNSERVED AREAS

UNDERSTANDING THE COSTS TO DEPLOY AND SERVE UNSERVED AREAS ACROSS THE U.S. WITH 4G LTE MOBILE BROADBAND

INTRODUCTION

Much of rural America is still unserved by mobile broadband. This includes roads, homes, and businesses across many states, not just those in the West. Clearly, a lack of economic viability in these areas has left them unserved by mobile carriers, large or small. Factors that contribute to leaving these markets un-built include density, difficult terrain and the high cost of ongoing maintenance in places far-removed from the core network. The following summary of the 4G Unserved Cost Study (Study) gives a glimpse into the economic reality of mobile broadband in rural areas of the U.S. This study does not represent a detailed network design or even a bill of goods for a network to serve these rural areas. This analysis simply gives an estimate of the cost to build and maintain a 4G LTE network over time.

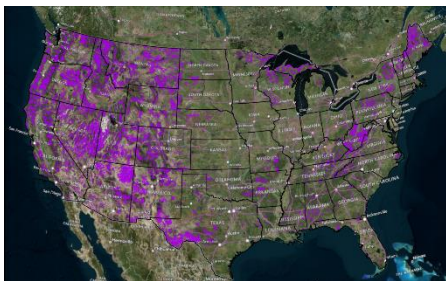
APPROACH FOR THE ESTIMATION OF COSTS

CostQuest Associates (CQA) developed a geospatial approach to assigning service and costs to currently unserved areas across the U.S. by identifying areas of potential service along roads. The following section gives a short summary of the approach that supported this study. This Study looks at the entire U.S., including Alaska, Hawaii, and Puerto Rico. A more detailed description to the methodology can be found in the full study.

The Network

CQA developed a four-stage model to estimate the upfront investment and ongoing costs needed to deploy a 4G Network to the uncovered portions of the U.S.

In the first stage, census blocks of the country not served by 4G LTE were identified. These unserved areas were defined by using the latest coverage data as shown in the FCC's Form 477 data for providers that have deployed 4G LTE. The second stage in the process was to estimate the mobile traffic from the unserved roads. In the third and final stage of the modeling effort, the model analysis developed the total counts of tower / cell sites that need to be deployed for those portions of the country that are currently unserved by LTE wireless service. The cell site selected for an area was based on demand, terrain, and density triggers.



Roads and Geographic Area

CQA has modeled coverage to serve all unserved roads across the U.S. (this includes highways, ramps, primary roads, secondary roads, 4WD roads, local, rural and city roads, alleys, private roads for service vehicles, and parking lot roads).

RESULTS

CQA is providing (below) a high-level overview of the total estimated investment for all unserved areas across the U.S. The Study assumes all costs related to building a 4G LTE network and maintaining that network over 10 years.

Initial Investment

It is estimated that most of the network investment will be related to new tower builds. There are very few existing towers within reasonable proximity to leverage for the service of currently unserved roads. The following is an estimate of the total towers and the related upfront investment needed to serve unserved roads:

Total New Towers: ~37,500

Upfront Investment: \$12.5bn

Annual Operations and Maintenance

The ongoing costs of operating and maintaining networks in rural areas are significant. Maintenance Capital and Operational Expenses related to Network Operations, Customer Operations, and Roaming are included in the costs estimated below.

Annual Maintenance Capital: \$1.05bn

Annual Operational Expense: \$1.08bn

Annual Revenue

As stated in the full study, the lack of economic viability in these areas has left them unserved. This is largely due to having costly network assets shared by so few customers. Subscriber revenue expected to support a network that serves these areas would not approach the costs to build and maintain the network over a 10-year period. The annual expected revenue for subscribers who would utilize the new deployment is estimated below.

Annual Expected Revenue: \$236m

The Business Case

As rational market players have looked at these unserved roads, they have chosen not to deploy network coverage. In looking at the cash flow and 10-year net present value of the cash flow from our model, we understand their decision. That is, it is uneconomic to deploy on these roads.

10 Year Net Present Value: -\$25.6bn

Annualized Cash Flow: -\$3.8bn (expected annual funding shortfall)

Note that other costs such as Edge and Core network assets, advertising and marketing costs, general and administrative costs, handset subsidies, and more were not included. Including these costs would worsen the business case even further.

ABOUT THE AUTHOR

CQA serves as the frontrunner in designing, developing and implementing economic models for the telecommunications industry. CQA has provided proprietary profitability, cost, telecom engineering, and metrics systems along with demographic data, data analysis, and GIS support to enhance decision making in some of the world's leading companies. CQA is also known for its work for federal government agencies such as the FCC and NTIA, and with state and local governments.

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Appendix A

Cost Study for 4G Unserved Areas in the U.S.

UNDERSTANDING THE COSTS TO DEPLOY AND SERVE UNSERVED AREAS ACROSS THE U.S. WITH 4G LTE MOBILE BROADBAND

Results Summary, State Table and Maps

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Release Date: February 15, 2017

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RESULTS SUMMARY

CQA is providing (below) a high-level overview of the total estimated investment for all unserved roads across the U.S. The study assumes costs related to building a 4G LTE network and maintaining that network over 10 years that were overviewed in CQA's February, 2016 paper filed with the FCC.¹ All other methods and assumptions for this study can be found in Appendix B.

INITIAL INVESTMENT

It is estimated that most of the network investment will be related to new tower builds. There are very few existing towers within reasonable proximity to leverage for the service of currently unserved roads. The following is an estimate of the total towers and the related upfront investment needed to serve unserved roads:

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ANNUAL OPERATIONS AND MAINTENANCE

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Annual Maintenance Capital: \$1.05bn

Annual Operational Expense: \$1.08bn

ANNUAL REVENUE

As stated in the Executive Summary, the lack of economic viability in these areas has left them unserved. This is largely due to having costly network assets shared by so few customers. Subscriber revenue expected to support a network that serves these areas would not approach the costs to build and maintain the network over a 10-year period. The annual expected revenue for subscribers who would utilize the new deployment is estimated below.

Annual Expected Revenue: \$236m

THE BUSINESS CASE

As rational market players have looked at these unserved roads, they have chosen not to deploy network coverage. In looking at the cash flow and 10-year net present value of the cash flow from our model, we understand with their decision. That is, it is uneconomic to deploy on these roads as shown below. Note that we have not included other cost that may be incurred in the expansion of the network. This includes: Edge and Core network assets, advertising and marketing costs, general and administrative costs, handset subsidies, and more. With the inclusion of these costs, the business case would look even worse.

10 Year Net Present Value: -\$25.6bn

Annualized Cash Flow: -\$3.8bn

¹ "United States Cellular Corp., Ongoing Support for Operations & Maintenance of Rural Mobile Networks". See: <https://ecfsapi.fcc.gov/file/60001518777.pdf>

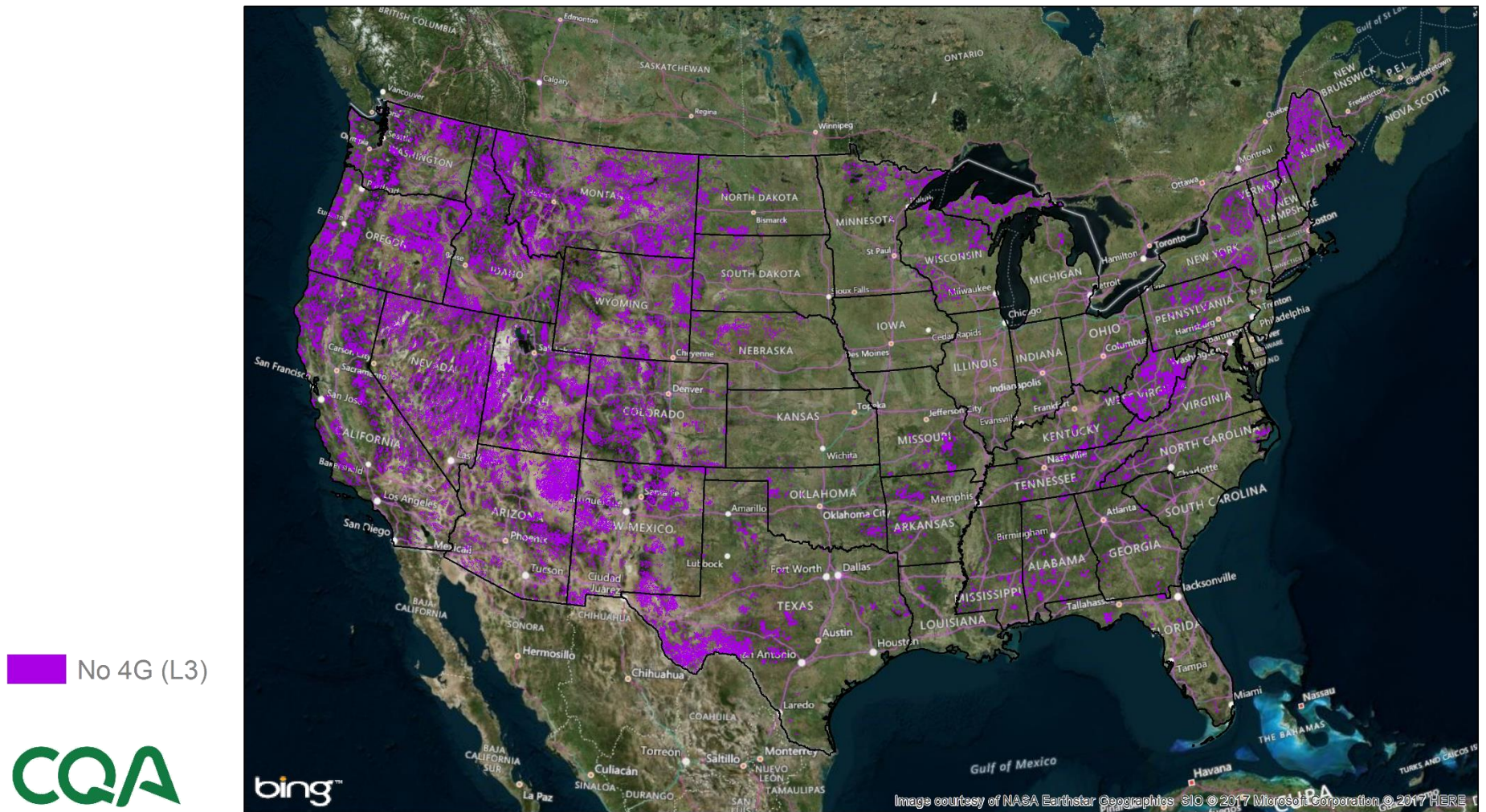
RESULTS BY STATE

| State | 10 yr NPV | Annual Funding Needed | Annual Revenue | Annual Opex | Annual Maintenance Capital | Initial Investment - Tower | Tower Count | Area (sqmi) | Road Miles |
|--------------|-------------------------|-----------------------|--------------------|------------------------|----------------------------|----------------------------|---------------|----------------|----------------|
| AK | (1,489,541,590) | \$221,985,622 | 26,448,744 | (68,364,149) | (64,041,670) | (761,780,000) | 2,161 | 5,434 | 19,503 |
| AL | (66,499,152) | \$9,910,335 | 4,286,603 | (5,174,984) | (3,270,363) | (37,935,000) | 122 | 1,016 | 4,117 |
| AR | (73,530,894) | \$10,958,272 | 2,622,739 | (4,355,581) | (3,312,089) | (38,880,000) | 118 | 971 | 4,057 |
| AZ | (1,299,124,843) | \$193,607,911 | 15,847,865 | (56,238,180) | (54,442,464) | (647,770,000) | 1,835 | 8,728 | 39,452 |
| CA | (4,464,291,571) | \$665,311,090 | 15,323,079 | (175,527,947) | (179,243,520) | (2,132,805,000) | 6,040 | 8,401 | 37,795 |
| CO | (1,344,785,573) | \$200,412,706 | 7,478,609 | (54,190,852) | (54,561,682) | (649,190,000) | 1,839 | 4,884 | 20,718 |
| CT | (1,821,463) | \$271,452 | 58,095 | (124,752) | (74,782) | (850,000) | 3 | 5 | 23 |
| DE | (2,142,583) | \$319,308 | 114,964 | (192,816) | (89,955) | (990,000) | 4 | 3 | 15 |
| FL | (36,388,724) | \$5,422,993 | 1,173,471 | (2,010,222) | (1,640,329) | (19,375,000) | 57 | 415 | 1,748 |
| GA | (64,850,669) | \$9,664,662 | 1,749,075 | (3,547,155) | (2,819,503) | (33,135,000) | 100 | 462 | 1,911 |
| HI | (199,358,205) | \$29,710,251 | 1,426,790 | (8,374,130) | (8,094,351) | (96,045,000) | 276 | 144 | 611 |
| IA | (7,738,202) | \$1,153,220 | 107,556 | (337,795) | (327,849) | (3,905,000) | 11 | 23 | 96 |
| ID | (1,548,171,264) | \$230,723,172 | 7,795,043 | (61,759,443) | (62,726,480) | (746,685,000) | 2,110 | 7,369 | 34,067 |
| IL | (27,714,107) | \$4,130,219 | 214,876 | (1,255,483) | (1,103,849) | (12,985,000) | 39 | 43 | 178 |
| IN | (12,437,750) | \$1,853,592 | 256,164 | (702,439) | (507,760) | (5,885,000) | 19 | 48 | 204 |
| KS | (31,220,625) | \$4,652,794 | 82,009 | (1,204,936) | (1,251,788) | (14,910,000) | 42 | 76 | 322 |
| KY | (57,985,450) | \$8,641,542 | 5,625,639 | (5,335,218) | (3,239,475) | (37,730,000) | 119 | 714 | 3,185 |
| LA | (21,344,206) | \$3,180,916 | 438,229 | (1,270,032) | (851,866) | (9,780,000) | 33 | 119 | 482 |
| MA | (10,288,212) | \$1,533,247 | 234,507 | (612,295) | (418,346) | (4,820,000) | 16 | 30 | 120 |
| MD | (7,701,896) | \$1,147,810 | 122,793 | (495,924) | (284,497) | (3,185,000) | 12 | 16 | 56 |
| ME | (201,870,560) | \$30,084,666 | 4,258,109 | (9,982,940) | (8,692,608) | (102,845,000) | 300 | 2,894 | 10,787 |
| MI | (78,988,640) | \$11,771,637 | 4,120,678 | (5,170,933) | (3,848,028) | (45,345,000) | 135 | 1,752 | 7,355 |
| MN | (80,670,212) | \$12,022,240 | 3,015,482 | (4,615,767) | (3,727,726) | (44,075,000) | 129 | 1,373 | 5,477 |
| MO | (52,025,480) | \$7,753,331 | 2,040,373 | (3,045,366) | (2,415,787) | (28,530,000) | 84 | 698 | 2,895 |
| MS | (46,281,059) | \$6,897,243 | 2,204,979 | (3,148,544) | (2,149,715) | (25,035,000) | 79 | 542 | 2,119 |
| MT | (1,968,035,219) | \$293,295,282 | 11,564,429 | (79,343,559) | (80,044,501) | (952,715,000) | 2,694 | 13,359 | 57,665 |
| NC | (107,912,905) | \$16,082,205 | 6,247,898 | (7,726,760) | (5,268,346) | (61,570,000) | 191 | 775 | 3,737 |
| ND | (86,221,402) | \$12,849,531 | 911,132 | (3,695,949) | (3,577,078) | (42,525,000) | 121 | 1,282 | 5,565 |
| NE | (108,535,680) | \$16,175,017 | 551,451 | (4,338,910) | (4,396,430) | (52,325,000) | 148 | 831 | 3,343 |
| NH | (28,301,281) | \$4,217,725 | 1,633,825 | (1,853,153) | (1,431,156) | (16,965,000) | 49 | 375 | 1,642 |
| NM | (1,223,562,957) | \$182,346,962 | 7,023,665 | (49,451,093) | (49,673,750) | (590,970,000) | 1,675 | 6,575 | 27,091 |
| NV | (2,857,328,242) | \$425,826,167 | 3,762,528 | (108,993,608) | (113,692,660) | (1,353,660,000) | 3,821 | 10,934 | 43,377 |
| NY | (146,572,352) | \$21,843,603 | 8,861,479 | (10,346,079) | (7,324,854) | (86,065,000) | 260 | 1,363 | 5,697 |
| OH | (22,564,099) | \$3,362,716 | 1,529,295 | (1,805,296) | (1,120,106) | (12,975,000) | 42 | 188 | 801 |
| OK | (68,864,915) | \$10,262,903 | 933,366 | (3,361,827) | (2,804,871) | (32,920,000) | 100 | 713 | 3,043 |
| OR | (1,881,378,119) | \$280,380,819 | 11,226,453 | (76,163,286) | (76,484,764) | (910,030,000) | 2,578 | 12,113 | 56,630 |
| PA | (56,548,033) | \$8,427,324 | 5,859,946 | (5,600,294) | (3,166,860) | (36,580,000) | 120 | 1,031 | 4,673 |
| PR | (13,912,561) | \$2,073,382 | 1,177,319 | (1,140,463) | (760,827) | (8,940,000) | 27 | 49 | 306 |
| RI | (653,721) | \$97,424 | 19,541 | (33,229) | (35,229) | (29,804) | 1 | 1 | 5 |
| SC | (18,734,798) | \$2,792,037 | 442,819 | (1,082,869) | (776,542) | (9,005,000) | 29 | 91 | 372 |
| SD | (92,176,962) | \$13,737,086 | 1,248,632 | (4,039,704) | (3,889,754) | (46,290,000) | 131 | 734 | 2,877 |
| TN | (72,503,792) | \$10,805,203 | 5,133,677 | (5,505,008) | (3,759,698) | (44,130,000) | 134 | 748 | 3,470 |
| TX | (768,204,912) | \$114,485,185 | 3,667,471 | (30,938,082) | (30,971,718) | (368,170,000) | 1,048 | 6,946 | 28,091 |
| UT | (1,900,083,392) | \$283,168,456 | 5,737,570 | (74,125,218) | (76,199,183) | (906,995,000) | 2,564 | 8,092 | 33,720 |
| VA | (110,642,565) | \$16,489,005 | 7,258,120 | (7,885,342) | (5,696,988) | (67,205,000) | 199 | 1,279 | 6,818 |
| VT | (57,979,417) | \$8,640,643 | 4,068,310 | (4,239,242) | (3,042,223) | (35,910,000) | 106 | 469 | 2,092 |
| WA | (1,583,759,018) | \$236,026,797 | 10,887,926 | (64,936,873) | (64,623,128) | (768,665,000) | 2,181 | 5,588 | 25,906 |
| WI | (62,757,087) | \$9,352,657 | 6,279,306 | (5,684,967) | (3,596,044) | (42,140,000) | 129 | 1,645 | 6,800 |
| WV | (52,219,947) | \$7,782,312 | 19,135,051 | (11,548,277) | (5,627,083) | (65,680,000) | 205 | 3,197 | 15,753 |
| WY | (1,067,906,256) | \$159,149,523 | 3,637,038 | (41,710,468) | (42,949,320) | (511,405,000) | 1,443 | 5,003 | 20,453 |
| TOTAL | (25,584,132,561) | 3,812,790,194 | 235,844,716 | (1,082,587,436) | (1,054,312,415) | (12,531,855,000) | 35,679 | 129,543 | 557,219 |

MAPS

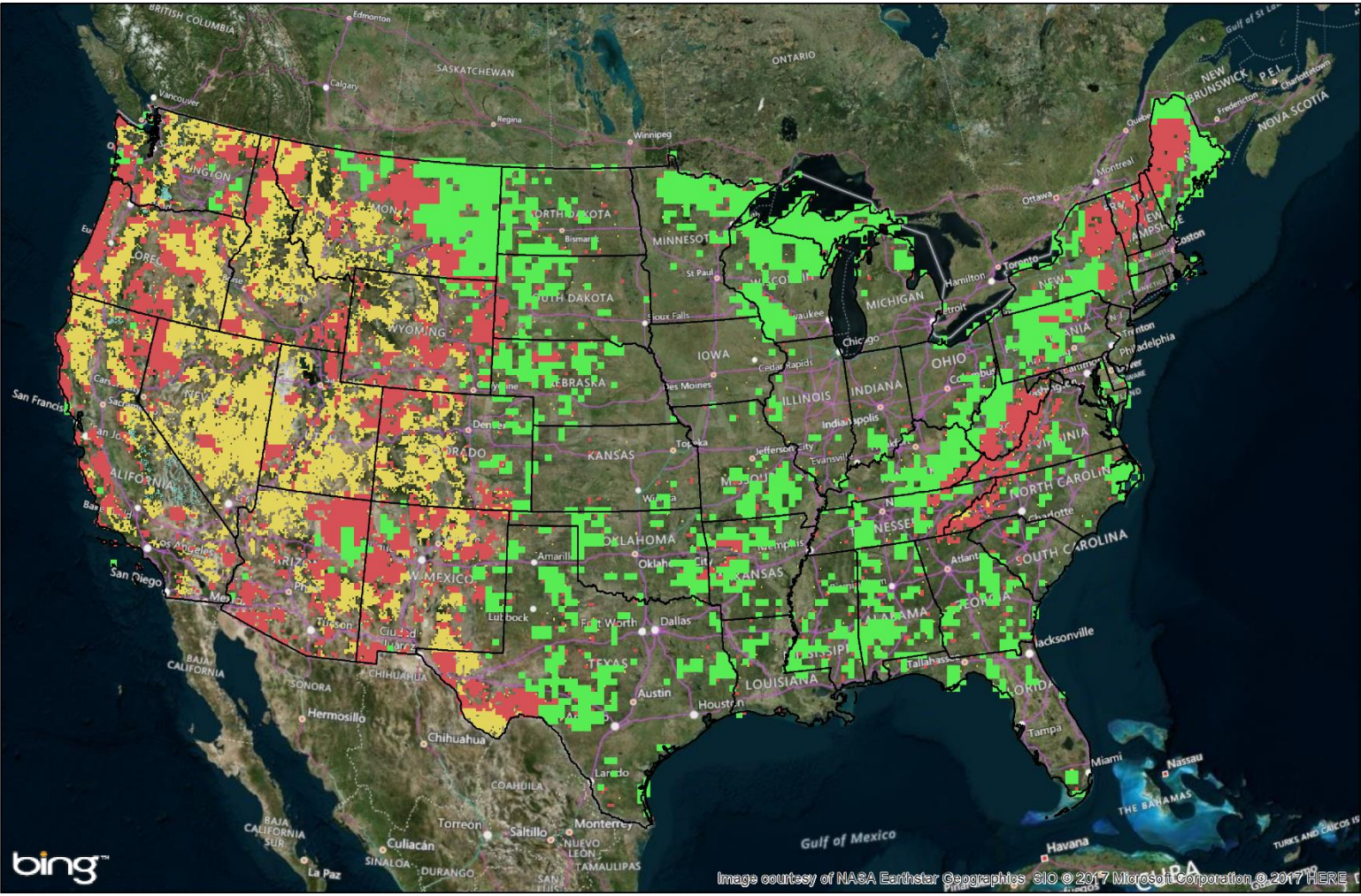
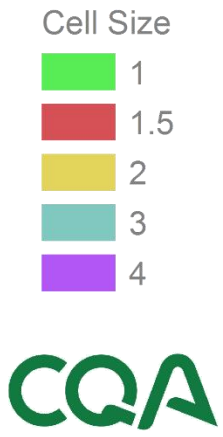
The following maps show the currently unserved areas and the assumed tower locations if a network were to be built to serve these locations.

CURRENTLY UNSERVED BY 4G LTE²



² Service availability as of December, 2015 from the FCC Form 477 Shapefiles. The shaded areas represent 800 meter grids along unserved roads. CostQuest Associates, Inc., base map BING.

UNSERVED AREAS WITH ASSIGNED TOWER GRIDS³



³ See Appendix B for Cell Sizes/Grid Radius

Appendix B

Methodology Documentation

Cost Study for 4G LTE Unserved Areas in The U.S.

Understanding the costs to deploy and serve unserved areas across the U.S. with 4G LTE mobile broadband

DEVELOPED FOR UNITED STATES CELLULAR CORP

Publication Date: 2/15/2017

COSTQUEST ASSOCIATES | ECONOMIC RESEARCH & ANALYSIS

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INTRODUCTION

In our prior paper, “United States Cellular Corp., Ongoing Support for Operations & Maintenance of Rural Mobile Networks”¹, we examined the total cost of deployment of networks in rural areas of the country. The approach and findings from this prior study, referred to it as the “Opex Paper” in this document, provide a foundation for this study.

As a follow on to our prior paper, CostQuest Associates (“CQA”) has been asked to develop a cost study that estimates the initial investment and ongoing operations and maintenance costs to serve currently unserved areas across the United States with 4G LTE mobile broadband. This study, commissioned by United States Cellular Corporate (USCC), will add to our prior research and findings and serve to support a more focused understanding of the aforementioned costs providing an in-depth analysis and greater detail of network attributes and expenditures. The following narrative provides further insight into the process and approach of CQA’s modeling efforts and design assumptions inherent in the study. The findings presented here demonstrate the significant investment that will be required to achieve ubiquitous access to 4G LTE mobile broadband services.

APPROACH FOR ESTIMATION OF COSTS (METHODOLOGY)

CQA Associates has developed an efficient approach estimate the number of cell sites across the United States ² needed to deploy a mesh 4G Network to the entire U.S. to cover all roads, buildings, and homes. Using the output from this approach, we were then able to determine required count of cell sites to augment existing 4G coverage to full ubiquitous coverage. However, before the count of cell sites could be determined, three fundamental methodological definitions had to be addressed:

1. The goal of 4G ubiquitous mobile broadband service had to be defined. For the purpose of this analysis, ubiquitous broadband was defined in terms of LTE mobile broadband technology.
2. The geographic scope of what was uncovered had to be determined. For the purpose of this study, we pulled in the 4G LTE layer from the most recent FCC 477 data set (December 2015 vintage data). Based on the data, those census blocks without any 4G LTE coverage were identified.
3. The geographic unit of coverage had to be defined. We felt that road paths would capture both populated areas and paths for movement. As such, our target for coverage is road paths. The TIGER road types used are shown in the following table:

¹ Ongoing Support for Operations and Maintenance of Rural Mobile Networks. See: <https://ecfsapi.fcc.gov/file/60001518777.pdf>

² Includes: Alaska, Hawaii and Puerto Rico

| TIGER RoadType | Description |
|----------------|------------------------------------------------------------------------|
| S1100 | Primary Road |
| s1200 | Secondary Road |
| s1400 | Local Neighborhood Road, Rural Road, City Street |
| s1500 | Vehicular Trail (4WD) |
| s1630 | Ramp |
| s1640 | Service Drive usually along a limited access highway |
| s1730 | Alley |
| s1740 | Private Road for service vehicles (logging, oil fields, ranches, etc.) |
| s1780 | Parking Lot Road |

With the fundamentals set, the count of cell sites could be identified that take into account several network characteristics including the radio access network (RAN), backhaul, geographic area, and road coverage. With the required count of towers identified, the next step in the process was to develop the business case for each tower's deployment. A 10-year study period was used. The approach and inputs used in our prior Opex Paper were applied to the towers in this study. As such, the model captures both the capital, revenue, operational costs and maintenance costs associated with a cell site deployment.

Below we provide additional detail on our methods to develop the total cost of deployment in unserved areas

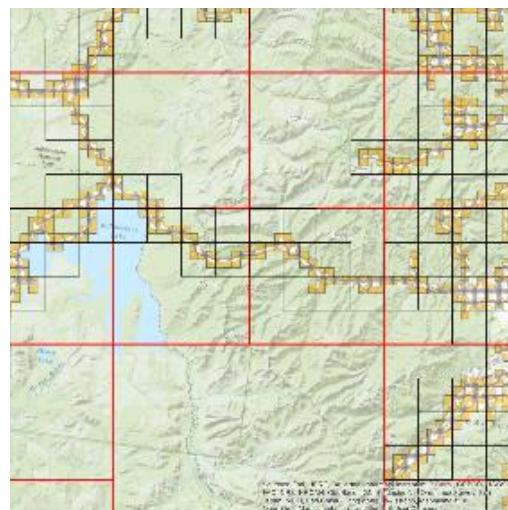
THE RAN NETWORK

In the first stage of the modeling effort, the model analysis developed the total counts of tower / cell sites that need to be deployed for those portions of the country that are currently unserved by LTE wireless service.

As a first step in the process, CQA has gridded up the entire country (including AK, HI, and Puerto Rico) using 5 different Grid sizes with the following estimated serving radii:

- Grid Level1: 8 mile grids
- Grid Level1.5: 4 mile grids
- Grid Level2: 2 mile grids
- Grid Level3: 800m grids
- Grid Level4: 200M MicroGrids

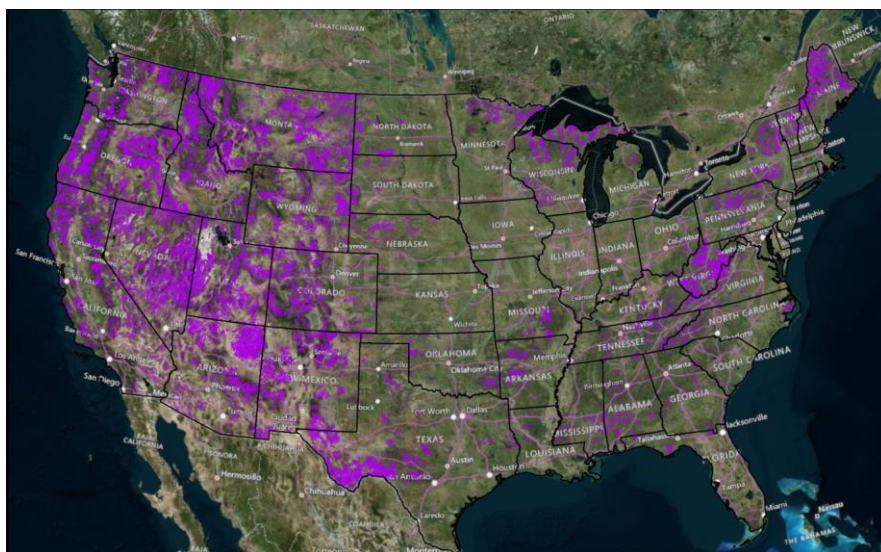
For each grid, the variance in terrain in the general area and the type and length of roads within the grid were identified. Those grids without any roads were discarded. The image at left shows the grids with roads in a sample area from the western U.S.



The next step in the process was to estimate the mobile traffic from every road in the U.S. As a starting point, population and employee counts were extracted from the CQA National Demand data set for every census block group.

Using an assumed monthly total demand, subsequently converted to estimated busy hour traffic, from each person and employee, and an assumed take rate the busy hour traffic in census block group was calculated. This busy hour traffic was then distributed to each road meter within the CBG (distributing more traffic to major roads than minor roads). Overlaying the grids over this road/demand data, the busy hour traffic in each grid was identified.

In the third step, census blocks of the country not served by 4G LTE were identified. Unserved areas were defined by using the latest coverage data as shown in the FCC's Form 477 data for providers that have deployed 4G LTE. The map below shows the areas that were unserved by 4G LTE as of December, 2015, using the Shapefile data that was made publicly available by the FCC. The shaded areas represent 800 meter grids with unserved roads³.



Larger versions of this and other maps can be found in Appendix A.

As a final step in the determination of tower counts to cover the unserved roads in the U.S., the grids covering the roads in the unserved census blocks were pulled. Using the busy hour demand, the appropriate grid size was selected based on demand, terrain and density triggers.

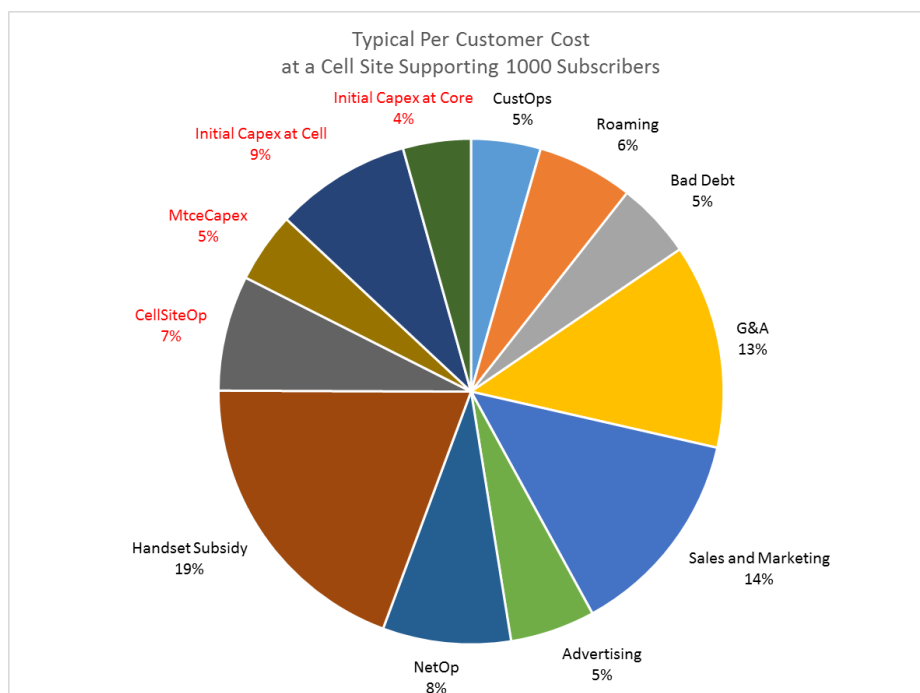
BACKHAUL

It was assumed that a mix of fiber and microwave leased backhaul would be needed serve all site locations. Backhaul costs were applied to each site location.

³ To highlight the areas of the country with unserved roads in a national map, we 'lit' up our 800 meter radii grids that contained unserved roads.

INVESTMENT DEVELOPMENT

Given the count of required cell sites, the investment and operating expenses required to deploy the 4G LTE mobile broadband assets were calculated. The methods and costs mirror the approach used in the Opex Paper. As shown in the Opex Paper, all of the various costs of implementing, running and maintaining a tower site were identified. The image below shows the typical breakout of the total cost for a cell site service 1000 subscribers. It should be noted that for this study, Bad Debt, G&A, Sales and Marketing, Advertising, Handset Subsidies, and Capex for Core were not included. This exclusion does not infer that these costs will not be incurred. Rather, we were focused, in this paper, on specific costs associated with the new sites:



THE BUSINESS CASE

With the tower counts, capital and operational costs available, the business case for each site was developed. The assumptions, rules and inputs used for this study are provided below.

| Variable | Value | Description |
|------------------------------------|------------|-----------------------------------------------------------------------------------------------|
| Monthly Cost per Subscriber | | |
| Discount Rate | 0.08 | Discount rate at 8% |
| Term of Ownership | 10 | 10 years |
| Leased Or Owned Backhaul | Leased | It was assumed that all backhaul would be a mix of microwave and fiber leased to the site |
| Minimum Road Meters | 50 | The minimum meters of road unserved in a grid to trigger costs/deployment |
| ARPU | \$ 50.00 | Annual Revenue per Unit/User |
| Assumed Rural Take | 40% | Assumed subscriber take rate of provider bringing LTE to unserved areas |
| Monthly Cost per Subscriber | | |
| CustOperations | \$ 2.85 | |
| Roaming and SystemOperations | \$ 3.94 | If ARPU is inclusive of roaming revenue, set retain to 1, else 0. |
| Network operation | \$ 5.26 | |
| Monthly Cell Site Costs | | |
| Network Operations | 650.00 | Includes Colo Lease, power, backhaul, maintenance |
| Network Operations - Tower Lease | 2100.20 | Monthly tower lease cost |
| Network Operations - BH Lease | 1650.00 | Monthly backhaul lease cost |
| Rural impact to network Operation | 7.5% | Percent bump in cell network operations cost in rural areas |
| Maintenance Capex | 108.4% | Represents Maintenance/upgrade capex as % of initial capex.Sourced from Replacement Capex Tax |
| Upgrade Capex | 140,000.00 | Very few towers could be used for upgrade to LTE |
| Initial Capex at Cell | 275,000.00 | Full deployment costs for a new site |
| TowerCostFor New Site | 80,000.00 | Costs to purchase and place tower at site |

RESULTS

The results of the study are provided in Appendix A. The assumptions, inputs and methods included in our methodology present solid high-level estimates of populations, roads, and total investment necessary to build-out meaningful 4G LTE mobile broadband service. This study is not an attempt at creating the actual final cost, the precise tower/site count, or the bill of materials to deploy mobile broadband services in any one particular area.