PUBLIC NOTICE

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WIRELINE COMPETITION BUREAU SEEKS COMMENT ON A REPORT AND PRELIMINARY COST CATALOG AND REPLACEMENT LIST TO HELP PROVIDERS PARTICIPATE IN THE SUPPLY CHAIN REIMBURSEMENT PROGRAM

WC Docket No. 18-89

Comments Due: April 26, 2021

By this Public Notice, the Wireline Competition Bureau (Bureau) invites interested parties to comment on the Supply Chain Reimbursement Program Study (Report) and a preliminary Catalog of Eligible Expenses and Estimated Costs (Catalog) to assist the Commission with establishing the Secure and Trusted Communications Networks Reimbursement Program (Reimbursement Program). The Report and Catalog will help eligible providers of advanced communications services participate in the Reimbursement Program. The Bureau also seeks comment on a preliminary List of Categories of Suggested Replacement Equipment and Services (Replacement List) to aid with the replacement of communications equipment and services deemed to pose an unacceptable risk to U.S. national security or the security and safety of U.S. persons (i.e., covered communications equipment or services).

Section 4 of the Secure and Trusted Communications Networks Act of 2019 (Secure Networks Act), as amended, directs the Commission to establish a Reimbursement Program for the reimbursement of costs incurred by eligible providers of advanced communications services for the removal, replacement, and disposal of any covered communications equipment or services.[1] Eligible providers include those providers that have previously obtained covered communications equipment or services, and, as recently amended, includes providers with up to 10 million or fewer customers.[2] Eligible providers seeking reimbursement are required to submit an "initial reimbursement cost estimate at the

[1] Pub. L. 116-124, 133 Stat. 158 (2020), *codified at* 47 U.S.C. § 1601 *et seq.* (Secure Networks Act), *amended by*, Consolidated Appropriations Act, 2021 (CAA), Pub. L. 116-260, Division N-Additional Coronavirus Response and Relief, Title IX-Broadband Internet Access Service, §§ 901, 906, 134 Stat. 1182 (2020). The Consolidated Appropriations Act, 2021, appropriated $1.9 billion to implement the Secure Networks Act, of which $1.895 billion shall be used to carry out the Reimbursement Program. Pub. L. 116-260, § 906(2).

[2] CAA § 901. The Commission recently adopted a Third Further Notice of Proposed Rulemaking, seeking comment on proposals to modify its rules in accordance with the amendments to the Secure Networks Act by the CAA. *See Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs*, WC Docket No. 18-89, Third Further Notice of Proposed Rulemaking, FCC 21-26 (Feb. 22, 2021). Consistent with the CAA, the Commission proposed to raise the eligibility threshold for providers of advanced communications service from providers with two million or fewer customers to providers with 10 million or fewer customers. *Id.* at 3, para. 9. The Commission also proposed to limit the use of Reimbursement Program funds to the removal, replacement, and disposal of equipment and services produced or provided by Huawei or ZTE or their subsidiaries, parents, and affiliates, consistent with the CAA. *Id.* at 3-5, paras. 10-16; CAA § 901; *see* Secure Networks Act § 4(c).

time of application, with supporting materials substantiating the costs."[3] The Commission is required, as part of the Reimbursement Program, to develop a Replacement List to assist participants.[4]

On December 11, 2020, the Commission adopted the *Supply Chain Second Report and Order*, which, among other measures, promulgated rules for the Reimbursement Program and the Replacement List.[5] The Commission interpreted "providers of advanced communications service" to mean those providers with a broadband connection to an end user with at least a speed of 200 kbps in one direction[6] and promulgated a "costs reasonably incurred" standard to determine reimbursement expense eligibility.[7] The Commission also directed the Bureau to develop and finalize a Catalog to "identify reimbursable costs with as much specificity as possible, provide guidance to entities seeking reimbursement, streamline the reimbursement process, and increase accountability."[8]

The Bureau contracted with Widelity, Inc. (Widelity) to produce a report detailing the anticipated steps in removing, replacing, and disposing of covered communications equipment or services and an initial proposed version of the Catalog and Replacement List.[9] Widelity conducted a series of confidential interviews with a broad range of communications industry stakeholders to understand the process and costs associated with removing, replacing, and disposing of covered communications equipment or services.[10] The Bureau now seeks comment on the Report, Catalog, and Replacement List.

Report: Supply Chain Reimbursement Program Study. Widelity produced the attached Report detailing the "requirements, timing, and costs involved in the removal, replacement, and disposal of covered communications equipment, or services, from the networks of advanced communications service providers" participating in the Reimbursement Program.[11] The Report provides an industry and technology overview and explains Widelity's methodologies used to develop the initial version of the proposed Catalog and Replacement List. In preparing the Report, Widelity focused on the removal, replacement, and disposal of communications equipment and services produced or provided by Huawei and ZTE.[12] Widelity acknowledges that the reimbursement process will be "complex and resource intensive" but concludes that the Reimbursement Program "can be achieved with the desired outcomes."[13]

[3] Secure Networks Act § 4(d)(2).

[4] *Id*. § 4(d)(1)(A).

[5] *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs*, WC Docket No. 18-89, Second Report and Order, 35 FCC Rcd 14284 (2020) (*Supply Chain Second Report and Order*); 86 Fed. Reg. 2904 (Jan. 13, 2021); *see* 47 CFR § 1.50000 *et seq*.

[6] *Supply Chain Second Report and Order*, 35 FCC Rcd at 14310, para. 55.

[7] *Id.* at 14334-36, paras. 118-121.

[8] *Id*. at 14339, para. 128.

[9] Widelity provides business and network engineering consulting in the communications industry. More information about Widelity is available on its website. *See* Widelity, https://widelity.com/ (last visited Mar. 15, 2021); Attach. 1 at 14.

[10] Attach. 1 at 8.

[11] *Id.* at 13.

[12] *Id*. at 13. Huawei and ZTE, and their subsidiaries, parents, or affiliates, were designated as companies that may pose a national security risk to communications networks or the communications supply chain. *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs – Huawei Designation*, PS Docket No. 19-351, Order, 35 FCC Rcd 6604 (PSHSB 2020); *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs – ZTE Designation*, PS Docket No. 19-352, Order, 35 FCC Rcd 6633 (PSHSB 2020).

[13] Attach. 1 at 78.

The Bureau seeks comment from interested parties on the attached Report, including Widelity's methodologies, and how the Report should inform the Reimbursement Program. In particular, does the Report accurately capture all anticipated steps and categories of expenses associated with the removal, replacement, and disposal of covered communications equipment or services?

Catalog of Eligible Expenses and Estimated Costs. The Catalog is intended to "help the Commission and applicants satisfy the Secure Networks Act's requirements[,] not only by helping applicants with transition planning and estimating costs for application submissions, but also with identifying potential replacement equipment and services and expediting the Commission's reimbursement request review process."[14] When requesting funding from the Reimbursement Program, applicants "can reference the final [Catalog], which will contain a list of many, but not necessarily all, of the relevant expenses in lieu of providing additional supporting documentation to justify the specific cost estimate."[15] As the Commission said, "[i]f an applicant believes the predetermined estimate does not fully account for its specific circumstances or a predetermined cost estimate is not provided in the [Catalog] for the cost identified by the applicant, the applicant can provide its own individualized cost estimate."[16]

Widelity produced the attached proposed Catalog, which includes a range of cost estimates, organized by category and subcategory of communications equipment and services, that may be eligible for reimbursement under the Reimbursement Program.[17] These suggested costs are estimates only and are not meant to indicate that reimbursement will reflect the estimated costs. As the Commission explained, listing in the Catalog is not a guarantee of reimbursement for any individual expense under the Reimbursement Program.[18] All claimed cost estimates submitted in a reimbursement application are subject to review by Commission staff to ensure each expense and request for reimbursement is reasonable.[19] The Catalog is not exhaustive and inclusion or exclusion of a particular category of costs should not be read to state or imply that the expense will or will not be eligible for reimbursement.[20] After considering public comments on the proposed Catalog, the Bureau will issue a public notice adopting a final version of the Catalog.

The Bureau seeks comment from interested parties on the proposed Catalog, including the suggested ranges of estimated costs and cost categories and subcategories, and how the Catalog should inform the Reimbursement Program. To what extent are the cost estimates included in the proposed Catalog reasonable? Are the suggested cost ranges likely to help carriers estimate the costs for application submissions and identify potential replacement equipment and services? Are there additional cost categories and subcategories that should be included in the final Catalog?

List of Categories of Suggested Replacement Equipment and Services. Section 4(d)(1) of the Secure Networks Act directs the Commission to establish a Replacement List that "will identify categories of suggested replacements of real and virtual hardware and software equipment and services to guide providers removing covered communications equipment from their networks."[21] The Commission explained that the Catalog would "inform the Replacement List by helping to target the type of equipment

[14] *See Supply Chain Second Report and Order*, 35 FCC Rcd at 14399-40, para. 129.

[15] *Id*. at 14346, para. 149.

[16] *Id*.

[17] *See* Attach. 2. Widelity based the network categories of cost estimates on the categories used by the Commission's Office of Economics and Analytics to collect cost estimate data from providers to evaluate the scope of the cost for a "rip and replace" reimbursement program. Attach. 1 at 15 (citing Appx. B).

[18] *Supply Chain Second Report and Order*, 35 FCC Rcd at 14339, para. 128.

[19] *Id*. at 14340, para. 129.

[20] *See id*. at 14346, para. 149.

[21] *Id*. at 14663-68, paras. 197-208.

that will be removed and replaced."[22] The Commission found that the "Replacement List should include equipment and services equipped, or upgradable to, be used in [Open Radio Access Networks (O-RAN)], or in virtualized networks."[23] In adopting a rule for the Replacement List, however, the Commission declined "to identify specific equipment and services" or a "list of manufacturers" due to concerns about "inadvertently overlooking some equipment or manufacturers," "influenc[ing] purchases" by appearing "to convey that the Commission believes certain equipment meets quality and security metrics," and possibly leading to "security threats."[24]

Widelity produced the attached proposed Replacement List which includes categories of replacement equipment and services that may be used to replace potentially covered equipment and services under the Reimbursement Program.[25] Widelity relied on the network categories the Commission's Office of Economics and Analytics developed to identify Huawei and ZTE equipment and services potentially subject to replacement, removal, and disposal.[26] Based on these network categories, Widelity analyzed core layer, distribution layer, access layer software, and services to prepare the proposed Replacement List.[27] After considering public comments on the proposed Replacement List, the Bureau will release a public notice adopting the final version of the Replacement List which will be published on the Commission's website and annually updated to ensure that it remains current consistent with the *Supply Chain Second Report and Order*.[28]

The Bureau seeks comment on the proposed Replacement List. Are there additional categories of equipment and services that could be used to replace potentially covered communications equipment and services that we should include in the Replacement List?

Pursuant to sections 1.415 and 1.419 of the Commission's rules,[29] interested parties may file comments on or before the dates indicated on the first page of this document. Comments must reference WC Docket No. 18-89 and must be addressed to the Commission's Secretary, Office of the Secretary, Federal Communications Commission. Comments and reply comments may be filed using the Commission's Electronic Comment Filing System (ECFS).[30]

- Electronic Filers: Comments and reply comments may be filed electronically using the Internet by accessing ECFS: https://www.fcc.gov/ecfs/.
- Paper Filers: Parties who choose to file by paper must file an original and one copy of each filing. Filings can be sent by hand or messenger delivery, by commercial overnight courier, or by first-class or overnight U.S. Postal Service mail.
    - Commercial overnight mail (other than U.S. Postal Service Express Mail and Priority Mail) must be sent to 9050 Junction Drive, Annapolis Junction, MD 20701.
    - U.S. Postal Service First-Class, Express, and Priority mail must be addressed to 45 L Street NE, Washington, DC 20554.

[22] *Id*. at 14365, para. 201.

[23] *Id*. at 14366, para. 202.

[24] *Id*. at 14364-65, paras. 199-200.

[25] *See* Attach. 3.

[26] Attach. 1 at 13 (citing Appx. B).

[27] Attach. 3 at 4; Attach. 1, Appx. B.

[28] *Supply Chain Second Report and Order*, 35 FCC Rcd at 14363, para. 198; 47 CFR § 1.50006.

[29] 47 CFR §§ 1.415, 1.419.

[30] *See Electronic Filing of Documents in Rulemaking Proceedings*, 63 FR 24121 (1998).

- Effective March 19, 2020, and until further notice, the Commission no longer accepts any hand or messenger delivered filings at its headquarters. This is a temporary measure taken to help protect the health and safety of individuals, and to mitigate the transmission of COVID-19.[31] We encourage outside parties to take full advantage of the Commission's electronic filing system. Any party that is unable to meet the filing deadline due to the building closure may request a waiver of the comment or reply comment deadline, to the extent permitted by law.

People with Disabilities. To request materials in accessible formats for people with disabilities (Braille, large print, electronic files, audio format), we ask that requests for accommodations be made as soon as possible in order to allow the agency to satisfy such requests whenever possible. Send an email to fcc504@fcc.gov or call the Consumer and Governmental Affairs Bureau at (202) 418-0530.

This matter shall be treated as a "permit-but-disclose" proceeding in accordance with the Commission's *ex parte* rules.[32] Persons making *ex parte* presentations must file a copy of any written presentation or a memorandum summarizing any oral presentation within two business days after the presentation (unless a different deadline applicable to the Sunshine period applies). Persons making oral *ex parte* presentations are reminded that memoranda summarizing the presentation must (1) list all persons attending or otherwise participating in the meeting at which the *ex parte* presentation was made, and (2) summarize all data presented and arguments made during the presentation. If the presentation consisted in whole or in part of the presentation of data or arguments already reflected in the presenter's written comments, memoranda or other filings in the proceeding, the presenter may provide citations to such data or arguments in his or her prior comments, memoranda, or other filings (specifying the relevant page and/or paragraph numbers where such data or arguments can be found) in lieu of summarizing them in the memorandum. Documents shown or given to Commission staff during *ex parte* meetings are deemed to be written *ex parte* presentations and must be filed consistent with rule 1.1206(b). In proceedings governed by rule 1.49(f) or for which the Commission has made available a method of electronic filing, written *ex parte* presentations and memoranda summarizing oral *ex parte* presentations, and all attachments thereto, must be filed in their native format (e.g., .doc, .xml, .ppt, searchable .pdf). Participants in this proceeding should familiarize themselves with the Commission's *ex parte* rules.

For additional information on this matter, please email supplychain@fcc.gov.

- FCC -

[31] *See FCC Announces Closure of FCC Headquarters Open Window and Change in Hand-Delivery Policy*, Public Notice, 35 FCC Rcd 2788 (OMD 2020).

[32] 47 CFR § 1.1200 *et seq.*

ATTACHMENT 1

Report
Supply Chain Reimbursement Program Study

Submitted by:
Widelity, Inc.
4031 University Drive
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March 25, 2021

Acknowledgments

Widelity would like to thank all of the industry participants, telecom companies, equipment suppliers, engineers, associations, attorneys and vendors, who graciously spent their time to speak with us about the challenges and the costs facing the industry for this program.

In addition to their time, the industry has been very generous by providing us with extensive pricing data which we have incorporated into the catalog of allowable costs.

Lastly, we would like to thank the Wireline Communications Bureau for their support and guidance for this effort.

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1. Introduction

The Secure and Trusted Communications Networks Act of 2019 (Secure Networks Act), signed into law in March of 2020, directed the Federal Communications Commission (FCC) to establish a Secure and Trusted Communications Networks Reimbursement Program (Reimbursement Program) to assist providers of advanced communications services (Providers) with the removal, replacement, and disposal of certain communications equipment and services that poses a national security risk from their networks.[1] In a *Second Report and Order*, released on December 11, 2020, the FCC adopted rules creating the Reimbursement Program.[2] The Consolidated Appropriations Act, 2021, enacted on December 21, 2020, appropriated almost $1.9 billion for the Reimbursement Program and amended the Secure Networks Act to, among other things, increase the pool of program eligibility to advanced communications service providers with ten million or fewer subscribers from Providers with two million or fewer subscribers.[3]

As part of the initiative, the FCC engaged Widelity to create this report to provide an overview of the impacted technology, and the uses and challenges faced by the eligible entities choosing to participate in the voluntary Reimbursement Program. Specifically, we focused on the requirements, timing, and costs involved in removing, replacing, and disposing of covered communications equipment or services from the networks of advanced communications service providers with ten million or fewer subscribers.

[1] Secure Networks Act, H.R.4998, Pub. L. No. 116-124, 133 Stat. 158 (2020) (codified as amended at 47 U.S.C. §§ 1601–1609).

[2] *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs*, WC Docket No 18-89, Second Report and Order, 35 FCC Rcd 14284 (2020) (*Second Report and Order*).

[3] Pub. L. 116-260, Division N-Additional Coronavirus Response and Relief, Title IX-Broadband Internet access Service, §§ 901, 906, 134 Stat. 1182 (2020).

Widelity interviewed a broad range of industry personnel to better understand the issues that may be encountered throughout the process of replacing the covered communications equipment that poses a threat to national security. We conducted interviews with impacted telecommunications carriers, equipment suppliers, associations, RF and structural engineers, support companies, manufacturers, attorneys, and network engineers. The majority of the information that we reflect in our report was received directly from our interviews with industry participants.

Throughout our due diligence process, we consistently found the participants generous with their time, cooperative, forthright in their observations, helpful, and insightful. Industry participants we spoke with have provided us with extensive insights and materials to incorporate into this report.

In addition to this report, the materials provided by the industry participants have been incorporated into a catalog of potential costs and a list of replacement equipment.

Through our interviews with industry personnel, Widelity identified potential bottlenecks and other operational issues, which we brought to the attention of the FCC.

The replacement program will pose significant challenges to the telecommunications industry. Replacing equipment in an operating broadband or wireless network, in a rural or frontier setting without seriously disrupting services that customers rely on in their daily lives and business is challenging. There are many technologies, frequencies, locations and topologies that will need to be coordinated by each carrier, as it removes covered communications equipment and installs replacement communications equipment.

The process of transitioning a broadband or wireless network to replacement communications equipment has very distinctive elements that must be completed for a successful transition. We anticipate that implementing the transition will likely involve some or all of the distinct elements listed below:

- Pre-planning
- Network Engineering
- RF Engineering
- Site surveys

- Structural Engineering
- Negotiating with tower owners
- Permitting
- Tower work
- Tower rigging services
- Tower engineering (loading) studies
- Tower replacement
- Acquiring equipment/manufacturing
- Equipment installation
- Field Engineering
- Drive testing for baseline coverage
- Engineering studies
- Installing new network cores
- Installing base station transmitters
- Installing antennae
- Evaluating spectrum/backhaul capabilities
- Permits
- Fiber network construction
- Building modifications
- Electrical service modifications
- Obtaining replacement equipment
- Proof-of-performance testing
- Coverage verification
- Installing transmission line
- Leasing tower space or building towers
- Migrating traffic
- Legal services

We will examine each of these elements and others in this report as each relates to the transition process.

2. Background

Broadband and wireless services have become foundational services for many Americans and businesses across the US and its territories. Connectivity, either on wire, coax, fiber or in the air is an essential part of daily American life, whether at home, in industry, or at work. The future of America is inextricably bound with the creation of a robust communications network. Ensuring the security and safety of our nation's communications infrastructure is thus critical.

3. Legislation

The FCC is an independent agency established in the Communications Act of 1934, as amended, to regulate communications by wire, radio, television, satellite, and cable. On March 12, 2020, the President signed into law the Secure Networks Act. The legislation, as amended, directs the FCC to establish the Reimbursement Program to fund the removal, replacement, and disposal of covered communications equipment or services that pose a national security risk from the networks of advanced communications service providers with ten million or fewer subscribers. The FCC will publish and regularly update a list, which will identify the communications equipment and services considered covered and eligible for reimbursement under the Reimbursement Program for the reasonable expenses related to the removal, replacement, and disposal of such covered equipment and services.

Advanced communication service providers, as defined by the Secure Networks Act, means providers of advanced telecommunications capability as defined in section 706 of the Telecommunications Act of 1996 (Telecommunications Act).[4] The FCC has historically interpreted providers of advanced telecommunications capability to mean facilities-based providers, whether fixed or mobile, with a broadband connection to end users with at least 200 Kbps (Kilobits per second) service in one direction and requires entities meeting this speed threshold to file the FCC Form 477 "Local Telephone and Broadband Reporting" to report information on their broadband deployments.[5]

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[4] 47 U.S.C. § 1302(d)(1).

[5] 47 C.F.R. § 1.7001; *Inquiry Concerning Deployment of Advanced Telecommunications Capability to all Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate such Deployment to Section 706 of the Telecommunications Act of 1996,* CC Docket No. 98-146, Report, 14 FCC Rcd 2398, 2406, para. 20 (1999).

In the *Second Report and Order*, the FCC interpreted providers of advanced communications services, for purposes of determining eligibility for the Reimbursement Program, to encompass those entities required to file the FCC Form 477, provided they do not have more than the statutory number of subscribers required for eligibility.[6]

3.1Comparable Facilities and Technology Upgrades

Eligible entities will have to plan their upgrade path from 2G/3G/4G to 5G ready network topologies.

For entities that are facing the path to upgrades from 2G and 3G to 4G/LTE or are planning to upgrade directly to 5G (or 5G ready) equipment, Providers will have to meet the specific requirements of the Report and Order. The FCC is clear that the 5G standard is not a blanket approval of an upgrade path.

In the *Second Report and Order*, the FCC stated:

"Language from the House Report demonstrates that Congress 'expects the Commission, when implementing regulations . . . to preclude network upgrades that go beyond the replacement of covered communications equipment or services from eligibility; however, [Congress] expects there to be a transition from 3G to 4G or even 5G- ready equipment in instances where equipment being replaced was initially deployed several years ago."[7] The FCC further stated: "We will therefore allow providers replacing older technology to obtain reimbursement for the cost of new replacement equipment that is 4G LTE compatible and is capable of subsequently being upgraded to provide 5G service.
However, operators that elect 'to purchase optional equipment capability, or make other upgrades' beyond those reasonably needed to replace existing equipment, must do so using their own funds, consistent with the approach we took in the broadcast incentive auction proceeding and the recent C-Band auction proceeding."[8]

[6] *Second Report and Order* at paras. 110-111.

[7] *Id*. at para. 123.

[8] *Id*. at para. 126.

Entities migrating network topology with additional capacity should plan to work with their vendors to apply the 5G ready standard for the replacement equipment that they purchase.

4. Covered Communications Equipment or Service

The Secure Networks Act, as amended, limits the use of Reimbursement Program funds to the removal, replacement and disposal of communications equipment and services deemed "covered" in accordance with section 2(a) of the Secure Networks Act.[9] The FCC's Public Safety and Homeland Security Bureau formally designated Huawei Technologies Company (Huawei) and ZTE Corporation (ZTE), their corporate parents, subsidiaries, and affiliates as companies that pose a national threat to the integrity of communications networks or the communications supply chain per section 54.9 of the Commission's rules.[10] The FCC found that Huawei and ZTE equipment are highly susceptible to influence and coercion by the Chinese government, military and the intelligence community. As a result of the finding, the FCC designated Huawei and ZTE as covered equipment and imposed a ban on the use of universal service support to purchase equipment or services from these companies in accordance with section 54.9 of the Commission's rules. The Commission recently adopted a *Third Further Notice of Proposed Rulemaking*, seeking comment on how the amendments to the Secure Networks Act by the Consolidated Appropriations Act affected the designation of covered communications equipment and services.[11] The Commission specifically stated that "We believe this amendment demonstrates Congressional intent to change the scope of equipment and services eligible for reimbursement from the equipment and services on the Covered List [designated per section 2(a) of the Secure Networks Act] to the equipment and services subject to the Designation Orders" and sought comment on that interpretation.[12]

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[9] 47 U.S.C. §§ 1603(c)(2), 1608(5); Consolidated Appropriations Act § 901.

[10] *See* 47 CFR § 54.9(b); *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs – Huawei Designation*, PS Docket No. 19-351, Order, 35 FCC Rcd 6604 (PSHSB 2020); *Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs – ZTE Designation*, PS Docket No. 19-352, Order, 35 FCC Rcd 6633 (PSHSB 2020). These orders involving Huawei and ZTE are collectively referred to as the Designation Orders.

[11] *See Protecting Against National Security Threats to the Communications Supply Chain Through FCC Programs*, WC Docket No. 18-89, Third Further Notice of Proposed Rulemaking, FCC 21-## (rel. Feb. #, 2021).

[12] *Id*.at para. 13.

Notwithstanding the outcome of the *Third Further Notice of Proposed Rulemaking*, communications equipment or service deemed covered and subject to Reimbursement Program eligibility is not a static list and is subject to change over time as communications equipment or services can be periodically added or removed from the "covered list."

For purposes of developing this Report and the Catalog of Cost Estimates and the Covered Communications Equipment and Service Replacement List, we have focused the analysis on the removal, replacement, and disposal of equipment and services produced or provided by Huawei and ZTE. Huawei and ZTE equipment have been deployed throughout many rural telecom and broadband networks. The equipment can be found in the wireless portion of the network (the radio access network RAN) and the core of the networks as well as the customer premise equipment in businesses and homes. For additional information on the communications equipment and services produced or provided by Huawei and ZTE by network category, see the explanatory document attached hereto as Appendix B that was prepared by the FCC's Office of Economics and Analytics for a prior data collection completed in 2020.

On March 12, 2021, the Federal Communications Commission's Public Safety and Homeland Security Bureau released a list of communications equipment and services (Covered List) that are deemed to pose an unacceptable risk to the national security of the United States or the security and safety of United States persons.[13i] The list includes five companies: telecommunications companies Huawei and ZTE, and video surveillance and telecommunications equipment produced by Hytera Communications Corporation, Hangzhou Hikvision Digital Technology Company, and Dahua Technology Company. For this report, Widelity focused on the Huawei and ZTE telecommunications equipment that will need to be replaced.

[13] DA 21-309

5. Brief from the FCC

The FCC engaged Widelity to complete three tasks directly related to the Reimbursement Program.

The three tasks are:

5.1 Report

Widelity has created this report covering the requirements, timing, and costs involved in the removal, replacement, and disposal of covered communications equipment, or services, from the networks of advanced communications service providers choosing to voluntarily participate in the replacement reimbursement program.

We based this report on a series of interviews with many eligible telecom carriers, equipment providers, service providers, engineering experts, and attorneys practicing in the telecommunications field.

5.2 Catalog of Cost Estimates

Widelity has produced a catalog, providing cost estimates for the removal, replacement, and disposal of covered communications equipment or services, namely Huawei and ZTE equipment and services, that may be eligible for reimbursement under the Reimbursement Program, as proposed by the FCC and required by the Secure Networks Act.

Based on industry interviews, we have organized the catalog to reflect the way that equipment and service providers offer their products and services.

5.3 Covered Communications Equipment and Services Replacement List

Widelity produced a replacement provider equipment and services list. We used the Network Categories Information Collection Guide[14] produced by the FCC's Office of Economics and Analytics to organize the data collection process with vendors. The Network Categories provide a basic structure for the list, which we then augmented with services that we determined, through our industry interviews, were crucial to the process of replacing the covered communications equipment. Our Replacement List includes the manufacturer or supplier of the replacement communications equipment or services. The Replacement List represents the baseline that can be updated and maintained going forward throughout the Reimbursement Program.

6. Report Methodology

Widelity has extensive experience designing and deploying communications networks. With our expertise, we were able to organize a fact gathering process that we are confident reflects the requirements of a report that will prove useful to the FCC, and the entities impacted by the legislation. Widelity wrote the 'Widelity Report and Catalog of Costs" for the broadcast incentive auction reimbursement program. From that process we created an interview and data collection process that assured us that the information we were gathering reflected a comprehensive study of the needs and challenges that eligible entities are facing. We endeavored to reflect the industry as was presented during our interviews.

[14] *See* Appx. B.

7. Catalog Methodology

The Catalog is made up of categories and subcategories of costs that eligible entities are expected to incur.

Through our interviews, we have obtained current cost ranges for equipment, software and services from equipment manufacturers and service providers (e.g., tower crews, attorneys, RF engineers, and field engineers). In some cases, we were either provided a range of costs or quoted different costs for similar equipment or services by multiple sources. In those cases, we provided the range of costs we received. It is possible that tower crews, engineering services and some other costs may rise with high demand.

Some categories of costs for carriers in remote and island locations are expected to be higher than the average costs. These are addressed in section 11.1 and on the section Services Specific to: Alaska, American Samoa, Hawaii, Puerto Rico, and Virgin Islands in the Catalog of Expenses Eligible for Reimbursement.

8. Covered List Data Collection Methodology

Widelity used the Network Categories[15] document to identify Huawei and ZTE equipment and services that would potentially require replacement, removal, and disposal. For this analysis, we used the Network Categories that are listed in the five basic areas: Core Layer, Distribution Layer, Access Layer Software and Services. The list of services represents the items we expect may be incurred by the Providers, along with the issues brought up in our interviews with suppliers and service providers. Because many service providers provided a selection of detailed service categories, we have aggregated the subcategories into the highest reasonable level of service.

[15] *See* Appx. B.

9. Reimbursement Program Process

For eligible entities who voluntarily participate in the replacement program, how the Reimbursement Program is structured and operates significantly impacts the timing of the removal, replacement, and disposal process by Reimbursement Program recipients. The experience with the broadcast incentive auction reimbursement program makes it clear that the requirements of the reimbursement process will be numerous; including issuing guidelines of allowable costs, accepting, reviewing and approving cost estimates, monitoring expenditures, reviewing documentation, reimbursing eligible entities, auditing expenses, and managing exceptions to cost estimates.

The Commission has adopted a standard of reasonableness to determine whether costs are eligible for reimbursement.[16] That is, costs are only eligible for reimbursement if they are reasonable, accounted for, incurred in the appropriate period, and directly associated with the removal, replacement, and disposal process, "costs reasonably incurred."[17] This includes both "hard" expenses, such as for new equipment and tower rigging, and "soft" expenses, including legal and engineering expenses.[18] In our Catalog, we have identified the major expenses that eligible entities are likely to incur in the replacement process. The removal, replacement, and disposal process will need to be closely managed by the FCC.

[16] *See Second Report and Order* at para. 118-121.

[17] *Id*.

[18] *Id*. at para. 121.

10.Industry overview

Broadband networks and ubiquitous wireless networks are becoming crucial to the well-being of individuals and communities. Businesses and individuals rely on connectivity to function. Business, education, entertainment, and social activities are increasingly moving online and driving the need for broadband connectivity. As we have seen in the recent pandemic, broadband access has become a literal lifeline for individuals and businesses. Broadband has allowed Americans to remotely work, attend schools, access health care, engage civically, interact with friends and family, and purchase essentials from a burgeoning e-commerce industry.

Widelity interviewed a wide selection of telecommunications carriers. Of the carriers we spoke with and considered in our report, networks have been categorized into two basic topologies that have been deployed: broadband and wireless. Some entities have both of these topologies offering wireless services, and broadband services including: internet, voice, and video.

In either topology, eligible entities will face logistical challenges to replace and deploy new equipment. Entities may have tens of thousands of physical items that will need to be removed and replaced. The sheer volume of devices will pose a significant challenge to replace and dispose.

10.1 Broadband Networks

Broadband networks can be deployed in a number of architectures including fiber optics, cable, fixed wireless access (microwave point-to-point or point-to-multipoint), copper lines (DSL) and satellite. For the purposes of this report, the potentially eligible entities we have interviewed with covered communications equipment or services in their networks are primarily using fiber and fixed/mobile wireless access technologies to bring broadband to their customers. Broadband networks can also include cable systems (MSOs or MVPDs).

Replacement equipment and software may be needed in the core network, distribution layer, access layer, and customer premise, both at homes and businesses. These devices include routers, switches, microwave radios and antennas, and customer devices.

Broadband networks cannot tolerate significant connectivity outages for any extended periods of time given the critical role that Internet access plays in our nation for both businesses and individuals. Many of the broadband entities that we spoke with will have challenges maintaining the quality of service expected by their customers. To maintain the quality of service for its customers, broadband providers will likely have to create a parallel network of replacement equipment in all or some portion of their network. Once the parallel network is created and tested, then they will be able to migrate their existing customers to the new network to accomplish a seamless transition. A parallel network may involve the deployment of additional fiber for local access where fiber capacity is inadequate to support a parallel network.

10.2 Wireless Networks

The wireless cellular networks for the eligible entities are deployed across many states, geographies, and cover urban, suburban, rural and frontier communities.

Wireless networks, similar to broadband networks, provide crucial services in today's society. Next generation services, particularly 5G, are rapidly being deployed, ushering the next wave of service for consumers and businesses.

Some networks may experience a situation whereby removing and replacing prohibited equipment may negatively impact existing networks causing the removal and replacement of equipment that is not prohibited but that will be incompatible with the replacement equipment.

Though 3G is slated to be phased out by most service providers, a number of carriers still have an installed base of 3G customers, some carriers also still have 2G networks, and they have an installed base of customers in addition to international customers who count on 3G networks for their roaming connectivity.

11.Potential Issues Encountered

In our interviews with many key industry members, some identified a number of issues that are a cause of concern for a smooth replacement transition process. The following is a list of concerns that we heard in our interview process that may impact the timing and duration of the replacement process.

Manufacturers and RF Consulting, Structural, and Field Engineers may not be in a position to handle the potential onslaught of requests that will occur once the replacement program begins. There may be thousands of towers requiring structural analysis, as well as wireless and broadband networks that will need network engineering design and review.

In particular, the replacement process for both broadband and wireless may place a significant demand on a finite number of skilled, trained, and experienced resources. These may include network and RF engineers, structural engineers, manufacturing resources, tower crews and field engineers.

The Telecommunications Industry Association ("TIA") TIA-222-H "Structural Standard for Antenna Supporting Structures and Antennas and Small Wind Turbine Support Structures" sets minimum standards and industry accepted practices for steel tower structures commonly used for supporting antennas. The most recent revision (Rev. H) is a significant revision that modifies and adds parameters to the analysis. It provides the requirements for modification of existing supporting structures as well as the modifications of existing structures. The impact for many towers is that they may require additional structural work or will need to be replaced if antenna or line loading is changed.

Those sites requiring tower, antenna, or other outside work may have to undertake a permitting process that is highly unpredictable. In addition to permitting, some locations (such as those that are in close proximity to residential neighborhoods) may have to work through community issues for RF analysis and related public concerns.

Some networks with legacy 2G and 3G networks face a number of challenges. Retiring the networks will require a significant coordination with their existing customer base and their 2G and 3G customer equipment. International visitors may also be visiting the service area with their 3G (CDMA) equipment. They will not have roaming services once the networks are retired and there may be a safety issue with accessing 911 services.

Some eligible entities operate in regions that will face additional challenges in their replacement programs. In this report we have discussed the challenges faced with weather and potentially difficult access to locations.

11.1 Alaska, Islands and US territories

Eligible entities located on islands and in Alaska have special challenges not usually faced by entities in the continental US.

Following are some issues we encountered when speaking with entities in remote locations:

American Samoa (4,768 miles from Los Angeles), U.S. Virgin Islands (1,100 miles from Miami), Hawaii (,562 miles from Los Angeles), and Puerto Rico (1,044 miles from Miami), and potentially other island states and territories, face significant shipping and logistics challenges bringing equipment, and engaging off island qualified resources. Due to the Jones Act (which requires that maritime shipping between U.S. ports be transported on ships that are built, owned, and operated by United States citizens or permanent residents) the costs of ocean shipping to any of the islands will have increased costs. Once a shipment, likely in containers, arrives at a port of entry the material will have to be broken down into location-based Bill of Materials (BOM), and then further shipped by water to additional islands. Shipments to some territories may also require a commercial invoice adding the transportation burden. There may be additional taxes, duties and customs fees creating the need for more paperwork.

Ocean shipping transit times to some locations may be long. Los Angeles to American Samoa can be as much as 30 to 45 days. Shipping originating from other vendor distribution locations may be even longer. This will add to the replacement program timeline and will require extensive pre-planning so that all required materials are accounted for in the ordering process. Air shipment is available but even that can take a week, and will be expensive, and should only be used for special conditions.

For many of the Island territories, warehousing is likely to be limited. This will require temporary and potentially costly solutions for storing significant amounts of replacement equipment imported into the territory, and the outbound equipment that may have to be shipped out for secure off island disposal. The additional logistics costs, warehousing, fees, paperwork, and personnel travel costs will be reflected in their replacement process.

Experienced personnel are limited in many remote locations. Technical personnel will have to be flown in for a significant portion, if not all, of the installation work; this will add additional cost and time to any replacement efforts.

11.2 Alaska

Alaska has the most remote, rugged and culturally diverse geographic areas in the United States. As a result, the eligible entities in Alaska face unique challenges due to the geography, topology, weather, lack of contiguous roads, transportation, accommodations in towns, and demographics of the state. Following are some issues that will impact the replacement program:

Alaska is vast. When superimposed on the continental US, the landmass of Alaska stretches from the west coast of California to Florida. Many served communities are remote and not interconnected by roads or fiber backbones. There can be thousands of miles between served communities. Many of the disparate communities are Alaska Native rural villages.

Figure 1 Alaska map superimposed on CONUS

Many remote communities are served in the access/middle mile layer by satellite. There is no other option. Satellite middle mile is slow (compared to fiber or microwave), has high latencies and has limited bandwidth capacity. Fiber middle mile is starting to be deployed in some denser areas but for many communities utilizing fiber backbones will not be an option.

A very high percentage of the covered communities do not have any road access.

Logistics costs in Alaska will be significantly higher than in the lower 48 due to the shipping distance to the state, then the additional challenges of distribution of the replacement equipment, and personnel into disparate locations in the state.

Intra state travel for material and personnel is limited by rivers that are navigable for a small portion of the year, small gravel air strips that limit plane size, and harsh weather conditions. Transporting materials, equipment and supplies may be restricted to seasonal barges that travel up the west coast of Alaska when sea ice moves north, and May to September when rivers thaw out and barges can travel river systems to remote villages. In some locations, barges make two deliveries a year, once in June and once in August. Barges often deliver via landing craft to the high-water mark when there is no dock or formal port.[19]

Use of air transportation is limited and costly. Most villages only have a gravel airstrip that is not capable of handling jet aircraft, and some only single engine Cessna type aircraft. Air transportation of technicians and/or equipment adds significant costs to projects. Any equipment that must be moved by plane must be broken down to accommodate the weight restriction of smaller planes, if there is no water access.

Construction equipment is not readily available in most remote villages, adding challenges for construction. For many sites, there is a short construction season; this poses many challenges in managing long range programs. Extremely cold temperatures, and long winter seasons, severely limit time for construction season. In some locations, temperatures reach 90 degrees in the summer and 50 degrees below zero in winter. Winter weather can cause travel challenges in rural Alaska, particularly when travel from community to community is involved. In many served communities, snow often causes white-out conditions, and drifts, that keep planes on the ground for extended periods, or prevents them from landing.

[19] *See* Appx. C for images.

Technicians must travel via commercial air flight to a regional hub, then charter a single engine aircraft or a boat to get to remote villages. Traveling technicians may have to contend with limited to no housing availability in villages. The local school is the most common place for outsiders to stay. Local stores do not stock large amounts of food, as everyone lives a subsistence lifestyle, so technicians must bring their own food. Water is not available in many remote villages, some of them only have a centralized washeteria (for laundry and showers) for the community to use. All of this adds time, cost, logistics challenges for technicians, and can add stress to their work environment.

Some Alaska villages are only accessible by helicopter, adding to the complexity of replacing the replacement equipment, retrieving the replaced equipment, and deploying personnel. Limited resources available at each site can add to installation time and add to on-site environmental risks. All of these challenges will add costs to the replacement process in Alaska.

Some wireless locations on towers, rooftops and water towers share space with other entities, such as other carriers, FM radio stations, emergency management communications, LPTV stations, and microwave communications. Tower work required for the replacement program will require the adherence to RF safety guidelines, which will likely cause the other tenants to broadcast at reduced power for extended periods. Extensive coordination with other tenants on the tower will likely be required to create a safe working environment for tower workers. This will add coordination time as other tenants are notified and climbers are scheduled in the appropriate safety window.

11.3 Other Challenges

There will be timing and deployment implications due to weather and seasonal influences in certain areas. Northern climates will have snow and ice that will prevent tower crews from climbing. At certain times of the year, migratory bird flight paths may impact scheduling and access to towers. If helicopters are needed for heavy lifts, it may be necessary to schedule the installation outside of fire season, as the helicopters used for tower installations may be booked during that period. Beyond fire season, helicopter access may be further constrained due to an extensive permitting process in many localities, requiring extensive scheduling and preparation.

Broadband networks will face unique challenges as they deploy the replacement equipment in their networks. They may have to build a parallel network requiring additional resources to maintain two networks running simultaneously before a cut over. This may involve the acquisition or construction of additional fiber strands for access to buildings, additional space in facilities, or power and HVAC requirements. Where fiber building access becomes an issue, additional access construction may be required for network laterals if there are no alternative fiber strands available. Temporary additional space in the "meet me room" (usually a machine room or demarcation point in the basement or on the first floor of a building) may have to be negotiated with landlords as well as the plans for upgrading or modifying the entry point facilities. If the access must be upgraded with underground fiber, costs can be significant. Entities adding capacity to building access fiber may face extensive permitting, construction costs, traffic management, and restorations among other expenses. They may also face weather related moratoriums in certain jurisdictions that do not allow underground construction in winter months.

Negotiations with site and tower owners will add variability to an eligible entity replacement progress. Some entities share tower space, rooftops, or water towers, or lease land, with other entities at certain locations. These additional entities on a tower may include other wireless carriers as well as emergency management agencies and other users. These negotiations are unpredictable in length and may cause uncertainty in the timing of the process.

Tower condition, upgrades and structural integrity is a major challenge and is addressed in other parts of this report.

12.Timing Issues

The following is a list of planning and process issues that may impact the timing of the replacement transition. A detailed plan can be found in Appendix D

12.1 Pre-Planning

Prior to beginning the replacement process, eligible entities may make preliminary plans for the replacement process. The internal process will vary in length based on the number of locations impacted and the complexity of the wired and wireless network components. Entities may have the resources available internally, and others may have to rely on outside expertise to complete the process.

In the pre-planning stage, many technical and deployment decisions will have to be made that will impact the processes later in the replacement program.

12.2 Site Surveys

Site surveys will be required for any locations where equipment will be replaced. The surveys will cover space, power, HVAC, tower conditions, facility conditions, and access issues.

Fiber surveys will be required to establish capacity and locations. The network will need a complete survey to identify the equipment to be removed, and any constraints resulting from a lack of capacity, to support a parallel network if it is required.

12.3 Customers and Third-Party Planning

Planning will be required to coordinate the many levels of communication that a replacement program will require. Communications with facility owners, landlords, tower owner jurisdictions, and customers may be required in the transition.

12.4 Migration

Once the planning for the installation is completed, as outlined above, the teams will have to implement the migration plan.

12.5 Decommissioning and Disposal

Once the parallel network is in place, and the customers and services are migrated to the new network, the Huawei and ZTE equipment can be removed and disposed of in a compliant manner.

12.6 Planning and Initial Steps

The network planning for wired and wireless services has been, and will continue to be, extensive.

Business process management, a planning framework, resources inventory of existing equipment and assets, and the placement plan and configuration management planning will be required.

12.7 Project Management and Equipment

Project management should also begin during the development of the facility parameters, in order to formulate an implementation plan. Beyond the RF and network associated with the antennas, core, wireline architecture and the transition plan must be developed, and contact established with equipment vendors, contractors, and other service providers. Detailed quotations for equipment and services must then be obtained. Some eligible entities will need outside assistance with project management, due to insufficient staffing levels to support a major replacement project of this size.

At the acquisition phase, actual orders for equipment would typically occur. Equipment ordering, of the potentially tens of thousands of items, will be a project management challenge to specify and order the equipment from potentially multiple vendors.

13.Technology Issues

13.1 Trends in 5G

5G wireless services is more than just another version of LTE/4G. The 5G technology offers many new developments for services and enhanced applications for users and businesses. Significantly increased throughput speeds, very low latency and the ability to support many more devices and device types with significantly improved services levels.

13.2 Open RAN/Virtual RAN/Cloud

What is it?

The virtual radio access network, or cloud radio access network is often referred to as Centralized-RAN (CRAN) or Open Radio Access Network (Open RAN). This concept is an evolution in base station architecture that migrates many of the features previously performed on site to a centralized or cloud location. Within the CRAN/Open RAN architecture, remote radio heads (RRHs) are physically located at a wireless transmission site, but they communicate with a centralized base band unit via a direct fiber connection.

1G, 2G, 3G and 4G radio networks have generally been built in vendor homogeneous networks (where one vendor is providing, and integrating, all equipment on a proprietary basis from Customer Premise Equipment (CPE) to Antenna/Radio to Baseband Unit and Core Elements), inhibiting the interoperable mixing and matching of similar network equipment from other vendors. There have been exceptions, but often mixing equipment from multiple vendors has required extensive custom interface development by all vendors as well as exponential lab pairwise testing to ensure each element is capable of interacting with all relevant counterparts.

A key part of CRAN/Open RAN is the design paradigm of having the interfaces and protocols that the different components of the network use to communicate and coordinate be open and standardized. These include the connection between the Radio and the Baseband Unit, and the Baseband Unit to the Core Elements

CRAN/Open RAN reflects an intention to standardize the functionality and allow networks to be built with multiple vendors providing equipment that meets the standard and therefore can be expected to be compliant without the need for extensive pairwise testing.

What does it allow?

By providing open standards to allow different components of the RAN to communicate with each other, equipment from different vendors can be combined without a need to first design custom interfaces and test them for compatibility. Radio Units (RU), from multiple vendors, can be used in the same network as with Distribution Units (DU) from the same or additional vendors, and they can all coordinate with a core network Centralized Units (CU) that may or may not be from those vendors or even additional vendors; this provides several benefits for Providers. First and foremost, increases the number of competitive choices so a Provider can pick and choose their preferred vendors on a component-by-component basis.

A Provider may choose to use Vendor A for RUs, Vendor B for DUs, and Vendor C for CUs based on their individual performance characteristics, costs, or other features. Additionally, a Provider can combine multiple vendors into the same equipment type. Such as using Vendor A for RU in one region and Vendor D for RUs in a separate region. Or a Provider could slowly migrate from Vendor A to Vendor E unit-by-unit without having to hot swap the entire network all at once or overbuild parallel networks. Providers will also benefit by not having to worry about making tradeoffs in performance of one part of the network in order to achieve performance in another part because of a need to be locked into a single network-wide vendor.

This also provides a number of benefits for equipment vendors. Equipment vendors will be able to bid individually on each component of a network. Additionally, vendors will be able to specialize their offering to focus on their component strengths without having to worry about losing all business for not having one component of a network.

Relevance to Supply Chain

The level of relevance to the Supply Chain program depends on who is being asked, and what assumptions are made about near-term developments of this quickly developing technology. All vendors we asked are implementing CRAN/Open RAN on some kind of roadmap but are at different stages of that roadmap. The vendor(s) that the Provider wishes to use, and the timeframe in which they are ready to purchase their equipment will govern how much opportunity they have for implementing CRAN/Open RAN.

More conservative vendors stated that CRAN/Open RAN has not yet reached sufficient maturity that it can be implemented without pairwise testing and is not yet able to outperform closed RAN solutions. These vendors state that not all equipment being deployed today can be made "Open Ready" and therefore more time and development is needed. They also confirm that while they are converting their equipment to being CRAN/Open RAN compatible, the more sophisticated equipment will take longer to be ready.

While some Providers have implemented CRAN/Open RAN into their networks very publicly, these conservative vendors counter that the Providers still needed to complete an extensive amount of pairwise testing similar to a pre-CRAN/Open RAN mixed network would have needed (but then immediately emphasize that they are contributing the lessons learned towards the CRAN/Open RAN standard). One conservative vendor warned that the operational cost of maintaining compatibility through software updates will make the Open RAN concept difficult to implement in the short term but conceded that eventually the approach would catch up.

More CRAN/Open RAN positive vendors state that CRAN/Open RAN is available today (and point to their own offerings as proof). They acknowledge that the Providers often want to see laboratory testing of the equipment to demonstrate interoperability but downplay the significance. They point out that Open RAN has already allowed them to mix and match the radio vendor with their baseband offering. They state that the price benefits this flexibility provides makes their prices more competitive than a closed RAN solution.

Virtualization

Related, but not explicitly a part of Open RAN, is the virtualization of the RAN (vRAN). This involves separating the physical hardware of the network components from the software controlling each of them. Therefore, the radio elements (antenna and radio) can be from one vendor and proprietary, while the baseband unit software can be from another vendor, and the hardware that the baseband unit is running on at the base of the tower can be general Commercial Off the Shelf (COTS) hardware.

A benefit of virtualization, pointed out by one vendor, was that the hardware development cycles of commercial hardware are a lot shorter and faster than a single RAN vendor's custom equipment, and thus a Provider could benefit significantly from having faster, and more frequently upgraded equipment. It also is dramatically simpler, and cheaper to change software on a machine rather than having to physically swap equipment.

There are three levels of virtualization. The legacy approach involves a single vendor providing integrated hardware and software. The next level is running one or more virtual servers on COTS hardware. The third level is containerizing the software to remove the host OS, Hyperviser and VM overhead costs. See below diagram shared by Rakuten:

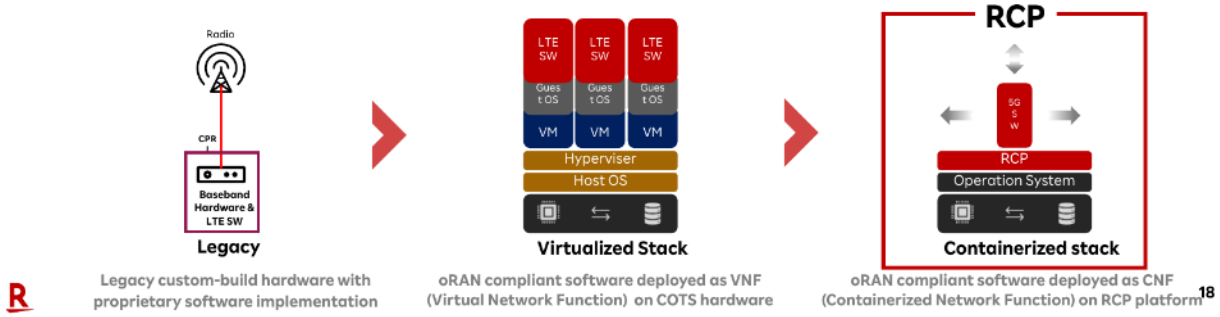


Figure 2 Virtualization architecture

13.3 Likely Need for System Integrators

As mentioned above, many telecom entities are considering migrating to Open Ran or Virtual solutions. This implementation of the new technologies will require integration and testing skills. Multi-vendor solutions will pose challenges as equipment, and software must be matched and integrated. The role of system integrators and managed service providers will increase in an environment where open standards will require extensive integration and pairwise testing prior to deployment.

A multivendor model for the RAN and the Core will be attractive to many telecom entities. However, the multi-vendor model adds significant network complexity for design, construction, integration, deployment, and operations. When operational issues arise, there can be challenges identifying and isolating the communications gaps so that they can be remedied. Once issues are identified, without a System Integrator, vendors can point to each other and an operator can waste significant time managing the communications, analysis, and the remedy, assuming that, they have the skills in-house.

Security is also an issue in the multi-vendor model. Security in the network is a fundamental aspect of communications technology. The more interfaces that are utilized the more opportunity there will be for security vulnerabilities. A fundamental aspect of the system integrator must be to maintain a high level of security throughout the entire network.

Open Standards and Virtualization of significant parts of the network form the basis of a new potential architecture. The role of the System Integrator will be crucial. They will need to provide simplicity, over-all design, security, equipment integration, testing, and network visibility and monitoring.

13.4 Chipset Availability

In our recent discussions, we have begun to encounter vendors who have concerns about the availability of key parts for their equipment. Chipsets and parts are potentially in short supply. Chipsets are foundational to all deployments and any interruption to the equipment supply chain could negatively impact the timing of the deployments.

Timing of the replacement program will have an impact on chipset availability; because the material is getting allocated to projects that are more near-term. It is not clear how long the shortages will last and how the likely deliveries in 2022 will be impacted.

Semiconductor manufacturers are increasing capacity this year. However, if the shortages are not resolved by the time the replacement program is underway there may be delays as suppliers increase their delivery times.

14. 5G NR (New Radio)

5G NR is a new access technology (air interface) standard developed by 3rd Generation Partnership (3GPP). It provides support for a wide range of services, devices, and 5G deployments. The standard focuses on the communications between mobile user devices and the base station. The new standard will improve performance and increase the spectral efficiency of the network; and enhance the flexibility and scalability of the network communications.

NR will also support antenna technologies such as beam forming, MIMO (Multiples Input Multiple Output), spectrum sharing, small cells, and a wide range of spectrums including low, medium and millimeter wave bands; it will also support licensed, unlicensed, and lightly licensed bands.

With NR, the customer experience will be significantly improved, with better mobile service, flexibility of devices and support for new business models for Providers.

15.General Planning Services Required

The planning process for the replacement program will be extensive, for the participating entities; they will also have to undertake an end-to-end network review process. The end-to-end review will have to identify the prohibited equipment that will be replaced. The review will cover a wide range of network requirements, equipment inventories and integration procedures. Following is a partial list that eligible entries are likely to have to undertake. Planning will cover:

- Site surveys of all facilities in the wireless, broadband network and the core deployments
- Staffing and project management requirements
- Ordering and Logistics
- Network integration testing
- Installation logistics
- Commissioning
- Network testing
- NOC (network operations center)
- Software integration and testing

16.Site Surveys

Multiple site visits are in required for the various functions that need to be completed, even before construction starts, as they save time and money by collecting the myriad bits of information imperative for the multiple phases in the deployment at a cell site or in a broadband network. The Engineering firm responsible for the Structural Analysis must document the current state of the tower; gathering data as to what equipment is on the tower, and where on the tower it is, what modifications have been done since the last analysis, and other critical loading details. To produce a coherent quote, the Construction firm needs data on the site's location and layout, availability, and location of utilities, availability of space, to lift the aerial equipment properly and safely onto the tower, even the location of the nearest hospitals. If the tower is a green-field construction, A&E personnel will need access to the site to collect other information for the Service Provider's Network Engineer and Project Manager

17.RF Engineering

There are many challenges involved with deploying a wireless network. To identify the best approach for addressing these, RF engineering resources will need to be involved in the development of a detailed radio network plan.

The radio network design will specify how the operator will use their specific radio frequencies to optimize the use of spectrum, and meet the capacity needs of the overall network plan.

Once the design is finalized, it will guide operators in purchasing the proper equipment. The radio network plan will also act as a blueprint for the buildout of the radio network.

RF engineers will need to work closely with the network engineers in developing the overall plan, as there are many points of overlap between the radio network and the wired network.

18.Network Engineering

Prior to network deployment, an engineering study will be performed to determine initial network design. This planning process includes evaluating network capacity, and performance projections. The engineered design will consider the needs of all layers of the network. Technical resources will perform an analysis utilizing software tools loaded with specific equipment parameters, and anticipated network growth. The engineered design will be used to generate a bill of materials for network equipment needs. The engineered design will be evaluated during initial network deployment by benchmark testing.

18.1 Interim Facility Requirement

Wireline and wireless service providers alike could find Interim facilities necessary, when their new networks are incompatible with the existing networks, and they must deploy a parallel Core Network, but there is insufficient space in the existing facility.

Wireless service providers may also need to use interim facilities to avoid extended periods of coverage outage, when they cannot flash cut a tower site or deploy a parallel set of radios and antennae on the same tower. It is highly possible, with current co-location directives, that some towers will not have sufficient structural capacity to temporarily install the parallel equipment. In situations such as this, service providers may need to rent tower space on a nearby tower, rent or buy a Cell-On-Wheels (COW); they may even be forced to build a second tower.

“Co-location” refers to a single antenna support structure (tower) which is used to support multiple antenna/radio combinations operated by different carriers. Cell tower co-location is the use of one structure to field mobile telecommunications equipment; belonging to more than one wireless service provider within a single location. The added radio capacity of LTE has moved more equipment up the tower, bringing the radio closer to the antennae. As more telecommunications equipment is deployed on the same tower structure, the total structural capacity is decreased. As the structural capacity decreases, the chance of structural failure increases. A failed tower not only impacts the service provider’s financial well-being, it can also result in the loss of life.

Another factor impacting tower loading is the acceptance of the TIA-222-H standard. One of the changes from the G to the H Standard is the rooftop wind speed-up factor. This factor is used to increase wind pressure on rooftop-mounted structures where the wind converges and accelerates as it blows over the roof to get around the building. This factor, which could increase wind pressures up to 30%, applies to towers mounted on top of buildings that are 50 feet higher than the ground or other nearby buildings. Higher wind pressures could lower the structural capacity of existing building mounted towers.

When a structurally-challenged tower cannot be made sound by structural reinforcements, which often affects the tower steel and the foundation, the service provider may be forced to use an interim tower. An interim tower could be a nearby existing structure that has sufficient structural capacity, a Cell-On-Wheels (COW), or if no other options exist, a new tower build would be required.

19.Leasing

Eligible wireless or wireline entities will have a large number of leases and access agreements for many aspects of their network. These leases and agreements may cover everything from tower leases, fiber leasing agreements (temporary or IRUs), building access agreements, leased rights of way, space in co-location rooms (in office buildings or data centers), rooftop space, equipment leases, and land leases.

The leases and access agreements will need to be reviewed and any modifications will take time and legal resources to execute. Leases and modifications can take a long time to complete and may be s sources of delays in the replacement program.

20.Project Management

Extensive project management resources will be required for the replacement project management. Project management will underpin all aspects of the replacement program from procurement to installation, customer communications, and filings for reimbursements.

The project managers will be responsible for ensuring project scope, scheduling, planning, coordination, integrations, closing out the project and sites and ensuring that all applicable costs are accounted for and where appropriate are reimbursed.

21.Transition Planning for Cutover

It is entirely possible that a network transition may involve standing up a new separate core and/or RAN and then migrating customers over to the new network. A parallel network with the same capabilities will have to be built and tested before customers can be migrated. Then, once a parallel network is established the customers can be migrated to the new network.

A migration plan for moving all customer connections over to the new access layer network will be required. There are several things to consider in developing the transition plan, including:

- Coordination with customers for site visits
- Installation of new CPE and distribution equipment
- Removal of old CPE and distribution equipment
- Reconciliation of equipment records
- Network planning for IP address changes

Upon migration of all connections to the new network, operators can begin working on the turndown of the old network. This portion of the plan requires less technical expertise, as the primary functions involved are powering down equipment, removing cabling, and uninstalling equipment.

22.Spectrum Planning and Management

Operators will need to determine the available spectrum they are able to utilize as they transition to a new network; this will include any FCC licensed spectrum as well as unlicensed band access. Equipment technical specifications will need to be captured to determine channel sizes, and any potential frequency reuse opportunities. This data will be used to populate an engineered RF network design with propagation studies.

If operators need to replace microwave backhaul connections for new cell site locations, path analysis and frequency coordination work will need to be completed prior to the deployment of those microwave links, to ensure proper performance and capacity. Operators will need to follow the frequency coordination process for all licensed microwave backhaul connections.

As operators of wireless networks work to deploy the new network in parallel with their existing, they may introduce further frequency challenges. Beyond simply needing added spectrum, special considerations will need to be taken into account, to determine the ability of those systems to operate within the same geographic region; without causing interference amongst one another. Operators and their spectrum planning experts will need to evaluate the RF details of the system; including channel sizes, capacity, cell size and downlink and uplink ratios, to determine how to deploy the new network with optimal performance.

23.Device Conformance Testing

In order to eliminate problems with user equipment, 3GPP has established a set of standards for equipment design and testing.

These 3GPP conformance testing focuses on three main areas when it comes to verification of wireless device performance. Those areas are:

- Protocol
- Radio Frequency
- Radio Resource Management

Completion of the 3GPP conformance test certifies that a device will operate within the proper parameters of an operator’s standards-based wireless network.

24.VoLTE Voice Coordination with Providers

VoLTE (Voice over LTE) is a digital packet technology that uses LTE networks to route voice traffic and transmit data. This voice service is the standard for high-speed wireless communications in devices such as smartphones, data terminals. It is a method for provisioning and managing high-speed voice, video and messaging services on an LTE wireless network for mobile and portable devices. VoLTE (voice over LTE) is the beginning of the evolution of voice and communication services for packet switched networks, LTE, Wi-Fi and 5G. This network technology enables interoperable IP-based voice and communication services, using IP Multimedia Subsystem (IMS).

25.Technology Topology

Our study follows the original FCC data collection designations. Our report and catalog are based on the five categories designated in the Protecting the Communications Supply Chain. The categories are: (1) Access layer equipment; (2) Distribution layer equipment; (3) Core layer equipment; (4) Software; and (5) Services.

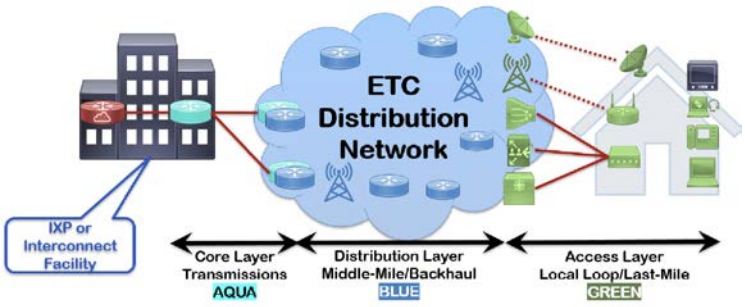


Figure 3 FCC Network Topology

Figure 7 FCC Network Topology, above, can be used to reference Eligible Telecommunications Carriers but it can also apply equally to less advanced communications service providers.

Access Layer Equipment

The access layer is responsible for connecting users to their immediate service providers. First, the communications start by enabling users to communicate with the communication system to allow the start of information exchange/transmission. These communications can either be wired or wireless.

25.1 Technology Overview – Access Layer

Service providers extend their services to customers via the Access Layer. This is oftentimes referred to as the last mile portion of the network. Whether it is a wired or wireless network, Providers place equipment at the customer's location. This equipment is managed by the Provider and performs the functions necessary for connecting to the distribution layer of the network. These functions include connecting to the core services for authentication, quality of service, and routing of all packets.

Within a wireless network, the access portion of the network is the segment that involves the device utilized by the user to access the network and includes the tower where the radio equipment is located.

The access layer of a wired network is represented by equipment like the optical line terminal or digital subscriber line access multiplexer, which are located at a customer's location. These devices provide the necessary means for connecting to the customer's home network, and devices to provide connectivity.

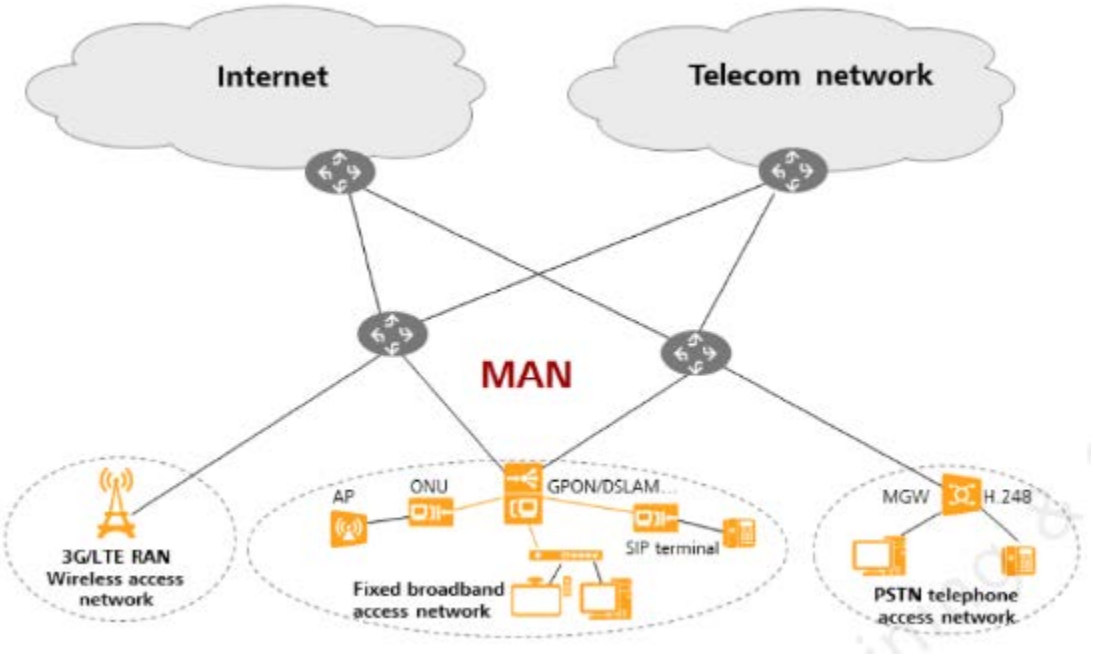


Figure 4 Example of Wired and Wireless Access Layer

25.2 Optical Line Terminal Equipment (OLT)

The optical line terminal/termination (OLT) is an integral point of an operator's fiber access network that coordinates communications between the interfaces of the electrical network and the optical network. Additionally, the OLT is a centralized point of communications activity within a fiber to the premises network. The optical distribution network devices (ODN) transmit and receive directly with the OLT.

25.3 Optical Distribution Network Devices (ODN)

Within a customer's home, operators will place an optical distribution network device (ODN). These are sometimes referred to as an optical network terminal (ONT). The ODN/ONT converts the optical signal coming in through the fiber at the home to separate signal for data, video, or voice services; it is capable of converting the signal from the optical network to an electrical signal.

25.4 MSAN & DSLAM

The multi-service access node (MSAN) is utilized in operators' networks for integrating telephone lines into a central network. The MSAN node enables providers to deliver broadband services along with voice services via a single platform. This solution eliminated the need for operators to maintain a multitude of equipment and technologies to deliver various services to a customer.

Operators that delivered voice services to customers also utilized the same network to provide data services as well. Many operators leveraged the digital subscriber line access multiplexer (DSLAM) to deliver data services to customers. This equipment is located within a telephone exchange and connects customers to the data network, utilizing signal messages, that allow the sharing of a single data backhaul connection.

25.5 LAN MDUs

When an operator extends the access layer of their network to locations that are multi-tenant buildings, they utilize a local area network (LAN) multi dwelling unit (MDU) device. This device is capable of providing multiple services via a single fiber connection back to the operators' distribution network. Operators simply have to extend electrical/ethernet connections from a centralized location at the MDU to each specific customer location.

25.6 Optical Network Units

An optical network unit (ONU) is a user side equipment used in a passive optical network (PON). It terminates the fiber at the user premises and transfers the signals to the user network either in a business or residence.

25.7 Site cabinets

Access layer equipment is typically placed at a location that is not managed or controlled by the operator. Operators will install their equipment inside a site cabinet to provide added security and weather protection. These cabinets can be installed on a wall, pole, concrete pad, or elevated platform. The setup is dependent on the location and amount of equipment needed at the location.

25.8 Home Network & Customer Premises Equipment (CPE)

Operators will install within a customer's home additional equipment that provides the final connection to the network called customer premises equipment (CPE). These devices are more commonly referred to as a modem. The CPE connects back to the operators ONT and provides an electrical data port for connecting the customer's network to the operator's network.

Whether that operator network serves the customer with a wired or wireless connection via the access layer, the customer will utilize one of these devices to connect. In the instances where the network serves customers via a wireless or fixed-wireless connection, the CPE will include an antenna for receiving the RF signals at the location.

25.9 Smart Home

The smart home refers to a home that utilizes the Internet of Things. These are devices designed with internet capabilities that enhance their core functions. Many features include remote monitoring and operation and offer automation for many everyday home use items.

25.10 Cable Coaxial Media Converters

The coaxial cable media converter is equipment that performs the necessary signal conversions that allow coax and fiber cables to provide a seamless connection across the two different types of media.

25.11 WLAN

The wireless local area network is also more commonly known as the Wi-Fi network. This type of network utilizes wireless frequencies to communicate locally for direct access amongst computers and devices and from the wireless device out to the internet. Most wireless networks function within a building or campus sized environment.

25.12 Access WDM & OTN

When utilizing WDM (Wave Division Multiplexing) technology, along with the addition of OTN (Optical Transport Network), within the distribution and/or core layers of the network, operators may choose to extend that technology to the access layer. When doing so, operators are able to benefit from the simplicity of a flattened network.

25.13 Distributed Antenna Systems (DAS)

A DAS is a network of antenna nodes that are geographically separated, and that are connected to a common source by a wired or wireless transport layers. The antennas in a DAS system can be viewed as sophisticated extenders to create specific coverage patterns. Outdoor installations can be referred to as (oDAS)

DAS systems are also deployed in buildings (iDAS) to improve or enhance coverage in areas in a building where coverage is lacking or inadequate. iDAS installations are common in office buildings, malls, stadiums, public halls, and locations with expected high usage patterns periodically.

25.14 Distribution Layer Equipment

Middle-mile, backhaul, or RAN (Radio Access Network) equipment layered between the access and core layers of the network in which network traffic management policies are defined and enforced.

25.15 Technology Overview – Distribution Layer

The distribution layer of the network aggregates all access layer traffic prior to sending it to the core, if necessary. Depending on the network architecture, different segments of the distribution layer may be able to communicate directly with one another or to other access layers without communicating to the core network. The main functions of the distribution layer are to aggregate connections between the distribution and access layers and route traffic throughout the distribution layer and to the core layer.

25.16 Routers

The function of a router is to receive and forward data in a computer network. Routers are devices that direct the traffic based on its configuration. Routers maintain a directory of connected networks and utilize that information to direct data to the destination.

25.17 Switches

A switch is a device with multiple ports, it is capable of reading the addresses of the ports. Switches are similar to hubs, but they are intelligent and offer greater performance. When a network contains a large number of devices, switches are preferred over hubs as they can send the data they receive to a specific port as per the configuration.

25.18 Network Security

Equipment vendors will be expected to maintain an appropriate cybersecurity posture. Vendors should review the details of various security standards to ensure their equipment meets best practice requirements that will help minimize risk to each operator's network. These security standards include National Institute of Standards and Technology CyberSecurity Framework and Alliance for Telecommunications Industry Solutions. Vendors should plan to provide operators with certification of these items similar to the Service and Organization Controls (SOC II) certification.

25.19 Metro WDM & OTN

Metro WDN & OTNs can be deployed in the access, distribution, or core of a network

When utilizing WDM technology, along with the addition of OTN, within the distribution and/or core layers of the network, operators may choose to extend that technology to the access layer. When doing so, operators are able to benefit from the simplicity of a flattened network.

Wave Division Multiplexing (WDM) is a point-to-point network technology that allows network providers to deliver ultra-large capacity services. WDM is capable of carrying multiple wavelengths via a single network link. This results in increased bandwidth for existing fiber network infrastructure.

Incorporating WDM and the added features of OTN at the distribution network layer provides an optimal end-to-end transport solution from the core layer to the distribution layer. This enables operators to quickly develop full-range services that are suitable for integrated transmission scenarios, such as broadband video, mobile backhaul, enterprise and government private line, and DCI (data center interconnection).

25.20 Microwave

Microwave is a line-of-sight wireless communication technology that leverages narrow focused beams of radio waves to provide high speed wireless data and voice connections. Operators incorporate microwave technology for providing point-to-point and point-to-multipoint solutions within their network. Microwave communications depends on the availability of wireless spectrum. Operators need to determine the best options for their specific networks when evaluating whether to deploy the technology with licensed or unlicensed frequencies.

25.21 Antennas

An antenna is a device to transmit and/or receive electromagnetic waves. It is a specialized transducer that converts radio frequency (RF) fields into alternating current (AC) or vice-versa. Antennas are designed and configured according to the applications including the configurations of MIMO (multiple input multiple output).

25.22 Wireless Networks

Wireless networks are communication systems that transmit and receive signals without cables (over air). There are several use cases of wireless communications including cellular networks.

25.23 Bearer

The function of the bearer service or data service is the transmission of information signals between network interfaces. These services give the subscriber the capacity required to transmit appropriate signals between certain access points, i.e., user network interfaces.

25.24 5G

5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices. This technology is meant to deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connects new industries.

25.25 LTE FDD & LTE TDD

Long Term Evolution Frequency Division Duplexing (LTE FDD) and Long-Term Evolution Time Division Duplexing (LTE TDD) are two standards of LTE technology that utilize different modulation schemes.

The primary aspect of LTE FDD is that it utilizes different frequencies for the systems to transmit and receive data. A TDD system operates on the same frequency channel for both its transmit and receive, and it relies on a GPS timing system to coordinate.

25.26 GSM & UMTS

These are the two different Mobile Communications Systems. The Global System for Mobile Communications (GSM) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets.

The Universal Mobile Telecommunications System (UMTS) is a third-generation mobile cellular system for networks based on the GSM standard. It is developed and maintained by the 3GPP. UMTS uses wideband code division multiple access (W-CDMA) radio access technology to offer greater spectral efficiency and bandwidth to mobile network operators. UMTS specifies a complete network system, which includes the radio access network (UMTS Terrestrial Radio Access Network, or UTRAN), the core network (Mobile Application Part, or MAP) and the authentication of users via SIM (subscriber identity module) cards.

25.27 Small Cell

A small cell is a low power, small form factor, low range radio access point. It is operator-controlled, and can be deployed indoors or outdoors, and in licensed, shared or unlicensed spectrum, these are also used for densification purposes and have a range of 10 meters to a few kilometers. As wireless carriers seek to 'densify' existing wireless networks to provide for the data capacity demands of "5G"; small cells are currently viewed as a solution for increasing cellular network capacity, quality and resilience.

25.28 Tower Shelter

A safe and secure structure for sensitive telecommunications equipment, these are rugged structures designed to withstand high winds and provide weather protection for equipment at the base of towers.

25.29 Outdoor Cabinets

Outdoor cabinets are secure, environmentally controlled structures for housing telecommunications equipment. Operators will opt to deploy equipment in an outdoor cabinet instead of a larger tower shelter when there is less of an equipment footprint needed.

25.30 Core Layer Equipment

The Core Layer of the network is the central element that provides services to those elements connected at the access layer of the network. One of the main functions of the core layer is that it is an aggregation point that provides proper routing of all voice and data traffic. All access and distribution layers of the network will be connected to the core via fiber or microwave backhaul connections. Additional services that may exist within the core layer are authentication, call control/switching, and inter-network gateways.

25.31 Technology Overview – Core Layer

Core networks consist of high-capacity routers and switches that are interconnected by high-capacity links. These links are from distribution layer backhaul links and upstream carrier connections. Core networks transfer a higher volume of traffic coming from and going to the access and distribution layers.

The new components will be commissioned alongside the existing network. In preparation for this, additional space and power accommodations will need to be put in place. New network connections will need to be put in place as well, so additional network cabling (most likely fiber jumpers) will be needed as well.

Operators will need to evaluate vendor specifications to determine the rack size (typically 23” or 19”) and number of rack units (RU) required for the new network components. A site survey will need to be performed to confirm space availability and location of the equipment rack.

Equipment power requirements will need to be identified. During the site survey, operators will need to confirm the availability of proper power or any additional accommodations that need to be put in place.

The new network will require data connectivity to the other network layers alongside the existing network. This will require new cable/fiber runs from the equipment to network routers and switches. During the site survey, the work should be performed to confirm the availability of open switch/router ports and any optic needs for fiber connections.

25.32 Metro WDM & OTN

Wave Division Multiplexing (WDM) is a point-to-point network technology that allows network providers to deliver ultra-large capacity services. WDM is capable of carrying multiple wavelengths via a single network link. This results in increased bandwidth for existing fiber network infrastructure.

Incorporating WDM and the added features of OTN at the metro network layer provides an optimal end-to-end transport solution from the core layer to the distribution layer. This enables operators to quickly develop full-range services that are suitable for integrated transmission scenarios, such as broadband video, mobile backhaul, enterprise and government private line, and DCI (Data Center Interconnection).

WDM technology can be leveraged to provide connectivity at either the core or the distribution layer of the network.

25.33 Microwave

Please see the definition of Microwave above (25.20)

25.34 Antenna

Please see the definition of Antenna above (25.21)

25.35 RAN Core

The radio access network core provides all the necessary services for providing seamless connectivity and optimal performance at the access layer. These functions are centralized at the core to allow for optimal network performance and efficient management for a multi-location radio network. These services include authentication, authorization, accounting, quality of service enforcement, advanced radio functionality, and element management.

25.36 Cloud Core & Cloud Computing

Some operators may opt to utilize a vendor that provides hosted services that perform the functions normally performed within the core layer of the operator's own network.

Cloud Core is a network functions virtualization (NFV) that changes the network architecture from dedicated hardware and software solutions within the local core layer to a cloud hosted solution. This relies on cloud computing which provides operators with the flexibility of on-demand computing system resources. This provides a more scalable and performance optimized central system.

25.37 Fiber Infrastructure Network

Fiber Infrastructure is the key component to scalable networks for the future. It leverages fiber optic glass cables to carry beams of light. Each fiber cable is made up of many small optical fibers. The optical fibers consist of a glass inner core where the light passes, and a cladding that is made of thicker plastic or glass. The cladding is wrapped around the core. These fiber cables connect to an optical network terminal (ONT) that converts the light pulses into electric ethernet.

25.38 Optical Transmission

Optical transmission is a measure of what proportion of light is transmitted through a turbid medium. Light may be attenuated due to absorption in the medium, or it may be scattered out of the beam. In other words, the transmission of light depends on the area of a 'particle'.

Optical transmission sends pulses of light over a fiber cable. At each end of that transmission is a receiver and transmitter where the binary data signal is converted between optical and electrical.

25.39 Data Transmission

Data transmission and data reception is the transfer and reception of data over a point-to-point or point-to-multipoint communication channel. Examples of such channels are copper wires, optical fibers, wireless communication channels, storage media and computer buses.

25.40 Software

Vendors provide software solutions to operators that provide network management, monitoring, and provisioning functions. Network management tools interact directly with the various network components to perform tasks that include configuration updates and backup. Monitoring relies on regular samples of network traffic for analysis that will then determine network performance. The provisioning tools assist the operator with establishing network connectivity for new devices.

25.41 Services

For design, implementation, installation, testing, or other costs and/or fees paid to deploy the replacement equipment and/or systems.

26.Installing Base Station Transmitters & Antennas

When preparing for the installation of the new base station transmitters and antennas, the same space, power, and network preparations that are being performed with the Installation of New Core Network will need to be completed for these items as well.

Additional verifications and data gathering will be needed during the site survey to allow proper preparation for the base station transmitters and antennas. The Site Survey, RF Plan, and Tower Engineering Study will provide the necessary information for antenna and radio placement.

New antennas and transmitters will be placed on the tower or vertical structure at the height and azimuth defined by the RF Plan along with proper mechanical down tilt.

27.About Towers, Rooftops and Water Towers

There are a number of locations that an eligible entity might use for the installation of their wireless access equipment. In the replacement project we expect that we will see every type of installation in use.

Here is an overview of the primary locations for wireless equipment.

Monopole - usually 50 feet to 200 feet in height. This is the most common type of cell tower. They are easy to erect and can support a number of carriers and equipment radiation centers. Monopoles can also be concealed with designs to mimic the look of trees, flag poles, and other structures.

Lattice Towers - These are also sometimes referred to as self-supporting towers or SSTs. They can be 200 feet to over 400 feet tall. Typically, these towers are three- or four-sided lattice construction made out of rods or pipes or angle steel.

Guyed Towers - usually 300 feet to 2,000 feet. These are lightweight structures that rely on guy wires to maintain their structural integrity. They require a lot of land to support the guy wires.

COWs - cell on wheels - For eligible entities who need a temporary installation of equipment while they replace equipment on a permanent location a COW may provide a solution. COW's can be pre-provisioned, trailered into location, and deployed on a temporary basis; then they can be redeployed, as necessary. Cows can reach 120 feet in height. For some installations where an eligible entity will require a rad center above 120 feet this may not be a solution.

Water Towers - These can be an attractive location for cell antennas. They are often over 100 feet tall and already provisioned for additional service. Water towers have installation challenges as they do not have the same anchor points and may not have safety rails. Water tower installations will require specially trained installers familiar with the constraints of a tower topology. Due to the large reflective surface, water tanks pose certain RF Engineering problems; antenna design and placement is critical to ensure proper operation of the RF network.

Rooftop installation - cell equipment can be installed on building rooftops quickly and safely. Often rooftops have access planned, and roof mounts are varied and readily available. Maintenance of the equipment can be easier, and the installation does not require other trained climbers.

28.Structural Engineering/Tower Studies

Operators will be standing up parallel networks, and for those with wireless systems, there will be a need for additional vertical space. The Telecommunications Industry Association has established standards for antenna and radio supporting structures. Vertical structures used for telecommunications equipment should be designed under the provisions of TIA-222 Revision H, which is the latest version of the standard. Many municipalities have not adopted Revision H and are still governing by the guidelines of TIA-222 Revision G. TIA-222 also provides guidance on when a comprehensive structural analysis should be performed on a tower. If the proposed changes for a vertical structure increase the demand capacity ratio, a structural analysis must be performed. A more detailed overview of the current structural standard is provided as part of this report.

The structural analysis may determine that updates need to be made to the vertical structure prior to implementing changes.

After discussions with key industry experts from the major engineering firms we estimate that a maximum of 40 structural analyses can be done a month in the United States (this assumes that all firms operate at peak capacity). If all of the stations turn to the structural engineers at one time, the limited number of resources may be overwhelmed. Therefore, proper planning and sequencing of the transition process will be of paramount importance.

The implementation of any required modifications that come out of the structural analysis will need to be coordinated with tower crew and field crew resources. Tower modifications can then take 4-6 weeks to get material prepared and another 4-6 weeks to install.

Field crews doing tower mapping and tower modifications may be subject to limited availability and scheduling issues (see the Tower Crews Section).

29.Negotiating with Tower/Site Owners

Many of the eligible wireless entities lease space on third party towers for parts of their network infrastructure. Entities making antenna changes usually have to negotiate with the tower owner or the site owner to modify their antenna location. It is likely that the process of installing new equipment, while maintaining service to customers, will require the addition of the new equipment while the equipment to be removed is still active. This will involve adding equipment at a new temporary Radiation (RAD) center, center height of the antennas on the structure. The process of removing equipment on a tower to replace the antenna with a different size/model antenna. Wireless entities may also have to negotiate for more ground space in the equipment building, and in extreme cases for rights to use a new tower. Often lease agreements may include the process by which such site modifications are made, such as notifications to other tenants, and outline who must bear the costs when making a tower modification. If contractual changes to a lease agreement are required to accommodate an equipment change, such negotiations can potentially delay the planning and decision-making timeline for stations and station groups.

30.Impact of Multi-Tenant Towers

With Co-location directives in many municipalities, many towers serve multiple Service Providers. Antennas for other services such as FM stations, LPTV, microwave and emergency services may all be present at different locations on a tower. Depending on the configuration, and the RF power levels, work required by a service provider to remove and replace Huawei/ZTE equipment might need to be coordinated with the other tenants on the tower to create low power periods.

Tenants of towers with several service providers may need to put in place a replacement schedule for the different providers, so only one Provider is replacing at any one time, especially if each of the Providers will need to add a parallel set of equipment in order to transition to the new equipment. In addition to this slow down, the entire replacement schedule may need to be on hold until the tower gets a structural analysis, and any necessary augmentation (structural) is completed.

In some cases, there may still be unused antennas and equipment on the tower that will need to be removed, if located in the rad center that will be required for the replacement equipment.

Other tenants on the tower will also be impacted by the replacement process in terms of requiring lower power operations during periods when tower crews are working on the equipment modifications and replacements, to comply with RF electromagnetic field exposure limits.

Agreements between entities co-located on the tower usually allow for reasonable periods of lower power operations to accommodate safe working conditions, and the provisioning of tower rigging equipment, particularly at sites owned by third parties. However, work may be limited to certain hours during the day, or to overnight periods, which could slow the transition and increase costs.

31.Tower/Water Tower/Barn/Rooftop Preparation

Service providers that will take part in the Supply Chain Reimbursement program will need to exert a substantial amount of effort in preparing their sites for the replacement of the old equipment. The network operators will need to assess the state of their networks, decide on what changes need to be made, design the network making necessary changes, and finally make the changes. But before actually making the changes, the operators will need to make some preparations to aid the actual network changes.

The largest assessment piece with towers/water tanks/barns/silos/rooftops is, simply, will the structure safely support the necessary changes. If the structure is old, it may need to be mapped and a structural analysis be performed to find out what changes, if any, will be necessary to handle the network changes. It is likely that many towers will need modifications to handle the stresses imposed by the new equipment, which could include a doubling of the equipment while in the process of transitioning from one network design to the next.

Other preparations in getting sites ready will be to increase the available utilities, power and data. With the increased scale of powered telecommunications equipment, comes the need for more electricity and data bandwidth. If the utilities are currently maxed out, it is a large possibility the power lines would need to be doubled or the size of the lines increased, along with all the transmission line equipment. And, if the data transport is also maxed out, new fiber assets will be necessary.

Space is another preparation that will likely be needed. Fences might need to be moved, leases adjusted, and roads changed to accommodate the work of site preparation. It is likely that cranes will be used to make the changes in the ground and tower equipment. Roads may need to be widened and repairs to damaged roads and grounds made due to crane operations.

32.Overview of the Current Structural Standard

Adoption of the most recent tower structural standard, EIA (Electronic Industry Alliance)/TIA (Telecommunication Industry Association) RS-222-H (“Rev. H”), is a significant issue that will affect the timing and cost of broadcasters’ relocation to new channel assignments post-transition. Although RS-222-H is the latest version, many municipalities are still governing by the previous version, RS-222-G.

This standard, (Rev. G) adds parameters to the analysis which will impact many towers. Towers may require additional structural work or need to be replaced if additional equipment will be installed. The Rev. G standard applies to all steel antenna structures and antenna supporting structures used to support communications equipment. The new standard reflects new requirements for wind loading, icing, safety facilities, foundations and seismic considerations. Among other things, Rev. G includes additional ice and wind loading impacts having significant implications for towers in winter climates and coastal communities, and introduces

classifications based on the operational use of the tower and surrounding topography. The Rev. G standard has not been adopted ubiquitously by all states, municipalities, and insurance companies, though a majority require it. Industry sources estimate that 30% of towers are currently compliant with Rev. G.

All changes to towers, beyond the original design scope, will require compliance review by a Structural Engineer and may require upgrades and modifications to the tower. Exact kind, one-for-one swaps, generally do not trigger a new review, but, adding new equipment or change outs to different equipment types does. In some cases, tower upgrades may not be possible or economically feasible, triggering the need for a total tower replacement.

33.Antenna Structure Registration (ASR)

Any change in height of a tower that requires an ASR, including the topmost location of the antenna(s), will require an ASR modification (or a new ASR for a new tower structure). A "Determination of No Hazard" must first be obtained from the FAA for towers that may create a hazard to air navigation. Generally, this involves a tower taller than 200 feet or a structure's proximity to an airport. Processing can take 2 weeks to several months depending on the nature of the change. More significantly, there are now additional environmental requirements and a notification period for certain ASR modifications (and new ASRs) that will add to complexity and processing time (WT Docket 08-61). Waiting for the grant of an ASR can cause construction to be postponed.

34.Site Work

Similar to the work necessary to build a house, site work at a cell site is performed by many different trades and often there is a most efficient way to schedule the different trades.

The work typically done at an existing cell site is a subset of the work needed at a greenfield, or new, site. This section will focus on the existing site and touch on the greenfield site towards the end.

At an existing 4G/5G cell site, the work can be divided into tower work and groundwork. Groundwork is work done to feed power and data to the RF equipment up on the tower. Tower work is performed by personnel trained to work safely at heights and is done in order to produce the RF signal that winds up communicating with our handsets.

The site survey, which has been previously completed, informs the construction crew where the new ground equipment will be placed. Ground equipment could be the base-band unit (BBU), data transport equipment like routers and switches, power distribution and/or generation equipment like generators, power inverters, etc., and the cabinets or small shelters that house the sensitive equipment. This equipment is oftentimes mounted on a concrete pad slightly above ground level, or on an "H-frame", a frame consisting of vertical and horizontal metal channel that is concreted into the ground, and sometimes, especially in flood zones, on elevated platforms.

Once the ground equipment is placed on its pad, platform or H-frame, data and utility power connections are made, connecting the equipment to the power and data demarcations. These connections are typically made using conduit to protect the data and power from damage and the elements. The conduit needs to be placed in the ground, so trenching, often by hand, is necessary. An important item to note is that before any construction crew begins to dig, they need to contact owners of local utilities, so that the underground utilities may be marked. This is law in most states.

Other items considered groundwork is the placing of an ice bridge. The ice bridge, also known as a waveguide bridge or line bridge, is a hot-dipped galvanized support structure used to horizontally secure power and data cabling from the equipment building or BTS cabinet to the tower. The ice bridge typically has an extruded or waffle type metal grate over the cabling to protect from falling ice.

Telecom site grounding is an extremely important task performed at all telecom sites. At a typical cell site, multiple ground rods are driven into the ground around the building, pad or platform and connected together in a ring with heavy gauge wire and then connected back to the building, platform and equipment. The ground system is then tested to ensure it meets local standards.

Tower work typically consists of installing sector frames or mounts to the tower itself and then mounting antenna and radio units to the mounts. On monopole towers, a ring mount gets installed around the tower body and then sector arms or a platform is attached to the ring mount. On a guyed or self-supporting tower (SST) a frame made of galvanized pipes is attached to the tower legs on which the antennae and radio units are mounted.

In 4G/5G networks a hybrid cable connects the ground equipment to the radios up on the tower. A hybrid cable is simply several power conductors and fiber optic cables incorporated in one jacketed package. The hybrid cable runs from the power and data connections on the ground, across the ice bridge, up the tower to a distribution box (PDU) near the radios. Other, shorter, data and power cables run from the PDU to the radio, and coaxial cable jumpers connect the output of the radios to the input of the antenna. Each antenna and radio pair can have multiple cable connections, depending on which MIMO (multiple-input/multiple-output) scheme is used.

Grounding of the equipment aloft is as important as the ground equipment, if not more. The antennae, radios, and mounts are grounded to the tower itself, which is grounded below.

In situations where the existing tower cannot structurally handle the loads imposed by the Supply Chain Reimbursement project, a new tower might be necessary. This greenfield project, to build a new tower, will have all of the previous work, and much more work in addition. Once the site of the new tower is designated a new road is made. This could entail the use of loggers in a forested area, along with excavators and large earth moving equipment. Different types and sizes of gravel are trucked in and spread over the newly dug road to allow delivery and construction equipment. Once the road is ready the tower's foundation is excavated, formed to hold the concrete, reinforcement is added and finally concrete is poured.

In addition to building the tower in a greenfield project, utilities are needed. Power poles may be used to string utilities aerially, or the utilities may be subterranean, which requires more excavation and/or trenching. The physical security of the site is a necessary but often overlooked item. Tall chain link fence is used to keep cows, horses, sheep, and other four-legged animals from damaging the site equipment.

On the wireline side, site work can be very similar to wireless, but wireline would have a smaller number of large sites, and especially with FTTH, more in the way of small sites and much trenching, directional boring, setting pole and underground vaults (or handholds), and aerial fiber lashed to power/telecom poles. Outside of the setting poles, trenching, boring and lashing fiber cable, site work for the typical wireline site would be trenching, or aerial fiber, to the closest splice node, pouring concrete bases for the large outdoor enclosures and pulling the fiber to the enclosure. The enclosures would have installed various types of optical (or copper) network equipment, bringing data to the home or premise.

35.Connectivity Upgrades or Extensions

Operators will need to review network planning and forecasting statistics along with the network implementation plan, to determine if there will be needs for additional capacity or network extensions. Operators may see increased bandwidth demands and the need for network extensions as many of the network layers will be duplicated for an extended period of time.

Within a Provider's network, they will need to make the necessary network changes to increase capacity for areas that are expected to see increased bandwidth usage. This will be accomplished by the addition of network equipment capable of supporting the higher capacity. In some instances, operators may need to acquire additional fiber strands to connect the new equipment prior to turning up the added capacity.

If Providers are utilizing microwave equipment for backhaul transport where they expect increased demand, they will need to make the necessary spectrum and licensing adjustments along with the equipment changes. Further costs will be attributed to engineering tasks and tower crews implementing the changes.

35.1 Tower/Installation Crews

Tower crews usually are a team of no less than two climbers and may be up to four to five people. They can be local or deploy from a remote location. Traveling to a site to work usually involves a team driving (often referred to as windshield time) to the site in a truck, and possibly a trailer, with the equipment for the job. Engaging a tower crew usually involves a team day rate, mobilization fee and a rate for any weather-related delays.

Tower crews must work in safe conditions to assure worker safety. Weather related delays are common for snow, high winds, and heavy rain.

Usually tower crews will be responsible for loading and transporting the material from the site for salvage or recycling. In the case of this project, E-waste removed from the site will have to be securely transported to an aggregation site before it can be securely sent to an ITAR certified recycler.

In addition to equipment installation and removal, tower crews may also be engaged to do structural mapping, tower structural studies, repairs, structural work, and lighting maintenance.

As mentioned previously, there may also be guyed towers that require additional reinforcing, and a tower crew may be engaged to replace the existing guy wires with stronger one to accommodate the increased loads.

Special conditions may arise if the tower crew is responsible for the fabrication and installation of specialized mounts for the replacement items on the tower/water tower/rooftop.

When there is a need for new towers, tower crews may also be the specialized team that can construct the new tower. Service can involve site work, permit, grounding, excavation, footings, fencing, lightning protection systems, PE engineering, lighting, guy wires and footings, and electrical work, in addition to the tower erection service.

36.Addressing Tower Crew Availability

In our discussions with participants in the industry, we have not encountered any concerns about tower crew availability. Generally, the industry believes that there will be adequate resources to install the new replacement equipment.

37.Tower Work Requiring Helicopters

In some cases, helicopters may be the preferred installation methodology for RAN installation work, either for lifting equipment into place on towers, or water towers, or for building new towers to replace older towers that can no longer support the new loading requirements. Where helicopters are used, this can reduce the amount of time a tower crew must spend on the tower or *potentially* solve severe access issues. Unlike the broadcast repack effort where lifts often involved heavy TV antennas weighing thousands of pounds, the replacement program will have antennas that are much lighter. Lighter equipment will vastly expand the inventory of helicopters that can be used for installation in the US. The lighter lift helicopters (generally lifts under 6,000 lbs) are also well distributed across the country so mobilization costs will be lower as travel distances will be minimized.

Heavy lift helicopters are available when needed for tower construction where the lifts are heavier. For the helicopters capable of the heavy lifts for building towers, there is a risk that the helicopters might be deployed to support fighting forest fires in fire season. That would then require the tower construction requiring a heavy lift to be scheduled outside of fire season adding to the timing risk of construction.

Urban, suburban and helicopter lifts in dense areas often require streets to be closed, traffic rerouted, pedestrians restricted to safe locations, and the clearing of landing areas (including an emergency drop location). The weather conditions must also cooperate to ensure safe helicopter operating conditions so a specifically scheduled day may have to be postponed and rescheduled to a safe flying day. Helicopters always operate flying into the wind so if access flight paths are not available the lift may need to wait for another day, into the wind.

38.Tower Work at Remote Sites

Tower crews working at remote sites will face some unique challenges, such as difficulty getting to the site, narrow roads, switchbacks, and an inability to get large trucks to the site. Some remote sites also have very limited ground working areas. This lack of working space makes staging of equipment particularly difficult and requires extensive coordination for any major installation. In our discussions with eligible entities, it is clear that there may be many sites where they may be special conditions. Remote sites may have significant mobilization and logistics costs due to distance or even the possibility that there are no roads to the site. Weather also can play a role as certain sites will require the use of snow capable vehicles to gain access.

39.Equipment Rental

For the replacement process, we expect that many eligible entities will need to rent a wide range of equipment and vehicles. This may include specialized equipment for installation and network monitoring, trucks and forklifts for installation and transport. We have started to capture some of the expected costs in the catalog but for projects of this size, the equipment and vehicles rented will be varied.

40.Special Access Sites

In our discussions with eligible entities, it is clear that there will be a number of wireless sites that will pose significant issues with access for crews. Access issues can be physical in nature or they can involve permits permissions. Some sites are on Federal, state, or tribal lands requiring special access permits and coordination. There may be a significant paperwork process that will involve legal and specialist consulting fees. Sites may also have physical access issues involving limited road access or weather-related limitations restricting access to certain parts of the year

These special access sites will have additional coordination costs associated with the deployment of the replacement program.

41.Location Upgrades for New Equipment

Excluding towers, we expect that, in most cases, existing facilities will support the addition of the replacement equipment that may have to be deployed in parallel for a period of time. There may be cases, however, where base facilities may have to be expanded or upgraded to accommodate additional equipment. These can include a requirement for more space, additional HVAC or power.

These potential upgrades may involve construction, site work, electricians and environmental specialists.

42.Field Engineering - Core Interoperability Testing for New Equipment

Each cell site that has installed replacement equipment will be required to optimize the performance of the RAN network. Field engineering will ensure that the replaced equipment meets the prescribed performance metrics. They may also provide the field support for cell site upgrades and new site construction. When the replaced equipment is integrated into the existing network the field engineers will be responsible for ensuring that all the equipment in the RAN performs as expected. The field engineers will be expected to access all the sites to ensure that the RAN is fully integrated and do any required network tuning.

43.National Environmental Policy Act (NEPA) & National Historic Preservation Act (NHPA)

Occasionally, certain tower modifications trigger NEPA and NHPA (Section 106) reviews and possibly an Environmental Assessment (EA) and/or historical or tribal consultation. Conducting the appropriate study or consultation will add time to any process involving the tower work. As was discovered during the implementation of the National Telecommunications and Information Administration's ("NTIA") Broadband Technology Opportunities Program ("BTOP"), Environmental Assessments can be a source of delays for data gathering analysis. Gathering information and Environmental Assessment Reporting proved to be one of the single biggest causes of delays in BTOP.

As an example, a NEPA and/or NHPA screening may be triggered by the following conditions:

- Increasing the overall height of an existing tower (including antennas & appurtenances by either 10% or 20' (whichever is smaller).
- Doing ANY ground disturbance (digging of any kind) that expands the boundaries of leased or owned property surrounding the tower by more than 30 feet in any direction or involves excavating outside these expanded boundaries or outside any existing access or utility easement related to the site.
- Pouring significant concrete pads.
- Building a new tower.
- The tower is located on federal or tribal land, including the Bureau of Land Management and US Forest Service land.
- The tower will be taller than 450 feet above ground level ("AGL").
- Changing the tower lighting.
- Modifying or collocating on a tower that in error has not previously gone through NEPA and/or NHPA review.

Other factors that may trigger additional analysis and requirements (such as an Environmental Assessment or consultation) include:

- Is the tower in an officially designated wilderness area, wildlife preserve area, wetland, or a flood plain?
- Is the tower in a critical habitat of an endangered species?
- Will the tower impact a protected species or migratory birds? If a protected bird is nesting on a tower, the window to work on a tower may be limited to certain periods during the year?
- Are there any historical or culturally significant landmarks near the tower?
- Is the tower located on tribal land, may it affect a Native American religious site, or is the tower located on a historically significant Native American site?
- Will the facility be in a residential neighborhood equipped with high intensity white lights or might there be other local zoning peculiarities?
- Whether a designated Bureau determines, in response to a petition or on its own motion, that the proposed facilities may have a significant environmental impact?

44.Legal Services

Widelity has spoken with attorneys practicing in the telecommunications industry about potential legal services that may be required as part of the replacement of the covered communications equipment and services. Attorneys have identified categories of services that may be necessary to support their client's participation in the replacement of the covered communications equipment and services project. The following are some of the identified areas where legal assistance may be required by the telecommunications operators:

- Pre-Planning Stage
    - Consultation with counsel on Finalized Rules & Regulations
- Contracts
    - Negotiation and review of RF engineering contracts and/or statements of work
    - Negotiation and review of structural engineering contracts and/or statements of work
    - Negotiation and review of field engineering contracts
    - Legal review of environmental consultant contracts and statements of work for Phase 1 environmental review
    - Negotiation and review of network engineering contracts and/or statements of work
    - Negotiate and review vendor contracts
    - Negotiation and review of disposal vendor contracts to ensure compliance with law and liability related issues
- Project Management
    - Review work orders and related purchase orders
- Tower Sites
    - Legal review of tower leases and support of negotiations
    - Due diligence review for compliance with FCC NEAP and Section 106 rules for collocation
    - Legal review of environmental consultant statements of work for NEPA and Section 106 work
    - Preparation of any required FAA and ASR filings

  - Review insurance requirements and OSHA standards for tower climbers
  - Research and ensure compliance with tower standards (ANSI/TIA-22-H) due to modifications triggering non-compliant towers
  - Due diligence review of modifications/upgrades for compliance with CDD NEPA rules, including Section 106 review, and FAA and ASR rules
  - Preparation and submission of any post-construction filings including FAA and FCC notifications
- Spectrum Acquisition
  - Legal review of spectrum acquisition contracts
- Transition Planning for Cut-Over
  - Legal review of customer communications related liability, indemnification and risk management in associated contracts and statements of work

These are just a few of the potential issues that attorneys have identified that may be associated with the replacement of the covered communications equipment. A more detailed listing is provided in the Catalog of Potential Costs.

45.Legal Fees and Zoning/Permitting Issues

Zoning is usually not an issue for like-for-like antenna and tower equipment swaps. However, there are some sites that are rigorously constrained and monitored. Zoning and permitting can be a big issue for tower extensions, or for additional equipment or replacement of existing equipment. In some cases, this process can add significantly to a timeline. Zoning and permitting issues are usually associated with major metropolitan areas, locations with sensitive environmental, scenic, or historical considerations, or where there are residential areas in close proximity to the transmission site location. Timeframes associated with zoning and permitting vary widely from jurisdiction to jurisdiction.

Coordinate with Bureau of Land Management and National Forest Service (This may be necessary for towers located on land managed by these agencies and would include the cost of preparation and submission of relevant forms)

If a new tower must be built there may be additional legal fees. New towers may involve more extensive zoning and permitting reviews, land acquisition, and more extensive legal coordination with local jurisdictions.

46.Disposal Cost/Logistics

Equipment that poses a national security threat must be disposed of in a responsible and secure manner.

The 2nd Report and Order – WC Docket No. 18-89 requires that "disposal must result in the destruction of the covered communications equipment or service, making the covered communications equipment or service inoperable permanently."[20] and further "will require recipients to dispose of covered communications equipment and service in a manner to prevent the use of the equipment or service in the networks of other providers."[21]

Subject to the 2nd Report and order, eligible telecom entities face the challenge of disposing and recycling of two types of waste streams. The first applies to any equipment that meets the definition of a national security threat as defined in Public Law 116-124. Such defined equipment must be disposed of in a secure and compliant manner that assures the FCC that all data, however it is stored or captured, is effectively destroyed.

The second disposal stream will apply to equipment and materials that does not store or capture data.

[20] Second Report and Order – WC Docket No. 18-89 at 176
[21] Id. Appendix A, § 1.50004 Secure and Trusted Communications Networks Reimbursement Program (j)

47.Secure and Compliant Disposal

The secure destruction process must assure that all e-waste that could pose a threat to national security is not resold, exported, or repurposed and that the media must be completely destroyed. For sensitive equipment there are usually three classifications of media sanitization: Clear, Purge, or Destroy. Following R2 Certification, State and Federal Guidelines will ensure that all sensitive equipment is securely destroyed, and the remaining material be recycled in a responsible manner**.**

Sensitive equipment can be recycled by an ITAR (International Traffic in Arms Regulations) registered recycler. (ITAR Section 122.5) ITAR registered recyclers are registered with the Office of Defense Trade Controls Compliance and are approved by the Directorate of Defense Trade Controls (DDTC) thereby complying with the International Traffic and Arms Regulations. ITAR disposal rules establish a methodology for secure destruction of sensitive e-waste. ITAR registered recyclers are in a position to effectively track individual items, facilitate secure logistics, provide complete destruction services, maintain records, provide documentation and certification of destruction.

Eligible sensitive equipment must be rendered unrecognizable and ultimately unusable. Secure shipping will also be required to ensure that the sensitive equipment is documented at the site of the eligible entity and arrives at the R2 certified/ITAR Registered recycler. For entities that do not have a local ITAR registered recycler, shipping and logistics costs will be required. Most ITAR registered recyclers can provide secure shipping and all major shippers can provide the service/documentation as well. There are a number of recycling services that are registered with the U.S. State Department's Directorate of Defense Trade Controls (DDTC), that complies with the ITAR regulations for disposal and documentation; they are located across the country and can meet the needs of this program.

Once the sensitive equipment is removed and documented at the site, a secure "chain of custody" will need to be kept until the equipment arrives, and is verified, at the certified recycler. While this will not be a problem in areas with ubiquitous shipping and freight services, in areas where these services are infrequent or unscheduled, the equipment will need to be securely warehoused until it can be handed off to the freight forwarder or other intermediate consignee. At each hand-off, the equipment would need to be verified and transferred, until it reaches the certified recycler. Extra time and expense will be encountered in areas with scarce freight forwarding services.

48.Other Disposal

Projects of this size will have a significant amount of E-waste material that does not include sensitive equipment that might store customer or traffic data and potentially material that is not electronic in nature but that must be disposed of in an environmentally responsible manner. There will be reasonable transportation costs to disposal sites and potentially additional charges as suppliers remove, install and dispose of non-sensitive equipment as additional services for the installation of non-sensitive equipment. It is suggested that an R2 Certified Recycler be utilized to ensure environmentally compliant disposal.

49.Security – On-site

In some locations additional site security may be required. Site security may involve temporary on-site secure facilities (i.e., containers), guard services or construction site video monitoring, for multi day construction projects.

50.Storage, Logistics, and Warehousing

Eligible entities will be ordering and potentially taking possession of tens of thousands of items for their network rebuilds in a short period of time. This may necessitate the leasing of storage and or warehouse space to securely store the equipment before it can be deployed into the final locations.

Some equipment may be pre-configured/pre-provisioned prior to deployment. These processes may require additional space during the replacement program. If this space may need to be leased.

Logistic requirements may require the hiring of specialist companies and/or dedicated project managers. Eligible entities with widely disparate geographies may face challenges getting equipment and resources to the right locations at the appropriate time. Once replaced logistic challenges may occur as equipment is tracked and shipped to the appropriate recyclers.

51.Shipping

Shipping costs will be important in the replacement process. As mentioned earlier in the report, some eligible entities will be purchasing tens of thousands of items. With so many items they will be facing large shipping and logistics efforts. Shipping will be required for the equipment coming for suppliers to the carrier. There may also be shipping/transportation costs from local warehouses to the field where the equipment will be installed.

There will also certainly be shipping costs from the field to warehouses and then ultimately into the secure disposal stream.

As mentioned earlier in the report, certain eligible entries in Alaska, or islands in the U.S. territories will have significant shipping challenges.

52.KPIs Pre & Post Installation Support

Eligible entities may choose to establish and monitor their network KPIs (Key Performance Indicators). The RAN KPIs are often used as a measure of the quality of service for subscribers. Network performance monitoring, and network optimization, will be important once new equipment is installed and then optimized. Establishing acceptable network performance will involve specialized monitoring equipment and may involve drive or drone testing.

As an example, KPI testing may involve measuring latency, modulation quality, beam strength, timing, spurious noise, signal integrity, and mobility evaluations.

Any performance levels discovered in the new equipment deployments will have to be rectified.

53.Drone Testing & Inspection Services

Aerial drones have become indispensable tools in telecommunications. More and more labor intensive (and potentially dangerous) functions can be performed by drones.

For many efforts, drones can be cheaper and safer than the way things were done previously. Here are a few ways that drones can be used in the replacement program:

Tower inspections - drones can perform a number of functions such as structural examinations, video cataloging of existing equipment, documentation, installation quality monitoring, etc.

Signal strength and coverage monitoring can now also be done by drone either in a flight pattern close to the towers and the antennas sectors or farther out in the field. Airborne measurement has become a trusted way to determine radiation patterns, RF coverage prediction verification, etc.

54.Drive Testing

Drive testing is an expected part of any wireless telecom deployment. Drive testing involves the use of a mobile vehicle that contains measurement equipment to perform network benchmarking, coverage assessment, capacity, and quality of services of a network across a specified geography. Drive testing can cover, signal levels, signal quality, dropped calls, performance statistics, QoS, etc.

Drive testing may also be required for 911 accuracy verifications for the replacement equipment coverage. Typically, selected points to assure that 50-meter location accuracy is maintained and that, on the borders between jurisdictions the correct PSAPs (Public Safety Access Points or 911 centers) are contacted by users making emergency calls.

Upon completion of the installation and turn-up of new network equipment, the wireless access layer will need to have its engineered coverage design verified. This will be accomplished by drive testing the coverage area to perform various network measurements to determine coverage, capacity, and quality of service.

Technical staff will utilize a vehicle outfitted with drive testing measurement equipment and software tools. Additional equipment should include all necessary components for connecting to the access layer of the network. Measurements will be performed to record the following information:

- GPS Coordinates
- Cell Connection Details
- Signal Levels
- Signal Quality/Modulation Levels
- Interference
- Quality of Service Information
- Handover Information
- Neighboring Cell Details
- Performance Throughput Metrics
- Call Statistics

These results will be utilized as a primary network benchmark that will be evaluated alongside the engineered design to make further adjustments to the network.

55. 911 Verification Services

When wireless networks replace equipment in their networks, they will have to coordinate with their 911 software provider and with their local PSAPs (Public Safety Access Points). Re-homing and verification of location accuracy will likely be required to ensure that the network and software are providing accurate location information and that the correct PSAP is contacted in a multi-jurisdiction coverage area. Required functions to monitor and verify 911 service and assure location accuracy may include:

- Test communication with PSAP or county locations
- Ensure FCC compliance and reporting
- Measure accuracy drive testing
- Monitor text to PSAP performance
- Ensure correct call routing regardless of device or location

As continued innovation in emergency communication technology has brought increased benefits, the move from a telephony-based system to an IP or digital based platform has brought an expanded risk of cyber-attacks, and other threats that the Providers will need to consider and plan for. Where early, telephony-based 911 systems had only TDoS (Telephony Denial of Service) attacks, E911 (Enhanced 911) and NG911 (Next Generation 911) systems will have to deal with DDoS (Distributed Denial of Service) and malware attacks, as well as TDoS attacks. Network security for the 911 servers and transport devices will need to be carefully thought through and put in place.

56. Customer CPE (Truck Roll or Self-Install)

Customer premise equipment (CPE) covers a broad range of equipment at a customer's home or businesses. For wireless networks (LTE and fixed wireless access (FWA)) this may include an outdoor antenna, roof mounted or side mounted, and equipment inside the structure which can include an internal modem and broadband router possibly with a wireless access point to distribute signal throughout the premises or office. The internal CPE may also serve as an access point to a wider area network in the home or location.

For a wired network, CPE can include:

- Optical Network Terminal (ONT), internal or external, that delivers signals from a fiber deployment.
- DSL modem for copper lines
- A broadband router, or a premise gateway with wireless (Wi-Fi) capabilities.

CPE replacements pose a few challenges for the eligible entities. CPE can involve a "truck roll" or the CPE can, in some cases, be user installed. In either installation scenario, customers must be informed of the impending change. For user installed CPE here is a preliminary list of required functions:

- a notification program must be initiated
- users must be shipped equipment,
- call center tech support must be trained on the new equipment to field customer trouble calls

- materials must be prepared and replaced equipment must be returned for complaint disposal.

For CPE that will require a truck roll:

- installers must be trained
- access to office or homes must be arranged
- customers must be prepared for the disruption that new equipment in their office or home networks may cause.

57. Taxes

There may be a wide range of federal, state and local tax implications for eligible entities.

There may be state and local sales taxes due on equipment and services received in the course of the replacement program. We expect that sales taxes will be a separate line item on invoices received from vendors.

For the U.S. Territories, there may also be additional taxes and tariffs on imports.

There may also be tax and reporting implications for entities as they must replace the retiring of equipment that has been partially depreciated on their balance sheets and then replaced with new equipment that has been purchased. There may be a balance sheet, P&L and tax filing impacts as significant amounts of equipment is replaced. For public entities and member coops the replacement program may have tax and accounting impacts.

58.Conclusion

In preparing this report, the Widelity team interviewed a significant number of Providers, industry experts and suppliers. Our interviews, as well as the expertise of our team, served as the basis of our report. We have summarized the issues that we feel the industry and the FCC will face when implementing the replacement program. The recommendations we have made are based on our insights into the issues. The process will be complex, and resource intensive but the security risks overshadow and challenges that the industry will face, and the program will and must succeed. As with any project of this scope, there are many unknowns, but the telecommunications industry is very experienced at equipment deployment, upgrades and deployments. With guidance from the FCC, the replacement program can be achieved with the desired outcomes.

We thank the Commission for this opportunity to support the effort

Appendix A Network Diagrams

Network Diagrams

The network diagrams below represent a variety of wireline and wireless network architectures. Through evaluation of vendor solutions, the items outlined by the red boxes would represent network components that are applicable for potential replacement.

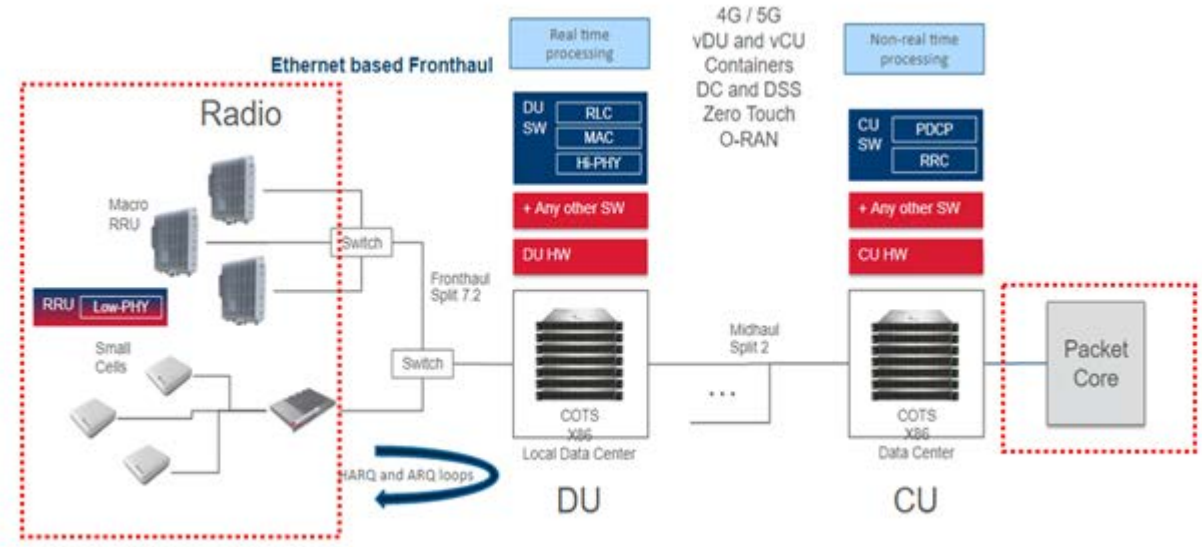


Figure 5 Open RAN Logical Diagram

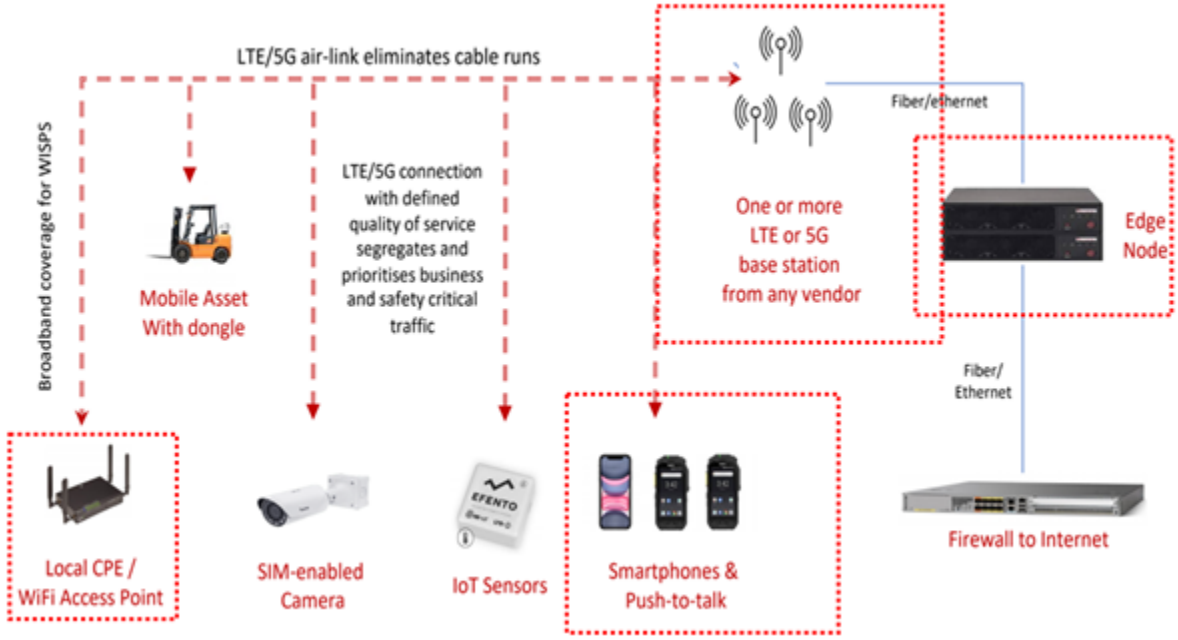


Figure 6 VLTE Network Overview

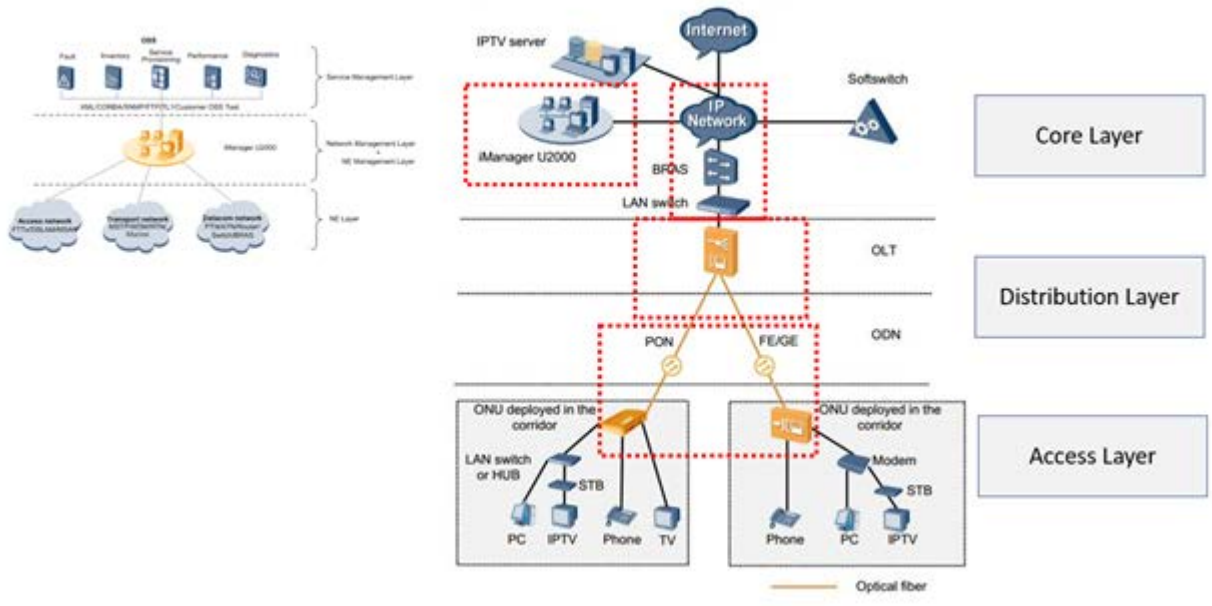
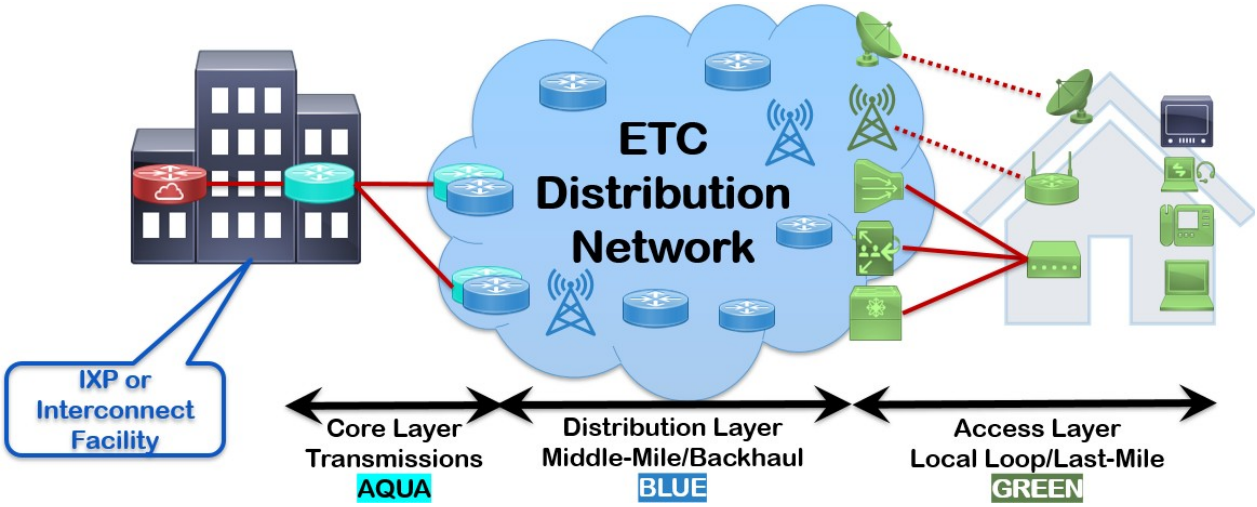


Figure 7 Wired Network Overview

Appendix B Network Categories

Network Categories

This data collection applies to the costs and estimated replacement costs[1] for *covered equipment or services* purchased with federal Universal Service Funds. These costs are to be maintained in accordance with generally accepted accounting principles.[2] Costs must be allocated across five categories: (1) Access layer equipment[3]; (2) Distribution layer equipment;
(3) Core layer equipment; (4) Software; (5) Services.[4]



Access Layer Equipment—equipment associated with providing and controlling end-user access to the network over the "last-mile", "local-loop", or "to the home." [5]

Customer premises equipment (CPE) is considered to be *covered equipment* if it is owned by the provider, including CPE that is in use and leased by the provider to end-user customers.

This category includes *access layer* equipment such as:

- Huawei optical line terminal equipment (OLT)
    - https://carrier.huawei.com/en/products/fixed-network/access/OLT

[1] Filers should explain how they determine their estimated costs of removing and replacing covered equipment and services in the Explanation box of the form. For a general discussion of replacement costs, *see Implementation of Section 19 of the Cable Television Consumer Prot. & Competition Act of 1992*, Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, CS Docket No. 94-48, First Report, 9 FCC Rcd 7442, 7544, para. 210 (1994).

[2] *See* 47 CFR §§ 32.1, 32.12.

[3] *See, generally*, Cisco, The Hierarchical Network Design Model, https://www.cisco.com/web/learning/netacad/demos/CCNP1v30/ch1/1_1_1/index.html (last visited Feb. 14, 2020).

[4] Several of the websites and products listed are shown in more than one of the network layers. For example, the "Huawei Metro WDN & OTN" can be used at Access, Distribution, or Core Layers as per Huawei website.

[5] *See, generally*, 47 CFR §§ 32.2310, 32.2311, 32.2341.

- ZTE optical line terminal equipment (OLT)
    - https://www.zte.com.cn/global/products/access/xpon
- Huawei optical distribution network devices (ODN)
    - https://carrier.huawei.com/en/products/fixed-network/access/ODN
- Huawei multi-service access node and digital subscriber line access multiplexing equipment (MSAN & DSLAM)
    - https://carrier.huawei.com/en/products/fixed-network/access/msan-dslam
- ZTE MSAN (Copper Access)
    - https://www.zte.com.cn/global/products/access/msan
- ZTE LAN MDUs
    - https://www.zte.com.cn/global/products/access/xpon/LAN-MDU
- Huawei optical network units (ONU)
    - https://carrier.huawei.com/en/products/fixed-network/access/ONU
- Huawei site cabinets
    - https://carrier.huawei.com/en/products/fixed-network/access/site
- Home network and customer premises equipment (CPE)
    - https://carrier.huawei.com/en/products/fixed-network/access/cpe

- ZTE CPE
  - https://www.zte.com.cn/global/products/access/cpe
- ZTE Smart Home
  - https://www.zte.com.cn/global/products/access/201901240914
- Huawei cable coaxial media converters
  - https://carrier.huawei.com/en/products/fixed-network/access/Cable-CMC
- Huawei access wavelength-division multiplexing (WDM) and optical transport networking (OTN) equipment
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Access-WDM--OTN
- Huawei WLAN
  - https://e.huawei.com/en/products/enterprise-networking/wlan
- Huawei Metro WDN & OTN – (can be deployed in the access, distribution or core of a network)
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Metro-WDM-OTN
- Huawei Access WDM & OTN
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Access-WDM--OTN

Distribution Layer Equipment—middle-mile, backhaul, or radio area network (RAN) equipment layered between the access and core layers of the network in which network traffic management policies are defined and enforced.[6]

[6] *See* 47 CFR §§ 32.2230, 32.2231, 32.2232.

This category includes *distribution layer* equipment such as:

- Huawei Routers
  - https://carrier.huawei.com/en/products/fixed-network/data-communication/router
- Huawei Switches
  - https://carrier.huawei.com/en/products/fixed-network/data-communication/switches
- Huawei Network security equipment

    - https://carrier.huawei.com/en/products/fixed-network/data-communication/Security
- Huawei Metro WDN & OTN – (can be deployed in the access, distribution or core of a network)
    - https://carrier.huawei.com/en/products/fixed-network/transmission/Metro-WDM-OTN
- Huawei Microwave
    - https://carrier.huawei.com/en/products/wireless-network/microwave
- Huawei Antennas
    - https://carrier.huawei.com/en/products/antenna
- Huawei Wireless Network
    - https://carrier.huawei.com/en/products/wireless-network
- ZTE LAN MDUs
    - https://www.zte.com.cn/global/products/access/xpon/LAN-MDU
- ZTE Bearer
    - https://www.zte.com.cn/global/products/bearer
- ZTE Wireless
    - https://www.zte.com.cn/global/products/wireless
- ZTE 5G
    - https://www.zte.com.cn/global/products/core_network/packet_core/202003251501/5g%20common%20cor
- ZTE LTE FDD
    - https://www.zte.com.cn/global/solutions/wireless%20access/flexible%20spectrum/fdd%20assisted%20super%20tdd
- ZTE LTE TDD
    - https://www.zte.com.cn/global/solutions/wireless%20access/flexible%20spectrum/fdd%20assisted%20super%20tdd
- ZTE GSM&UMTS
    - https://www.zte.com.cn/global/solutions/201905201709/201905201739/common%20core
- ZTE Small Cell
    - https://www.zte.com.cn/global/products/wireless
- ZTE Shelter Tower
    - https://www.zte.com.cn/global/products/wireless

Core Layer Equipment—backbone infrastructure that provides for fast routing of traffic with minimal processing and interconnection to other networks.[7]

This category includes *core layer* equipment such as:

- Huawei Backbone wave-division multiplexing / optical transport networking equipment
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Backbone-WDM-OTN
- Huawei See "Transmission Network" (Backbone WDM & OTN)
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Backbone-WDM-OTN
- Huawei Metro WDN & OTN – (can be deployed in the access, distribution or core of a network)
  - https://carrier.huawei.com/en/products/fixed-network/transmission/Metro-WDM-OTN
- Huawei Microwave
  - https://carrier.huawei.com/en/products/wireless-network/microwave
- Huawei Antennas
  - https://carrier.huawei.com/en/products/antenna
- ZTE RAN Core
  - https://www.zte.com.cn/global/products/core_network
- ZTE Cloud Core
  - https://www.zte.com.cn/global/products/201904031549
- ZTE Cloud Computing
  - https://www.zte.com.cn/global/products/201903111056
- ZTE Fiber Infrastructure Network
  - https://www.zte.com.cn/global/products/access/xpon/201707241446
- ZTE Optical Transmission
  - https://www.zte.com.cn/global/products/bearer/optical_transmission
- ZTE Data Transmission
  - https://www.zte.com.cn/global/products/bearer/data_communication
- ZTE Microwave
  - https://www.zte.com.cn/global/products/bearer/microwave

Software—for conceiving, specifying, designing, programming, testing, maintenance and developing equipment applications, components or systems that are continuously used.[8]

This category includes *software* such as:

- Huawei iManager U2000

[7] *See* 47 CFR §§ 32.2210, 32.2211, 32.2212.

[8] *See* 47 CFR § 32.2690.

    - https://carrier.huawei.com/en/products/fixed-network/single-oss/imanager-u2000
- Huawei iMaster NCE-Super
    - https://carrier.huawei.com/en/products/fixed-network/nce/NCE-Super
- Huawei iMaster NCE (IP Domain)
    - https://carrier.huawei.com/en/products/fixed-network/nce/NCE-IP
- Huawei iMaster NCE (Transport Domain)
    - https://carrier.huawei.com/en/products/fixed-network/nce/NCE-T
- Huawei iMaster NCE (Access Domain)
    - https://carrier.huawei.com/en/products/fixed-network/nce/NCE-FAN
- Huawei Agile Controller-DCN
    - https://carrier.huawei.com/en/products/fixed-network/nce/Agile%20Controller-DCN
- Huawei Agile Controller-Campus
    - https://carrier.huawei.com/en/products/fixed-network/nce/Agile%20Controller-Campus
- ZTE NetNumen U31
    - https://www.zte.com.cn/global/products/wireless/201903111102

Services—for design, implementation, installation, testing, or other costs and/or fees paid to deploy Huawei or ZTE equipment and/or systems.[9]

Appendix C Images

Cell tower types

Image 1 A Guyed cell tower

Image 2 A Wireless rooftop installation

Image 3 COW A monopole deployment

Image 4 Guyed mast guy line anchor

This anchor may need to be replaced if it has deteriorated.

Image 5 A self-supporting tower

Image 6 A deployed cell on wheels (COW)

Image 7 A stealth deployment with camouflage

Image 8 A deployment on a power pole

Helicopters

Image 9 Kaman K-Max 6,000 lbs lift capable

Image 10 Sikorsky S-64 Skycrane with lift harness

Image 11 Landing craft barges delivering above the high water mark

Appendix D Broadband Process requirements

Re-Planning

a. Planning team analyzes the existing Huawei or ZTE system, understanding the endpoints and the routing/path of the system.

b. The planning team analyzes the existing circuits on the Huawei/ZTE/ZTE system, understanding the endpoints and the routing/path of the circuits.

Space and power site surveys

a. The planning team submits requests to field personnel to understand any space/power/HVAC constraints, and to receive space and power assignments.
   i. If there are any space/power/HVAC constraints, the facility planning team will be engaged to resolve these issues.

Fiber site surveys

a. The planning team submits requests to field personnel to understand any fiber constraints (including auditing the current fiber path as well as identifying available fibers and any splicing requirements), receive fiber assignments for the new system, and test/characterize the fiber for the new system.

   i. If there are any fiber constraints, the fiber planners/engineers will be engaged to resolve these issues.

Negotiate/coordinate/communicate with the customer and/or any third-party for any necessary space/power/fiber for the new system

System installation planning

a. Incorporating all of the above, the planning team develops the plan for the new system taking into consideration the above while optimizing as much as possible to minimize capital expenditures (i.e., may have to build like-for-like, but may be able to build a more optimal system).

b. The planning team submits this plan to the equipment implementation team.

System installation

a. The equipment implementation team:
   i. Manages all of the timeframes/dates,
   ii. Orders the new equipment from the warehouse or the vendor,

iii. Works with the supply chain team to coordinate the shipment/delivery of the new equipment,
iv. Sends tasks to field personnel,
v. Project manages the installation/testing/turn-up (including alarming and management/visibility) of the new equipment with the field personnel,
vi. Updates the logical inventory system,
vii. Completes the paperwork and closes the plan.

Migration planning

a. Analysis of existing circuits on the Huawei/ZTE system, understanding the endpoints and the routing/path of the circuits.
   i. If there are any data integrity issues (the information in the logical inventory system doesn't match the physical information in the field), these will be resolved by the planning team working with other teams.
   ii. If needed, the planning team will submit site surveys to field personnel for additional/clarifying information.
   iii. If needed, the planning team will submit requests for any third-party connections with third-party vendors or coordinate with mutual customers.
   iv. If needed, the planning team will submit capacity augment requests.
b. Depending on the customer and their requirements, approval may need to be obtained from the customer-facing teams.
c. Incorporating the above, the planning team develops the plan to migrate these circuits from the Huawei/ZTE system to the new system while maintaining any diversity, latency, and custom routing requirements.
d. Once all necessary migration approvals have been received, the planning team submits the plan to the circuit migration team.

Migration execution

a. The circuit migration team:
   i. Manages all of the timeframes/dates,
   ii. Designs the new circuit paths based on the migration plan,
   iii. Schedules/coordinates with the customers,
   iv. Sends tasks to field personnel,
   v. Works with field personnel to create new connections,
   vi. Tests the new circuit paths,
   vii. Implements the circuit migrations with field personnel,
   viii. Updates the logical inventory system,
   ix. Completes the paperwork and closes the plan.

System decommission planning

a. The planning team verifies that the Huawei/ZTE system has been completely cleared of all circuits.
   i. If there are any data integrity issues (i.e., the information in the logical inventory system doesn't match the physical information in the field), these will be resolved by the planning team working with other teams.
   ii. If required, the planning team will submit site surveys to field personnel for additional/clarifying information.

b. The planning team ensures that Huawei/ZTE system does not carry any housekeeping or other alarms, and ensure that the Huawei/ZTE system does not provide management/visibility to any other systems.
   i. If it does, then housekeeping/other alarms and management/visibility to other systems will have to be moved to a system that is not being decommissioned.
   ii. If required, the planning team will submit site surveys to field personnel for additional/clarifying information.

c. The planning team creates a list of all of the Huawei/ZTE equipment to be decommissioned.

d. Incorporating the above, the planning team develops the plan to decommission the Huawei/ZTE system.

e. The planning team submits the plan to the equipment decommission team.

System decommission

a. The equipment decommission team:
   i. Manages all of the timeframes/dates,
   ii. Sends tasks to field personnel,
   iii. Project manages the turn-down/decommission of the Huawei/ZTE equipment with the field personnel,
   iv. Updates the logical inventory system,
   v. Completes the paperwork and closes the plan.

b. Once the Huawei/ZTE system is completely turned down/decommissioned, the field personnel will send the Huawei/ZTE equipment back to the warehouse for disposal.

c. The supply chain team will coordinate with a third party to destroy (and certify the destruction) of all of the Huawei/ZTE equipment in accordance with FCC guidelines.

Appendix E Example for a 50 Site MW and Transport core Network

1. Access Layer
   - 500 Fixed Wireless CPE

2. Distribution Layer – 50 sites with:
   - eNodeB supporting 3 B12/700 radios and 3 B25/PCS radios
   - 200 foot towers with 6 Radios, 6 antennas and cabling and over voltage protection
   - Cabinet with Power Distribution, Batteries, Rectifiers
   - Cell Site Routers
   - Microwave Hop

3. Core Layer
   - 20K Subscribers
   - Enhanced Packet Core (SGW, PGW, MME, PCRF)
   - IMS Core
   - Subscriber Management (HSS, AAA)
   - Aggregation Router

4. Software
   - RAN Element Management
   - Packet Core Element Management
   - IMS Element Management
   - Routing (cell site router and aggregation router) Element Management
   - PCMD Call Trace Network Tool

5. Services
   - Site Acquisition
   - Logistics and Warehousing
   - Installation, Commissioning, Integration of 50 RAN sites
   - Installation, Commissioning, Integration of Core site
   - RF Design, Optimization, KPI Monitoring
   - Program Management / Governance
   - Equipment Removal (at a 2nd visit later in time)
   - E2E Testing Across RAN/MW/Core/IMS
   - Security Audit
   - Resident Engineer (6 months)
   - Training

FCC Layer	Catalog of Cost Multi-Vendor Sample Range Low	High
Access Layer - CPE	$135,000.00	$267,500.00
Distribution Layer – 50 eNodeBs	$2,400,000.00	$5,350,000.00
Distribution Layer – Antennas, OVP, Cabling, Backup Power (at each eNB site)	$1,679,000.00	$4,540,350.00
Distribution Layer – 50 Cell Site Routers and 50 Microwave Hops	$599,520.00	$3,160,000.00
Core Layer – EPC, IMS and Aggregation Router	$1,412,500.00	$3,357,352.00
Software Layer – eNodeB, EPC, IMS and Routing Element Management +Tools	$600,000.00	$1,490,000.00
Services Layer – Per Site Deployment Services	$5,726,000.00	$14.873,150.00
Services Layer – EPC, IMS, Aggregation Router and E2E Testing	$1,852,000.00	$4,576,839.00
Total	$14,404,020.00	$37,615,191.00

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ATTACHMENT 2

WIDELITY
Service Ethics Commitment

CATALOG OF POTENTIAL EXPENSES AND ESTIMATED COSTS.

THE SECURE NETWORKS ACT PROTECTING AGAINST NATIONAL SECURITY THREATS TO THE COMMUNICATIONS SUPPLY CHAIN

PREPARED BY WIDELITY

MARCH 25, 2021

Contents

ABOUT THIS CATALOG

Widelity has produced a catalog, providing cost estimates for the removal, replacement, and disposal of covered communications equipment or services that may be eligible for reimbursement under the Reimbursement Program, as proposed by the FCC and required by The Secure Networks Act.

Based on industry interviews, we have organized the catalog to reflect the way that equipment and service providers offer their products and services.

The Catalog is made up of categories and subcategories of costs that eligible entities are expected to incur.

Through our interviews we have obtained current cost ranges for equipment, software and services from equipment manufacturers and service providers (e.g., tower crews, attorneys, RF engineers, and field engineers). In some cases, we were either provided a range of costs or quoted different costs for similar equipment or services by multiple sources. In those cases, we provided the range of costs we received. It is possible that tower crews, engineering services and some other costs may rise with high demand.

The list of services represents the issues brought up in our interviews with suppliers and service providers. Since many service providers provide selection of detailed service categories, we have aggregated the subcategories into the highest reasonable level of service.

	Range of Estimated Costs	
Description	**Low**	**High**
Access Layer Equipment The access layer is responsible for connecting users to their immediate service providers. First, the communications start by enabling users to communicate with the communication system to allow the start of information exchange/transmission. These communications can either be wired or wireless.		
Optical line terminal equipment (OLT)	$ 1,200.00	$ 39,000.00
CPE - FTTH		
Customer ONT - indoor	$ 100.00	$ 425.00
Customer ONT - outdoor	$ 270.00	$ 535.00
Small Business/SOHO CPE	$ 595.00	$ 30,000.00
Large Business/Enterprise CPE	$ 6,400.00	$ 25,000.00
Optical distribution network devices (ODN) - See Metro WDM & OTN		

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Multi-service access node and digital subscriber line access multiplexing equipment (MSAN & DSLAM)		
VDSL (Very high speed Digital Subscriber Line) CPE	$ 62.00	$ 199.00
Ethernet Service Access Node (ESAN) (includes outdoor cabinet & install)	$ 8,146.56	$ 8,146.56
LAN MDUs		
LAN MDUs (Local Area Network Multi-Dwelling Units), Small, includes subscription	$ 2,500.00	$ 79,000.00
LAN MDUs (Local Area Network Multi-Dwelling Units), Medium, includes subscription	$ 40,000.00	$ 117,000.00
LAN MDUs (Local Area Network Multi-Dwelling Units), Large, includes subscription	$ 115,000.00	$ 240,000.00
Home network and customer premises equipment (CPE)		
CPE - CBRS/B48 Category 15 15-19 dBi Gain Outdoor Unit	$ 200.00	$ 375.00
CPE - CBRS/B48 Category 15 High Gain Indoor Unit	$ 200.00	$ 260.00
CPE Swap Messaging/PR		
Legal review of customer notices & communications; public relations - (2-4 hours)	$ 1,000.00	$ 2,000.00
Smart Home - Reimbursable portions of Smart Homes are in the CPE (other portions: IP cameras, wifi doorbells, wifi, light switches, etc. would not be reimbursable)		
Cable coaxial media converters	$ 89.00	$ 289.00
WLAN (Wireless Local Area Network)		
WLAN - small	$ 795.00	$ 2,300.00
WLAN - medium to large network	$ 2,400.00	$ 3,825.00

	Range of Estimated Costs	
Description	**Low**	**High**
Access WDM (Wavelength Division Multiplexing) & OTN (Optical Transport Network)		
Access WDM & OTN equipment, Small, includes subscription	$ 83,000.00	$ 120,000.00
Access WDM & OTN equipment, Medium to Large, includes subscription	$ 165,000.00	$ 330,000.00
Site Cabinets - Optical Network Units (ONU)	$ 5,780.00	$ 7,225.00
Fiber - FTTP (Fiber To The Premises) - per mile, trenched & buried, rural, flat, rocky - to urban	$ 22,500.00	$ 61,116.00
Fiber - FTTP (Fiber To The Premises) - per mile, aerial lashed, rural - to urban	$ 18,500.00	$ 34,000.00
Distribution Layer Equipment Middle-mile, backhaul, or RAN (radio access network) equipment layered between the access and core layers of the network in which network traffic management policies are defined and enforced.		
Routers		
CellSite Router (1 Gig Port config L2 switch - 10 Gig Port config MPLS (Multiprotocol Label Switching) L3 router)	$ 795.00	$ 12,000.00
10G L2/Ethernet only NID/CellSite Router to IP/MPLS NID/CellSite Router	$ 4,500.00	$ 19,995.00
100G IP/MPLS Aggregation (non redundant - redundant controllers)	$ 17,500.00	$ 170,000.00
Switches		
Switches - small business and campus networks, cloud grade	$ 2,195.00	$ 239,270.00
Switches - medium business and campus networks, cloud grade	$ 239,270.00	$ 478,537.00
Switches - Large business and campus networks, cloud grade	$ 478,537.00	$ 720,000.00
Switches - small enterprise and service provider, cloud grade	$ 38,200.00	$ 270,600.00
Switches - medium enterprise and service provider, cloud grade	$ 270,600.00	$ 541,200.00
Switches - large enterprise and service provider, cloud grade	$ 541,200.00	$ 850,000.00
FTTH (Fiber To The Home) - GPON (Gigabyte Passive Optical Network) / XGS (10-Gigabit-capable symmetric passive optical network)		$ -
GPON/XGS Element Management System (10k subs)	$ 15,000.00	$ 190,100.00
GPON/XGS OLT	$ 20,000.00	$ 80,855.00
GPON/XGS OLT - Outside Plant	$ 28,050.00	$ 39,635.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
VDSL (Very high-speed Digital Subscriber Line) Access Network		
VDSL - ISP vs. OSP (Inside Plant vs. Outside Plant)	$ 19,805.00	$ 26,475.00
Cell Edge Aggregation		
Edge Aggregation - for 8 Cell Sites	$ 312,000.00	$ 415,000.00
Edge Aggregation - for 16 Cell Sites	$ 450,000.00	$ 600,000.00
Edge Aggregation - for 32 Cell Sites	$ 628,000.00	$ 835,000.00
Network security equipment		
Network security equipment - small network	$ 1,000.00	$ 33,667.00
Network security equipment - medium network	$ 33,667.00	$ 150,000.00
Network security equipment - large network	$ 67,333.00	$ 500,000.00
Metro WDM & OTN – (can be deployed in the access, distribution, or core of a network)	$ 136,000.00	$ 2,100,000.00
Optical Network Terminal (ONT)	$ 3,250.00	$ 3,750.00
Microwave PTP (point to point links)		
Microwave Radio pair (5.8 GHz 2+0 500 Mbps basic hop - 11 GHz 4+0 2.8 Gbps hop with switching)	$ 6,560.00	$ 36,200.00
Microwave Radio pair (Indoor, split-mount, small varying radio link capacities and capabilities	$ 7,327.00	$ 53,674.00
Microwave Radio pair (Indoor, split-mount, small to medium radio link capacities and capabilities	$ 10,318.00	$ 56,666.00
Microwave Radio pair (Indoor, split-mount, medium to large radio link capacities and capabilities	$ 16,043.00	$ 62,390.00
Microwave Radio pair, 2+0, 80MHz Channel, 1.4 Gbps (11GHz or 18GHz)	$ 10,700.00	$ 16,000.00
Microwave Radio pair, 4+0, 80 MHz Channel, 2.8 Gbps (11GHz or 18GHz)	$ 24,200.00	$ 36,300.00
Microwave Radio pair, 2+0, 50MHz Channel, 850 Mbps (23 GHz)	$ 10,700.00	$ 16,000.00
Microwave Radio pair, 4+0, 50 MHz Channel, 1.7 Gbps (23 Ghz)	$ 24,200.00	$ 36,300.00
Microwave Radio pair, 1+0, 2000 MHz Channel, 10 Gbps (80 GHz)	$ 9,600.00	$ 14,400.00
Microwave L2 Processing Shelf	$ 5,500.00	$ 8,500.00

	Range of Estimated Costs	
Description	**Low**	**High**
Microwave PTMP (point to multipoint)		
28/39 GHz PTMP Microwave Hub Node (access point), includes 90° sector antenna (LMDS A2/A3 or B Band)	$ 3,400.00	$ 11,500.00
28/39 GHz PTMP Microwave Remote Node, includes 1' parabolic antenna	$ 1,614.00	$ 4,000.00
28/39 GHz PTMP Microwave Remote Node, includes 2' parabolic antenna	$ 1,701.00	$ 4,100.00
28/39 GHz PTMP Microwave Remote Node, includes 3' parabolic antenna	$ 1,439.00	$ 4,100.00
Microwave Antennas - Single Pole		
0.3 - 1.2 meter (1 - 4 foot)	$ 425.00	$ 1,850.00
1.8 - 3.0 meter (6 - 10 foot)	$ 2,475.00	$ 3,668.50
Microwave Antennas - Dual Pole		
0.3 - 1.2 meter (1 - 4 foot)	$ 425.00	$ 1,976.70
1.8 - 3.0 meter (6 - 10 foot)	$ 2,700.00	$ 4,268.00
Microwave Antennas - mmWave Flat Panel		
Flat Panel	$ 3,852.00	$ 4,708.00
0.3 to 0.6 meter (1-2 foot, single polarization)	$ 430.00	$ 1,650.00
0.3 to 0.6 meter (1-2 foot, dual polarization)	$ 1,400.00	$ 2,050.00
Antenna - LTE (Long Term Evolution) Multi-band, >16dBi		
2 port - 2T2R through 8 port - 8T8R	$ 544.00	$ 6,450.00
12 port - 12T12R through 20 port - 20T20R	$ 2,087.00	$ 10,994.50
Antenna - LTE & CBRS (Citizens Broadband Radio Service), >16dBi		
8 port - 8T8R through 20 port - 20T20R	$ 4,455.00	$ 9,795.50
Antenna - CBRS only		
2 port - 2T2R through 16 port - 16T16R	$ 895.50	$ 5,225.00

	Range of Estimated Costs	
Description	**Low**	**High**
Cable Breakout Interconnection - Hybrid cable		
Cable breakout interconnect 100', NEMA (National Electrical Manufacturers Association) box, patch panel, power termination and 100' LC/LC (Lucent Connector) optic cables	$ 1,527.00	$ 2,560.00
Cable breakout interconnect 200', NEMA box, patch panel, power termination and 200' LC/LC optic cables	$ 1,693.00	$ 2,800.00
Cable breakout interconnect 300', NEMA box, patch panel, power termination and 300' LC/LC optic cables	$ 1,913.00	$ 7,200.00
Cable breakout interconnect 400', NEMA box, patch panel, power termination and 400' LC/LC optic cables	$ 4,699.00	$ 10,000.00
LAN MDUs (Local Area Network Multi-Dwelling Units)		
Small Networks	$ 1,900.00	$ 75,000.00
Medium Networks	$ 69,366.00	$ 150,000.00
Large Networks	$ 139,700.00	$ 250,000.00
Bearer - 5G Transport connects all categories of the mobile network infrastructure, including fronthaul, midhaul, and backhaul		
Bearer - small network	$ 17,000.00	$ 20,000.00
Bearer - medium to large network	$ 23,000.00	$ 34,000.00
Backbone WDM/optical transport networking equipment - small network	$ 83,000.00	$ 102,000.00
Backbone WDM/optical transport networking equipment - medium to large network	$ 165,000.00	$ 330,000.00
5G		
LTE FDD (Frequency Division Duplex)		
2-port capable, low-mid band radio for 1 sector (5Mhz, FDD, LTE or W-CDMA (Wideband Code Division Multiple Access))	$ 4,000.00	$ 14,872.00
4-port capable, low-mid band radio for 1 sector (5Mhz, FDD, LTE or W-CDMA)	$ 11,525.00	$ 22,496.00
Expansion of 2-port low-mid band radio for 1 sector (additional 5Mhz of (FDD), nominal to large amount of power)	$ 1,609.00	$ 5,844.00

	Range of Estimated Costs	
Description	**Low**	**High**
Expansion of 4-port low-mid band radio for 1 sector (additional 5Mhz of (FDD), nominal to large amount of power)	$ 1,735.00	$ 7,844.00
LTE TDD (Time Division Duplex)		
4-port capable, low-mid band radio for 1 sector (20Mhz, TDD)	$ 4,000.00	$ 21,842.00
8-port capable, low-mid band radio for 1 sector (20Mhz, TDD)	$ 21,318.00	$ 28,517.00
Expansion of 2,4,8-port low-mid band radio for 1 sector (additional 20Mhz of (TDD), nominal to large amount of power)	$ 3,000.00	$ 13,000.00
LTE BBU (Baseband Units)		
Rack Mounted baseband unit (BBU)	$ 7,461.00	$ 54,773.00
W-CDMA RNC (Radio Network Controller, small network, <50k subscribers)	$ 391,278.00	$ 840,918.00
W-CDMA RNC (Radio Network Controller, medium network, <250k subscribers)	$ 840,918.00	$ 1,070,246.00
W-CDMA RNC (Radio Network Controller, large network, <500k subscribers)	$ 1,070,246.00	$ 2,274,859.00
1 Sector Bundle - 10/20MHz channels - RU (Radio Unit), CDU (Cabinet Distributed Unit), shelf, cables, SFP's, and antennas		
Single sector CBRS 4T4R base station and Baseband Unit - 10/20MHz channel	$ 16,538.00	$ 17,504.00
Single sector CBRS 64T64R base station and Baseband Unit - 10/20MHz channel	$ 28,792.00	$ 30,412.00
1 Sector Bundle - 40MHz channels - RU, CDU, DU shelf, cables, SFP's, and antennas		
Single sector CBRS 4T4R base station and Baseband Unit - 40MHz channel	$ 16,538.00	$ 17,504.00
Single sector CBRS 64T64R base station and Baseband Unit - 40MHz channel	$ 34,365.00	$ 36,315.00
1 Sector Bundle - 60MHz channels - RU, CDU, DU shelf, cables, SFP's, and antennas		
Single sector CBRS 4T4R base station and Baseband Unit - 60MHz channel	$ 16,807.00	$ 17,788.00
Single sector CBRS 64T64R base station and Baseband Unit - 60MHz channel	$ 39,940.00	$ 42,217.00
4T4R CBRS Radio Unit, 4T4R pole mounting bracket, 4T4R 10meter CPRI optical cable	$ 4,842.00	$ 5,137.00
64T64R CBRS Radio Unit, 64T64R pole mounting bracket, 64T64R CPRI Optical module, 10 meter CPRI cable	$ 15,963.00	$ 16,902.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Bundled BBU/RRH (Base Band Unit/Remote Radio Head)		
Fixed Wireless		
nonMIMO (Multiple-Input and Multiple-Output) eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (20W) vs High Power radio (up to 320W). Price includes Remote Radio Units (RRU), Base Band Unit (BBU), Ancillaries, Software Features, and Capacity Licensing. Price excludes antennas, tower cabling, tower ancillaries and over voltage protection (OVP)	$ 27,000.00	$ 56,000.00
mMIMO eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (120W) vs High Power radio (up to 240W). Price includes Radio+Antenna, BBU, Ancillaries, Software Features, and Capacity Licensing. Price excludes tower cabling, tower ancillaries and over voltage protection (OVP).	$ 85,000.00	$ 115,000.00
Mobility Wireless - nonMIMO		
nonMIMO eNodeB with 3 sectors, single spectrum band of up to 20 MHz/sector. Fixed Wireless features. Range due to Low Power radio (20W) vs High Power radio (up to 320W). Price includes RRHs, BBU, Ancillaries, Software Features, and Capacity Licensing. Price excludes antennas, tower cabling, tower ancillaries and over voltage protection (OVP)	$ 45,000.00	$ 69,000.00
Mobility Wireless - mMIMO		
mMIMO eNodeB 3 Sector Per Band (64T64R 20 MHz 1 Band FWA - 64T64R 60 MHz 1 Band with Advanced Mobility Features)	$ 85,000.00	$ 368,172.00
Bundled Open-RAN		
Macrocell 4G 20MHz Carrier (Bundle - Antennas, RU/RRU, BBU Software, GPS Receiver, STU (Subscriber Terminal Unit), RIU (Radio Interface Unit), Mechanical Mounting, Cables and Connectors, SFPs (Small Form-Factor Pluggable))	$ 39,000.00	$ 52,000.00
Macrocell - 5G Sub6 100MHz Carrier (Bundle - Antennas, RU/RRU, BBU Software, GPS Receiver, STU, RIU, Mechanical Mounting, Cables and Connectors, SFPs)	$ 91,000.00	$ 125,000.00
Macrocell - 5G mmWave (Bundle - RU/RRU, BBU Software, GPS Receiver, DU (Open RAN Distributed Unit), Mechanical Mounting, Cables and Connectors, SFPs)	$ 45,000.00	$ 60,000.00

	Range of Estimated Costs	
Description	**Low**	**High**
Open vRAN eNodeB **Model is based on single band 50 site cluster. It includes RRU (Remote Radio Unit)/CU (Control Unit)/DU (Distributed Unit)/SW (Software)/NFVi (Network Functions Virtualization infrastructure). SW include all features, power licenses, optional features**		
B71 (3 sector site) or B5 (3 sector) One RRU Type	$ 43,225.60	$ 64,838.40
B41 (3 sector site) One RRU Type	$ 45,113.60	$ 67,670.40
B66 or B4(3 sector) One RRU Type	$ 48,233.60	$ 72,350.40
B2 or B25 (3 sector) One RRU type	$ 48,233.60	$ 72,350.40
B48 One RRU Type	$ 44,753.60	$ 67,130.40
B71/B25 (3 Sector for each RRU) Two RRU Type (dual band per sector)	$ 69,049.60	$ 103,574.40
B71/B12/B41 (3 Sector for each RRU) Three RRU Type (tri-band per sector)	$ 101,166.40	$ 151,749.60
RAN (Open RAN/ vRAN) Components		
RRU - band 71 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 8,688.00	$ 13,032.00
RRU - band 41 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 9,104.00	$ 13,656.00
RRU - band 12 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 66 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 25 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 2 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 5 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 4 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc.	$ 10,144.00	$ 15,216.00
RRU - band 48 - Perpetual license, w/ SW; all-inclusive power, features, carriers etc. SW price is per RRU for B48	$ 6,048.00	$ 9,072.00
NFV Server	$ 13,000.00	$ 15,000.00
DU		
Kontron 1210	$ 3,680.00	$ 5,520.00
Super Micro	$ 9,642.40	$ 14,463.60
vDU Server	$ 8,000.00	$ 10,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
CU		
Dell PowerEdge R740 XL-2x 6230R -26c 512GB 4x600GB HDD TB(2.4TB) (AC) vCompute NODE	$ 11,975.20	$ 17,962.80
vCU Server	$ 10,000.00	$ 12,000.00
SPF - Small form-factor pluggable transceiver		
SFP - 10G	$ 175.00	$ 175.00
GPS		
GPS Antenna, Lightning Arrestor, GPS Splitter 1:8, Cable Assembly-Coaxial (35')	$ 1,560.00	$ 1,694.00
GSM&UMTS (Universal Mobile Telecommunications System)		
3G/UMTS RNC (Radio Network Controller) Small - Medium (50 - 1000 nodes)	$ 300,000.00	$ 750,000.00
3G/UMTS NodeB HW/SW addition to eNodeB	$ 11,000.00	$ 13,000.00
3G/UMTS MSC, Mobile Switching Center, 3G/UMTS MGC, MGW (up to 50K subs)	$ 2,000,000.00	
Small Cell		
Small Cell, LTE B42 B43 B48 integrated antenna eNodeB	$ 4,000.00	$ 20,000.00
Tower Shelter		
New shelter: Shelter, delivery, crane, labor, pad	$ 75,000.00	$ 85,000.00
Outdoor Cabinets		
Cabinet, Power Distribution Unit, 4 to 8 Rectifiers, 1 to 2 Battery Strings, optional Heat Exchanger	$ 10,000.00	$ 33,813.00
Outdoor Cabinet Install (Provide and Install)	$ 5,250.00	$ 6,300.00
Relocate CSR to New Cabinet	$ 1,950.00	$ 2,350.00
Install batteries and rectifiers	$ 1,500.00	$ 1,850.00
Install Outdoor Mounting Rack H-Frame	$ 750.00	$ 900.00
Indoor Cabinets		
Indoor cabinet (small to large site, optional battery backup included.	$ 9,766.00	$ 29,561.00

	Range of Estimated Costs	
Description	**Low**	**High**
Core Layer Equipment The Core Layer of the network is the central element that provides services to those elements connected at the access layer of the network. One of the main functions of the core layer is that it is an aggregation point that provides proper routing of all voice and data traffic. All access and distribution layers of the network will be connected to the core via fiber or microwave backhaul connections.		
EPC		
4G/5G-NSA Evolved Packet Core - Small, SGW, PGW, MME (10K subs to 50K subs, includes deployment)	$ 250,000.00	$ 1,200,000.00
4G/5G-NSA Evolved Packet Core - Medium, SGW, PGW, MME (50K subs to 200K subs), cost per site, includes deployment	$ 100,000.00	$ 2,550,000.00
4G/5G-NSA Evolved Packet Core - Large, Distributed, SGW, PGW, MME (greater than 200K subs - redundant solution, per site, includes deployment)	$ 1,250,000.00	$ 4,250,000.00
4G/5G-NSA Evolved Packet Core - Large, Distributed, SGW, PGW, MME (greater than 200K subs - distributed, geo-redundant solution, per site, includes deployment)	$ 4,401,710.00	$ 8,320,688.00
HSS Subscriber Data - Small, HSS (up to 50K subs, includes deployment)	$ 400,000.00	$ 650,000.00
HSS Subscriber Data - Medium, Per site - HSS (50K subs vs 250K subs, includes deployment)	$ 1,250,000.00	$ 2,250,000.00
HSS Subscriber Data - Medium, Per site - HSS (250K subs vs 500K subs, includes deployment)	$ 2,500,000.00	$ 6,000,000.00
3G HLR added to HSS - Small, HLR (up to 50K subs, includes deployment)	$ 250,000.00	$ 500,000.00
3G HLR added to HSS - Medium, Per site - HLR (50K subs vs 250K subs, includes deployment)	$ 500,000.00	$ 1,000,000.00
3G HLR added to HSS - Medium, Per site - HLR (250K subs vs 500K subs, includes deployment)	$ 1,000,000.00	$ 2,500,000.00
Design, Installation, Commissioning, Integration, Migration Services - Medium solution, 3G HLR added to HSS - Medium	$ 500,000.00	$ 500,000.00
AAA Server - Small, AAA (up to 50K subs)	$ 150,000.00	$ 150,000.00
Design, Installation, Commissioning, Integration, Migration Services - Small solution, AAA Server - Small	$ 70,000.00	$ 80,000.00
AAA Server - Medium, Per site - AAA (50K subs vs 250K subs)	$ 250,000.00	$ 400,000.00
AAA Server - Medium, Per site - AAA (250K subs vs 500K subs)	$ 400,000.00	$ 800,000.00
Design, Installation, Commissioning, Integration, Migration Services - Medium solution, AAA Server - Medium	$ 375,000.00	$ 425,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Design, Installation, Commissioning, Integration Services, Mobile Switching Center	$ 475,000.00	$ 525,000.00
IMS Core, Per site - CSCF, TAS, A-SBC, ES, LIG, MRF, DRA/DEA, DNS, ENUM (50K - 250K subs)	$ 6,250,000.00	$ 6,250,000.00
IMS Core, Per site - CSCF, TAS, A-SBC, ES, LIG, MRF, DRA/DEA, DNS, ENUM (250K - 500K subs)	$10,000,000.00	$ 10,000,000.00
3G Packet Core addition to 4G EPC - Small to Medium, SGSN, GGSN (up to 500K subs, includes deployment)	$ 750,000.00	$ 1,409,947.00
WiFi Packet Data Gateway - ePDG (Small - 10K subs vs 50K subs, includes deployment)	$ 550,000.00	$ 650,000.00
WiFi Packet Data Gateway - ePDG (Medium - 50K subs vs 250K subs, includes deployment)	$ 650,000.00	$ 1,000,000.00
Cloud Core		
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, Small Network)	$ 320,000.00	$ 1,200,000.00
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, Medium Network)	$ 1,500,000.00	$ 8,320,688.00
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, Large Network)	$ 2,000,000.00	$ 24,381,688.00
Cloud - Virtual Stand Alone IMS (CTAS, IMS Core, MRF, AGW, A-SBC, HSS, ePDG, I-SBC, DRA, PCRF, 4G EPC, E-CSCF, LI interface, SMSC, MMSC, VM)	$ 849,230.00	$ 1,049,230.00
RAN Core / EMS		
IMS and RAN Element Management System, Compact EMS with Basic Licensing, includes hardware (10K to 50K subs)	$ 300,000.00	$ 690,000.00
IMS and RAN Element Management System, Medium EMS with Premium Licensing, includes hardware (50K subs to 500K subs)	$ 1,000,000.00	$ 2,500,000.00
Packet Core Element Management System, Packet Core EMS (50K subs vs 250K subs)	$ 150,000.00	$ 470,000.00
Per Call Measurement Data Server (PCMD)	$ 100,000.00	$ 500,000.00
Design, Installation, Commissioning, Integration Services IMS/EMS Add-Ons	$ 150,000.00	$ 500,000.00
Design, Installation, Commissioning, Integration Services, Packet Core Element Management System Add-ons	$ 150,000.00	$ 300,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Metro WDM & OTN (Wavelength Division Multiplexing & Optical Transport Network) (can be deployed in the access, distribution, or core of a network) (see Distribution Layer)		
Metro WDM & OTN equipment, Small, includes subscription	$ 83,000.00	$ 120,000.00
Metro WDM & OTN equipment, Medium to Large, includes subscription	$ 165,000.00	$ 330,000.00
Microwave - (see Distribution Layer)		
RAN Core		
RAN Element Management System (Small EMS with Basic Licensing - Medium EMS with Premium Licensing)	$ 450,000.00	$ 1,000,000.00
Core Element Management System (10K subscriber core - 250K subscribe core)	$ 150,000.00	$ 540,000.00
Core Server Hardware		
RGS Server	$ 17,500.00	$ 18,000.00
RGS-E Server	$ 19,500.00	$ 20,000.00
Aggregation Router (range is Small 1G ports L2 Switch - Medium 10G/25G ports MPLS L3 Router)	$ 10,000.00	$ 250,000.00
Core Routers, small networks	$ 25,000.00	$ 391,667.00
Core Routers, medium networks	$ 391,667.00	$ 783,333.00
Core Routers, large networks	$ 783,333.00	$ 1,200,000.00
Core Switches, small networks	$ 25,000.00	$ 325,000.00
Core Switches, medium networks	$ 325,000.00	$ 650,000.00
Core Switches, large networks	$ 650,000.00	$ 1,000,000.00
Network Security Equipment (Highly Variable)		
Operation Support Systems (OSS)		
OSS/BSS Design - Process Automation & Network Roll-out (based on 1 million subscribers)	$ 500,000.00	$ 550,000.00
OSS/BSS Design - Network & Service Assurance (based on 1 million subscribers)	$ 700,000.00	$ 750,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
OSS/BSS Design - Network Testing & Management (based on 1 million subscribers)	$ 200,000.00	$ 250,000.00
OSS/BSS Yearly License Costs & Fees (based on 1 million subscribers)	$ 700,000.00	$ 750,000.00
Orchestration		
Orchestration Design - Service Design & Creation (based on 1 million subscribers)	$ 550,000.00	$ 600,000.00
Orchestration Design - Universal Cloud Orchestration (based on 1 million subscribers)	$ 1,200,000.00	$ 1,300,000.00
Orchestration Yearly License Costs & Fees (based on 1 million subscribers)	$ 900,000.00	$ 950,000.00
Cloud Computing	$ 55,000.00	$ 330,000.00
Optical Transmission		
Small to Medium Network	$ 60,000.00	$ 170,000.00
Medium to Large Network	$ 170,000.00	$ 240,000.00
Data Transmission		
Small to Medium Network	$ 19,000.00	$ 26,000.00
Medium to Large Network	$ 26,000.00	$ 38,000.00
Software Instructions that tell a computer what to do. Software comprises the entire set of programs, procedures, and routines associated with the operation of a computer system. Applications include conceiving, specifying, designing, programming, testing, maintenance and developing equipment applications, components or systems that are continuously used		
Active Ethernet (AE) functionality for provisioning and alarming	$ 4,500.00	$ 7,300.00
Voice Core	$ 500,000.00	$ 1,000,000.00
Data (Ran CORE)	$ 950,000.00	$ 1,300,000.00
Network Management SW	$ 100,000.00	$ 115,000.00
SDN-enabled management and control software (per device, 1yr to 3yr sub)	$ 2,000.00	$ 105,000.00
Network Automation (Highly Variable)		

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Licenses		
4G IOT License - Perpetual - per Subscriber	$ 0.02	$ 1.04
4G Connectivity License - Perpetual - per Subscriber	$ 0.09	$ 4.74
4G Communications License - Perpetual - per Subscriber	$ 0.11	$ 5.76
5G SA/NSA IOT License - Perpetual - per Subscriber	$ 0.11	$ 1.18
5G SA/NSA Connectivity License - Perpetual - per Subscriber	$ 0.12	$ 6.62
5G SA/NSA Communications License - Perpetual - per Subscriber	$ 0.11	$ 6.07
4G+5G NSA IOT License - Perpetual - per Subscriber	$ 0.03	$ 1.73
4G+5G NSA Connectivity License - Perpetual - per Subscriber	$ 0.15	$ 8.04
4G+5G NSA Communications License - Perpetual - per Subscriber	$ 0.13	$ 7.14
LTE Software License, perpetual license, technology LTE TDD/FDD, per cell/carrier	$ 1,000.00	$ 10,000.00
5G NR (new radio) Software License, perpetual license, technology 5G NR TDD/FDD, per cell/carrier	$ 1,000.00	$ 10,000.00
5G NR (new radio) mMIMO (massive MIMO) Software License, perpetual license, technology 5G NR TDD/FDD, per cell/carrier	$ 1,000.00	$ 10,000.00
LTE Open RAN eNB SW Fee, cost of (1) perpetual license per cell site, technology LTE TDD/FDD	$ 2,000.00	$ 20,000.00
5G NR Open RAN eNB SW Fee, cost of (1) perpetual license per cell site, technology 5G NR TDD/FDD	$ 2,000.00	$ 20,000.00
Open RAN Management System, cost of one perpetual license for 1 cell/carrier, technology LTE/5G NR TDD/FDD	$ 100.00	$ 5,000.00
Services **For design, implementation, installation, testing, or other costs and/or fees paid to deploy the replacement equipment and/or systems in the conterminous (contiguous) United States. An additional 30-50% needed for Services Specific to: Alaska, American Samoa, Hawaii, Puerto Rico and Virgin Islands**		
Preplanning		
NTP (Notice to Proceed) Package	$ 850.00	$ 1,000.00
A&E Walk	$ 3,150.00	$ 5,500.00
Utility Coordination	$ 250.00	$ 2,744.17
Participation in FCC Rulemaking - (8-15 hours per filing)	$ 4,000.00	$ 7,500.00
Consultation with Counsel on Finalized Rules & Regulations - (3-10 hours)	$ 1,500.00	$ 5,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Site Acquisition		
Existing Colocation (per site) - dependent on site type	$ 2,900.00	$ 8,797.50
Site Surveys		
Drone - Visual Inspection	$ 925.00	$ 2,058.13
Drone - Infrared Inspection - expenses not included	$ 5,000.00	$ 10,000.00
Drone - Additional field work - day rate - expenses not included	$ 1,500.00	$ 2,000.00
Site survey - (from ground) distance to site/complexity of site (including ground measurement)	$ 945.00	$ 25,000.00
RF Engineering		
Construction Drawings	$ 2,031.00	$ 5,333.33
MPE Survey RF Emissions	$ 1,219.24	$ 1,700.00
Modeling, Site Design, Performance Troubleshooting, Internal Team Optimization	$ 3,585.20	$ 5,053.00
Drone - Performance Mapping (RF Measurements)	$ 15,000.00	$ 30,000.00
Interim Facility Requirement		
Cost of temporary site (COW) during tower replacement or modification	$ 37,710.53	$ 60,000.00
Leasing		
Negotiation of co-location contracts/leases (2-4 hours per contract)	$ 1,000.00	$ 2,000.00
Lease review	$ 450.00	$ 823.25
Site Plan - (lease exhibit)	$ 1,250.00	$ 2,150.00
Co-location application	$ 479.27	$ 800.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Project Management		
Project Management - carrier internal (per person per month)	$ 7,785.00	$ 12,975.00
Review work orders and related purchase orders - (1-4 hour per work order)	$ 500.00	$ 2,000.00
Project Management (per person per month)	$ 25,950.00	$ 51,900.00
Construction Management (per person per month)	$ 21,666.00	$ 25,950.00
NOC Staff Augments	$ 14,705.00	$ 17,300.00
Transition Planning for Cutover - complexity of equipment changes	$ 5,000.00	$ 15,000.00
Legal review of customer communications related liability, indemnification and risk management in associated contracts and SOW - (6-8 hours)	$ 3,000.00	$ 4,000.00
Hot/Cold/Warm swap Planning	$ 3,500.00	$ 11,000.00
Spectrum Planning and Management		
Leasing or purchase of additional spectrum and related negotiations - (8-10 hours per agreement)	$ 4,000.00	$ 5,000.00
Preparation of purchase or lease agreement (3-5 hours per agreement)	$ 1,500.00	$ 2,500.00
Preparation and submission of any required FCC filings for permission (2-4 hours)	$ 1,000.00	$ 2,000.00
Training		
Product, Engineering and Operations Training Courses (classroom or web per student/day)	$ 750.00	$ 1,625.00
Onsite-Knowledge Transfer (per week)	$ 7,000.00	$ 12,000.00
Subscription (per person)	$ 17,300.00	$ 32,900.00
Optical Training Service - 3 to 4 day instruction	$ 13,030.00	$ 15,704.00
Open vRAN Training - 3 to 4 day	$ 10,000.00	$ 15,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Resident Engineer/Staff		
RAN/CORE Engineer - to provide on-site support during and after turn-over for 1 year (per person/per quarter)	$ 50,000.00	$ 100,000.00
Network Operations - to provide on-site support during and after turn-over (per person/per year)	$ 93,600.00	$ 156,000.00
VoLTE voice coordination with providers		
VOLTE Optimization (per site)	$ 3,675.00	$ 4,928.00
Structural Engineering / Tower studies		
Structural Analysis - complexity of design	$ 2,261.14	$ 4,550.00
Mount Analysis - size of tower, complexity of loading scenarios	$ 1,250.00	$ 8,000.00
Tower/Mount Mapping	$ 11,084.03	$ 13,720.86
Review Contracts and Statements of Work - (2-3 hours per contract)	$ 1,000.00	$ 1,500.00
Negotiating with tower owners		
Executed Agreement	$ 3,688.76	$ 5,200.00
Fully Executed Amendment	$ 3,250.00	$ 4,390.68
Fully Executed Amendment - Non-MLA	$ 3,000.00	$ 4,939.51
Legal review of tower leases and support of negotiations - (8-10 hours per lease)	$ 4,000.00	$ 5,000.00
Network Engineering Services		
CIQ creation/review (per site)	$ 384.62	$ 840.00
SCF Creation / WO for new sites up to 12 carriers	$ 600.00	$ 3,200.00
Engineering Services (RAN) (per site)	$ 250.00	$ 500.00
Engineering Services (Core) (per core)	$ 5,000.00	$ 50,000.00
Engineering Services (IP Network) (per site)	$ 250.00	$ 1,000.00
Engineering Services (Microwave Backhaul) (per link)	$ 250.00	$ 650.00
Engineering Services (Microwave Backhaul) FCC PCN Coordination) (per link)	$ 2,500.00	$ 2,500.00
Negotiation & Review of RF engineering, AM Detuning, Interference or Intermodulation analysis, RF Emissions Study, and RF Exposure Measurements contracts - (2-3 hours per contract)	$ 1,000.00	$ 1,500.00
Open RAN deployment services, CU/DU deployment instantiation support, per man/hour	$ 100.00	$ 500.00

	Range of Estimated Costs	
Description	**Low**	**High**
Tier 2 & Tier 3 Operational Support, per man/hour	$ 100.00	$ 500.00
Network Integrator Services (Highly Variable)		
Tower/Water Tower/Barn/Rooftop Preparation		
Remove RRH/RRU, Antenna and cabling	$ 1,850.00	$ 3,000.00
Remove 3 RRH/RRU, 3 Antenna and 3 cabling	$ 3,250.00	$ 3,700.00
Remove BBU	$ 500.00	$ 700.00
Remove BBU and replace with new BBU	$ 2,500.00	$ 3,200.00
Antenna Install (with material)	$ 5,650.00	$ 6,850.00
Radio Install - each radio - height of radios on tower; # RF jumper cables per radio/antenna	$ 1,000.00	$ 3,500.00
Install new Power Trunk	$ 3,850.00	$ 4,650.00
Install new Fiber Trunk	$ 4,200.00	$ 5,100.00
Install Hybrid Cable (without Material)	$ 1,199.35	$ 7,625.00
Fiber Inspection, Cleaning and Light Source & Power Meter Testing * Post Installation	$ 2,000.00	$ 4,423.65
Rip & Replace - Up to (12) New Radios, (6) New Antennas (Install/Swap up to (12) new radios, (6) new antennas with associated jumpers, plumbing/re-plumbing etc. No new hybrid)	$ 29,212.94	$ 49,602.02
Antenna/Radio R&R - Non-penetrating Roof Mounted		
Rip & Replace - Up to (3) Antenna Replacement (Install/Swap up to (3) new antennas, with associated jumpers, plumbing/re-plumbing etc.)	$ 6,805.30	$ 9,073.73
Rip & Replace - Up to (6) Antenna Replacement (Install/Swap up to (6) new antennas, with associated jumpers, plumbing/re-plumbing etc.)	$ 12,470.48	$ 16,627.31
Rip & Replace - Up to (3) Radios (RRH/RRU) Replacement (Install/Swap up to (3) new radios, with associated jumpers, plumbing/re-plumbing accordingly etc. No new antennas or hybrid)	$ 9,475.84	$ 12,634.46
Rip & Replace - Up to (6) Radios (RRH/RRU) Replacement (Install/Swap up to (6) new radios, with associated jumpers, plumbing/re-plumbing accordingly etc. No new antennas or hybrid)	$ 13,291.30	$ 17,721.73

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Rip & Replace - Up to (6) New Radios, (3) New Antennas (Install/Swap up to (6) new radios, (3) new antennas with associated jumpers, plumbing/re-plumbing etc. No new hybrid)	$ 16,582.07	$ 22,109.42
Rip & Replace - Up to (9) New Radios, (3) New Antennas (Install/Swap up to (9) new radios, (3) new antennas with associated jumpers, plumbing/re-plumbing etc. No new hybrid)	$ 18,063.61	$ 24,084.82
Rip & Replace - Up to (12) New Radios, (6) New Antennas (Install/Swap up to (12) new radios, (6) new antennas with associated jumpers, plumbing/re-plumbing etc. No new hybrid)	$ 32,201.51	$ 42,935.35
Shelter Cable Entry Port Additions		
Up to six (6) entry ports (provide and install)	$ 406.25	$ 2,032.56
Ground Buss Bars		
Tower or Shelter Buss bar addition	$ 231.25	$ 520.72
Tower Modifications		
Modification Design	$ 1,100.00	$ 5,159.04
Foundation Drawings/Inspection	$ 6,858.19	$ 9,514.28
Foundation Install <200' (Monopole/SS)	$ 39,726.54	$ 130,999.37
Foundation Install <200' (Monopole/SS) - Batch Plant	$ 85,794.41	$ 282,909.46
Demo Existing Tower	$ 13,109.00	$ 25,000.00
Minor Tower reinforcement/modifications - size of tower, extent of reinforcing	$ 1,000.00	$ 10,000.00
Build new <200' monopole (Erection only including crane)	$ 14,154.00	$ 29,000.00
Build new <200' monopole - Materials	$ 36,063.00	$ 117,651.05
Build new <300' SST (Erection only including crane)	$ 16,332.00	$ 42,500.00
Build new <300' SST - Materials	$ 33,000.00	$ 93,514.98
Major Tower reinforcement/modifications - size of tower; tower design; tower foundations; guy wires	$ 10,000.00	$ 100,000.00
Serous Tower reinforcement/modifications - tower foundation mods; tower "wrap"	$ 100,000.00	$ 250,000.00
Carrier Relocation BOM	$ 650.00	$ 14,789.99
Carrier Relocation Civil Work	$ 1,785.71	$ 32,357.15

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Carrier Relocation L&A Work	$ 23,332.30	$ 65,391.43
Site Work	$ 3,000.00	$ 10,000.00
Pre-Construction Site Walk - distance to site, size of tower	$ 971.19	$ 2,150.00
Parallel/New 200A Service	$ 8,792.00	$ 27,721.79
Upgrade to 200A Service	$ 6,000.00	$ 7,000.00
Conduit and Fiber from Cabinet to H Frame	$ 1,750.00	$ 2,150.00
Hand Trenching from Backhaul Cabinet to New Cabinet (25')	$ 1,724.46	$ 2,750.00
Trenching and Cabling from New Cabinet to Power Panel	$ 15,150.00	$ 18,350.00
Re-cable MW Dish to New Cabinet	$ 1,450.00	$ 1,750.00
Install Ice Bridge (~30')	$ 4,680.00	$ 6,450.00
Cement Pad Install	$ 3,683.94	$ 8,252.03
Install BBU (rack or cabinet)	$ 1,900.00	$ 3,893.46
GPS install	$ 370.00	$ 2,075.47
Install Platform (With Materials)	$ 6,300.00	$ 7,650.00
DC Cable Pull Through Conduit Sizes #16AWG to #2AWG	$ 550.00	$ 700.00
Install Hybrid Cable (with Material)	$ 17,100.00	$ 20,700.00
Upgrade Generator (modification reports, labor and modification)	$ 23,500.00	$ 75,000.00
Site Inspection - distance to site/complexity of site	$ 800.00	$ 25,000.00
Environmental Work	$ 6,000.00	$ 7,000.00
Solar Design	$ 15,000.00	$ 20,000.00
25-50 Amp Solar Upgrade (Install and Material)	$ 62,500.00	$ 162,500.00
75-100 Amp Solar Upgrade (Install and Material)	$ 187,500.00	$ 325,000.00
Cable Sweep & PIM Testing		
PIM Test and Remediate* 0 to 12 Paths	$ 1,050.00	$ 9,014.25
PIM Test and Remediate* 13 to 24 Paths	$ 2,950.00	$ 5,450.00
PIM Test and Remediate* 25 to 36 Paths	$ 4,500.00	$ 6,250.00
Sweep Test (per line)	$ 171.00	$ 900.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Connectivity Upgrades or Extensions		
Review of interconnection and colocation agreements - (2-5 hours per contract)	$ 1,000.00	$ 2,500.00
Tower/Installation Crews		
Mobilization Less than or Equal to 250 Miles (2-4 Member Crew)	$ 1,800.00	$ 3,000.00
Mobilization 251-500 Miles (2-4 Member Crew)	$ 1,620.00	$ 4,050.00
Mobilization Greater than 500 Miles (2-4 Member Crew)	$ 2,187.00	$ 7,967.50
Mobilization Ground Crew - (2-4 Member Crew) - day rate	$ 4,363.61	$ 8,571.00
Mobilization Tower (2-4 Member Crew) - day rate	$ 11,429.00	$ 17,142.00
Troubleshooting – RRU Replacement during the maintenance window on site per hour (Up to four-man crew)	$ 872.72	$ 1,105.91
Troubleshooting – RRU Replacement during the non-maintenance window on site per hour (Up to four-man crew)	$ 872.72	$ 1,105.91
General Troubleshooting – Up to 4 hours of onsite troubleshooting (Up to four men crew)	$ 3,490.89	$ 4,423.65
General Troubleshooting – Up to 8 hours of onsite troubleshooting (Up to four men crew)	$ 6,981.77	$ 8,847.30
Troubleshooting – Single Antenna replacement during the maintenance window	$ 1,570.90	$ 4,887.24
Troubleshooting – Antenna replacement during the non-maintenance window	$ 1,570.90	$ 4,887.24
Maintenance window work per night/per 3 man crew (per night)	$ 5,890.87	$ 8,063.95
Microwave Pathing - During Construction	$ 2,250.00	$ 3,000.00
Microwave Pathing - Post Construction	$ 3,500.00	$ 4,666.67
Microwave Commissioning and Integration	$ 2,093.00	$ 3,000.00
Microwave relocation during construction	$ 16,692.00	$ 26,742.85
Helicopter Lift (e.g., for a rooftop tower, complex tower, tall structure, or terrain constrained location requiring helicopter lift)		
Max 1000 lbs - 6 hr day rate + hourly	$ 14,000.00	$ 30,000.00
Max lift 3,200 lbs - 6 hr day rate + hourly	$ 36,000.00	$ 76,000.00
Mobilization/demobilization is priced by the hourly rate for each helicopter - 6 hours/each	$ 15,000.00	$ 54,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Equipment Rental		
Crane - Ave 8 hour hook time based on tower height, miles, size, hourly rate	$ 1,450.00	$ 30,450.00
Bucket Truck (day rate) - dependent on location	$ 937.50	$ 1,250.00
Manlift or Boomlift 45-135' (day rate) - dependent on location	$ 395.00	$ 2,359.47
Manlift or Boomlift 45-135' (week rate) - dependent on location	$ 869.00	$ 7,524.54
Manlift or Boomlift 45-135' (year rate) - dependent on location	$ 1,777.00	$ 10,833.00
Gin Pole Cost (per job)	$ 7,725.49	$ 32,447.07
Matting for Temporary Roads - Grid Mats Cost per 100ft	$ 2,500.00	$ 7,500.00
Snow Removal Equipment - Operated Rate	$ 500.00	$ 1,500.00
Prime Mover or Similar for Towing - Operated Rate	$ 2,500.00	$ 10,000.00
Straight Truck or Similar for Counterweight - Operated Rate	$ 500.00	$ 2,000.00
Forklift of Similar for Component Transport - Operated Rate	$ 500.00	$ 2,000.00
Special Access sites - Varies by Site/Region		
Virtual/Cloud Core Deployment		
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, up to 10k subscribers)	$ 150,000.00	$ 1,324,893.00
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, up to 50k subscribers)	$ 1,324,893.00	$ 1,852,250.00
Cloud - Virtual EPC (SAE-GW, Firewall, Carrier Grade NAT, eCGF, MME, PCRF, >200k subscribers)	$ 1,852,250.00	$ 2,401,168.00
Cloud - Virtual IMS (CTAS, IMS Core, MRF, AGW, A-SBC, HSS, ePDG, I-SBC, DRA, PCRF, 4G EPC, E-CSCF, LI interface, SMSC, MMSC, VM), up to 10k subscribers	$ 500,000.00	$ 1,497,230.00
Cloud - Virtual IMS (CTAS, IMS Core, MRF, AGW, A-SBC, HSS, ePDG, I-SBC, DRA, PCRF, 4G EPC, E-CSCF, LI interface, SMSC, MMSC, VM), up to 50k subscribers	$ 1,325,000.00	$ 2,354,630.00
Cloud - Virtual IMS (CTAS, IMS Core, MRF, AGW, A-SBC, HSS, ePDG, I-SBC, DRA, PCRF, 4G EPC, E-CSCF, LI interface, SMSC, MMSC, VM), >200k subscribers	$ 2,150,000.00	$ 3,000,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
GPON/XGS (FTTH) Deployments		
Backbone WDM/optical transport networking equipment	$ 75,000.00	$ 300,000.00
Deployment - Cloud Computing	$ 50,000.00	$ 20,000,000.00
Deployment - Optical Transmission	$ 50,000.00	$ 20,000,000.00
Deployment - Data Transmission	$ 15,000.00	$ 10,000,000.00
Deployment - GPON/XGS EMS - FTTH	$ 10,000.00	$ 100,000.00
RAN EMS Deployment	$ 200,000.00	$ 750,000.00
Location (Facility) Upgrades for New Equipment		
Research to ensure compliance with tower standards (ANSI/TIA-222-H) due to modifications triggering non-compliant towers to comply - (3-5 hours per site)	$ 1,500.00	$ 2,500.00
Due diligence review of modifications/upgrades for compliance with FCC NEPA rules, including Section 106 Review, and FAA and ASR rules (3-5 hours per site)	$ 1,500.00	$ 2,500.00
Depending on spectrum licenses, preparation and submission of any required FCC applications for modifications for facility upgrades, equipment changes, and preparation of any FAA applications and ASR applications for structure modifications or lighting changes - (2-4 hours)	$ 1,000.00	$ 2,000.00
Preparation and submission of any required post-construction filings including notifications to FAA and FCC of completion of construction, and any required application filings for spectrum applications or licenses - (2-4 hours)	$ 1,000.00	$ 2,000.00
Field Engineering		
Optical Fiber Optic Characterization - 8 Strands	$ 6,634.00	$ 6,634.00
Onsite Sr. Optical Engineer Support	$ 19,049.00	$ 19,049.00
Remote Sr Optical Engineer Support	$ 12,536.00	$ 12,536.00
Off-site Integration & Staging		
NAIC Integration Add-on for UPS, Router, Switch, Server, Appliance, Storage 10RU+ per Device (from 5 to 15 devices)	$ 3,135.00	$ 6,051.00
NAIC Integration Add-on for UPS, Router, Switch, Server, Appliance, Storage Up to 9RU per Device (10 - 20 devices)	$ 3,664.00	$ 4,683.00
Optical 2-Slot to 16 Slot Level 1 Staging	$ 5,267.00	$ 5,283.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Lab Testing - Interoperability Testing and Compliance for New Equipment		
FOA Testing, E2E Network Interoperability Testing, VoLTE testing, E911 testing, Troubleshooting, Security Validation	$ 1,250.00	$ 1,600.00
IoT (Interoperability testing) for RAN & Core compatibility (per network)	$ 80,000.00	$ 336,000.00
IoT (Interoperability testing) for RAN compatibility (per network)	$ 80,000.00	$ 336,000.00
Contract review - (2-4 hours)	$ 1,000.00	$ 2,000.00
National Environmental Policy Act (NEPA) & National Historic Preservation Act (NHPA)	$ 1,300.00	$ 1,550.00
Due Diligence Review for compliance with FCC NEPA and Section 106 rules for collocation - (3-5 hours per site)	$ 1,500.00	$ 2,500.00
Legal Review for Environmental Consultant SOWs for NEPA and Section 106. and all work related - (2-3 hours per site)	$ 1,000.00	$ 1,500.00
Regulatory Management	$ 1,000.00	$ 1,200.00
Attorney		
Negotiate and review vendor contracts - (6-12 hours per contract)	$ 3,000.00	$ 6,000.00
Legal review of Environmental Consultant Contracts and SOWs for Phase I Environmental Review - (1-3 hours per contract)	$ 500.00	$ 1,500.00
Preparation of any required FAA and ASR filings - (5-8 hours per application)	$ 2,500.00	$ 4,000.00
Legal fees for research and preparation and filing for any zoning or local permitting requirements - (3-4 hours per site)	$ 1,500.00	$ 2,000.00
Review insurance requirements and OSHA standards for tower climbers - (3-6 hours)	$ 1,500.00	$ 3,000.00
Spectrum acquisition agreement - (4-8 hours per contract)	$ 2,000.00	$ 4,000.00
Review contracts for proper insurance, indemnification, liability and risk management - (2-4 hours)	$ 1,000.00	$ 2,000.00
Review contracts for disposal to ensure compliance with law and liability related issues - (2-4 hours per contract)	$ 1,000.00	$ 2,000.00
Review of applicable tax code (2-4 hours per inquiry)	$ 1,000.00	$ 2,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Legal Fees Zoning/Permitting issues		
Zoning and Permitting determination	$ 500.00	$ 823.25
Zoning drawing	$ 2,000.00	$ 2,606.96
Zoning Approval	$ 1,800.00	$ 2,881.38
Attendance at additional zoning hearings	$ 1,150.00	$ 1,400.00
Complex zoning (including attendance at 2 hearings)	$ 4,433.61	$ 5,750.00
Completion and submittal of permit (building or electrical)	$ 1,330.08	$ 1,650.00
Permit Pickup	$ 665.04	$ 900.00
Legal fees for research and preparation and filing for any zoning or local permitting requirements	$ 1,500.00	$ 2,000.00
Jurisdictional Fees	$ 3,500.00	$ 4,250.00
Phase 1 ESA	$ 1,800.00	$ 4,665.09
NEPA/SHPO Checklist only	$ 416.76	$ 515.90
Photo Simulation	$ 1,350.00	$ 1,650.00
Negotiation & Review of RF engineering contracts - (2-4 hours per contract)	$ 1,000.00	$ 2,000.00
Legal Fees Zoning/Permitting issues - Microwave		
FCC Licensing - Microwave - (1-2 hours)	$ 500.00	$ 1,000.00
New facilities - (1-2 hours)	$ 500.00	$ 1,000.00
Modify facilities - (4-6 hours)	$ 2,000.00	$ 3,000.00
Requests for Special Temporary Authority - (6-8 hours)	$ 3,000.00	$ 4,000.00
Rule Waivers - (4-6 hours)	$ 2,000.00	$ 3,000.00
Spectrum Leasing (De Facto) - (2-4 hours)	$ 1,000.00	$ 2,000.00
FCC legal review and application filings - Fixed Wireless Link Replacement (2-4 hours)	$ 1,000.00	$ 2,000.00
Disposal costs/Logistics		
Staging, transportation, warehousing and disposal (per site)	$ 1,992.00	$ 5,000.00
Decommission - Up to (3) antennas (6) runs of coax, mounts and miscellaneous hardware from tower top to inside the shelter to QWS	$ 3,125.00	$ 9,169.72
Decommission - Up to (9) antennas (12) runs of coax, mounts and miscellaneous hardware from tower top to inside the shelter to QWS	$ 5,625.00	$ 21,249.53
Decommission - Each additional antenna (including) , associated mount, line and miscellaneous hardware.	$ 438.45	$ 625.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Decommission - Microwave antenna (including), associated mount, elliptical line and miscellaneous hardware.	$ 1,687.50	$ 6,058.12
Decommission In Shelter - 2nd eNodeB Rack, diplexers w/mount, RF coax jumpers:	$ 1,437.50	$ 4,293.98
Decommission - existing hybrid cable	$ 898.39	$ 5,174.72
Decommission - remove waveguide, fiber, CAT5/6, coaxial cable up to 1 5/8" (per foot)	$ 104.00	$ 675.00
Decommission - one outdoor cabinet	$ 1,891.00	$ 3,619.97
Decommission - Indoor 19" Rack with existing legacy BBU	$ 4,071.65	$ 6,333.68
Decommission - Indoor 19" Rack with up two battery strings	$ 4,316.48	$ 6,714.53
Decommission - Single antenna	$ 317.18	$ 401.93
Compliant Disposal		
Inventory, processing, destruction, disposal, recycling reporting and certification of Recycling - Citing ITAR (per site) - Transport not included	$ 900.00	$ 3,000.00
FCC filing fees		
New, Modification (Microwave) - per call sign (with $250 regulatory fee)	$ 555.00	$ 555.00
Modify facilities - per call sign	$ 140.00	$ 305.00
Extension of Construction Authority (Microwave) - per call sign	$ 110.00	$ 110.00
Duplicate License (Microwave) - per call sign	$ 70.00	$ 70.00
Requests for Special Temporary Authority (Microwave) - Fee Exempt	$ 140.00	$ 140.00
Rule Waivers/Spectrum Leasing for new or sublease, Transfer of Control of a Lessee or a Sublessee or Extend Term of a Lease or Sublease (Microwave/Broadband 2.5GHz) - per call sign - $70 each additional	$ 110.00	$ 110.00
Major modification for spectrum leasing (Microwave/Broadband 2.5GHz) - per lease ID	$ 305.00	$ 305.00
New, Modification or Major Modification (Broadband 2.5GHz) - per call sign	$ 305.00	$ 305.00
Certification of Completion of Construction (Broadband 2.5GHz) - per call sign	$ 895.00	$ 895.00
Extension of Construction Authority (Broadband 2.5 GHz) - per call sign	$ 305.00	$ 305.00
Special Temporary Authority (Broadband 2.5 GHz) - per call sign or Market/Channel Block	$ 140.00	$ 140.00
New, Additional Facility, Major Modification (Cellular Radiotelephone) - per call sign	$ 450.00	$ 450.00
Minor Modification (Cellular Radiotelephone) - per call sign	$ 120.00	$ 120.00
Special Temporary Authority (Cellular Radiotelephone) - per request	$ 395.00	$ 395.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
Spectrum Leasing for new or sublease / Assignment of authorization or Transfer of Control (Full or Partial) / Transfer of Control of a Lessee or a Sublessee, Extend Term of a Lease or Sublease or Major Modification for Spectrum Leasing (Cellular Radio Telephone) - per call sign/lease	$ 450.00	$ 450.00
Minor modification for spectrum leasing (Cellular Radiotelephone) - per lease ID	$ 120.00	$ 120.00
Domestic 214 Application - $1,155.00	$ 1,155.00	$ 1,155.00
Tariff Filings		
Tariff Filing Fee (per transmittal or cover letter)	$ 925.00	
Application for Special Permission Filing (request for waiver of any rule in Part 61)	$ 925.00	
Waiver of Part 69 Tariff Rules (per request)	$ 925.00	
Accounting		
Review of Depreciation Update Study (single state)	$ 35,000.00	$ 40,000.00
Each Additional State	$ 1,285.00	
Petition for Waiver (per petition)	$ 8,000.00	$ 9,000.00
Part 36 Separation Rules	$ 8,000.00	$ 9,000.00
Security - onsite		
Fence/Compound Work	$ 6,000.00	$ 19,003.20
Security Guard - Hourly Rate	$ 25.00	$ 45.00
Snow Cat Usage (8-12 hours day, plus operator expense)	$ 1,590.00	$ 2,310.00
Storage, Warehousing, Material Handling		
Contract review & negotiations (2-4 hours)	$ 1,000.00	$ 2,000.00
Logistics and Material Management & Warehousing (per site)	$ 500.00	$ 21,429.00
Kitting (per site) (receive products from multiple OEMs and suppliers and integrate the related items into a single package, pallet or other format as desired)	$ 125.00	$ 1,200.00
Storage (monthly)	$ 4,000.00	$ 6,000.00

Supply Chain Reimbursement Program Study - Catalog of Expenses Potentially Eligible for Reimbursement

	Range of Estimated Costs	
Description	**Low**	**High**
KPIs Pre & Post Installation Support		
Pre and post swap cluster KPI monitoring (per site)	$ 1,652.00	$ 3,000.00
Drive Testing - Signal Strength Verification		
Pre and post swap cluster drive testing (per site)	$ 2,677.00	$ 5,264.00
Single site verification drive testing (per site)	$ 1,800.00	$ 2,856.00
Troubleshooting (per hour/per man)	$ 100.00	$ 392.00
Pre-Launch Cluster Optimization - Pre and Post Drive Test (Up to 12 Carrier) (per site)	$ 2,600.00	$ 5,712.00
911 & E911 Services and Drive Test Services (47 CFR § 9.10(i)(2)(i)(B)(4)) (50m x/y)		
Rehome E911 Drive Cost (per Cell Site) - ensuring call connects to right 911	$ 375.00	$ 568.00
Accuracy Testing (50 meter x/y) (Cost per Test Point, Average about 10 test points per County)	$ 275.00	$ 300.00
PSAP or County level KPI Accuracy Results Reports (Per Report)	$ 300.00	$ 350.00
TXT2911 Rehome/Reset (Per Radio Technology, One Time Fee)	$ 2,000.00	$ 3,000.00
VoWiFi Rehome/Reset (Per Radio Technology, One Time Fee)	$ 4,500.00	$ 5,500.00
Mobilization fee	$ 1,000.00	
Stand-by Fee (Per day)	$ 1,000.00	$ 1,400.00
Hosted SMLC Location Server License and Set-up- One Time Fee (“OTF”)	$ 40,000.00	
Hosted SMLC Location Server Monthly Recurring Fee per Cell Site (“MRF”)	$ 20.00	$ 30.00
Project Management Set-up - One Time Fee (“OTF”)	$ 5,000.00	$ 10,000.00
LPM Reporting Tool reset up One Time Fee (“OTF”) Per Radio Technology	$ 4,500.00	$ 5,500.00
Customer Premise Equipment (CPE) - Truck roll or self-install	$ 2,500.00	$ 12,500.00
Legal review of customer notices & communications; public relations (2-4 hours)	$ 1,000.00	$ 2,000.00
Taxes - Dependent on location and or exemption		

	Range of Estimated Costs	
Description	**Low**	**High**
Services Specific to: Alaska, American Samoa, Hawaii, Puerto Rico and Virgin Islands Plus 30-50% additional costs for the service items listed in the conterminous (contiguous) United States. Additional taxes, duties and/or custom fees will be required		
Mobilization Costs - Virgin Islands	$ 14,350.00	$ 17,250.00
Freight: requires special transportation charges such as Ferry/Barge - **minimum examples below**		
Hawaii: 40' Flat - 100' Monopoles in Sections | 2 Pieces per Platform, Non-Stackable | Max 48' Length, 3.5' Diameter (5 Sites @ 8 Pallets - container(s) needed)	$ 59,621.00	
Hawaii: 20' Container High Cube - Palletized Outdoor Cabinets with BBU, RRHs, Antenna, EPCs (5 Sites @ 1 Container)	$ 5,622.00	
Hawaii: Fuel Surcharge - subject to the rate in effect at the time of shipment.	$ 14,533.00	
Seattle to Dutch Harbor: 1-20' Container Concrete	$ 6,731.47	
Seattle to Dutch Harbor: 20' Flat - 15K pounds minimum (Rated at $41.02 per 100 pounds, subject to a minimum of $34.88 per square foot plus transfer fee)	$ 6,502.00	
Dutch Harbor: Fuel Surcharge - subject to the rate in effect at the time of shipment	$ 2,023.28	
Dutch Harbor to Adak: 2-20' Container Concrete and 1-20' Flat	$ 13,427.40	

ATTACHMENT 3

Replacement List
Supply Chain Reimbursement Program Study

Submitted by:
Widelity, Inc.
4031 University Drive
Fairfax, VA 22030

WIDELITY
Service Ethics Commitment

March 25, 2021

Table of Contents

1. Introduction

Widelity used the Network Categories1 document to identify Huawei and ZTE equipment and services that would potentially require replacement, removal, and disposal. For this analysis, we used the Network Categories that are listed in the five basic areas: Core Layer, Distribution Layer, Access Layer Software and Services. The list of services represents the items we expect may be incurred by the Providers of Advance Communications Services, along with the issues brought up in our interviews with suppliers and service providers.

2. Access Layer Equipment

The access layer is responsible for connecting users to their immediate service providers. First, the communications start by enabling users to communicate with the communication system to allow the start of information exchange/transmission. These communications can either be wired or wireless.

2.1 Optical line terminal equipment (OLT)

2.2 Optical distribution network devices (ODN)

2.3 Multi-service access node and digital subscriber line access multiplexing equipment (MSAN & DSLAM)

2.4 LAN (Local area network) MDUs (Multi dwelling unit)

2.5 Site Cabinets - Optical Networks Unit (ONU)

2.6 Home network and customer premises equipment (CPE)

2.7 CPE

2.8 Smart Home - Reimbursable portions of Smart Homes are in the CPE (other portions: IP cameras, wi-fi doorbells, wi-fi, light switches, etc. would not be reimbursable)

2.9 Cable coaxial media converters

[1] *See* Appx. B – Supply Chain Reimbursement Program Study - Report

2.10 **WLAN**

2.11 **Access WDM & OTN**

3. Distribution Layer Equipment

Middle-mile, backhaul, or RAN (radio access network) equipment layered between the access and core layers of the network in which network traffic management policies are defined and enforced.[2]

3.1 **Routers**

3.2 **Switches**

3.3 **Network security equipment**

3.4 **Metro WDM & OTN – (can be deployed in the access, distribution, or core of a network)**

3.5 **Microwave**

3.6 **Antennas**

3.7 **Wireless Networks**

3.8 **LAN MDUs**

3.9 **Bearer**

3.10 **5G**

3.11 **LTE FDD & LTE TDD**

3.12 **GSM & UMTS**

[2] *See* 47 CFR §§ 32.2230, 32.2231, 32.2232

3.13 Small Cell

3.14 Tower Shelter

3.15 Outdoor/Indoor Cabinets

4. Core Layer Equipment

The Core Layer of the network is the central element that provides services to those elements connected at the access layer of the network. One of the main functions of the core layer is that it is an aggregation point that provides proper routing of all voice and data traffic. All access and distribution layers of the network will be connected to the core via fiber or microwave backhaul connections. Additional services that may exist within the core layer are authentication, call control/switching, and inter-network gateways.

4.1 Backbone wave-division multiplexing / optical transport networking equipment

4.2 Metro WDM & OTN – (can be deployed in the access, distribution, or core of a network

4.3 Microwave

4.4 Antenna

4.5 RAN Core

4.6 Cloud Core & Cloud Computing

4.7 Fiber Infrastructure Network

4.8 Optical Transmission

4.9 Data Transmission

5. Software

Instructions that tell a computer what to do. Software comprises the entire set of programs, procedures, and routines associated with the operation of a computer system. Applications include conceiving, specifying, designing, programming, testing, maintenance and developing equipment applications, components or systems that are continuously used.

6. Services

For design, implementation, installation, testing, or other costs and/or fees paid to deploy the replacement equipment and/or systems.