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Guide for procuring last-mile connectivity data networks

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Acknowledgements

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Abbreviations and acronyms

ARPU	average revenue per user
ATP	acceptance test plan
FRAND	fair, reasonable and non-discriminatory
FTA	final testing and acceptance
FTTH	fibre-to-the-home
GNI	gross national income
Goods	A category of procurement that includes commodities, raw materials, machinery, equipment, vehicles, plant and related services such as transportation, insurance, installation, commissioning, training, and initial maintenance.
ITB	invitation to bid
IPR	intellectual property rights
ITU	International Telecommunication Union
KPI	key performance indicator
KVA	kilovolt-ampere
LCS	least-cost selection
LMC	last-mile connectivity
LTA	long-term agreement
MSP	managed service provider
MRTG	multi router traffic grapher
QBS	quality-based selection
QCBS	quality and cost-based selection
QoS	quality of service
PoP	point of presence
Requisitioner	An institution that initiates a request for goods/equipment/services/works. It has primary responsibility for capturing demand data, consolidating needs from end users and stakeholders, defining clear specifications, and managing resources.
REOI	request for expressions of interest
RFB	request for bids
RFP	request for proposals
RFQ	request for quotations

(continued)

RFI	request for information
R&D	research and development
ROI	Return on investment
Services	This covers all technical, logistical, management, consultancy, and any other services to be provided by the bidder under the contract to supply, install, customize, integrate, and operationalize the products provided. Such services may include but are not limited to activity management and quality assurance, design, development, customization, documentation, transportation, insurance, inspection, expediting, site preparation, installation, integration, training, data migration, pre-commissioning, commissioning, maintenance, and technical support.
SI	systems integrators
SLA	service-level agreement
SMART	specific, measurable, achievable, relevant, and time-bound
SOW	statement of works
SCC	special conditions of contract
ToR	terms of reference
SSID	service set identifier
TVWS	television white space
UPS	uninterruptible power supplies
VSAT	very-small-aperture terminal
WiMAX	worldwide interoperability for microwave access
Works	A category of procurement that refers to construction, repair, renovation, demolition, restoration, maintenance of civil work structures and related services, such as transportation, insurance, installation, commissioning, and training.

Definitions[1]

Bandwidth: The range of frequencies available to be occupied by signals. In analogue systems, it is measured in terms of Hertz (Hz) and in digital systems in bit per second. The higher the bandwidth, the greater the amount of information that can be transmitted in a given time.

Broadband wireless access: Wireless access in which the connection(s) capabilities are higher than the primary rate.

Connectivity: The capability to provide connection to the Internet or other communication networks to end users.

Customer premises equipment: The equipment/network administered by the user.

End user: A human being, organization or telecommunication system that accesses the network to communicate via the services it provides.

Infrastructure: Refers to the hardware and physical aspects of the network.

Internet service provider: An entity, usually a private company but in some cases a non-profit or government owned, that provides Internet access through data connectivity using a variety of technologies such as telephone cables (dial-up), DSL, cable (coaxial), wireless or fibre.

Last-mile network: This is where the Internet reaches the end users and includes the local access network, such as the local loop, the central office, exchanges and wireless masts.

Network: The communications and data transmission environment composed of hardware, software, applications and transmission of data.

Network operator: An entity that provides connectivity services over either its own network infrastructure or another operator's infrastructure

Procurement notice: A notice published by a requisitioner inviting interested suppliers to submit a request for participation, a bid, or both.

Specifications: Technical specifications are mainly used for the procurement of goods, but may also apply to straightforward, quantifiable services. Specifications are typically the description of the technical requirements for materials or products. They usually refer to defined requirements for materials or products, but in some instances can also relate to requirements for services.

Statement of work: A requirement specification for work assignments outlining the specific services, and/or goods a contractor is expected to provide, generally indicating the type, level, and quality of service, as well as the time schedule. A SOW usually includes detailed requirements for the goods and the services to be provided.

Terms of reference: A description of the scope of work for services, generally indicating the work to be performed, the level of quality and effort, the timeline, and the deliverables. ToRs are mostly used to define the performance requirements for expert and advisory services, which are not easily quantified, e.g. where a solution to a requirement is offered.

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[1] Some definitions were adapted from The Last-mile Internet Connectivity Solutions Guide. ITU (2020).

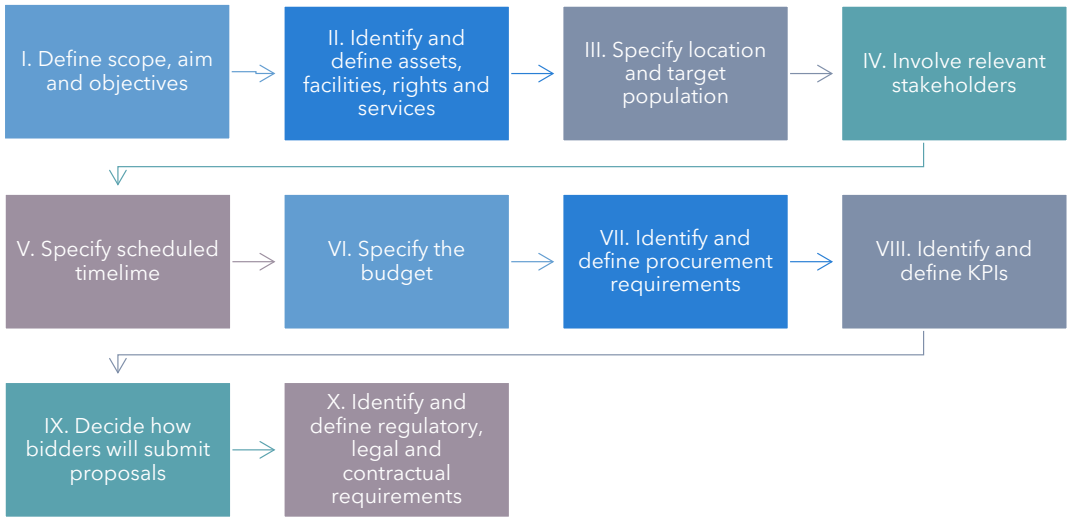
Introduction

Internet service providers (ISP) are traditionally the stakeholders responsible for building, deploying and providing data networks and services to end users. However, in some instances, building connectivity networks and providing connectivity services are initiated by other public or private institutions such as banks and electricity companies or by educational institutions and communities, to ensure additional coverage, quality of service and/or affordability. In such cases, it is often important to procure the connectivity project in order to build resilient data networks and provide required services.

This guide shall serve as a roadmap for requisitioners, in procuring last-mile connectivity networks and services based on the principles of affordability, use, financial viability, structure and sustainability. It complements ITU's The Last-mile Internet Connectivity Solutions Guide, which was designed for governments, service providers, communities, civil society and technical organizations in order to address the lack of telecommunication services, in particular data communications, in developing countries around the world.

This guide is broken down into ten sections, each dealing with a different topic: section I – defining the scope, aim and objectives of last-mile connectivity networks and services; section II – identifying assets, facilities, rights and services; section III – specifying network location and target populations; section IV – involving relevant stakeholders; section V – specifying project timeline; section VI – specifying the budget for the last-mile connectivity projects; section VII –identifying and defining procurement requirements; section VIII – identifying KPIs in the procurement of last-mile connectivity networks and services; section IX – ways of inviting bidders to submit proposals; and section X – key regulatory, legal and contractual requirements in procuring last-mile connectivity networks.

Figure 1: Structural overview of the guide



1 Define scope, aim and objectives

The first step in planning the deployment of a last-mile connectivity network is defining the scope, aim and objectives of the project. The objectives should be based on the principles of affordability, use, financial viability, structure and sustainability and also need to be specific, measurable, achievable, relevant and time-bound (SMART).

When defining the scope of the project, the requisitioner should review and assess all available connectivity options. In addition to analysing available interventions, the requisitioner should consider the connectivity requirements and the intended use of technology, both for the present and the future, e.g. in five years' time. Understanding the connectivity needs and use from the user perspective is key and must be addressed before solutions to meet those needs can be identified.

Providing infrastructure for end-to-end last-mile connectivity is not sufficient for proper network operation. Mechanisms need to be developed to make network connections reliable and failure-resilient, offering guaranteed bandwidth, especially for delay-intolerant services such as e-learning, health applications and emergency services. Different external factors that affect the performance and consistency of network connectivity need to be identified and analysed, and network technologies and solutions that are tolerant and independent of these external factors need to be explored.[1] *Table 1* gives an overview of the factors that the requisitioner should take into account when formulating the scope, aim and objectives for procuring last-mile connectivity networks.

Table 1: Factors influencing the scope of the last-mile connectivity network

Factor	Key considerations for the scope of the last-mile connectivity network	Examples
Needs (current and projected)	• The current and projected needs of the target population (e.g. community, hospital, school, university, or office) for access to data (e.g. real-time video applications, gaming, or online collaboration tools). • The needs of the target population in terms of bandwidth, latency and network speed. • Expectations of the target population regarding data and content sharing.	• Connecting a given population (size and type) to a last-mile connectivity network. • Identifying areas of limited or unaffordable connectivity (e.g. schools, hospitals, villages, communities).
Feasibility and technological neutrality	Method of addressing the need	• Deciding whether the procurement will be technology neutral, or whether the deployment of specific infrastructure technologies will be required, for example, wireless (cellular 3G, 4G, 5G), fixed wireless (Wi-Fi, satellite), or wired (fibre, copper, coax).

[1] Thota et al. (2013). Computing for Rural Empowerment: Enabled by Last-Mile Telecommunications (Extended Version).

Table 1: Factors influencing the scope of the last-mile connectivity network (continued)

Factor	Key considerations for the scope of the last-mile connectivity network	Examples
Affordability	Is the LMC solution affordable for the target population?	Ensuring that the user price for connectivity services falls within affordability thresholds (e.g. entry-level broadband services that are at less than 2 per cent of monthly GNI per capita for 1 GB of mobile broadband data).[2]
Financial viability	Will the LMC solution be financially viable for the bidder to implement? Factors to consider in this regard are the following: • locality size by geographic area and population; • population density; • per capita income levels; • electrical grid availability; • cost of bandwidth; • distance to backhaul PoP in some cases; • demographic data, such as adult share of population, literacy levels and gender distribution.	In the school connectivity projects, which are often associated with high socio-economic pay-offs even with limited financial viability, this principle is more focused on efficiency or choosing the right technology option/business model in order to connect schools.
Intended use	The intended use influences the operational and technical choices/requirements of interventions, most obviously when it comes to considering the required QoS to provide. It may be that QoS, and thus general use, should be determined by whatever the market can support; alternatively, use could be more prescriptive in that specific activities are required for the LMC service, such as providing connectivity for healthcare services (telemedicine), distance learning, and government services.	One notional categorization of use levels has been presented in the World Economic Forum's 2018 White Paper on Financing Forward-Looking Internet for All. *Example: different educational activities, such as taking an online class or searching the web, require different levels of use.*
Timeline	How long will the contract last? Specific stages of project implementation and the timeline should be tied to specific deliverables and the price/fee schedule.	12/24/36 months.

[2] ITU, UNESCO, Broadband Commission for Sustainable Development (2019). The State of Broadband: Broadband as a Foundation for Sustainable Development.

Table 1: Factors influencing the scope of the last-mile connectivity network (continued)

Factor	Key considerations for the scope of the last-mile connectivity network	Examples
Ownership and sustainability	• Have different ways of meeting the identified needs been analysed? Could the network infrastructure/ service be bought, leased or rented? Or, could a public-private partnership be set up to obtain the target of the procurement? • Own and operate, or managed service? Will the solution be leased or built from scratch and owned? • Would a ready-made solution be appropriate? Or is a tailored solution required to satisfy the identified needs? • Is the LMC network going to be a fully commercial operation? Or is it going to be subsidized with in-kind contributions or government/municipal contributions/ subsidies? Are the contributions or subsidies going to be a one-time or recurring financing mechanism? • Is the LMC network community or private-led?	Requisitioners should consider their core competencies and whether they want to manage and own the network internally or hire an outside resource. They can hire systems integrators (SIs) or managed service providers (MSPs) for any or all of the major activities related to implementation of LMC data network, including planning and design, deployment and ongoing network operations. *Examples of business models that provide a certain level of service in the last-mile local access network:* • *Integrated international operator: owns national transmission infrastructure, backhaul and last-mile access network infrastructure and may provide retail services.* • *Integrated local operator: owns the regional backhaul infrastructure and last-mile access network and provides retail services.* • *Infrastructure as a service operator: owns passive network infrastructure but does not operate active network equipment or provide network services.* • *Connectivity as a service operator: owns active network infrastructure in the last-mile access network but does not provide its own branded retail services.* • *LMC integrated operator: owns last-mile local access network infrastructure and provides its own branded retail services.* • *LMC service operator: does not own any network infrastructure but provides its own branded services.*[3]
Environmental and social impacts	The requisitioner should consider what impact the LMC solution (network and/or services) will have on the environment, community and society at large.	• Climate change considerations. • Green solution considerations.

[3] For more please see ITU (2020). The Last-mile Internet Connectivity Solutions Guide.

Table 1: Factors influencing the scope of the last-mile connectivity network (continued)

Factor	Key considerations for the scope of the last-mile connectivity network	Examples
Regulations	It is important to understand which regulations would enable the use of the different LMC solutions for the provision of affordable connectivity. Issues that need to be considered include: • ISP licensing; • spectrum use; • data protection/ confidentiality; • right of way; • pole attachment; • intellectual property rights; • cybersecurity.	• In many countries, the telecommunication sector tends to be highly regulated, and market restrictions can lead to less competition, higher prices, poor quality of service and fewer connectivity options. • Some regulations might inhibit connectivity options (e.g. the requirement to use only licensed operators or the inability to use certain radio-spectrum frequencies); while other regulations might aim at expanding access in rural or remote areas, which can benefit target populations by making infrastructure more available. • Spectrum is typically an issue for wireless technologies. In rural areas, spectrum is often available; the problem, however, is its reusability.

The complexity of identifying the scope, aim and objectives will vary from case to case. For instance, for a community cellular network focused on providing services to previously unconnected remote villages, the objectives and desired outcomes may already be clearly defined in the institution's procurement strategy, as it is a bottom-up mapping procurement exercise. In other instances, such as in the case of a complex and high-value LMC solution that is critical to the institution, there may be complex project aims and objectives influenced by a network of stakeholders, each with their own ideas of objectives and desired outcomes.[4]

Box 1 gives examples in defining the main aim and objectives for the procurement of LMC solutions.

[4] UN Procurement Practitioner's Handbook.

Box 1: Defining the main aims and objectives for LMC solutions – examples

Main aim

This RFP/RFI is being released with the intent of _____ _____, in order to develop and implement new broadband services or enhance existing services and to_____.

The requisitioner is seeking network solutions and business models that are innovative and which prepare the region for future technological innovations while serving today's needs for higher speeds, more complete coverage and a wider range of choices for consumers. This RFP is focused specifically on last-mile partners.

Defining SMART objectives for procuring the last-mile connectivity network and/or services

The objectives of the project are to:

a. Establish xyz[1] partnerships between xyz for the betterment of the communities involved and improvement of quality of life.
b. Extend service to xyz underserved area.
c. Provide enhanced service levels (e.g. bandwidth, dedicated assistance, faster response time).
d. Reduce the cost of service by xyz.
e. Facilitate the development of cost-effective broadband in xyz county/school/etc., with a focus on the underserved and unserved areas.
f. Provide an architecture that enables the deployment of last-mile fibre/fixed wireless/etc. technologies.
g. Enable the deployment of state-of-the-art technologies, services and applications that are often found in more developed urban areas but may not be currently available in xyz.
h. Create a competitive advantage for xyz with respect to economic development, job creation, and growth opportunities.
i. Provide a collaborative foundation to serve the area for the foreseeable future.

To achieve these goals, the requisitioner will provide the bidder with access to existing fibre, vertical assets, co-location space and more. Where needed, points of presence (PoPs) and co-location can be developed within towns and other desirable locations within each community.

[1] Throughout this publication, xyz represents an unidentified number – when working on a particular project the requisitioner will fill in and specify the exact number.

2 Identify and define assets, facilities, rights, and services

The procurement notice[5] should identify the assets, facilities, rights and services required for successful procurement of LMC solutions. For instance, the procurement notice should identify and define if the requisitioner or the bidder should provide or give access to fibre and conduit, rack space, nodes, buildings and facilities, available land, spaces for telecommunication and network equipment (e.g. in telecommunication closets or equipment huts at tower sites, fire stations, municipal buildings or other locations). In addition, the procurement notice should identify if there is a need to gain access to rights of way or easements owned or controlled by third parties or to utility poles owned or controlled by third parties. The terms of procurement notice should also identify if there is a need for 24/7 access to the space for equipment maintenance and repair.

Table 2 gives examples of assets, facilities, rights, and services that should be taken into account by the requisitioner in the procurement of last-mile connectivity networks.

Table 2: Examples of assets, facilities, rights and services to be considered when procuring LMC networks

Assets, facilities, rights and services	Key considerations
Available network infrastructure	• Access and backhaul networks and pricing. • Mobile network towers. • Radio spectrum use. • Wi-Fi hotspots. • Cable and fibre PoPs.
Electricity	• What network components require external power? • How many outlets are required to meet these needs? • Will a generator be necessary to support the network in the case of a power outage?
Roads	• Gauge the locality's accessibility and the sites where infrastructure may need to be constructed.
Topography	• Important for determining radio frequency propagation. Estimates of network service coverage can differ dramatically when topography and radio frequency propagation are taken into consideration.
Cabling and wiring needs	• Where will access points be installed, and what cabling is needed to connect them? • Cabling is often subject to local and state electrical building and fire codes.
Access points	• Who will conduct the site survey to determine both the number and types of access points? Will a consultant assist with this process? Configuring network hardware for use with wireless access points requires considerable expertise. For instance, larger rooms (e.g. school cafeteria) will require more than one access point.

[5] In some documents, the procurement notice is referred to as procurement terms of reference. In this publication, the procurement terms of reference are considered either included in the notice (e.g. in the requirement section) or a separate document that presents detailed specifications/requirements and annexed to the notice.

Table 2: Examples of assets, facilities, rights and services to be considered when procuring LMC networks (continued)

Assets, facilities, rights and services	Key considerations
Speed of entire network	• The slowest segment of a network determines the speed of the network downstream from that point. Routine inspection and continuous network monitoring will help identify misconfigured and/or failing equipment, inferior or damaged cables, or radio interference that is causing dropped connections. • For instance, to get high-speed connectivity to classrooms, every segment of the network must be able to accommodate high speeds. However fast the connection, user experience will be poor if the network inside the school is outdated.
Device requirements	Consider the technology used and the user device requirement when planning a network.
Security	Intrusion detection: Are monitoring systems in place to identify malicious software activity and unauthorized network access? Do these systems notify key personnel after hours? Security: Is network equipment secured and kept safe from theft, vandalism and physical or virtual hacking? Are security processes and policies documented and maintained regularly? Firewalls: Can IT staff restrict what data enter and exit the network? Are enterprise-level systems in place to detect unsolicited and unwanted e-mail and prevent those messages from getting to user inboxes? Load balancing: Can network resources scale to meet the needs of target populations? Content filtering: Are tools in place to restrict access to inappropriate content while still permitting access to useful tools? Privacy: Are tools in place to guarantee the privacy of network users? Network management: Are systems in place to monitor network traffic and push out software updates to networked devices? Uninterruptible power supplies (UPS): Are key network appliances connected to UPS equipment designed to protect them from power surges and allow controlled server shutdowns in the event of an extended outage? Mobility: Is the network configured so that users can remain connected even if they move to different physical locations in the building? Does the wireless network provide adequate coverage? Is it able to handle high-density usage, e.g. a class of students using mobile devices simultaneously? User logins: Will users need to log in to access the network? Does the network hardware support the kinds of login services to be provided?
Maintenance, fault management and monitoring	Procurement plans should include requirements for a comprehensive network monitoring, maintenance and fault management service for the LMC network.

Source: Adapted from the US Department of Education, Office of educational technology (2017). Building Technology Infrastructure for Learning; and the ITU (2020): The Last-mile Internet Connectivity Solutions Guide.

3 Specify project location and target population

The procurement notice should also specify the project location and population, i.e. identify digitally unconnected communities. The notice can contain maps and information/data about demographics, such as population, median income, and square areas.

The requisitioner should also identify all environmental and geographical constraints, such as electrical grid presence, road networks, topography, and weather patterns. Location governs the costs associated with the development of infrastructure and transport of telecommunication equipment, troubleshooting and network maintenance.

The potential customers/beneficiaries of the project's activities should also be identified and defined. Socio-economic and demographic data that should be considered in this respect are the following: population size and per capita income estimates based on direct survey/census and/or government databases.

Potential customers include the number of residents in households and existing and future businesses, public institutions, educational institutions and healthcare facilities that exist within the territory/location.

ITU's The Last-mile Internet Connectivity Solutions Guide contains a roadmap for identifying digitally unconnected and underserved geographies and communities.

4 Involve relevant stakeholders

Last-mile connectivity projects are often complex, and so it is a good idea to systematically analyse the stakeholders involved. A stakeholder is anyone who has an interest in the procurement activities delivering on their procurement objectives, e.g. development partners, LMC providers/bidders, end users, communities that need to be connected (villages, towns, schools, universities), financial and technical experts. It is important to identify the interests and relative importance of each stakeholder. The interests of the various stakeholders can sometimes be in conflict or competition with each other. In practice, the requisitioner usually needs to develop a collaborative but focused relationship with key stakeholders, which includes understanding concerns and ideas, seeking agreement where necessary, keeping them informed, challenging needs and wants and adapting to their needs where necessary.

Specific needs of key stakeholders may relate to:

- the delivery timelines for the last-mile connectivity network;
- the geographical scope of the project;
- adherence to specific regulatory frameworks;
- sourcing from specific groups of bidders.

Depending on the nature of the last-mile connectivity network, the procurement planning process requires perspectives and viewpoints from different industry players – supply infrastructure players (e.g. tower infrastructure providers, fibre providers), service providers (e.g. telecommunication service providers, Internet service providers, FTTH providers), demand-side players (e.g. media, healthcare, e-governance service providers), and representatives of the local community. For example, if the aim of the project is to build a small network to provide LMC services to previously unconnected remote villages, the requisitioner can reach out to villagers in order to inquire about device use, signal availability and locations to access signal.

The process of sourcing from specific groups of bidders should include enterprises that work on:

- setting up or extending (including leveraging/re-purposing existing) infrastructure where it may be unavailable, for example, through wireless, fixed-wireless or fixed last-mile networks;
- improving efficiency in operations to lower costs, thereby making connectivity affordable for low-income populations;
- enhancing the relevance of connectivity services for local populations to improve levels of engagement and use for diverse purposes.[6]

Not involving the right people early on, can cost at a later stage. Failing to recognize the need to involve both internal and external stakeholders is a common criticism of many procurement processes. It often has a negative impact on the contract's success and sometimes results in additional costs to rectify omissions or errors. Inadequate specifications lead to complex adjustments and higher workload covering unforeseen questions and corrections. In addition, when tender documents are unclear the tenderers usually cover their risks with higher prices.

Designing and procuring for top-down last-mile connectivity solutions might result in numerous project inefficiencies. For instance, in one UNHCR operation, community mobile phone charging stations were simply too large and bulky, which could have been avoided with more community involvement in the project's procurement design stage. Issues could

[6] USAID, Investing to connect.

have been addressed with adequate and appropriately driven community consultation and feedback. Where communities have ownership and buy-in, connectivity projects tend to be more effective.[7]

Focusing on affordability emphasizes the importance of members of a locality, i.e. the potential customers of the new service, playing a role in determining how the service is established. The process of procuring and designing the LMC solution should include participatory multistakeholder mechanisms to account a wide range of perspectives.

5 Specify scheduled timeline

The procurement notice should request that bidders specify and provide project milestones, locations and delivery schedules. Timelines are very important in the procurement of LMC networks. For landlocked countries and remote areas, the geographical challenges and additional time required for project completion add costs to the procurement. Rural villages in developing countries are often located far away from electrical grids and optical fibre networks, leaving many citizens without Internet access.

[7] https://www.unhcr.org/innovation/wp-content/uploads/2019/11/CfR-Publication-Connections.pdf.

6 Specify the budget

After defining the procurement scope, aim and objectives; identifying assets, facilities, rights and services; specifying the project location and target population; involving the relevant stakeholders; and specifying the scheduled timeline, the next step is to identify and select the most feasible and affordable connectivity solution in accordance with the following principles:

- Affordability: ensuring that network services are affordable for end users is an ultimate driving force in the development of cost-effective solutions. Low-cost network solutions are required for rural areas in developing countries. Customer density and economic demographics determine the selection of technology. For example, operating in the unlicensed industrial, scientific and medical (ISM) spectrum band, which is open for use without a regulatory fee, tends to require lower capital or operating expenditure unlike the licensed spectrum bands, which have a spectrum-use licence fee. Therefore, suitable network solutions need to be selected based on affordability for users, with an appropriate return on investment for service providers.[8]
- Use: identifying the applications and services that need to be available and the QoS that those applications and services require.
- Financial viability: this includes measuring the economic viability for private and/or public investment of the connectivity service, based on estimates of ARPU, availability of backhaul/middle-mile connectivity, options for different local access technologies and the potential QoS.
- Structure: articulation of the business model for service delivery and identification of any regulatory constraints on the model and technologies used.
- Sustainability: an understanding of the service's revenue model and any potential subsidies (one-time and/or recurring) if necessary.

Table 3 compares common wired access network technologies based on several factors that might help the requisitioner to determine the budget and the technical requirements: (i) potential throughput/QoS; (ii) range; (iii) capital expenditure to deploy new network; (iv) operating expenses; (v) infrastructure required; (vi) suitability for rural deployment; (vii) regulatory issues; and (viii) access device type.

Table 3: Comparison of common wired access network technologies

Access network technology	Potential through-put/QoS	Range	Capital expenditure to deploy new network	Oper-ating expenses	Infrastructure required	Suitability for rural deployment	Regulatory issues	Access device type
Fibre	100 - 1 000 Mbit/s	100 s of km	Overhead cabling: low to medium	Medium	Tower, poles, cabinets, active network equip-ment	If there is sufficient population density and purchasing power	Pole attach-ment	Fibre modem to Ethernet-enabled devices or to Wi-Fi
			Below ground: medium to high (new excava-tion)	Low to medium	Subterranean duct work, cabinets, active network equip-ment	No	Right of way	
Coax (cable)	Up to 200 Mbit/s	Up to 100 km	Low to medium	Low to medium	Tower, poles, cabinets, active network equip-ment	If there is sufficient population density and purchasing power	Pole attach-ment	Cable modem to Ethernet-enabled devices or to Wi-Fi

[8] Thota et al. (2013). Computing for Rural Empowerment: Enabled by Last-Mile Telecommunications (Extended Version).

Table 3: Comparison of common wired access network technologies (continued)

Access network technology	Potential through-put/QoS	Range	Capital expenditure to deploy new network	Oper-ating expenses	Infrastructure required	Suitability for rural deployment	Regulatory issues	Access device type
Copper	0 to 24 Mbit/s (for ADSL, ADSL 2, ADSL 2+); 100 Mbit/s (for VDSL, VDSL2, Vecto-ring); 1 Gbit/s (G.Fast)	0.1 to 5 km	Low to medium	Low to medium	Tower, poles, cabinets, active network equip-ment	If there is sufficient population density and purchasing power	Pole attach-ment	Modem to Ethernet-enabled devices or to Wi-Fi

Source: ITU (2020) The Last-mile Internet Connectivity Solutions Guide.

Table 4 compares common wireless access network technologies based on several factors that might help the requisitioner to determine the budget and the technical requirements: (i) potential throughput/QoS; (ii) range; (iii) capital expenditure to deploy new network; (iv) operating expenses; (v) infrastructure required; (vi) suitability for rural deployment; (vii) spectrum licensing requirements; and (viii) access device type.

Table 4: Comparison of common wireless access network technologies

Access network technol-ogy	Potential through-put/QoS	Range	Capital expendi-ture to deploy new network	Oper-ating expenses	Infrastruc-ture required	Suitability for rural deployment	Spectrum licensing requirements	Access device type
Wi-Fi: 802.11	2 Mbit/s (a) to 10 Gbit/s (ax)	100 s of m	Low	Low	Wi-Fi routers	Yes, but back-haul required (satellite, microwave or fibre)	No specific licence but compliance with technical specifications via "blanket licence" under non-interference/ non-protection regime	Wi-Fi enabled smartphone, tablets, computers
Mobile cellular (2G, 3G, 4G, 5G)	0.1-1 000 Mbit/s	5 to 15 km	Medium to high	Medium to high	Towers and radio equip-ment	Yes, but back-haul required (satellite, microwave or fibre)	Yes	Cellular mobile phones, laptops, personal computers (via dongles)
Fixed wire-less access (4G/ 5G)	20–1 000 Mbit/s	Up to 10 km	Low to medium	Low	Towers and radio equip-ment	Maybe, depending on financial viability and demand	Depends on country regula-tions	Consumer premises modems to Ethernet or Wi-Fi
Satellite (HTS GEO and MEO)	5–150 Mbit/s	1 000 s of km	High (for new satellite deployment); low (for end-user terminals)	Low	Earth station, satellite, very-small-ap-erture terminal	Yes	Yes	Very-small-aperture terminal, consumer premises modems to Ethernet or Wi-Fi

Source: ITU (2020). The Last-mile Internet Connectivity Solutions Guide.

7 Identify and define procurement requirements

The requisitioner should identify the procurement requirements, i.e. the list of functions, performances and technical characteristics that will be included in the schedule of requirements. Working on the procurement requirements involves defining and describing what is needed and will be procured, collecting information, identifying appropriate network solutions and specifying these in *specifications* for goods and equipment, *terms of reference (ToR)* for services (e.g. hiring a consultant) or *statement of work (SOW)* for works (e.g. building a tower).

Specifications, terms of reference, and statements of work constitute the technical basis for the solicitation of offers and their subsequent evaluation to determine if they satisfy the requirements stipulated in the solicitation documents. They serve as the basis on which the contract is written and administered. Clear and appropriate definition and description of needs are of the utmost importance.

The following issues are important in defining technical requirements for last-mile connectivity network solutions:

- when describing a specific requirement to be met by the bidder, it is advisable that the requisitioner use the following phrase "shall *support a minimum of*: "
- when describing a solution that is sought from bidders to meet a specific requirement, the requisitioner could use the following phrase "describe *how the proposed solution shall meet a minimum of:* "
- requirements should include all the technical details that bidders will need to prepare realistic, responsive, and competitive bids, i.e. covering all their obligations under the contract, if awarded.

Specifications for procuring LMC networks

The procurement specifications for an LMC network must provide a detailed description of the requirements. They should be generic to enable the broadest possible competition. Specifications may be stated as one or a combination of the following: performance, functional and technical specifications.

Identifying and defining procurement requirements should be clear, generic, and free of ambiguities and promote fair competition among bidders.

Requirements should be defined with the aim of opening competition, i.e. no use of brand names or other unnecessary restrictions.

They should identify the exact need in technical and quality terms, avoid over-specifications, as this may increase costs, or under-specifications – where needs will not be met, and the timeline, i.e. when it is needed, in order to avoid progress delays or losses due to, for example, extra storage and handling charges if delivered earlier than required.

Technical specifications

The technical specifications define the exact design and details of the LMC network (i.e. the physical attributes, material to be used, power input and output, the manufacturing process required or, in the case of a service, the working methods to be used). Technical specifications, owing to their nature, may limit competition because of differences in engineering practices.

Technical specifications are used where a full understanding of the requirements already exists, and there is little or no desire for the bidder to innovate. The requisitioner has a comprehensive understanding of what they need and can describe it in detail, including from technical, design, performance and delivery viewpoints. Technical specifications work best for purchases of LMC network solutions, where there is a focus on defining specific quantities and specifications for the requirements, unit price costing and/or specifications around the time, place and manner for delivery and acceptance. The main risk in technical specifications is that if they are incorrect and the design does not work, for example, all risk lies with the requisitioners because they specified exactly what they wanted.

All three specification types can be combined, allowing bidders to offer alternative and innovative ideas and solutions to problems, which often results in more cost-effective use of the resources.

In addition, minimum requirements should be stated. The bidder should never be put in the position of having to decide on which physical attributes are essential and which are not. Instead of minimum requirements, the requisitioner may accept equipment within a limited range of specifications.

Performance (outcome-based) specifications

Performance specifications are used where the requisitioner can describe what is required in terms of outcomes but is uncertain of the best processes or methods for LMC network or service delivery, or where bidders are known to have the capability to design fit-for-purpose solutions.

Thus, performance specifications focus on achieving results rather than on detailing the production, construction, and delivery process. They are particularly effective at allowing bidders to bring their own expertise, creativity, innovation and resources to the bidding process without restricting them to predetermined methods or detailed processes, thereby allowing bidders to reduce costs and passing the risk of both cost and performance, i.e. supplying something that works, to the bidder.

Functional specifications

These specifications concentrate more on what an LMC network is to do and less on materials and dimensions. Functional specifications specify the functions that a system or component must perform.

Table 5 provides a list of information that may be included in specifications and some guidelines and examples on what they should contain.

Table 5: Functional, technical and performance requirements

Functional, technical and performance requirements		
Sub-type	**Guidelines**	**Examples**
Functional requirements	• Focus on what the LMC network is to do and less on materials and dimensions.	• Bidders will provide all necessary equipment and services to deliver a fully managed Wi-Fi Internet service for a minimum of xyz entities (e.g. households, schools, universities, municipalities, and so on) with at least 1 000 access points in total. • The requisitioner should describe in process terms the relevant conditions under which the system must achieve the performance standards (e.g. the number of concurrent users, type of transactions, type and quantity of business data that the system must process in achieving the performance standards, etc.).
Performance requirements	• Describe what is to be achieved rather than providing a fixed description of how it should be done. To ensure the requisite quality, a reference to product standards (e.g. ISO) and environmental requirements (e.g. Energy Star) should be made. • Whenever feasible, outputs should be stated and used as the basis for performance specifications. Relying solely on technological requirements can inadvertently restrict competition.	• QoS: an industry standard QoS scheme prioritizing end-user experience must be implemented. Priority 1 – browsing (HTTP/HTTPS); priority 2 – social media; priority 3 – audio/video streaming. • Describe each relevant throughput and/or response times at the appropriate level of detail for the particular LMC network being supplied and installed. For example, a requirement of 1 Gbit/s bandwidth with minimal delay of 100 ms can be specified for a given entity.
Technical requirements	• Define the exact technical design and details of the LMC network solution (i.e. the physical attributes, material to be used, power input and output, the manufacturing process required or, in the case of a service, the working methods to be used).	Example of technical specifications for wireless access points: • supports concurrent dual-band (2.4 GHz/5 GHz); • dedicated and centralized management for all access points; • complies with IEEE 802.11ac Wave; • able to handle concurrent users of up to 50 max without performance issues; • at least 2x2 multiple-input-multiple-output (MIMO); • hotspot 2.0 (Passpoint Wi-Fi Alliance) compliant.

Develop technology-neutral specifications

LMC networks should respond to the specific needs of target populations. Different technologies can be used depending on the context, specific connectivity needs and intended use. In many

instances, it might even be necessary to blend different technologies to achieve connectivity. The main aim is to provide target populations with affordable, and high-quality connectivity, a goal that could be technology agnostic. For further details on this topic, please refer to the ITU's The Last-mile Internet Connectivity Solutions Guide, which provides a comprehensive repository of available technologies that can be evaluated for adoption in specific settings.

- The requisitioner should ensure that the development of the procurement options and accompanying technical specifications used in the tender are not unduly influenced by bidders that have been involved in discussions or in previous tenders. The information gathered from bidders on the options should be written within tenders in a more technology-neutral way. Brand names or similar references should be avoided. If it is necessary to refer to a brand name, the words "or equivalent" should be included (e.g. Corning optical fibre cable or equivalent). Before determining the desired technology or technologies in the specifications, the requisitioner should define the desired procurement objective/outcome, and then the requirements in terms of throughput (bandwidth) thresholds or QoS will inform the choice of technologies. To allow more competition, technology-neutral specifications can be considered whenever circumstances permit. Myriad technologies can be used to achieve a specific objective/outcome in LMC projects, including both wireless technologies (mobile cellular, satellite, Wi-Fi, and so on) and wired technologies (optical fibre, coaxial cable, asymmetric digital subscriber line (ADSL), etc.). Instead of specifying the technology, when a specific technology is preferred, specification should not be locked to specific vendors, brands or providers.
- Example of specifications for extending infrastructure where there is a lack of network coverage: "Development of models that seek to deploy infrastructure that will extend more specific target of cost-effective access to underserved populations, depending on availability, cost, and regulatory constraints."
- Example of specifications for use of complementary technologies to bridge the affordability gap where connectivity exists: "Development of models that use new technologies – or repurpose existing technology – to provide an alternative, or a complement, to access networks in rural area X of country Y."

Procuring and selecting the most suitable last-mile access network requires striking a balance between catering to present (or expected) use and enabling future growth. It should be noted that LMC technologies can have versatile application requirements (energy consumption, range, bandwidth, mobility, cost, etc.), depending on the circumstances. These technologies have also different signal penetration, frequency use, cost, market size, age and integration.[9] For example, in areas, in particular rural ones, where neither fibre nor cable services are available, wireless solutions may be a good option as it connects buildings to the Internet using radio links between the customer's location and the service provider's facility. Wireless broadband can be fixed or mobile.[10] On the other hand, a high-speed, high-bandwidth network might not be the most practical network to deploy in sparsely populated rural communities that are likely to use only basic messaging applications. Simultaneously, the network should also be able to accommodate demand growth and shifting usage patterns. For more information, please refer to ITU's The Last-mile Internet Connectivity Solutions Guide.

It seems sometimes more practical to specify a brand name for the purpose of defining acceptable functional, performance and/or technical standards. This should, however, be avoided as much

[9] https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2019/Workshop%20Kyiv/Aminata%20Garba%203%20Last%20Mile%20Connectivity%20Kiev.pdf .

[10] https://tech.ed.gov/infrastructure/ .

as possible. Whenever brand names are used to define functional, performance and/or technical requirements, the following considerations should be observed:

- The products should only be referred to for defining the required product standard.
- Brand names should never be used without also specifying the minimum requirements that are considered essential. The bidder should not be left to decide which characteristics are essential and which are not.
- The specification should clearly invite offers of equivalent products, i.e. products meeting similar functional, performance and/or technical standards, by adding the wording "or equivalent," for example: Quality Assurance Certification (e.g. ISO 9000 or equivalent).
- The specification should clearly indicate that when the offers are being evaluated no preference will be given to those which include brand names.

In some unique circumstances, restrictive specifications or even particular brand names may be needed. For example, restrictive specifications may be needed to ensure that the product is compatible with existing equipment at the equipment installation site. If restrictive specifications are needed, justification should be documented.

Suggestions for developing robust specifications

- State the requirement clearly, concisely and logically in functional and performance terms unless specific technical requirements are needed.
- Include enough information for bidders to identify what is required and to cost it accordingly.
- Provide equal opportunity for all potential bidders to offer goods or equipment which satisfy the user's needs, including alternative solutions.
- Do not over-specify requirements as this might limit the number of responses.
- Do not include unnecessary features that might prevent some bidders from participating.
- Indicate requirements regarding delivery and after-sales service, for example.
- Whenever possible, indicate the final use (e.g. cables for power supply and installation of IT networks).
- Avoid requesting one particular product brand or manufacturer, as this might limit competition and offers.
- For technical equipment with specifications originating from a particular manufacturer or brand, make the specifications neutral and generic to allow for similar products of other brands. Check specifications of products originating from other known bidders to ensure that the minimum requirements included in the invitation to bid will allow other bidders to make offers as well.
- For goods or equipment not previously procured and lacking specifications from the requisitioner, ask commonly used bidders for similar equipment to provide their specifications as input for drafting the specifications. Be careful, though, not to reveal too much information to the bidders contacted in order not to give them a potential advantage. For instance, do not reveal the intention to issue an invitation to bid very soon, the country of destination, or the quantity to be purchased.

Box 2 gives an example of the process of drafting specifications for LMC projects for access to education[11].

Box 2: Example: drafting specifications for LMC projects in education

The bandwidth needs of small, medium and large school districts differ and this should be properly reflected in the procurement planning and the specifications. Moreover, actual network costs will vary significantly from district to district based on local circumstances. The following factors will most likely have the greatest impact on the total cost of ownership:

- the number of devices and types of digital learning resources a network must support;
- the capacity and age of existing physical infrastructure, including conduits, cables, and wireless access points;
- the distance and geographic difficulty (terrain, weather) of connecting school buildings to the Internet;
- the available Internet connection paths for joining an existing network such as a Research and education network (REN) and leasing dark fibre;
- the level and type of security measures needed.

Two cost drivers that many schools underestimate are human capital and ongoing network monitoring and maintenance, and they should be properly reflected in the procurement planning. Human capital costs include the time, personnel, sustained professional development and expertise to manage the network and provide technical support for teachers, staff and students. Staff can also include consultants or third-party bidders that assist with technology planning, configuration, testing and maintenance.

[11] The values used in Box 2 are shown as examples and are not meant as reference values.

Example of Internet service provider requirements

School year	2017-2018 school year target	2020-2021 school year target
Small school district	At least 1.5 Mbit/s per user (minimum 100 Mbit/s for district)	At least 4.3 Mbit/s per user (minimum 300 Mbit/s for district)
Medium school district	At least 1 Gbit/s per 1000 users	At least 3 Gbit/s per 1000 users
Large school district	At least 0.7 Gbit/s per 100 users	At least 2 Gbit/s per 1000 users
Wide area network (WAN) recommendations		
Connections to each school to link to the Internet via a district aggregation point and for in-house administrative functions	At least 10 Gbit/s/1 000 users	At least 10 Gbit/s/1 000 users

Source: Building Technology Infrastructure for Learning

What should NOT be part of procurement requirements

A common mistake is to include information that should not be part of the specifications/ToR/SOW. As the specifications/ToR/SOW are incorporated into the contract, they should NOT address, for example, the following:

- Pre-award issues – these should not be included in the contract, even though they might have a significant effect prior to award. They belong in the solicitation but not in the specifications/ ToR /SOW. The entire specifications/ToR/SOW will become a part of the contract. The most obvious example of pre-award–related documentation is the evaluation criteria that appear in the RFP/ITB.
- Terms and conditions – contract terms and conditions determine the rights and responsibilities of each contracting party. They are included in the solicitation and in the contract, but not in the specifications/ ToR/SOW. If any terms and conditions are included in the specifications/ToR/SOW, there are two risks: being repetitious, which can lead to an unnecessarily lengthy document; and the presence of contradictions/ambiguities, which can lead to contract disputes.

8 Identify and define KPIs

KPIs are measures of contract performance aligned to the key outcomes that the procurement has been designed to deliver. The KPIs should be SMART and directly linked to both project and procurement, which will help to ensure that contract delivery is fully aligned with the desired outcomes. The KPIs should be included in the contract management plan and, if they link to incentive mechanisms/payment decisions, will need to be agreed and included as part of the contract before it is signed.

Figure 2 gives an overview of seven KPI categories used when procuring last-mile connectivity data networks.

Figure 2: KPI categories for procuring LMC networks

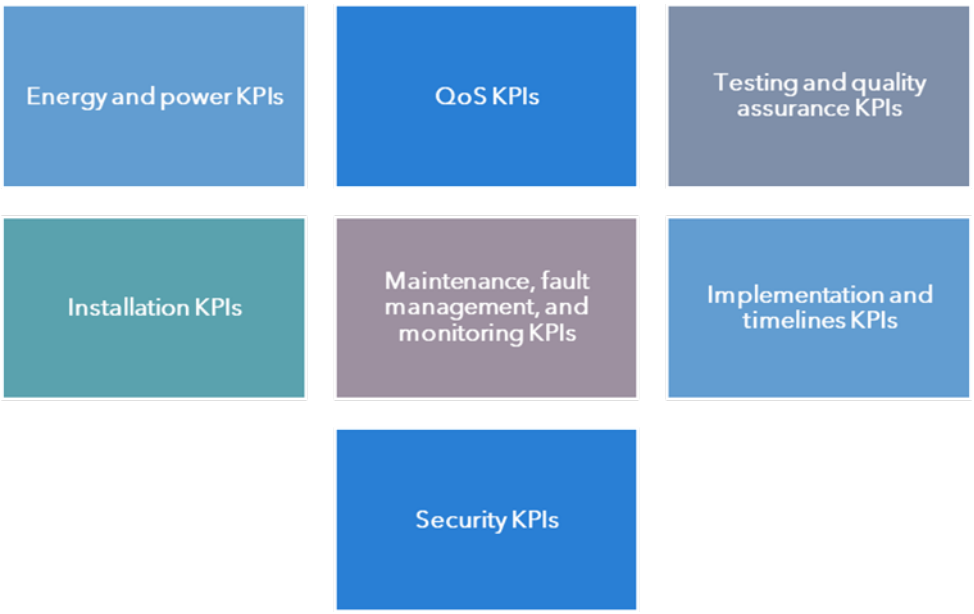


Table 6: Energy and power KPIs

Energy and power KPIs	
Power supply	Define requirements related to power supply. *Example: All active (powered) equipment must operate on [specify voltage range and frequency range, e.g. 220 V +/- 20 V, 50 Hz +/- 2 Hz]. All active equipment must include power plugs standard in [insert requisitioner's country].*
Environmental requirements	Define requirements related to the environment where the LMC network would function. *Example: Unless otherwise specified, all equipment must operate in environments of [specify temperature, humidity, and dust conditions, e.g. 10°C–30°C, 20%–80% relative humidity and 0–40 g/m³ of dust].*
Power generator	Define if power generator is needed for power supply.
Solar panels	Define if solar panels are needed for power supply.

ITU defines QoS as the "totality *of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service."*[12] *Table 7* gives an overview of QoS KPIs pertinent to the procurement of LMC networks.

Table 7: QoS and network performance KPIs

Quality of service (QoS) KPIs		Range	Factors	Example
Through-put	The throughput (in bits/s) is the average number of successfully delivered bits per time slot over a communi-cation channel.[13]	kbit/s to Gbit/s. Throughput ranges per tech-nology are shown in Table 4.	*Key factors affect-ing the throughput are the number of hops, node mobility and transmission range.*[14] *Additional factors are:* • number of total users. • types of appli-cations and services (for example, video vs text). • frequency of usage.	• Mbit/s /user • and/or aggregated throughput of 100 Mbit/s for the link.
Delay	The delay is the finite amount of time it takes a packet to reach the receiving endpoint after being transmit-ted from the sending end-point.[15]	-	• *the delay usually dramatically increases with network con-gestion, and it negatively affects the perceived QoS.*	

12 ITU-T Rec. E.800
13 A. Behera and A. Panigrahi (2015). Determining the network throughput and flow rate using GSR and AAL2R.
14 A. El Gamal, J. Mammen, B. Prabhakar, and D. Shah (2006). Optimal throughput-delay scaling in wireless networks, Part I: The fluid model. IEEE Trans. Inf. Theory, vol. 52, pp. 2568-2592.
15 V. Joseph and B. Chapman (2009). Deploying QoS for Cisco IP and Next Generation Networks. Elsevier Science, Morgan Kaufmann.

Table 7: QoS and network performance KPIs (continued)

Quality of service (QoS) KPIs		Range	Factors	Example
Latency	The average packet delay is referred to as a *latency* and is usually one of the main QoS performance indicators. The delay variations or delay jitter are the variations in latency for packets within a given data stream.	Latency varies also per technology: • 1 ms environed 5G latency while practical 5G networks have reported latencies of up to 30 ms. • ~ 30 ms for cable. • up to 600 ms for satellite GEO.[16]	*For some applications latency has little impact on performance and experience. For others, the impact on user experience can be considerable and even render some applications unusable.* • Real-time applications such as online gaming, video conferencing, voice, require lower latency. • Other applications such as e-mail and web browsing are less sensitive to latency.	< 15 ms may be unnoticeable. < 50 ms could be acceptable for applications that are latency sensitive.[17] > 100 ms is perceptible delay for real time applications.

16 https://www.viasat.com/about/newsroom/blog/satellite-internet-latency-whats-the-big-deal/
17 https://www.lightreading.com/the-edge/how-5g-is-pushing-envelope-on-latency-/d/d-id/766273

Table 7: QoS and network performance KPIs (continued)

Quality of service (QoS) KPIs		Range	Factors	Example
Packet loss	The packet losses result from the buffer overflows during network congestion, from the link and equipment failures, and from the transmission errors due to signal propagation effects over an unreliable medium and the electromagnetic interference. The packet loss rate crucially depends on the packet size and the transport protocol used.	• 0 to 10%. • depends on technologies. • wireless technologies are more prone to packet loss than wired technologies like fibre.	The *packet loss* is especially meaningful for real-time interactive applications requiring high data throughput with low latency.[18] • Packet loss up to a certain level can be overcome with error-control coding. • However, error-control coding increases data processing and hence latency. • Some applications such as voice and videos are more sensitive to packet losses than others. • Packet loss can be overcome by increasing the SNR, i.e. the input signal energy, which requires a trade-off between energy and bit rate. • The higher the packet loss, the lower the quality of services.	e.g. < 1% for voice over IP (VoIP)[19].

[18] A. Oodan et al. (2003). Telecommunications Quality of Service Management. IET, 2003. DOI: 10.1049/PBTE048.

[19] https://www.sciencedirect.com/topics/computer-science/packet-loss-ratio

Table 7: QoS and network performance KPIs (continued)

Quality of service (QoS) KPIs		Range	Factors	Example
Availability	Availability is defined as the ability of a functional unit to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.[20]	<= 100%.	Depends on the type of usage.	For example, for schools or work offices, availability can be limited within working hours or can be extended to 100%, depending on usage
End-user experience (priorities)	The requisitioner should also indicate priorities with respect to end-user experience.	1,2,3,…	• Can depend on importance of services and applications. • Standards also implement Q0S prioritization.	*Example: Must implement an industry standard QoS scheme prioritizing end-user experience.* • *Priority 1 - Browsing (HTTP/HTTPS).* • *Priority 2 - Social media.* • *Priority 3 - Audio/Video Streaming.]*

Table 8: Testing and quality assurance KPIs

Testing and quality assurance KPIs	
Inspections	The requisitioner should specify the items, criteria and methods for inspection by the requisitioner, or its agent, upon delivery/installation of the LMC network and other equipment to the site(s).
Pre-commissioning tests	The requisitioner can require, in addition to the bidder's standard check-out and set-up tests, the bidder (with the assistance of the requisitioner) to perform xyz tests on the system and its subsystems before installation. The requisitioner should specify the tests, test conditions, success criteria, etc.

[20] M. van der Meulen (2000). Definitions for Hardware and Software Safety Engineers.

Table 8: Testing and quality assurance KPIs (continued)

Testing and quality assurance KPIs	
Operational acceptance test	The requisitioner can also plan on (with the assistance of the bidder) performing xyz tests on the system and its subsystems following installation to determine whether the system and subsystems meet all the requirements mandated for operational acceptance. *Note: The complexity of the operational acceptance testing needed will vary in accordance with the complexity of the system being procured. For more complex systems, operational acceptance testing will require extensive, clearly defined tests under either production or mock-production conditions.*

Table 9: Installation KPIs

Installation KPIs	
Responsibility for installing structure and equipment	The requisitioner can require that the successful bidder be fully responsible for: installing all structures and equipment funded under the procurement notice; coordinating with other workers and infrastructure owners, as necessary; and performing the work in a manner demonstrating professional skill.
Tools and instrumentation required for installation	The requisitioner can require that the successful bidder be responsible for providing all materials, cabling/wiring, labour, tools and instrumentation to ensure a complete and successful implementation. *Example: All tools and instrumentation will be considered to be normal and customary items provided by the bidder. All work related to the structure and equipment installations shall be supervised by the successful bidder and performed in accordance with all applicable codes and the manufacturer's recommendations.*
Regulatory compliance	The requisitioner should require that all civil works must be in accordance with the appropriate provisions of the xyz building code and that all electrical installations must be in accordance with the appropriate provisions of the xyz electrical code. The requisitioner should also look into issues such as intellectual property rights, spectrum licensing, right of way and cybersecurity regulations. *Example: The proposed equipment, structures, and labour practices must comply with all applicable codes, standards and regulations including, but not limited to, the following requirements:* *i. All proposed wireless equipment must have a valid certification number;* *ii. Any new or upgraded tower built or modified under this project must comply with the applicable sections of code xyz _____ appropriate for the proposed telecommunication structure and its location within xyz _____ location; and* *iii. All new radio frequency transmitter installations for middle-mile, last-mile and wireless PoPs must meet the health code xyz _____.*

Table 9: Installation KPIs (continued)

Installation KPIs	
Ownership of equipment/ equipment inventory	The requisitioner can require that all equipment be owned by the bidder and, consequently, that any faulty, damaged or stolen items be immediately replaced by the bidder to ensure seamless service. *Examples:* • All equipment will be owned by the bidder and, consequently, any faulty, damaged or stolen items should be replaced immediately by the bidder to ensure seamless service. • *The bidder will provide all necessary equipment including modem, UPS, optical fibre, terrestrial link, router and other accessories to provide the required speed and quality of Internet connectivity.* • *The bidder shall provide the equipment inventory for the following major components: wireline, fixed wireless and satellite equipment. Include details such as equipment types, manufacturer, cable types and length, installed throughput capacity and the use of licensed spectrum and unlicensed spectrum for fixed wireless equipment.*
Equipment upgrades	Most servers, routers and wireless access points need to be refreshed every four to six years. The requisitioner should plan for network equipment upgrades when developing procurement budgets.

Table 10: Maintenance, fault management and monitoring KPIs

Maintenance, fault management and monitoring KPIs	
Warranty defect repair service	The requisitioner can specify: the coverage period of the warranty defect repair service; response time and problem – resolution performance standards; modes of service, such as on-site, on-call or return to warehouse; etc.
Fault management	The requisitioner should also identify and define requirements related to fault management. *Examples:* • Fault Management shall be proactively initiated by the bidder. Ownership remains with xyz. • *Help desk/system: the bidder shall provide full access to an industry grade incident management system where all incident tickets are recorded and updated operating on an 8/5 basis with telephone support. Each ticket shall also involve root-cause analysis. Bidders shall also provide a public-facing complaints hotline (SMS/phone/e-mail) for the public to report outages, for which the contact information will be posted on the site. Automatic notifications will be transmitted to the requisitioner and bidder as complaints are submitted.* • *Incident notification shall be immediately reported with corresponding incident ticket number.* • *Bidders shall decide on a preventive maintenance plan to ensure that equipment operate in peak condition. A copy of the report shall be submitted to the requisitioner.*

Table 10: Maintenance, fault management and monitoring KPIs (continued)

Maintenance, fault management and monitoring KPIs	
Monitoring	The requisitioner should investigate the following issues that need to be monitored: • network traffic and saturation; • time and conditions of peak network use; • system-wide status and capacities such as detecting when a service (e.g. VoIP) is failing or when network storage needs expansion or archiving; • unreachable or misconfigured devices. *Example: The bidder shall provide a client software tool or web-based tool to monitor the bandwidth received compared to the bandwidth subscribed.*

Table 11: Implementation and timeline KPIs

Implementation and timeline KPIs	
Implementation plan	The requisitioner should require that bidders provide detailed descriptions of how required services will be delivered, keeping in mind suitability to local conditions and environment. Bids should also include details of bidders' internal technical and quality assurance review mechanisms. Bids should clearly explain whether any work would be subcontracted, to whom, what percentage of the requirements, the rationale for doing so, the roles of the proposed subcontractors and how everyone will function as a team.
Timelines for installation	The requisitioner might also ask bidders to submit a detailed implementation plan including a Gantt Chart or Project Schedule on installation and commissioning/go-live.
Timelines for service	The requisitioner should also plan for timelines related to service.

Security KPIs

The ISO definition states that "network security is the security of devices, and security of management activities related to the devices, applications, services, and the end users, in addition to security of information being transferred across the communication links. "[21] The security metrics aim to assess the vulnerability of end users to any unauthorized access, theft of sensitive information and privacy invasion. The security metrics can be, in general, categorized with respect to the purpose that they are aiming to accomplish. For instance, there are security metrics for the information security, intrusion detection, risk management, impact assessment and so on. Another classification of the security metrics considers a type of attack or threat and its duration.[22]

[21] ISO/IEC FDIS 27033-1 (2009). Information technology - Security techniques - Network security - Part 1: Overview and concepts.

[22] Al-Shehri et al (2017). Common Metrics for Analyzing, Developing and Managing Telecommunication Networks.

Table 12: Security KPIs

Security KPIs	
Cybersecurity	Describe the bidder's approach to identifying and introducing security-related patches and firmware updates to its infrastructure software to maintain and protect (confidentiality, availability and integrity) services and subscribers. *Example: The bidder should install and maintain content filtering on the network and transport layers to protect against students accessing unauthorized content.*
Equipment enclosure and security	The requisitioner should identify and define any and all equipment enclosure and security requirements. *Examples:* • Enclosures and/or fence with lock and key. • *Adequate ventilation for stable operating temperature and humidity levels.* • *Power strip in line with appropriate electrical requirements.*
Safety	The requisitioner should also define the safety requirements related to the procurement of the LMC network and/or services. *Examples:* • *Unless otherwise specified, all equipment must operate at noise levels no greater than [insert maximum number] dB.* • *All electronic equipment that emits electromagnetic energy must be certified as meeting [insert emission standard, e.g. US FCC class B, END 55022, END 50082-1, or equivalent emission standards].*

9 Decide how bidders will submit the proposals

There are many standard options available for procurement. These vehicles may vary from agency to agency, but the overall purpose and details are largely similar and easily portable. There are several ways of inviting bidders to submit information, bids or proposals:

Prior to submitting solicitation documents, the following methods can be used for information collection:

- request for information (RFI);
- request for expression of interest (REOI).

Prior to submitting solicitation documents, the following method can be used to select the bidders that can submit proposals:

- pre-qualification.

Following publication of the solicitation documents, the following methods are usually used

- request for proposals (RFP);
- invitation to bid (ITB);
- request for quotations (RFQ);
- direct selection.

Table 13: Types of procurement method

Procure-ment method	Definition	Features
Request for information (RFI)	An RFI is used to obtain information from potential bidders on specifications of their latest products, price indications or any other information. It is mostly used in the sourcing process but can also be used specifically to obtain information for developing specifications, ToR and/or SOW. It is not used to design specifications which suit a specific bidder but rather to learn about what is available on the market. Policy on contact with bidders may differ between organizations, and procurement officers should follow the guidelines of their organizations. The request can be advertised openly or sent to particular bidders known to the procurement officer, depending on the type of information to be obtained and the knowledge of the market. An RFI should always be written as a non-binding inquiry.	• Prior to submitting solicitation documents • Information collection • Informal • Non-binding • Non-competitive

Table 13: Types of procurement method (continued)

Procure-ment method	Definition	Features
Request for expression of interest (REOI)	An REOI is used to broadcast the need widely and allows bidders to present themselves for consideration for inclusion on a shortlist. An REOI is a cost-effective method for identifying potential bidders for particular goods, equipment, services or works. An expression of interest (EOI) consists of a written communication prepared by a bidder providing information about its products, services, resources, qualifications and experience. A procurement officer can solicit an EOI by advertising the need on websites, in newspapers or by other means adapted to the local context. The resulting responses can be used to populate a roster for future use or directly for a specific procurement action. If relevant, the REOI can include specific shortlisting criteria. Some organizations, in particular those that apply mandatory pre-qualification of bidders, could issue an REOI to all pre-qualified bidders for a product range and develop a shortlist based on the results.	• Prior to submitting solicitation documents • Information collection • Informal • Non-binding • Non-competitive
Pre-qualification	Pre-qualification is a method whereby bidders are assessed against pre-determined qualification criteria, and only those bidders who comply with the criteria are invited to tender. A pre-qualification of bidders will ensure that bids are only received from bidders which are able to comply with the requirements. Some organizations apply mandatory pre-qualification for all bidders. Pre-qualification is recommended when: • complex or specialized goods, equipment or services are procured (e.g. computer engineering); • a particular type of good, equipment, works or service is procured on a regular basis (e.g. for long-term agreements); • a high degree of risk is involved in the procurement (e.g. cybersecurity and safety equipment and services); • high importance is attached to the project's goods, equipment or services (e.g. late delivery or delivery of the wrong product or service would have costly implications). If pre-qualification is required, each of these stages should be followed: • definition of criteria for pre-qualification; • preparation of invitation for pre-qualification; • advertisement of pre-qualification on websites or other appropriate media; • evaluation of received pre-qualification applications; • shortlisting of bidders.	• Prior to submitting solicitation documents • Information collection • Formal • Non-binding • Competitive

Table 13: Types of procurement method (continued)

Procurement method	Definition	Features
Request for proposals (RFP)	An RFP is a competitive method for the solicitation of proposals and is used when the requisitioner's business needs are better met by allowing bidders to offer customized solutions or proposals that may vary in the manner in which they meet or exceed the RFP requirements. **Single RFP option** A requisitioner can procure all services and infrastructure required for the programme under one single RFP. In this case, a single service provider may offer all the service components or a lead bidder may bring in multiple service providers as a consortium and/or as sub-contractor. The single bidder would be wholly responsible for delivering the services outlined in its contract. Advantages • *Lesser management oversight*: this option reduces administrative overheads and ensures that the accountability for meeting all contractual commitments (e.g. service levels and timelines) rest with a single bidder. • *Shorter procurement timelines*: requisitioners only need to evaluate a single RFP and save time for the contracting process and onboarding of the bidder. • *Optimized effort and cost*: less effort is required to assess each bid component; for example, defining scope of work, pre-bid meetings, technical and financial evaluation and obtaining multiple approvals. Disadvantages • *Process inflexibility*: the requisitioner may not be able to optimize multiple components as there will be only one comprehensive offer by the bidder. • *Limited number of participants*: including all services and infrastructure in one RFP increases the size and complexity of the contract, which may limit the number of potential bidders participating in the bidding process to those with the size and scale to implement large and complex contracts and exclude some smaller niche bidders with potentially better capabilities and solutions for specific components (e.g. application development and maintenance). • *Higher dependency*: in the case of a single RFP, the requisitioner is dependent on a single bidder for all services. The requisitioner may thus have limited flexibility to replace the bidder or introduce new bidders for specific components.	• Method for solicitation of proposals • Formal • Binding • Competitive

Table 13: Types of procurement method (continued)

Procure-ment method	Definition	Features
	Multiple RFP option • The requisitioner may opt to procure the various services separately or from a few logical groups. In such cases, the requisitioner needs to decide on the services to be grouped together, balancing procurement efficiency, complexity in coordination, in-house expertise, preferred flexibility and cost.	
Invitation to bid (ITB)	The essential characteristic of an ITB is that the technical requirement can be clearly and completely specified in a qualitative and quantitative manner, and the award is normally made based on lowest cost among commercially and technically compliant bids. Offers are normally provided in a single envelope, and the price can be read out at a public bid opening. This assumes and necessitates that: • negotiations are not expected to be necessary; • no premium is to be given for bids that exceed the specified technical requirement (only RFPs can consider different qualities of proposals); • other requirements can be specified in yes/no form as the threshold qualifying conditions; • delivery requirements can be specified in a manner to adjust price (e.g. 0.5-per-cent increase or decrease per week) if relevant; • some organizations allow weighted scoring to be used to determine compliance. In such cases, good practice would be to use a two-envelope system to prevent knowledge of the price from influencing the technical evaluation.	• Method for solicitation of proposals • Formal • Binding • Competitive
Request for quotations (RFQ)	An RFQ is a competitive method based on comparing price quotations obtained from bidders. This method may be appropriate for procuring limited quantities of readily available off-the-shelf goods or equipment or non-consulting services, standard specification commodities or simple civil works of small value, when it is more efficient than more competitive methods.	• Method for the solicitation of proposals • Formal • Binding • Competitive
Direct selection	Proportional, fit-for-purpose and value-for-money considerations may require a direct selection approach, i.e. approaching and negotiating with only one firm. This selection method is limited to exceptional cases, when there is only one suitable firm or there is justification to use a preferred firm.	• Method for solicitation of proposals • Formal • Binding • Non-competitive

10 Identify and define regulatory, legal, and contractual requirements

Service-level agreement (SLA)

An SLA should be a part of the solicitation documents for LMC networks/services to guide the contractual relationship with the professional service vendors implementing the LMC solution and providing ongoing system support services. The SLA should contain the required KPIs. Typical KPIs are outlined in section 8.

The SLA can be part of the master service agreement. It is an important legal instrument for enforcing the obligations of the LMC service provider and imposing penalties. It outlines the responsibilities of both parties, including the services the MSP will provide, minimum response time and other maintenance responsibilities, and liability protection for the MSP.[23]

Below is an SLA template that could be used as an integral part to the procurement for last-mile connectivity data networks.

a. Purpose of service level agreement

[Define the purpose of the SLA.]

b. Scope

[Describe the scope of the document.]

c. Background

[Provide a brief background of the LMC solution.]

d. Audience

[Describe the intended audience for the document and the parties involved in the agreement.]

e. Assumptions

[List and describe the assumptions associated with this agreement.]

f. Roles and responsibilities

[Provide a list of roles and associated responsibilities for the agreement.]

Role	Responsibility

g. Contacts

[List the contacts associated with the agreement.]

[23] Upcounsel, Managed services contract.

Service details

- Requirements
  [Provide a list and description of any KPIs related to maintenance, fault management, testing, quality assurance and monitoring.]
- Service level expectations
  [List the expectations that <Party A> and <Party B> agree to.]
- Escalation Actions
  [Provide a description of escalation actions.]
- Service provider/service recipient
  [Provide the name and phone number of the service provider and recipient.]
- Service hours for problem resolution
  [Specify the service hours available to resolve problems.]
- Performance guarantee
  [Specify the period of performance and any performance guarantees with associated penalties should the service not be performed as contracted.]
- Agreement change process
  [Document the process that will be used to address changes to the agreement.]

Example of an agreement table

Requirement	Service-level expectation	Party A	Party B	Service hours	Escalation actions	Performance guarantee
System availability	System available 8 a.m. to 10 p.m., Monday - Friday	Party A	Party B	8 a.m. to 10 p.m., Monday - Friday	Contact Help Desk if system is not available	95% availability

Intellectual property rights

Intellectual property rights cover any and all copyright, moral rights, trademark, patent and other intellectual and proprietary rights, title and interests worldwide, whether vested, contingent, or future, including without limitation all economic rights and all exclusive rights to reproduce, fix, adapt, modify, translate, create derivative works from, extract or re-utilize data from, manufacture, introduce into circulation, publish, distribute, sell, license, sublicense, transfer, rent, lease, transmit or provide access electronically, broadcast, display, enter into computer memory, or otherwise use any portion or copy, in whole or in part, in any form, directly or indirectly, or to authorize or assign others to do so.

It is important to ensure that the way in which bidders license the intellectual property rights (IPR) embedded in their solutions meets the requisitioner's needs. Issues that the requisitioner should pay attention to, depending on the type of solution and technology procured, are the reuse and sharing of ICT assets procured (e.g. software),[24] while licencing models relating to individual standards should also be checked. For example, certain FRAND-licensed standards

[24] New Zealand Government (2008). Guidelines for Treatment of Intellectual Property Rights in ICT Contracts.

are not compatible with certain open-source software licences, and it is therefore essential that the requisitioner check that the standards being requested will not inadvertently limit the types of solutions that can be provided.

Indemnity

It is important that requisitioners are aware of the provisions that the bidder should make in order to indemnify the requisitioner against possible IPR infringements relating to the bidder's solution. Such indemnification may differ under different business models, e.g. provisions relating to open-source software may differ from those relating to proprietary software, and the requisitioners must consider this when requesting indemnification in tender documents as this may affect the type of solution offered.

Spectrum licensing

Requisitioners should look into regulations that pertain to spectrum licensing. For example, access to wireless spectrum differs from country to country. For licence-exempt/unlicensed technologies and spectrum bands (e.g. Wi-Fi), some countries require registration and an annual fee for each point-to-point line, while permitted power output levels can also vary, limiting the technology's effectiveness. For IMT spectrum, mobile cellular spectrum has been licensed nationwide but Mexico, Brazil, the United States and the United Kingdom are pioneering licence frameworks that enable the use of unused IMT spectrum in rural areas. Dynamic spectrum regulations in other countries, such as Mozambique, South Africa, Nigeria and Uganda, are beginning to allow for the use of TVWS technology.

Right of way

Requisitioners should be mindful of regulations pertaining to communication network providers' rights to install facilities on public and, in the case of public networks, private land or buildings. Requisitioners need to be mindful of regulations related to co-location and facility sharing. Digging up roads to lay cables can inconvenience the public, while installing masts or antennas may distort the landscape. Therefore, authorities may restrict rights to install facilities on grounds of environmental protection, public health or town and country planning.[25]

Contract management

The purpose of this section is to describe the type of contract to be used so the contracts and purchasing department can proceed accordingly. There are many different types of contract, such as fixed price, time and materials (T&M), and cost-reimbursable; and different procurement items may require different contract types. A well-defined product may necessitate a fixed-price contract, while a product which will require R&D may come under a T&M contract.

When defining the contract management requirements, it is important to consider the following:

- the level of monitoring the requisitioner may have over the bidder;
- how much monitoring the requisitioner needs over the bidder;
- how the bidder will be managed through review meetings, progress reports, risk logs, action plans, and so on;
- the key milestones and when they should be reviewed;
- the level of resources required to manage the contract effectively; and

[25] European Commission (2020). Rights of way.

- how performance will be assessed against pre-agreed measures, including KPIs.

The approach to contract management should be proportionate to the value, risk, length, type and complexity of the contract and the type of market/bidders who will be fulfilling the contract.

The level of effort needed from the requisitioner may change depending on the nature of the relationship with the bidder.

For simple and low-value contracts, the contract management plan should include the following:

- key roles and responsibilities;
- key contractual dates and delivery milestones;
- budget and payment milestones; and
- record-keeping requirements.

For high-value, high-risk or complex contracts identified in the procurement plan, the contract management plans typically contain a summary of contract details, such as:

- identified potential risks (e.g. delays in the bidder's right of site access, payment delays and other defaults in the requisitioner's contractual obligations that could potentially lead to contractual disputes) and an adequate mitigation strategy;
- key contacts, roles and responsibilities of the parties;
- the names and contact details of the key contacts for each party shall be clearly identified in the contract;
- ensuring that each party has established the necessary authorizations and delegations for its personnel at the beginning of the contract to ensure all contracting decisions are valid and enforceable;
- communication and reporting procedures;
- key contractual terms and conditions that relate to delivery;
- contractual milestones including critical path (identified to ensure early detection and mitigation of issues) and payment procedures consistent with contractual provisions;
- key contract deliverables: identified and properly described so they can be easily monitored and updated to account for change orders during the implementation of the contract;
- KPIs and measurement process;
- contract variation/change control mechanisms;
- record-keeping requirements; and
- issue management and escalation plan.

Depending on the nature and value of the contract, the contract management function is the responsibility of either the requisitioner or the project manager designated by the requesting unit. The project manager/requisitioner is responsible for monitoring the performance of the contractor and for receiving, accepting, and approving the deliverables specified in the contract. Acceptance is carried out by the project manager/requisitioner upon receipt of the procured goods/equipment or satisfactory services by recording the goods/equipment receipt in the enterprise resource planning (ERP) system.

The project manager/requisitioner shall inform the procurement officer in charge of the contract of any not accepted deliverable, necessary contract amendment or extension, contractual disputes or claims, and any other issues related to the administrative aspects.

If permitted, price adjustment provisions are not usually necessary in simple contracts involving delivery of goods/equipment or completion of works, non-consulting services and consulting services within 18 months but should be included in contracts extending beyond 18 months. Contracts of less than 18 months can also include similar provisions for price adjustments when future local or foreign inflation is expected to be high.

Annex

Table 14 gives an outline of a dashboard that can be used for procurement planning purposes. It should be noted that each institution has its own procurement process, and requisitioners will follow the procurement rules of their institutions.

Table 14: Example of simplified dashboard for procurement planning

Tasks and key milestones	Person in charge	Stakeholders involved	Timeline/ expected completion	Budget allocation	Risks/bottlenecks *The purpose of this section is to identify any potential risks associated with the procurement. Depending on the contract type, items or services being purchased, vendor history or uncertainties in the project's scope, schedule or budget, potential risks may require more detailed planning and mitigation strategies.*
Preparation and planning					
Identify and define procurement need					
Engage stakeholders (appoint working group)					
Conduct market research for available bidders					
Define subject matter					
Choose procurement approach					
Publication and transparency					
Draft procurement documents					
Publish selection method					

Table 14: Example of simplified dashboard for procurement planning (continued)

Tasks and key mile-stones	Person in charge	Stake-holders involved	Timeline/ expected completion	Budget alloca-tion	Risks/bottlenecks *The purpose of this section is to identify any potential risks associated with the procurement. Depending on the contract type, items or services being pur-chased, vendor history or uncertainties in the project's scope, sched-ule or budget, potential risks may require more detailed planning and mitigation strategies.*
Provide clar-ifications to potential ten-derers					
Evaluation and award					
Open and evaluate ten-ders					
Award the contract					
Sign the con-tract					
Publish the contract award notice					
Contract implementation					
Manage and monitor the implemen-tation of the contract against KPIs					
Issue pay-ments					
Modify contract if necessary					
Terminate contract if necessary					

Table 15 provides a template for a procurement notice for LMC networks. As already indicated, each institution has its own procurement process, and requisitioners will follow the procurement rules of their institutions.

Table 15: Procurement notice template

Topic	Guidelines	Examples
Title	• Use a simple and broad description of the specified solution for the title. • Potential bidders may decide not to make an offer based only on the title; if it is too specific, it might limit the pool of bidders.	• "Portable satellite equipment." • "Mobile wireless data service" • "Fiber-optic network"
Background information	A well-written introduction increases potential bidders' interest in the invitation and helps them to understand the needs. A good understanding of the purpose ensures that offered solutions (networks, equipment, services or works) are fit for purpose.	"The desired outcomes are technologies that enable the provision of low-cost, high-speed Internet access that is scalable and easily accessible by xyz in remote locations."
Standards	• Standards are the most common document referred to in a specification. Refer as much as possible to international standards such as ISO and EN rather than national standards, as they might limit the competition. • National standards might be appropriate if a national competition is anticipated.	• If a specific standard is not mandatory, indicate "or equivalent standards."
Constraints and limitations	List all the anticipated constraints and limitations for the procurement of the LMC solution. Any constraints which must be considered as part of the project's procurement management process should be included. They may relate to schedule, cost, scope, resources, technology or buyer/seller relationships. As constraints are identified, they must be considered every step of the way as procurement activities are planned and conducted. Every effort must be made to identify all constraints prior to any project or procurement planning as constraints identified later in the project lifecycle can significantly affect the project's likelihood of success.	Non-exhaustive list of examples of specific constraints and limitations: • Operating conditions e.g., maximum and minimum temperatures, noise, pressure, humidity, wind velocity, altitude, dust, etc.; • Physical space available for installing equipment; • Compatibility with existing equipment, systems, etc.; • Availability of power supply; • Servicing or maintenance requirements or limitations, etc.

Table 15: Procurement notice template (continued)

Topic	Guidelines	Examples
Requirements	There are three specification types: functional characteristics, performance characteristics and technical characteristics. Usually, requirements are a combination of these three types. Examples: The proposed solutions must: • be easily deployed in remote locations and able to be monitored and maintained/administered remotely; • be able to outperform current bandwidth speeds and at prices better than rural areas that are close to major urban centres; • be able to be deployed and supported in diverse locations which may be several hundred kilometres from the closest larger urban centre; and • be weather resistant and able to operate in harsh environments. The proposed solutions should target improvements in: • Internet speeds: 100 Mbit/s or better; • latency: 30 ms or less; • cost effectiveness: USD 0.50/Mbit/s or less; and/or • uninterrupted Internet connections: for at least 12 hours over normal business hours. Consideration is given to proposals that focus either on hardware or software solutions or a combination thereof. Novel solutions that improve network traffic and optimize the performance of web caching that results in reduced bandwidth consumption, server load and latency are also of interest.[26]	
Quality	Specifying quality requirements reduces risks associated with the goods or equipment. For example, "only goods/equipment produced by bidders adhering to the ISO 9000 quality system are acceptable."	
Testing	Testing might be required for some equipment: • by the bidder (the requisitioner should specify the test requirements); • by a third-party organization; • if testing is specified, the provision of test results should be specified as well.	
Timeline	Identifying specific schedules and timelines is of the utmost importance for successful procurement of LMC networks, especially in landlocked areas and remote regions of less-developed countries, where bidders are less incentivized to supply Internet connectivity solutions.	
Service and maintenance	The procurement objectives might state that the service provided by the bidder will be for a duration of 12 months renewable for an additional period of up to 24 months.[27]	

[26] https://buyandsell.gc.ca/procurement-data/tender-notice/PW-18-00846844.

[27] UNDP, Invitation to bid, Public access Wi-Fi services for State Universities and Colleges in the Philippines; see also UNDP, Invitation to Bid, Public access wi-fi services through VSAT technology in 11 provinces in the Philippines.

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