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ITU-T L.1700 – Setting up a low-cost sustainable telecommunication network for rural communications in developing countries using satellite systems

ITU-T L-series Recommendations – Supplement 31

ITU-T

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Supplement 31 to ITU-T L-series Recommendations

ITU-T L.1700 – Setting up a low-cost sustainable telecommunication network for rural communications in developing countries using satellite systems

Summary

Supplement 31 to ITU-T L-series Recommendations provides requirements for a low-cost sustainable telecommunication infrastructure for rural communications in developing countries with focus on very small aperture antennas for users. It provides details on the generic requirements set out in Recommendation ITU-T L.1700. These requirements are drawn up taking account of examples of best practices from systems already in use and the special needs of remote communities, such as cost and the lack of access to grid electricity. Broadband satellite is available in many countries at an entry cost comparable or even lower than terrestrial systems. To close the digital divide, developing countries should consider using broadband satellite. This will provide coverage to all rural and remote locations.

History

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Introduction

Very small aperture terminal (VSAT) technology has been available for Internet access since the early 1990s [b-GVF, 2003]. The widespread use of VSATs has been limited by factors such as: the round trip delay being longer than that for terrestrial systems, high capital cost of the satellite network, higher electricity power requirements of VSAT terminals compared with terrestrial alternatives and lower bandwidth per link than terrestrial alternatives. Many of the shortcomings have been increasingly addressed by advances in modern satellite broadband systems derived from earlier VSATs. The aim of this Supplement is to provide an up-to-date review of the technology with focus on geostationary satellite systems.

VSATs comprise the only technology which offers ubiquitous coverage from day one. While VSATs may not be able to compete with terrestrial technology for delay-sensitive traffic such as some games and other interactive applications, it is capable of narrowing the digital divide by providing Internet access to remote communities for the first time. These communities will therefore be able to exploit the Internet using a wide range of online services and through it develop the local economy. Once sufficient wealth is generated, the additional investment needed for dedicated terrestrial links, such as those described in other Supplements in the L.1700 series, can be found.

Supplement 31 to ITU-T L-series Recommendations

ITU-T L.1700 – Setting up a low-cost sustainable telecommunication network for rural communications in developing countries using satellite systems

1 Scope

This Supplement addresses satellite systems that provide low-cost deployable broadband services in remote regions. The generic requirements set out in [ITU-T L.1700] are addressed with reference to VSAT systems, including options for providing "off-grid" electricity. The focus is on example systems already in use or novel systems already commissioned for deployment.

2 References

[ITU-T L.1700] Recommendation ITU-T L.1700 (2016), *Requirements and framework for low-cost sustainable telecommunications infrastructure for rural communications in developing countries*.

3 Definitions

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

GEOS	Geostationary Earth Orbit Satellite
GW	Gateway
HTS	High Throughput Satellite
LEOS	Low Earth Orbit Satellite
LTE	Long-Term Evolution
MEOS	Medium Earth Orbit Satellite
MTBF	Mean Time Between Failures
NCC	Network Control Centre
NMS	Network Management System
RF	Radio Frequency
SCC	Satellite Control Centre
VoIP	Voice over Internet Protocol
VSAT	Very Small Aperture Terminal

5 Conventions

None.

6 Use of satellite systems to provide communications in remote areas

Figure 1 shows the terminology commonly used in satellite systems overlaid in red on the generic network. In a commercial system, an additional satellite would be deployed to act as a standby.

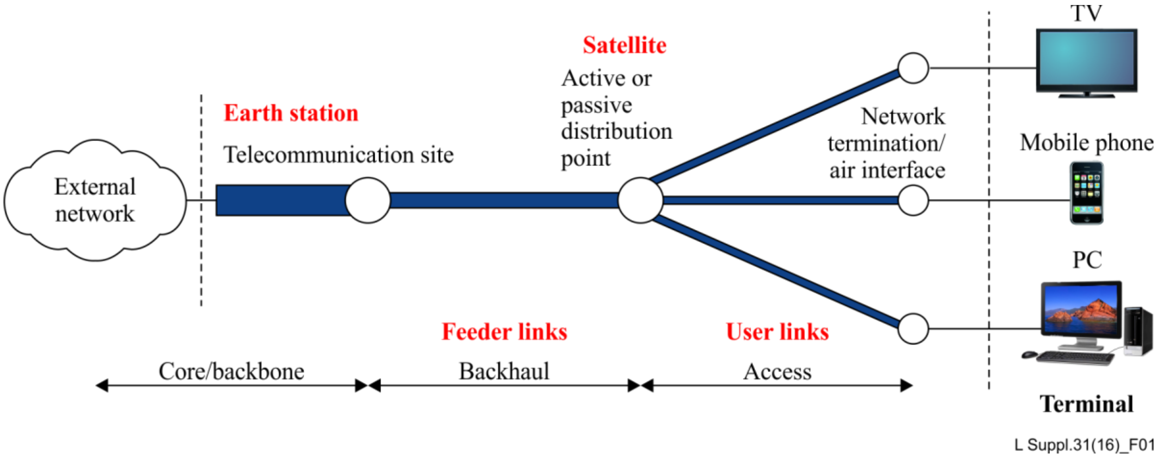

Figure 1 – Generic network of [ITU-T L.1700], showing satellite network elements (in red)

Satellite-based systems have the following advantages compared with a fixed or mobile (terrestrial) telecommunication infrastructure:

- coverage of a wide area compared with fixed or mobile systems;
- rapid deployment, using satellites already in orbit;
- ease of setting up and flexible reconfiguration;
- very cost competitive with terrestrial systems, using multi-spot beam satellites;
- relatively low cost for a particular coverage area, and can have lower green house gas emissions compared to terrestrial systems.

Note that because satellite-based systems can be set up and configured rapidly, they are particularly suited to responding to disaster situations. this is the topic of the [b-ITU, 2006] handbook of emergency and disaster relief, which includes, for example, portable satellite terminals as an integral part of the document.

The following types of communications satellite systems are available.

- Geostationary Earth orbit satellite (GEOS) systems orbit at an altitude of 35,786 km and are in synchrony with the rotation of the Earth, which eliminates the need for VSAT antenna tracking and allows fixed antennas to be used at the user terminal. GEOS systems are used for commercial telecommunications, broadband Internet service and broadcast services. They have a relatively high latency (round trip delay) compared with low Earth orbit satellite (LEOS) or terrestrial systems and so cannot be used where short data response times are required.
- LEOS systems are used for telecommunication services, such as semi-mobile telephony in remote locations, but are not known to be used for broadband fixed access, because of tracking difficulties. These have a much lower latency, but require many more satellites, more frequent handover between satellites, and a more complicated and higher cost system. There are some plans to develop LEOS systems for commercial service. Although used for narrow-band services with an omnidirectional antenna, for broadband services a LEOS system requires a tracking antenna, which adds to the cost.
- Medium earth orbit satellite (MEOS) systems orbit at altitudes between 2 000 and 35 786 km, are similar to LEOS in functionality and are used for fibre-like services to locations, such as oceanic islands and large cruise liners. A MEOS system requires a tracking antenna, which adds to the cost.

6.1 Bidirectional satellite

Figure 2 shows the main components of a two-way service satellite network architecture with:

- the satellite platform;
- the satellite terminals composed of the antenna system (dish), the radio frequency (RF) part (including power amplifier, low noise amplifier and filters) and the modem implementing the baseband processing of the satellite radio interface;
- the Hub that includes both a network control centre (NCC) to manage the in-orbit radio resources and a gateway (GW) with its antenna system, the RF part and a set of modems.

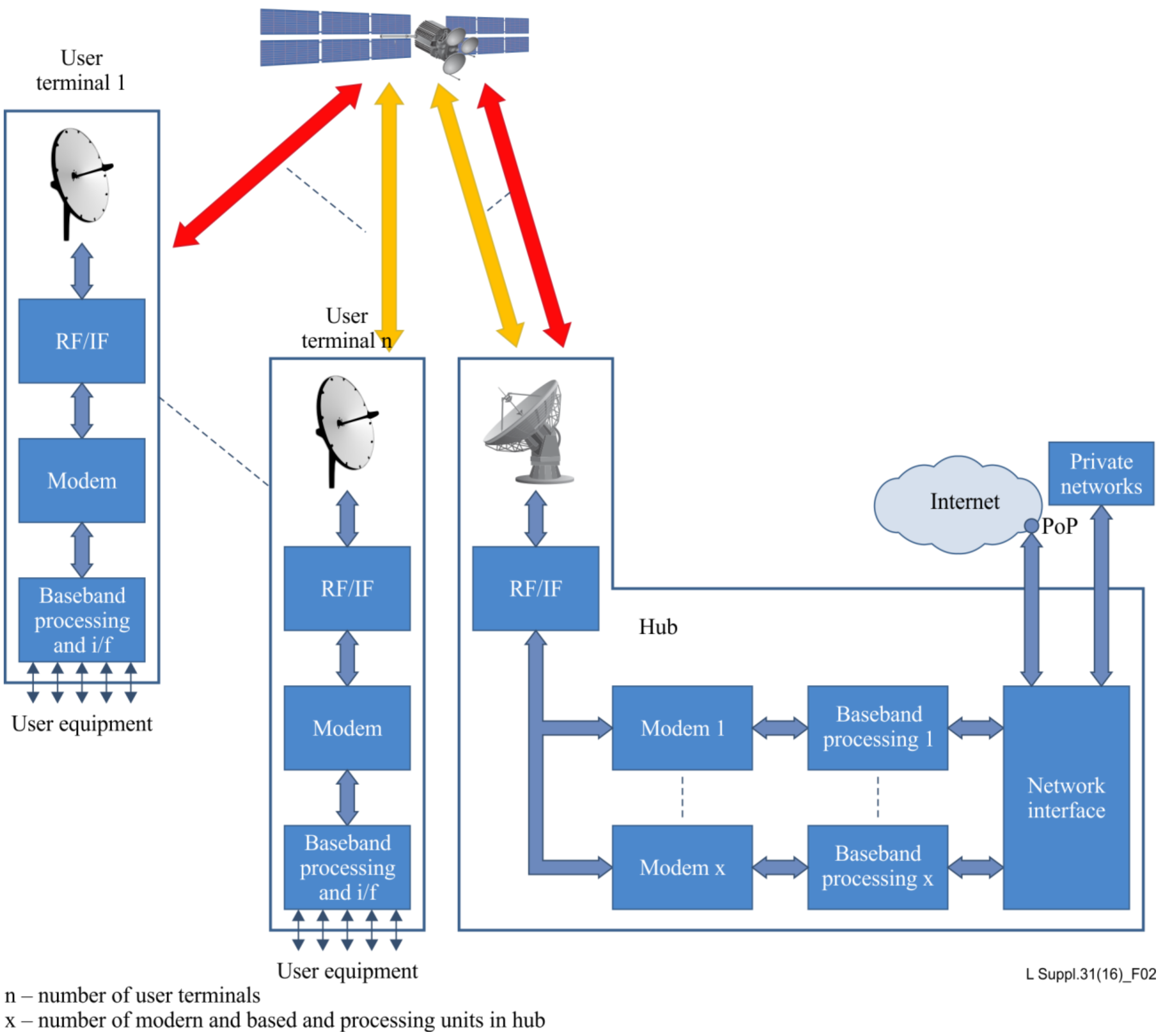

Figure 2 – Two-way service satellite network architecture

A geostationary-based satellite access network typically comprises the following parts.

- A space segment composed of one or more high throughput satellites (HTSs) in geostationary orbit. The satellite connects the GWs of the ground segment to the user terminals, by means of a set of feeder and user beams.
- A ground segment which includes the following.
  - A main NCC that has the responsibility to control and synchronize the overall network.
  - A main network management system (NMS) that handles the management of the resources in the network.

– A satellite control centre (SCC) to monitor and control the space segment.

– A set of GWs that are in charge of transmitting and receiving data, control and management traffic to or from the user terminals. Each GW is equipped with its own local NCC/NMS to ensure their individuality and their operation sequence in case of a total system malfunction originating from a main NCC/NMS failure.

• A user segment which is composed of a set of user terminals.

6.2 Geostationary Earth orbit satellite systems: Analysis against requirements identified in [ITU-T L.1700]

The following requirements were identified in [ITU-T L.1700]. It is assumed that any investment in satellites will take advantage of the latest HTSs [b-Thaicom, 2012].

6.2.1 Cost

This covers the system cost per user; cost per service area, cost per megabit and cost per user.

For HTS systems, the cost of the satellite launch and payload is projected to be US$600 million in year 2020 [b-ITSO, 2016].

> "Most communications satellite projects range from $300–$600 million, including the spacecraft, launch and launch insurance. These are typically high, up-front and fixed costs, with unique risk factors, which are typically recouped over the expected 15-year lifetime of the satellite." ([b-SIA, 2014], p. 2)

This compares favourably with terrestrial alternatives, depending on whether a reserve satellite is required if the initial satellite fails.

The cost of the system is recovered from the large number of users, depending on the capacity or bandwidth required by individual users. (Note that other users of transponders may be businesses who will contribute to the overall costs.) For individuals, such as those owning smartphones on mobile networks, this is often quoted in gigabytes per month, whereas for fixed subscribers it is quoted as megabits per second, but may also have a monthly usage allowance measured in gigabytes.

• **Fixed broadband example**. A 45 Gbit/s satellite provides 84 spot beams of 471 Mbit/s per spot beam [b-Little, 2015][b-Gunter, 2017]. At low utilization, based upon long-term evolution (LTE) practice [b-Heath, 2010], each spot beam could typically cover 3 000 users at an average of 0.157 Mbit/s per user and with a typical data concentration factor of 300 could burst at up to 47.1 Mbit/s. Such a broadband satellite system with 84 spot beams could support 252 000 users. If the VSAT satellite user system cost $450 and over the 15 year life cycle the operating cost is also $450, then in 1 year $60 million would need to be recovered to break even. This averages at $238 per user per year. The IPSTAR system claims to be able to serve up to 2 million fixed broadband access users. This would be an average bit rate of 22 kbit/s per user terminal. The cost would then average $30 per user per year.

• **Mobile broadband example**. The number of broadband users claimed to be possible on the IPSTAR system is 2 million broadband or 30 million mobile users [b-IPSTAR, 2016]. It is assumed that, if connected to mobiles, the data rate will be much lower than for fixed subscribers, averaging 1 500 bits/s. Even so, with the cost of a smartphone falling to as low as $10 for a second hand device in developing countries and with 30 million customers connected to the satellite via Wi-Fi, the cost could be as low as $3 per year.

Note that the figures quoted for the number of users may have been realistic when the IPSTAR system was launched in August 2005. In 2016, the average bit rates required by users had risen 10-fold and satellite capacity is rising accordingly.

The number of subscribers served within an area varies between operators. For mobile services, it typically varies between 300 and 3 000 according to retail prices and customer usage patterns. The actual numbers are normally a trade secret, as the figures affect the competitive edge and profitability of the operating company. A technical presentation on this topic is given in [b-Celplan, 2014].

The cost per user depends upon the way in which the satellite modem is deployed. Some examples follow.

- The modem is connected to provide service to a single household. More information about terminals is given in [b-Thaicom, 2010], for example. Modem costs are not generally released to the public, as they are normally included in the monthly rental from a service provider. An example of a service provider's service plans can be seen in [b-VSAT Systems, 2013a]. One example of a VSAT user system cost has been found. This is in the region of $160 [b-Tooway, 2015] and can be connected in north Africa. The cost of such a modem over 15 years is around $11 per year, which could be shared among the number of users. To this would have to be added the cost of service in gigabytes per month. One example cites a price of $33/month for 4 Gbytes [b-Tooway, 2015]. This would be sufficient for four smartphones each averaging 1 Gbyte/month. The cost per user would be around $8/month.
- The modem is connected to a Wi-Fi hotspot with sharing in the region of 1–30 users. The costs will then depend upon the service provider or reselling agreement. An example is given in [b-Privasia, 2015].
- The modem is used to provide service via a mobile base station with LTE/3G/4G broadband services. In this case, up to 3 000 users could be accommodated. More information about mobile backhaul by satellite is given in [b-Newtec, 2017]. Further study is needed on whether standalone systems, without an existing terrestrial voice system, are commercially feasible.

The economics of the system depend upon the expected user profile over the 15 year satellite lifetime. During the first year, the satellite will be underutilized. Peak occupancy could be expected around year 7 and by the final year terrestrial services may be bringing competitive low-delay high bandwidth services to the neighbourhood, which would replace the satellite service.

In summary, broadband satellite is available in many countries at an entry cost comparable or even lower than terrestrial systems. Developing countries should consider expanding their networks to include all rural and remote locations using broadband satellite systems. This will pave the way for expansion of terrestrial mobile networks to reach isolated communities.

6.2.2 Energy consumption/energy efficiency

The energy consumption of a VSAT satellite user modem is likely to be in the range 15–30 W [b-WNDW, 2013].

6.2.3 Coverage area

Coverage area can be measured in square metres or square kilometres. This depends upon the size of the region requiring service.

Single or multiple spot beams can be steered over the desired region to provide the required capacity.

A typical spot beam can provide 471 Mbit/s [b-Little, 2015][b-Gunter, 2017] total capacity to an area with a 300 km radius, which equates to 270 000 km^2. This is illustrated in Figure 3. Note that the shape and area cast by the spot beam varies according to angle of incidence. Unless the satellite compensates, the power density will be lower at the edges of the total coverage area and larger user antennas will be needed.

Also shown on Figure 3 is a larger shaped beam, the area above the thick blue line, which is more sparsely populated.

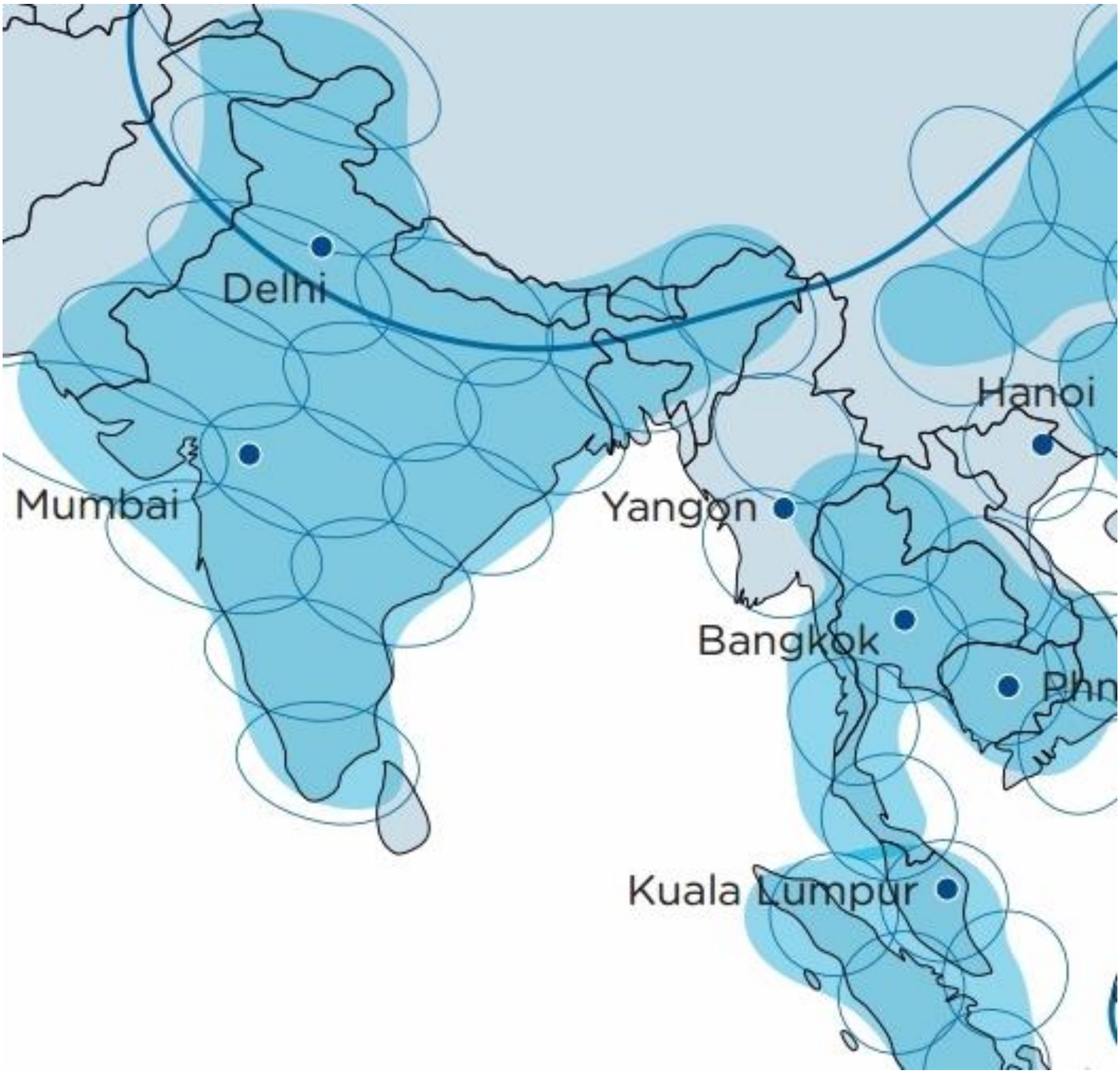

Figure 3 – Spot beam coverage [b-Thaicom, 2013]

6.2.4 Number of subscribers

For a satellite-based system, the number of subscribers served by a satellite-based system depends on the number of beams, the size of the beam from the satellite and potential the number of subscribers. In an area served by multiple satellites the number of subscribers will be divided according to competition between operators.

6.2.5 Bandwidth per user

This is the number of bits per second provided per user and depends upon the satellite system and number of users [b-IPSTAR, 2016]. For example, Thaicom-4 has a capacity of 45 Gbit/s and could serve up to 2 million fixed broadband at 22 Mbit/s per user or 30 million mobile subscribers with 1.5 Mbit/s per user. The perceived bandwidth available can seem much more when the duty cycle of the user's device is considered. If the duty cycle is 1/10 then the bit rate in IP bursts will be 220 and 15 Mbit/s, respectively.

6.2.6 Power feeding systems

For a satellite-based system, power only has to be supplied at end points, i.e., at the satellite earth station and the users' premises. This is approximately 15 W for a satellite modem. Some savings in the overall energy consumption can be expected if the satellite modem can be turned off at night.

In developing countries, satellite modems are likely to be shared by terrestrial radio systems such as Wi-Fi or LTE. In that case, additional power would be needed for these transponders. Wi-Fi typically serving 1–0 users adds 1 W to the modem power requirements for a domestic application and up to 8 W for a hotspot. Whereas LTE with a serving area of up to 3 000 users needs 700 W [b-JRC, 2013].

A typical off-grid installation requires around 20 W power. A typical solar panel has a peak power output of 250 W for a unit measuring 1 m × 1.6 m [b-Mitsubishi Electric, undated]. The duty cycle depends on location and will typically be 1/4 without rotating the panel during the day to face the sun. Other losses could be 20%, which would reduce the average power to 50 W. This would be sufficient to provide power for the satellite modem and have additional power to recharge smartphones. In the example given, the voltage at maximum power is 37 V, but this depends on the arrangement of solar cells. A typical solar cell produces only 0.5 V, so a number must be wired in series to provide the required voltage to charge a battery to power the satellite modem [b-FSP, undated].

A typical developing country is located near the equator, where seasonal variations in insolation are small. A typical 12 V battery would need to hold sufficient charge to power the terminal overnight and when the sun is not overhead. If the standing load is 20 W at 0.6 A, the minimum capacity would be 18 × 0.6 Ah = 11 Ah. This capacity could more than be met with a marine or camper van deep-cycle battery [b-FSP, undated]. A typical leisure battery of 100 Ah can typically be purchased for $100. This has the capacity to power the modem for 2.5 days and would provide service at night and during cloudy days.

6.2.7 Availability/mean time before failure

The ratio of availability to mean time between failures (MTBF) provides an estimate of the number of hours before failure of the system.

Satellite-based systems typically do not have to be replaced during the lifetime of a service. This can be up to 15 years. Satellite modems can be purchased as network equipment that typically has a lifetime of 15 years and an MTBF of greater than 200 000 h (20 years) [b-UHP, 2015].

Availability also depends upon the architecture of the satellite system, the likelihood of heavy storms and whether a standby system is provided.

GW availability can be expected to be 99% for a single GW and 99.99%, assuming two GWs are available that are sufficiently far apart not to be affected by the same weather events [b-Inmarsat, 2013].

6.2.8 Protection against environmental impacts

Telecommunication systems require protection against wind, water, ice, snow, landslides and rodent attack.

Provided the satellite Earth station is located in an area not susceptible to flooding or landslides, then a satellite-based system can be specified so as not to be susceptible to environmental impacts. Extreme storm winds can displace the antenna requiring a trained installer to visit the location to reposition and restore service. Other than that, occasional checking for the growth of trees near the antenna may be necessary – similar to a domestic satellite TV installation.

6.2.9 Scalability

Once the satellite has been launched and the satellite Earth station has been built and brought into service, a satellite-based system can supply a large number of additional users for only the extra cost of supplying and deploying a satellite user terminal at the user's premises. Therefore, there would be a minimum extra cost to supply an additional user [b-IPSTAR, 2016].

When this capacity is exhausted, additional satellite systems can be provided in a different orbital position.

6.2.10 Skills requirements and auto-configuration

A visit to a user's premises may be required to add a new user to the system depending on the auto-configuration aspects built in. However, it is estimated that 25% of systems will be installed by users in 2020 in some countries.

6.2.11 Voice services

In remote or rural applications in developing countries, a standalone VSAT system will be able to carry voice services using voice over Internet protocol (VoIP) [b-Which VoIP, 2017]. In this system, round-trip delays of 700–1 500 ms have been observed [b-VSAT Systems, 2013b]. Nevertheless, long-haul telephony services have been provided via satellite in the absence of terrestrial links since the advent of the satellite in the 1960s. In some countries, users prefer free VoIP services via Wi-Fi to conventional dial-up on their smartphones to save cost, even though the round-trip delay may be up to a second [b-India Today in Tech, 2015].

6.2.12 Disaster relief

Broadband satellite systems are capable of providing Internet service in the event of disaster. The VSAT terminals may be connected to specialist networks or to existing public networks using portable VSAT equipment [b-VSAT Systems, 2013c][b-DCS Telecom, 2015]. One example is capable of running at a wide range of direct current and alternating current voltages including 12 V from a vehicle battery. ITU runs a disaster relief service including broadband satellite terminals [b-ITU Media Centre, 2015][b-ITU-T FG-DR&NRR, 2013][b-ITU-D, 2017]. This service depends upon partnerships and the presence of existing communications infrastructure, including broadband satellite systems capable of closing the digital divide.

6.2.13 Points of presence

Broadband satellite systems have the option of providing GWs in any country or region to meet national or regional requirements. Normally two or three GWs are deployed with geographical separation to avoid storm outages. One example is a contract between Thaicom selling satellite capacity to Malaysia's MEASAT satellite operator [b-Gunter, 2017][b-IPSTAR, 2007].

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