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

ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable

ITU-T L-series Recommendations – Supplement 22

International Telecommunication Union

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 22 to ITU-T L-series Recommendations

ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable

Summary

Supplement 22 to ITU-T L-series Recommendations identifies a low-cost, sustainable optical cable solution for potential users of broadband digital services in remote or rural areas who are unlikely to have such services. This solution would quickly and inclusively close the digital divide which is a key target of the ITU Connect 2020 Agenda.

Mature and proven technologies are best integrated into affordable and reliable solutions suitable for local, non-skilled people to install, operate, maintain and repair so that the system will become part of their community, thus leading to better system maintenance and quicker damage recovery.

Best practice examples use lightweight, thin and robust optical cables and commodity-type media converters. The results of field trials are presented in this Supplement. The cost of such cables, with their simple construction, is estimated to be one tenth that of using conventional optical cables.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L Suppl. 22	2016-04-27	5	11.1002/1000/12964

Keywords

Backhaul networks, digital divide, lightweight optical cable, robust networks, rural communities.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable

1 Scope

This Supplement identifies low-cost, sustainable optical cable solutions for potential users of broadband digital services in remote or rural areas who are unlikely to gain such services when based solely upon conventional urban practices needing a positive return on investment, thus quickly and inclusively closing the digital divide.

Best practice examples are included using lightweight, thin and robust optical cables and commodity-type media converters. The results of field trials are presented in this Supplement. The cost of cables and their construction are estimated to be a fraction of the costs when using conventional optical cables with underground ducts.

2 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

CAPEX	Capital Expenditure
DIY	Do It Yourself
MTBF	Mean Time Between Failure
MTTR	Mean Time Between Repair
ODA	Official Development Assistance
OPEX	Operating Expense
USF	Universal Service Fund
US FCC	United Sates Federal Communications Commission

3 Key points of consideration for cost-effective, sustainable optical fibre backhaul solutions

3.1 System overview

Figure 1 provides an example of an optical cable backhaul layout. The optical cable backhaul connects the point of presence in the backbone with remote centres in rural/remote areas, and also with fixed access or mobile base stations, Wi-Fi stations and/or worldwide interoperability for microwave access (WiMAX) stations to the end users. The backhaul can take a ring form with redundant configuration for link survivability and improved resilience.

Figure 2 illustrates the best-of-class relationship between signal capacity vs. transmission distances without demanding electric power for the cable. Currently, typical practical capacities and distances in the backhaul are 10 Gbit/s/fibre-pair and 100 km, respectively. An optical cable solution is very attractive from an environmentally conscious standpoint; well over 100 km can be passively covered with passive optical cable, while respecting the landscape and allowing ease of construction, maintenance and disposal without the use of heavy machinery. Optical cable solutions require no power generators, solar panels, antennas or towers; only lightweight, manually-deployable robust cables are needed.

In order for optical cable solutions to be widely and quickly deployed across difficult terrains and environments, the solutions should seek cooperation with the local community. This relationship could reduce human interference, such as theft and/or vandalism. Affordability (capital expenditure (CAPEX) and operating expense (OPEX) including long-term total cost of ownership) would be improved if installation, operation, maintenance and repair of the infrastructure are supported by the benefitting local community, as they would be involved in a do-it-yourself (DIY) manner.

3.2 Optical cables

Thin, lightweight robust optical cables accommodating up to 24 to 48 fibres are key to enabling a low CAPEX/OPEX backhaul solution across difficult terrains and changeable landforms. With such cables, local communities can take part in system deployment, daily operations/maintenance, and service provisioning. Cables need to be waterproof, rodent-proof, highly durable against lateral pressure, and fire resistant to a certain extent.

It is best if the same cable structure allows direct burial application, direct surface application and, if required, aerial application. In fact, ITU-T SG15 is currently developing planned Recommendation on "Optical fibre cables for direct surface application (DSA)". Since a length of such a cable, when installed on the surface, could later become covered by soil, sand, snow or a flood, and may need to be aerially suspended to cross a river, valley or road, planned Recommendation will be identifying the requirements for withstanding direct burying, submerging and aerial wiring.

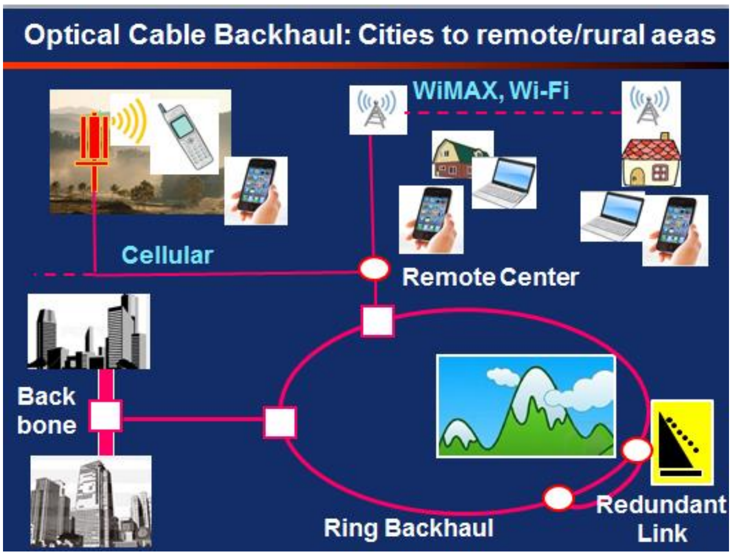

Figure 1 – Optical cable backhaul layout example

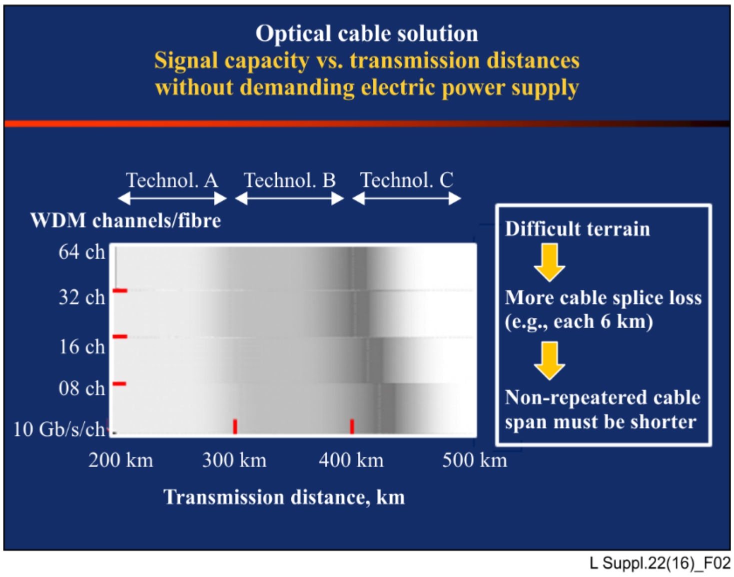

Figure 2 – Optical cable signal capacity vs. maximum transmission distances without amplification

The use of such cables can avoid the need for precise cable-route surveys, cable-type selection, cable laying selection and cable length adjustment, and the need for joining different cable types at the construction site. Thus, the cable laying construction can be made simple and at low-cost over difficult terrain and changeable landforms.

3.3 Transmission equipment

To simplify the construction, operation, maintenance and repair of the system, the use of commodity-type transmission equipment is relatively low cost and readily available. The transmission equipment can be placed in a waterproof outdoor storage box to avoid the use of costly air-conditioned buildings. Power consumption of the equipment could then be covered by, for example, a solar panel and battery. Direct connection to the electric grid is not always necessary.

3.4 Cable laying

Thin, lightweight and robust long-length optical cables are desired for direct surface, shallow direct burying, aerial wiring, long-length suspension and even submerged application for changeable terrain.

The cable laying cost can be further reduced if cable laying is largely provided by non-skilled local labour in a DIY manner, without the need for heavy machinery or special infrastructure such as cable ducts, trenches and poles. The direct underground burial of the cable, even shallowly by using hand spades and pickaxes, would secure the link. Over specific terrain and landforms where cable laying through the ground is difficult, cable laying using a helicopter may be considered as a last resort.

4 Best practices for cost-effective optical fibre backhaul solution

According to a 2013 report commissioned by the Groupe Speciale Mobile (GSM) Association, more than one-third of the 64 Universal Service Funds (USFs) studied have yet to disburse any of the funds they have collected. Although the reason for this might be not very simple, it could partially be because meaningful and cost-effective real broadband solutions have not yet been made available, as evidenced by field data. It is desired that the best practice solution presented in this Supplement will lead to funding by USFs, subsidies or public funds, which will contribute to effectively reducing the digital divide**.**

4.1 Optical cables

All three types of optical cables shown in Figure 3 are thin, lightweight, robust, waterproof, rodent-proof, highly durable against lateral pressure, and fire resistant to a certain extent; thus, direct surface and direct-buried applications are acceptable.

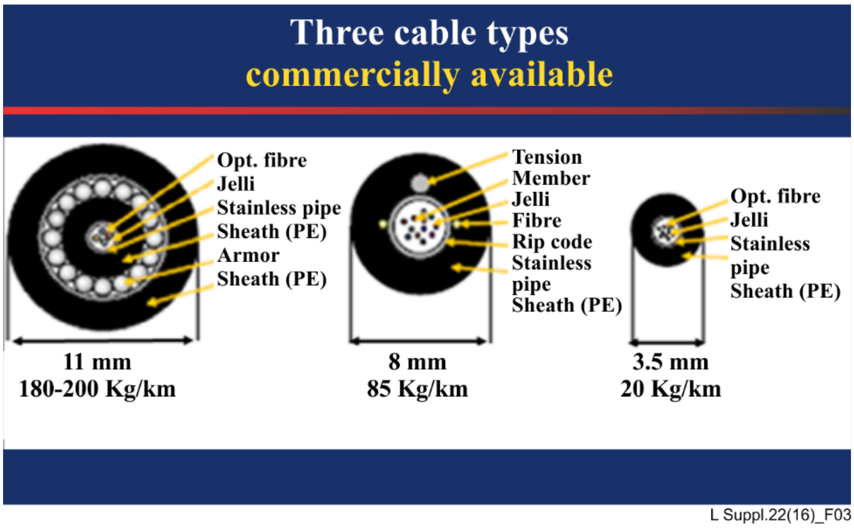

Figure 3 – Example optical cable types for direct surface and direct buried application

The welded steel pipe, shown in Figure 3, accommodates up to 48 single-mode standard optical fibres. It is not necessary to use different types of cable structures for different outdoor environments, such as direct-buried, submerged, aerial wiring or exposure to open air on ground surfaces. This not only avoids the need for a cable-route pre-survey, cable-type selection and cable length adjustment, but also the need for joining different cable types at the construction site. Thus, although the cable cost is a slightly higher than conventional optical cables without welded steel pipe, their cable laying construction over difficult terrain can be made at significantly low cost and more quickly.

Figures 4 and 5 show a side view and cross-sectional view of an optical cable with a welded stainless-steel pipe, where perfect welding is electrically confirmed in the process. This type of cable is widely commercially available, including for the submerged use under lakes and slow-moving rivers.

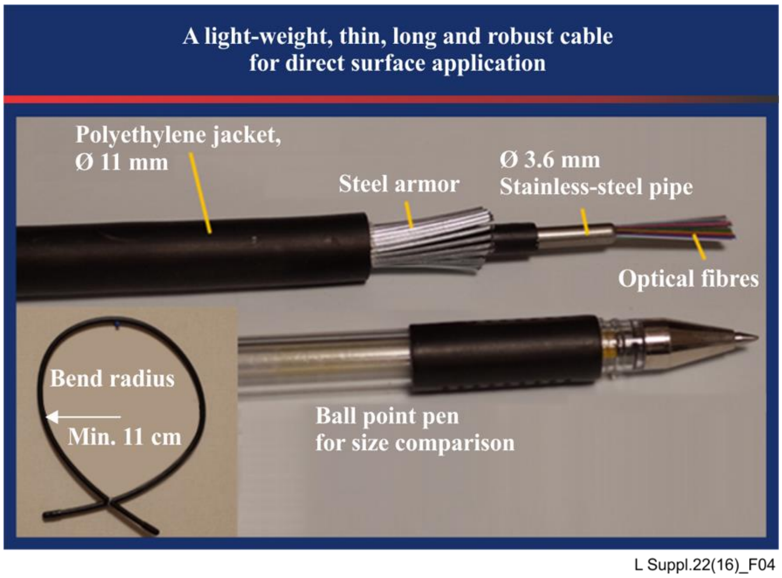

Figure 4 – Example optical cable with welded stainless-steel pipe

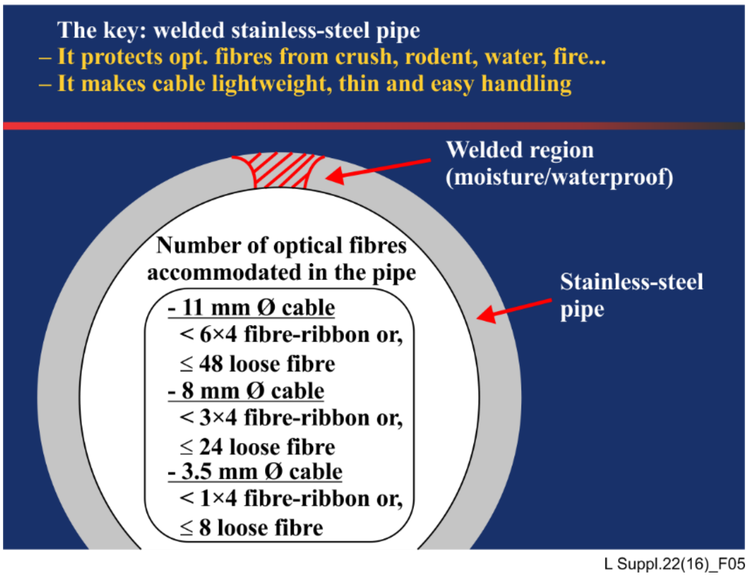

Figure 5 – Example optical cable cross-sectional view of welded stainless-steel pipe

Figure 6 shows a fire test at 1180 degrees C for 15 minutes. Figure 7 shows a lateral-pressure test where the fibre indicated no optical loss for up to 2 tons/100 mm of pressure applied from a heavy vehicle.

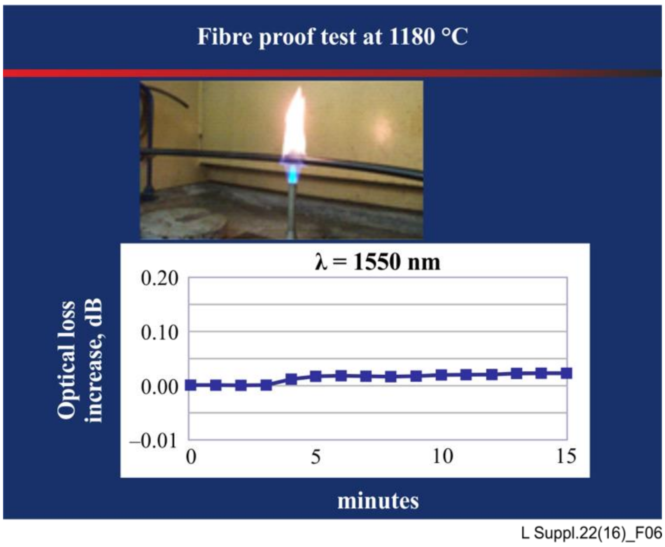

Figure 6 – Fire test results for optical cable with welded stainless-steel pipe

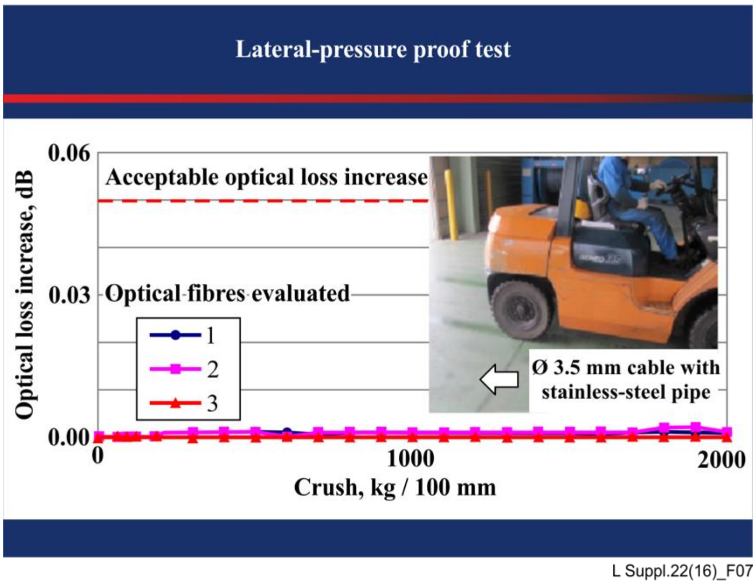

Figure 7 – Crush test results for optical cable with welded stainless-steel pipe

Figure 8 shows optical cable rodent-proof testing. Whereas rats were able to fatally damage the conventional optical cable, the fibres survived when protected by the steel pipe. Figure 9 shows a cable vibration test for aerial wiring; no damage was observed against simulated cable vibration of one million cycles.

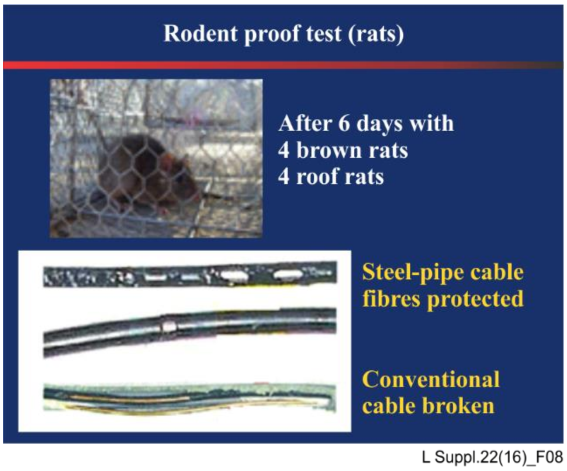

Figure 8 – Rodent-proof test results for optical cable with welded stainless-steel pipe

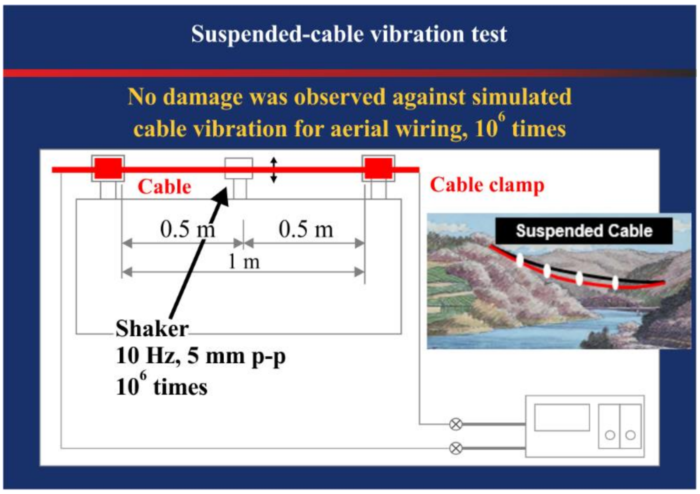

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Figure 9 – Vibration testing observation results for aerial wiring of optical cable with welded stainless-steel pipe

Figure 10 shows a waterproof type closure that connects optical cables. Optical fibre splicing portion together with a length of optical fibres at both sides of the splicing point is accommodated. Figure 11 shows another type of optical cable that has also been in commercial use that does not use welded steel pipes, but rather uses corrugated steel armour and water-swellable tape to allow the cable to be directly buried under the ground.

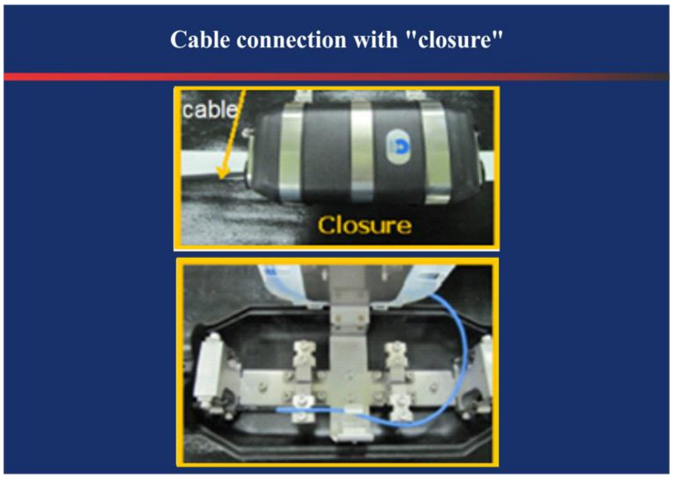

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Figure 10 – Waterproofing closure to connect optical cable with welded stainless-steel pipe

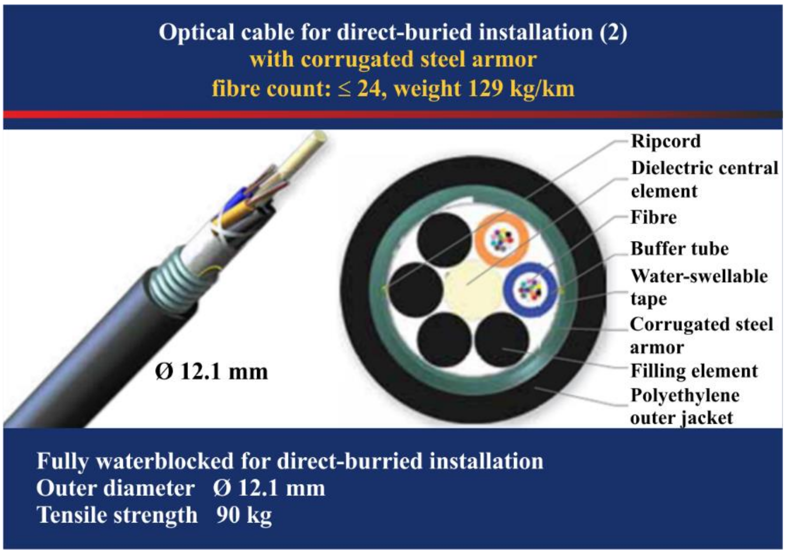

Figure 11 – Optical cable with corrugated steel armour for direct burial

4.2 Transmission equipment

Figure 12 shows typical high-speed, long-distance media converters. Typical transmissible distances for 1 Gbit/s and 10 Gbit/s are 140 km and 100 km, respectively. With 10 Gbit/s and a 33 dB type media converter (see Figure 12), passive cable-link lengths can be over 100 km; no electric power is needed between converters and cable splicing at every 5 km plus cable repair of 20 times are theoretically acceptable for the splice loss of 0.1 dB each and fibre loss of 0.25 dB/km. A system margin of 1.5 dB is still theoretically left after repairing 20 occurrences of fibre/cable breaks. The largest outer dimensions are approximately 100 mm for the media converters shown in Figure 12. Their typical power consumption of below 10W would be covered by solar panels (approx. 5 US$/W, 100~200 W per square meter), and batteries. An electric grid is not always necessary.

Figure 12 – Typical high-speed, long-distance media converters

Figure 13 provides an example of a waterproof, outdoor storage box accommodating a media converter in which anti-corrosion film and/or a moisture absorber could be used to avoid the use of costly air-conditioned buildings.

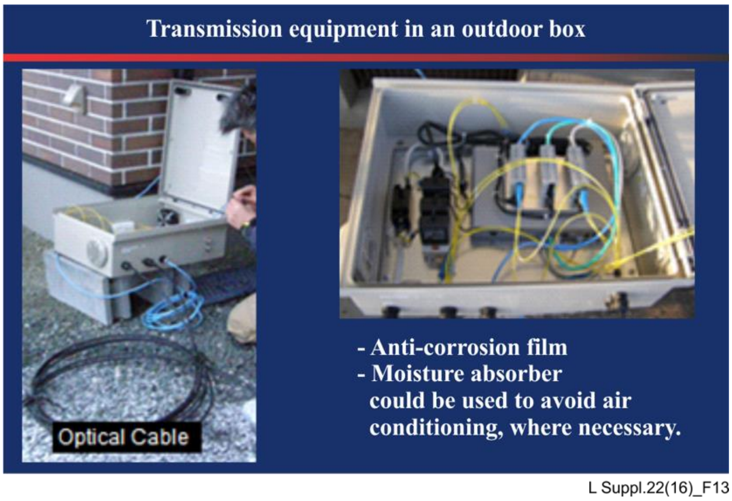

Figure 13 – Example waterproof, outdoor storage box accommodating media converters

4.3 Cable laying

Laying thin, lightweight and robust optical cable that accommodates direct-burying, aerial wiring, long-length aerial suspending and even underwater submergence is sufficiently easy as to allow local non-skilled people to help in a DIY manner, without the need for precise cable-route surveys or length-adjustments. Moreover, heavy machinery and skilled engineers are not needed, except when using a helicopter as shown in Figure 14.

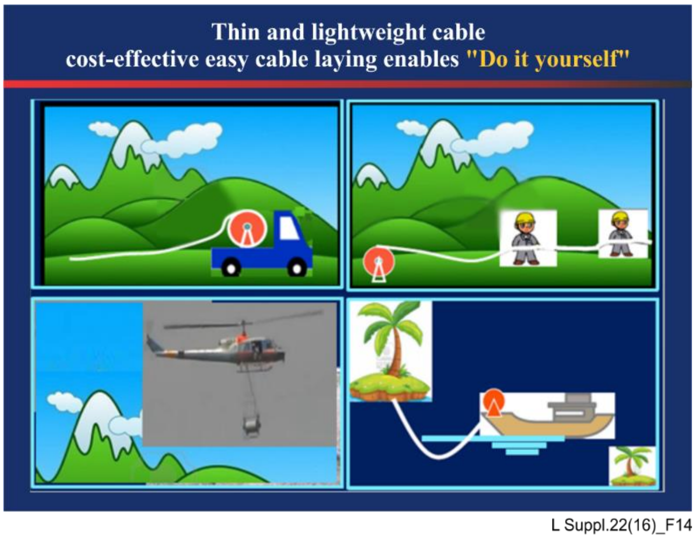

Figure 14 – Simple installation methods for lightweight, thin robust optical cables

Figure 15, from [b-Yoshitoshi], shows a field test successfully conducted in rural/remote areas in Japan in 2011 using the cables shown in Figures 4 and 5, together with a commodity type media converter, installed in an unairconditioned outdoor storage box of the type shown in Figure 13.

In March 2013, a 1.2 km optical cable was installed in a rural/remote area in a developing country in Asia after four days of construction. This was conducted as an Asia-Pacific Telecommunity (APT) J3 project (see Figure 16). The Internet was made available at a local government office, a school and a hospital. No problems have been reported to date.

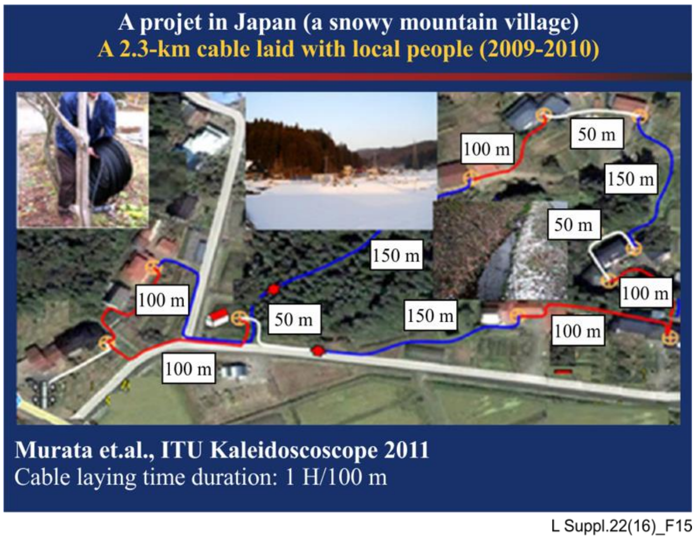

Figure 15 – Field test of optical cable installation in rural/remote areas in Japan

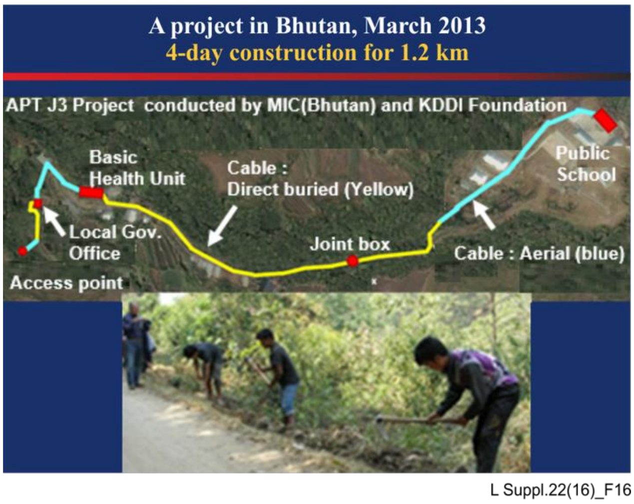

Figure 16 – Installation example in rural Asia of optical cable with welded stainless-steel pipe

4.4 Comparison of cable construction costs

Figure 17 shows an example of conventional cable construction costs, averaging 70,800 US$/km, without including cable costs, using an underground duct; this was presented as a case study by Korea Telecom at UNESCAP meeting, Sept. 24, 2013. In addition, a report from an ITU-R chair to ITU-D SG2/Q25 in 2013 stated that "the lowest OPEX route is to install conventional fibre optic cables, but with costs of around 85,000 US$/km" using a conventional optical cable. Figure 18 shows the construction cost of approximately 300 to 400 US$/km, without including cable cost, with cables using a welded steel pipe that needs no heavy construction machinery but rather only non-skilled local people with handy picks and light tools and choosing direct surface application, shallow burying, submerging or areal wiring, depending on the conditions.

The robustness and ease of handling of these cable made the DIY approach possible and thus largely reduced the construction cost under the tested condition.

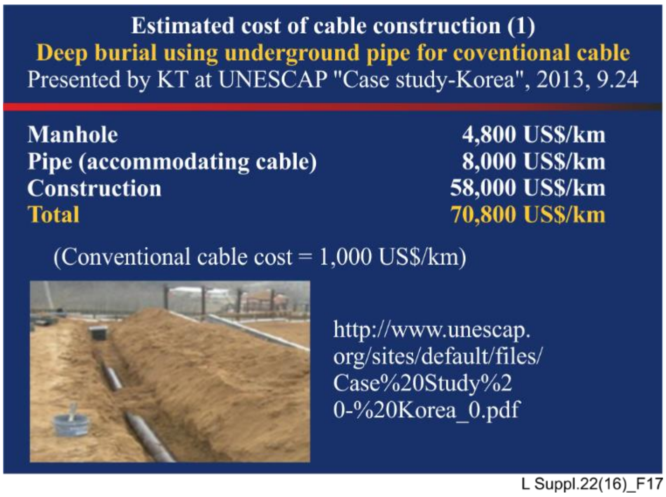

Figure 17 – Example conventional cable construction costs when using underground pipe

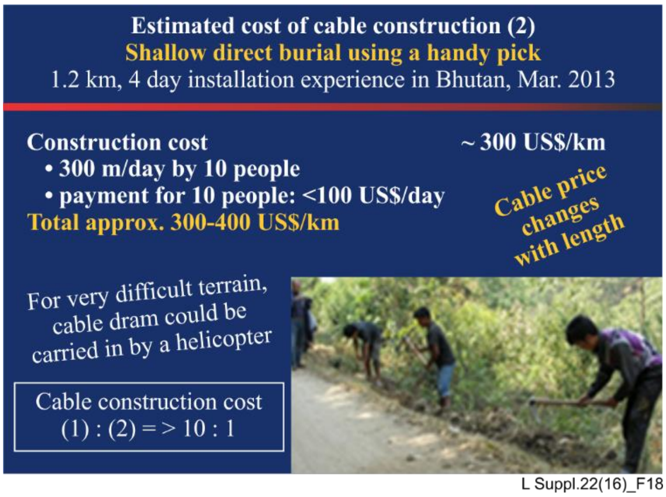

Figure 18 – Estimated cable construction costs for low-cost, optical cables with welded stainless-steel pipe

Appendix I

The relationship between the metrics in ITU-T L.1700 and the best practice solution

Table I.1 – Evaluation of the best practice example of low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable

Metrics	Evaluation aspect	Analysis	Evaluation
Cost	Per user, per service area, per Mbit/s Per socio-public benefit to bring in USFs	– Cable cost: ~4,000 to 5,000 US$/km free on board (FOB) shipping, varies with lengths – Construction Cost: 300 to 400 US$/km if 10 US$/head/day applies – Media converter (list price): ~8,500 US$/fibre pair: 10 Gbit/s ~50 km.	Excellent
Energy consumption / Energy efficiency	Absolute power per network element, Watts/Mbit/s or Watts/m2	No power needed for cable. Power needs only for equipment (commodity media converter) at cable end with typical power consumption < 10 W. Solar panel usable. (~5 US$/W, 100~200 W per square meter) plus battery.	Excellent
Geographical coverage	Limitations on the topography (e.g., mountainous terrain) In m^2 or km^2	Flexible because various installation and branching configurations are possible. A part of one length of cable can be on the surface, buried, aerially suspended or submerged.	Excellent
Population coverage	Max. no. of subscribers served by the system	Cable has maximum of 48 fibres. If 10 Gbit/s each fibre pair, total 240 Gbit/s/cable. Wave division multiplexing (WDM) of 10 channels leads to 2.4 Tbit/s.	Excellent
Bandwidth	Mbit/s provided in total and per user		
Power feeding points needed	No. of power feeding points per area. Power needed at intermediate points. Power needed at feed point: renewable, diesel, grid	No power needed between 100 km, 5-km long 20 cable pieces (0.25 dB/km loss) with 0.1 dB splice loss (total 27 dB) are well covered with a 33-dB Media converter allowing 20 repairs each using additional 100 m cable while still leaving 1.5 dB margin.	Excellent
Availability (mean time between failure (MTBF)/mean time to repair (MTTR))	Target can be set as 99.999% in urban area 99% in rural area	Local community can continuously improve availability using cable re-routing and protection measures. Welded stainless pipes are highly robust against rodents, crush, water/moisture, high/low temperature with a pipe's outer/inner diameter of, e.g., 3.6/3.0 mm.	Good
Protection against	Balance of cost and reliability	Rodent-proof was proved against rats (Figure 8). 20,000 km of cable have been in commercial use for 20 years in	Excellent

Table I.1 – Evaluation of the best practice example of low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable

Metrics	Evaluation aspect	Analysis	Evaluation
environmental impacts		Japan, partially submerged under lakes or exposed to moles, squirrels and birds.	
Scalability	Ability to add new users to a network without significant extra (other than incremental) cost	In addition to excellent coverage of geography and population, ease of cable branching realizes excellent scalability.	Excellent
Skills requirements	The infrastructure and network elements should not require highly skilled local people to help install and operate, thus CAPEX/OPEX, time to repair, training are reduced	The lightweight and robust cables can be easily placed on the surface, buried, suspended and submerged mostly manually without using heavy machinery. Cable kinking and excessive bending could be avoided by simply training the local people.	Highly-skilled labor not needed, but simple training for local people needed

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