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ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using cellular radio technologies

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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 29 to ITU-T L-series Recommendations

ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using cellular radio technologies

Summary

Supplement 29 to ITU-T L-series Recommendations identifies a low-cost sustainable telecommunication solution using cellular radio technologies consisting of a base station system and backhaul for potential users of digital services in remote or rural areas.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Cellular radio technologies, digital divide, integrated base stations, low-cost sustainable networks, mobile networks.

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Introduction

Cellular radio technologies offer a lot of convenience in rural areas as once a cellular tower is set up, people can start using the services instantaneously as compared to the time it takes to provision a connection up to the user's home for a wireline solution. Wireline solutions are also labour intensive and costly when providing coverage to rural areas as the area covered is generally large with a low density of users. The cost and possibility of laying a wireline connection also depends to a large extent on the geographical terrain. Wireless solutions on the other hand are not dependant on the terrain, except for the need for radio line-of-sight, are more robust and as they only need the installation of a tower to provide coverage to an area, they offer a rapid system integration time. Cellular radio solutions are also more secure against human interference as the base stations are generally within a secure perimeter whereas the wires in wireline solution can be prone to interference and damage.

Another advantage with cellular radio technologies is that they are generally available in most regions and if a way can be found of extending mobile services to rural and remote regions then they allow seamless connectivity and roaming.

Another basic disadvantage of wireline along with difficulties in maintenance, is that the laying of wireline for the first time to rural and remote areas or through difficult terrain is costly and may take a long time. But cellular wireless systems also have capital expenditure (CAPEX) and operating expenditure (OPEX) issues when the service is to be provided to rural and remote regions where, because these regions are not densely populated, the increased costs might not be recovered. In such cases, government funding may be available to give financial incentives to operators to set up networks in such areas. Other issues in setting up cellular networks in rural and remote regions are that skilled manpower is generally not available and the power supply might be erratic.

To provide services to a remote or rural area, where there might be problems of maintenance and power supply provision, modified base stations are available that can work on renewable sources of energy. These are integrated and easy to maintain. Such a solution is discussed in this Supplement.

Supplement 29 to ITU-T L-series Recommendations

ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using cellular radio technologies

1 Scope

This Supplement identifies a low-cost sustainable cellular radio technology solution consisting of a base station system and backhaul which can be used in rural and remote areas to provide digital services. The cellular radio technology solution discussed here utilises renewable sources of energy, is integrated and can be easily maintained.

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

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AMR	Adaptive Multi-Rate
BTS	Base Transceiver Station
CAPEX	Capital Expenditure
CDMA	Code Division Multiple Access
DeNB	Donor eNB
DSSS	Direct Sequence Spread Spectrum
EMF	Electromagnetic Field
eNB	evolved Node B
FDD	Frequency Division Duplex
FHSS	Frequency Hopping Spread Spectrum
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
IMT	International Mobile Telecommunications
ISM	Industrial, Scientific and Medical (radio band)
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplexing

OMC	Operations and Maintenance Centre
OPEX	Operating Expenditure
RF	Radio Frequency
RN	Relay Node
RRH	Remote Radio Head
SAIC	Single Antenna Interference Cancellation
SMS	Short Messaging Service
TDD	Time Division Duplex
TRX	Transceiver
Un	LTE-A Air interface
Uu	Modified LTE-A air interface between RN and DeNB
VAMOS	Voice services over Adaptive Multi-user channels on One Slot
WiFi	Wireless Fidelity

5 Conventions

None.

6 General overview

To promote the setting up of low-cost and sustainable cellular radio technology services in rural and remote regions, the Department of Telecom in India has issued technical specifications for different types of infrastructure required to set up telecom networks in such regions which are differentiated on the basis of number of subscribers, the services to be supported and the coverage.

These guidelines are being used by network equipment vendors to come up with cellular radio technology solutions that are suitable for rural and remote regions. The infrastructure categories are discussed in clause 7. Infrastructure categories include possible combinations of tower height, the number of transceivers (TRXs) and radiation power. Infrastructure categories also include the power backup, battery and type of integrated backhaul that will be required. The cellular radio technology in the solution is based on GSM/GPRS [b-Tech] as this technology has higher penetration into rural and remote regions than International Mobile Telecommunication: IMT-2000 [b-IMT2000] and IMT-Advanced. Separately, best practices are also mentioned that can be used by operators. In Section 8, the power backup options are discussed. In clause 9, use of microwave backhaul in an unlicensed band is discussed. Clause 10 describes various technical features that might be used to improve the cost-effectiveness of the cellular radio technology solution.

7 Infrastructure categories

Depending on the geographical terrain, the coverage to be provided and the number of users, the infrastructure required for setting up cellular radio technologies for rural communications has been divided into three categories. Each of the categories also includes a condition on the electromagnetic field (EMF) radiation limits. These can be changed to reflect national limits. In addition, for each of the infrastructure categories, the radio frequency (RF) and transmission equipment should be integrated as this brings down the total power requirement. Also, all equipment should preferably be at the top of the tower so that cable losses can be avoided. Categories A, B and C are as follows:

– **Category A**: A base transceiver station (BTS) mounted on a 20 metre ground based tower with 2-5 Watt power per carrier, 2 omnidirectional transceivers (TRXs) with a coverage radius of up to 1-2 km respectively for a population of 1 000. Typical examples of such areas are secluded habitations in hilly regions and also in desert plains.
– **Category B**: A BTS mounted on 30 metre ground based tower with up to 10 Watt power per carrier, 2 omnidirectional TRXs and with coverage radius above 2 km and up to 4 km for populations between 1 000-2 500. Typical examples of such areas are the uncovered areas located in plains regions or regions with low hills.
– **Category C**: A BTS mounted on a 40 metre ground based tower with up to 20 Watt power per carrier, a 2+2+2 configuration (GSM) or equivalent code division multiple access (CDMA), sectoral antenna, with a coverage radius beyond 4 km for a population above 2 500. Typical examples of such areas are villages with low populations spread over a relatively large geographical area.

The infrastructure requirements of the categories A, B and C are as follows:

– **Category A**:
  – BTS to be equipped with up to 2 TRXs for GSM with omnidirectional antenna. The CDMA equivalent is a single carrier BTS with omnidirectional antennae. Category A may be further classified into category 'A1' and category 'A2'.
  – Category 'A1' and category 'A2' to have a 20 metre ground based tower.
  – Category 'A1' has a transmit power of 2 Watts and Category 'A2' has a transmit power of 5 Watts at the antenna port with coverage radius of 1km and 2 km respectively.
  – To operate on non-conventional energy sources, such as solar power.
  – To provide voice communication, short messaging service (SMS) and additionally to support data communication services with data rates of 100 to 128 kbps capability.
  – It must adhere to license conditions including the latest electromagnetic field (EMF) radiation norms of the country.
– **Category B**:
  – It may support 2 TRXs with omnidirectional antennas for GSM or CDMA with 1 carrier and omnidirectional antennas.
  – It may be mounted on a tower of up to 30 metres in height and may transmit up to 10 Watts power at the antenna port for a coverage radius above 2 km and rising up to 4 km.
  – It should operate on a non-conventional energy source such as solar power.
  – It shall support voice communication, SMS and shall additionally support data communication rates of 100 to 128 kbps capability.
  – It may use sectoral antennae depending on the location of equipment and the distribution of the population around it.
  – It must adhere to license conditions including the latest EMF radiation norms of the country.
– **Category C**:
  – It may support a 2+2+2 configuration (GSM) or the equivalent CDMA configuration of one carrier for three sectors (1C3S).
  – It should have a ground based tower of 40 metres in height and transmit up to 20 Watts power at the antenna port for coverage of distances beyond a radius of 4 km to 6 km.
  – It should operate on non-conventional energy sources such as solar power.

– It shall support voice communication, SMS and additionally support data communication rates of 100 to 128 kbps capability.
– It must adhere to license conditions including the latest EMF radiation norms of the country.

8 Power backup

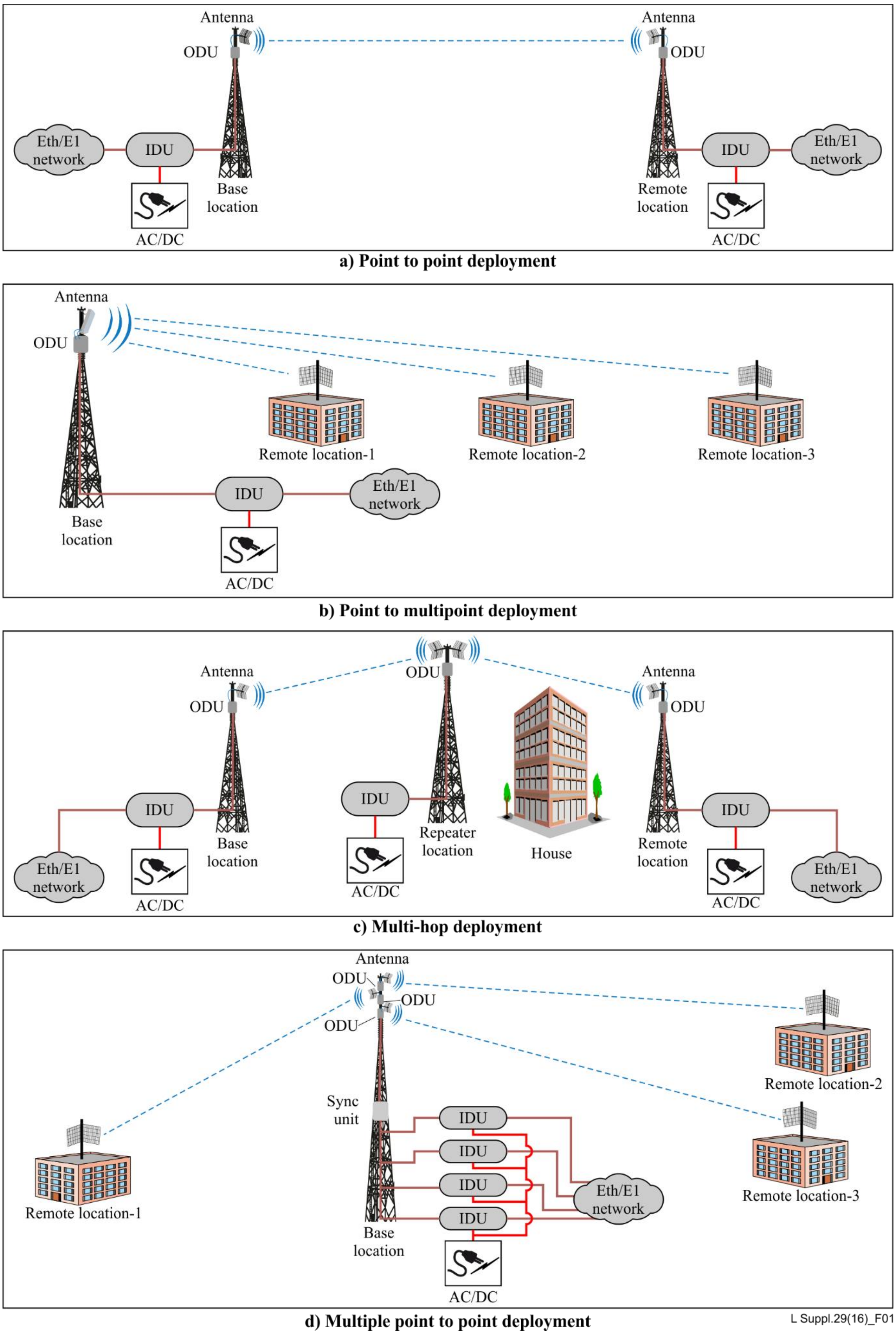
In the given solution, the BTS should be capable of working in an outdoor environment (i.e., non-A/C, dusty, etc.) and should be capable of using renewable sources of energy. This also helps to reduce OPEX as there will be less energy drawn from grid supply. Power backup of up to 2 days is required with non-renewable sources of energy.

9 Backhaul

Integrated microwave backhaul has been proposed for all categories of BTS. In order to fit into the requisite of economical deployment, microwave backhaul in the license-free bands is preferable. This solution is suitable in rural areas as not much interference is to be expected in the unlicensed band. The unlicensed bands in India generally employed for microwave backhaul are as follows:

– 2 400-2 483.5 MHz.
– 5 825-5 875 MHz.

The microwave backhaul system in unlicensed bands generally employs modulation techniques such as frequency hopping spread spectrum (FHSS), direct sequence spread spectrum (DSSS) and orthogonal frequency division multiplexing (OFDM), etc., and will work in time division duplex (TDD) or frequency division duplex (FDD) mode with different channel bandwidths. The system can be of the fully outdoor type or of split type with an indoor unit and outdoor unit. The different architecture types supported and used under different deployment conditions are shown in Figure 1.



a) Point to point deployment

b) Point to multipoint deployment

c) Multi-hop deployment

d) Multiple point to point deployment

Figure 1 – Microwave backhaul deployment types

10 Technological advancements

– VAMOS: Voice services over adaptive multi-user channels on one slot (VAMOS) is an air-interface technology option to reduce the energy requirement per erlang. VAMOS may double the cell capacity by multiplexing two co-cell users onto the same radio resource, while reducing radio base station power consumption. VAMOS is based on quaternary modulation and multi-user MIMO techniques in the downlink and uplink, respectively.

– SAIC: Single antenna interference cancellation (SAIC). To ensure immediate gains this technique can be applied with typical GSM handsets that support SAIC. With these two key techniques linked to adaptive multi-rate (AMR) half-rate, four legacy SAIC handsets can be served at the same time within a radio time slot. It is expected that VAMOS will reduce operator's capital expenditure (CAPEX) and operational expenditure (OPEX) for voice services by up to 50%. In rural areas, as interference may be much lower than in urban environments; VAMOS implementation may be suitable.

– In rural areas, low interference levels may permit the enhancement of radio capacity using bandwidth efficient codecs e.g., AMR as this may reduce power requirement per user.

– Use of long-term evolution (LTE) relay nodes (RN). These are low-power base stations that will provide enhanced coverage and capacity at cell edges for hot-spot areas and it can also be used to connect to remote areas.

– Two options for connection of RN with donor eNB are possible. In the first, the Uu and Un use different frequencies and the relay node is referred to as a Type 1a RN. In the second option, Uu and Un utilize the same frequencies and the relay node is referred to as a Type 1 RN. In the latter case there is a high risk for self-interference in the relay node, when receiving on Uu and transmitting on Un at the same time (or vice versa).

– Use of WiFi for access and backhaul: In rural and remote regions, WiFi can be used to provide access to the network as well as for backhaul as there is less chance of problem due to interference due to large scale use of 2.4 GHz industrial, scientific and medical (ISM) [b-300328] band in such areas.

11 Best practices for low cost sustainable solutions

– Lower frequency bands: In rural areas, lower frequency spectrum bands will have good propagation characteristics and would be most attractive. This may help in reducing the number of BTS required to cover the rural area and thus may be cost-effective from both CAPEX and OPEX perspective.

– Reduction of power requirements by using small cells. In rural scenarios where clusters of 500 to 2 000 habitants are often in open fields with almost free-space propagation. Individual clusters may be of 1-2 km diameter and clusters may be separated by a few kilometres. In such a scenario, instead of covering the area with a macro-BTS and using a higher configuration BTS, a low power BTS with lower power transmitters may be used. These small cells may be placed closer to inhabited areas bringing down the total power to be radiated to reach the user. The capacity requirement of each BTS will also be limited to lower configurations as total traffic requirement of individual clusters will easily be met by this type of BTS. Such a type of BTS may require only 200-250 Watts. However, there will be a requirement for multiple such BTS's serving individual clusters or groups of clusters closely-spaced. Usage of a low power BTS makes solar or other non-conventional energy sources feasible. Moreover, power amplifiers and the cooling system designed for a low-power BTS will be more efficient than operating macro BTS's with reduced configuration. However, this solution may not be cost-effective in cases of very-very low population density as the number of such BTS's required may be very high.

Appendix I

Technical characteristics of sustainable cellular radio technology – Small size base station system (SS BSS)

The typical technical and operational characteristics of a cellular radio system being used for a pilot project in India and also for installation in various rural and remote locations are summarized in Figure I.1.

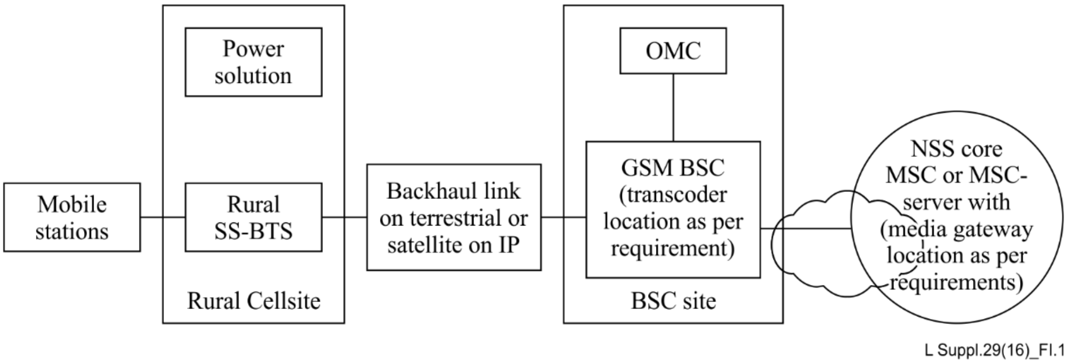


Figure I.1 – GSM network for remote access

Since the base station's transceiver will be used for rural connection and disaster management applications, they may be located mainly on rooftops in villages or in mobile vans. Equipment must therefore be compact, robust, tower or pole mountable and be capable of full remote-control operation. The base station should be capable of installation on pole, tower, stacked or tower top with a remote radio head (RRH) to provide a complete outdoor solution. The base station system should also be capable of supporting renewable sources of energy as the BTS transmit power can be low in rural and remote regions. The equipment should support the relevant 3GPP specifications for GSM and GPRS [b-Tech]. The outdoor BTS should meet IP65 [b-60529] level environmental ingress protection specifications and the BTS should have no forced cooling. Also, it should support remote software updates and maintenance from the operations and maintenance centre (OMC) for easy maintainability.

Appendix II

Technical characteristics of sustainable cellular radio technology – Backhaul system in unlicensed band

Description

The typical technical and operational characteristics of a typical backhaul system in unlicensed band are described in Table II.1 and Table II.2.

Table II.1 – Technical characteristics

Sr. No.	Characteristic	Value
1	Frequency range	i) 2 400-2 483.5 MHz. ii) 5 825-5 875 MHz.
2	EIRP	4 Watts
3	Modulation	FHSS, DSSS, OFDM
4	Adaptive coding and modulation	Supported
5	Supported data rates	As per Table: Supported data rates of this Appendix.
6	Duplexing mode	FDD, TDD
7	Configurable channel bandwidth	Channel bandwidth of 5/10/20/40 MHz supported which can be configured in the system.
8	Ethernet service requirements	Support for IEEE 802.3, IEEE 802.1Q, 802.1ad (Q-in-Q), 802.1d. Classification of traffic as per IEEE 802.1p, VLAN ID, IP TOS/DSCP.
9	Support for network management	GUI based NMS/EMS management. Support for full SNMP protocol.

Table II.2 – Supported data rates

Modulation and FEC	Minimum unidirectional throughput (in Mbps) for different channel widths			
	Data rate (5 MHz)	Data rate (10 MHz)	Data rate (20 MHz)	Data rate (40 MHz)
BPSK-1/2	0.5	1.0	3.5	8.0
QPSK-1/2	1.5	3.0	7.0	15.0
QPSK-3/4	2.0	4.5	10.5	23.0
16QAM-1/2	3.0	6.5	14.0	30.0
16QAM-3/4	4.5	9.5	21.0	45.0
64QAM-2/3	6.5	13.0	28.0	60.0
64QAM-3/4	7.0	14.5	32.0	68.0
64QAM-5/6	8.0	16.0	35.0	75.0
256QAM-5/6	12.0	25.0	50.0	100.0

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