Recommendation

ITU-T Y.4218 (05/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Requirements and use cases

Internet of things and information and communication technology requirements for deployment of smart services in rural communities

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Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

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Recommendation ITU-T Y.4218

Internet of things and information and communication technology requirements for deployment of smart services in rural communities

Summary

Recommendation ITU-T Y.4218 aims to contribute to bridging the digital divide by establishing the information and communication technology (ICT) and Internet of Things (IoT) requirements for the deployment of smart services (such as e-government, telehealth, tele-education, precision agriculture, etc.) in rural communities.

There are numerous efforts underway to provide the necessary tools for the transformation into smart cities, but similar efforts are not observed with the transformation into smart rural communities. This is considered a digital divide in most developing countries where the population in those rural areas is mainly dependent on agriculture, forestry, dairy production, fisheries, livestock farming, etc., for its livelihood. They have limited access to good hospitals, schools, banks, etc. in rural areas, that can have an impact on the quality of their life. As a result, there is continued migration from rural to urban areas in search of higher paid jobs, better education, and improved health care. These issues can be alleviated by bridging the digital divide, which may be achieved by enhancing the access of information and communication technology (ICT) services (telephony as well as high speed Internet) in rural communities. As the ICT density, both voice and Internet is lower in rural areas compared to urban areas, therefore a high speed communication network may be established as a backbone for providing reliable ICT services. Provisioning of high speed Internet facilities at the household or local community level will open new opportunities for the rural population in several diverse fields.

The perspective of every household having access to at least one smartphone with a minimum set of required features and the Internet may enable access to various online services, thereby bridging the digital divide.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.4218	2023-05-07	20	11.1002/1000/15481

Keywords

Digital divide, education, health care, ICT, Internet of Things, IoT, smart rural community, smart services.

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FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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1 Scope

By establishing the information and communication technology (ICT) and Internet of things (IoT) requirements for the deployment of smart services in rural communities, this Recommendation aims to bridge the digital divide and promote the extension of telecommunications networks to rural areas, in order to ensure the equality of all citizens regardless of where they live, smart cities or rural communities.

This Recommendation covers the following aspects:

- Introduction to smart rural communities;
- Smart services in rural communities;
- ICT and IoT requirements for deployment of smart services in rural communities.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[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*.

[ITU-T Y.4450] Recommendation ITU-T Y.4450/Y.2238 (2015), *Overview of Smart Farming based on networks*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 device [b-ITU-T Y.4000]: With regard to the Internet of Things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.2 gateway [b-ITU-T Y.4101]: A unit in the Internet of Things, which interconnects the devices with the communication networks. It performs the necessary translation between the protocols used in the communication networks and those used by devices.

3.1.3 Internet of things [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broad perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.4 sensor [b-ITU-T Y.4105]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

3.1.5 smart farming based on networks [ITU-T Y.4450]: A service that uses networks to actualize a convergence service in the agricultural field to attain more efficiency and quality improvement and to cope with various problems.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 smart rural community (SRC): A rural community that uses smart services to address the various issues of daily life in diverse application domains, for improving the quality of life of residents or a more sustainable, innovative, and inclusive economic growth.

NOTE – Examples of application domains include, but are not limited to, health care, education, agriculture, aquaculture, livestock farming, automotive, and power.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
BTS	Base Transceiver Station
CCTV	Closed-Circuit Television
ECG	Electrocardiography
EC-GSM	Extended Coverage – GSM
EHR	Electronic Health Record
FAO	Food and Agricultural Organisation
FM	Frequency Modulation
FTTH	Fibre To The Home
GNSS	Global Navigation Satellite System
GPON	Gigabit Passive Optical Network
GSM	Global System for Mobile Communication
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunication Union
LTE	Long-Term Evolution
LPWAN	Low Power Protocol for Wide Area Wireless Networks
LoRa	Long Range Applications
M2M	Machine to Machine
ML	Machine Learning

NB-IoT	Narrow Band – Internet of Things
OFC	Optical Fibre Cable
OLT	Optical Line Terminal
ONT	Optical Network Terminal
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
SRC	Smart Rural Community
TSP	Telecom Service Provider
UAV	Unmanned Aerial Vehicles
USOF	Universal Service Obligation Fund
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity

5 Conventions

In this Recommendation:

The expression "is required" indicates a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The expression "is recommended" indicates a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance with this Recommendation.

The expression "can optionally" and "may" indicates an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Introduction to smart rural communities

A country is generally divided into different areas from the administrative point of view, and the areas into districts. Each district has a city, town, or urban and suburban areas. The geographical areas within a district but outside the boundaries of a city or town are the rural areas, which comprise villages. The population in the villages could be significant but with low density and a certain distance to urban areas.

The rural population lives in villages and is mainly involved in agriculture, forestry, dairy production, fisheries, livestock farming, etc. To improve the living quality of people in rural areas and, where applicable to reduce migration from rural to urban areas, it is required to resolve issues such as jobs, education, health care, and income in rural areas. Some of the facilities may be provisioned by extending ICT infrastructure from urban to rural areas. In an ambitious bid to transform rural areas into economically, socially, and physically sustainable spaces, the need of the hour is the development of a cluster of villages that preserve and nurture the essence of rural community life with a focus on equity and inclusiveness without compromising with the facilities perceived to be essentially urban in nature, thus creating a cluster of smart villages. This may help reduce the migration of rural workers especially youth to major urban cities by improving the living conditions in villages and providing necessary amenities and access to technology.

Therefore, a smart rural community (SRC) may be defined as a rural community that uses a smart infrastructure through the adoption of innovative solutions using IoT and ICT technologies for the provisioning of smart services, in order to improve the quality of life of rural residents towards more sustainable, innovative and inclusive economic growth.

Emerging technologies such as machine to machine (M2M) communication, Internet of things (IoT), cloud computing, artificial intelligence (AI)/machine learning (ML), big data and data analytics along with adequate ICT infrastructure will provide the benefit of various innovative applications in rural areas.

IoT and ICT will enable rural development, urban-rural cooperation, preservation of the natural environment, social and cultural connectivity, and tourist information including sustainable tourism for smart rural communities. This will also help in the development of enterprises and create conditions for making smart rural communities attractive to the larger population. Affordability and adoption of smartphones with high speed mobile networks will play a key role in the proliferation of Internet access as well as smart services in rural areas.

Figure 1 describes the role of IoT and ICT in various applications in rural areas. This guarantees accessibility to services, efficacy and efficiency in their provision, the adoption of participatory governance practices entrepreneurship and improvement of personal and family conditions for improving the quality of life and the sustainable economic growth of citizens, both in rural areas and in each municipality that can integrate it.

Figure 1 – The role of IoT and ICT in various applications in rural areas [b-ITU-FAO]

7 Smart services in rural communities

7.1 IoT and ICT importance for rural communities

Rural households face several challenges in their daily life, mostly related to better education, health care, transportation, electricity, employment, access to citizen centric services, and so on.

The rapid growth of ICT provides new avenues to share and access information. Economic growth is a key success factor for reducing undernourishment, but it must be inclusive and provide opportunities for improving the livelihoods of the poor. Enhancing the productivity and incomes of smallholder family farmers is the key to progress.

Agriculture is around four times more effective at raising incomes among the poor than other sectors. Enhancing the ability of farming communities to connect with knowledge banks, networks and institutions using ICT has improved their productivity, profitability, food security, and employment opportunities substantially [b-ITU-FAO].

These services are a necessity and may be provided by creating a smart infrastructure using IoT and ICT in rural areas. Some of the services available in urban areas, such as telehealth, tele-education, e-government, e-banking, e-postal, etc., may be further extended to rural communities using IoT and ICT infrastructure.

Some of the expected applications in different verticals in rural communities are shown in Table 1.

Table 1 – Expected smart applications in various verticals in rural communities

Vertical	Smart applications
Agriculture	Smart irrigation, weather monitoring and forecasting, precision agriculture, remote crop monitoring, remote monitoring of soil quality, smart warehousing, logistics and distribution, and remotely controlled irrigation.
Health care	Telemedicine, remote diagnostics, remote monitoring of a patient after surgery (e-health), medication reminders, and e-ICU based applications.
Education	Tele-education, e-attendance (biometric).
Livestock farming	Animal production, animal tracking, and remote monitoring of the health of the animals.
Aquaculture	Water quality (dissolved oxygen, ammonia, pH, etc.) management, intelligent feeding, and aquatic animal health management.
Energy	Renewal energy sources like solar, and biomass and connecting to the smart microgrid, smart distribution network, smart metering, smart grid, electric line monitoring, gas / oil / water pipeline monitoring, and smart street lighting.
e-government	Citizen centric services like birth/death certificates, electronic attendance in government projects, connecting police stations, banks, post offices, etc.
Food processing	Production and storage, better food safety, and wastage reduction.
Automotive	Vehicle tracking, e-call, and asset tracking.
Closed-circuit television (CCTV) based real time public safety system	Public safety applications using CCTV cameras at various locations across the village along with public address systems, emergency/fire alert applications, etc.

Verticals especially healthcare, education, and agriculture are quite important for rural communities. Using IoT and ICT, these verticals may be made smart and various applications may be created as detailed in the following clauses, which help in improving the quality of life of the rural communities.

UN sustainable development goals, such as 1 (No poverty), 2 (Zero hunger), 3 (Good health and well-being), 4 (Quality education) and 5 (Gender equality), may be achieved by creating smart applications using IoT and ICT technologies in various verticals (see Table 1) in rural areas. It may result in the development of sustainable smart rural communities.

7.2 Some key verticals of rural areas

7.2.1 Agriculture

Agriculture is the main backbone of many countries' economic growth. The most important barrier arising from traditional farming methods is climatic change. The impact of climatic change includes heavy rainfall, intense storm heat waves and drought. As a result, productivity decreases to a major extent.

The critical issue for the future of agriculture is to evolve mechanisms for linking the front-end activities of the agricultural supply-chain such as processing, logistics, storage, retailing and wholesale, with the back-end activities of farm production that would lead to enhanced efficiencies, ensured remunerative prices to producers, and assured markets with reduced production and market risks.

Communication technology will play an important role and may be decided depending on the use case. 5G technology will play an important role as and when it is deployed. 5G technology in precision agriculture will ensure greater profitability and efficient utilization of resources by use of automated tractors, harvesters, precision seeders, and automated weed and pest controllers. Drones with 5G technology may be used for efficient and precise spraying of fertilizers in fields, and also to scan and identify unwanted weeds through the use of AI/ML and big data technologies. It will help farmers to better organize and allocate their time and attention towards areas that really need it.

Low power protocol for wide area wireless networks (LPWAN) technologies may be used to transmit very small data (a related use case concerns the transmission of soil parameters.

To boost productivity and minimize the barriers in the agriculture field, there is a need to use an innovative technology called the Internet of Things (IoT). IoT may transform the agriculture sector and enable farmers to compete with the enormous challenges they face [b-Malavade].

IoT devices with reliable connectivity can be of great help in enhancing the production and yield in the agriculture sector since these devices may be used to monitor soil parameters, temperature levels, and other variables. Moreover, smart agriculture will help in monitoring livestock productivity and health. IoT sensors are capable of providing farmers with information about crop yields, rainfall, pest infestations, and soil nutrition, which can be used to improve farming techniques over time. Smartphone based sensors and communication technologies that can be used in various agricultural applications are shown in Table 2 (clause 8.3). Electrochemical sensors are mostly used to assess soil characteristics such as the pH value and soil nutrient levels (micro-nutrients/macro-nutrients) etc. Soft water level-based (SWLB) sensors are used for measuring the water level and water flow in agricultural applications.

The world population increases continuously however the land size remains constant, resulting in higher productivity demand for farms. IoT in agriculture is a possible solution to cater to the need of enhancing crop productivity. The rapid growth of ICT generates new avenues to share and access information as depicted in Figure 2.

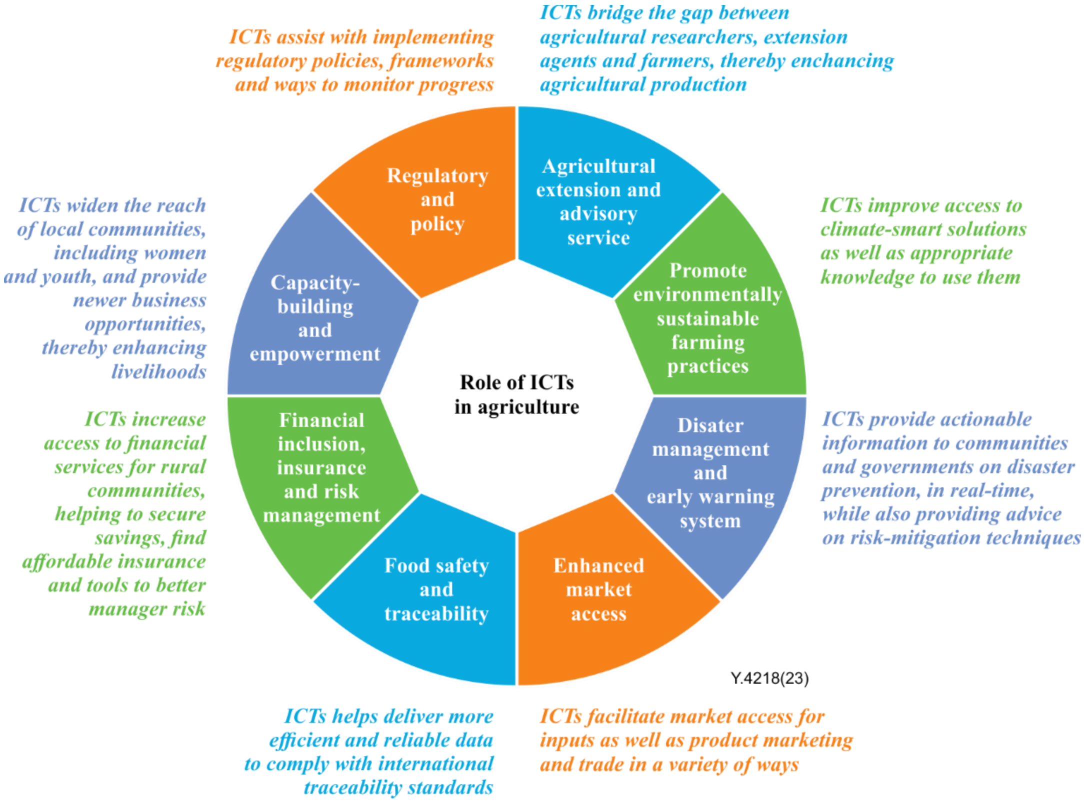

Figure 2 – Role of ICT in Agriculture [b-ITU-FAO]

Intelligent farming may provide farmers and the agricultural industry with the infrastructure to use IoT and ICT technologies for tracking, monitoring, automating, and analysing their agricultural and industrial activities [ITU-T Y.4450].

The following provides a non-exhaustive list of advantages of using IoT and ICT in agriculture:

1) Water management can be efficiently performed using IoT to reduce water waste.
2) Soil management such as measuring pH level, moisture content, and nutrients can be performed by using IoT devices having related sensors so that farmers can plant seeds according to the soil quality.
3) The increase in productivity reduces manual work and time, and makes farming more efficient.
4) Unmanned aerial vehicles (UAVs) with sensors and cameras may enable surveillance of the crop field.
5) UAVs with sprayers may be used to handle locust attacks.
6) Crop monitoring can be performed to observe the growth of crops.
7) Crop sales may be increased in the global market. The farmer can be connected to the global market without the restriction of any geographical area.

7.2.2 Healthcare

Medical facilities are of prime importance for citizens. The number of hospitals and doctors in rural areas are not adequate at present. Many rural residents are not able to take treatment for basic ailments due to a lack of health care services in the vicinity. The infrastructure as well as the staff that is required to provide the health care service in rural areas is insufficient. For providing health services in these areas, smart health care solutions such as e-health, m-health and telemedicine solutions are required to be implemented.

Telemedicine, e-health, m-health, and wearable personal health devices along with a unique identifier of the person for identification may be used to capture the vital parameters using smartphones / laptops and may be further transmitted to the system. A specialist sitting in the urban areas may monitor the vital parameters and advise the doctors/patients in the rural areas.

Using remote health monitoring in rural areas, even a person with moderate education or semi-skilled worker may use wearable devices to measure the vital parameters of patients which may be communicated to the laptop/tablet and stored in the concerned page. A unique identity number allotted to an individual may be used as an identifier and data may then be transferred to the platform located in the cloud [b-ITU-T Y-Sup.53].

Above mentioned applications may also be used for remote monitoring of patients after surgery who can be sent to their homes, and vacant beds may be used for other patients. It also reduces the cost of treatment in case of surgery.

Smart devices like thermometers, SpO2 meters, portable electrocardiography (ECG) machines with Bluetooth connectivity may be used to monitor the patients remotely by doctors as there may be a shortage of beds in the hospitals, in particular during pandemics.

Once 5G network is deployed, the ultra-reliable low latency communication (uRLLC) feature [b-ITU-R M.2441-0] may be used for remote surgery of patients. For places that are not connected to the optical fibre cable (OFC), 5G will be beneficial in providing high speed connectivity for the provisioning of smart services in rural areas.

NOTE – Figure 3 illustrates a remote health monitoring architecture based on [b-ITU-T H.810] which may be used in rural areas for improving rural health services.

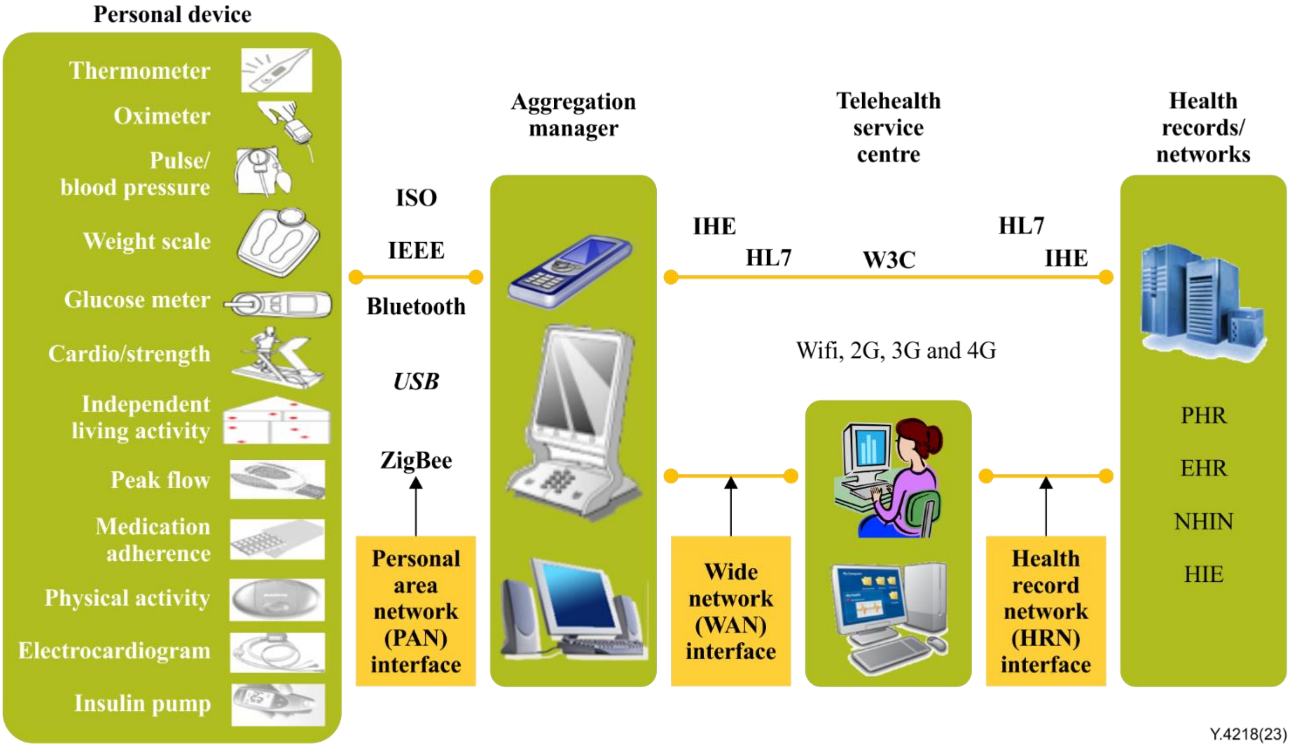

Figure 3 – Remote health monitoring architecture (based on [b-ITU-T H.810])

The following provides a non-exhaustive list of advantages of using IoT and ICT in healthcare:

1) Wearable IoT healthcare devices help in remote monitoring of vital parameters of patients.

2) Specialists sitting in urban areas may monitor the vital parameters and advise the doctors / patients in the rural areas.

3) Using uRLLC features of 5G technology, remote surgery of patients will be possible.

4) Health related data of a patient, with their prior consent may be stored on a cloud/server for future use without human intervention.

5) After surgery, patients may return home in an e-ICU type environment.

NOTE – e-ICU is a 24x7 monitoring system designed to remotely treat critically ill patients [b-eICU-Fortis healthcare]. Vital parameters of the patient may be transmitted to the hospital for monitoring. It will help in managing the shortage of beds in the hospital.

6) Connected devices in the healthcare domain will be useful in pandemics and thereafter in managing health care in urban as well as rural areas.

7) Use of AI in healthcare helps in better prediction, diagnosis, and treatment of diseases.

8) AI enabled healthcare tools augment medical professionals' capabilities to deliver better healthcare services.

9) AI/ML may be used to analyse increasingly sophisticated medical images to diagnose fractures, cancers, strokes, and many other medical conditions.

7.2.3 Tele-education

ICT and Internet access is a 'pull-factor' providing incentives for school attendance and for attracting and retaining good teachers. Tele-education brings together different technologies such as the Internet, mobile and smart devices hence assist in the learning process. The use of LCD screens and interactive videos can foster learning in students especially children. Schools in rural areas can be equipped with the Internet and other devices so that learning can be made a fun activity, turning schools into smart schools.

During a pandemic, such as Covid-19, and after that, various types of applications and remote participation platforms are being used for organising virtual classes in the education sector for students living in cities as well as in rural areas. Other applications are also being used to send video lectures and study material online. For this purpose, low-cost smartphones / tablets / laptops with basic minimum features such as wireless fidelity (Wi-Fi) and long battery life, may be used to provide school education in rural areas. During such a time as this, many online learning platforms offered free access to their services. It is believed that, even after the pandemic is over, traditional offline learning and e-learning may co-exist.

The following provides a non-exhaustive list of advantages of using IoT and ICT in tele-education:

1) Smart classrooms may be created in villages having connectivity with other educational institutions around the world.

2) Student's drop-out rate may be reduced.

3) Distant and adaptive learning is possible, thus reducing the need to move to towns or cities to achieve a better quality of education.

4) Various applications and remote participation platforms assist in organizing virtual classes.

7.2.4 Livestock farming

The economy of farmers in villages depends on two major activities agriculture and animal husbandry. Animal husbandry practices are followed by the animal keepers while their health is looked after by veterinarians. Due to the paucity of appropriate number of veterinarians, the health of animals is not maintained properly and in a timely manner, so it takes time to identify a sick animal at an early stage.

If by using newer technologies we can identify a sick animal, appropriate therapeutic, preventive and control measures can be taken to reduce the losses on account of production, morbidity and mortality. Biosensor technology can offer the livestock industry new types of monitoring and measuring devices for specificity, sensitivity, reproducibility, and speed, and thus ease the use of the latest technologies in this sector. Sensor based IoT devices can be used in the early detection and identification of infectious diseases in livestock, contaminants, and toxins in feed and therapeutic drug residues in animal husbandry.

Some applications of biosensors that highlight the advantages of using various types of biosensors chips in the animal husbandry sector are listed below:

a) Tracking of animals at the time of migration from one state to another or across national borders.

b) Traceability of adulterations in milk.

c) Checking possible infections from animals to humans.

d) Monitoring the health of the animals.

e) Monitoring and detection of the oestrus cycle.

f) Increasing productivity of animals and in turn increasing the income of farmers and veterinarians.

By applying IoT/ICT technologies, the livestock industry may be able to transform and approach breeding in a scientific way. IoT may increase industry profits, reduce drug use, increase the well-being of animals, and also increase the quality of livestock products.

7.2.5 Aquaculture

Fisheries and aquaculture are one of the fastest-growing sub-sectors of agriculture. The sector plays an essential role in meeting the food and nutritional security of the rising population. The sector also makes vital contributions to the global food production.

IoT technology may be used to monitor the water quality as well as vital parameters related to the health and development of fish in aquaculture. The smart device for aquaculture may have sensors like feeding sensors, water level sensors and water quality parameter sensors (temperature, pH, turbidity, carbonates and bi-carbonates, ammonia, etc.) to monitor various parameters in real time.

This data may be sent to a data centre/cloud which may be further analysed using AI algorithms or by specialized personnel and the results may be transmitted to the fishermen's smartphones/mobiles for taking further necessary actions.

Besides this, IoT may be also used to monitor and manage the following items in aquaculture:

1) Weather monitoring: Farmers can be alerted to the daily forecast so that they can plan their schedule and alternate any fishing practice with the pre-knowledge of the weather. This weather monitoring can also save their produce from any natural calamities and prevent any future loss.

2) Feed management: Intelligent automatic feeders ensure the feeding of the cultured fish by monitoring accurate feeding patterns, analysing the behaviour of the fish such as the hunger level and controlling dispensers that release the right amount of feed. This application aids in avoiding wastage of feed and deterioration of water quality.

3) Remote monitoring: Satellite imaging and drones can aid farmers to monitor their remotely located farms. This can assist them with accurate information regarding size, feeding patterns, health, and water quality. As a result, preventive and corrective measures can be taken in time to minimize the losses ensuring good animal health and increasing the productivity.

8 IoT and ICT requirements for the deployment of smart services in rural communities

8.1 Requirements of telecommunication infrastructure in rural areas

The expansion of telecommunications services in rural areas has been slower than in urban areas due to poor return on investment (ROI) for the telecom service providers (TSPs). Low teledensity in rural areas is due to poor economic condition of most of the villagers and due to poor coverage of telecom services. There are limited numbers of mobile towers such as base transceiver stations (BTS), abrupt electricity supply, poor transport systems and roads, and distant locations of petrol pumps, etc. in the interior portion of the rural areas.

NOTE 1 – In recent years there has been a large expansion of Internet services, mostly driven by cheaper smartphones and affordable mobile Internet tariffs. However additional work is required to enable further expansion of the telecom networks in rural areas, at least in the developing as well as underdeveloped countries.

The requirements for the development of telecommunication infrastructure in rural areas are as described below:

- It is required to provide a high-speed communication network with a transmission capacity of 1 Gbit/s in the backhaul for a population of around 1 000 persons [ITU-T L.1700]. This level of bandwidth may be easily created on an optical fibre network, which may be further extended to provide around 100 Mbit/s bandwidth in a village or for a cluster of 2-3 adjacently located villages. Provisions may be made in the transmission equipment to upgrade the bandwidth to 10 Gbit/s in the backhaul and 1 Gbit/s in the village for future requirements.
- To provide services to the rural community at their doorstep, it is required to further extend the connectivity in the village or nearby villages using Wi-Fi hotspots.
- The connectivity may be further extended to the nearby villages through an OFC or radio link depending upon the local terrain.
- The connectivity to hilly and remote areas may be provided using satellite links.
- It is required to further extend the bandwidth to other locations by laying OFC by telecom service providers for commissioning new mobile towers (BTS) to provide mobile coverage in the rural areas.
- It is recommended that one infrastructure provider installs the infrastructure such as towers of 20 / 40 / 60-metre height (as per requirement), diesel generator sets, battery sets, containers, etc. which may be used by telecom service providers/LPWAN providers. The tower height will depend upon the terrain and the region to be covered. Cost effective solar panels capable of replacing electric generators may be a solution for the fast expansion of mobile networks in rural areas.
- Sharing of passive/active infrastructure and the unused spectrum in the rural areas is recommended, which will help in reducing the overall cost of the project.
- It is recommended that towers and bandwidth may also be used by frequency modulation (FM) broadcasters for transmitting regional programmes. Besides entertainment, FM channels may play an important role in spreading important news such as cyclones / heavy rains weather forecasts, etc., to alert the people and civil agencies for moving to safer areas. It may save thousands of lives during such events.
- It is required that all efforts aim to utilise the OFC as soon as it is commissioned, and it should be monitored from the central monitoring server (CMS). OFC, if lying idle for a long time and damaged in some development activities such as road widening, drainage work, etc., is required to be repaired in a timely manner before starting the services.
- The role of the equipment manufacturer is also very important. Due to poor electricity conditions, poor condition of roads and distant location of petrol pumps in rural areas, it is quite difficult and expensive to run the rural BTS with even 90% availability. For those

reasons, it is recommended that low power BTS and transmission equipment are used to reduce the overall power consumption.

- A complete ecosystem is required to be developed for the rural area. Governments as policymakers, telecom service providers, equipment manufacturers, and local bodies are expected to work together for a win-win situation for the expansion of telecom services in rural areas.

  NOTE 2 – As an example, see Appendix I.

8.2 Requirements of low cost and sustainable communication network in rural areas

In order to guarantee accessibility to various smart services, it is required that a low cost and sustainable communication network be created in rural areas, in order to have economies of scale.

It is recommended that the communication network meets the requirements that are developed into [ITU-T L.1700].

NOTE – Related ITU-T Supplements for developing low-cost sustainable telecommunications infrastructure for rural communications in developing countries, namely [b-ITU-T L-Sup.22] using optical fibre cable, [b-ITU-T L-Sup.23] using radio links, [b-ITU-T L-Sup.29] using cellular technologies, [b-ITU-T L-Sup.30] using cellular network with capacity transfer and [b-ITU-T L-Sup.31] using satellite systems, are useful complementary documents in terms of technical information.

Optical fibre cable (OFC) may be used to create the backbone network for the provisioning of wireline/wireless services in rural areas. It can provide high bandwidth at low cost.

OFC network may be extended in rural areas according to the following process:

i) For providing OFC connectivity in the villages and to also have economies of scale, incremental OFC (approximately 1.5 km – 2 km) for last mile connectivity may be planned from the existing OFC passing through the nearby route and other villages also in the 1-2 km range. Optical fibre cables being laid for the villages may be connected with the existing OFC using a splitter. Two fibres will be used to connect a number of villages through a splitter.

ii) If the OFC coming from the optical line terminal (OLT) towards the village areas is having a sufficient number of good quality fibres, then each village may be connected on separate pair of fibres and a splitter is not required. The planner may decide depending on the availability of fibres and the requirement.

iii) Fibre to the home (FTTH) and gigabit passive optical network (GPON) technology [b-ITU-T G.984.1] may be used to create a network for connecting the villages. OLT equipment may preferably be installed in the telephone exchange, having stable connectivity at the backend with different networks/servers on Gigabit connectivity (1 Gbit/s extendable to 10 Gbit/s). Optical network terminal (ONT) may be installed in the village and connected with the OLT over the OFC as detailed above. Initially, 100 Mbit/s bandwidth may be provided on the ONT which may be further extended to 1 Gbit/s in the future.

   - In the villages, issues related to proper housing of equipment, environment, power, safety, etc. may arise at some of the locations. Therefore OFC, ONT, power supply, patch cord, etc. may be placed in a box (so-called "Fibre optics network terminal box") suitable for indoor as well as outdoor applications [b-ITU-T L.209].
   - This connectivity may be further extended in the village or nearby village area by using Wi-Fi hotspots, for providing Internet facilities to the villagers at their doorstep (refer to Appendix II for more details).
   - This bandwidth may be hired / leased by telecom service providers, including LPWAN (Low power protocol for wide area wireless networks) providers, and the network can be extended to their location through OFC/radio links, for expansion of their networks.

iv) Villages not accessible through OFC may be connected using radio links from the nearby village having an ONT switch and the tower for mounting the radio link.

v) Provisions may be made for upgrading the bandwidth for the village from 100 Mbit/s to 1 Gbit/s and in the backbone from 1 Gbit/s to 10 Gbit/s in the future.

The OFC network extension may improve the backbone network for telecom and ICT services in the rural area. Using this network, a smart rural community may be supported by a range of narrowband and broadband technologies for the transmission of voice, video, and data over networks and ICT applications.

8.3 Requirements of IoT devices

IoT devices are necessary for connecting physical things in the verticals, such as agriculture, fisheries, healthcare, animal husbandry, water management, etc., with virtual things using interoperable information and communication technologies (ICT). IoT devices are extremely varied in nature and may consist of some or all of the components such as sensors, actuators, power supply, processing capability (microcontroller / microprocessor unit), memory, operating system and an application.

IoT devices are often resource-constrained. Most IoT devices use a microcontroller rather than a full-fledged microprocessor and run at a few hundred MHz rather than GHz. The IoT devices could also be as advanced as in a connected car with powerful electronic control units (ECUs), varied wireless communication interfaces and millions of lines of code or a simple temperature monitoring device.

There are different types of sensors available at present time and the related sensors are used in the IoT devices as per the requirement of the use case. The availability of sensors and other electronic items is a necessity for developing IoT products.

A smartphone is supporting a number of sensors and communication technologies; therefore it may be used as an IoT device and also as an IoT gateway. Applications of smartphone-based sensors and communication technologies are listed in Table 2.

Table 2 – Smartphone sensors and communication technologies

Smartphone sensor(s) and communication technologies	Purpose	Common usage
Image sensors (Camera)	Take pictures of any object	Disease detection, chlorophyll status, fruit ripeness, leaf area index (LAI), harvest readiness, soil erosion and other analysis in agriculture
Global navigation satellite system (GNSS)	Measures the latitude and longitude of the device and location	Local information is attached to generate alerts. Mostly used for machine driving and control, and tracking, land management and crop mapping
Inertial sensor	Uses an accelerometer and gyro sensor to determine the object's altitude in relation to the inertial system	Precise distance of plants, leaves or any other object is measured by the camera
Pressure sensor	Measures air pressure as an altimeter. Mostly used in correcting altitude measurements by the GNSS	Measurement of the elevation height in hilly agricultures
Gyroscope	Senses the angular velocity to track the object's rotation or twist	Equipment movement and canopy structure measurement

Table 2 – Smartphone sensors and communication technologies

Smartphone sensor(s) and communication technologies	Purpose	Common usage
Accelerometer	Measures acceleration forces that are used to observe the tilting motion and orientation of the object	Precise movement or rotation of the camera during use and detection of workers or machine activities
Microphone	Detects usual/unusual sound and converts them to electrical signals	Machine maintenance and bug detection to make audio queries
Bluetooth low energy	Communication between IoT nodes and smartphones	Mobile apps can receive IoT node sensor data deployed in the field
Near field communication	Commissioning / calibration / diagnosis	IoT node sensor data can be calibrated and diagnosed
Wi-Fi / GPRS communication	Communication with Internet	Data can be exchanged between cloud and IoT sensor node

8.4 Communication technology related requirements

Communication technologies play an important role in transmitting the data from the device to the headend system. In most IoT use cases, the timely transmission of data is of utmost importance. For this, the communication network is required to be reliable with low latency and is also recommended to have wide coverage.

The data size may vary from use case to use case. As an example, data may be from a few bytes (metre reading/soil data) to several megabytes (surveillance video) and may be in the form of bursts. The communication technologies for connecting the IoT devices will depend upon the use case.

There are various types of communication technologies being used in connecting IoT devices. These include, but are not limited to, low power wireless communication technologies (NFC [b-NFC], Bluetooth [b-Bluetooth], etc.), covering a short range [b-ITU-T H.810], LPWAN – Cellular/non-cellular, cellular (2G, 3G, 4G, 5G), fixed line (wireline, PLC). In the view of the development of cellular technologies at a fast pace, it is recommended to adopt 4G/5G technologies in rural areas.

5G is critical in the digitization, automation and connectivity of society. 5G is a technology designed for vertical industries to provide features such as enhanced mobile broadband, mission critical services (ultra-reliable and low latency communication) with latency < 1 ms suitable for applications such as vehicle to vehicle (V2V) / vehicle to infrastructure (V2I) applications, robotics surgery, drones, etc., and massive M2M (10x more connected devices, one million devices may be connected per square km) [b-ITU-R M.2441-0]. 5G provides features such as beam forming and small cells and consumes less energy than 4G. 5G radio access addresses a wide range of requirements with features not available in 2G-4G technologies.

Services such as voice, Internet, video, smart applications, etc., as illustrated in Figure 1 as well as in LPWAN technologies have been developed to carry small data packets to large distances while consuming very low power. They cover 2-3 km in urban (dense) areas and 12-15 km in rural (open) areas. The expected battery life is around 10 years. LPWAN technologies are available according to 3GPP as well as non-3GPP standards as shown in Figure 4.

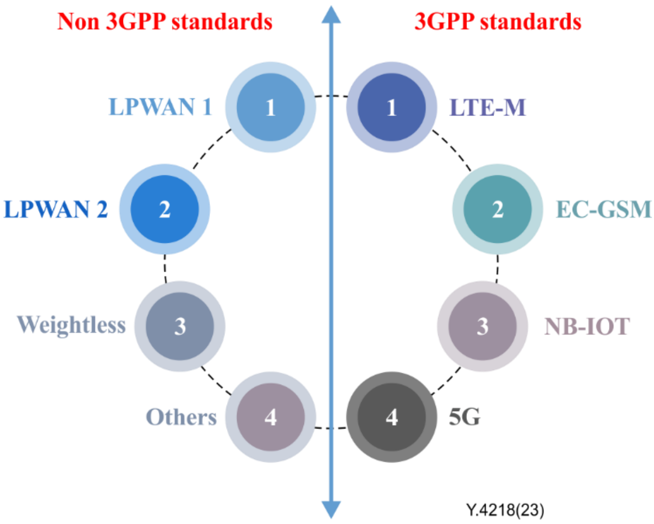

Figure 4 – LPWAN technologies [based on b-ITU-D IoT standards]

NOTE 1 – 3GPP has released specifications in its Release 13 and onwards for LPWAN services [b-ITU-D IoT standards II], which may co-exist in the existing cellular networks. The three variants in LPWAN technologies in the cellular domain are extended coverage – global system for mobile communication (EC-GSM), narrow band – Internet of Things (NB-IoT) and LTE MTC [b-ITU-R M.2440-0]. Cellular operators may enable LPWAN services in the existing GSM/LTE networks by upgrading the software.

NOTE 2 – Communication technologies and related IoT applications have been described in Appendix II.

Figure 5 illustrates a representative example of a network diagram with various IoT devices connected with the cloud, through IoT gateways or directly over WAN technologies.

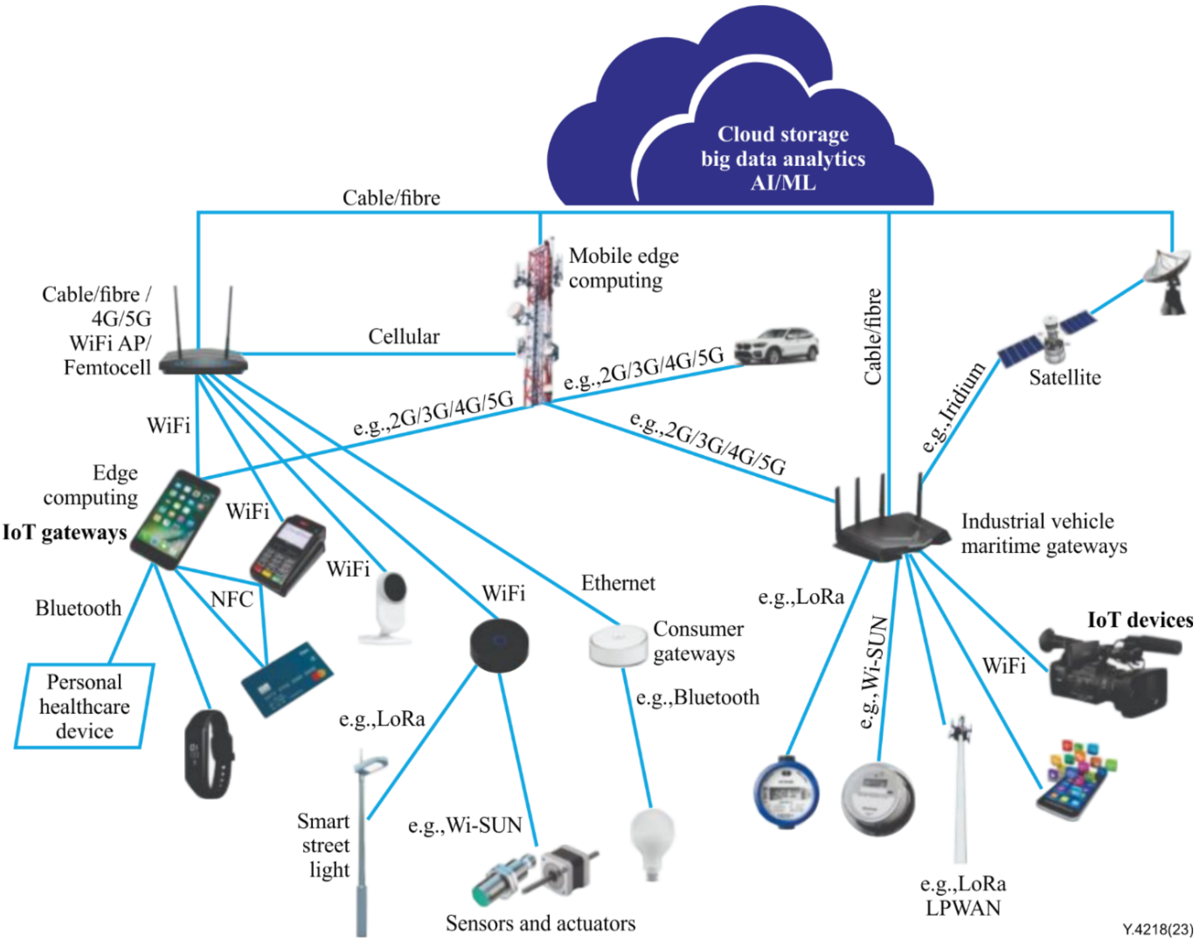

Figure 5 – Representation example of a network diagram

As shown in Figure 5, devices working on low power wireless communication technologies may be connected on IoT gateways and the data received may be transmitted to the headend system on cellular/wireline connectivity. IoT gateway interconnects the devices with the communication networks. It performs the necessary translation between the protocols used in the communication networks and those used by devices. Smartphones / tablets having Wi-Fi, Bluetooth, and cellular connectivity features may also be used as a gateway for low power wireless devices, especially in health care.

NOTE 3 – Devices/IoT gateways to be connected directly to public switched telephone network (PSTN) / public land mobile network (PLMN) should have IPv6 or dual stack (IPv4 and IPv6) capability. In view of the IAB statement on IPv6 [b-IAB IPv6], IPv4 compatibility may not be available in future developments, i.e., in new or extended protocols. Therefore, transition to IPv6 only in PSTN / PLMN networks will be required in the future. Gateways and devices to be connected directly to these networks will also be required to switch over to IPv6 only capability.

8.5 Requirements of platforms

In order to have interoperability and sharing of data across verticals, it is necessary to implement platform solutions based on a common standardized framework. Since villages are part of a district, therefore smart devices deployed in rural areas may be connected to a smart city platform available in the district.

If such a smart city platform is not available, then it is recommended to establish a connection to other appropriate standard-based platform(s) (in other districts or cities) capable of supporting all related verticals of the rural areas. Such platforms allow to reuse and share resources, thus reducing operational costs.

All these platforms are recommended to be agnostic to communication technologies.

It is recommended that the platforms have the feature of a common service layer [b-ITU-T Y.4413] [b-ITU-T Y.4500-1] for sharing of data across verticals.

It is also recommended that the platforms be interoperable with other platforms and use open interfaces for sharing of data [b-ITU-T Y.4200] [b-ITU-T Y.4201] and [b-ITU-T Y.4413].

8.6 Security related requirements

End to end security, i.e., from devices to applications, is required for the development of a secured ecosystem. Each segment of the communication network is responsible to ensure security within its zone.

Secure onboarding of IoT devices on the platforms is required to manage device identity for the lifecycle.

NOTE 1 – This can be handled, e.g., by provisioning the secure device identities with a PKI-based platform [b-ITU-T X.509].

NOTE 2 – [b-ITU-T X.509] specifies public key infrastructure (PKI) for device identity. PKI provides a scalable way to declare unique identities and authenticating messages of the communicating parties.

Platforms are recommended to be able to detect the vulnerabilities / hackings of IoT devices.

8.7 Other requirement considerations for provisioning smart services to rural communities

For expanding the Wi-Fi network in a rural community, it is required to explore the possibilities for providing Wi-Fi hot spots to shopkeepers making them as "public data offices" (PDO), for providing Internet services to users on a payment basis. This will be a source of income for the shopkeeper and help in the proliferation of Internet services in the rural community. This will also aid in reducing the unemployment in rural areas. Appendix I can be referred to for details related to public data offices in the context of rural services.

Smartphones, laptops and tablets may be out of the budget of lower and medium income families in rural areas of most developing and underdeveloped countries. There may be a large market for cheaper and good quality smartphones, laptops, and tablets with long battery life which may accelerate the growth of mobile networks in rural areas. The cost of these devices may vary from country to country, but if the rural population is able to afford these devices, it will help in increasing the wireless teledensity (number of wireless subscribers / 100 population), Internet usage and in turn the digital literacy in rural areas [b-India-TEC Report].

Around one-third of the global population still cannot or do not have access to the Internet despite 97% of the global population having mobile data coverage as revealed in the report "Strategies towards universal smartphones access", published in September 2022 [b-ITU-smartphones access]. Gap in mobile data coverage in the developed and least developed countries is around 6% whereas in a number of Internet users it is above 43% (Internet users in the developed countries are around 92% whereas in the least developed countries it is around 36%). Less number of Internet users are due to the non-affordability of smartphones. High cost of the devices, data tariff, lack of consumer awareness and basic digital skills may be some of the factors limiting the adoption of smartphones. Increasing device financing options, introducing fair taxation and import duties, and improving the distribution to remote areas may be some of the key interventions in increasing the adoption of smartphones. Accessibility of smartphones to all will provide Internet access, which will help in reducing the digital divide, increase in gross domestic product (GDP) and empower individuals and communities across the world.

Appendix I

Government of India's initiative for the expansion of Internet services in rural areas

(This appendix does not form an integral part of this Recommendation.)

Department of telecommunication (DoT), Ministry of communications (MoC), Government of India (Republic of) created in 2011 a special purpose vehicle, named Bharat broadband network limited (BBNL), for accelerating the national optical fibre network project (NOFN, now BharatNet) in order to provide 100 Mbps connectivity to 0.25 million gram panchayats (GPs), with the vision to digitally connect all the gram panchayats and the villages to transform India into a digitally empowered society and knowledge economy. One gram panchayat has 2-3 nearby villages. This project is being implemented by the DoT through the universal service obligation fund (USOF) [b-USOF].

The scope of BharatNet now has been extended up to all inhabited villages beyond GPs in the country with the timeline being 2025.

BharatNet Phase-I project was completed in December 2017 connecting around 0.1 million GPs. For connecting GPs, approximately 1.5-2 kilometre OFC was planned to be laid as a last mile connectivity from the nearest point of existing OFC coming from the optical line terminals (OLT) installed / planned in the telephone exchange preferably at the block headquarters (BHQ). Optical fibre cable (OFC) as a last mile connectivity for the nearby GPs have been connected with the OFC coming from the OLT using a splitter and terminated in the GPs on the optical network terminal (ONT). Fibre to the home (FTTH) and the gigabit passive optical network (GPON) technologies have been used to provide 100 Mbit/s connectivity to each village panchayat. OLTs have been further connected at the backend with different networks on gigabit connectivity for providing the services. Necessary arrangements for proper environment and power backup have been made at the OLT as well as the ONT locations. Connectivity at the ONT may be further extended to nearby villages through the OFC, radio terminals, etc., depending upon the geography of the area.

Under BharatNet Phase-II, approved in July 2017, it was planned to connect the remaining around 0.15 million GPs with an optimal mix of media (OFC / radio / satellite). Further, all new 48 fibre OFC had been planned to be laid from the block POP (OLT) for connecting 6-8 GPs as a measure for strengthening the network to the GPs. From the nearest point to the GPs, 6 fibre cables have been laid to each GP and connected to the 48 fibre OFC.

As illustrated in Figure I.1, an Internet facility is being provided to the villagers using a Wi-Fi mesh network. It may be extended to nearby schools, hospitals and other institutions over Wi-Fi, OFC or / and radio modems depending upon the distance of local terrain. Internet bandwidth may also be taken on lease by the telecom service providers and LPWAN providers for extending their services in rural areas.

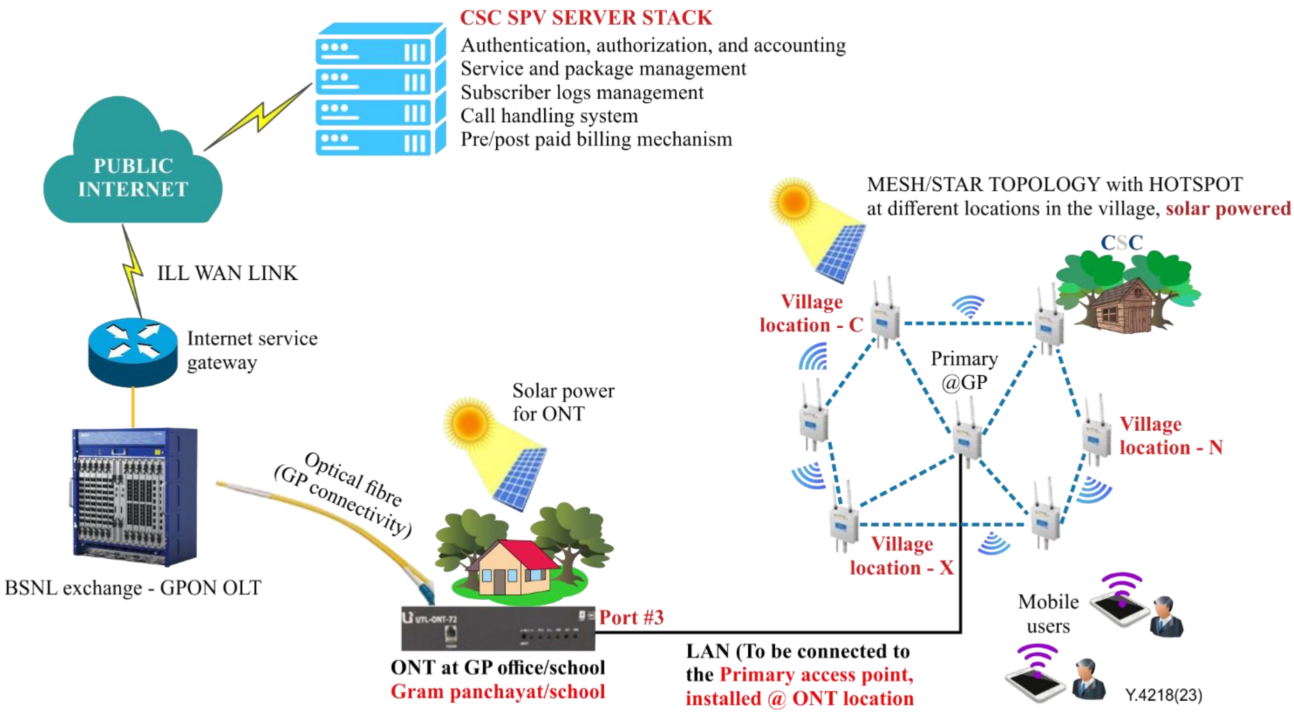

Figure I.1 – Deployment of telecom infrastructure through BharatNet [b-USOF]

The overall project status is available on the USOF webpage [b-USOF] and the execution details on the BBNL website [b-India-BBNL]. Around 0.19 million gram panchayats were connected on the optical fibre cable by December 2022 and the work is in progress to connect the remaining gram panchayats.

Department of telecom (DoT) released a framework and guidelines for Wi-Fi access network interface (PM-WANI) [b-India-DoT-WANI] to proliferate broadband access through public Wi-Fi networks. This framework takes forward the goal of the national digital communications Policy (NDCP)-2018 for creating a robust digital communications infrastructure. NDCP-2018 has also envisaged the connectivity of the GPs to be upgraded to 1 Gbit/s/10 Gbit/s from 100 Mbps in the near future [b-India-DoT-NDCP]. It will give a major boost to providing broadband Internet connectivity through Wi-Fi networks and will also help in enabling smart solutions in rural areas.

This project has improved the backbone network for telecom and ICT services in the rural areas where OFC has been laid and telecom services have been provided as detailed above. Voice as well as data services are being extended to the rural masses. This project will also facilitate various other smart services requiring high speed Internet connectivity, such as tele-education, telemedicine, e-banking, e-government and so on.

Appendix II

Communication technologies and related IoT applications

(This appendix does not form an integral part of this Recommendation.)

Communication technologies that may be used in smart rural communities for various IoT applications are listed below (not an exhaustive list).

Table II.1 – Communication technologies and related IoT applications

Technology / protocol	Frequency band (s)	Technological advantages	Technological limitations	Suitable for
1. Low power short range technologies				
Bluetooth low energy	2.4 GHz	• Mature technology • Easy to implement • Low power • Powered by coin cell • Longer battery life	• Small data packets	• Healthcare devices • Fitness devices • Remote health monitoring • Smart metering
NFC	13.56 MHz	• Consumes less power • Almost instantaneous connectivity between devices • No power is required in-case of passive tags	• Extremely short range • Expensive • Low information security • Low market penetration	• Healthcare devices • Fitness devices • Smart metering
Wi-Fi 4 Institute of Electrical and Electronics Engineers (IEEE) [b-IEEE 802.11n], Wi-Fi 5 [b-IEEE 802.11ac]	2.4 GHz and 5 GHz	• Mature technology • High home / office penetration • High data rates achievable • Easy to implement Wi-Fi 4 uses MIMO while Wi-Fi 5 MU-MIMO technology Maximum throughput speed Wi-Fi 4: 600 Mbit/s Wi-Fi 5: 3.5 Gbit/s	• Limited range • Poor building penetration • High interference from other sources • Power consumption is higher than those technologies that operate in the sub-GHz band	• Base station in health clinics • Smart metering • Home automation
Wi-Fi 6 [b-IEEE 802.11ax]	2.4 GHz and 5 GHz	MU-MIMO and OFDMA technology Maximum throughput speed 9.6 Gbit/s		• For better user experience even for dense indoor / outdoor deployments such as airports, railway stations, shopping malls, stadiums, homes,

Table II.1 – Communication technologies and related IoT applications

Technology / protocol	Frequency band (s)	Technological advantages	Technological limitations	Suitable for
				and school campuses
Wi-Fi 6 E [IEEE 802.11ax] devices capable of operating at 6 GHz also	2.4 GHz, 5 GHz and 6 GHz	• 6 GHz band provides 1 200 MHz additional spectrum to Wi-Fi 6 enabled devices, which doubles the bandwidth and throughput of Wi-Fi 6 enabled devices	• Smaller range compared to 5 GHz spectrum • 6 GHz band (5.925 GHz to 7.125 GHz) is required to be delicensed	• Applications like 8K video, AR/VR gaming and mission critical requirements
Wi-Fi HaLow [b-IEEE 802.11ah]	900 MHz delicensed band	• Low power • Longer connectivity range (approximately 1 km) • Internet protocol (IP) support available	• Comparatively larger antenna size	• IoT use cases in industrial applications, agriculture, health care smart building, smart homes, and smart city
Z-Wave	Sub 1 GHz (865-867 MHz) for India	• Standardised by CSR 564 (E), very successful due to its ease of use and interoperability • Majority share of the home automation market	• Proprietary radio systems available • Limited range drives up costs	• Security systems • Home automation • Lighting controls
2. Cellular technologies				
Cellular (2G-GSM / EDGE, 3G UMTS, 4G LTE)	Country or region specific	• Mature technology • Developed by a global community of 400+ companies from 39 countries • Rapid deployment • Communication modules are low cost and standardised. • Roaming • Wide availability of network infrastructure	• Coverage not 100% • Reliability not the best • Short technology life-cycle (2G, EDGE, 3G, LTE, etc.)	• Telehealth • Remote health monitoring • Smart metering • Remotely switching ON/ OFF the water pump in rural areas using a mobile phone

Table II.1 – Communication technologies and related IoT applications

Technology / protocol	Frequency band (s)	Technological advantages	Technological limitations	Suitable for
Cellular 5G: (Radio interface technology approved by ITU)	Country or region specific	• High speed internet services (eMBB) • Low latency (< 1 ms) (uRLLC) • Large number of devices may be connected/Sq km. (massive M2M) • Wider coverage • Technology for vertical applications		• e-government • Remote surgery • Drones • Remote maintenance of machines • Precision agriculture • Livestock monitoring and management
3. Cellular low power protocol for wide area wireless networks technologies				
Cellular: EC GSM IoT	Country or region specific	• Network infrastructure is backwards-compatible with previous releases to allow the technology to be introduced into existing GSM networks	• Eco system is yet to be developed	• Smart cities and homes • Smart utilities • Industrial automation • Wearables • Smart energy • Intelligent transport systems
Cellular: NB-IoT	Country or region specific	• Based on standards specified by 3GPP • Wide area ubiquitous coverage • Deployed through an upgrade of the existing network (reuses existing network infrastructure) • Ultra-low-power consumption in devices • Enhanced for 20+ dB additional coupling gain. (reaches deeper in-building and underground) • Low cost terminal • Plug and play • High reliability and high carrier-class E2E network security (based on LTE)	• Limited mobility is not yet supported (limited support based on cell reselection) • Voice is not supported • Low data rate applications with link peak DL = 60~100 kbit/s and UL = ~50 kbit/s	• Sensor based applications with low data rate requirement • Applications not requiring high speed mobility handovers • Systems where device / sensor measurements are expected to be for long ~10 years

Table II.1 – Communication technologies and related IoT applications

Technology / protocol	Frequency band (s)	Technological advantages	Technological limitations	Suitable for
Cellular: enhanced machine-type communication (eMTC)	Country or region specific	• Developed by 3GPP a mature global ecosystem • Low power consumption • Works over existing LTE networks • Easily configurable on-demand scaling is possible • Supports full mobility • Supports voice through VoLTE • High reliability and high carrier-class E2E network security (based on LTE)	• Support of higher bandwidth limits the other optimizations possible, compared to NB-IoT and EC-GSM-IoT	• Wearables • Asset tracking • Pet trackers • Telematics • KIOSK • Parking • Industry environment monitoring • Connected healthcare personal and enterprise equipment • Industrial IoT with emergency voice call support
4. Non cellular low power protocol for wide area wireless networks technologies				
Long range applications (LoRa) wide area network (WAN) (https://lora-alliance.org/)	Sub 1 GHz (865-867 MHz) for India	• Network can be defined by the individuals / owners • Support long range and high battery life • High security using Advanced encryption standard (AES) 128 encryption • Low cost infrastructure	• Own deployment with no subscription fees • Works in an unlicensed band • Limited data rate and payload size	• Smart metering • Smart street lighting solutions • Asset monitoring • Tracking • Transmission of soil data, transmitting fire alerts, etc. • Weather forecasting • Environment (CO_2, CO, humidity, temperature, etc.) monitoring
5. Wireline technologies				
DSL		• Inexpensive (installation and use) • High SLA • Less installation time • Bonded DSL provides inherent redundancy	• Low data security • Lower throughput • Higher latency	• Gateway for remote health monitoring • Concentrator for Telehealth • Home automation

Table II.1 – Communication technologies and related IoT applications

Technology / protocol	Frequency band (s)	Technological advantages	Technological limitations	Suitable for
Ethernet		• Inexpensive (installation and use) • Excellent throughput • Low installation time • Easily scalable	• Lowest data security • Lowest SLA • Highest latency • Bursts of additional bandwidth not possible	• Gateway for remote health monitoring • Concentrator for Telehealth • Smart metering • Home automation

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