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Recommendation

ITU-T F.780.5 (01/2024)

SERIES F: Non-telephone telecommunication services

Multimedia services

Requirements, reference framework and use cases for telemonitoring systems in rapid deployment hospitals

ITU-T F-SERIES RECOMMENDATIONS

Non-telephone telecommunication services

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Recommendation ITU-T F.780.5

Requirements, reference framework and use cases for telemonitoring systems in rapid deployment hospitals

Summary

Recommendation ITU-T F.780.5 describes the application scenarios, functional requirements, and reference architecture of telemonitoring systems in rapid deployment hospitals (RDHs) and applies them to planning and designing in RDHs. The appendix to this Recommendation includes use cases of the proposed reference system.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T F.780.5	2024-01-13	16	11.1002/1000/15763

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Rapid deployment hospital, reference framework, requirement, telemonitoring, use cases.

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Table of Contents

Recommendation ITU-T F.780.5

Requirements, reference framework and use cases for telemonitoring systems in rapid deployment hospitals

1 Scope

This Recommendation describes the use cases, reference framework and technical requirements for telemonitoring systems in a rapid deployment hospitals (RDHs). The scope of this Recommendation includes:

– Requirements for telemonitoring systems in rapid deployment hospitals.

– Reference framework for telemonitoring systems in rapid deployment hospitals.

– Use cases for telemonitoring systems in rapid deployment hospitals.

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 F.760.1] Recommendation ITU-T F.760.1 (2022), *Requirements and reference framework for emergency rescue systems*.

[ITU-T F.780.2] Recommendation ITU-T F.780.2 (V2) (2023), *Accessibility of telehealth services*.

[ITU-T H.860] Recommendation ITU-T H.860 (2014), *Multimedia e-health data exchange services: Data schema and supporting services.*

[ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary*.

[ITU-T Y.3502] Recommendation ITU-T Y.3502 (2014), *Information technology – Cloud computing – Reference architecture*.

[ITU-T Y.3601] Recommendation ITU-T Y.3601 (2018), *Big data – Framework and requirements for data exchange.*

[ITU-T Y.4101] Recommendation ITU-T Y.4101/Y.2067 (2017), *Common requirements and capabilities of a gateway for Internet of things applications*.

[ITU-T Y.4208] Recommendation ITU-T Y.4208 (2020), *Internet of things requirements for support of edge computing.*

[Bluetooth CS5.4] Bluetooth CS5.4 (2023), *Bluetooth Core Specification, v5.4.*

[ETSI GS MEC 003] ETSI GS MEC 003 V3.1.1 (2022), *Multi-access Edge Computing (MEC): Framework and Reference Architecture*.

[ETSI TS 123 501] ETSI TS 123 501 V17.10.0 (2023), *5G; System Architecture for the 5G System (5GS) (3GPP TS 23.501 version 17.10.0 Release 17).*

[IEEE 802.11] IEEE 802.11 (2020), *IEEE Standard for Information Technology – Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks – Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*.

[IEEE 802.15.4] IEEE 802.15.4 (2020), *IEEE Standard for Low-Rate Wireless Networks*.

[IETF RFC 6120] IETF RFC 6120 (2011), *Extensible Messaging and Presence Protocol (XMPP): Core.*

[IETF RFC 7252] IETF RFC 7252 (2014), *The Constrained Application Protocol (CoAP).*

[IETF RFC 8259] IETF RFC 8259 (2017), *The JavaScript Object Notation (JSON) Data Interchange Format.*

[ISO 18308] ISO 18308:2022, *Health informatics – Requirements for an electronic health record architecture.*

[ISO 19605-1] ISO 19605-1:2018, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 1: Concepts and principles.*

[ISO 23247-1] ISO 23247-1:2021, *Automation systems and integration – Digital twin framework for manufacturing – Part 1: Overview and general principles.*

[ISO/IEC 19464] ISO/IEC 19464:2014, *Information technology, Advanced Message Queuing Protocol (AMQP) v1.0 specification*.

[ISO/IEC 20922] ISO/IEC 20922:2016, *Information technology, Message Queuing Telemetry Transport (MQTT) v3.1.1*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 service level agreement (SLA) [ITU-T Y.3500]: Documented agreement between the service provider and customer that identifies services and service targets.

NOTE 1 – A service level agreement can also be established between the service provider and a supplier, an internal group or a customer acting as a supplier.

NOTE 2 – A service level agreement can be included in a contract or another type of documented agreement.

3.1.2 Internet of things (IoT) [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 exploiting identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, ensuring that security and privacy requirements are fulfilled.

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

3.1.3 electronic health record [ISO 18308]: It is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery settings. This information includes patient's demographics, progress notes, problems description, medication receipts, vital signs, past medical treatment history, immunizations, laboratory data and radiology reports.

3.1.4 personal health record [b-ISO/TR 14292]: It is an electronic, universally available, lifelong health information resource for individuals who need to make health decisions. Individuals own and manage the information in the PHR, which comes from healthcare providers and the individual.

3.1.5 fast healthcare interoperability resources [b-HL7 FHIR]: It is a set of rules and specifications for exchanging electronic healthcare data, such as EHR and PHR. It is designed to be flexible and adaptive and can be applied in a wide range of settings and different healthcare information systems.

3.1.6 user plane function [ETSI TS 123 501]: The UPF is a user plane network element in IMT-2020 system architecture and is responsible for all user plane functions, including traffic routing and forwarding, policy enforcement. Depending on different application scenarios, UPFs with different function sets are derived, including roles such as PSA UPF and ULCL UPF.

3.1.7 building information modelling (BIM) [ISO 19605-1]: The process of generating and managing building data through the whole life cycle of a built asset, from its initial design, and construction, to maintaining and de-commissioning. Implementing BIM facilitates project management and cross-disciplinary collaboration by sharing project information between engineers, owners, architects and contractors.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 rapid deployment hospital (RDH): The most important characteristic of RDH is rapid deployment to accept patients as soon as possible, including deployment of containers and facilities and deployment of computed tomography (CT) and information technology (IT) systems to support medical services.

3.2.2 telemonitoring: A continuous or non-continuous monitoring process that allows a healthcare professional to remotely interpret the data necessary for a patient's medical follow-up and, if necessary, make decisions regarding the patient's state of health.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

5G	5th Generation of Mobile Networks
5GC	5G Core Network
AMQP	Advanced Message Queuing Protocol
BIM	Building Information Modelling
CoAP	Constrained Application Protocol
COVID-19	Corona Virus Disease 2019
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
DNN	Data Network Name
ECG	Electrocardiogram
EHR	Electronic Health Record
EMR	Electronic Medical Record
FHIR	Fast Healthcare Interoperability Resources
HTTPS	Hypertext Transfer Protocol over Secure Socket Layer

IaaS	Infrastructure as a Service
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IoT	Internet of Things
IT	Information Technology
LR-WPAN	Low-Rate Wireless Personal Area Network
MEC	Multi-access Edge Computing
MEP	MEC Platform
MQTT	Message Queuing Telemetry Transport
NTN	Non-terrestrial Networks
PaaS	Platform as a Service
PACS	Picture Archiving and Communication System
PCF	Policy Control Function
PHR	Personal Health Record
PLMN	Public Land Mobile Network
PSA	PDU Session Anchor
QoS	Quality of Service
RDH	Rapid Deployment Hospital
REST	Representational State Transfer
SaaS	Software as a Service
SIM	Subscriber Identity Module
SLA	Service Level Agreement
TAC	Type Allocation Code
UAV	Unmanned Aerial Vehicle
ULCL	Uplink Classifier
URI	Uniform Resource Identifier
VPN	Virtual Private Network
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol

5 Conventions

In this Recommendation:

– The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

– The keywords "is recommended" and "should" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement needs not be present to claim conformance.

– The keywords "can optionally" and "may" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are 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 the specification.

6 Background

Both natural and complex disasters may produce a massive number of casualties that outstrip the ability of the local healthcare system to provide the necessary care. As a consequence, temporary hospitals, generally called field hospitals, mobile hospitals, or cabin hospitals, have been used to meet emergency requirements and have achieved notable success.

As defined by WHO in 2003, a field hospital is a mobile, self-contained, self-sufficient healthcare facility capable of rapid deployment and expansion or contraction to meet immediate emergency requirements for a specified period. A field hospital can be set up in an existing structure or a temporary structure, tent, or similar. Field hospitals are deployed in a wide range of scenarios, including natural disasters, epidemic outbreaks, armed conflicts, and refugee crises.

A mobile hospital is a medical centre or a small hospital with a full range of medical equipment that can be moved and settled in a new place and situation swiftly in order to provide medical services to patients or wounded persons in critical conditions such as wars or natural disasters. In particular, a mobile hospital is bigger than first-aid units and smaller than a permanent hospital. Also, the mobile hospital can be connected to another field hospitals to increase ward section capacity anytime and anywhere.

Cabin hospitals are intended for large-scale medical isolation and are instituted either by establishing rapidly constructed modular/portable buildings or through the acquisition of indoor spaces within existing venues and even in temporarily renovated gyms and dorms in colleges and universities with enclosed cubicles to assist social distancing.

Whether field hospital, mobile hospital, or cabin hospital, their most important characteristic is rapid deployment in order to accept patients as soon as possible, including not only deployment of containers and facilities, but also deployment of computed tomography (CT) and information technology (IT) systems to support medical services. It is recommended to unify the category name of these hospitals as rapid deployment hospitals (RDHs).

Telemonitoring refers to the transmission of symptom scores, physiological data, including heart rate, blood pressure, oxygen saturation, and weight, directly to care providers either via automated electronic means or by web-based or phone-based data entry. Integration of monitoring technologies in smartphones and wireless devices is a key trend in patient care.

Most RDHs face a shortage of doctors and nurses, and on the other hand, medical workers should avoid face-to-face contact with patients in epidemic scenarios. Telemonitoring technology in RDHs has thereby become a research hotspot.

7 Requirements for telemonitoring systems in rapid deployment hospitals

7.1 System functional requirements

This clause will provide a detailed description of the requirements of a telemonitoring system:

a) It should support the modular deployment and prefabricated construction of hospitals in open areas such as suburbs and the wild, that can be relocated and reused in different places, and the transformation of existing infrastructure based on ships, large gymnasiums, buses, and campervans;

b) It should support remote data exchange such as e-health data exchange [ITU-T H.860], big data exchange [ITU-T Y.3601] and video interaction to provide interoperable exchange among the RDH and a remote central hospital;

c) It should support a contactless medical environment to reduce or avoid cross-infection among patients and between patients and medical staff;

d) It should support at least one kind of wide-area network (WAN) to provide basic telemonitoring communication services, such as public cellular network (e.g., 2G, IMT-2000, IMT-advanced, IMT-2020), microwave network, or satellite network; the dedicated network should be supported if the public cellular network were available, providing private communication resources for guaranteed service level agreement (SLA) performance under massive medical terminal connection scenarios;

e) It should support multiple network connections for numerous category sensors and medical devices, such as a cellular network and non-3GPP network. The non-3GPP network includes wired network, wireless local area network (WLAN) [IEEE 802.11], wireless personal area network (WPAN) [Bluetooth CS5.4], and low-rate wireless personal area network (LR-WPAN) [IEEE 802.15.4];

f) It should support cloud-edge management to provide unified management on resource scheduling of the cloud platform, applications management, and services management, etc.;

g) It should support various applications under different telemonitoring scenarios, such as teleguidance, teleconsultation, telemedicine, and tele-radiotherapy;

h) It can optionally support building information modelling (BIM) [ISO 19605-1] technology during the RDH's deployment process, which enables three-dimensional visualization of building information and relative data to help reliable deployment for the RDH.

7.2 Requirements for application platforms

The requirements of telemonitoring application platforms are listed as follows:

a) It should support real-time data acquisition and monitoring of the use of hospital beds, drugs, medical equipment, and a series of equipment-related factors, such as heat dissipation, vibration, noise, safety, cross pollution, operation and maintenance of medical equipment;

b) It should support real-time data acquisition and monitoring of the patients' multiple physiological parameter data, such as electrocardiogram (ECG), heart rate, blood pressure, blood sugar, blood oxygen saturation, and body temperature;

c) It should support real-time data acquisition and monitoring of various environmental indicators, such as pressure, oxygen concentration, temperature, humidity, wind speed, noise, water quality and the concentration of solid particles in RDHs;

d) It should support the local storage of collected data by law-compliant and standards-based electronic health records, such as electronic health record (EHR) [ISO 18308] and personal health record (PHR) [b-ISO/TR 14292]. It should be noted that collecting PHR data must be authorized by individuals within the legal framework;

e) It should support different types of collected data (e.g., text, voice, image, and video) to be encoded in a common health data schema, such as extensible markup language (XML) [b-W3C XML 1.0], for data exchange [ITU-T H.860];

f) It should support the transmission of collected data between the RDH and remote central hospitals using fast healthcare interoperability resources (FHIR) [b-HL7 FHIR] representational state transfer (REST) APIs over a secure and encrypted channel (e.g., web service call over HTTPS);

g) It should support various telemonitoring applications, such as telemonitoring guidance, nursing, operation management, training and teaching, and multi-point telemonitoring;

h) It can optionally support a digital twin [ISO 23247-1] implementation for telemonitoring, which replicates the physical model and continuously adapts to operational changes based on real-time data from various sensors and devices. Using its digital twin model will enable remote control and monitoring of the actual equipment;

i) It can optionally support monitoring the generous and unpredictable demand for medical services to reduce the pressure on the medical staff;

j) It can optionally support intelligent robots, which can serve patients as human caregivers (e.g., delivering basic living supplies and providing clinical assistance) and perform predefined tasks autonomously in different scenarios (e.g., logistics, cleaning, and monitoring of patients) through remote manipulation and intelligent algorithms;

k) It can optionally support an indoor positioning system to realise the position monitoring of personnel and equipment in the cabins;

l) It can optionally support tele-radiotherapy management function to realise hierarchical diagnosis and treatment between the RDH and remote central hospitals. The management function includes formulating, verifying and implementing radiotherapy plans for patients in the RDH;

m) It can optionally support body posture detection and analysis functions based on smart wearable technology, multi-sensor fusion, or deep learning algorithms for bedridden patients;

n) It can optionally support the three-dimensional visualization, statistical analysis, and efficient storage of the telemonitoring data via integrating BIM and IoT technologies. BIM-IoT integration uses BIM models' geometric and parametric properties and the real-time streaming of environmental data (e.g., temperature, humidity) gathered by multiple sensors to create a basic example of digital twin for visualising telemonitoring data in real time;

o) It can optionally support monitoring the dietary structure (e.g., the variety of food, the taste of meals) of inpatients to improve nutritional status and dietary satisfaction in the RDH.

7.3 Requirements for telemonitoring terminals

A telemonitoring terminal is used for information collection and transmission. Two types of telemonitoring terminals are considered:

– cellular terminals; and

– access gateway.

Cellular terminals can access the cellular networks directly, and access gateways can support those traditional medical devices that access to the wireless network by converting a non-3GPP network to a cellular network. To better support data collection via numerous Internet of things (IoT) devices, the function of the access gateway is recommended to be enhanced with additional requirements.

7.3.1 General requirements

The cellular terminals should meet the general requirements [ITU-T F.760.1].

7.3.2 Access gateway requirements

The access gateway should meet the general and access gateway requirements [ITU-T F.760.1].

7.3.3 Enhanced access gateway requirements

Some additional requirements are recommended for the access gateway to support IoT gateway functions:

a) It is recommended to support common requirements and capabilities of a gateway for IoT applications, such as communication, scalability, addressing, and quality of service (QoS) [ITU-T Y.4101];

b) It is recommended to support computation, storage and connectivity functions and provide capabilities to support performance balance and collaboration among IoT devices [ITU-T Y.4208];

c) It is recommended to support at least one kind of IoT messaging protocol such as message queuing telemetry transport (MQTT) [ISO/IEC 20922], advanced message queuing protocol (AMQP) [ISO/IEC 19464], extensible messaging and presence protocol (XMPP) [IETF RFC 6120], constrained application protocol (CoAP) [IETF RFC 7252] for data acquisition from many connected devices or sensors in the RDH;

d) It is recommended to support connecting to multiple cloud platforms (e.g., public cloud, private cloud [ITU-T Y.3500], edge cloud) with IoT messaging protocol;

e) It is recommended to support converting the collected raw data to a semi-structured format such as JavaScript object notation (JSON) [IETF RFC 8259], or XML and adding global device ID to the semi-structured format.

7.4 Requirements for telemonitoring networks

This clause will provide a detailed description of the requirements of telemonitoring networks:

a) It should support continuous cellular network coverage in the urban and rural scenarios and should provide stable, fast and low-latency network connections to meet the needs of a significant amount of data creation, access and transmission between the RDH and remote central hospitals;

b) It should support the private cellular network deployed in the RDH, such as IMT-2020 LAN [ETSI TS 123 501], which should be isolated from the public cellular networks. Moreover, the cellular terminals should be able to access public and private networks simultaneously;

c) It should support discontinuous network coverage such as WLAN, WPAN, LR-WPAN, for vital signs data collection and medical equipment data acquisition in all cabins;

d) It should support stable and reliable telecommunication between the local RDH and remote central hospital in non-regular scenarios, including uninhabited areas, deserts, virgin forests, etc. Here, multiple types of backhaul modules (e.g., emergency communication vehicles, microwave links, drone communications, satellite communications) should be provided for network connection establishment;

e) It should support providing dedicated physical or virtualized network resources for video interaction in the diagnosis and treatment cabin;

f) It should support the modularization of base stations (e.g., macro base station, small cell base station) and other network equipment (e.g., router and switch), which could be relocated and reused in different places;

g) It should support interactive remote video monitoring (e.g., video conferencing, medical image transmission) for medical instrument operations, drug administration, and tele-radiotherapy guidance between the RDH and remote central hospital, which includes the performance requirements [b-3GPP TR 22.826] listed in Table 7-1.

Table 7-1 – Performance requirements of interactive remote video monitoring

Interactive remote video monitoring	Communication service availability: target value in %	Communication service reliability: Mean time between failure	End-to-end latency: maximum	Bit rate
Compressed 4K video stream	99.99	> 1 month	< 100 ms	25 Mbit/s
High quality audio stream	99.99	> 1 month	< 100 ms	128 kbit/s
CT/MRI scan data, max 300Mbyte of DICOM data	99.99	> 1 month	seconds	> 240 Mbit/s

7.5 Requirements for telemonitoring cloud platform

a) It should support cloud computing management [ITU-T Y.3500], [ITU-T Y.3502], which provides multiple cloud service categories such as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) and cloud deployment models (e.g., public cloud, private cloud, edge cloud);

b) It should support multi-access edge computing (MEC) [ETSI GS MEC 003] functions if the IMT-2020 network is available;

c) It should support multiple cloud management functions over telemonitoring applications, user, operation and maintenance;

d) It should support telemonitoring-specific cloud capabilities, including data processing (data acquisition, preprocessing, data buffering, data interpretation, data storage), video functions, object storage functions (database and file storage), etc.;

e) It should support the same IoT messaging protocol as the enhanced access gateway in the RDH.

7.6 Compatibility requirements

a) It should support telemonitoring applications to run seamlessly on different cloud platforms;

b) It should support telemonitoring cloud capabilities to work on different bearer networks;

c) It should support multiple emergency bearer networks to switch seamlessly in non-regular scenarios.

7.7 Scalability requirements

It should support the scalability of the capacities, performance and functions of networks and cloud platforms, which provides better coverage and connectivity in a high-density crowd environment.

7.8 Requirements for special needs

It should support the accessible provision of telehealth services for people with different types of impairments [ITU-T F.780.2].

8 Reference framework for telemonitoring system in rapid deployment hospital

8.1 Reference architecture of the overall system designing

The reference architecture of the telemonitoring system, shown in Figure 8-1, is required to include four layers, namely, terminal layer, network layer, cloud layer, and application layer.

a) The terminal layer is used for information collection and transmission as the medical tools and applications carrier. It can be classified into integrated terminals and data acquisition terminals. The integrated terminals are taken as an access gateway, connecting multiple medical terminals and transferring those data to a cellular network signal. The data acquisition terminals can correctly and continuously monitor and collect information on the cabin environment, medical equipment, and patients' physical signs.

b) The network layer plays a crucial role in telemonitoring data transmission and provides guaranteed SLA, is highly reliable and stable, and provides an interconnection link between the terminal and cloud layers. The communication link can be carried as cellular, microwave, satellite, etc.

c) The cloud layer cooperates with the network layer for the telemonitoring data and provides the virtualization infrastructure, including computing, storage, and network resources. Moreover, it can provide specific telemonitoring services (e.g., data processing, video, object storage, and collaboration with another cloud layer) to support specific applications. It can also provide telemonitoring-specific 5GC network ability (positioning, QoS management, etc.) if the IMT-2020 network is available.

d) Various applications should be provided in the application layer to support telemonitoring scenarios, such as telemonitoring guidance, nursing, operation management, training and teaching, tele-radiotherapy planning system, and big data analysis systems.

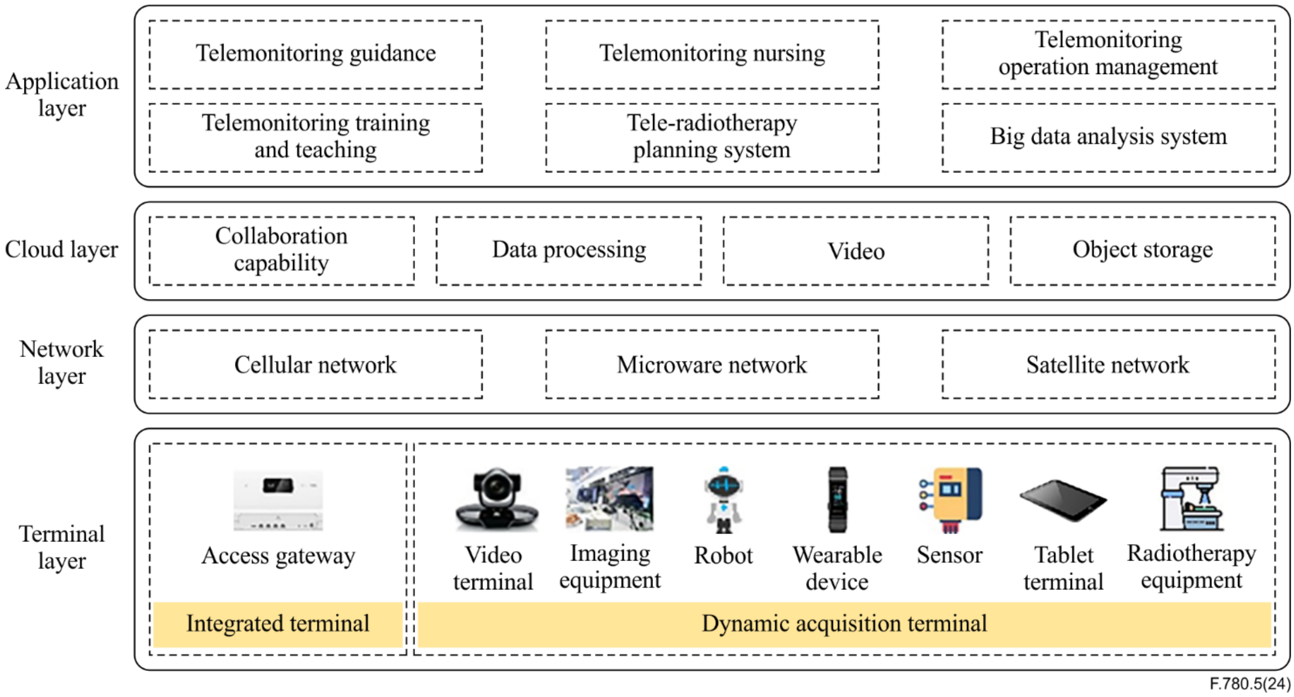

Figure 8-1 – Reference architecture of the telemonitoring system

8.2 Reference architecture of the network layer

Figure 8-2 shows the reference network architecture of the network layer. Under typical telemonitoring scenarios for the RDH, a wide-connected link between the local RDH and the remote central hospital is established through the bearer network and cellular core network, and the monitoring data will be transmitted to the telemonitoring application platform on the remote central hospital.

The RDH is usually covered by a non-3GPP network and a cellular network composed of macro base stations and small cell base stations. Medical terminals of different network types in the RDH can directly connect to the cellular network or indirectly connect to the cellular network through an access gateway. All cellular data in the RDH shall be transmitted to the cellular core network through the bearer network.

The bearer network can be classified into a backbone network and an emergency network. The backbone network is used as the bearer network in telemonitoring systems with continuous cellular network coverage. In contrast, emergency networks such as satellites and microwaves are used as the bearer network in unconventional telemonitoring scenarios, and the backhaul modules can be emergency communication vehicles, drones, etc. The cellular core network is responsible for the necessary switching functions for telemonitoring data.

The control and data link shall be established between the RDH and the remote central hospital to provide specific and detailed telemonitoring services. The control link is used for the RDH and remote hospital scheduling, and the transmitted information includes the network type, service type, configuration information, etc. After the control link is created, a corresponding data link is established between the local RDH and remote hospitals for transmitting telemonitoring data.

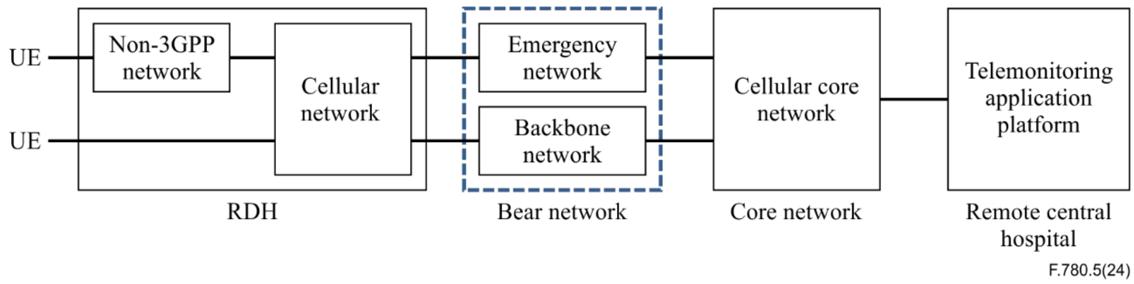

Figure 8-2 – Reference network architecture of the network layer

8.3 Reference architecture of private cellular network for the RDH

Traditionally, a remote access virtual private network (VPN) extends a private network across a public network over an IPsec-encrypted tunnel. However, several VPN disadvantages (scalability, performance, and security) could make deploying a remote access VPN challenging in the RDH.

Under a typical telemonitoring scenario in the RDH, the acquired data needs both local storage and processing and remote transmission, so the terminals need access to the private and public IMT-2020 networks in the RDH. As shown in Figure 8-3, the modular radio access network (RAN), uplink classifier (ULCL) user plane network (UPF), PSA2 UPF and MEC platform (MEP) [ETSI GS MEC 003] equipment are jointly deployed to establish a 3GPP-based private IMT-2020 network. During the initial configuration process, a traffic steering policy with a destination IP address and a type allocation code (TAC) list ought to be configured on the policy control function (PCF) [ETSI TS 123 501]. Smartphone users should subscribe to a private IMT-2020 business with an RDH-dedicated data network name (DNN).

When smartphones are outside of the RDH's network coverage, they can only access the public IMT-2020 network. After smartphones enter the RDH's network coverage, the traffic steering policy configured on the PCF will be triggered and distributed to the ULCL UPF through the SMF [ETSI TS 123 501]. The traffic accessing the MEP will be diverted to the private IMT-2020 network through the ULCL UPF and PSA2 UPF, which are often deployed together. The traffic accessing the telemonitoring cloud will be diverted to the public IMT-2020 network through the ULCL UPF and PSA1 UPF. Here, smartphones shall be able to access the public and private networks simultaneously without changing the mobile number and SIM card.

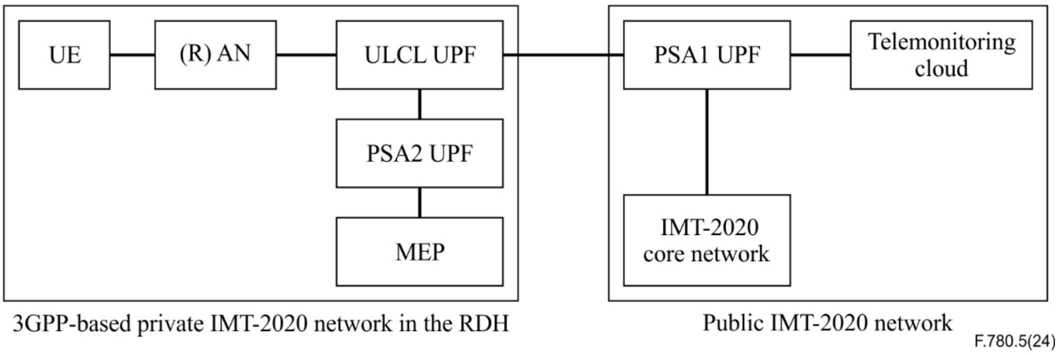

Figure 8-3 – Reference architecture of the private cellular network

8.4 Reference architecture of non-3GPP network optimization

In major telemonitoring scenarios for the RDH, medical terminals without cellular capabilities connect to the aforementioned access gateway through non-3GPP networks, commonly used as an access network, such as WLAN, WPAN, or wired network. Different non-3GPP networks have diverse network performance requirements. Only services with minimal throughput but high latency requirements can use WPAN, such as location-based services. WLAN applies to services like the big data analysis system and tele-radiotherapy planning system that don't need a reliable network. Optical fibre networks are implemented for services requiring high-quality networks, such as telemonitoring guidance and nursing.

As shown in Figure 8-4, the access gateway could convert a typical non-3GPP network into a cellular network. Transceiver, acquisition, and policy configuration modules are three functional modules installed on the access gateway that allow network equipment (e.g., MEP, 5GC) at different network layers to identify specific non-3GPP network information.

The acquisition module collects the following non-3GPP network information.

1) Medical terminal type's name and identifier;
2) Medical terminal manufacturer's name and identifier;
3) Non-3GPP access network type's name and identifier;
4) Non-3GPP network access point's identifier;
5) Non-3GPP network capabilities (e.g., uplink rate, downlink rate, latency, jitter, reliability);
6) Telemonitoring application data carried by non-3GPP networks.

The transceiver module transmits the gathered data to the network equipment periodically or when any non-3GPP network information changes. By integrating the incoming data and the cellular network's current status, the network equipment produces an association and affiliated priority between a specific non-3GPP network and network slice and then sends the following data to the transceiver module.

1) Specific non-3GPP network information sourced from the access gateway and corresponding network slice;
2) The priority of the above correspondence.

After the transceiver module receives the above data, the policy configuration module will implement or update the accepted policies to meet differentiated network performance requirements. Telemonitoring data from medical terminals will be delivered to the hospital's MEP via the access gateway on the specific network slice.

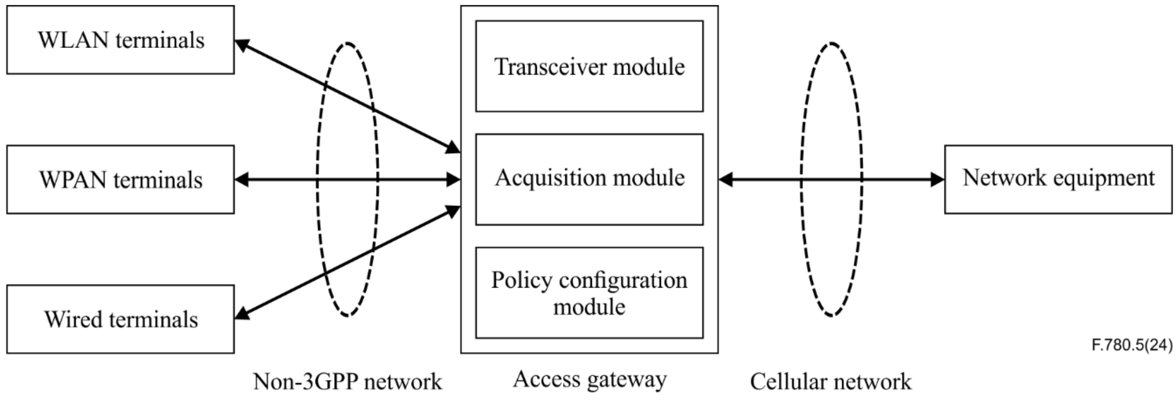

Figure 8-4 – Reference architecture of non-3GPP network optimization

8.5 Reference architecture of the cloud-edge collaboration

Figure 8-5 shows reference architecture of the cloud-edge collaboration. Under a typical telemonitoring scenario in the RDH, edge computing is deployed in the RDH, and cloud computing is deployed in a remote central hospital. The cloud layer includes the IaaS layer and PaaS layer [ITU-T Y.3500], and cloud-edge collaboration can be classified into resource collaboration for the IaaS layer and service collaboration for the PaaS layer.

a) Resource collaboration includes the underlying hardware abstraction from the single-node perspective and the resource scheduling from the global perspective. The edge cloud platform and central cloud platform resources can be used efficiently.

b) Service collaboration provides key capabilities and flexible docking mechanisms for building edge applications under a telemonitoring scenario. The central cloud provides basic management services (e.g., distribution subscription, access, discovery, usage, operation, maintenance) and telemonitoring-specific services (e.g., data processing, video, object storage) for edge services through a cloud-native architecture. It is convenient for the edge cloud to use the central cloud service capabilities.

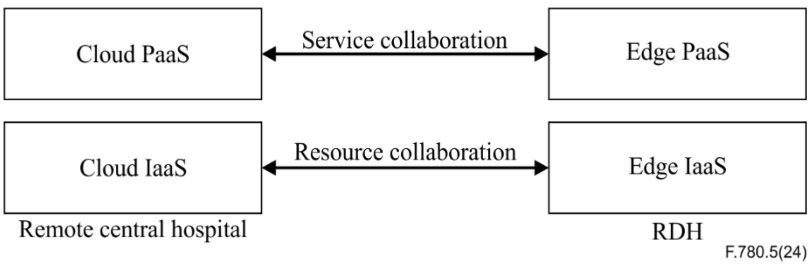

Figure 8-5 – Reference architecture of the cloud-edge collaboration

Appendix I

Use cases

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

This clause describes various scenarios for the telemonitoring system in rapid deployment hospitals.

I.1 Introduction

Use cases generated as part of this Recommendation are categorized as follow:

– Use cases covering the local rapid networking and telecommunication of RDHs. Those use cases are captured in the "Local rapid networking of the RDH" and "Establishment of telecommunication in non-regular scenarios" and "Private IMT-2020 network for the RDH" sections of this document.

– Use cases covering the delivery of data acquisition and monitoring from RDHs to monitoring centres. Those use cases are captured in the "Remote IoT data collection", "Remote live video monitoring", "Non-real-time data transferring", "Tele-radiotherapy application scenario in RDH", "FHIR-based interoperability for telemonitoring", "Digital twin technology for telemonitoring" and "Remote nursing services" sections of this document.

I.2 Local rapid networking of the RDH

The RDH usually consists of individual modular cabins, such as medical, communication, and business cabins. The communication and business cabins are typically deployed together. The communication cabin can also be replaced by an emergency communication vehicle or a large fixed-wing unmanned aerial vehicle (UAV) loaded with a IMT-2020 macro base station.

The medical cabin is responsible for the locally deployed network equipment (e.g., small base station, IMT-2020 access gateway) and medical services such as diagnosis and treatment, ward, inspection, surgery, and drug storage. Cellular terminals access the cellular networks directly, and traditional non-3GPP medical devices (e.g., medical bracelets, video terminal, smart box) access the cellular network through the IMT-2020 access gateway.

As depicted in Figure I.1, the communication and business cabin is responsible for the locally deployed network equipment (e.g., macro base station, UPF, MEC) and the backhaul link (e.g., satellite base station, microwave base station) with the public land mobile network (PLMN). In a modular deployment, automatic network configuration and cellular network connection can only be completed by power.

As depicted in Figure I.2, the emergency communication vehicle is responsible for the locally deployed macro base station and the backhaul link (e.g., satellite base station, microwave base station) with the PLMN.

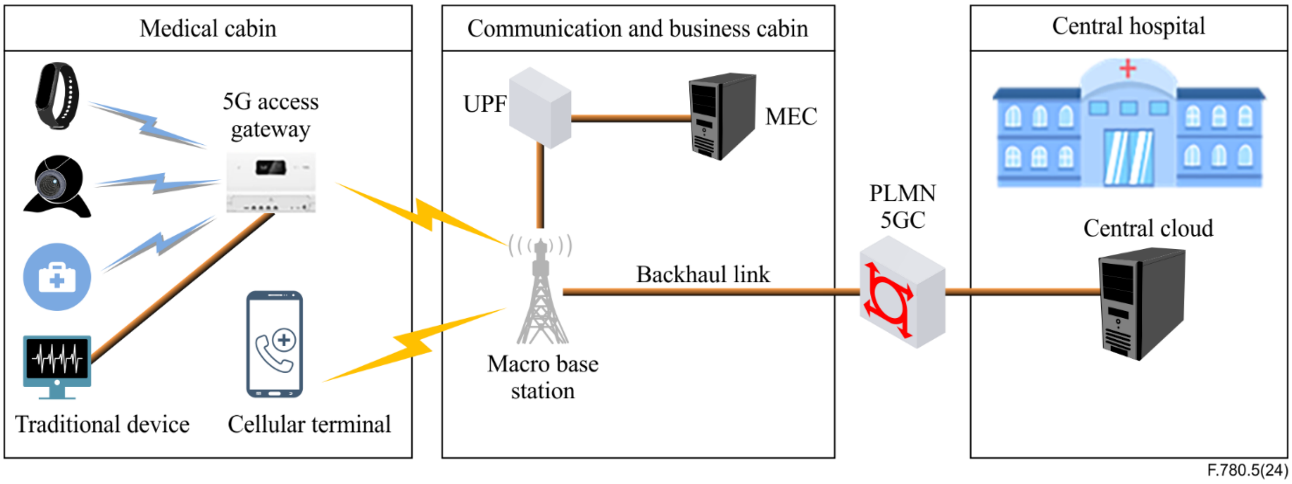

Figure I.1 – Scenario 1: Local rapid networking with a macro base station

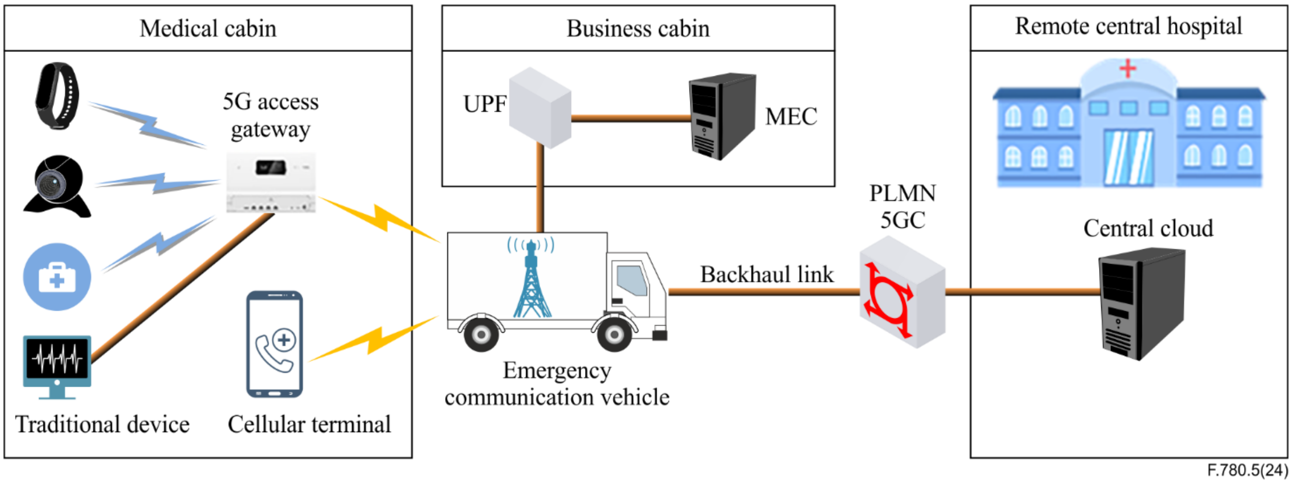

Figure I.2 – Scenario 2: Local rapid networking with an emergency communication vehicle

I.3 Establishment of telecommunication in non-regular scenarios

When deploying RDHs in an environment lacking a backbone network (e.g., deserts, uninhabited areas, and far seas), satellite or microwave communication can be used as the backhaul link according to the transmission distance. In this scenario, satellite or microwave base stations should be integrated into the communication cabin.

As depicted in Figure I.3, satellite communication has a wide transmission range. It is suitable for environments far from the backbone network.

As depicted in Figure I.4, the transmission range of microwave communication is about tens of kilometres, so several microwave relay stations should be deployed in a scenario far from the backbone network.

It is worth noticing that the non-terrestrial networks (NTN) family [b-3GPP TR 38.811], [b-3GPP TR 38.821], still being studied in 3GPP, is expected to provide scalable and efficient network solutions globally. The NTN use an airborne or space-borne vehicle to embark in a transmission equipment relay node or base station, including satellite communication networks, high-altitude platform systems (HAPS), and air-to-ground networks.

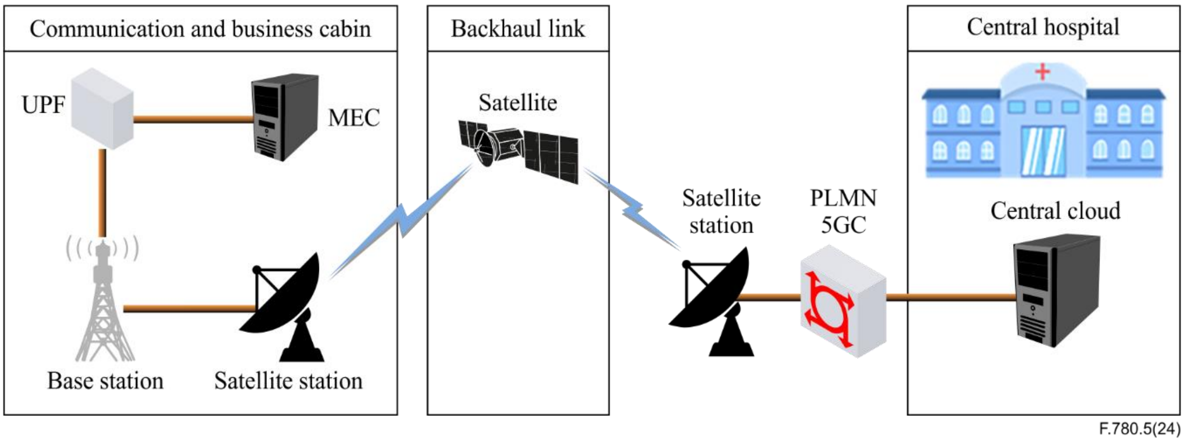

Figure I.3 – Scenario 1: Satellite communication as the backhaul link

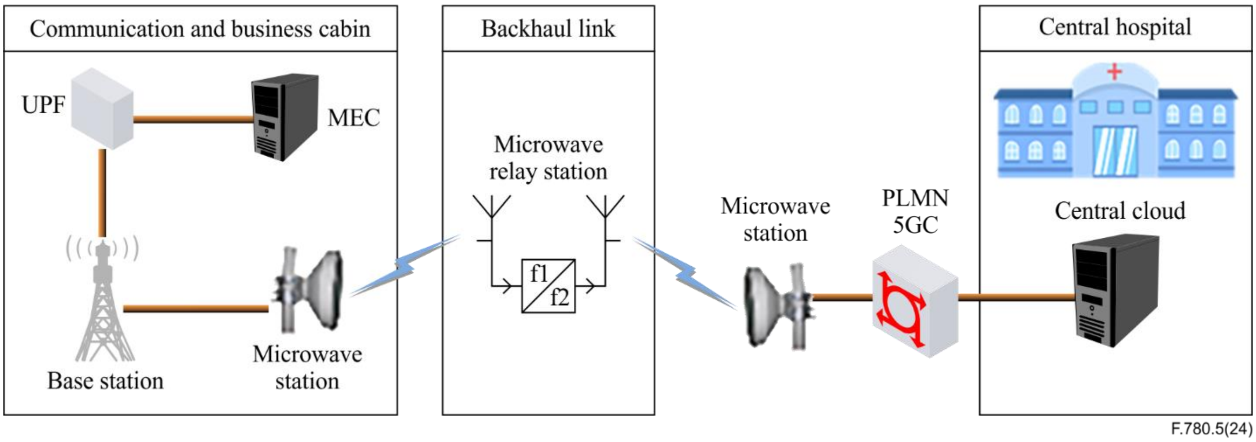

Figure I.4 – Scenario 2: Microwave communication as the backhaul link

I.4 Remote IoT data collection

Message queuing telemetry transport (MQTT) protocol is based on the publish/subscribe model for communication and data exchange. As an MQTT subscriber, the remote manager will subscribe to a data collection topic to the MQTT broker. The broker forwards the message under the topic to the IoT gateway.

As an MQTT client, the enhanced access gateway collects multiple data (i.e., patient-related, equipment-related, environmental, and drug-related data) every 10 seconds and converts those raw data to a JSON-based format. Those JSON-based data is remotely transmitted to the MQTT broker deployed in the central cloud. The central cloud will continue to process the collected data under the batch or stream processing model and store calculation results in the database (e.g., HBase, Redis, ElasticSearch). Based on those calculation results, the remote manager can monitor the vital signs of all patients, environmental factors such as temperature and humidity in all cabins, the operating status of the equipment, and the use of medicines and beds.

Figure I.5 shows remote IoT data gathering in the RDH.

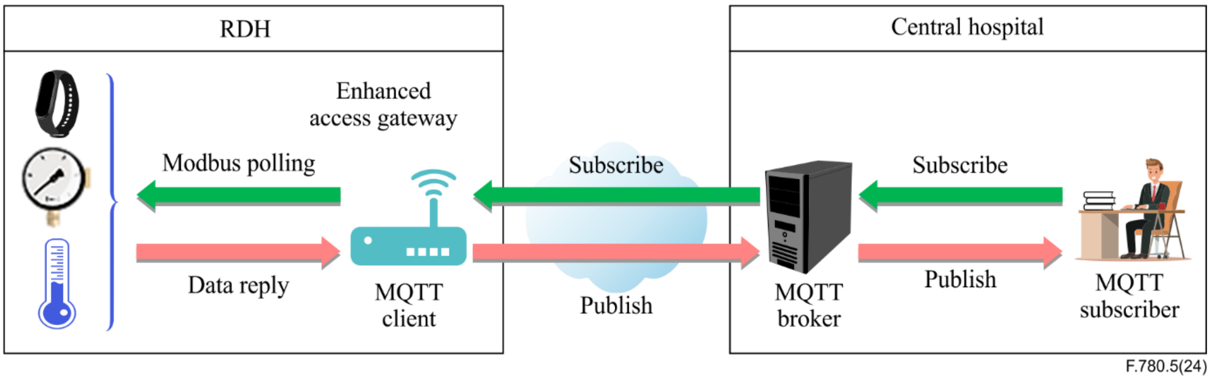

Figure I.5 – Remote IoT data gathering in the RDH

I.5 Remote live video monitoring

Using remote video monitoring, the remote managers can monitor the patient's condition and medical staff's working status, assign medical resources rationally, and maintain RDH stability and orderly 24/7.

Based on HD video monitoring, specialists in remote central hospitals can guide doctors to treat patients with intractable diseases.

I.6 Non-real-time data transferring

Electronic medical records (EMRs) contain patients' medical and treatment history, and picture archiving and communication system (PACS) handles images from various medical imaging instruments. Data of EMR and PACS may be required to be securely uploaded to the telemonitoring centre for archiving, inspection, and further analysis.

I.7 Tele-radiotherapy application scenario in RDH

The typical tele-radiotherapy application scenario in China appears in the National Cancer Centre or Cancer Hospital, Chinese Academy of Medical Sciences (CAMS). The radiotherapy centre in the cancer hospital includes a clinical trial management system (CTMS), radiotherapy quality assurance platform, radiotherapy planning system and cloud storage centre, etc.

Radiotherapy planning systems, at the heart of radiation therapy (RT), provide a set of computerized tools that allow the radiation oncologist, medical physicist, and treatment planner to create and visualize radiotherapy treatments, given the imaging data available.

As depicted in Figure I.6, DICOM-formatted CT images generated in RDHs are uploaded to the cloud storage centre through an IMT-2020 network. Based on those CT images, experts in the radiotherapy centre will carry out multidisciplinary consultation, target delineation, radiotherapy quality assurance, and plan evaluation. The prepared radiotherapy treatment plans will be sent to the edge cloud (e.g., MEC) deployed in the RDHs, and then be implemented by doctors.

As depicted in Figure I.7, remote video conferencing based on high-end camera and audio systems could be conducted by a remote expert in the radiotherapy centre.

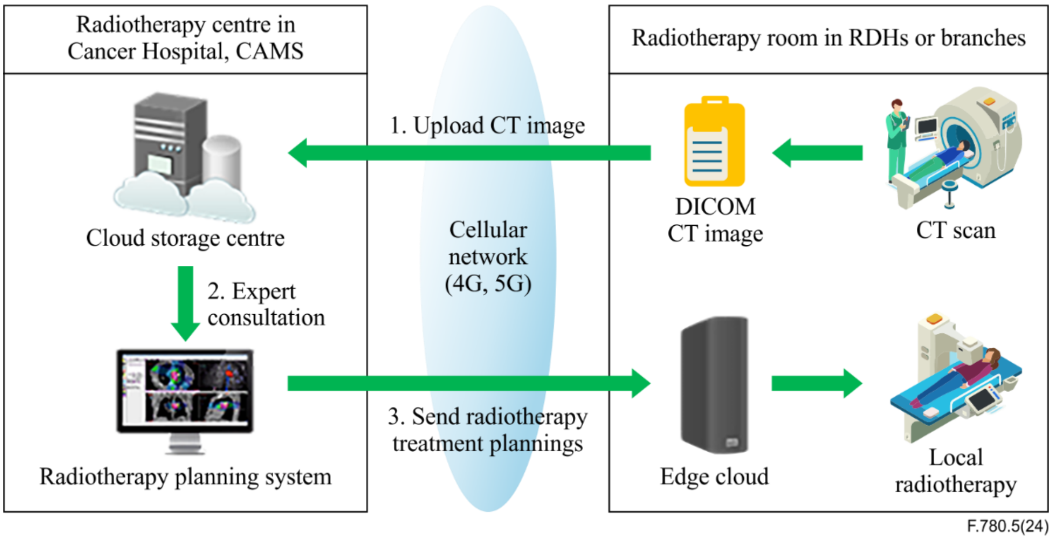

Figure I.6 – Tele-radiotherapy application scenario in RDH

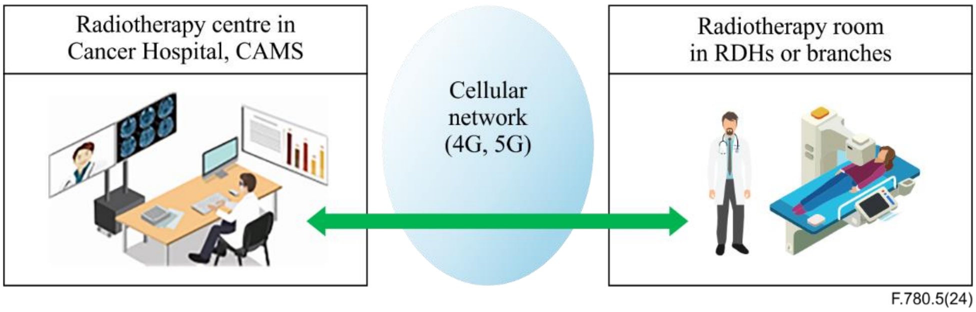

Figure I.7 – Remote video conferencing in RDH

I.8 Private IMT-2020 network for the RDH

In a typical telemonitoring situation, as shown in Figure I.8, the lightweight and modular RAN, MEP, and ULCL UPF are co-deployed in the RDH. To reduce network latency and ensure data security, the MEP offers local service processing capabilities, and the ULCL UPF sends service data to the MEP server for processing.

Smartphone users (such as patients and medical staff) who subscribe to a private network business can only access the Internet over the public IMT-2020 network outside the RDH. They can securely access the private and public IMT-2020 networks when they enter the RDH's private IMT-2020 network coverage.

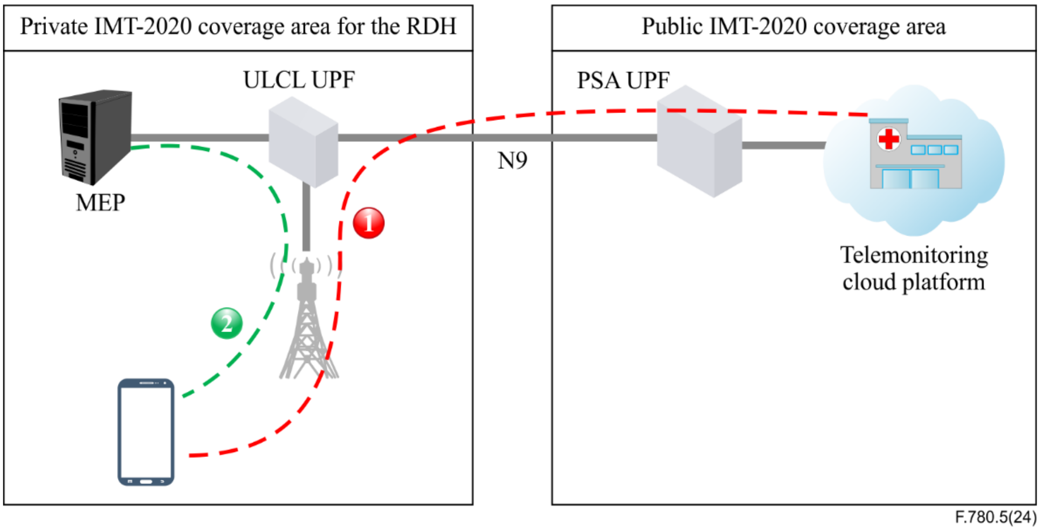

Figure I.8 – Private IMT-2020 network coverage of the RDH

I.9 FHIR-based interoperability for telemonitoring

Fast healthcare interoperability resources (FHIR) enables mapping healthcare concepts into "resources", such as the patient and observation. Although Turtle, XML and JSON formats can be used to encode HL7 FHIR resources, JSON is usually chosen because it is popular and has a relatively small overall data size. The communication between local and remote systems is done through most-commonly-used HTTP requests. An FHIR client in the remote system posts resources to an FHIR server in the RDH, and then the server returns a result with the URI address of the created resources.

The FHIR standard enables the RDH to quickly and securely exchange telemonitoring data with remote systems and makes it simple to integrate new monitoring terminals and external applications.

I.10 Digital twin technology for telemonitoring

Under the sudden COVID-19 epidemic, remote monitoring and control of various terminals (e.g., medical sensors) have become necessary. Digital twin technology can collect data through multiple sensors to realistically represent a virtual patient. By providing comprehensive data about each patient, a digital twin could assist doctors in monitoring and treating infected patients continuously and remotely.

I.11 Remote nursing services

Due to the unexpected COVID-19 epidemic, there was a sharp increase in the number of patients admitted to the RDH as well as a shortage of medical staff and distant care services.

Remote nursing could control a camera remotely, mark the shared patient case data cooperatively, and perform nursing warnings and medical order processing. It could provide rich expert services to the RDH through video conferences without sufficient medical staff.

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