International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.4421

(10/2021)

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 – Frameworks, architectures and protocols

Functional architecture for unmanned aerial vehicles and unmanned aerial vehicle controllers using IMT-2020 networks

Recommendation ITU-T Y.4421

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Computing power networks	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3599
BIG DATA	Y.3600–Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	**Y.4400–Y.4549**
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4421

Functional architecture for unmanned aerial vehicles and unmanned aerial vehicle controllers using IMT-2020 networks

Summary

Widely-used civilian unmanned aerial vehicles (UAVs) generate increasing requirements for communication and network capabilities, including seamless coverage, low latency, Gbps-level rate and high-accuracy positioning. Existing commercial products of civilian UAVs utilize a direct radio link, which is limited by service distance and quality. Therefore IMT-2020 can be employed for UAV communication. UAVs require simultaneous services with different characters, for which a brand new type of user terminal to IMT-2020 is required. Likewise, IMT-2020 is a novel communication network for UAVs since it was originally designed for ground coverage. With the purpose of implementing the support of civilian UAV operations in IMT-2020 networks and improving the quality of UAV application services, a set of functionalities is needed to bridge the gap for interoperation between unmanned aerial system (UAS) and IMT-2020 networks. Recommendation ITU-T Y.4421 provides a functional architecture for UAVs and UAV controllers using IMT-2020 networks and functionalities defined in the application layer, service and application support layer, and security capabilities. The motivation of this Recommendation is to solve the issues of civilian UAVs accessing and communicating in IMT-2020 networks using its transmission capabilities.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4421	2021-10-11	20	11.1002/1000/14738

Keywords

Functional architecture, IMT-2020, unmanned aerial vehicles.

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

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.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

Table of Contents

		Page
1	Scope	1
2	References	1
3	Definitions	1
3.1	Terms defined elsewhere	1
3.2	Terms defined in this Recommendation	2
4	Abbreviations and acronyms	2
5	Conventions	3
6	Overview	3
7	Functional requirements	4
7.1	Application layer requirements	4
7.2	Service and application support layer requirements	6
7.3	Security capability requirements	6
8	Functional architecture	7
8.1	Flying status demonstration	8
8.2	Service quality demonstration	9
8.3	Public information distribution	9
8.4	UAV and controller service and congestion management	9
8.5	UAV task management	9
8.6	UAV and controller identity storage	10
8.7	UAV and controller status monitoring	10
8.8	UAV and controller matching	10
8.9	UAV and controller authorization and authentication	10
8.10	User authorization and authentication	11
9	Security considerations	11
Appendix I – Use cases of UAV registration, security flight controlling/monitoring and route planning based on IMT-2020 networks		12
I.1	Use case of a UAV and the user registration based on IMT-2020 networks	12
I.2	Use case of a UAV security flight controlling/monitoring process based on IMT-2020 networks	13
I.3	Use case of a UAV route planning based on IMT-2020 networks	14
Bibliography		16

Recommendation ITU-T Y.4421

Functional architecture for unmanned aerial vehicles and unmanned aerial vehicle controllers using IMT-2020 networks

1 Scope

The scope of this Recommendation includes:

– **Functional architecture**: a reference architecture of functionalities for civilian unmanned aerial vehicles (UAVs) and UAV controllers using IMT-2020 networks as user terminals.

– **Functionalities**: functionalities defined in the functional architecture, including application layer, service and application support layer and security capabilities.

Additionally, relevant requirements, procedures, security considerations and deployment use cases for using the functional architecture are defined in this Recommendation.

NOTE 1 – The existing IMT-2020 generic functionalities and capabilities, as well as the powering and monitoring modules already integrated in the UAVs for flight are out of the scope of this work item.

NOTE 2 – The regulations and supervision of civilian unmanned aerial vehicle flights, such as for example category specification and functionality defined for registration, identification, traffic management addressed by the International Civil Aviation Organization (ICAO), are out of the scope of this work item. Any implementation based on this Recommendation should be limited by being aligned with regional and national regulations.

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 Y.2012] Recommendation ITU-T Y.2012 (2010), *Functional requirements and architecture of next generation networks*.

[ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking*.

[ITU-T Y.3501] Recommendation ITU-T Y.3501 (2016), *Cloud computing – Framework and high-level requirements*.

[ITU-R M.1645] Recommendation ITU-R M.1645 (2003), *Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000*.

[ITU-R M.2083-0] Recommendation ITU-R M.2083-0 (2015), *Framework and overall objectives of the future development of IMT for 2020 and beyond*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 capability [b-ITU-R M.1224-1]: The ability of an item to meet a service demand of given quantitative characteristics under given internal conditions.

3.1.3 civilian unmanned aerial vehicle [b-ITU-T F.749.10]: An unmanned flying device controlled by a ground control station or telecontroller via various wireless communication means. It usually consists of an aeroplane body, a power device, aviation electrical and electronic equipment and mission payload equipment, etc. and is used in non-military application areas such as industrial and consumer areas to complete the specific operation and transportation of data including audio, video and image.

3.1.4 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.

3.1.5 Internet of things (IoT) [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 – In a broad perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.6 reference point [ITU-T Y.2012]: A conceptual point at the conjunction of two non-overlapping functional entities that can be used to identify the type of information passing between these functional entities.

3.1.7 service [b-ITU-T Y.2091]: A set of functions and facilities offered to a user by a provider.

3.1.8 thing [b-ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or of the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

4G	Fourth Generation
eMBB	Enhanced Mobile Broadband Services
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identification
IoT	Internet of Things
MTC	Machine Type Communication
mMTC	Massive Machine Type Communication
NFV	Network Functions Virtualization
QoS	Quality of Service
SDN	Software-Defined Networking
SIM	Subscriber Identity Module

SON	Self-Organizing Network
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
uRLLC	ultra-Reliable and Low-Latency Communication

5 Conventions

The following conventions are used 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 Recommendation is to be claimed.

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

6 Overview

According to [ITU-R M.2083-0], IMT-2020 can be seen as "systems, system components, and related aspects that provide far more enhanced capabilities than those described in [ITU-R M.1645]". Note that [ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000, and systems beyond IMT-2000, for radio access networks.

The IMT-2020 network will differentiate itself from fourth generation (4G) networks [ITU-T Y.2012] for not only further evolution in terms of radio performance, but also greatly increased end-to-end flexibility. This end-to-end flexibility will come in large part from the introduction of the network softwarization approach in IMT-2020 network components. Technologies such as software-defined networking (SDN) [ITU-T Y.3300], network functions virtualization (NFV) [b-ETSI NFV-WP1], [b-ETSI NFV-WP5G] and cloud computing [ITU-T Y.3501] will together allow unprecedented flexibility in the IMT-2020 network. Such flexibility will enable a large number of new capabilities in the IMT-2020 network, including network slicing [b-ITU-T Y-Sup.44].

The services expected to be supported by the IMT-2020 network can be classified into three categories [ITU-R M.2083-0]: enhanced mobile broadband (eMBB) services, ultra-reliable and low-latency communication (uRLLC)-based services, and massive machine type communication (mMTC)-based services.

– eMBB allow users to experience high-speed and high-quality multimedia services, e.g., virtual reality, augmented reality, 4K or 8K ultra-high-definition videos and even hologram services, at any time and place.

– uRLLC enables delay-sensitive and mission-critical services that require very low end-to-end delay, e.g., tactile Internet, remote control of medical or industrial robots, driverless cars and real-time traffic control.

– mMTC involves a massive number of MTC devices.

With its improved capabilities compared to IMT-advanced and other mobile communication networks in data rate, latency, coverage, positioning, security and energy efficiency, the IMT-2020 network will better help in UAV applications and cope with their requirements. In addition, by introducing new technologies such as network slicing, large-scale antennas, and self-organizing networks (SONs), it will further guarantee aerial network coverage, end-to-end service quality, and efficient identification and control for connected UAVs.

High-definition video feedback from a UAV to the service centre or the controller is required in most UAV applications and services. For example, UAV-aided pipeline and base station inspection, search and rescue missions and entertainment require an uplink transmission data rate of up to 30 Mbit/s, which can be provided in the typical urban and rural coverage scenario of IMT-2020. Some specialized applications such as panoramic video, virtual reality, agriculture and forestry surveillance may require data rates higher than 100 Mbit/s, which can be supported in IMT-2020 networks with its coordinated coverage of high and low frequencies.

To achieve UAV attitude stabilization and adjustment, a mission equipment management and emergency countermeasure remote control is another typical demand in UAV applications and services. The end-to-end latency requirement may vary depending on application scenarios and service characteristics, e.g., entertainment, pipeline and base station inspection require a remote control latency of up to 500 ms, while search, rescue and surveillance require a remote control latency of less than 100 ms. This can be guaranteed by IMT-2020 networks thanks to its quality of service (QoS) mechanism and flexible frame and scheduling designs.

The demand for positioning of UAVs has gradually increased with the diversification of applications. While ordinary surveillance and entertainment only require positioning accuracy within 50m, pipeline and base station inspection, search and rescue, and automatic returning and landing require a higher positioning accuracy of 1m or even 0.1m. Through its hybrid positioning technology of a cellular network and differential GNSS, IMT-2020 networks can achieve such positioning accuracy and thus meet the demand of UAV applications and services.

In addition to the breadth, the connected UAVs also impose in height of communication network coverage. The coverage height requirement for entertainment, search and rescue and surveillance is about 100 m, while pipeline and base station inspection, surveying and mapping may require 300 m to 1000 m. Through large-scale antennas and interference cancellation technologies, IMT-2020 networks can greatly enhance aerial coverage performance for UAV applications and services.

From this perspective, the IMT-2020 networks (which are currently under early commercial deployment) will be able to meet the above-mentioned requirements and play a key role in providing ubiquitous coverage and sustainable services for unmanned aerial systems (UASs) [b-ITU-R M.2171]. This functional architecture is for civilian UAVs and UAV controllers to access and communicate in IMT-2020 networks using its transport and transmission capabilities, and to bridge the gap for interoperation between UAS and IMT-2020 networks. The user information of UAVs and controllers including application data, control command, flying status and identity information is transparent to the IMT-2020 networks.

7 Functional requirements

Clauses 7.1 to 7.3 describe the functional requirements, including application layer, service and application support layer and security capabilities.

7.1 Application layer requirements

This clause describes the functional requirements in the application layer. The application layer provides applications that emerge functionalities by using capabilities from the service and application support layer to the UAVs, the UAV controllers and other authorized users.

Flying status demonstration: provides the function of demonstrating the flying status of a UAV/UAVs for controllers and other authorized users for this application.

- It is required to demonstrate the altitude (above ground level) of the UAV;
- it is required to demonstrate the velocity (horizontal and/or vertical) and direction of the UAV;
- it is recommended to demonstrate the propeller speed of the UAV;

– it is recommended to demonstrate the remaining battery and duration of the flight of the UAV;

– it is recommended to demonstrate the flight attitude (e.g., fuselage level) of the UAV;

– it is recommended to demonstrate the current flight procedure (e.g., taking-off, cruising and landing) of the UAV;

– it is recommended to demonstrate waypoints (e.g., three-dimensional coordinates) of the UAV.

Service quality demonstration: provides the function of demonstrating service quality for UAVs, controllers and other authorized users for this application.

– It is required to demonstrate end-to-end latency between the UAV and the UAV controller or the UAV control centre;

– it is required to demonstrate a transmission rate between the UAV and the UAV controller or the UAV control centre;

– it is required to demonstrate the loss ratio of the data packet between the UAV and the UAV controller or the UAV control centre.

Public information distribution: provides the function of distributing public information to UAVs, controllers and other authorized users for this application.

– It is required to distribute air traffic control information to the UAV and the UAV controller;

– it is required to distribute restricted and warning area information for UAV flying to the UAV and the UAV controller;

– it is recommended to distribute weather information to the UAV and the UAV controller;

– it is recommended to distribute disaster information to the UAV and the UAV controller;

– it is recommended to distribute commercial information (e.g., network quality information) to the UAV and the UAV controller.

UAV and controller service and congestion management: provides the function of application level scheduling and priority handling based on the service type and importance. The UAV and controller service and congestion management function ensure QoS above the network layer. It works as part of end-to-end QoS including IMT-2020 QoS mechanisms and can invoke network slices as defined in IMT-2020 for different applications.

– It is required to support static (in absolute orders) scheduling and priority handling for the UAV and UAV controller services;

– it is recommended to support dynamic (in relative orders) scheduling and priority handling for the UAV and UAV controller services.

UAV task management: provides the function of managing task-related and/or flight-related applications for the UAVs.

– It is required to support control command executing for the UAV and the UAV controller;

– it is required to support flight logging for the UAV;

– it is recommended to support route planning for the UAV;

– it is recommended to support navigating for the UAV;

– it is recommended to support task scheduling for the UAV and the UAV controller;

– it is recommended to support UAV grouping for the UAVs;

– it is recommended to support audio/video/monitor data processing for the UAV and the UAV controller.

7.2 Service and application support layer requirements

This clause describes the functional requirements in the service and application support layer. The service and application support layer consists of capabilities which can provide application interfaces to collect data for different applications in the application layer.

UAV and controller identity storage: stores the UAV and controller identity information for authorization and authentication to access IMT-2020 network. The stored identity information can be used for emerging identity-related functionalities defined in application layer and security capabilities.

– It is required to support storage of permanent identity for the UAV and the UAV controller;

– it is recommended to support storage of temporary identity for the UAV and the UAV controller.

UAV and controller status monitoring: monitors the flying status and service quality information for demonstration. Information required by the application layer can be obtained by monitoring relevant parameters and systems, e.g., UAV powering system and engine system. The monitoring operation can be triggered by the UAV itself, or by the request from the controllers or other authorized users.

– It is required to support UAV triggered monitoring operation;

– it is required to support UAV controller triggered monitoring operation;

– it is recommended to support other authorized users triggered monitoring operation.

UAV and controller matching: stores the matching relation of the authorized UAV and controller. The matching relation can be used for emerging peer-to-peer (e.g., a UAV to its matched UAV controller) functionalities defined in application layer and security capabilities.

– It is required to support adding, removing and modifying matching relations between the UAV and the UAV controller.

7.3 Security capability requirements

This clause describes the functional requirements in security capabilities. IMT-2020 security capabilities including encryption and integrity protection for user data transmission can be reused for the network layer and below.

UAV and controller authorization and authentication: provides the function of authorizing and authenticating a UAV or a UAV controller to access IMT-2020 networks. IMT-2020 user authorization and authentication rules and procedures can be adopted as baselines. Additional and specific authorizing and authenticating rules and procedures can be developed in the application level based on UAV and UAV controller identities.

– It is required to support adding, removing and modifying the association of certification or license of a UAV or a UAV controller for IMT-2020 network access, to its identity or subscription information used in IMT-2020.

User authorization and authentication: provides the function of authorizing and authenticating a user other than a UAV or a UAV controller to use functionalities defined in clauses 7.1 and 7.2. IMT-2020 user authorization and authentication rules and procedures can be adopted as baselines. Additional and specific authorizing and authenticating rules and procedures can be developed in the application level.

– It is required to support adding, removing and modifying the association of certification or license of a user other than a UAV or a UAV controller for accessing all or part of the functionalities, to its identity or subscription information used in IMT-2020.

8 Functional architecture

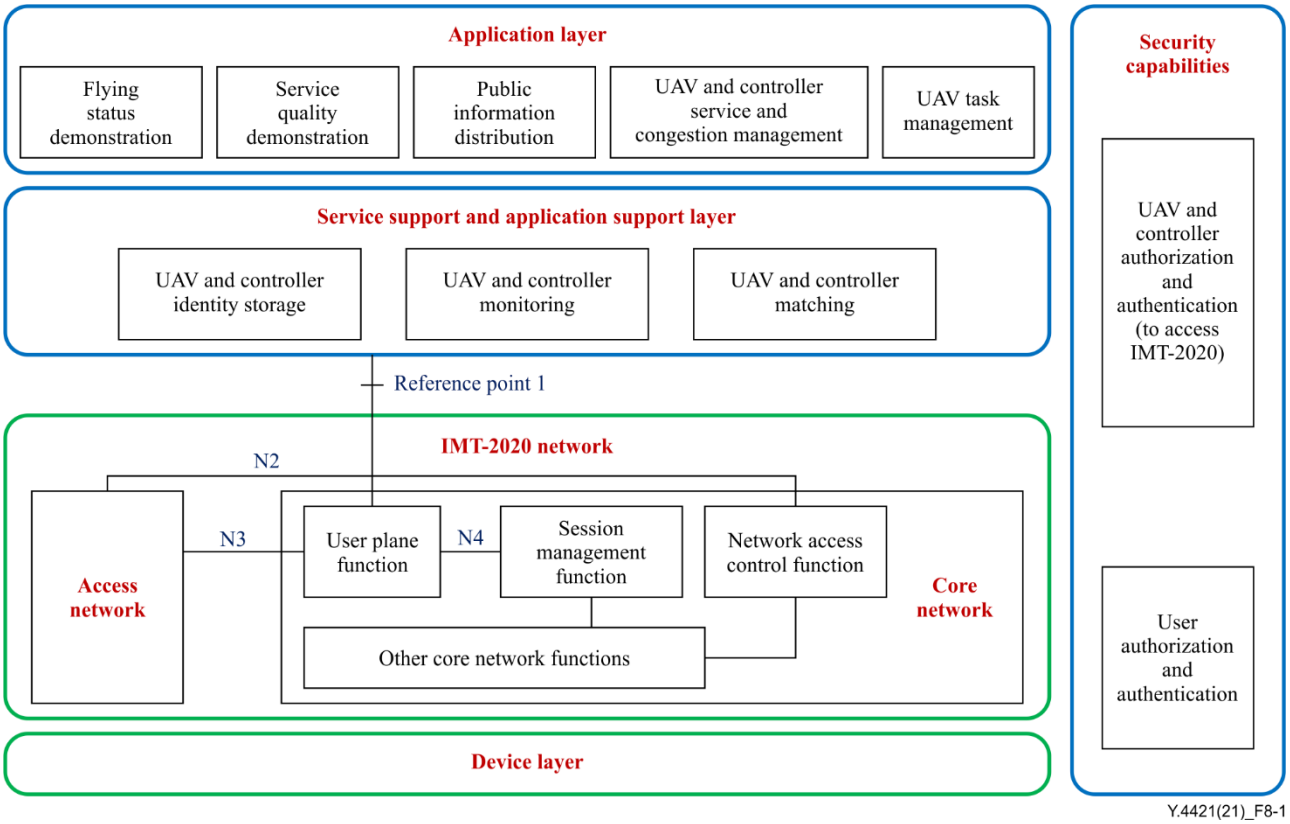

Figure 8-1 – Functional architecture of UAVs and UAV controllers using IMT-2020 networks

Reference point 1 is between the support layer and the user plane function in the core network of IMT-2020. For reference, the position is between the "User plane function" and the "Data network" in Figure 8-1 of [b-ITU-T Y.3102]. It is also defined as N6 in [b-3GPP TS 23.501]. For example, weather information, disaster information and commercial information can be distributed from network operators to UAVs, UAV controllers and other authorized users via Reference point 1. Based on IMT-2020 rules, authorization and authentication for the UAVs, UAV controllers and users can be performed by the interaction between IMT-2020 networks and UAVs. Specifically, the digital identifier can be embedded in the message reported to networks via Reference point 1. A certification or license can be associated with the UAVs, UAV controllers and users by the above information.

Reference point 1 is in the scope of IMT-2020. No more definition or modification to Reference point 1 is required in this Recommendation.

Despite this, the defined functional architecture is of universality for various communication networks (e.g., IMT-2000), the technical reasons for using functions of IMT-2020 by this Recommendation include but are not limited to:

User plane function

It is the key to implement the new QoS mechanism developed for IMT-2020 networks. Different from other communication networks (e.g., IMT-2000), the IMT-2020 network employs a 2-level QoS mechanism for the core network and the access network, e.g., the core network maps data

flows into QoS flows according to their QoS requirements, while the access network further maps the QoS flows into data radio bearers according to the current wireless channel condition and load. The mechanism delegates part of the QoS guaranteeing rights to the access network and therefore achieves more flexible adaptation between the service demand and transmission capability. With this QoS mechanism the access network is able to ensure critical UAV services such as remote control at maximum effort and apply a preliminary adjustment of the data bearer to reduce latency or avoid interruption.

Session management function

In addition to the new QoS mechanism implemented by the user plan function, the session management function further guarantees appropriate scheduling of services to different destinations by priority handling of sessions. This is vital for the UAV services especially ensuring the efficiency of the remote control while the continuity of other services like video feedback can be maintained. Furthermore, this function also allows suspension and resumption of sessions, which allows UAV service pending on demand for energy-saving and quick recovery if needed.

Network access control function

With the network access control function, the IMT-2020 network leverages relevant security technologies while implementing new security protocols to address previously unresolved threats. Instead of authenticating users through subscriber identity module (SIM) cards, which is hard to meet with the various services and requirements of UAVs, the IMT-2020 network solves this problem by assigning a unique identity to each device. Moreover, it also provides better encryption (256-bit instead of 128-bit) especially for the procedure of the first-step verification to avoid UAV identity and location information leakage.

Other core network functions

The IMT-2020 core network is designed based on service-based architecture. Instead of integrating functions into physical network elements, this architecture allows IMT-2020 core network to invoke functions based on logical interfaces. It realizes dynamic network load sharing, disaster recovery, simpler capacity expansion and openness of network functions that better supports a large volume of UAVs and UAV services.

Another important feature for UAV services is network slices. The IMT-2020 network defines a set of slice-related functions including a network slice selection function, network repository function and network data analytics function. With the network slice selection function, the UAVs in the IMT-2020 network can form one or more types of tenants based on their own attributes, application industries or business requirements. By assigning (or permitting to use) a dedicated slice set for the UAVs, it is possible to logically distinguish the service policies of the UAVs from other users. By refining the dedicated slice identification of the UAVs, it is possible to distinguish the UAVs in different application industries, as well as control data and multi-type application data services, which can be guaranteed using different slices.

8.1 Flying status demonstration

This function enables the capability of demonstrating flying status of the UAVs. The demonstrating flying status function can be used for information sharing or applications/services. The demonstrated flying status function comprises one or more parameters described in clause 7.1.

This function gathers flying status information from the functions of UAV task management defined in clause 8.5 and UAV and controller status monitoring defined in clause 8.7. It translates the gathered information into parameters which can be demonstrated and shared to the UAV controllers or other authorized users. The matching relations between the UAVs and the UAV controllers or other authorized users can be determined by the matching relations provided by the

function of UAV and controller matching defined in clause 8.8, or by the authority of using this function provided by the function of user authorization and authentication defined in clause 8.10.

8.2 Service quality demonstration

This function enables the capability of demonstrating service quality of the UAVs from/to the UAV controllers or the control centres. The demonstrating service quality function can be used for information sharing or applications/services. The demonstrated service quality function comprises one or more parameters described in clause 7.1.

This function gathers service quality information from the function of UAV and controller status monitoring defined in clause 8.7. It translates the gathered information into parameters which can be demonstrated and shared to the UAV controllers or other authorized users. The matching relations between the UAVs and the UAV controllers or other authorized users can be determined by the matching relations provided by the function of UAV and controller matching defined in clause 8.8, or by the authority of using this function provided by the function of user authorization and authentication defined in clause 8.10.

8.3 Public information distribution

This function enables the capability of distributing public information to the UAV controllers or other authorized users. The distributing of public information function can be used for information sharing or applications/services. The distributed public information function comprises one or more parameters described in clause 7.1.

This function gathers public information from administrative departments e.g., civil aviation management, public safety or disaster warning, or commercial information from enterprises (e.g., network operators). It translates the gathered information into parameters which can be distributed to the UAV controllers or other authorized users. The matching relations between the UAVs and the UAV controllers or other authorized users can be determined by the matching relations provided by the function of UAV and controller matching defined in clause 8.8, or by the authority of using this function provided by the function of user authorization and authentication defined in clause 8.10, or by the location or route information provided by the function of UAV task management defined in clause 8.5.

8.4 UAV and controller service and congestion management

This function enables the capability of service scheduling and priority handling at the application level. Services can be statically or dynamically scheduled as described in clause 7.1.

This function gathers service information from the function of UAV task management defined in clause 8.5. It then sorts the services in an absolute or relative order based on the service type and importance, aiming to guarantee service quality of prioritized tasks and avoid possible congestions of transmission.

8.5 UAV task management

This function enables the capability of task or flight management for the UAVs. It supports one or more applications described in clause 7.1.

This function gathers task-related or flight-related information or flying command from the UAV controllers, the control centres, or the administrative departments (e.g., civil aviation management). It can provide functions including forwarding control commands, logging flight, planning route or scheduling task accordingly for the corresponding UAV, etc.

This function is also able to obtain network quality information (e.g., service load, signal strength, interference or coverage holes in a certain area) from IMT-2020 networks via open interfaces if

supported. It can plan flight route or waypoint accordingly for the UAVs based on network quality information from IMT-2020 networks to guarantee service quality.

This function also provides necessary information including flying status and service type and importance to the functions of flying status demonstration and UAV defined in clause 8.1 and controller service and congestion management defined in clause 8.4, respectively.

8.6 UAV and controller identity storage

This function enables the capability of storing identities of the UAVs and the UAV controllers which are defined for applications and service support functions, or other identity-related functionalities defined in this functional architecture.

This function gathers device identity information from the UAV and controller or certification or license information from their manufacturing or administration departments. It generates identities of the UAVs and the UAV controllers that to be used within this functional architecture from the gathered information via certain algorithms. Each generated identity of a UAV or controller will be stored and served as dedicated identifiers for matching as defined in clause 8.8 and associating with the identity or subscription information used in IMT-2020 as defined in clause 8.9.

8.7 UAV and controller status monitoring

This function enables the capability of monitoring the flying status and service quality information triggered by the UAVs or the UAV controllers. It can be triggered by other authorized users (e.g., in the command centre) as well.

This function gathers status information (mostly measured parameters) from the sensors or software installed in the UAVs or the UAV controllers. It translates the gathered information into monitored parameters as requested by other functions (e.g., velocity for flying status demonstration or transmission latency for service quality demonstration) and delivers the results.

This function is also able to provide gathered information or monitored items to the IMT-2020 network via open interfaces, if supported. With the information from this function, IMT-2020 can configure cell relations, measurement report and cell reselection rules according to altitude or velocity information of the UAVs.

8.8 UAV and controller matching

This function enables the capability of matching relation management for the UAVs and the UAV controllers. The matching relations can be used to ensure the communicating source and destination via IMT-2020 networks, or to emerge pairing-related functionalities defined in the application layer.

This function gathers matching information from the UAVs and the UAV controllers or from their manufacturing or administration departments. It generates a matching table including the identities of matched UAVs and UAV controllers, which are generated by the function of UAV and controller identity storage defined in clause 8.6. The matching table can be further used to determine the destination of delivering status information or distributing public information as described in clauses 8.1, 8.2 and 8.3.

8.9 UAV and controller authorization and authentication

This function enables the capability of authorizing and authenticating the UAVs or the UAV controllers to access IMT-2020 networks by using the existing IMT-2020 user authorization and authentication rules and procedures.

This function gathers certification or license information of the UAVs and the UAV controllers from their manufactures or administration departments. It derives permission settings based on the gathered information to authorize the UAVs and the UAV controllers to access IMT-2020 network.

It is also responsible for authentication by verifying the permission when the UAVs or the UAV controllers require access.

This function may further provide certification or license information to the IMT-2020 network to assist dedicated network deployment, scheduling or QoS guaranteeing for the UAVs and the UAV controllers.

8.10 User authorization and authentication

This function enables the capability of authorizing and authenticating users other than the UAVs or the UAV controllers to use functionalities defined in clause 8 at the application level.

This function gathers certification or license information of users other than the UAVs or the UAV controllers from their manufacturing or administration departments. It derives permission settings based on the gathered information to authorize the users to access certain functionalities. It is also responsible for authentication by verifying the permission when the users require access to any functionality.

9 Security considerations

IMT-2020 security capabilities including encryption and integrity protection for user data transmission can be used for supporting security requirements of the application layer, service and application support layer and security capabilities defined in this Recommendation.

NOTE – Flight safety considerations related to the regulations and supervision are addressed and guaranteed by ICAO recommendations and therefore out of the scope of this Recommendation.

Appendix I

Use cases of UAV registration, security flight controlling/monitoring and route planning based on IMT-2020 networks

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

NOTE – Use cases in Appendix I are only to provide implementation examples in theory to use this Recommendation.

I.1 Use case of a UAV and the user registration based on IMT-2020 networks

Based on the authorized spectrum, the IMT-2020 network can provide large bandwidth, low delay and high reliability communication services, and support the efficient and orderly air traffic management of UAVs in the future. Each UAV has a unique digital identifier and a serial number which is composed of country code, industry domain code, enterprise name code and enterprise's own definition code. A UAV shall be registered to the civil aviation management department before flight. Each UAV shall have at least one IMT-2020 communication module associated with the digital identifier (e.g., international mobile equipment identity (IMEI)). The communication module can optionally use the SIM card with an international mobile subscriber identification (IMSI) number.

Figure I.1 presents a use case of a UAV and the user registration based on IMT-2020 networks.

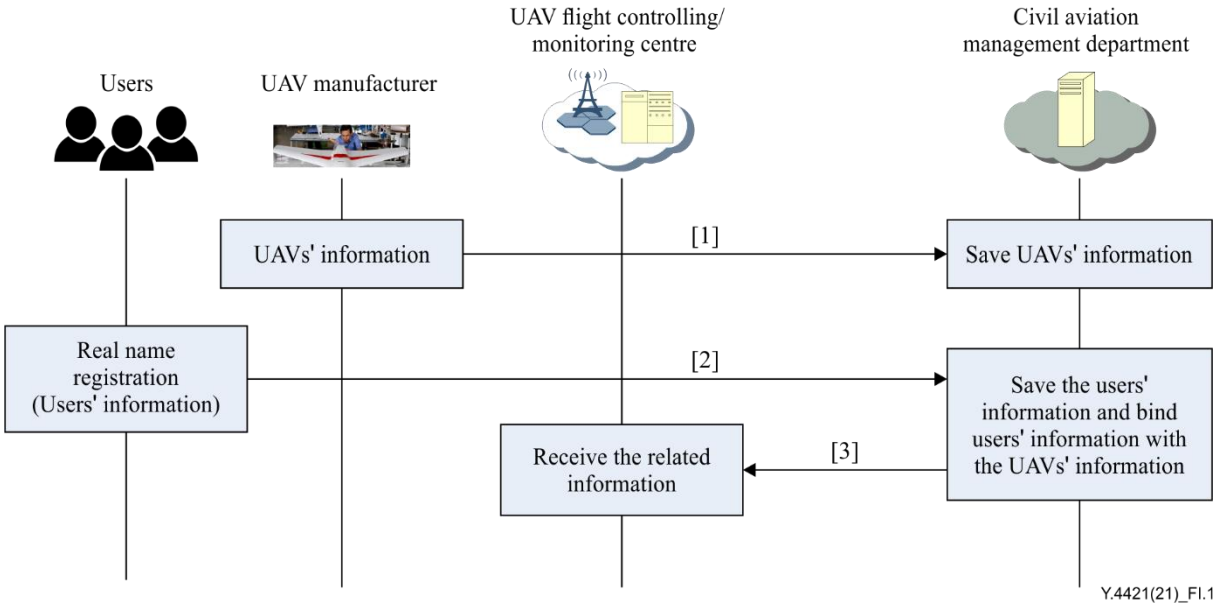

Figure I.1 – The UAV and the user are registered based on IMT-2020 networks

1) UAVs' information, such as the UAV number, UAV digital identifier and SIM card/communication module, are sent to the civil aviation management department.

2) Users' information, such as users' ID, name and mobile number, are sent to the civil aviation management department. The civil aviation management department binds users' information with the UAVs information after verification and checkout.

3) Civil aviation management department sends both the user information and UAVs information to the UAV flight controlling/monitoring centre, and the UAV flight controlling /monitoring centre saves this information.

I.2 Use case of a UAV security flight controlling/monitoring process based on IMT-2020 networks

The above registration process is ready for the follow-up safety flight and monitoring, but the civil aviation management department is a management department, not a flight controlling/monitoring department. Therefore, a flight controlling/monitoring centre/entity (the entity can optionally be telecommunication operators), relying on a high reliability, low delay and wide coverage communication network, is required to control/monitor real-time UAVs safety flights and collect flight data for the civil aviation management department.

Figure I.2 presents a use case of the UAV security flight controlling/monitoring process based on IMT-2020 networks.

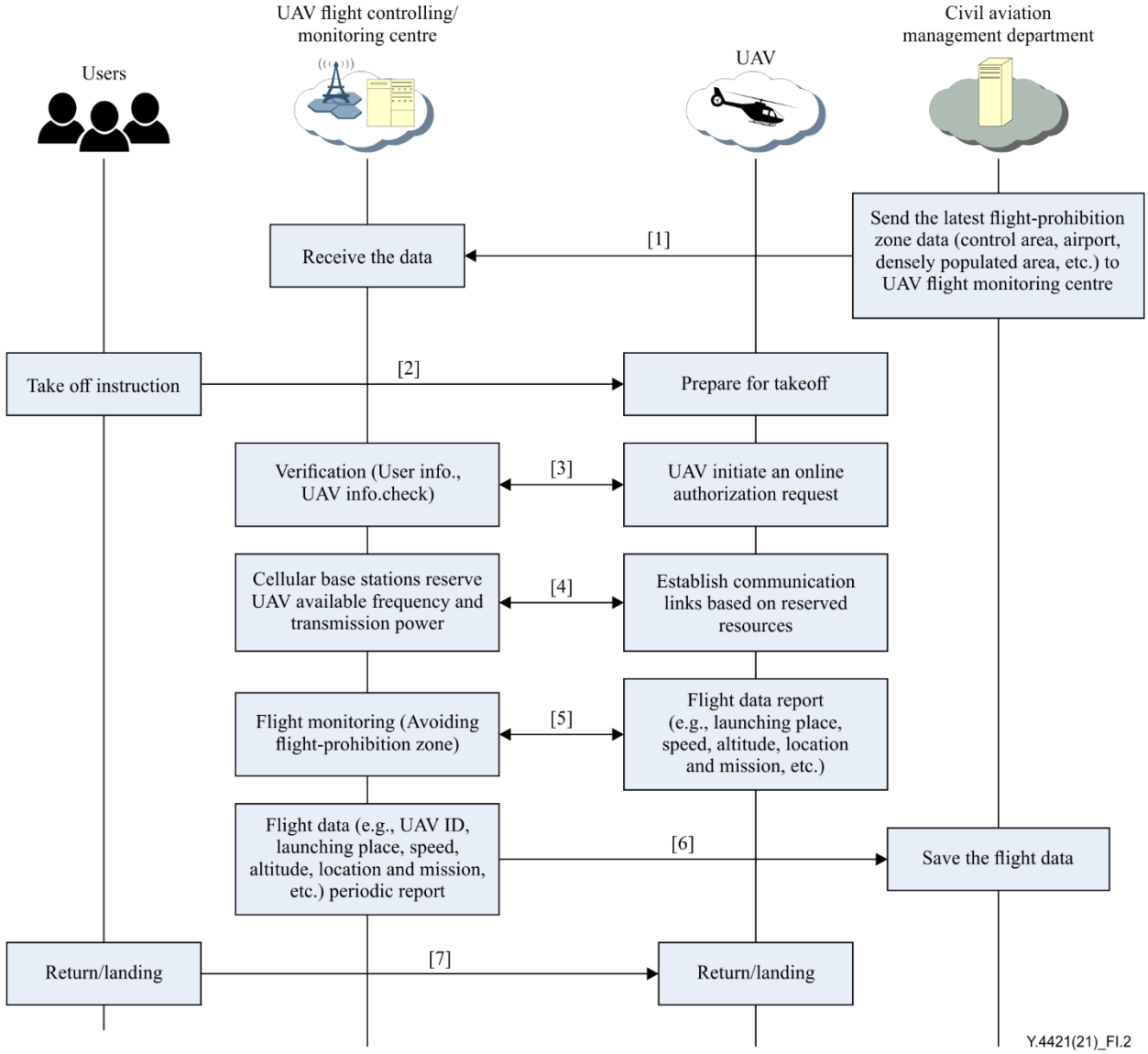

Figure I.2 – UAV security flight monitoring process based on IMT-2020 networks

1) Before flight, the civil aviation management department shall send the latest flight-prohibition zone data (control area, airport, densely populated areas, etc.) to UAV flight controlling/monitoring centre. This data will be used to monitor the UAV's flight.

2) The user sends out take-off instructions, and the UAV prepares for take-off.

3) The UAV initiates an online authorization request to the UAV flight controlling/monitoring centre by device check (serial number, digital identifier and the IMEI) with the user's

telephone number and trusted location. The UAV flight controlling/monitoring centre verifies and tests the UAV information with the user information.

4) If the authorization and authentication is passed, then cellular base stations reserve available frequency and transmission power for the UAV, and notify the UAV to establish communication links based on reserved resources. If not, then the UAV is locked until the right UAV information with the user information is received, or the flight is prohibited, and waiting for the next take-off instruction.

5) After launching, the UAV reports real-time flight data (e.g., speed, altitude, location and mission, etc.) to the UAV flight controlling/monitoring centre. The UAV flight controlling /monitoring centre monitors the UAV flight process to avoid a flight-prohibition zone by the high reliability, low delay and wide coverage communication network.

6) The UAV flight controlling/monitoring centre periodically reports flight data (e.g., UAV ID, speed, altitude, location and mission, etc.) to the civil aviation management department.

When a mission is complete, the user instructs the UAV to return/land.

I.3 Use case of a UAV route planning based on IMT-2020 networks

A flight controlling/monitoring centre which can be telecommunication operators can plan flight routes accordingly for the UAVs based on network quality information from IMT-2020 networks to guarantee service quality.

Figure I.3 presents a use case of UAV route planning based on IMT-2020 networks.

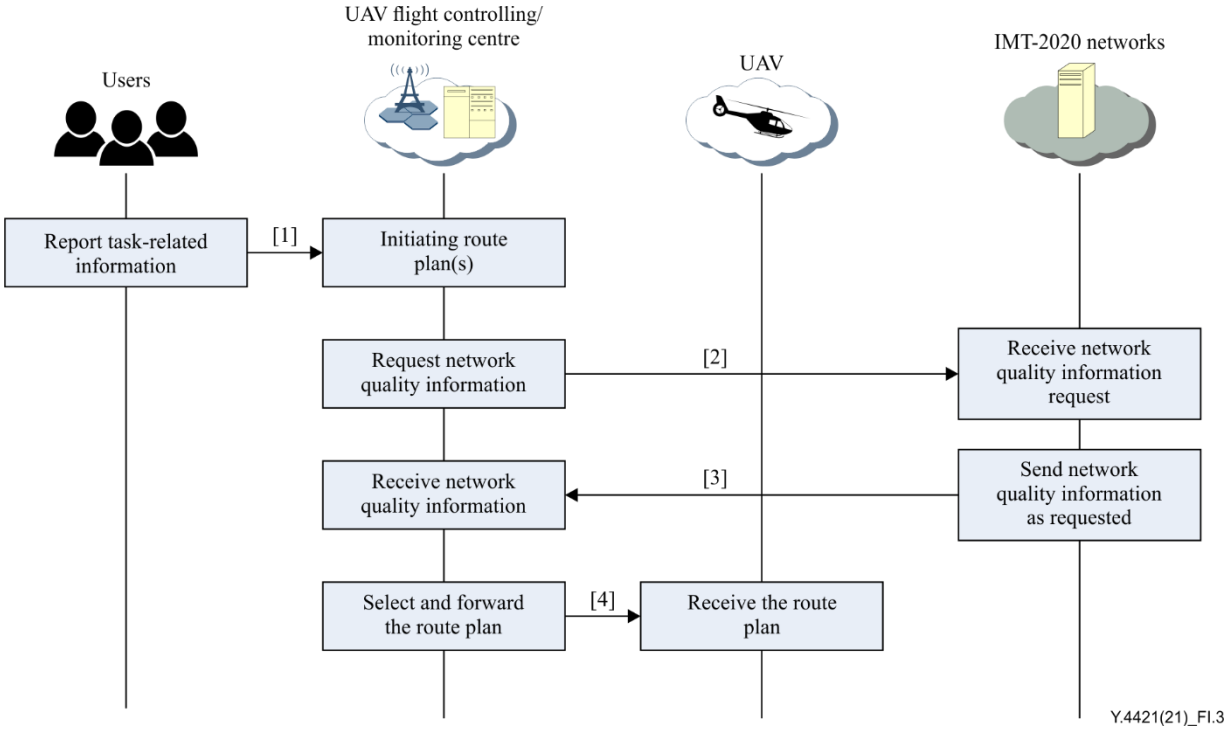

Figure I.3 – UAV route planning based on IMT-2020 networks

1) Before flight, the user (as UAV controller) sends the task-related information to the UAV flight controlling/monitoring centre and the centre initially generates one or multiple route plans.

2) The UAV flight controlling/monitoring centre requests network quality information along the initially planned routes from IMT-2020 networks.

3) IMT-2020 networks will send the network quality information (e.g., signal strength, average latency, transmission rate, service load, etc.) as requested. This data will be used to adjust the UAV's initial route plans or rank the routes.

4) The UAV flight controlling/monitoring centre may adjust the initial route plans based on the network quality information. The optimal route plan selected from initial route plans or adjusted route plans is forwarded to the UAV. The UAV executes the task based on the received route plan.

Bibliography

[b-ITU-T F.749.10] Recommendation ITU-T F.749.10 (2019), *Requirements for communication services of civilian unmanned aerial vehicles.*

[b-ITU-T Y.2091] Recommendation ITU-T Y.2091 (2011), *Terms and definitions for next generation networks.*

[b-ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network.*

[b-ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.

[b-ITU-T Y-Sup.44] Recommendation ITU-T Y Suppl.44 (2017), *Standardization and open source activities related to network softwarization of IMT-2020*.

[b-ITU-R M.1224-1] Recommendation ITU-R M.1224-1 (2012), *Vocabulary of terms for International Mobile Telecommunications (IMT).*

[b-ITU-R M.2171] Report ITU-R M.2171 (2009), *Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace.*

[b-3GPP TS 23.501] 3GPP TS 23.501 (2019), *3rd Generation Partnership Project – Technical Specification Group Services and System Aspects – System architecture for the 5G System (5GS); Stage 2*.

[b-ETSI NFV-WP1] ETSI NFV-WP1 (2012), *Network Functions Virtualisation – Introductory White Paper. Available [viewed 2021-05-24] at:* <https://portal.etsi.org/NFV/NFV_White_Paper.pdf>

[b-ETSI NFV-WP5G] ETSI NFV-WP5G (2017), *Network Functions Virtualisation – White Paper on Network Operator Perspectives On NFV priorities for 5G. Available [viewed 2021-05-24] at:* <https://portal.etsi.org/NFV/NFV_White_Paper_5G.pdf>

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	**Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities**
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2021