NO-TRANSMIT ZONES FOR UNCREWED AERIAL VEHICLES

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to wireless communications relating to operation of uncrewed aerial vehicles (UAVs).

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

SUMMARY

[0003] An article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a

condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0004] Some implementations of the method and apparatuses described herein may further include a network entity for wireless communication, the network entity comprising instructions executable by at least one processor to cause the network entity to obtain at least one indication of at least one expected route of an uncrewed aerial vehicle (UAV); obtain information defining at least one no-transmit zone corresponding to the expected route; provision at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; transmit the at least one service parameter to a second network entity.

[0005] The network entity may comprise one or more of an application enablement entity and an uncrewed aerial system (UAS) application enabler (UAE).

[0006] The second network entity may comprise a UAS associated with the UAV.

[0007] The information defining the at least one no-transmit zone may comprise one or more of at least one geographical area, at least one topological area, at least one spectrum restriction, and at least one transmission power restriction.

[0008] The at least one indication may comprise mobility information associated with the UAV. The instructions may be further executable by the at least one processor to cause the network entity to determine the at least one expected route for the UAV based on the mobility information.

[0009] The at least one indication may comprise a planned route of the UAV. The instructions may be further executable by the at least one processor to cause the network entity to determine the at least one expected route for the UAV based on the planned route.

[0010] The instructions may be further executable by the at least one processor to cause the network entity to monitor an expected mobility of the UAV; and transmit a notification,

to a third network entity, of an expected event associated with the UAV and the no-transmit zone.

[0011] The third network entity may comprise one or more of a UAS provider, a UAS server, an Unmanned Aircraft System Traffic Management (UTM), and a UAS service supplier (USS).

[0012] Transmitting the notification may comprise triggering the third network entity to select an alternative route for the UAV based on the notification.

[0013] The instructions may be further executable by the at least one processor to cause the network entity to detect a trigger event corresponding to mobility of the UAV in relation to the at least one no-transmit zone; and determine a trigger action in response to the trigger event.

[0014] The trigger event may correspond to at least one of a geographical location of the UAV being within, or being expected to be within, a geographical area associated with the at least one no-transmit zone; the UAV leaving, or being expected to leave, a geographical area associated with the at least one no-transmit zone; and the UAV entering, or being expected to enter, a geographical area associated with the at least one no-transmit zone.

[0015] The trigger action may comprise a selection of an alternative route for the UAV, said selection being based on one or more of reducing a number of the one or more no-transmit zones to be transited by the UAV; reducing an expected performance degradation of the UAV, associated with the one or more no-transmit zones; changing a public land mobile network (PLMN) for the UAV; and changing a USS for the UAV.

[0016] The obtaining the information defining the at least one no-transmit zone may comprise requesting the information from an external entity; and receiving the information from the external entity.

[0017] The external entity may comprise at least one of an entity associated with a regulator, an entity associated with an operator, a third party server, and a UAV client.

[0018] The at least one service parameter may comprise one or more of: a registration area of a UAS corresponding to the UAV; an allowed route for the UAV; one or more of the no-transmit zones; one or more policies associated with the one or more no-transmit zones; an identification of a public land mobile network within which the parameter applies; one or more allowed USSs for the UAS; a geographical area associated with the one or more USSs; and one or more service requirements associated with the one or more USSs.

[0019] The instructions may be further executable by the at least one processor to cause the network entity to receive the indication based on a subscription request from an a UAS provider, wherein the subscription request comprises at least one of the following: a time of validity; a geographical area of validity; an availability of the UAV; a connectivity status; and one or more alternative routes for the UAV.

[0020] In some implementations of the method and apparatuses described herein, there is provided a method, performed by a network entity for wireless communication, the method comprising: obtaining at least one indication of at least one expected route of an uncrewed aerial vehicle (UAV); obtaining information defining at least one no-transmit zone corresponding to the expected route; provisioning at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; and transmitting the at least one service parameter to a second network entity.

[0021] In some implementations of the method and apparatuses described herein, there is provided a wireless communication system comprising a first network entity, a second network entity, and an uncrewed aerial vehicle (UAV), wherein the first network entity is configured to: obtain at least one indication of at least one expected route of the uncrewed aerial vehicle (UAV); obtain information defining at least one no-transmit zone corresponding to the expected route; provision at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; and transmit the at least one service parameter to a second network entity.

[0022] The system may comprise a third network entity. The first network entity may be configured to: monitor an expected mobility of the UAV; and transmit a notification, to the third network entity, of an expected event associated with the UAV and the no-transmit

zone. The third network entity may be configured to, based on receiving the notification, select an alternative route for the UAV.

[0023] In some implementations of the method and apparatuses described herein, there is provided a method, performed within a wireless communication system comprising a first network entity, a second network entity and an uncrewed aerial vehicle (UAV), the method comprising: obtaining, by the first network entity at least one indication of at least one expected route of an uncrewed aerial vehicle (UAV); obtaining, by the first network entity information defining at least one no-transmit zone corresponding to the expected route; provisioning, by the first network entity at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; transmitting the at least one service parameter from the first network entity to the second network entity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0025] Figure 2 illustrates a network architecture in accordance with aspects of the present disclosure.

[0026] Figure 3 illustrates a network in accordance with aspects of the present disclosure.

[0027] Figure 4 illustrates a method in accordance with aspects of the present disclosure.

[0028] Figures 5A to 5C illustrate communication flows in accordance with aspects of the present disclosure.

[0029] Figure 6 illustrates an example of a network equipment (NE) 600 in accordance with aspects of the present disclosure.

[0030] Figure 7 illustrate a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0031] Figure 8 illustrates a system in accordance with aspects of the present disclosure.

[0032] Figure 9 illustrates a flowchart of a method performed by a system in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0033] Some wireless communication systems may support operation of unmanned aerial systems that include an unmanned/uncrewed aerial vehicle (UAV) controller and a UAV, which may perform UAV operations, such as command and control (C2) operations. However, these wireless communication systems may be unable to comply with no-transmit zones (NTZs), which may be enforced by a third-party entity. For example, no-transmit zones may be geographical areas in which a UAV is permitted to operate, but in which transmissions (e.g., on one or more frequency bands) are prohibited, for example, to mitigate or reduce interference with other receivers and transmitters such as radars.

[0034] In some cases, these wireless communication systems may incur performance degradations in flight as a consequence of complying with NTZs, for example for data services such as video feeds transmitted from a UAV, e.g. for surveillance.

[0035] Various aspects of the present disclosure relate to enabling a UE, such as a UAV, to operate appropriately in one or more NTZs. Particularly, aspects of the present disclosure relate to identifying NTZs along a route of a UAV, and configuring UAV operation to comply with such NTZs while reducing or avoiding disruptions and improving compliance with performance metrics such as key performance indicators (KPIs). Such aspects may relate to mechanisms at an application enablement layer (e.g. a UAS enabler), which can provision NTZ information to UAVs of interest from application layer, track the UAV status, and provide notifications of expected entries and leavings of a UAV from a NTZ in a predicted manner.

[0036] Aspects of the present disclosure are described in the context of a wireless communications system.

[0037] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0038] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0039] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some

implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0040] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0041] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0042] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0043] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an

evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0044] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0045] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0046] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first

numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0047] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0048] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended

cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0049] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0050] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0051] In the wireless communication system 100, a UE 104 may be, for example, a UAV configured to manage operation (e.g., refrain from performing transmission(s)) when the UE 104 is within at least one NTZ associated with at least one geographical area of the wireless communication system 100. The UE 104 may be configured with (e.g., indicated) the at least one NTZ associated with at least one geographical area of the wireless communication system 100 as described herein with reference to the following figures.

[0052] In such systems providing cellular-enabled UAS, the NTZs may together form "lakes" of restricted connectivity within overall coverage of a public land mobile network (PLMN) e.g. across a wider region such as nationally. This may strongly affect the performance of UAVs having on-going sessions when traveling in routes including these NTZ areas. This will be even more complex in multi-operator services (roaming) and multi-USS deployments.

[0053] In example wireless communication systems there may be provided an enabler for UAS communications, for example in conformance with 3GPP TS 23.255. Such an enabler may provide support for the connectivity of UAS and quality of service (QoS) optimizations in an application layer, as well as middleware support for command & control (C2) and detect & avoid (DAA). A UAS enabler, which may for example be a UAE server or client, may be conceptually positioned between a Core Network and a UAS service supplier/UAS traffic management (USS/UTM), and may allow interaction among multiple mobile network operators (MNOs).

[0054] Figure 2 depicts an example of a UAS application enabler (UAE) architecture in accordance with aspects of the present disclosure.

[0055] The architecture includes a UAS application server 205 in communication with a UAS 210a of a first UAV UE (UE1), which may for example be a UAV controller (UAV-C) or UAV. This communication is performed via a 3GPP network system 215. The architecture further includes a UAS 210b of a second UAV UE (UE2), which may also be a UAV-C or UAV. The second UAS 210b is in communication with the first UAS 210a.

[0056] The architecture includes three layers, which may for example form part of a layered communication architecture such as an open systems interconnect (OSI) model. These comprise a UAS application specific layer 220a, a UAE layer 220b, and a service enabler architecture layer (SEAL) 220c.

[0057] Each UAS 210a, 210b comprises a respective UAS application specific client 225a, 225b, in the UAS application specific layer 220a, a respective UAE client 230a, 230b, in the UAE layer 220b, and respective SEAL clients 235a, 235b in the SEAL 220c.

[0058] The UAS application server 205 comprises a UAS application specific server 240 in the UAS application specific layer 220a, a UAE server 245 in the UAE layer 220b, and SEAL layers 250 in the SEAL 220c.

[0059] Figure 2 additionally depicts API/application layer interfaces specified in SA6, and comprise among others:

a. U1-AE: The interactions related to UAS application layer 220a support functions between a UAE client 210 and UAE server 205 are supported by U1-AE reference point.

b. U2-AE: The interactions related to UAS application layer 220a support functions between the UAE clients 210a, 210b are supported by U2-AE reference point.

c. UAE-E: The interactions related to UAS application support functions between UAE servers 245 in a distributed deployment are supported by UAE-E reference point.

d. SEAL-UU, SEAL-PC5 may for example be as defined in 3GPP TS 23.434 and are used for SEAL 220c services which are utilized by the UAE layer 220b for offering services. For example, group management and location management services may be consumed to offer some services for UAS.

[0060] In the present example the total service area (defined based on USS or UTM, or based on UAE layer coverage area) includes NTZs. The present example can thus include one or more of the following considerations:

a. A UAV UE 210 plans to travel in an area (based on the allowed list of areas) which includes one or more NTZs. The sessions apart from C2, can be also for data services. For example, a UAV 210 may intend to send video feeds to the UASS 240 or to the UAV controller. In this scenario, a KPI for the data service may be defined between the UAV and the UASS or the UAV and the UAV-C.

b. One or both of the UAVs 210a, 210b may have been made aware of the NTZs during a pre-configuration process (for example at a corresponding UAV

application, or by the UTM or UAV-C), and/or one or both of the UAVs 210a, 210b may be unaware of the NTZs

c. One or more of the following sessions may be applicable to this scenario and may be affected by the existence of NTZs:

i. One or more network sessions (PDU session) between a UAV UE 210 and the NW (one or more networks) 215

ii. An off-network session (PC5) between a UAV UE and a UAV-C UE

iii. An application session (U1-APP, U2-APP) between a UAV application client 225 and the UASS 240

iv. An application session (U1-AE, U2-AE) between a UAE client 230 and the UAE server 245.

v. An application session between UAE clients of UAV and UAV-C.

[0061] In examples, a UAV 210 may have dual connectivity via more than one PLMN.

[0062] A NTZ may be translated to a topological area. For example, such a topological area may have coverage which is equal to one or more cells, or an area smaller than a cell area.

[0063] A UAV UE 210 may be provisioned by one or more USSs which cover orthogonal or overlapping service areas. A USS is an entity that assists UAS Operators with meeting UTM operational requirements that enable safe and efficient use of airspace. A USS acts as a communications bridge between federated UTM actors to support operators' abilities to meet the regulatory and operational requirements for UAS operations. A USS may provide the operator with information about planned operations in and around a volume of airspace so that operators can ascertain the ability for the UAV 210 to conduct its mission safely and efficiently.

[0064] In multi-USS scenarios, each USS may be physically located in different clouds, and it is also possible that a USS is deployed at the edge. In such multi-USS scenarios, the interaction with the communication network for supporting a UAS session which requires

the interaction to more than one USS e.g. due to UAV mobility to different geographical area covered by different edge cloud, may be required in case of NTZ areas.

[0065] Figure 3 depicts an example multi-USS system in which a PLMN 315 has associated NTZs 320a, 320b, 320c. In this example, three USSs 305a, 305b, 305c are deployed in different edges/clouds and are clustered in different LUNs. In these cases, the interaction with 5GS may be via different data network access identifiers (DNAIs), and the UAV/UAV-C may be travelling to any location which is allowed to be based on the UAV route and the UAS operator wishes/restrictions. Additionally, one or more of the NTZs 320 may have associated spectrum restrictions.

[0066] Aspects of the present disclosure relate to methods for making a UAV 210a, 210b aware of the existence of no-transmit zones along a planned route, to allow for adapting its behaviour to ensure meeting the service requirements for a UAS service. Aspects further relate to avoiding or preventing UAS service disruptions which may be imposed by resource starvation in NTZs.

[0067] Figure 4 depicts such a method according to an example. The method provides a mechanism at the application enablement layer for providing undisrupted UAS application sessions in scenarios where NTZs exist along the route of a UAV. This mechanism includes the notification of the NTZ and the generation of a trigger action to prevent service disruption and loss of data due to the UAV transmit restrictions.

[0068] The method may for example be performed within the architecture of Figure 2. Figure 4 depicts a UAS enabler layer 220b of a network architecture, in communication with two UAVs 230a, 230b. The network further comprises a 5G core network 405 and a radio access network (RAN) 410. Additionally, a repository 415, which may for example be a UTM, operations administration and maintenance (OAM), unified data repository (UDR), or in general a repository provided by an authority, comprises information defining one or more NTZs. One or more USSs 420, and a UAV-C with associated UAS enabler client 430, are shown.

[0069] Steps depicted in Figure 4 will now be described. Operations between the above-referenced entities may be performed in a different order than the example shown, or

at different times. Some operations may be omitted from the process flow, and some may be added.

[0070] At 1, data defining an expected or predicted route of the UAV is provided to the UAE server 245. This may include one or more of UAV route information, UAV-C location, QoS requirements, and PC5/Uu data. This can be done via different ways according to various examples, for example:

a. The UASS 240 may provide the predicted route, to the UAE server 245 as part of a subscription to NTZ related events. For example, a notification may be issued when a UAV 210 is predicted to arrive at a NTZ, and this may include a prediction of how long the UAV 210 will stay in the NTZ.

b. The UASS 240 or UASC 225 may subscribe for real-time UAV status information (which may for example include information on allowable routes).

c. The data may be provided as part of a multi-USS management request/response by the USS.

d. The UAV 210 may provide the data to the UAE server 245, e.g. in a registration phase (for example when the UAV 210 registers to the UAE layer 220b)

e. The data may be provided during establishment of a UAE session.

[0071] At 2, the UAE server 245 fetches NTZ information for the given area from the repository 415. The UAE server 245 may also translate the coordinates of one or more NTZs to one or more topological areas (for example corresponding to one or more cells of the network, or parts thereof).

[0072] At 3, the UAE 245 server starts monitoring a location of the UAV 210a. This may for example include monitoring elevation/height of the UAV (for example received from the application layer). This may include monitoring network conditions and/or analytics in the target area.

[0073] At 4, the UAE server 245 configures the involved UAV or UAVs 210a, 210b. Other UAVs in the vicinity of the NTZ may also be configured. The UAE server 245 configures UAVs to report their location when close to, or approaching, the NTZ. A UAE

client of another UAV may report that an aerial UE (e.g. operating in another PLMN) is approaching the NTZ area. The UAE server 245 may evaluate whether the NTZ restrictions impact, or are expected to impact, the end-to-end QoS requirements or specification for a UAV session. This evaluation may be performed continuously, periodically, or based on a UAV entering or nearing the NTZ.

[0074] At 5, the UAE server 245 receives a report when a target UAV 210a approaches the NTZ, or in response to abnormal behaviour, or if an NTZ lies along the UAV route and the UAV density is high. A UAE client of another UAV may report that an aerial UE (e.g. operating in other PLMN) is approaching the NTZ area

[0075] At 6, the UAE server 245 generates a trigger event for the UAV. The trigger event is conditional on the reported location and/or status of the UAV.

[0076] At 7a, the UAE server 245 notifies the UAS enabler client 230a of the target UAV 210a status. This may include proposing a trigger action to be performed in response to the trigger event, which can be either application or network or device related. At 7b, the trigger action may be notified to the network layer. Examples of trigger actions include one or more from the following:

a. A change of route for the UAV 210a to avoid NTZs, and/or a selection of an alternative route for example a route, from a list of allowable routes, having a minimum number of NTZs and/or a minimum expected performance degradation. In examples, the UAE server 245 may select the alternative route. Alternatively, the UAE server 245 may notify the UASS 240 to select a new route for the UAV 210a. In this example, the USS 420 may determine a new route if the network indicates that the network has no alternative carrier frequencies for the UAV 210a to operate in the NTZ area.

b. An adaptation of traffic schedule and/or QoS requirements, for example per waypoint, to take into account the NTZ. For example, an encoding rate for video traffic may be altered e.g. reduced in the NTZ.

c. Some processing may be moved from the cloud to the edge (for example by USS 420 relocation), to account for a potential increase in latency when the UAV 210a is within the NTZ.

d. A change of USS 420 or implementation of USS redundancy.

e. A change of PLMN, non-public network (NPN), dual connectivity, and or RAT. For example, the trigger action may comprise a change from one PLMN to another PLMN, a change from one NPN to another NPN, or a change from a PLMN to a NPN (or vice-versa).

f. Change from Uu to PC5. UAV1 in NTZ sends to UAV2 outside NTZ; and UAV2 relays message to NW.

g. Implementation of buffering of application messages by the UAE client 230a for the period that UAV 210a is on NTZ. For example, the UAE client 230a may buffer transmissions while the UAV 210a is within the NTZ, and then transmit them following leaving the NTZ.

[0077] The method of Figure 4 thus allows an assessment of when a UAV will enter a NTZ, and for action to be taken to mitigate the performance impact of this.

[0078] Specific aspects of the method of Figure 4 will now be discussed with reference to Figures 5, 6 and 7. In general, these aspects relate to triggering of NTZ provisioning by the UAE server 245.

[0079] Figure 5A depicts a subscription/request phase, in which NTZ events are subscribed to. Figure 5B depicts a configuration phase, which comprises configuration of UAVs for monitoring. Figure 5C depicts a run-time phase, comprising a notification phase to the application side and the UE/network side.

[0080] Figure 5A depicts a communication flow between a UASS 240, UAE server 245, and 5GS (or UTM) 405, for example as discussed above. . Operations between the above-referenced entities may be performed in a different order than the example shown, or at different times. Some operations may be omitted from the process flow, and some may be added.

[0081] At 1, the UAE application specific server 240 transmits a subscription request for no-transmit zone information to the UAE server 245. The request may include one or more of the following information items:

Information element	Description
UASS ID	The identifier of the UAS application specific server 240 which initiated this request. This can be for example a USS ID.
UAV ID (s)	The identifier of one or more UAV(s) 210 (e.g. 3GPP UE ID or CAA level UAV ID) for which the NTZ info is requested.
Area of Interest	Geographic area location information where the UASS server 240 wishes to monitor the UAS's location adherence.
PLMN / NPN ID	The ID of the PLMN or NPN (or a list of them) for which the NTZ is requested to be monitored.
UAS service ID/profile	Type of UAS service and/or service profile including the KPI/KQI for the UAS sessions. One example is the UAS service to be video feeds to be sent from the UAV 210 to the UASS 240.
Connectivity report	Reporting UAV connectivity status/issues etc. This may include UAV UE availability status or expected availability within a certain time and area.
Reporting configuration / trigger criteria	Triggering criteria and report configuration (for example periodicity of reporting, thresholds for reporting if a UAV 210 is expected to enter or leave the NTZ, reporting based on prediction with certain confidence levels.
Notification Target URI	Target URI where the UAS application specific server wishes to receive the notifications about real-time UAV status information.
Alternative UAV route	Alternative path if UAV 210 cannot transmit at all in case of NTZ.

[0082] At 2, the UAE server 245 interacts with the 5GC, or UTM, or an external entity (e.g. the regulator) 405 to fetch the NTZ for the given area of interest. This can be towards 5GC (e.g. UDM/UDR) or OAM or an external entity/ regulator (e.g. UTM), depending on the specifics of a given implementation.

[0083] At 3, the UAE server 245 stores the subscription information.

[0084] At 4, the UAE server 245 sends a subscription response to the UAS application specific server 240. The response may include one or more of the following elements:

Information element	Description
Result	Result from the UAE server 245, in response to subscription request, indicating success or failure
Subscription ID	Identifier of a successful subscription.

[0085] The above description relates to a subscription. However, in alternative examples, this may be a one-time request.

[0086] Figure 5B depicts a communication flow between a host UAV 210a comprising a UAS client 225a and UAE client 230a, a SEAL LMS 505 (which may alternatively or additionally be a 5GC 405), and a UAE server 245, for example as discussed above. Operations between the above-referenced entities may be performed in a different order than the example shown, or at different times. Some operations may be omitted from the process flow, and some may be added. The communication flow of Figure 5B may be performed following subscription of the UAS application server 240 to the UAE server 245 for NTZ information.

[0087] At 1, the UAE server 245 starts monitoring the location of the UAV(s) 210 of interest based on the subscription (as established in the method of Figure 5A). This may for example be monitored from SEAL LMS 505 (for example as specified in 3GPP TS 23.434), or using LCS services from 5GC 405 (LMF). In examples, this monitoring may be predictive (for example from NWDAF or another analytics function e.g. ADAES). The predicted mobility of the UAV 210 of interest may thus trigger sending the NTZ provisioning request (for example for a UAV 210 approaching the NTZ).

[0088] At 2, the UAE server 245 discovers the UAE clients 230a of the UAV UE(s) 210a of interest. If the clients are not connected, this may lead to establishing a connection with the UAE clients 230a of interest. After connecting, the UAE server 245 transmits to the UAE client(s) 230a of interest a NTZ information provisioning request to provide the NTZ information, as well as the reporting configuration for receiving trigger events based on the local UAV monitoring. This message includes one or more of the following parameters:

Information element	Description
UASS ID	Identity of the UAS application specific server 240 which requests the NTZI info provisioning. This ID can be the USS identifier, when the UAS application specific server 240 is the USS.
UAS ID	The identification of the UAS. This could be in form of identifier for the UAS, e.g group ID; or collection of individual identifiers for the UAV and UAV-C, e.g. CAA level UAV ID, GPSI
UAS registration area	The registration area where the UAV 210a is allowed to fly
UAS allowed route	The UAV 210a allowed route within the registration area.
No Transmit Zone (NTZ) areas	Geographical and/or topological area of the NTZ
NTZ-related policies	The NTZ-related policies consist of the policies which apply when reaching a NTZ. These policies may be related to selecting alternative RAT/PLMN within a NTZ.
PLMN/NPN ID	The PLMN/NPN ID for which the provisioning applies
> Allowed USS(s) information	The information for the allowed USSs for the UAS.
>> USS ID	The identity of the allowed USS from the list of USSs for the target UAS (identified e.g. by FQDN)
>> USS service area	The geographical area per USS
>> USS service requirements	The capabilities and key performance requirements per each USS service.
>> List of USS DNAI(s)	DNAI(s) associated with the target USS.

[0089] At 3, the UAE client 230a interacts with the UAS client 225a and optionally with a UE modem/OS of the UAV 210a to pass and store the provisioning policies/parameters provided at 2.

[0090] At 4, the UAE client 230a sends a NTZ information provisioning response to the UAE server 245. This response comprises a positive or negative acknowledgement of the provisioning request.

[0091] Figure 5B depicts a communication flow between the UE client 230a, 5GC/SEAL 405/505, UAE server 245, and UAS application specific server 240, for example as discussed above. Operations between the above-referenced entities may be performed in a different order than the example shown, or at different times. Some operations may be omitted from the process flow, and some may be added. The communication flow of Figure 5C may be performed following NTZ information provision for example as set out in relation to Figure 5B.

[0092] At 1, the UAE server 245 monitors the UAV of interest 210a location from SEAL LMS 505 or 5GC (LMF) 405. This monitoring comprise performing analytics on the predicted location of the UAV 210a from NWDAF or ADAES.

[0093] At 2, the UAE server 245 may (additionally or alternatively to 1) receive a report from the UAE client 230a indicating an expected enter/leave of the UAV 210a to/from the NTZ (for example based on provisioning procedure of Figure 5B).

[0094] At 3, the UAE server 245 generates a trigger action which may comprise a recommended action towards the UASS 240. This trigger action may for example be the proposal of an alternative route for the UAV 210a, or a change of USS, or a change of RAT/PLMN for the UAS service, or other actions as discussed in more detail above.

[0095] At 4, the UAE server 245 sends the notification for the UAV 210a approaching/leaving the NTZ together with the trigger action to the UAS application specific server 240. In examples, this may comprise sending only the notification, or only the trigger action, or both. This may be implemented as separate steps / commands and may also include negotiation on the recommended action between the UAE server 245 and the UASS 240.

[0096] As a further example, this may comprise transmitting the notification to the UASS 240 after which the UASS 240 provides the trigger action to the UAE server 245 for enforcement.

[0097] As a further example, this step may comprise transmitting the trigger action to the UASS 240, after which the UASS 240 confirms the trigger action to the UAE using a complete message.

[0098] In examples, the UASS 240 may be the USS and may determine a new route if the network indicates that the network has no alternative carrier frequencies for the UAV 210a to operate in the NTZ area.

[0099] In summary, the present disclosure provides for methods and apparatuses for supporting no-transmit zones for a UAV operating as a UE in a mobile communications network.

[0100] Figure 6 illustrates an example of a NE 600 in accordance with aspects of the present disclosure. The NE 600 may for example implement a UAE server 245 as described above. The NE 600 may include a processor 602, a memory 604, a controller 606, and a transceiver 608. The processor 602, the memory 604, the controller 606, or the transceiver 608, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0101] The processor 602, the memory 604, the controller 606, or the transceiver 608, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0102] The processor 602 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 602 may be configured to operate the memory 604. In some other implementations, the memory 604 may be integrated into the processor 602. The processor 602 may be configured to execute computer-readable instructions stored in the memory 604 to cause the NE 600 to perform various functions of the present disclosure.

[0103] The memory 604 may include volatile or non-volatile memory. The memory 604 may store computer-readable, computer-executable code including instructions when executed by the processor 602 cause the NE 600 to perform various functions described

herein. The code may be stored in a non-transitory computer-readable medium such the memory 604 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0104] In some implementations, the processor 602 and the memory 604 coupled with the processor 602 may be configured to cause the NE 600 to perform one or more of the functions described herein (e.g., executing, by the processor 602, instructions stored in the memory 604). For example, the processor 602 may support wireless communication at the NE 600 in accordance with examples as disclosed herein. The NE 600 may be configured to support a means for obtaining at least one indication of at least one expected route of an uncrewed aerial vehicle (UAV); obtaining information defining at least one no-transmit zone corresponding to the expected route; provisioning at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; and transmitting the at least one service parameter to a second network entity..

[0105] The controller 606 may manage input and output signals for the NE 600. The controller 606 may also manage peripherals not integrated into the NE 600. In some implementations, the controller 606 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 606 may be implemented as part of the processor 602.

[0106] In some implementations, the NE 600 may include at least one transceiver 608. In some other implementations, the NE 600 may have more than one transceiver 608. The transceiver 608 may represent a wireless transceiver. The transceiver 608 may include one or more receiver chains 610, one or more transmitter chains 612, or a combination thereof.

[0107] A receiver chain 610 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 610 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 610 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 610 may include at

least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 610 may include at least one decoder for decoding and/or processing the demodulated signal to receive the transmitted data.

[0108] A transmitter chain 612 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 612 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 612 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 612 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0109] Figure 7 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0110] At 702, the method comprises obtaining at least one indication of at least one expected route of the uncrewed aerial vehicle (UAV).

[0111] At 704, the method comprises obtaining information defining at least one no-transmit zone corresponding to the expected route.

[0112] At 706, the method comprises provisioning at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV.

[0113] At 708, the method comprises transmitting the at least one service parameter to a second network entity.

[0114] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0115] Figure 8 illustrates a system according to an example of the present disclosure. The system comprises a first network entity 805, a second network entity 810, and a UE 815 implementing a UAV. The first network entity 805 may be the UAE server 245 discussed above. The second network entity 810 may be the UAS application specific server 240 discussed above. The UE 815 may implement the UE 210a discussed above. The first network entity 805 is configured to obtain at least one indication of at least one expected route of the uncrewed aerial vehicle (UAV) 815; obtain information defining at least one no-transmit zone corresponding to the expected route; provision at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV; and transmit the at least one service parameter to the second network entity 810.

[0116] Figure 9 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method may be implemented within the system of Figure 8. In some implementations, the network elements 805, 810 and UAV 815 may execute a set of instructions to control the function elements thereof to perform the described functions.

[0117] At 902, the method comprises obtaining at least one indication of at least one expected route of the UAV 805.

[0118] At 904, the method comprises obtaining information defining at least one no-transmit zone corresponding to the expected route.

[0119] At 906, the method comprises provisioning at least one service parameter associated with the at least one no-transmit zone and an application associated with the UAV.

[0120] At 908, the method comprises transmitting the at least one service parameter to the second network entity 810.

[0121] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0122] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.