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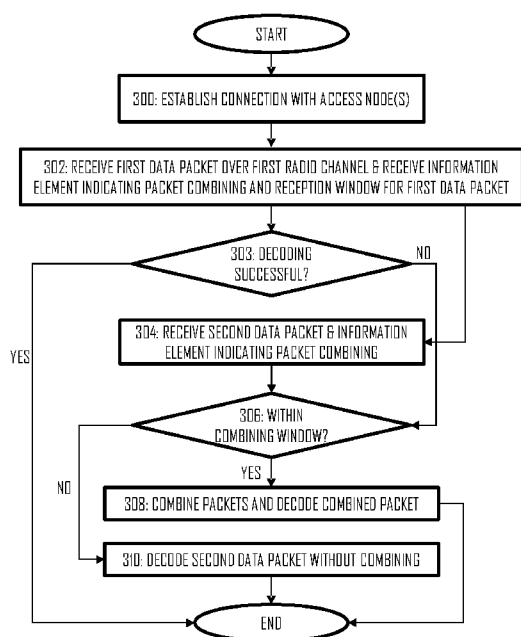


Fig 3

(57) Abstract: There is provided a solution for performing packet duplication in a wireless network. According to an aspect, a method comprises: establishing, by a terminal device, a communications connection with at least one access node, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet; receiving, by the terminal device, a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a duplication mode and a second indication informing a reception time window for combining duplicates of the data packet; carrying out, by the terminal device, decoding of the first duplicate of the data packet; receiving, by the terminal device, a second duplicate of the data packet over the second radio channel; and as a response to the decoding being unsuccessful, performing one of the following by the terminal device: decoding, if the second duplicate of the data packet was received within the reception time window, a combination of the first duplicate of the data packet and the second duplicate of the data packet; decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.



PACKET COMMUNICATIONS

TECHNICAL FIELD

The invention relates to communications in a system suitable for packet delivery with regard to multi-connectivity, dual-connectivity, carrier
5 aggregation or like scenarios.

BACKGROUND

Multi-connectivity or dual-connectivity of a terminal device to multiple radio access points is a 5G key enabler in order to satisfy the demanding requirements of 5G mobile networks. Multi-connectivity supports simultaneous
10 connectivity and aggregation across different technologies such as 5G and 4G as well as unlicensed technologies. In addition, it provides connectivity to multiple network layers such as macro and small cells and multiple radio access technology (RAT) layers such as below 6GHz and mmwave. Carrier aggregation is a key technology in LTE Advanced (LTE-A) to enable higher capacities in radio
15 networks.

BRIEF DESCRIPTION

According to an aspect, there is provided the subject matter of the independent claims. Some embodiments are defined in the dependent claims.

According to an aspect, there is provided an apparatus comprising
20 means for performing: establishing a communications connection with at least one access node, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet; receiving a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a
25 duplication mode and a second indication informing a reception time window for combining duplicates of the data packet; carrying out decoding of the first duplicate of the data packet; receiving a second duplicate of the data packet over the second radio channel; and as a response to the decoding being unsuccessful, performing one of the following: decoding, if the second duplicate of the data
30 packet was received within the reception time window, a combination of the first duplicate of the data packet and the second duplicate of the data packet; decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.

In an embodiment, the at least one access node comprises a master access node of the communications connection, and wherein the means are further configured to receive, from the master access node, information identifying a secondary access node providing one of the first radio channel and the second radio channel.

In an embodiment, the means are further configured to establish the first radio channel with the master access node and the second radio channel with the secondary access node, and to receive from the master access node in connection with the first duplicate of the data packet, an information element identifying the secondary access node as a transmitter of the second duplicate of the data packet.

In an embodiment, the means are configured to discard the second duplicate of the data packet as a response to the decoding of the first duplicate of the data packet being successful.

In an embodiment, the means are configured to start counting the reception time window from the reception of the information element indicating the reception time window.

In an embodiment, said second indication is received as a semi-static parameter via downlink control information of a physical downlink control or data channel, or via radio resource control signaling.

In an embodiment, the means are configured to decode the combination of the first duplicate of the data packet and the second duplicate of the data packet based on soft combining of the first duplicate of the data packet and the second duplicate of the data packet.

According to another aspect, there is provided an apparatus for a master access node of a wireless network, comprising means for performing: establishing a communications connection associated with a terminal device, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node; defining a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding; defining a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the reception time window; transmitting the scheduling window to the secondary access node; transmitting to the terminal

device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and a third indication identifying the secondary access node; and transmitting a first duplicate of the data packet to the terminal device and a
5 second duplicate of the data packet to the secondary access node.

In an embodiment, the means are further configured to transmit to the secondary access node an indication that the second duplicate of the data packet is transmitted in the duplication mode.

According to another aspect, there is provided an apparatus for a
10 secondary access node of a wireless network, comprising means for performing: establishing a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device; establishing a communications connection with the terminal device, comprising at least a first radio channel of the plurality of radio channels; receiving, from the
15 master access node, a scheduling window for scheduling timing of a duplicate of the data packet; receiving, from the master access node, the duplicate of the data packet for forwarding to the terminal device; scheduling transmission of the duplicate of the data packet according to the scheduling window; and transmitting the duplicate of the data packet as scheduled to the terminal device
20 over the first radio channel and, further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted from the master access node.

In an embodiment, the means are further configured to: determine
25 that the scheduling according to the scheduling window has failed; upon said determining transmitting the duplicate of the data packet to the terminal device without said indication.

In an embodiment, the means are further configured to receive from the master access node an information element indicating a modulation and
30 coding scheme for the duplicate of the data packet, and to transmit the duplicate of the data packet to the terminal device by using the modulation and coding scheme.

In an embodiment, the means comprises: at least one processor; and at least one memory including computer program code, the at least one memory and
35 computer program code configured to, with the at least one processor, cause the performance of any one of the above-described apparatuses.

According to another aspect, there is provided a method comprising: establishing, by a terminal device, a communications connection with at least one access node, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet; receiving, by the terminal device, a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a duplication mode and a second indication informing a reception time window for combining duplicates of the data packet; carrying out, by the terminal device, decoding of the first duplicate of the data packet; receiving, by the terminal device, a second duplicate of the data packet over the second radio channel; and as a response to the decoding being unsuccessful, performing one of the following by the terminal device: decoding, if the second duplicate of the data packet was received within the reception time window, a combination of the first duplicate of the data packet and the second duplicate of the data packet; decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.

In an embodiment, the at least one access node comprises a master access node of the communications connection, and the method further comprises receiving, by the terminal device from the master access node, information identifying a secondary access node providing one of the first radio channel and the second radio channel.

In an embodiment, the method further comprises the terminal device establishing the first radio channel with the master access node and the second radio channel with the secondary access node, and receiving from the master access node in connection with the first duplicate of the data packet, an information element identifying the secondary access node as a transmitter of the second duplicate of the data packet.

In an embodiment, the method further comprises discarding the second duplicate of the data packet as a response to the decoding of the first duplicate of the data packet being successful.

In an embodiment, the further comprises starting counting the reception time window from the reception of the information element indicating the reception time window.

In an embodiment, said second indication is received as a semi-static parameter via downlink control information of a physical downlink control or data channel, or via radio resource control signaling.

In an embodiment, the method further comprises decoding the combination of the first duplicate of the data packet and the second duplicate of the data packet based on soft combining of the first duplicate of the data packet and the second duplicate of the data packet.

5 According to another aspect, there is provided a method comprising: establishing, by a master access node, a communications connection associated with a terminal device, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access
10 node; defining, by the master access node, a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding; defining, by the master access node, a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are
15 receivable by the terminal device within the reception time window; transmitting, by the master access node, the scheduling window to the secondary access node; transmitting, by the master access node to the terminal device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and a third
20 indication identifying the secondary access node; and transmitting, by the master access node, a first duplicate of the data packet to the terminal device and a second duplicate of the data packet to the secondary access node.

In an embodiment, the method further comprises transmitting to the secondary access node an indication that the second duplicate of the data packet
25 is transmitted in the duplication mode.

 According to another aspect, there is provided a method comprising: establishing, by a secondary access node, a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device; establishing, by the secondary access node, a
30 communications connection with the terminal device, comprising at least a first radio channel of the plurality of radio channels; receiving, by the secondary access node from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet; receiving, by the secondary access node from the master access node, the duplicate of the data packet for forwarding to
35 the terminal device; scheduling, by the secondary access node, transmission of the duplicate of the data packet according to the scheduling window; and

transmitting, by the secondary access node, the duplicate of the data packet as scheduled to the terminal device over the first radio channel and, further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted from the master access node.

In an embodiment, the method further comprises: determining that the scheduling according to the scheduling window has failed, upon said determining, transmitting the duplicate of the data packet to the terminal device without said indication.

In an embodiment, the method further comprises receiving from the master access node an information element indicating a modulation and coding scheme for the duplicate of the data packet, and transmitting the duplicate of the data packet to the terminal device by using the modulation and coding scheme.

According to another aspect, there is provided a computer program product embodied on a computer-readable medium and comprising a computer program code readable by a computer, wherein the computer program code configures the computer to carry out a computer process comprising: establishing a communications connection with at least one access node, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet; receiving, by the terminal device, a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a duplication mode and a second indication informing a reception time window for combining duplicates of the data packet; carrying out decoding of the first duplicate of the data packet; receiving a second duplicate of the data packet over the second radio channel; and as a response to the decoding being unsuccessful, performing one of the following: decoding, if the second duplicate of the data packet was received within the reception time window, a combination of the first duplicate of the data packet and the second duplicate of the data packet; decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.

According to another aspect, there is provided a computer program product embodied on a computer-readable medium and comprising a computer program code readable by a computer, wherein the computer program code configures the computer to carry out a computer process comprising: establishing a communications connection associated with a terminal device, the

communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node; defining a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding; defining a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the reception time window; transmitting the scheduling window to the secondary access node; transmitting, to the terminal device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and a third indication identifying the secondary access node; and transmitting a first duplicate of the data packet to the terminal device and a second duplicate of the data packet to the secondary access node.

According to another aspect, there is provided a computer program product embodied on a computer-readable medium and comprising a computer program code readable by a computer, wherein the computer program code configures the computer to carry out a computer process comprising: establishing a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device; establishing a communications connection with the terminal device, comprising at least a first radio channel of the plurality of radio channels; receiving, from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet; receiving, from the master access node, the duplicate of the data packet for forwarding to the terminal device; scheduling transmission of the duplicate of the data packet according to the scheduling window; and transmitting the duplicate of the data packet as scheduled to the terminal device over the first radio channel and, further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted from the master access node.

One or more examples of implementations are set forth in more detail in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

In the following some embodiments will be described with reference

to the attached drawings, in which

Figure 1 illustrates an example of a wireless network to which embodiments of the invention may be applied;

Figures 2A and 2B illustrate different multi-connectivity scenarios for
5 a terminal device;

Figures 3 to 5 illustrate some embodiments for enabling a terminal device to perform packet combining of duplicate packets received over different radio bearers;

Figure 6 illustrates a signaling diagram of a procedure for performing
10 duplicate transmissions and for signaling a combining criterion to the terminal device according to some embodiments of the invention;

Figure 7 illustrates an embodiment for combining duplicate packets under various reception timings of the duplicate data packets;

Figure 8 illustrates a procedure for a secondary access node to handle
15 an exception in scheduled transmission of a duplicate data packet; and

Figures 9 to 11 illustrate apparatuses according to some embodiments.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

The following embodiments are exemplifying. Although the specification may refer to “an”, “one”, or “some” embodiment(s) in several
20 locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

In the following, different exemplifying embodiments will be described
25 using, as an example of an access architecture to which the embodiments may be applied, a radio access architecture based on long term evolution advanced (LTE Advanced, LTE-A) or new radio (NR) (or can be referred to as 5G), without restricting the embodiments to such an architecture, however. It is obvious for a person skilled in the art that the embodiments may also be applied to other kinds
30 of communications networks having suitable means by adjusting parameters and procedures appropriately. Some examples of other options for suitable systems are the universal mobile telecommunications system (UMTS) radio access network (UTRAN or E-UTRAN), long term evolution (LTE, the same as E-UTRA), wireless local area network (WLAN or WiFi), worldwide interoperability for
35 microwave access (WiMAX), systems using ultra-wideband (UWB) technology,

sensor networks, mobile ad-hoc networks (MANETs) and Internet Protocol multimedia subsystems (IMS) or any combination thereof.

Figure 1 depicts examples of simplified system architectures only showing some elements and functional entities, all being logical units, whose implementation may differ from what is shown. The connections shown in Figure 1 are logical connections; the actual physical connections may be different. It is apparent to a person skilled in the art that the system typically comprises also other functions and structures than those shown in Figure 1.

The embodiments are not, however, restricted to the system given as an example but a person skilled in the art may apply the solution to other communication systems provided with necessary properties.

The example of Figure 1 shows a part of an exemplifying radio access network.

Figure 1 shows user devices 100 and 102 configured to be in a wireless connection on one or more communication channels in a cell with an access node 104 (such as (e/g)NodeB) providing the cell. The link from a user device to a (e/g)NodeB is called uplink (UL) or reverse link and the physical link from the (e/g)NodeB to the user device is called downlink or forward link. The links may comprise a physical link. It should be appreciated that (e/g)NodeBs or their functionalities may be implemented by using any node, host, server or access point etc. entity suitable for such a usage. Said node 104 may be referred to as network node 104 or network element 104 in a broader sense.

A communications system typically comprises more than one (e/g)NodeB in which case the (e/g)NodeBs may also be configured to communicate with one another over links, wired or wireless, designed for the purpose. These links are sometimes called backhaul links that may be used for signaling purposes. Xn interface is an example of such a link. The (e/g)NodeB is a computing device configured to control the radio resources of communication system it is coupled to. The (e/g)NodeB includes or is coupled to transceivers. From the transceivers of the (e/g)NodeB, a connection is provided to an antenna unit that establishes bi-directional radio links to user devices. The antenna unit may comprise a plurality of antennas or antenna elements. The (e/g)NodeB is further connected to core network 110 (CN or next generation core NGC). Depending on the system, the counterpart on the CN side can be a user plane function (UPF) (this may be 5G gateway corresponding to serving gateway (S-

GW) of 4G) or access and mobility function (AMF) (this may correspond to mobile management entity (MME) of 4G).

The user device 100, 102 (also called UE, user equipment, user terminal, terminal device, mobile terminal, etc.) illustrates one type of an apparatus to which resources on the air interface are allocated and assigned, and thus any feature described herein with a user device may be implemented with a corresponding apparatus, such as a part of a relay node. An example of such a relay node is an integrated access and backhaul (IAB) -node (a.k.a. self-backhauling relay).

The user device typically refers to a portable computing device that includes wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following types of devices: a mobile station (mobile phone), smartphone, personal digital assistant (PDA), handset, device using a wireless modem (alarm or measurement device, etc.), laptop and/or touch screen computer, tablet, game console, notebook, and multimedia device. It should be appreciated that a user device may also be a nearly exclusive uplink-only device, of which an example is a camera or video camera loading images or video clips to a network. A user device may also be a device having capability to operate in Internet of Things (IoT) network which is a scenario in which objects are provided with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The user device (or in some embodiments mobile terminal (MT) part of the relay node) is configured to perform one or more of user equipment functionalities. The user device may also be called a subscriber unit, mobile station, remote terminal, access terminal, user terminal or user equipment (UE) just to mention but a few names or apparatuses.

Various techniques described herein may also be applied to a cyber-physical system (CPS) (a system of collaborating computational elements controlling physical entities). CPS may enable the implementation and exploitation of massive amounts of interconnected ICT devices (sensors, actuators, processors microcontrollers, etc.) embedded in physical objects at different locations. Mobile cyber physical systems, in which the physical system in question has inherent mobility, are a subcategory of cyber-physical systems. Examples of mobile physical systems include mobile robotics and electronics transported by humans or animals.

It should be understood that, in Figure 1, user devices may have one or more antennas. The number of reception and/or transmission antennas may naturally vary according to a current implementation.

Additionally, although the apparatuses have been depicted as single
5 entities, different units, processors and/or memory units (not all shown in Figure 1) may be implemented.

5G enables using multiple input – multiple output (MIMO) antennas, many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and
10 employing a variety of radio technologies depending on service needs, use cases and/or spectrum available. 5G mobile communications supports a wide range of use cases and related applications including video streaming, augmented reality, different ways of data sharing and various forms of machine type applications, including vehicular safety, different sensors and real-time control. 5G is expected
15 to have multiple radio interfaces, namely below 6GHz, cmWave and mmWave, and also being integrable with existing legacy radio access technologies, such as the LTE. Integration with the LTE may be implemented, at least in the early phase, as a system, where macro coverage is provided by the LTE and 5G radio interface access comes from small cells by aggregation to the LTE. In other words, 5G is
20 planned to support both inter-RAT operability (such as LTE-5G) and operability in different radio bands such as below 6GHz – cmWave, below 6GHz – cmWave – mmWave. One of the concepts considered to be used in 5G networks is network slicing in which multiple independent and dedicated virtual sub-networks (network instances) may be created within the same infrastructure to run
25 services that have different requirements on latency, reliability, throughput and mobility.

The current architecture in LTE networks is fully distributed in the radio and fully centralized in the core network. The low latency applications and services in 5G require to bring the content close to the radio which leads to local
30 break out and multi-access edge computing (MEC). 5G enables analytics and knowledge generation to occur at the source of the data. This approach requires leveraging resources that may not be continuously connected to a network such as laptops, smartphones, tablets and sensors. MEC provides a distributed computing environment for application and service hosting. It also has the ability
35 to store and process content in close proximity to cellular subscribers for faster response time. Edge computing covers a wide range of technologies such as

wireless sensor networks, mobile data acquisition, mobile signature analysis, cooperative distributed peer-to-peer ad hoc networking and processing also classifiable as local cloud/fog computing and grid/mesh computing, dew computing, mobile edge computing, cloudlet, distributed data storage and retrieval, autonomic self-healing networks, remote cloud services, augmented and virtual reality, data caching, Internet of Things (massive connectivity and/or latency critical), critical communications (autonomous vehicles, traffic safety, real-time analytics, time-critical control, healthcare applications).

The communication system is also able to communicate with other networks, such as a public switched telephone network or the Internet 112, or utilize services provided by them. The communication network may also be able to support the usage of cloud services, for example at least part of core network operations may be carried out as a cloud service (this is depicted in Figure 1 by "cloud" 114). The communication system may also comprise a central control entity, or a like, providing facilities for networks of different operators to cooperate for example in spectrum sharing.

Edge cloud may be brought into radio access network (RAN) by utilizing network function virtualization (NVF) and software defined networking (SDN). Using edge cloud may mean access node operations to be carried out, at least partly, in a server, host or node operationally coupled to a remote radio head or base station comprising radio parts. It is also possible that node operations will be distributed among a plurality of servers, nodes or hosts. Application of cloudRAN architecture enables RAN real time functions being carried out at the RAN side and non-real time functions being carried out in a centralized manner.

It should also be understood that the distribution of functions between core network operations and base station operations may differ from that of the LTE or even be non-existent. Some other technology advancements probably to be used are Big Data and all-IP, which may change the way networks are being constructed and managed. 5G (or new radio, NR) networks are being designed to support multiple hierarchies, where MEC servers can be placed between the core and the base station or nodeB (gNB). It should be appreciated that MEC can be applied in 4G networks as well.

5G may also utilize satellite communication to enhance or complement the coverage of 5G service, for example by providing backhauling. Possible use cases are providing service continuity for machine-to-machine (M2M) or Internet

of Things (IoT) devices or for passengers on board of vehicles, or ensuring service availability for critical communications, and future railway/maritime/aeronautical communications. Satellite communication may utilize geostationary earth orbit (GEO) satellite systems, but also low earth orbit (LEO) satellite systems, in particular mega-constellations (systems in which hundreds of (nano)satellites are deployed). Each satellite in the mega-constellation may cover several satellite-enabled network entities that create on-ground cells. The on-ground cells may be created through an on-ground relay node or by a gNB located on-ground or in a satellite.

It is obvious for a person skilled in the art that the depicted system is only an example of a part of a radio access system and in practice, the system may comprise a plurality of (e/g)NodeBs, the user device may have an access to a plurality of radio cells and the system may comprise also other apparatuses, such as physical layer relay nodes or other network elements, etc. At least one of the (e/g)NodeBs or may be a Home(e/g)nodeB. Additionally, in a geographical area of a radio communication system a plurality of different kinds of radio cells as well as a plurality of radio cells may be provided. Radio cells may be macro cells (or umbrella cells) which are large cells, usually having a diameter of up to tens of kilometers, or smaller cells such as micro-, femto- or picocells. The (e/g)NodeBs of Figure 1 may provide any kind of these cells. A cellular radio system may be implemented as a multilayer network including several kinds of cells. Typically, in multilayer networks, one access node provides one kind of a cell or cells, and thus a plurality of (e/g)NodeBs are required to provide such a network structure.

For fulfilling the need for improving the deployment and performance of communication systems, the concept of “plug-and-play” (e/g)NodeBs has been introduced. Typically, a network which is able to use “plug-and-play” (e/g)NodeBs, includes, in addition to Home (e/g)NodeBs (H(e/g)nodeBs), a home node B gateway, or HNB-GW (not shown in Figure 1). A HNB Gateway (HNB-GW), which is typically installed within an operator’s network may aggregate traffic from a large number of HNBS back to a core network.

Packet duplication has been proposed as a mechanism for ultra-reliable low latency connections (URLLC). The duplication may be understood as a concept where the same packet is delivered from a source to a destination in multiple copies and via different routes that typically are uncorrelated to the largest possible extent. In this manner, the probability of the packet reaching the destination within a specific time frame is improved. One specific example of

duplication is Carrier Aggregation (CA) duplication which can be understood as duplication with CA where the LCHs of a duplicated radio bearer are mapped to different serving cells or carriers with CA. Figure 2A illustrates a scenario where the CA duplication is used between a single access node 104 and the UE 100.

5 Multiple carriers 200, 202 may be configured between the access node 104 and the UE. The carriers 200, 202 may be configured, for example, with different beamforming configurations to provide spatial diversity for the duplication. Other type of diversity may be used as well. Figure 2B illustrates a scenario where the duplication is used between the UE and several access nodes 104, 104A, 104B.

10 Each access node 104, 104A, 104B may have configured at least one radio channel 210, 212, 214 for communication with the UE 100. The access node 104 may be a master access node of a connection of the UE, and the access nodes 104A, 104B may be secondary access nodes of the connection. A master access node may be a gNB serving as a master for the duplication (e.g. hosting the PDCP entity) and

15 perform overall control and management of the communication of the UE 100. One or more secondary access nodes may be gNBs that provide additional routes for duplicate packets via the respective radio channels. The concept of Figure 2B where the UE 100 is simultaneously connected with multiple access nodes is called multi-connectivity, or multi-node connectivity, which is an extension to the

20 dual connectivity concept. In the dual connectivity, the number of access nodes to which the UE 100 may be connected is limited to two.

An example of a protocol stack in the terminal device and the access nodes may be illustrated as:

PDCP
RLC
MAC
PHY

The packet duplication can take place in the radio access network of the cellular communication system, e.g. on a radio protocol layer or on a higher layer. In the context of the present invention, radio duplication may be applied, in particular Packet Data Convergence Protocol (PDCP) layer duplication. In the PDCP duplication, the duplication of a data packet takes place on the PDCP layer. This means that a PDCP transmitter creates PDCP PDU duplicates and sends the

25 duplicates to the two or more radio link layer (RLC) entities that deliver the PDCP duplicates to the terminal device via different channels. The RLC entities may belong to the same access node, as in Figure 2A, and the duplicates may be

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transferred to the terminal device via two or more component carriers managed by the same access node in a carrier aggregation mode. In another example, the RLC entities may belong to different access nodes, as in Figure 2B, and the duplicates are transferred via distinct access node nodes, such as a master access node and a secondary access node. In such case, the terminal device may be served in a dual-connectivity or multi-connectivity mode mode). A combination of the carrier aggregation and dual/multi connectivity is also a possible scenario.

At the receiver side, all transmissions will be processed and the related PDCP PDUs will be sent to the PDCP layer. The PDCP receiver will then take care of discarding duplicates, if any present.

Packet duplication may refer to duplication of control and/or user plane packets. In the packet duplication, data is duplicated on the PDCP layer of a source, e.g. the master access node, delivered independently via multiple radio paths, and aggregated at a receiver PDCP layer, resulting in an improvement of the achieved reliability. When the PDCP layer of the master access node performs the duplication, it may output one duplicate to the RLC layer of a secondary access node and one duplicate to the RLC layer of the master access node for delivery to the RLC layer of the terminal device. It is therefore a potential solution for URLLC applications, particularly for industrial use cases. In general, URLLC is a key factor for many vertical markets, such as factory automation, smart cities, autonomous vehicles, public safety and remote healthcare.

In addition to the transmission diversity introduced by the PDCP packet duplication, further reliability improvement can be harnessed by soft combining (SC) of independently transmitted data packets. In the SC concept, a receiver combines the duplicates before performing decoding. The SC may be performed on a lower protocol layer such as a physical layer (PHY) or a medium access control layer (MAC). Since the combining is performed before making hard decisions on received data bits or symbols, the term soft combining is used.

The terminal device may have established a protocol data unit (PDU) session via the one or more access node, and the PDU session may comprise a quality-of-service (QoS) flow and at least one corresponding data radio bearer for the terminal device. In the duplication in both scenarios of Figures 2A and 2B, a data packet of the same data radio bearer may be duplicated and transmitted over multiple different channels. In the multi-connectivity of Figure 2B, the master access node may assign the data radio bearer and QoS parameters to the duplicates of the data packet and, then, transmits one duplicate directly to the

terminal device and another duplicate to the secondary access nodes for forwarding to the terminal device.

3GPP specifications define that each terminal device (UE) has at least one PDU session. One or more QoS flows are associated to this PDU session. The
5 QoS flows are then associated with the data radio bearers (DRBs). This is conducted on Service Data Adaptation Protocol (SDAP) protocol layer in the access node. This mapping may be based on 5G QoS class indices (5QI) in a transport header of a data packet, and on corresponding QoS parameters that are signaled from a core network when a PDU session is established. Multiple DRBs
10 may be established for QoS flows requiring different packet forwarding requirements in terms of latency budget, packet loss rate tolerance, etc. The 5QI contains a set of default QoS parameters for a large number of services, e.g. the URLLC. The QoS parameters in the 5QI table include a resource type (guaranteed bit rate (GBR), delay critical GBR, and non-GBR), priority, packet delay budget,
15 packet error rate, and averaging window.

When a downlink packet arrives at the master access node hosting the transmitting PDCP entity, it is duplicated on the PDCP layer and forwarded over an Xn interface or a similar interface to the secondary access node(s) providing a connection with the receiver UE of the packet. The same data packet, e.g. the same
20 PDCP PDU with the same sequence number, is then independently transmitted to the same UE through the multiple different links (by the master access node and the secondary access node(s)). The master access node and the secondary access node(s) may host associated radio link control (RLC) entities (i.e. associated to the PDCP entity), that transmit the duplicated packets, and a set of access nodes
25 configured to transmit the duplicates of the same packet are called a soft combining set in the description below.

In an embodiment, the packet duplication refers to Protocol Data Unit (PDU) duplication.

Soft combining requires coordination among access nodes, i.e. a
30 master access node and one or more secondary access node(s), and signalling to indicate to a terminal device which transmissions should be combined. In the case of carrier aggregation, such coordination would be internal to an access node. Without indication, PDCP duplication on a lower protocol layer such as the MAC or PHY may not be feasible because the terminal device first has to decode two
35 packets on the PDCP layer to detect the packets to be combined. In such a case, the detection would be based on detecting that sequence numbers of the packets

match.

Figures 3 to 5 illustrate some embodiments for enabling combining of the duplicate packets at a receiver (UE). Figure 3 illustrates a process performed by a terminal device (UE), Figure 4 illustrates a process performed by a master access node, and Figure 5 illustrates a process performed by a secondary access node.

Referring to Figure 3, the process comprises in the UE: establishing a communications connection with at least one access node (block 300), the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet; receiving (block 302) a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a duplication mode and a second indication informing a reception time window for combining duplicates of the data packet; carrying out decoding of the first duplicate of the data packet; receiving a second duplicate of the data packet over the second radio channel (block 304); and as a response to the decoding being unsuccessful (NO in block 303), performing one of the following: decoding (block 308), if the second duplicate of the data packet was received within the reception time window (YES in block 306), a combination of the first duplicate of the data packet and the second duplicate of the data packet; decoding (block 310), if the second duplicate of the data packet was received outside the reception time window (NO in block 306), only the second duplicate of the data packet.

Referring to Figure 4, the process comprises in the master access node: establishing a communications connection associated with a terminal device (block 400), the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node; defining a reception time window for the delivery of the data packet (block 402), the reception time window being used by the terminal device in decoding; defining a scheduling window for scheduling timing of the delivery of the data packet (block 402), wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the reception time window; transmitting the scheduling window to the secondary access node (block 406); transmitting to the terminal device (block 404), a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and

a third indication identifying the secondary access node; and transmitting a first duplicate of the data packet to the terminal device (block 404) and a second duplicate of the data packet to the secondary access node (block 406).

5 Referring to Figure 5, the process comprises in the secondary access node: establishing a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device (block 500); establishing a communications connection with the terminal device (block 500), comprising at least a first radio channel of the plurality of
10 radio channels; receiving (block 502), from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet; receiving (block 502), from the master access node, the duplicate of the data packet for forwarding to the terminal device; scheduling transmission of the duplicate of the data packet according to the scheduling window (block 506); and transmitting the duplicate
15 of the data packet as scheduled to the terminal device over the first radio channel and (block 510), further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted from the master access node.

Above, the duplication mode may be understood from the perspective
20 of a source (e.g. the master access node) that the data packet is duplicated into a plurality of copies that are transmitted to a sink (e.g. the terminal device) through different channels, e.g. by different access nodes. From the perspective of the sink, the duplication mode may be considered as a mode where the receiver may, upon failing to decode a single data packet, combine multiple duplicates of the
25 data packet before another attempt at the decoding.

The duplication mode and the above-described message duplication and forwarding may be applied to the reverse link (uplink) as well. In the uplink packet duplication, the UE operates as the source, and the master access node may be the sink for duplicates of uplink data packets. The terminal device may
30 then duplicate a data packet and transmit different duplicated via different channels to the master access node, e.g. in the scenario of Figure 2A or 2B. The terminal device may then transmit, in connection with each duplicate, the indication that the duplicate data packet is transmitted in the duplication mode.

In an embodiment, the secondary access node starts, upon receiving
35 the information element indicating the scheduling window or upon receiving the duplicate of the data packet in block 502, a counter counting the scheduling

window (block 504). The secondary access node may attempt to schedule (blocks 506 and 508) a downlink radio resource for the data packet within the scheduling window. If the secondary access node manages to schedule the data packet within the scheduling window (YES in block 508), the process proceeds to the transmission of the packet within the scheduling window. If the secondary access node fails to schedule a downlink resource to the data packet within the scheduling window (NO in block 508), the process proceeds to block 512 where the secondary access node performs a fallback procedure for determining whether or not to transmit the data packet at all. Embodiments of block 512 are disclosed below.

The embodiments of Figures 3 to 5 provide a coordinated transmission of the duplicate data packets with improved the radio efficiency, simplified coordination, and reduced signaling overhead compared with many conventional solutions.

Above, the indication identifying the secondary access node may comprise one or more information elements in a downlink message and serve as an indicator of the secondary access node providing a further radio channel or channels for delivering further duplicates of the data packet or, from another perspective, identifying the secondary access node as a transmitter of the second duplicate of the data packet. The information element may define a set of access nodes configured to transmit the duplicate data packets for the soft combining, a so-called soft combining set. Cell identifiers may be used as identifiers of the access nodes of the soft combining set.

The above-described information elements transmitted to the terminal device may be transmitted on a physical downlink control channel. The information elements may be transmitted as downlink control information (DCI). A new DCI format may be defined to carry the information element indicating that the data packet is subject to soft combining, the information element defining the combining window and, optionally, the information element indicating the soft combining set.

The above-described information elements transmitted from the master access node to the secondary access node may be transmitted over the Xn interface or a similar interface established between the access nodes of the wireless network. A new message type or format may be defined to carry the scheduling window, the information element indicating that the data packet is subject to combining, and the information element carrying a value of the

scheduling window. In another embodiment, the information element is added to an existing message as a new information element.

At least one of the scheduling window, the soft combining set, and the combining window may be a semi-static parameter that is not transmitted in connection with every data packet subject to packet combining. As a consequence, the respective information elements may be transferred less frequently than the data packets that are subjected to the combining. The combining window and a default soft combining set can be configured via radio resource control (RRC) signaling, e.g. as a part of dual/multi connectivity configuration, CA configuration, or PDCP configuration. The DCI may then carry only the indication that this packet is for soft combining and, optionally, an index of a soft combining set (may overrule the default soft combining set, if such has been configured).

Let us now illustrate embodiments of Figures 3 to 5 by referring to Figure 6 showing an example of a signaling chart and providing examples for the embodiments. Referring to Figure 6, the master access node (master gNB) may configure a combining mode to one or more secondary access nodes (secondary gNB) in block 600. The combining mode may be linked to a specific terminal device or data radio bearer(s). Block 600 may comprise the master access node signaling the scheduling window Δ_1 to the secondary access node(s). The purpose of the scheduling window may be twofold: 1) an implicit indication to the secondary access node(s) identifying that the packets addressed to the terminal device or data radio bearer(s) are subject to combining (in addition to being duplicated); and 2) an implication of a priority of the data packets addressed to the terminal device or data radio bearer(s) to guide the secondary access node(s) when scheduling timing of the data packets.

In an embodiment, the master access node computed a length of the scheduling window Δ_1 on the basis of at least one of the following input parameters: a maximum latency t_{target} allowed for the transmission of the one or more further data packets, duration t_{buffer} the first duplicate of the data packet has spent in a transmission buffer of the master access node, and an offset parameter t_{offset} defining transmission priority of the one or more further data packets. The following equation may be used:

$$\Delta_1 = t_{target} - t_{buffer} - t_{offset} \quad (1)$$

Parameter t_{offset} may be used to take into account any propagation and processing delays in or between the master access node and the respective secondary access node. A higher priority transmission may have a greater value of t_{offset} to reduce

the scheduling window. Different use cases may assign different priorities to the scheduling window. Autonomous vehicles, public safety and remote healthcare are taken as examples of typical high priority use cases where a shorter scheduling window is applied. In general, the scheduling window can be set according to service needs and service providers' requirements.

Block 600 may additionally comprise organizing discontinuous reception (DRX) policy for the terminal device, and/or other characteristics of the multi-connectivity.

In block 602, the master access node configures the multi-connectivity with the terminal device and configures the packet duplication and a packet combining mode with the terminal device. In block 602, the master access node may signal the access nodes participating to the packet duplication and the combining window parameter to the terminal device. Block 602 may comprise establishing necessary data radio bearer(s) between the terminal device and access nodes in the soft combining set for the terminal device. At least some of the data radio bearer(s) may have been established earlier.

In the embodiment of Figure 6, the soft combining set, the scheduling window, and the combining window are static or semi-static parameters that may be when instantiating the packet duplication. Duplicate data packets may be transferred without separate indication of the scheduling window and/or the combining window, but the window(s) may be updated repeatedly during the connection. Repeatedly may be understood such that the updating rate is much slower than packet transmission rate.

In block 604, the master access node receives a downlink data packet from a higher layer, e.g. a PDCP service data unit (SDU). The master access node may duplicate the PDCP SDU into a plurality of PDCP packet data units (PDU) in block 606. If the soft combining set is a dynamic parameter, the master access node may execute block 608 where the soft combining set is selected for the PDCP PDUs. Let us now assume that only the master access node and the secondary access node belong to the soft combining set of the PDCP PDU. As a consequence, the master access node may have selected the secondary access node as another transmitter of the duplicate packets to the terminal device in block 600 or 608, in addition to the master access node itself. The master access node may select the soft combining set on the basis of, for example, traffic load of the secondary access nodes and/or channel quality of a radio channel towards the terminal device at each access node. When the soft combining set is selected in a dynamic manner,

i.e. block 608 is executed, the soft combining set may be more limited than when the selection is semi-static. For example, the maximum number of access nodes in the soft combining set may be reduced. Accordingly, the signaling overhead may be reduced. In an embodiment, both semi-static and dynamic soft combining set
5 selection may be supported by the master access node. The semi-static configuration performed in blocks 600 and 602 may serve as a default soft combining set. In case the master access node determines to change the soft combining set for an individual PDCP PDU, it may execute block 608. In such a case, the information element identifying the soft combining set in step 612 may
10 be configured to refer only to the PDCP PDU transmitted in step 612 and its duplicates. Duplicates of a subsequent PDCP PDU may then be associated with the default soft combining set, unless otherwise specified by the master access node.

In step 610, the master access node transmits a duplicate of the PDCP PDU to the secondary access node together with the information element
15 indicating that the PDCP PDU is subject to packet combining. Upon receiving the information element and the PDCP PDU from the master access node, the secondary access node detects, on the basis of the information element, that the PDCP PDU is subject to the packet combining and, as a consequence, triggers a counter counting the scheduling window from the reception of the PDCP PDU.

20 The master access node may transmit the duplicate PDCP PDU to the secondary access node before sending another duplicate PDCP PDU to the terminal device. In such manner, probability of the secondary access node transmitting the other duplicate PDCP PDU within the scheduling window may be improved. In step 612, the master access node transmits the duplicate PDCP PDU
25 to the terminal device together with the information element indicating that the PDCP PDU is subject to the combining. In case the soft combining set is configured dynamically, the master access node may also transmit in step 612 an information element identifying the secondary access node as another transmitter of the duplicate PDCP PDU for the combining. If the soft combining set is semi-static,
30 this may have been signaled in block 602.

Upon receiving the PDCP PDU in step 612, the terminal device may attempt decoding the PDCP PDU in block 614. Let us assume that the decoding fails. Upon failing the decoding, the terminal device may store the undecoded PDCP PDU for later combining, e.g. physical layer soft symbol values for a
35 transport block that contains the PDCP PDU. The soft symbol values may refer to received sample values before demodulation and decoding. In some receiver

architectures, the soft symbol values may be probability values such as log-likelihood ratios. Upon receiving the PDCP PDU or the information element in step 612, the terminal device may trigger a counter counting the combining window and, upon failing the decoding in block 614, the terminal device may
5 monitor for another duplicate of the PDCP PDU within the combining window. In step 616, the secondary access node is successful in scheduling the transmission of the other duplicate PDCP PDU within the scheduling window. As a consequence, the secondary access node transmits the PDCP PDU and the information element indicating that the PDCP PDU is subjected to combining in
10 step 616. Upon receiving the second duplicate PDCP PDU within the combining window in step 616, the terminal device may determine that, since another PDCP PDU subjected to the packet combining has been received within the combining window, the PDCP PDU is to be combined with the earlier PDCP PDU received in step 612. As a consequence, the terminal device combines in block 618 the PDCP
15 PDUs received in steps 612 and 616 and attempts the decoding again. The combining of the two (or more) PDCP PDUs may be carried out on the physical layer in the terminal device. The combining may comprise summing respective sample values of the received PDCP PDUs. The summing reduces noise from the sample values through averaging and amplifies desired signal power. Upon
20 succeeding in the decoding in block 618, the terminal device may acknowledge successful reception of the packet to the master access node and the secondary access node in step 620.

If the terminal device succeeds in decoding the PDCP PDU in block 614, the terminal device may discard further duplicates of the data packet
25 received and execute step 620 directly after block 614.

It should be appreciated that while the transmission and combining of only two duplicates has been described in connection with Figure 6, the number of access nodes transmitting the duplicates, the number of duplicates transmitted, and the number of duplicates combined by the terminal device may be higher.
30 The other secondary nodes of the soft combining set may follow the principles described above with respect to the secondary access node so that further duplicates may be transmitted to the terminal device.

The length of the scheduling window and the combining window may be selected such that there are no other PDCP PDUs transmitted to the terminal
35 device within the combining window, at least no other PDUs that are not duplicates of the PDCP PDU transmitted in step 612. As a consequence, the mere

indication that a PDCP PDU is subjected to the packet combining is sufficient for the terminal device to know which PDUs to combine. In an embodiment, the master access node and/or the secondary access node may transmit, to the terminal device within the scheduling window and the combining window, one or more other PDUs that are not subjected to the packet combining. Since such other PDU(s) are not associated with the information element indicating that the PDU(s) is/are subjected to the packet combining, the terminal device may perform separate decoding to such other PDU(s).

In an embodiment, the first duplicate of the data packet is transmitted by using a determined modulation and coding scheme, and the master access node may indicate the determined modulation and coding scheme to the secondary node for use in transmission of the second duplicate of the data packet to the terminal device. As a consequence, the duplicates of the same data packet shall be transmitted by using one and the same modulation and coding scheme. This enables coherent soft combining of the duplicate data packets in the terminal device. In an embodiment, the master access node and the secondary access node(s) may be configured to transmit the duplicate data packets in the same time-frequency resources and by using the same modulation and coding scheme. In this manner, the duplicate data packets are transmitted according to a single-frequency network principle. The master access node may indicate the modulation and coding scheme and the time-frequency resources that shall be used to transmit the PDCP PDU in step 610, and steps 612 and 616 may be executed simultaneously. As a consequence, block 614 may be omitted.

As described above and also indicated in Figure 6, the scheduling window and the combining window are logically different windows, having different starting times and, optionally, durations. For example, in embodiments where the window values account for processing and propagation delays, the values of the different windows become different because of different hardware and radio channels.

Unless there is strict centralized scheduling, the terminal device may receive the duplicate PDCP PDUs from the master access node and the secondary access node(s) with different mutual timings. The secondary access node may transmit the PDCP PDU before the master access node. When the soft combining set is determined in a dynamic manner, this may result in the terminal device receiving the PDCP PDU from a secondary access node even before the terminal device receives the information element indicating the secondary access node as

belonging to the soft combining set. Figure 7 illustrates an embodiment for solving such a situation. The blocks in Figure 7 denoted by the same reference numbers as in Figure 3 refer to the same or substantially similar operations.

Referring to Figure 7, the terminal device receives a duplicate data packet first from the secondary access node in block 700 and, in connection with the duplicate data packet, the information element indicating that the data packet is subject to combining. Upon receiving the first duplicate of the data packet comprising the information element, the terminal device may trigger the counter or timer counting the combining window. In block 702, the terminal device receives a further data packet. In block 704, the terminal device determines whether or not the further data packet is transmitted with the information element indicating the combining. If there is no such information element, the process proceeds to block 310 where the further data packet is decoded without combining. If the information element is present, the process proceeds from block 704 to block 706 where the terminal device determines whether or not the further data packet is received with an information element indicating the secondary access node that transmitted the first duplicate of the data packet (block 700) as another transmitter of the duplicate data packets. If such an information element is not present or the secondary access node is not indicated by the information element, the process may return to block 702 to receive another data packet. If the information element indicating the secondary access node is detected in block 706, the process proceeds to block 308 for combining the packets received in blocks 700 and 702. This embodiment may be combined with the embodiment where the terminal device attempts decoding the first duplicate of the data packet between blocks 700 and 702. If the decoding is failed, the process may proceed to block 702.

As described above, the scheduling window is a parameter that specifies to the secondary access nodes a time limit for transmitting the duplicate data packet. Because of traffic load or other variables affecting the operation of the secondary access node, the secondary access node may not be able to schedule the transmission of the data packet within the scheduling window. However, instead of simply discarding the data packet in such a case, it might be beneficial to transmit the data packet. On one hand, it may be the only duplicate the terminal device is capable of decoding. On the other hand, because it is probably received by the terminal device outside the combining window and is thus not eligible for the combining, the transmission may be unnecessary. Figure

8 illustrates an embodiment for the secondary access node to determine whether or not to transmit the data packet after the expiry of the scheduling window. The blocks denoted by the same reference numbers as in Figure 5 represent the same or substantially similar operations or functions.

5 Referring to Figure 8, the secondary access node receives in block 800 the duplicate data packet from the master access node. The secondary access node may also receive from the master access node an information element indicating a total number M of duplicates of the data packet that shall be transmitted to the terminal device. The total number M may be the total number
 10 of duplicates transmitted by the access nodes of the soft combining set, and it may equal to the number of access nodes in the soft combining set. In block 508, the secondary access node determines that the transmission of the data packet to the terminal device within the scheduling window has failed and, as a consequence, the process proceeds to block 802. In block 802, the secondary access node
 15 compares the total number M of duplicates of the data packet that shall be transmitted to the terminal device with a threshold $M_{threshold}$. If $M < M_{threshold}$, the process may proceed to block 804 where the secondary access node transmits the data packet to the terminal device after the expiry of the scheduling window. The data packet may be transmitted with or without the indication that the data
 20 packet is subject to the packet combining. In this case, it may be considered that the total number of duplicates is so low that the transmission may provide an impact in the successful decoding. If $M > M_{threshold}$, the process may proceed to block 806 where the secondary access node discards the data packet without transmitting the data packet to the terminal device. In this case, it may be
 25 considered that the number of duplicates is high and the transmission of the additional duplicate is not efficient use of resources. If $M = M_{threshold}$, the process may proceed to block 804 or block 806, depending on the implementation.

Packet combining in the uplink is also an option with regard to carrier aggregation. In this procedure, a terminal device may transmit packets only by
 30 using the first component carrier using preconfigured resources or, alternatively, dynamically configured resources. The terminal device may be indicated by the network (gNB) to activate data duplication via a MAC activation field in DCI received, for example on the first component carrier. The terminal device may start duplicating packets, and some delay may be applied depending on the DCI
 35 processing delay at the terminal device. To avoid ambiguity on when the terminal device starts duplicating (the first packet), which would cause issues in the

combining, the terminal device may transmit the first duplicate of the packet along with a duplicating indication (or combining indication) on the first component carrier and sends a second duplicate on the second component carrier (potentially also with the combining indication) using preconfigured resources or, alternatively, dynamically configured resources. The indication may be repeated for a number of consecutive duplicates of the packet to avoid the case that an individual duplicate of the packet is lost (and thus also the indication is lost). The gNB starts combining packets received on the configured component carriers, as indicated by the duplication indication(s).

Figures 9 to 11 illustrate apparatuses comprising a communication controller 10, 30, 50, such as at least one processor or processing circuitry, and at least one memory 20, 40, 60 including a computer program code (software) 24, 44, 64, wherein the at least one memory and the computer program code (software) are configured, with the at least one processor, to cause the respective apparatus to carry out any one of the embodiments described above. Figure 9 illustrates an apparatus for the terminal device, Figure 10 illustrates an apparatus for the master access node (e.g. the gNB) or a controller controlling the operation of the access node according to the embodiments of the invention, and Figure 11 illustrates an apparatus for the secondary access node (e.g. the gNB) or a controller controlling the operation of the access node according to the embodiments of the invention. The apparatuses of Figures 9 to 11 may be electronic devices.

Referring to Figures 9 to 11, the memory 20, 40, 60 may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The memory may comprise a configuration database 26, 44, 66 for storing configuration parameters, e.g. the durations of the scheduling window and the combining window. The memory 20, 40, 60 may further store a data buffer 28, 48, 68 for data waiting for transmission (buffers 28 and 68) or data waiting to be combined (buffer 48).

Referring to Figure 9, the apparatus may further comprise a communication interface 42 comprising hardware and/or software for realizing communication connectivity according to one or more radio communication protocols. The communication interface 42 may provide the apparatus with radio communication capabilities with one or more access nodes of a wireless network.

The communication interface 42 may support the above-described multi-connectivity and/or carrier aggregation concepts. In an embodiment, the communication interface 42 comprises one or more antenna arrays providing the apparatus with capability of forming directive transmission radio beams and the reception radio beams. The communication interface may comprise standard well-known analog radio components such as an amplifier, filter, frequency-converter and circuitries, conversion circuitries transforming signals between analog and digital domains, and one or more antennas. Digital signal processing regarding transmission and reception of signals may be performed in the communication controller 30.

The communication controller 30 may comprise a multi-connectivity controller 34 configured to manage the one or more radio links or one or more radio bearers configured in the terminal device. The multi-connectivity controller 34 may also control reception of the duplicate data packets, as described above. The controller 34 may perform blocks 300 to 306, for example, and instruct a soft combiner 39 and/or PDU decoder 37 to execute block 308 or 310, as described above. The soft combiner 39 may perform the combining of the duplicate data packets in the above-described manner, upon the controller 34 determining that the conditions for combining have been fulfilled, e.g. the decoding of a firstly received duplicate has failed and at least one further duplicate has been received within the combining window. The soft combiner 39 may output the combined data packet to the PDU decoder 37 for decoding.

The apparatus may further comprise an application processor 32 executing one or more computer program applications that generate a need to transmit and/or receive data through the access nodes. The application processor may form an application layer of the apparatus. The application processor may execute computer programs forming the primary function of the apparatus. For example, if the apparatus is a sensor device, the application processor may execute one or more signal processing applications processing measurement data acquired from one or more sensor heads. If the apparatus is a computer system of a vehicle, the application processor may execute a media application and/or an autonomous driving and navigation application.

Referring to Figures 10 and 11, the apparatus for the access nodes comprises a communication interface 22, 62 comprising hardware and/or software for realizing communication connectivity according to one or more radio communication protocols. The communication interface 22, 62 may provide

the apparatus with communication capabilities to terminal devices camping in one or more cells controlled by the respective access node. In an embodiment, the communication interface may comprise one or more antenna arrays providing the apparatus with capability of forming directive transmission radio beams and the reception radio beams. The communication interface may comprise standard well-known components such as an amplifier, filter, frequency-converter, (de)modulator, and encoder/decoder circuitries and one or more antennas. The communication interface 22, 62 may be configured to control operation of the one or more antenna arrays for providing the radio beams.

The communication controller 10 may be configured to carry out the embodiment of Figure 4, and the communication controller 50 is configured to carry out the embodiment of Figure 5. The communication controller 10 may comprise a PDU duplication controller 14 that manages the duplicate transmissions of a given PDU. The controller 14 may comprise a soft combining set manager 19 configured to determine the set of access nodes that transmit the duplicate data packets. The manager 19 may carry out updating of the soft combining set repeatedly, e.g. for each PDU or in a semi-static manner as described above. The controller 14 may further comprise a window selector 17 configured to determine the lengths of the combining window and/or the scheduling window according to the embodiments described above.

The communication controller may further comprise a scheduler 12 configured to schedule downlink radio resources to data packets transmitted by the master access node to the terminal device.

The communication controller 50 of the secondary access node may comprise a PDU duplication controller 54 managing the duplicate transmissions by the secondary access node under the control of the master access node, as described above. The PDU duplication controller 54 may, for example, receive and apply the scheduling window received from the master access node and configure a scheduler 52 to schedule a downlink radio resource for a duplicate data packet within the scheduling window. Upon receiving from the scheduler a signal indicating failed scheduling within the scheduling window, the PDU duplication controller 54 may launch an exception handler 57 configured to perform block 802 of Figure 8.

At least some of the functionalities of the apparatus of Figure 10 or 11 may be shared between two physically separate devices, forming one operational entity. Therefore, the apparatus may be seen to depict the operational entity

comprising one or more physically separate devices for executing at least some of the processes described with respect to the access nodes. An apparatus utilizing such shared architecture, may comprise a remote control unit (RCU) or central unit (CU), such as a host computer or a server computer, operatively coupled (e.g. via a wireless or wired network) to a remote radio head (RRH) or distributed unit (DU), such as a Transmission Reception Point (TRP), located in the access node, e.g. the gNB 104, 104A, 104B. An RCU may generate a virtual network through which the RCU communicates with an RRH. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into a server computer or a host computer (i.e. to the RCU). External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking which provides network-like functionality to the software containers on a single system. A virtual network may provide flexible distribution of operations between the RRH and the RCU. In practice, any digital signal processing task may be performed in either the RRH or the RCU and the boundary where the responsibility is shifted between the RRH and the RCU may be selected according to implementation. As an example of the shared architecture case, once a SgNB-CU has received from a MgNB a packet combining indication and scheduling window (as shown in fig 5, 502) it would need to communicate the indication to the MAC layer in the gNB-DU. That could be carried out in a several manner. For instance by assigning an increased packet priority or adjusted latency target to the packet overwriting the QoS information established on the F1 interface between DU and CU (as part of the F1 procedure of UE Context Setup / Modification of the DRB). Alternatively, the scheduling window could be directly provided over the F1 to the MAC.

At least some of the processes described above may be performed by the RCU or shared among the RRH and the RCU.

As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal

processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

5 This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular
10 element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

In an embodiment, at least some of the processes described in connection with Figures 3 to 8 may be carried out by an apparatus comprising
15 corresponding means for carrying out at least some of the described processes. Some example means for carrying out the processes may include at least one of the following: detector, processor (including dual-core and multiple-core processors), digital signal processor, controller, receiver, transmitter, encoder, decoder, memory, RAM, ROM, software, firmware, display, user interface,
20 display circuitry, user interface circuitry, user interface software, display software, circuit, antenna, antenna circuitry, and circuitry. In an embodiment, the at least one processor, the memory, and the computer program code form processing means or comprises one or more computer program code portions for carrying out one or more operations according to any one of the embodiments of
25 Figures 3 to 8 or operations thereof.

According to yet another embodiment, the apparatus carrying out the embodiments comprises a circuitry including at least one processor and at least one memory including computer program code. When activated, the circuitry causes the apparatus to perform at least some of the functionalities according to
30 any one of the embodiments of Figures 3 to 8, or operations thereof.

The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations thereof. For a hardware implementation, the
35 apparatus(es) of embodiments may be implemented within one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs),

digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, 5 the implementation can be carried out through modules of at least one chip set (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled 10 to the processor via various means, as is known in the art. Additionally, the components of the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be 15 appreciated by one skilled in the art.

Embodiments as described may also be carried out in the form of a computer process defined by a computer program or portions thereof. Embodiments of the methods described in connection with Figures 3 to 8 may be carried out by executing at least one portion of a computer program comprising 20 corresponding instructions. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer 25 program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. The computer program medium may be a non-transitory medium, for example. Coding of software for carrying out the embodiments as shown and described is 30 well within the scope of a person of ordinary skill in the art. In an embodiment, a computer-readable medium comprises said computer program.

Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of 35 the appended claims. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will

be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

CLAIMS

1. An apparatus comprising means for performing:
establishing a communications connection with at least one access
node, the communications connection comprising at least a first radio channel
5 and a second radio channel for delivery of a data packet;
receiving a first duplicate of the data packet over the first radio
channel, and further receiving a first indication informing the delivery of the data
packet is carried out in a duplication mode and a second indication informing a
reception time window for combining duplicates of the data packet;
10 carrying out decoding of the first duplicate of the data packet;
receiving a second duplicate of the data packet over the second radio
channel; and
as a response to the decoding being unsuccessful, performing one of
the following:
15 decoding, if the second duplicate of the data packet was received
within the reception time window, a combination of the first duplicate of the data
packet and the second duplicate of the data packet;
decoding, if the second duplicate of the data packet was received
outside the reception time window, only the second duplicate of the data packet.
20
2. The apparatus of claim 1, wherein the at least one access node
comprises a master access node of the communications connection, and wherein
the means are further configured to receive, from the master access node,
information identifying a secondary access node providing one of the first radio
25 channel and the second radio channel.
3. The apparatus of claim 2, wherein the means are further configured
to establish the first radio channel with the master access node and the second
radio channel with the secondary access node, and to receive from the master
30 access node in connection with the first duplicate of the data packet, an
information element identifying the secondary access node as a transmitter of the
second duplicate of the data packet.

4. The apparatus of any preceding claim, wherein the means are configured to discard the second duplicate of the data packet as a response to the decoding of the first duplicate of the data packet being successful.

5 5. The apparatus of any preceding claim, wherein the means are configured to start counting the reception time window from the reception of the information element indicating the reception time window.

10 6. The apparatus of any preceding claim, wherein said second indication is received as a semi-static parameter via downlink control information of a physical downlink control or data channel, or via radio resource control signaling.

15 7. The apparatus of any preceding claim, wherein the means are configured to decode the combination of the first duplicate of the data packet and the second duplicate of the data packet based on soft combining of the first duplicate of the data packet and the second duplicate of the data packet.

20 8. An apparatus for a master access node of a wireless network, comprising means for performing:

establishing a communications connection associated with a terminal device, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node;

25 defining a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding;

defining a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the
30 reception time window;

transmitting the scheduling window to the secondary access node;

transmitting to the terminal device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and a third indication
35 identifying the secondary access node; and

transmitting a first duplicate of the data packet to the terminal device and a second duplicate of the data packet to the secondary access node.

9. The apparatus of claim 8, wherein the means are further configured
5 to transmit to the secondary access node an indication that the second duplicate of the data packet is transmitted in the duplication mode.

10. An apparatus for a secondary access node of a wireless network,
comprising means for performing:
10 establishing a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device;
establishing a communications connection with the terminal device, comprising at least a first radio channel of the plurality of radio channels;
15 receiving, from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet;
receiving, from the master access node, the duplicate of the data packet for forwarding to the terminal device;
scheduling transmission of the duplicate of the data packet according
20 to the scheduling window; and
transmitting the duplicate of the data packet as scheduled to the terminal device over the first radio channel and, further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted
25 from the master access node.

11. The apparatus of claim 10, wherein the means are further configured to:
determine that the scheduling according to the scheduling window has
30 failed,
upon said determining transmitting the duplicate of the data packet to the terminal device without said indication.

12. The apparatus of claim 10 or 11, wherein the means are further
35 configured to receive from the master access node an information element indicating a modulation and coding scheme for the duplicate of the data packet,

and to transmit the duplicate of the data packet to the terminal device by using the modulation and coding scheme.

13. The apparatus of any preceding claim, wherein the means
5 comprises:

at least one processor; and

at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

10

14. A method comprising:

establishing, by a terminal device, a communications connection with at least one access node, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet;

15

receiving, by the terminal device, a first duplicate of the data packet over the first radio channel, and further receiving a first indication informing the delivery of the data packet is carried out in a duplication mode and a second indication informing a reception time window for combining duplicates of the data packet;

20

carrying out, by the terminal device, decoding of the first duplicate of the data packet;

receiving, by the terminal device, a second duplicate of the data packet over the second radio channel; and

25

as a response to the decoding being unsuccessful, performing one of the following by the terminal device:

decoding, if the second duplicate of the data packet was received within the reception time window, a combination of the first duplicate of the data packet and the second duplicate of the data packet;

30

decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.

15. The method of claim 14, wherein the at least one access node comprises a master access node of the communications connection, and the method further comprises receiving, by the terminal device from the master
35 access node, information identifying a secondary access node providing one of the

first radio channel and the second radio channel.

16. The method of claim 15, wherein the method further comprises the terminal device establishing the first radio channel with the master access node and the second radio channel with the secondary access node, and receiving from the master access node in connection with the first duplicate of the data packet, an information element identifying the secondary access node as a transmitter of the second duplicate of the data packet.

17. The method of any preceding claim 14 to 16, further comprising discarding the second duplicate of the data packet as a response to the decoding of the first duplicate of the data packet being successful.

18. The method of any preceding claim 14 to 17, further comprising starting counting the reception time window from the reception of the information element indicating the reception time window.

19. The method of any preceding claim 14 to 18, wherein said second indication is received as a semi-static parameter via downlink control information of a physical downlink control or data channel, or via radio resource control signaling.

20. The method of any preceding claim 14 to 19, further comprising decoding the combination of the first duplicate of the data packet and the second duplicate of the data packet based on soft combining of the first duplicate of the data packet and the second duplicate of the data packet.

21. A method comprising:
establishing, by a master access node, a communications connection associated with a terminal device, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node;

defining, by the master access node, a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding;

defining, by the master access node, a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the reception time window;

5 transmitting, by the master access node, the scheduling window to the secondary access node;

transmitting, by the master access node to the terminal device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and
10 a third indication identifying the secondary access node; and

transmitting, by the master access node, a first duplicate of the data packet to the terminal device and a second duplicate of the data packet to the secondary access node.

15 22. The apparatus of claim 21, further comprising transmitting to the secondary access node an indication that the second duplicate of the data packet is transmitted in the duplication mode.

23. A method comprising:

20 establishing, by a secondary access node, a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device;

establishing, by the secondary access node, a communications connection with the terminal device, comprising at least a first radio channel of
25 the plurality of radio channels;

receiving, by the secondary access node from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet;

receiving, by the secondary access node from the master access node, the duplicate of the data packet for forwarding to the terminal device;

30 scheduling, by the secondary access node, transmission of the duplicate of the data packet according to the scheduling window; and

transmitting, by the secondary access node, the duplicate of the data packet as scheduled to the terminal device over the first radio channel and, further, transmitting to the terminal device an indication informing that the
35 duplicate of the data packet is to be combined in decoding with another duplicate

of the data packet transmitted from the master access node.

24. The method of claim 23, further comprising:

5 determining that the scheduling according to the scheduling window
has failed,
upon said determining, transmitting the duplicate of the data packet to
the terminal device without said indication.

10 25. The method of claim 23 or 24, further comprising receiving from
the master access node an information element indicating a modulation and
coding scheme for the duplicate of the data packet and transmitting the duplicate
of the data packet to the terminal device by using the modulation and coding
scheme.

15 26. A computer program product embodied on a computer-readable
medium and comprising a computer program code readable by a computer,
wherein the computer program code configures the computer to carry out a
computer process comprising:

20 establishing a communications connection with at least one access
node, the communications connection comprising at least a first radio channel
and a second radio channel for delivery of a data packet;

receiving, by the terminal device, a first duplicate of the data packet
over the first radio channel, and further receiving a first indication informing the
delivery of the data packet is carried out in a duplication mode and a second
25 indication informing a reception time window for combining duplicates of the
data packet;

carrying out decoding of the first duplicate of the data packet;

receiving a second duplicate of the data packet over the second radio
channel; and

30 as a response to the decoding being unsuccessful, performing one of
the following:

decoding, if the second duplicate of the data packet was received
within the reception time window, a combination of the first duplicate of the data
packet and the second duplicate of the data packet;

decoding, if the second duplicate of the data packet was received outside the reception time window, only the second duplicate of the data packet.

27. A computer program product embodied on a computer-readable medium and comprising a computer program code readable by a computer, wherein the computer program code configures the computer to carry out a computer process comprising:

establishing a communications connection associated with a terminal device, the communications connection comprising at least a first radio channel and a second radio channel for delivery of a data packet, wherein the second radio channel is provided to the terminal device by a secondary access node;

defining a reception time window for the delivery of the data packet, the reception time window being used by the terminal device in decoding;

defining a scheduling window for scheduling timing of the delivery of the data packet, wherein the scheduling window is defined in such manner that duplicates of the data packet are receivable by the terminal device within the reception time window;

transmitting the scheduling window to the secondary access node;

transmitting, to the terminal device, a first indication information that the delivery of the data packet is carried out in a duplication mode, a second indication informing the reception time window, and a third indication identifying the secondary access node; and

transmitting a first duplicate of the data packet to the terminal device and a second duplicate of the data packet to the secondary access node.

25

28. A computer program product embodied on a computer-readable medium and comprising a computer program code readable by a computer, wherein the computer program code configures the computer to carry out a computer process comprising:

establishing a communications connection with a master access node in relation to a plurality of radio channels for delivery of a data packet to a terminal device;

establishing a communications connection with the terminal device, comprising at least a first radio channel of the plurality of radio channels;

receiving, from the master access node, a scheduling window for scheduling timing of a duplicate of the data packet;

35

receiving, from the master access node, the duplicate of the data packet for forwarding to the terminal device;

scheduling transmission of the duplicate of the data packet according to the scheduling window; and

- 5 transmitting the duplicate of the data packet as scheduled to the terminal device over the first radio channel and, further, transmitting to the terminal device an indication informing that the duplicate of the data packet is to be combined in decoding with another duplicate of the data packet transmitted from the master access node.

10

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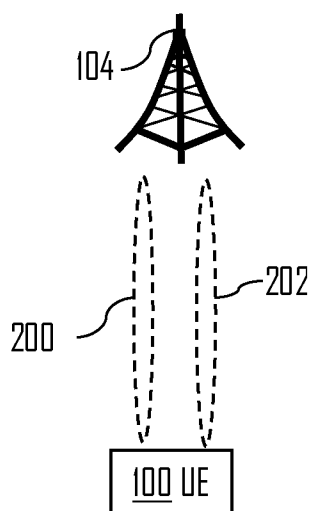
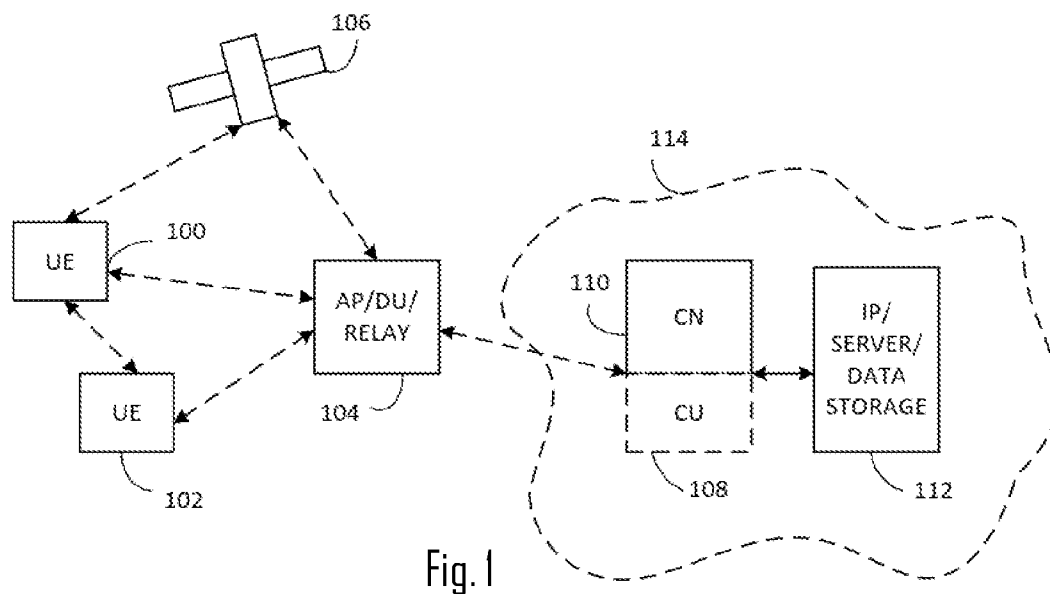


Fig. 2A

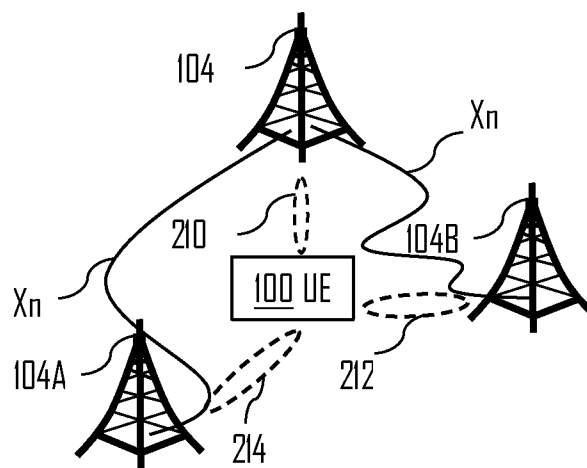


Fig. 2B

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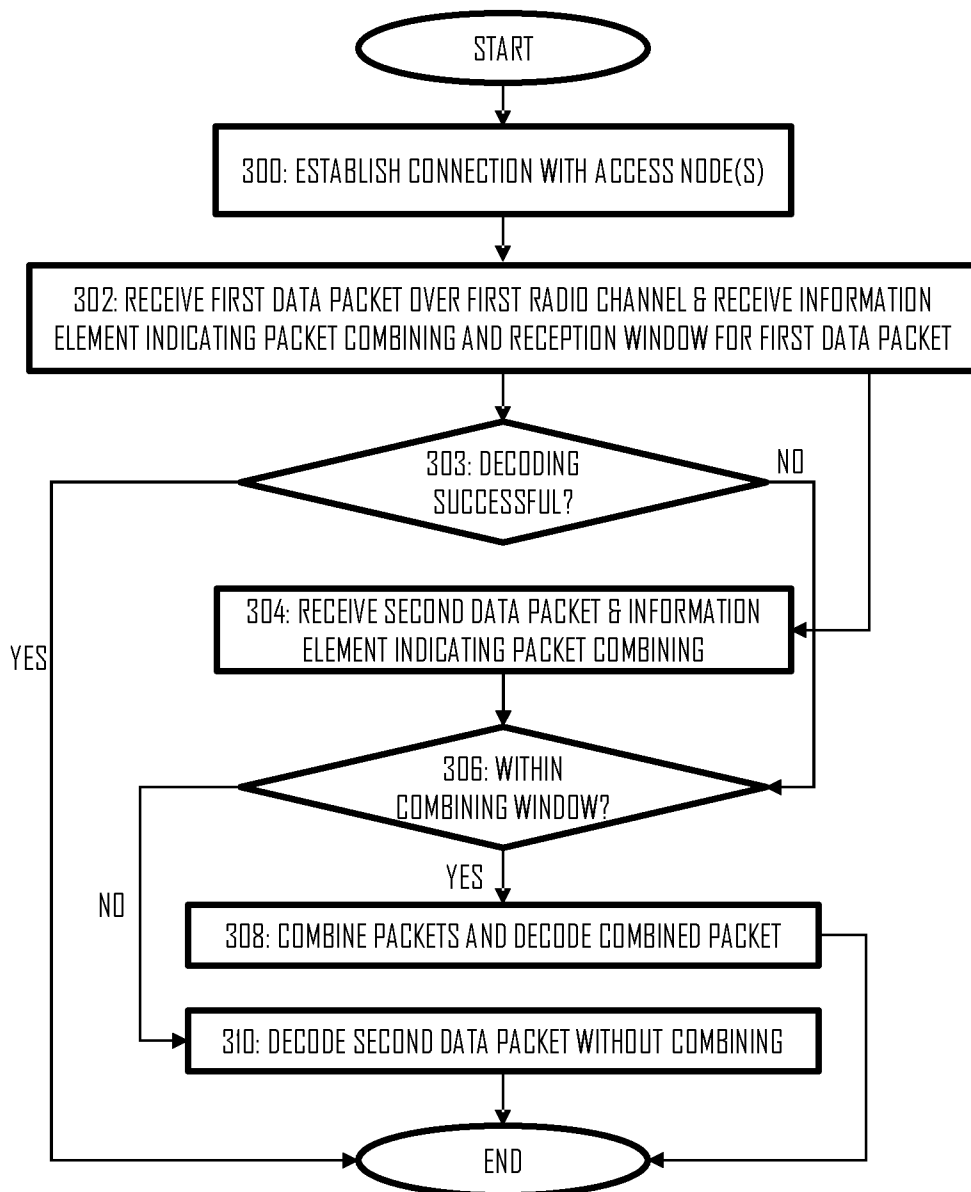


Fig 3

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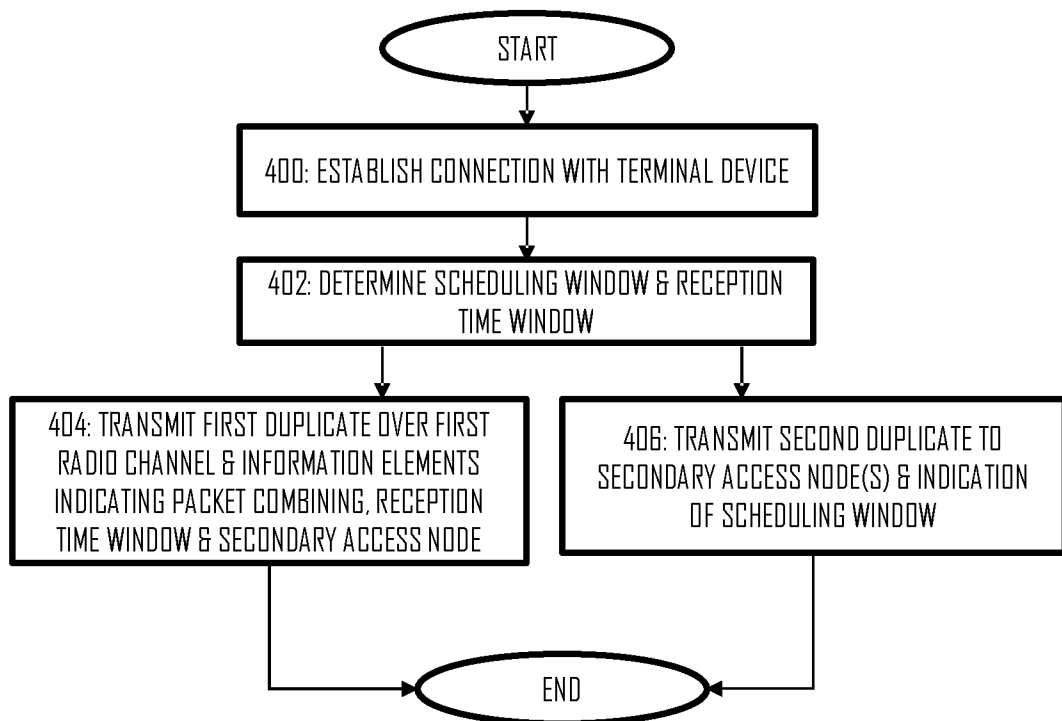


Fig 4

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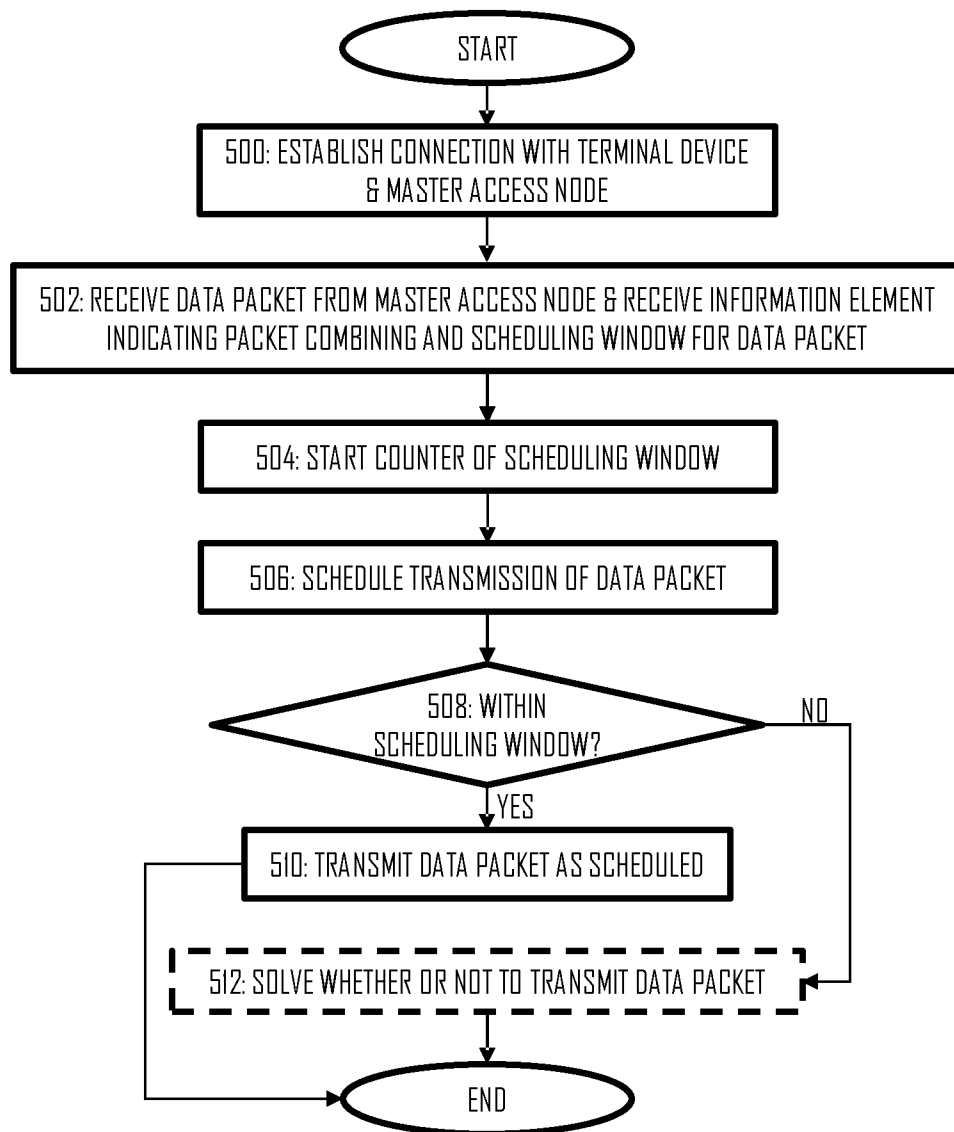


Fig 5

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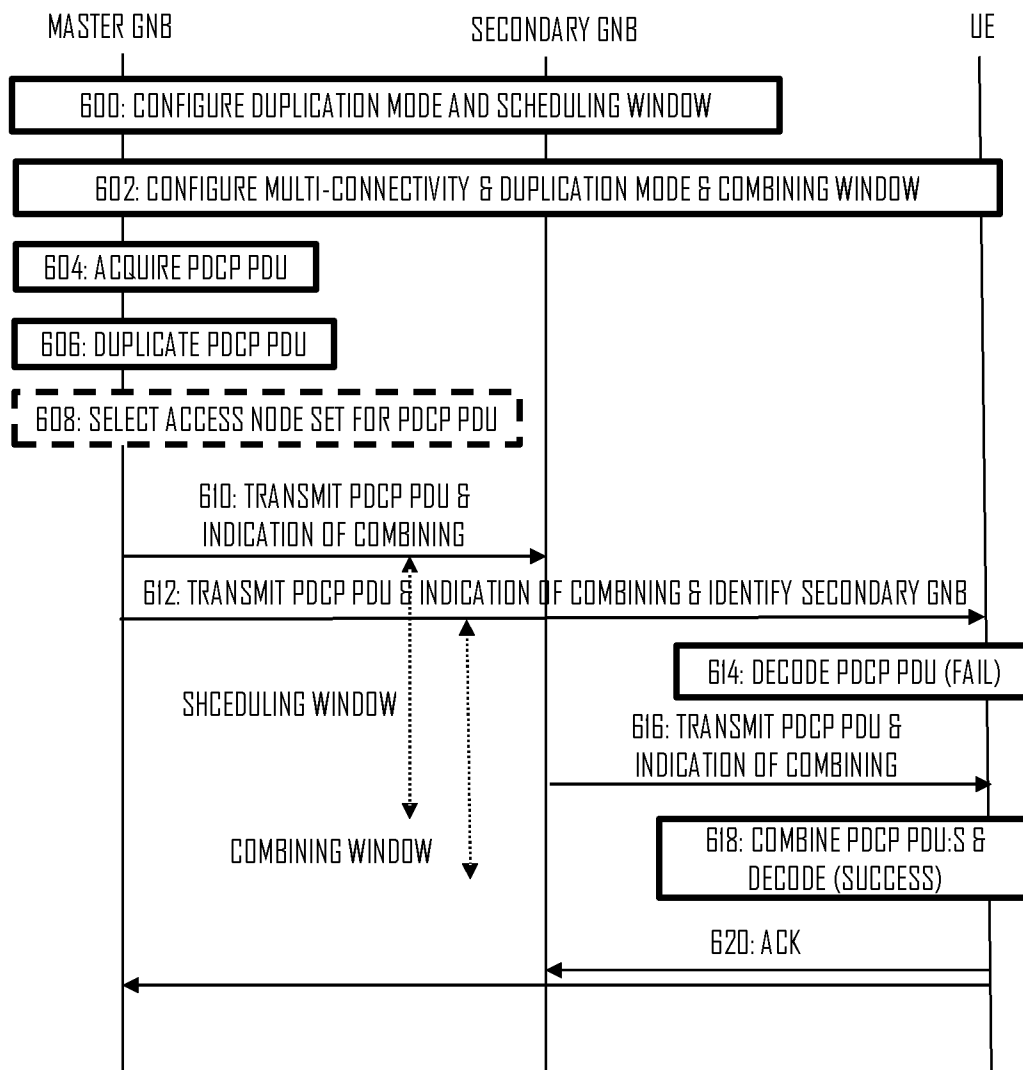


Fig 6

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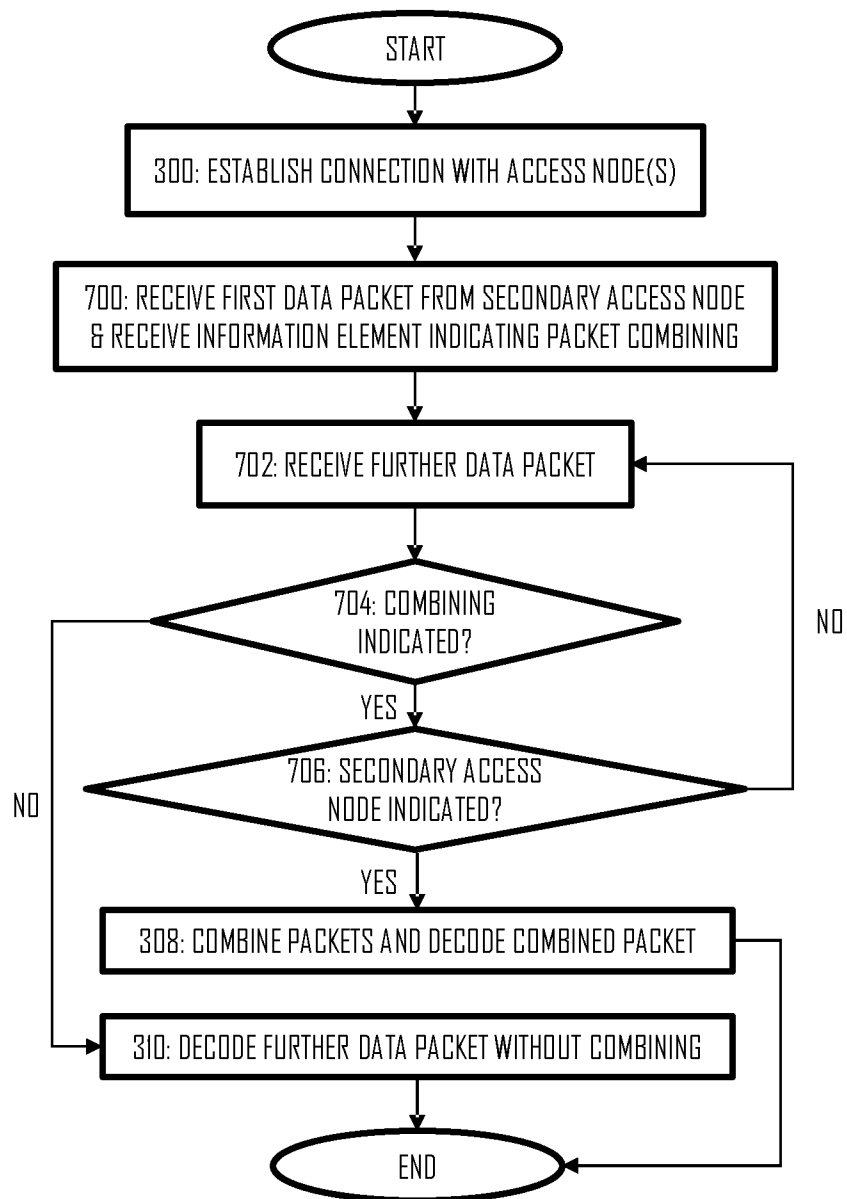


Fig 7

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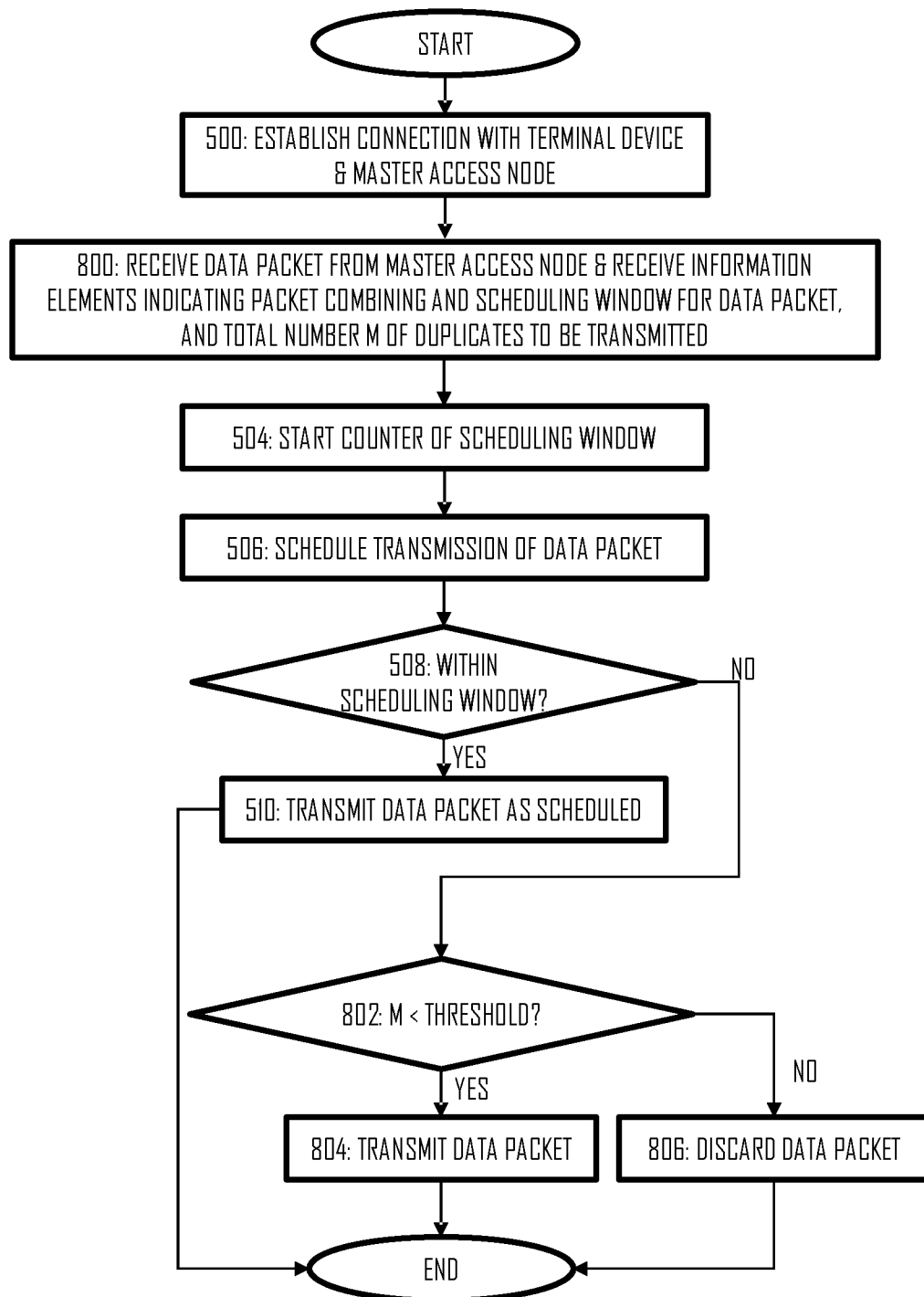


Fig 8

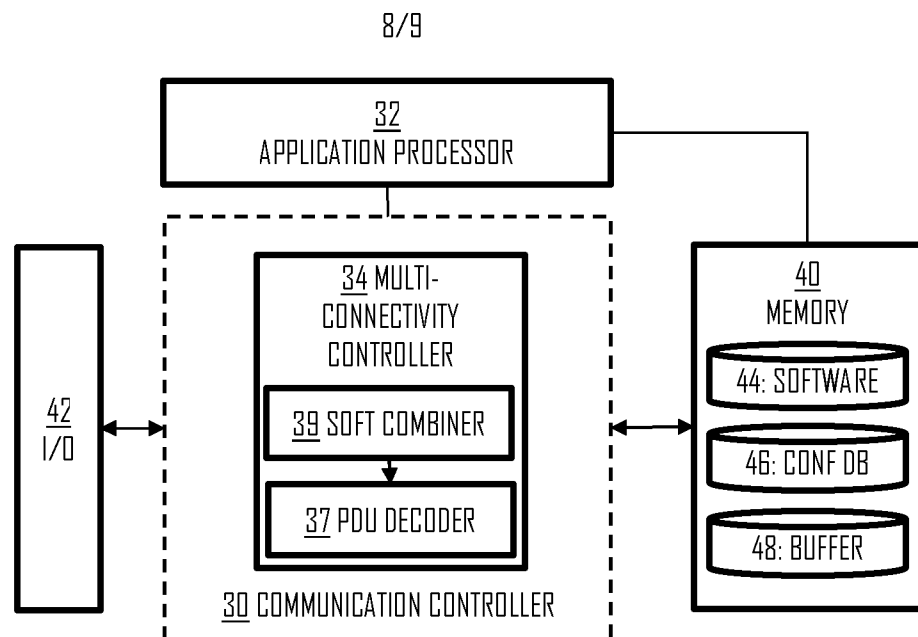


Fig 9

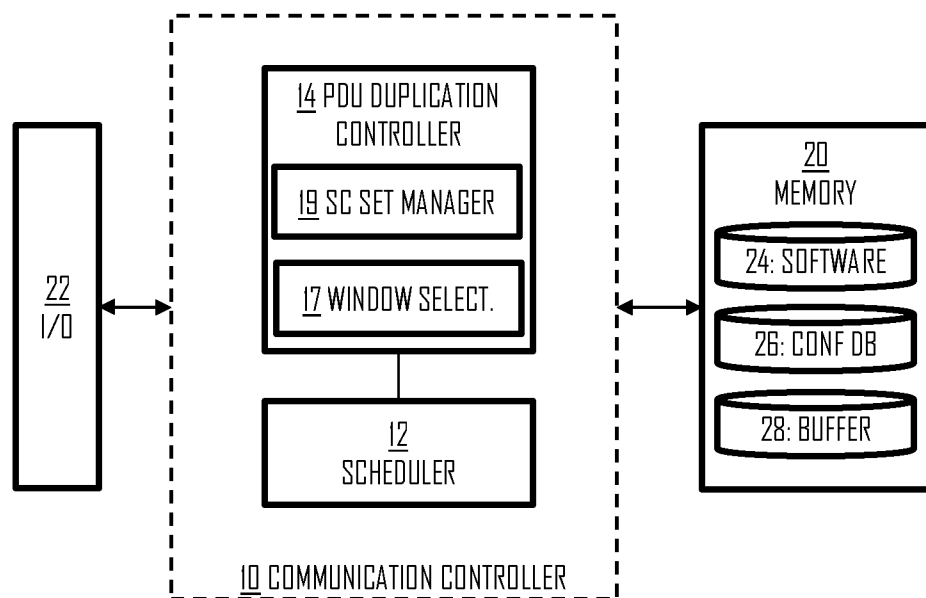


Fig 10

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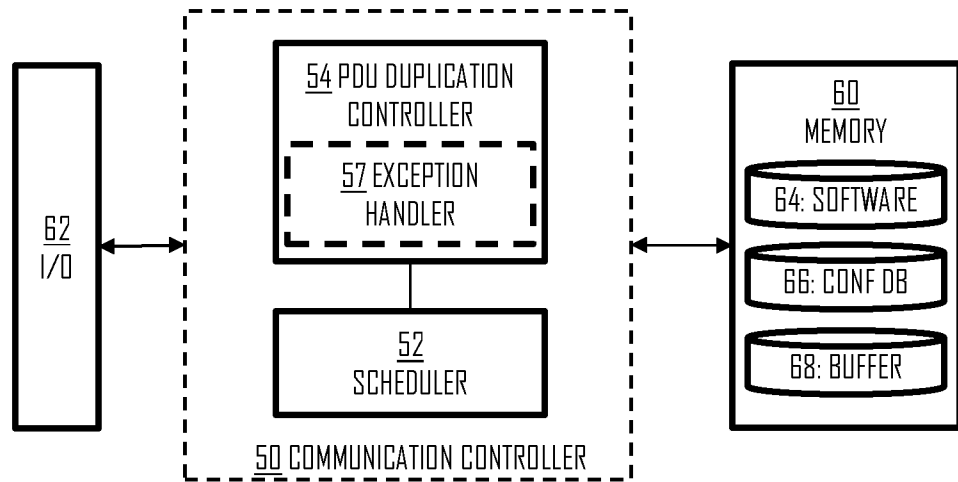


Fig 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050918

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, H04L, G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPODOC, EPO-Internal full-text databases, Full-text translation databases from Asian languages, WPIAP, XP3GPP, XPAIP, XPESP, XPETSI, XPI3E, XPIEE, XPIETF, XPIOP, XPIPCOM, XPJPEG, XPMISC, XPOAC, XPRD, XPTK, COMPD, INSPEC, TDB, NPL, PRH-Internal, Internet, ACM, Springer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018172136 A1 (FRAUNHOFER GES FORSCHUNG [DE]) 27 September 2018 (27.09.2018) abstract; Figs. 1-10, 23, 31; page 5, lines 11-25; page 19, lines 4-20; page 23, lines 29-33; page 24, lines 17-21; page 26, line 7 – page 27, line 6; page 31, lines 6-11; page 31, lines 19-36; page 49, lines 15-29; page 57, lines 7-25	1-28
A	US 2018324642 A1 (YU YU-TING [US] et al.) 08 November 2018 (08.11.2018) abstract; Figs. 1-3B, 9; paragraphs [0109]-[0149], [0239]-[0253]	1-28

☒ Further documents are listed in the continuation of Box C.
☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 29 March 2019 (29.03.2019)	Date of mailing of the international search report 02 April 2019 (02.04.2019)
Name and mailing address of the ISA/FI Finnish Patent and Registration Office FI-00091 PRH, FINLAND Facsimile No. +358 29 509 5328	Authorized officer Yrjö Raivio Telephone No. +358 29 509 5000

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050918

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018279262 A1 (BABAEI ALIREZA [US] et al.) 27 September 2018 (27.09.2018) abstract; Figs. 1-2B, 10A-10B; paragraphs [0172]-[0180], [0247]-[0251], [0281]-[0301], [0313]-[0318]	1-28
A	WO 2018156074 A1 (ERICSSON TELEFON AB L M [SE]) 30 August 2018 (30.08.2018) The whole document.	1-28
A	US 2018098250 A1 (VRZIC SOPHIE [CA] et al.) 05 April 2018 (05.04.2018) abstract; Figs. 10-11; paragraphs [0091]-[0105]	1-28
A	NOKIA, NOKIA SHANGHAI BELL. R3-185547. On Resource Efficient PDCP Duplication. 3GPP TSG-RAN WG3 Meeting #101bis, Chengdu, China, 8th – 12th October 2018: [online], 2018-09-29, [retrieved on 2019-03-27]. Retrieved from < https://www.3gpp.org/ftp/tsg_ran/WG3_lu/TSGR3_101bis/Docs/R3-185547.zip >. The whole document.	1-28
A	ERICSSON. R3-185878. Discussion on support for Resource-Efficient PDCP Duplication. 3GPP TSG-RAN WG3 #101bis, Chengdu, China, 8th – 12th October 2018: [online], 2018-09-29, [retrieved on 2019-03-22]. Retrieved from < https://www.3gpp.org/ftp/tsg_ran/WG3_lu/TSGR3_101bis/Docs/R3-185878.zip >. The whole document.	1-28

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2018/050918

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
WO 2018172136 A1	27/09/2018	None	
US 2018324642 A1	08/11/2018	WO 2018204828 A1	08/11/2018
US 2018279262 A1	27/09/2018	None	
WO 2018156074 A1	30/08/2018	None	
US 2018098250 A1	05/04/2018	WO 2018059557 A1	05/04/2018

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2018/050918

CLASSIFICATION OF SUBJECT MATTER

IPC

H04W 28/06 (2009.01)

H04W 36/28 (2009.01)

H04W 76/15 (2018.01)

H04L 5/00 (2006.01)

H04L 29/08 (2006.01)