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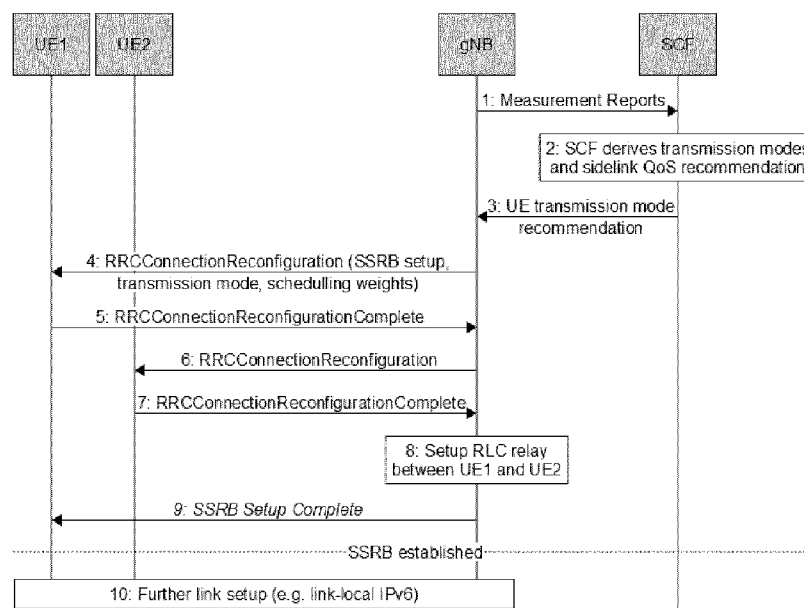
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(54) Title: METHODS AND APPARATUS FOR OFFLOADING DATA TRAFFIC IN A WIRELESS NETWORK

**Fig. 7**

(57) **Abstract:** A sidelink configuration function receives from at least one network access device measurement reports about communication links at two or more terminal devices and derives from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices. The sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device. The at least one recommendation is signalled to the at least one network access device.



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## Methods and apparatus for offloading data traffic in a wireless network

### Field

5           This disclosure relates to communications, and more particularly to methods and apparatus for data offloading in a wireless communication system.

### Background

10           A communication system can be seen as a facility that enables communication between two or more devices such as terminal devices (e.g. user terminals, machine-like terminals, user equipment (UE) or other types of end devices), base stations and/or other nodes by providing communication channels for carrying information between the communicating devices. The communication may comprise, for example, communication of data for carrying data for voice, electronic mail  
15 (email), text message, multimedia and/or content data communications and so on.

          A communication system and associated devices typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. Since introduction of fourth generation (4G) services increasing interest  
20 has been paid to the next, or fifth generation (5G) standard. 5G may also be referred to as a New Radio (NR) network. Standardization of 5G or NR networks has been finalized in 3GPP release 15.

          Direct communication among terminal devices via sidelink or device-to-device (D2D) communication is expected to be in focus of Release 17 of the 5G standard. Sidelink communication enables a paradigm shift away from star-like network  
25 topologies towards more meshed communication topologies. The current Release 15 standard does not specify how traffic will be handed off to sidelink, and it does not enable using infrastructure to optimize service quality. As an example, mobile data offloading can be achieved by using such or other complementary network  
30 technologies for delivering data originally targeted for cellular networks. Offloading may reduce the amount of data being carried on cellular bands, freeing bandwidth for other users and/or allowing users to connect via wired services with better connectivity.

### Summary

There is provided according to a first aspect an apparatus comprising means  
5 for performing:

receiving from at least one network access device measurement reports  
about communication links at two or more terminal devices;

deriving from the received measurement reports at least one recommenda-  
tion for a sidelink coordination at the two or more terminal devices, wherein the  
10 sidelink coordination determines at least one of a direct mode where data traffic is  
transmitted via a direct communication link between terminal devices and a split  
mode where data traffic is split between the direct communication link and a relayed  
communication link via the at least one network access device; and

signalling the at least one recommendation to the at least one network ac-  
15 cess device.

According to a second aspect, there is provided an apparatus comprising  
means for performing:

receiving at a network access device at least one recommendation for a  
sidelink coordination at two or more terminal devices, wherein the sidelink coordi-  
20 nation determines at least one of a direct mode where data traffic is transmitted via  
a direct communication link between terminal devices and a split mode where data  
traffic is split between the direct communication link and a relayed communication  
link via the at least one network access device; and

setting a communication mode for the two or more terminal devices accord-  
25 ing to the received recommendation for the sidelink coordination.

According to a third aspect, there is provided an apparatus comprising  
means for performing:

receiving, at a terminal device from an access device of a network, a config-  
uration command which indicates a direct mode where data traffic is transmitted  
30 via a direct communication link between the terminal device and a neighbouring  
terminal device, or a split mode where data traffic is split between the direct com-  
munication link and a relayed communication link via the network access device;  
and

performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

According to a fourth aspect, there is provided an apparatus comprising:

5       a receiving circuitry configured to receive from at least one network access device measurement reports about communication links at two or more terminal devices;

          a deriving circuitry configured to derive from the received measurement reports at least one recommendation for a sidelink coordination at the two or more  
10       terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

15       a signalling circuitry configured to signal the at least one recommendation to the at least one network access device.

According to a fifth aspect, there is provided an apparatus comprising:

          a receiving circuitry configured to receive at a network access device at least one recommendation for a sidelink coordination at two or more terminal devices,  
20       wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

          a setting circuitry configured to set a communication mode for the two or  
25       more terminal devices according to the received recommendation for the sidelink coordination.

According to a sixth aspect, there is provided an apparatus comprising:

          a receiving circuitry configured to receive, at a terminal device from an access device of a network, a configuration command which indicates a direct mode  
30       where data traffic is transmitted via a direct communication link between the terminal device and a neighbouring terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device; and

a link setup circuit configured to perform a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

5        According to a seventh aspect, there is provided a method comprising:  
receiving from at least one network access device measurement reports about communication links at two or more terminal devices;

deriving from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices, wherein the  
10        sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

signalling the at least one recommendation to the at least one network access device.  
15       

According to an eighth aspect, there is provided a method comprising:

receiving at a network access device at least one recommendation for a sidelink coordination at two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via  
20        a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

setting a communication mode for the two or more terminal devices according to the received recommendation for the sidelink coordination.

25        According to a ninth aspect, there is provided a method comprising:

receiving, at a terminal device from an access device of a network, a configuration command which indicates a direct mode where data traffic is transmitted via a direct communication link between the terminal device and a neighbouring terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device;  
30        and

performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

According to a tenth aspect, there is provided a computer program product  
5 comprising instructions for causing an apparatus to perform at least the following:

receiving from at least one network access device measurement reports about communication links at two or more terminal devices;

deriving from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices, wherein the  
10 sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

signalling the at least one recommendation to the at least one network access device.  
15

According to an eleventh aspect, there is provided a computer program product comprising instructions for causing an apparatus to perform at least the following:

receiving at a network access device at least one recommendation for a  
20 sidelink coordination at two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

25 setting a communication mode for the two or more terminal devices according to the received recommendation for the sidelink coordination.

According to a twelfth aspect, there is provided a computer program product comprising instructions for causing an apparatus to perform at least the following:

receiving, at a terminal device from an access device of a network, a configuration command which indicates a direct mode where data traffic is transmitted  
30 via a direct communication link between the terminal device and a neighbouring

terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device; and

performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

In a first example, the recommendation of the apparatus of the first or fourth aspects or the method of the seventh aspect or the computer program product of the tenth aspect may comprises at least one quality of service configurations and resource allocations for the two or more terminal devices.

In a second example which may be combined with the first example, the communication links of the measurement reports of the apparatus of the first or fourth aspects or the method of the seventh aspect or the computer program product of the tenth aspect may include direct communication links and relayed communication links.

In a third example which may be combined with the second example, the sidelink coordination of the apparatus of the first or fourth aspects or the method of the seventh aspect or the computer program product of the tenth aspect may determine a cellular mode where data traffic is transmitted via the relayed communication link via the at least one network access device.

In a fourth example which may be combined with any of the first to third examples, the means of the apparatus of the first aspect or the circuits of the apparatus of the fourth aspect or the method of the seventh aspect or the computer program product of the tenth aspect may be provided in a radio access network function or an application layer function.

In a fifth example, which may be combined with any of the first to fourth examples, the means of the apparatus of the first aspect or a request circuit of the apparatus of the fourth aspect or the method of the seventh aspect or the computer program product of the tenth aspect may be configured to request the measurement reports from the at least one network access device for a predetermined pair of terminal devices or a predetermined set of terminal devices.

In a sixth example, which may be combined with any of the first to fifth examples, the means of the apparatus of the first aspect or an optimization circuit of

the apparatus of the fourth aspect or the method of the seventh aspect or the computer program product of the tenth aspect may be configured to solve an optimization problem in order to derive the at least one recommendation.

5 In a seventh example, which may be combined with any of the first to sixth examples, the means of the apparatus of the first aspect or a selection circuit of the apparatus of the fourth aspect or the method of the seventh aspect or the computer program product of the tenth aspect may be configured to define a controlling network access device which relays signalling towards a terminal device associated with another network access device.

10 In an eighth example, which may be combined with any of the first to seventh examples, the means of the apparatus of the first aspect or a determination circuit of the apparatus of the fourth aspect or the method of the seventh aspect or the computer program product of the tenth aspect may be configured to determine based on the received measurement reports whether an optimal mode configuration  
15 tion has been achieved, and to repeat a mode selection process until the optimal mode configuration has been achieved.

In a ninth example, which may be combined with any of the first to eighth examples, the means of the apparatus of the second aspect or a configuration circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the  
20 computer program product of the eleventh aspect may be configured to configure a split sidelink radio bearer to set up the direct or split mode.

In a tenth example, which may be combined with any of the first to ninth examples, the means of the apparatus of the second aspect or a configuration circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the  
25 computer program product of the eleventh aspect may be configured to configure the split sidelink radio bearer by a radio resource control function.

In an eleventh example, which may be combined with any of the first to tenth examples, the means of the apparatus of the second aspect or a creation circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer  
30 program product of the eleventh aspect may be configured to create and dispose the split sidelink radio bearer in both terminal devices of the direct communication link.

In a twelfth example, which may be combined with any of the first to eleventh examples, the means of the apparatus of the second aspect or a setup circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer program product of the eleventh aspect may be configured to set up a traffic split  
5 function for the split mode in a packet data conversion protocol layer.

In a thirteenth example, which may be combined with any of the first to twelfth examples, the means of the apparatus of the second aspect or a support circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer program product of the eleventh aspect may be configured to use a control flow mechanism in each leg of the split sidelink radio bearer to support recommended throughput or quality targets.  
10

In a fourteenth example, which may be combined with the thirteenth examples, the means of the apparatus of the second aspect or the support circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer program product of the eleventh aspect may be configured to use a radio link control buffer status reporting for the control flow mechanism.  
15

In a fifteenth example, which may be combined with any of the first to fourteenth examples, the means of the apparatus of the second aspect or a relay circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer program product of the eleventh aspect may be configured to relay data packets of a medium access control layer via the relayed communication link.  
20

In a sixteenth example, which may be combined with any of the first to fifteenth examples, the means of the apparatus of the second aspect or a tunnel control circuit of the apparatus of the fifth aspect or the method of the eighth aspect or the computer program product of the eleventh aspect may be configured to tunnel the data traffic of the relayed communication link to another network access device by using a tunnelling protocol.  
25

In a seventeenth example, which may be combined with any of the first to sixteenth examples, the direct communication link of the apparatus of the second or fifth aspects or the method of the eighth aspect or the computer program product of the eleventh aspect may comprise a sidelink connection or a WiFi connection.  
30

In an eighteenth example, which may be combined with any of the first to seventeenth examples, the means of the apparatus of the third aspect or a split

and merge circuit of the apparatus of the sixth aspect or the method of the ninth aspect or the computer program product of the twelfth aspect may be configured to provide a split and merge function for mapping data packets of the data traffic in the direct communication link and the relayed communication link based on received recommended scheduling weights.

In a nineteenth example, which may be combined with any of the first to eighteenth examples, the means of the apparatus of the third aspect or a reporting circuit of the apparatus of the sixth aspect or the method of the ninth aspect or the computer program product of the twelfth aspect may be configured to provide measurement reports about direct and relayed communication links to access device.

In a twentieth example, which may be combined with any of the first to nineteenth examples, the means of the apparatus of the third aspect or a split control circuit of the apparatus of the sixth aspect or the method of the ninth aspect or the computer program product of the twelfth aspect may be configured to use the access device as a secondary node for a split sidelink radio bearer.

In a twenty-first example, the means of the apparatus of the first to third aspects and all its examples may comprise:

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.

The computer program products of the seventh to ninth aspects may be stored on a medium or may be downloaded from a network.

A chipset may comprise the apparatus as described herein.

### Brief Description of the Drawings

Some example embodiments will now be described with reference to the accompanying drawings in which:

Fig. 1 shows a schematic example of a wireless communication system where some example embodiments may be implemented;

Fig. 2 shows a scenario and functional overview of an example embodiment where involved terminal devices are in the coverage area of the same base station;

Fig. 3 shows a scenario and functional overview of an example embodiment with base station relay and cross-cell D2D communication;

Fig. 4 shows a scenario and functional overview of an example embodiment with a protocol stack example for relaying radio link control data packets in a radio  
5 node;

Fig. 5 shows a scenario and functional overview of an example embodiment with a protocol stack example for relaying media access control data packets in the radio node;

Fig. 6 shows a scenario and functional overview of an example embodiment with a protocol stack example for tunnelling data packets between two radio nodes;  
10

Fig. 7 shows a message sequence chart for quality reporting, transmission mode recommendation and split bearer configuration according to a sample embodiment;

Fig. 8 shows a flow diagram of a procedure for optimizing a mode configuration according to a sample embodiment; and  
15

Figs. 9A to 9C show diagrams with exemplary data rate characteristics achieved by enabling D2D communication for different system set-ups.

### Detailed Description

The following describes in further detail some examples of systems, apparatus and possible mechanisms for at least one of sidelink and infrastructure traffic offloading in a cellular network, such as a fifth generation (5G) cellular network. It is however noted that some embodiments may also be implemented in other systems, apparatus and possible mechanisms for other types of networks with sidelink  
20 or D2D communication options.  
25

As discussed in the background section above, sidelink or D2D communication enables a shift towards more mesh-like communication topologies, which may provide interesting options for industrial, vehicular and sensor networks. Apart from this, also peer-to-peer applications may benefit from the sidelink or D2D options.  
30

The current Release 15 standard (i.e. 3GPP (2018), TS 23.303 "Proximity-based services (ProSe); Stage 2" V15 (Vol. 0)) does not specify how traffic will be

handed off to sidelink, and it does not enable using infrastructure to optimize key performance indicators (KPIs) for quality of service (QoS).

An option to leverage a sidelink in a beneficial way may be to select traffic flows that should be offloaded to sidelink. Intuitively, two devices that are at spatially  
5 distant locations may not be able to maintain good communication quality via a sidelink, whereas they might strongly benefit if the source and target devices are near each other. However, even when sidelinks achieve a minimum communication quality, it can still make sense to use uplink-downlink communication nevertheless. A reason may be that using a 'too bad' sidelink can degrade communication of  
10 other concurrent links by consuming many resources. In fact, all traffic flows, be they sidelink, uplink or downlink, may be coupled via common transmission resources. As an example, they may be coupled by at least one of a scheduling strategy used by the operator and underlying physical layer capabilities. The problem of choosing the right traffic flows to use the sidelink is in general non-trivial and may  
15 be called "mode selection problem".

Apart from the mode selection problem itself, the design of a good handoff procedure may be desirable. A 'good' procedure thereby should be applicable to a variety of underlying systems, i.e., to devices with heterogeneous capabilities, resource structures and scheduling functions, while still leaving options of making  
20 reasonable decisions to reach a 'good' or favourable network state.

In some example, handoff may be tackled from a cross-layer optimization perspective. It may be part of an overall decision framework including at least one of scheduling and physical layer parameter choices. Also, it may be assumed that sidelinks operate in a semi-persistent fashion, i.e., they may use a single carrier for  
25 the whole or at least some duration of communication. Moreover, existing handoff procedures may be tailored to a specific system setup and/or may incorporate specialized scheduling and/or signaling procedures among the nodes.

A general handoff procedure may be provided without exactly specifying interfaces or, alternatively, offloading procedures may be tailored to specific use  
30 cases, which may incorporate specialized signalling structures. As another option, a generalized handoff procedure may be provided that is applicable to a variety of underlying system configurations. The handoff procedure may for example reside on higher protocol layers. It may then not require any signalling that depends on

the exact system. It may be used to make reasonable handoff decisions, i.e., to optimize the system configuration to a variety of objectives.

According to some examples described hereinafter, methods, apparatus, and systems for dynamically switching traffic towards and away from a sidelink are provided. This may allow at least one of handoff of traffic to a sidelink, re-integration of sidelink traffic into conventional uplink-downlink communication and concurrent multi-path connection using both, sidelink and uplink-downlink path for data transport. As a further option, performance monitoring of such traffic by the network (e.g. the radio access network (RAN) may be possible, which can be leveraged for making appropriate hand-off decisions.

Fig. 1 schematically shows a schematic example of a wireless communication system where some example embodiments may be implemented. The depicted exemplary RAN of the wireless communication system comprises a plurality of terminal devices (e.g. UEs) 101 to 105, which are termed "UE1" to "UE5".

Although in the example of Fig. 1 six terminal devices are shown, it will be understood that in other examples more or fewer terminal devices may be present.

The terminal devices form the endpoints of sidelink traffic between them. For simplicity, a two-terminal network is considered in the following, where the source terminal is termed "UE 1", while the target terminal is termed "UE 2". Extension to multiple terminal pairs follows later.

Furthermore, two base stations 108 and 109 are shown, which are termed "BS1" and "BS2". Each base station is the main anchor point or serving base station for all mobile communications in its respective defined cell. In the example of Fig. 1, the first base station (BS1) 108 currently serves three terminal devices 101 to 103 (UE1 to UE3) located in the coverage area or cell of the first base station 108. Furthermore, the second base station (BS2) 109 serves two terminal devices 104 and 105 (UE4 and UE5) currently located in the coverage area or cell of the second base station 109. Examples of such base stations could be a node B ("eNB" or "eNodeB" in 4G terminology, "gNB" or "gNodeB" in 5G terminology) or indeed any other type of access device, a small cell or similar.

Additionally, a sidelink coordination function (SCF) 110 is provided, which could be located at one or more of the base stations 108 and 109, in a co-located data center or at any other location within RAN.

According to some examples, the SCF 110 is configured to control the base stations and terminal devices to achieve an optimized transmission mode selection of terminal devices capable of direct D2D communication (e.g. sidelink communication). In an example, an enhanced split radio bearer structure is proposed for enabling dynamic connectivity between two devices, potentially relayed over the radio network.

It is assumed that two neighboring ones of the terminal devices 101 to 105 are in mutual proximity and have become aware of their proximity, e.g., by a proximity alert or any other kind of neighbour detection process. There are a set of neighbor discovery procedures, which involve regular transmission of beacons by the terminal devices ("beaconing"), in which they advertise their presence and D2D capable services. These procedures are expected to be triggered in reaction to a proximity alert, to verify proximity. Another option could be to trigger a process of mutual detection via a serving base station or even via some location service. For the latter, the terminal devices 101 to 105 need to be capable of some kind of signal exchange. In an exemplary setup, the SCF 110 may trigger a configuration of the terminal devices 101 to 105 by recommending the respective serving base station to install, tear down or alter a new type of bearer, called "split sidelink radio bearer" (SSRB).

According to some examples, the SSRB may be configured to support at least two of three transmission modes, which comprise a direct mode (DM), a cellular mode (CM) and a split mode (SM). For CM and SM, the respective base station (e.g. BS1 108 in Fig. 1) forwards traffic originating from the source terminal (e.g. UE1 101 in Fig. 1) towards the target terminal (e.g. UE 2 in Fig. 1).

According to some examples, depending on the set-up, the traffic may also pass a second base station (e.g. BS2 109 in Fig. 1), if the source and target terminals reside in different cells. Traffic is transported from the source terminal e.g. UE1 101 in Fig. 1) to the first base station (e.g. BS1 108 in Fig. 1) via a normal uplink channel (e.g., a radio link control (RLC) channel), which may be pre-defined depending on the used type of standard. The uplink channel may merely act as a tunnel to interface a connection of a packet data convergence protocol (PDCP) layer between the source terminal (e.g. UE1 101 in Fig. 1) and the first base station (e.g. BS1 108 in Fig. 1).

According to some examples, the SCF 110 may signal recommendations for transmission mode and QoS parameters used for a sidelink channel to the base station.

Furthermore, according to some examples, the SCF 110 may request from  
5 the base station 108, 109 measurement reports for a specific one or for a set of the terminal devices 101 to 105.

Fig. 2 shows a scenario and functional overview of an example embodiment where terminal devices UE1 and UE2 are in the coverage area of the same base station BS1 and a further terminal UE 3 is in the coverage area of a second base  
10 station BS2.

According to some examples, the terminal devices UE1 and UE2 may use direct (e.g., sidelink, WiFi, etc.) communication to other terminal devices as alternative to or in conjunction with network-based communication via the base station BS to enable optimized communication in terms of QoS, throughput, packet error  
15 rate, reliability, latency, interference or any other parameters that determine transmission quality.

According to some examples, the SCF may use measurements or estimates in different modes for coordinating transmission mode selection of the terminal devices UE1 and UE2.

According to some examples, the terminal devices UE1 and UE2 may be  
20 configured to report measurements on both sidelink and base station channels, including QoS or other quality metrics like PDCP or other throughput measures during communication.

According to some examples, measuring the achieved throughput may be  
25 provided as a minimum configuration.

According to some examples, other valid metrics such as queue backlog, packet error rate or delay may be configured in the alternative or in addition.

According to some examples, estimates of achievable quality (e.g. QoS) may be provided by the base station BS to the SCF. Such estimates may for example depend on at least one of available channel measurements, used scheduling  
30 policies or similar.

According to some examples, the SCF may be implemented as a RAN function or an application layer function, e.g., co-located with proximity-based service (ProSe) function, or both.

According to some examples, the SCF may provide a recommendation to  
5 the base station BS, which transmission mode shall be used by which of the terminal devices UE1 and UE2. As already indicated above, possible transmission modes may include DM (which is direct D2D communication via a sidelink channel or WiFi connection or another suitable connection), CM (where the communication  
10 between the terminal devices UE1 and UE2 is relayed over one or more base stations), and SM (a combination of DM and CM, where a terminal device may decide based on an indicator (e.g. a weight indicator) provided by the SCF or based on flow control or based on another suitable parameter, how traffic shall be split between the direct D2D link and the base station link).

Alternatively or additionally, in some examples, the traffic may be duplicated  
15 on both channels in the split mode in order to increase the reliability of the communication between both terminal devices UE1 and UE2.

According to some examples, the SCF may additionally or alternatively provide recommendations on resource allocation for sidelink terminal devices.

According to some examples, the SSRB may terminate at two terminal devices  
20 (e.g. UE1 and UE2 in Fig. 2) which are eligible for DM and CM communication. The SSRB may be uni- or bidirectional. A uni-directional SSRB may allow different configurations for both communication directions.

According to some examples, a traffic split function may be provided in the PDCP layer. In each communication direction, a base station leg of the SSRB may  
25 be relayed by the base station BS towards the receiving terminal device (e.g. UE1 or UE2 in Fig. 2). At both transmitting (e.g. source) and receiving (e.g. target) terminals a traffic split and merge function may for example be provided, as shown in Fig. 2).

According to some examples, a radio resource control (RRC) function in the  
30 controlling base station BS may create and dispose the SSRB in both source and target terminals.

According to some examples, at least one of minimum and maximum throughput targets may be defined for each active leg of the SSRB. Other QoS targets may also be set, if configured and applicable.

According to some examples, a flow control mechanism may be used on  
5 each leg of the SSRB to support the defined throughput, quality or other targets. As an example, an RLC buffer status reporting can be utilized for this.

In the case two terminal devices (e.g. UE1 and UE3 in Fig. 2) are not associated to the same base station, but rather to two different base stations BS1 and BS2, the traffic may be transferred via a base station to base station interface (BS-  
10 BS interface), as explained below in more detail with reference to Fig. 3.

Fig. 3 shows a scenario and functional overview of an example embodiment with base station relay and cross-cell D2D communication.

In the case of Fig. 3, both terminal devices UE1 and UE2 are not associated to the same base station, but rather to two different base stations BS1 and BS2.  
15 User data or traffic is transferred via a base station to base station interface (e.g., X2/Xn interface in NG-RAN or another BS-BS interface in another standard).

According to some examples, in case the SSRB is configured to traverse several base stations (e.g. BS1 and BS2 in Fig. 3), the SCF may select and define a controlling base station (e.g. BS1 in Fig. 3), which is configured to relay signalling  
20 and/or traffic towards the terminal device (e.g. UE2 in Fig. 3) associated with the other base station (e.g. BS2 in Fig. 3).

In the following, different exemplary configurations and protocol stack alternatives for the split mode (SM) are explained based on an exemplary 5G network architecture with reference to Figs. 4 to 6. They may for example be implemented  
25 for the user plane based on the current 3GPP Release 15 standard.

A plane, in a networking context, may be one of three components of a telecommunications architecture. These three components may be the user plane, a control plane and a management plane. They can be thought of as different areas of operations. Each plane may carry a different type of traffic and may conceptually  
30 (and often in reality) be an overlay network (i.e. a telecommunications network that runs independently on top of another one, although supported by its infrastructure).

The user plane (sometimes known as the data plane, forwarding plane, carrier plane or bearer plane) may carry network user traffic. The control plane organizes establishment, release of connections according to operator and end-user's QoS and security requirements, checks the user's authorisation/authentication and provides information needed for accounting/billing of the used services. The control plane may carry signalling traffic between control functions that are located at different devices and/or network nodes to coordinate these control tasks. The management plane, which may carry administrative traffic, may be considered a subset of the control plane.

According to some examples, the setup may consist of one or two radio access nodes (e.g. base stations, such as gNBs or eNBs) and two terminal devices UE1 and UE2 where data from a source terminal UE1 needs to be transported to a sink terminal UE2.

Note that Figs. 4 to 6 show a split mode user plane because the split mode user plane consists of cellular mode and direct mode user planes.

A bearer service may be a link between two points, which is defined by a certain set of characteristics. When a terminal device shall be provided with any service, the service may be associated with a bearer specifying the configuration for associated protocol layer(s) (e.g. physical layer and layer 2) of a protocol stack in order to have its QoS clearly defined. A bearer may thus be considered as a channel offered by the associated protocol layer(s) to higher protocol layers for the transfer of user or control data. In other words, the associated protocol layer(s) offer(s) to the upper protocol layers the service of information transmission between the terminal device and the RAN by means of bearers. Therefore, a bearer may be a service access point between the associated protocol layer(s) and the upper protocol layers.

As an example, the 5G protocol stack comprises layer 1, layer 2 and layer 3.

The 5G layer-1 corresponds to the physical layer. Functions of the physical (PHY) layer may include error detection on the transport channel and indication to higher layers, forward error control (FEC) encoding/decoding of the transport channel, hybrid automatic repeat request (HARQ) soft-combining, rate matching of the coded transport channel to physical channels, mapping of the coded transport

channel onto physical channels, power weighting of physical channels, modulation and demodulation of physical channels, frequency and time synchronisation, radio characteristics measurements and indication to higher layers, multiple input multiple output (MIMO) antenna processing, transmit diversity (TX diversity), digital and analog beamforming, and radio frequency (RF) processing.

The 5G layer-2 comprises MAC, RLC and PDCP sublayers.

Functions of the MAC sublayer may include beam management, random access procedure, mapping between logical channels and transport channels, concatenation of multiple MAC service data units (SDUs) belonging to one logical channel into a transport block (TB), multiplexing/demultiplexing of 5G-MAC SDUs belonging to one or different logical channels into/from transport blocks (TB) delivered to/from the physical layer on transport channels, scheduling information reporting, error correction through HARQ, priority handling between logical channels of one terminal device, priority handling between terminal devices by means of dynamic scheduling, transport format selection, and padding.

Functions of the RLC sublayer may include transfer of upper layer PDUs, error Correction through ARQ, reordering of 5G-RLC data PDUs, duplicate detection, protocol error detection, 5G-RLC SDU discard, segmentation/resegmentation, 5G-RLC re-establishment.

Functions of the PDCP sublayer may include transfer of user data, in-sequence delivery of upper layer PDUs at 5G-PDCP re-establishment procedure for 5G-RLC, duplicate detection of lower layer SDUs at 5G-PDCP re-establishment procedure for 5G-RLC, retransmission of 5G-PDCP SDUs at mobility in connected mode for 5G-RLC, ciphering and deciphering, timer-based SDU discard in uplink, ciphering and integrity protection and transfer of control plane data.

The 5G layer-3 corresponds to the RRC layer. Functions of the RRC layer may include broadcasting of system information, establishment, maintenance and release of RRC connections, security including key management, establishment, configuration, maintenance and release of point-point radio bearers, mobility functions along with cell addition and cell release, terminal device measurement reporting, control of terminal device reporting, terminal based mobility, and direct message transfer to/from network from/to terminal device.

According to some examples, in the direct mode (DM), a bearer is configured for direct data transport via a sidelink connection, or some other means like a WiFi link for example.

According to some examples, in the cellular mode (CM), the source terminal  
5 UE1 transmits traffic intended for the target terminal UE2 to the radio node (e.g. base station such as gNB or eNB) which relays directly to the target terminal UE2. ARQ may then be terminated in the respective RLC protocol entity of the terminal device.

According to some examples, the split-mode (SM) combines CM and DM,  
10 as is shown in the Figs. 4 to 6. A traffic split and merge function at the terminal device may be responsible for mapping data packets on the direct link and the cellular channel. The traffic split and merge function may for example be based on scheduling weights recommended by the SCF and set by an RRC protocol entity at the radio node (e.g. base station such as gNB or eNB or another access node)  
15 or based on flow control feedback.

Fig. 4 shows a scenario and functional overview of an example embodiment with a protocol stack example for relaying RLC data packets (e.g. RLC-SDUs) in a radio node (e.g. a gNodeB (gNB) in this example).

The RLC data packets are forwarded by the radio node from the source terminal  
20 UE1 to the sink terminal UE2. In an RLC acknowledged mode, when the RLC data packets got delivered successfully over the source-side and the sink-side RLC channel, then the final RLC acknowledgement for an RLC data packet is sent to the source terminal UE1. The RLC acknowledged mode feedback, i.e. the indication about successful delivery of RLC data packets to the target terminal UE2 may  
25 be transferred from sink side processing to source side processing of a relaying functionality at the radio node.

According to some examples, in the split mode there may be an alternative for the source terminal UE1 to request a PDCP packet delivery report via the direct branch of the split mode bearer.

30 Fig. 5 shows a scenario and functional overview of an example embodiment with a protocol stack example for relaying MAC data packets (e.g. MAC-SDUs) in the radio node (e.g. gNodeB in this example).

In the exemplary scenario of Fig. 5, the MAC data packets are relayed by the radio node. This means the RLC channels are not terminated in the radio node and therefore no special handling with respect to delivery feedback handling is necessary at the radio node. However, according to some examples, a special feedback coordination functionality may now be necessary for the MAC layer.

Fig. 6 shows a scenario and functional overview of an example embodiment with a protocol stack example for tunnelling data packets between two radio nodes (e.g. base stations such as eNB or gNB or other access nodes).

In the exemplary scenario of Fig. 6 two radio nodes (e.g. gNBs in this example) are involved. According to some examples, the radio nodes may be connected via an Xn interface or any other type of interface suitable for establishing an inter-connection between two access devices. RLC data packets and delivery indications may then be tunnelled in respective opposite directions between the radio nodes by using a suitable tunnelling protocol, such as the GPRS user plane tunnelling protocol (GTP-U) or the Xn user plane protocol (Xn-U), as indicated in Fig. 6.

According to some examples, the protocol stack of the tunnelling function may comprise an L1/L2 layer, UDP/IP layer and GTP-U layer on top of each other. Other options could be generic routing encapsulation (GRE) or the base station could act as a L2 switch or bridge, so that L2 data could be directly encapsulated (e.g., as LAN frames).

Fig. 7 shows a message sequence chart for quality reporting, transmission mode recommendation and split bearer configuration according to a sample embodiment, wherein time proceeds from the top to the bottom of the chart.

As is shown in Fig. 7, according to some examples, the SCF may first initiate in step 1 a quality reporting procedure where quality (QoS) parameters that have been measured at the terminal devices UE1 and UE2, or estimates of the achievable quality, which may be requested by the SCF. Upon receiving a respective command from the SCF, the radio node (e.g. a gNB in this example, or any other base station or radio access device) fetches the currently achieved quality (QoS) values from the terminal devices UE1 and UE2, or calculates estimates of the achievable quality, and provides them to the SCF.

According to some examples, in step 1, the radio node may provide a QoS report for UE-UE communication to the SCF, including some UE identifier.

As an example, for identification of the terminal devices UE1 and UE2 a unique identifier may be used, such as a cell radio network temporary identifier (C-RNTI), an application layer user ID (ALUID) or an evolved packet core (EPC) ProSe User ID (EPUID). e.g. C-RNTI/ALUID/EPUID.

According to some examples, the measurement provisioning may be periodic with some configured time interval, originated from the radio node based on some thresholds for UE measurements, or based on a request by the SCF.

Then, the SCF may initiate a mode recommendation procedure where transmission mode and QoS configuration recommendations can be optimized at the SCF, as shown in step 2 of Fig. 7. As an example, the SCF may derive recommendations for terminal transmission modes, QoS settings and QoS measurement settings, which may all be controlled by the radio node.

Then, in step 3, the recommendations may be indicated to the radio node by a corresponding message. The SCF may for example provide recommendations where the terminal devices UE1 and UE2 are identified by the identifier provided in step 1.

According to some examples, the recommendations in this message may for example refer to a specific terminal pair or to a set of terminal pairs.

Thereafter, the SCF may initiate a split bearer management procedure where the radio node may set, reconfigure or tear down the split bearer (i.e, SSRB) of each terminal pair in the network. The split bearer management procedure is shown by steps 4 to 9 in Fig. 7.

In steps 4 and 6, the radio node initiates SSRB configuration at the terminal devices UE1 and UE2 e.g. by transmitting respective configuration command (e.g. RRC connection reconfiguration messages which may indicate an SSRB setup, a transmission mode and scheduling weights).

According to some examples, the radio node may send the configuration command with a modified cell group configuration field (e.g. rlc-BearerToAddModList field) to establish the split bearer (i.e. SSRB). Additionally, a key for user plane encryption and integrity protection may be included in the message.

In steps 5 and 7, the terminal devices UE1 and UE2 may each respond with a respective completion message (e.g. RRC reconfiguration complete message) upon successful bearer establishment.

According to some examples, the configuration command may include at least one of a targeted mode (e.g. DM, CM or SM) and QoS parameters.

Then, in step 8, the RLC relay between source and target terminals UE1, UE2 may be setup. For CM, the radio node may prepare all affected radio nodes for relaying in step 8.

According to some examples, the radio node may configure RLC relay(s) between the terminal devices UE 1 and UE 2, if necessary. The UEs identifiers may be used for forwarding RLC data packets (e.g. RLC-PDUs).

Finally, in step 9 the source terminal UE1 may be notified by the radio node that the setup procedure has been finished (e.g. by a SSRB setup complete message).

After the split bearer (i.e. SSRB) has been set-up, the terminal devices UE1 and UE2 may undergo in step 10 further standard procedures for entirely setting up the uplink/downlink and/or the direct link communication. These may include layer 3 address exchange, key exchange etc., and may differ depending on whether the communication is relayed over several radio nodes (e.g. base stations (eNBs or gNBs) or other access devices), over WiFi or via a sidelink connection, respectively. An example may also be a link-local IPv6 procedure.

The proposed procedure of Fig. 7 may thus provide an optimization of direct communication usage over different underlying system settings.

According to some examples, a single LTE cell with an eNodeB as base station and a fixed number of potential D2D links may be considered, for which a mode selection procedure shall be performed. The base station may be deployed at the center of the cell, while for each D2D link, two nodes (e.g. terminal devices, UEs) may be placed within a maximum radius of the base station and a maximum distance of one another.

The network may have a resource grid of six 180 kHz frequency channels available, that are accessed in a Time Division Duplex (TDD) manner with six time slots of 1 ms available in the uplink frame and four time slots in the downlink frame. Both, uplink and downlink frames may be accessed arbitrarily by the D2D links, if

an involved scheduler allocates the resources accordingly. Channels may be generated according to the Winner-II channel model, which takes into account the distance based path loss, line-of-sight probability and shadowing, based on the devices' antenna heights. For each potential link of source terminal to base station, base station to destination terminal or the D2D source-destination pair, the receiver Signal to Interference and Noise Ratio (SINR) may be determined for fixed transmission powers. The determined SINR may then be mapped to a maximum-rate modulation and coding scheme (MCS), choosing among LTE MCS, which range from Quadrature Phase Shift Keying (QPSK) to 64-Quadrature Amplitude Modulation (QAM). The chosen MCS may be assumed to be used whenever the scheduler assigns that resource to the link, respectively.

According to some examples, each source node may run a transport-layer congestion control mechanism, deciding on how much traffic is admitted into a MAC-layer queue. The congestion control mechanism may aim at proportional fair throughput maximization, to avoid cases where all resources are assigned to a single link with good channel quality, while other links get zero rate.

Fig. 8 shows a flow diagram of a procedure for optimizing a mode configuration according to a sample embodiment.

Initially, in step S0, the SCF is provided with measurement reports and/or estimations as baseline. They may have been provided e.g. by channel quality indicators (CQI) of involved links. Then, in step S1, the SCF determines an optimal mode choice and/or rate target(s) according to its initial knowledge, e.g., by solving an optimization problem. In the following step S2, the mode choice and/or rate target(s) of the SCF are recommended (i.e. signalled) to a base station (BS), such as an eNodeB or gNodeB or any other access node or radio node, which enforces them in step S3 e.g. by setting communication modes for terminal links. In the subsequent step S4, the base station waits a predetermined number of frames and then reports the actual rates back to the SCF. Then, in step S5, the SCF takes the feedback (i.e. actual rates) received from the base station into account and determines whether it should re-iterate the procedure. The re-iteration can depend on, e.g., whether QoS is sufficient (not necessarily optimal), or whether a maximum number of iterations has been reached. The sufficiency of QoS may be based on

reported quality metrics (e.g. throughput, latency, reliability and/or interference parameters, or the like). The reported quality metrics may be of the same type as the ones based on which the original recommendation in step S2 was determined.

5 If the SCF decides in step S6 that another iteration is initiated, the procedure branches to step S6 and the SCF solves an improved optimization problem, taking into account the new feedback received from the base station. Then, steps S2 to S5 are repeated. Otherwise, no new recommendations are done and the procedure stops..

10 Accordingly, the proposed mode configuration optimization procedure can be repeated, until an optimal mode configuration has been found.

Figs. 9A to 9C show diagrams with exemplary data rate characteristics achieved by enabling D2D communication for different system set-ups.

Three different scenarios are considered here. In the first one, called "Overlay D2D", a backpressure scheduler assigns transmission resources e.g. based on  
15 at least one of queue back-logs and traffic. Resources may be assigned exclusively to one link here. Such a backpressure scheduler may take the buffer states of all nodes as an input, which are reported, e.g., by buffer status reports (BSRs), and knowledge on achievable data rates, e.g., channel quality index (CQI). Then, it calculates a "backpressure" value based on the differential backlog of each hop, i.e.,  
20 the transmitter backlog minus the receiver backlog, and uses these as weights to prioritize links, where links with larger differential backlog have larger priority. Based on these values, the backpressure scheduler may determine a schedule by solving a weighted sum-rate maximization problem.

In the second one, called "Underlay D2D", the same backpressure scheduler  
25 allows frequency reuse by sidelinks connections with fixed transmission powers. This may be realized by letting all links interfere at the beginning and measuring the achieved SINR values. The resulting SINR values may again be mapped to the selected MCS and used in the course of further scheduling. In the third one, called "Outband D2D", direct communication may be realized over WiFi, using at least  
30 one of carrier sense multiple access with collision avoidance (CSMA/CA) and exponential back-off rule.

In the diagrams of Figs. 9A to 9C results are shown for two to eight links, where the y-axis shows the total achieved data rate. Compared is a greedy cellular

mode (Greedy CM) and a greedy direct mode (Greedy DM), where all links use CM or DM irrespective of their direct channels, and a version that is optimized for a fair distribution of data rates (Optimum Fair). In "greedy" mode selection strategies, the links are forced to use the CM/DM whenever a non-zero rate can be achieved in the respective leg.

As can be gathered from the characteristics of Figs. 9A to 9C, DM creates larger data rates than CM, which is due to its better channels. The optimized version achieves less data rates for overlay and underlay communication. Here, parts of the achievable rate are sacrificed to achieve a fairer rate distribution.

It may thus be concluded that the proposed offloading procedures can be used to optimize network towards a desired metric, irrespective of how the direct link is actually realized.

According to some examples, a split bearer may thus be used for optimized D2D communication which may be configured by a radio resource control function of a base station.

According to some examples, a sidelink coordination function may be introduced, that determines at least one of an optimal mode and QoS configurations for eligible terminal devices.

According to some examples, the SCF may then coordinate across several base stations to improve at least one of inter-site interference and overall radio resource utilization. Via a respective interface, current QoS parameters achieved by the flow associated with the bearer, or estimates thereof, may be exposed to the SCF by the base station. The terminal device may then utilize the base station as a secondary node for the bearer, or in a split-mode fashion. The base station may for example relay traffic to another base station to complement inter-site direct device-to-device communication.

In general, the various example embodiments and examples may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects of the invention may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and

described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

As used in this application, the term “circuitry” may refer to one or more or all of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) combinations of hardware circuits and software, such as (as applicable): (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation. This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device. Some of the examples may be implemented by computer software executable by a data processor of the mobile device, such as in the processor entity, or by hardware, or by a combination of software and hardware. Computer software or program, also called program product, including software routines, applets and/or macros, may be stored in any apparatus-readable data storage medium and they comprise program instructions to perform particular tasks. A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out some of the examples. The one or more computer-executable components may be at least one software code or portions of it.

Further in this regard it should be noted that any blocks of the logic flow as in the Figs. 7 and 8 may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory  
5 chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD. The physical media is a non-transitory media.

The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as sem-  
10 iconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may comprise one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated  
15 circuits (ASIC), FPGA, gate level circuits and processors based on multi core processor architecture, as non-limiting examples.

Some of the examples may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for convert-  
20 ing a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

The foregoing description has provided by way of non-limiting examples a full and informative description of exemplary embodiments. However, various modifications and adaptations may become apparent to those skilled in the relevant arts  
25 in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of the described exemplary embodiments will still fall within the scope of this disclosure as defined in the appended claims. Indeed, there is a further exemplary embodiment comprising a combination of one or more exemplary  
30 embodiments with any of the other exemplary embodiments previously discussed.

**CLAIMS:**

1. An apparatus comprising means for performing:  
5 receiving from at least one network access device measurement reports about communication links at two or more terminal devices;  
deriving from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is  
10 transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and  
signalling the at least one recommendation to the at least one network access device.  
15
2. The apparatus of any preceding claim where the recommendation comprises at least one quality of service configurations and resource allocations for the two or more terminal devices.
- 20 3. The apparatus of any preceding claim where the communication links of the measurement reports include direct communication links and relayed communication links.
4. The apparatus of claim 3 where the sidelink coordination determines a cellular mode where data traffic is transmitted via the relayed communication link via  
25 the at least one network access device.
5. The apparatus of any preceding claim where the means are provided in a radio access network function or an application layer function.
- 30 6. The apparatus of any preceding claim where the means are configured to request the measurement reports from the at least one network access device for a predetermined pair of terminal devices or a predetermined set of terminal devices.

7. The apparatus of any preceding claim where the means are configured to solve an optimization problem in order to derive the at least one recommendation.
- 5 8. The apparatus of any preceding claim where the means are configured to define a controlling network access device which relays signalling towards a terminal device associated with another network access device.
9. The apparatus of any preceding claim where the means are configured to  
10 determine based on the received measurement reports whether an optimal mode configuration has been achieved, and to repeat a mode selection process until the optimal mode configuration has been achieved.
10. An apparatus comprising means for performing:  
15 receiving at a network access device at least one recommendation for a sidelink coordination at two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication  
20 link via the at least one network access device; and  
setting a communication mode for the two or more terminal devices according to the received recommendation for the sidelink coordination.
11. The apparatus of claim 10 where the means are configured to configure a  
25 split sidelink radio bearer to set up the direct or split mode.
12. The apparatus of claim 11 where the means are configured to configure the split sidelink radio bearer by a radio resource control function.
- 30 13. The apparatus of claim 11 or 12 where the means are configured to create and dispose the split sidelink radio bearer in both terminal devices of the direct communication link.

14. The apparatus of any of claims 10 to 13 where the means are configured to set up a traffic split function for the split mode in a packet data conversion protocol layer.
- 5 15. The apparatus of any of claims 10 to 14 where the means are configured to use a control flow mechanism in each leg of the split sidelink radio bearer to support recommended throughput or quality targets.
- 10 16. The apparatus of claim 15 where the means are configured to use a radio link control buffer status reporting for the control flow mechanism.
17. The apparatus of any of claims 10 to 16 where the means are configured to relay data packets of a medium access control layer via the relayed communication link.
- 15 18. The apparatus of any of claims 10 to 17 where the means are configured to tunnel the data traffic of the relayed communication link to another network access device by using a tunnelling protocol.
- 20 19. The apparatus of any preceding claim where the direct communication link comprises a sidelink connection or a WiFi connection.
20. An apparatus comprising means for performing:  
receiving, at a terminal device from an access device of a network, a configuration command which indicates a direct mode where data traffic is transmitted  
25 via a direct communication link between the terminal device and a neighbouring terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device;  
and  
30 performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

21. The apparatus of claim 20 where the means are configured to provide a split and merge function for mapping data packets of the data traffic in the direct communication link and the relayed communication link based on received recommended scheduling weights.

5

22. The apparatus of claim 20 or 21 where the means are configured to provide measurement reports about direct and relayed communication links to the access device.

10 23. The apparatus of any of claims 20 to 22 where the means are configured to use the access device as a secondary node for a split sidelink radio bearer.

24. The apparatus of any of the preceding claims wherein the means comprises at least one processor; and at least one memory including computer program code,  
15 the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

25. A method comprising:  
receiving from at least one network access device measurement reports  
20 about communication links at two or more terminal devices;  
deriving from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split  
25 mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and  
signalling the at least one recommendation to the at least one network access device.

30 26. A method comprising:  
receiving at a network access device at least one recommendation for a sidelink coordination at two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via

a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

5        setting a communication mode for the two or more terminal devices according to the received recommendation for the sidelink coordination.

27.    A method comprising:

10        receiving, at a terminal device from an access device of a network, a configuration command which indicates a direct mode where data traffic is transmitted via a direct communication link between the terminal device and a neighbouring terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device; and

15        performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

28.    A computer program product comprising instructions for causing an apparatus to perform at least the following:

20        receiving from at least one network access device measurement reports about communication links at two or more terminal devices;

25        deriving from the received measurement reports at least one recommendation for a sidelink coordination at the two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

30        signalling the at least one recommendation to the at least one network access device.

29.    A computer program product comprising instructions for causing an apparatus to perform at least the following:

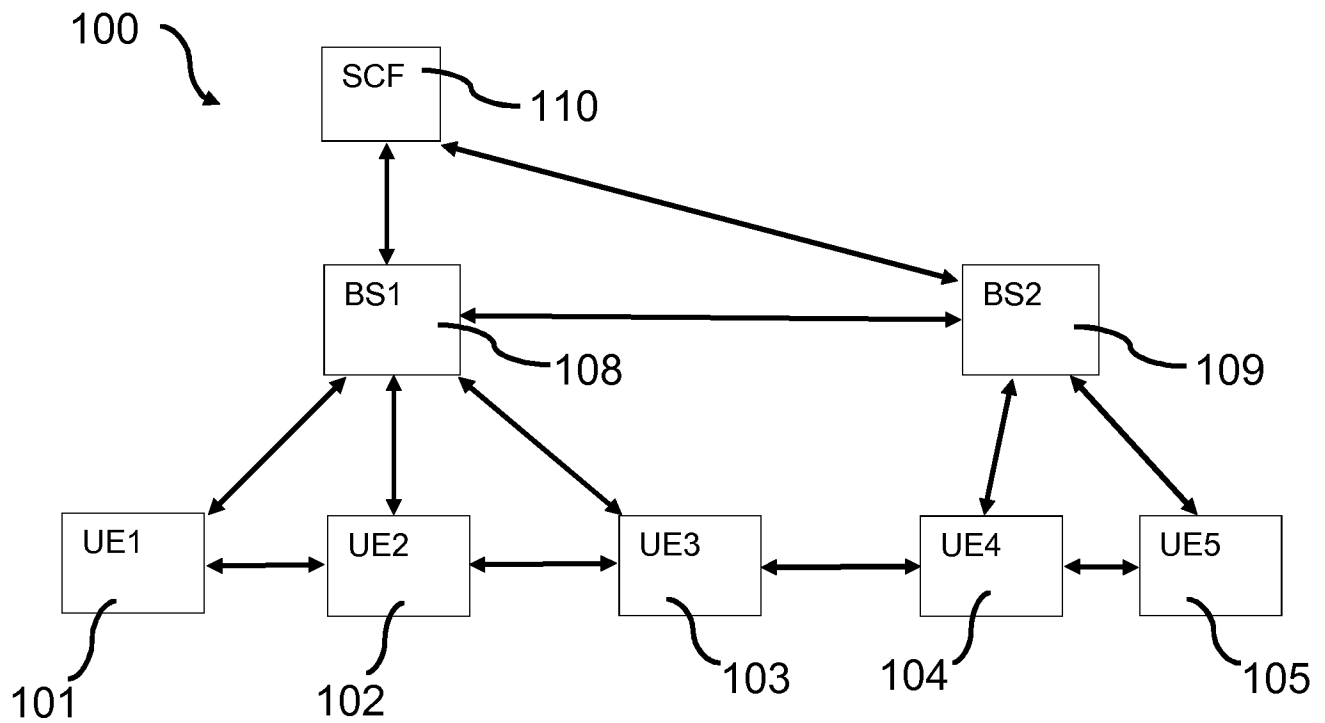
receiving at a network access device at least one recommendation for a sidelink coordination at two or more terminal devices, wherein the sidelink coordination determines at least one of a direct mode where data traffic is transmitted via a direct communication link between terminal devices and a split mode where data traffic is split between the direct communication link and a relayed communication link via the at least one network access device; and

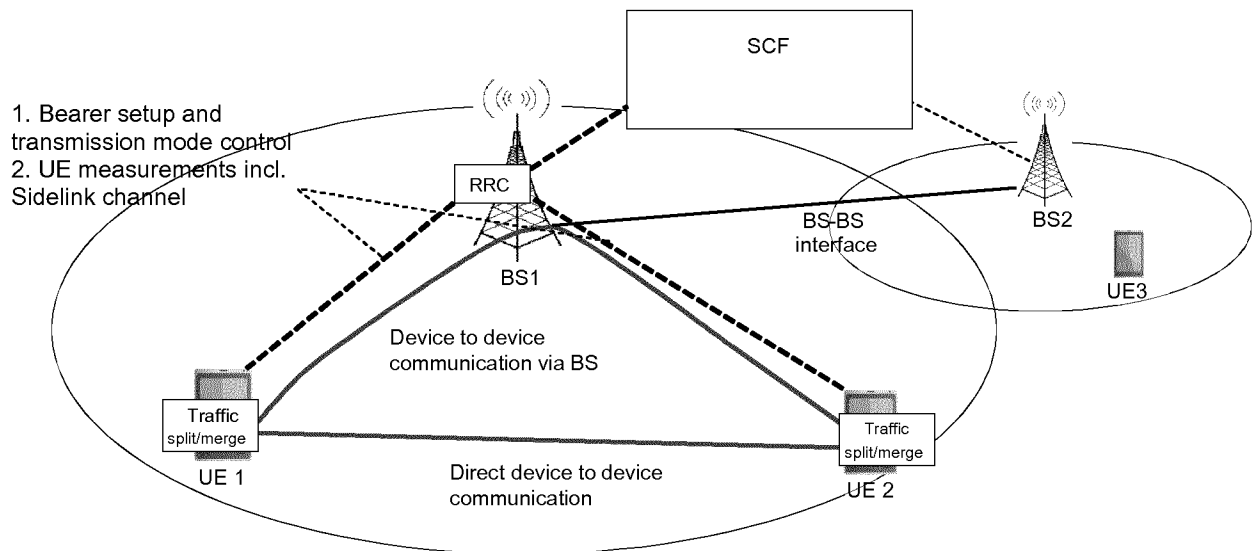
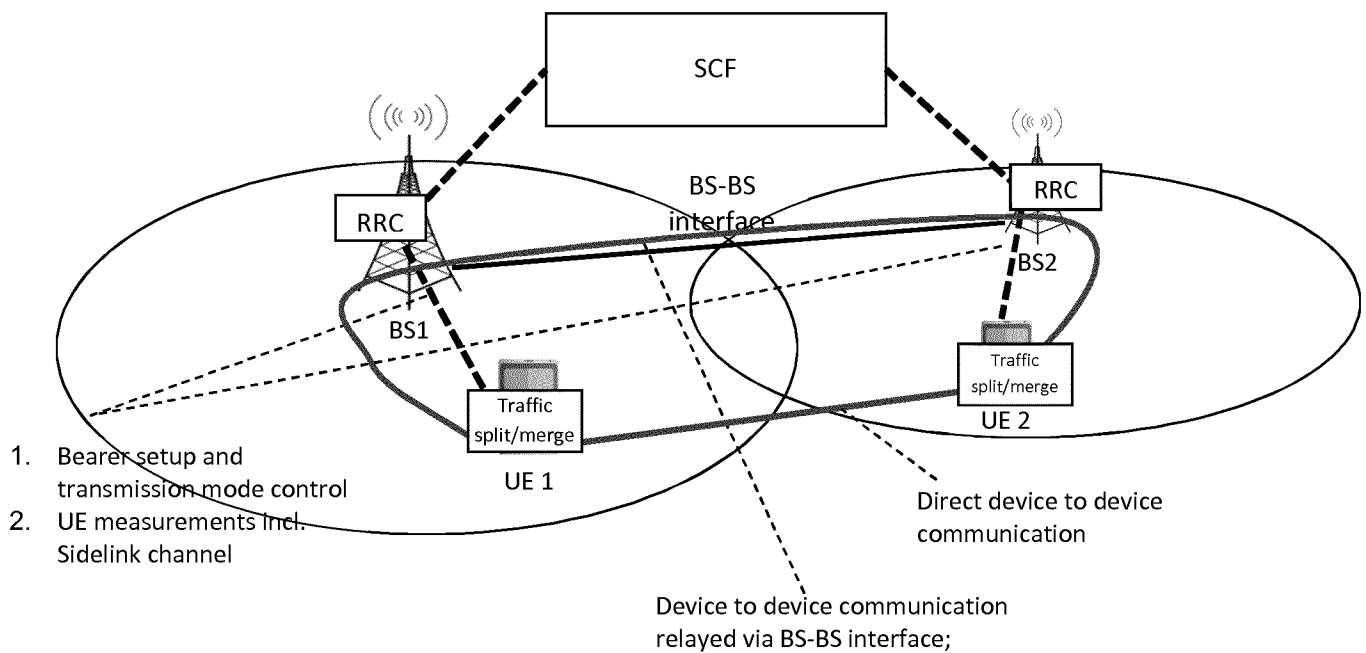
setting a communication mode for the two or more terminal devices according to the received recommendation for the sidelink coordination.

30. A computer program product comprising instructions for causing an apparatus to perform at least the following:

receiving, at a terminal device from an access device of a network, a configuration command which indicates a direct mode where data traffic is transmitted via a direct communication link between the terminal device and a neighbouring terminal device, or a split mode where data traffic is split between the direct communication link and a relayed communication link via the network access device; and

performing a link setup in accordance with the received configuration command, wherein the data traffic is split or merged according to the split mode or directed to the direct communication link according to the direct mode.

**Fig. 1**

**Fig. 2****Fig. 3**

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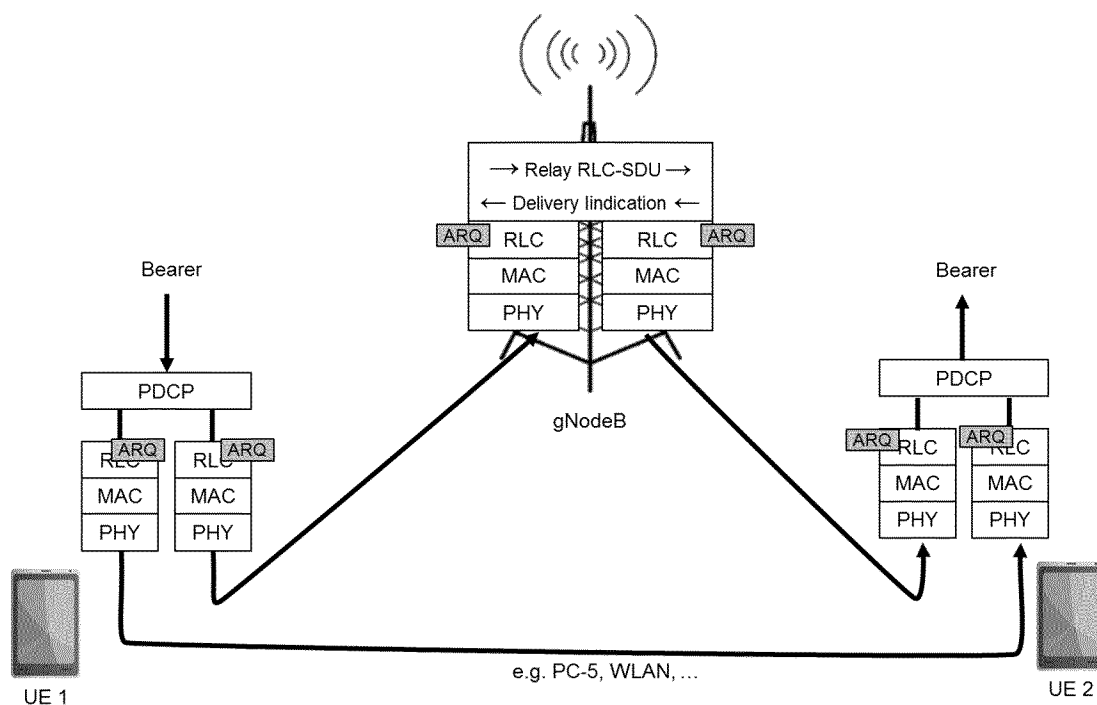


Fig. 4

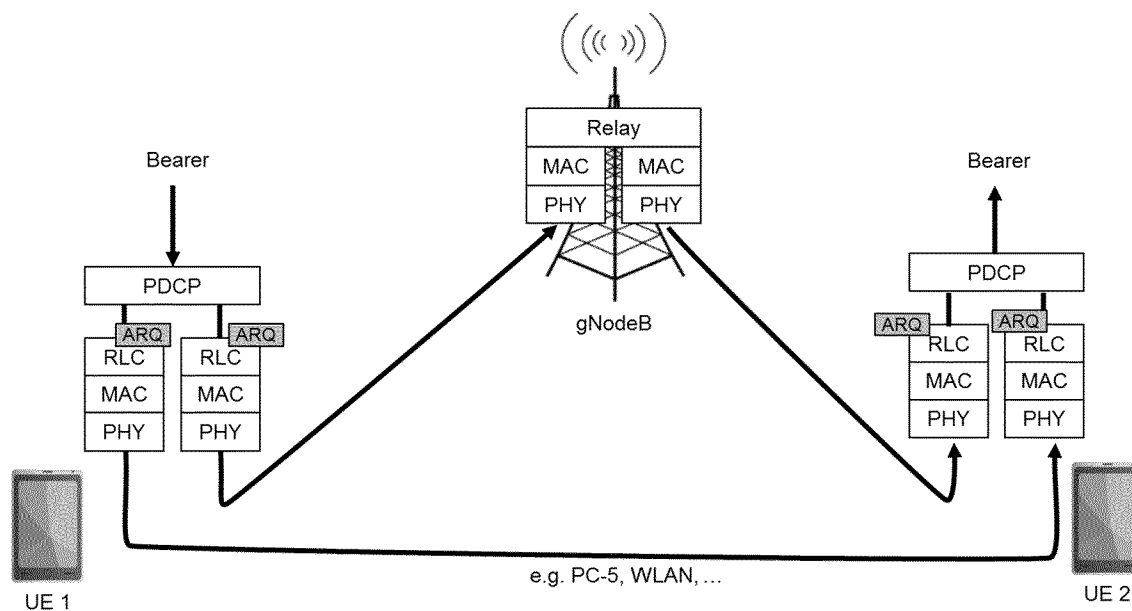


Fig. 5

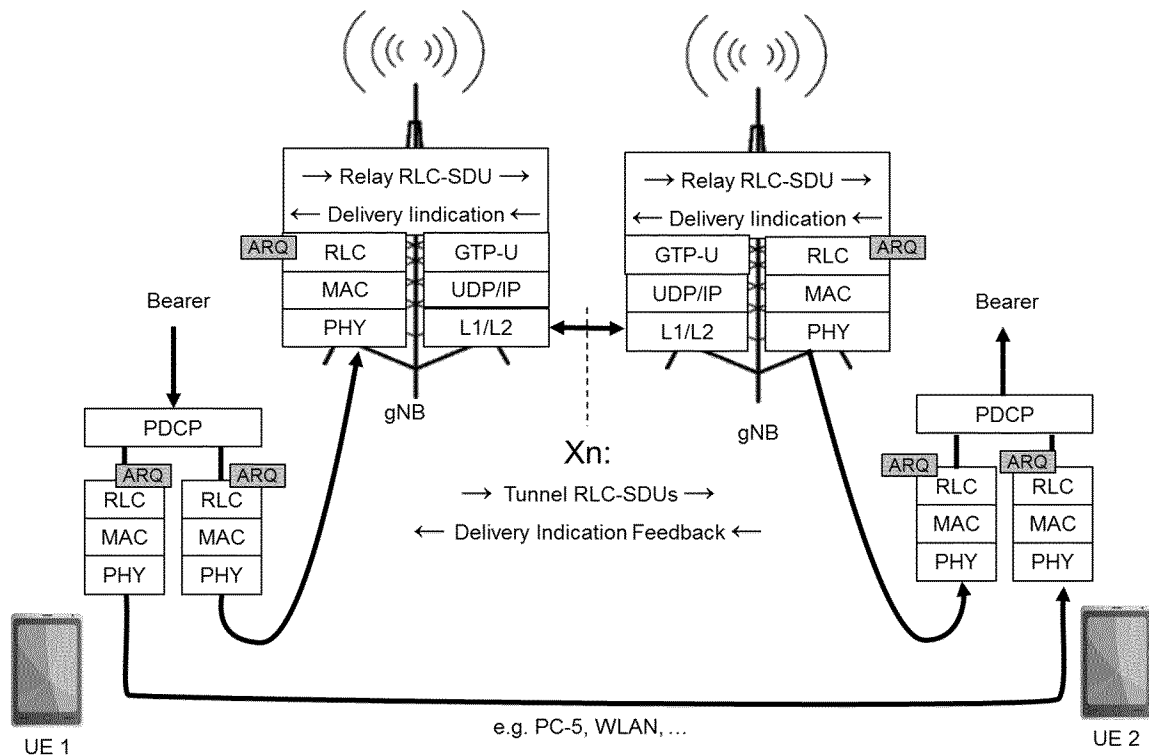


Fig. 6

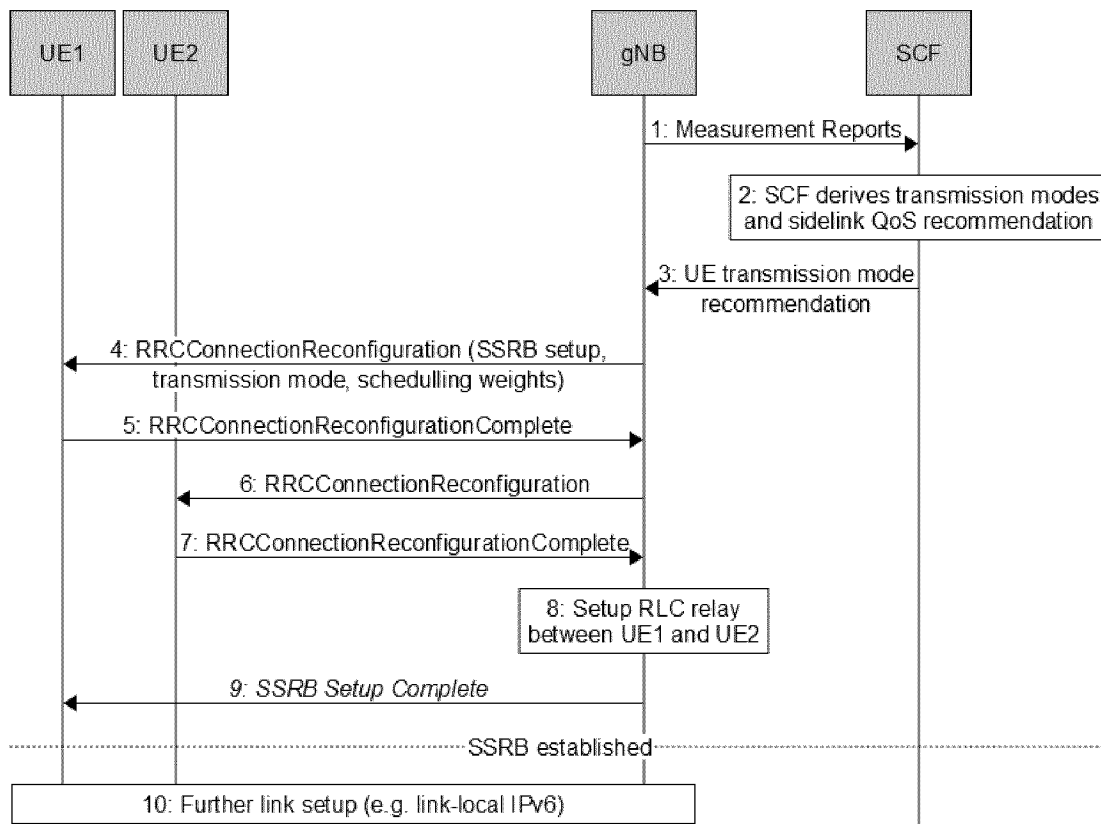
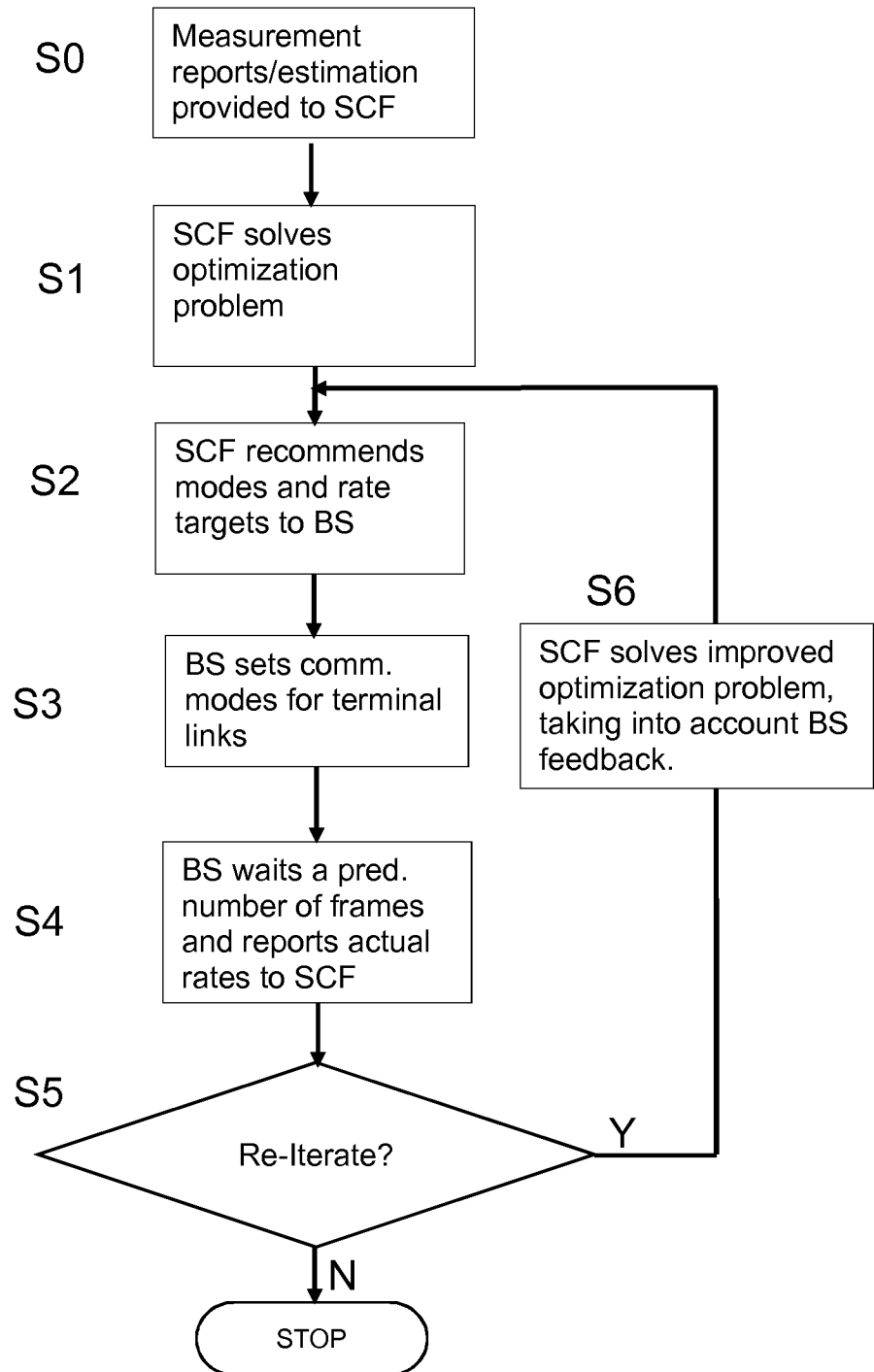


Fig. 7

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**Fig. 8**

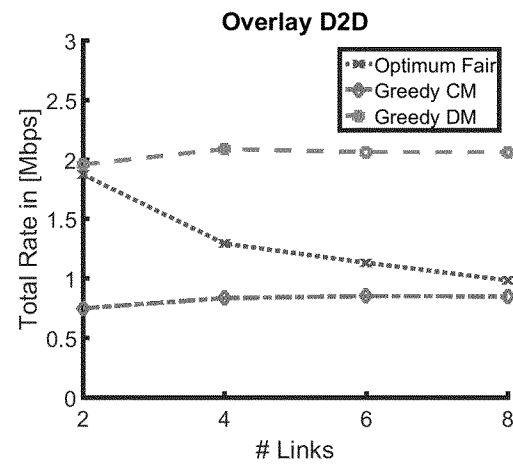


Fig. 9A

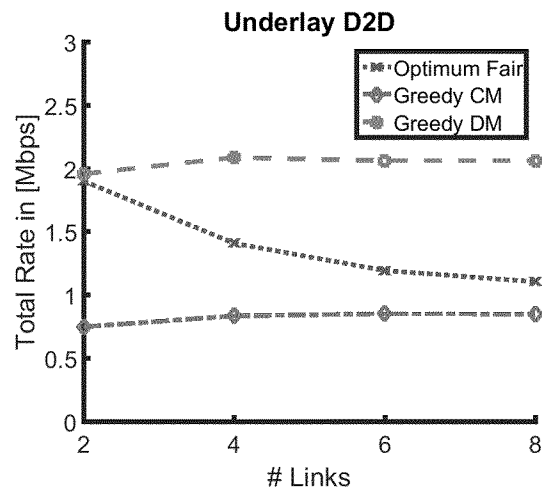


Fig. 9B

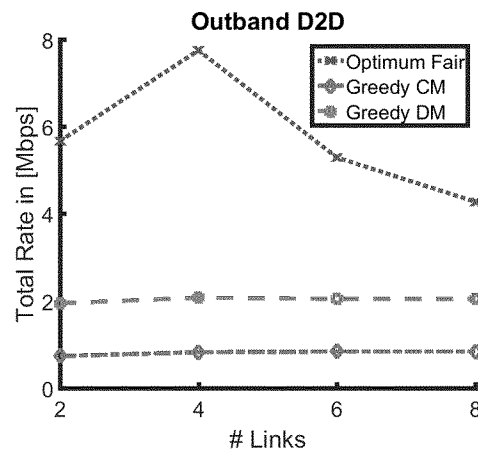


Fig. 9C

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/052419

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W28/02

ADD.

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)

H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

## \* Special categories of cited documents :

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

1 April 2019

Date of mailing of the international search report

09/04/2019

Name and mailing address of the ISA/

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Fax: (+31-70) 340-3016

Authorized officer

Lefeure, Guillaume

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/052419

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                       |
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Information on patent family members

International application No

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