in the above-mentioned LTE network, the E-UTRAN connects cellular IoT (CIoT) UEs to a CN and ultimately to services available through a PDN or other data network. However, in currently proposed implementations, there are security concerns for CIoT UEs in NB-IoT networks, for example, during operations such as radio link recovery.

**Summary**

Illustrative embodiments provide techniques for providing secure radio link recovery for user equipment in a communication system.

In an embodiment, the present disclosure provides a method comprising: in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane; recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via a mobility management node of the communication system using a non-access stratum security context previously established between the user equipment and the mobility management node.

In an embodiment, the present disclosure provides an apparatus comprising: in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane; a network node in the communication system configured to function as a mobility management entity, and further configured to enable recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via the mobility management entity using a non-access stratum security context previously established between the user equipment and the mobility management entity.

In an embodiment, the present disclosure provides a method comprising: in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane; recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a message to a mobility management node of the communication system through the target access node using a non-access stratum security context previously established between the user equipment and the mobility management node.

In an embodiment, the present disclosure provides an apparatus comprising: in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane; the user equipment configured to enable recovery of the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a message to a mobility management node of the communication system through the target access node using a non-access stratum security context previously established between the user equipment and the mobility management node.

In an embodiment, the present disclosure provides an article of manufacture comprising a non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to perform the method according to the first aspect or the third aspect.

In one embodiment, a method comprises, in response to a radio link failure between given user equipment and a source access node of a communication system during a data transfer operation over a control plane, recovering the radio link for the given user equipment through a target access node of the communication system. The radio link recovery is enabled via a mobility management node of the communication system using a non-access stratum security context previously established between the given user equipment and the mobility management node.

In another embodiment, a method comprises, in response to a radio link failure between given user equipment and a source access node of a communication system during a data transfer operation over a control plane, recovering the radio link for the given user equipment through a target access node of the communication system. The radio link recovery is initiated by the given user equipment by sending a message to a mobility management node of the communication system through the target access node using a non-access stratum security context previously established between the given user equipment and the mobility management node.

In an aspect, there is provided a method for recovering a radio link, the method comprising:

establishing, in a communication system, a non-access stratum security context between user equipment and a mobility management node of the communication system; and

~~in response to~~ receiving a first message indicating a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~recovering,~~ wherein at least a portion of the first message is protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node;

verifying, using the mobility management node, the user equipment using the cryptographic key;

initiating, via the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node, a ~~the~~ radio link for the user equipment through a target access node of the communication system by initiating set up of a signaling interface with the target access node and sending a second message to the user equipment through the target access node; and~~,~~ retrieving, by the mobility management node, buffered data associated with the data transfer over the control plane ~~wherein the mobility management node comprises a processor and memory configured to enable the radio link recovery~~ .

In an aspect, there is provided an apparatus configured for recovering a radio link, the apparatus comprising: a network node comprising a processor and memory, the network node being configured to function as a mobility management node of a communication system and to be in communication with user equipment and one or more access nodes of the communication system, wherein the network node is further configured to at least:

establish, in the communication system, a non-access stratum security context between the user equipment and the network node; and

~~in response to~~ receive a first message indicating a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~enable recovering,~~ wherein at least a portion of the first message is protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node;

verify the user equipment using the cryptographic key;

initiate within the non-access stratum security context previously established between the user equipment and the network node, a ~~the~~ radio link for the user equipment through a target access node of the communication system by initiating set up of a signaling

interface with the target access node and sending a second message to the user equipment through the target access node; and

retrieve buffered data associated with the data transfer over the control plane.

In an aspect, ~~–~~there is provided a method for recovering a radio link, the method comprising:

establishing, between user equipment and a mobility management node of a communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~initiating recovery of the radio link through a target access node of the communication system, by~~ sending a ~~non access stratum~~first message from the user equipment to the mobility management node of the communication system through a ~~the~~ target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, the first ~~non access stratum~~ message indicating that the radio link failure has occurred, , at least a portion of the first message being protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node, and

after the mobility management node verifies the user equipment using the cryptographic key and initiates setup of a signaling interface with the target access node, receiving, from the target access node, a second message acknowledging the radio link failure

~~wherein the user equipment comprises a processor and memory configured to initiate the radio link recovery~~.

In an embodiment, there is provided an apparatus configured for recovering a radio link, the apparatus comprising:

a processor and a memory storing program codes, wherein the memory and program codes are configured, with the processor, to cause the apparatus ~~is configured~~ to at least:

establish, between the apparatus and a mobility management node of a communication system, a non-access security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~initiate recovery of the radio link through a target access node of the communication~~

~~system, by~~ send~~ing~~ a first ~~non-access-stratum~~ message from the apparatus to the mobility management node of the communication system through a ~~the~~ target access node using the non-access stratum security context previously established between the apparatus and the mobility management node, the ~~non-access-stratum~~first message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node, and

after the mobility management node verifies the user equipment using the cryptographic key and initiates setup of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

In an embodiment, there is provided a method for recovering a radio link, the method comprising: establishing, in a communication system, a non-access stratum security context between user equipment and a mobility management node of the communication system;

receiving, at the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node of the communication system, a ~~non-access-stratum~~first message from the user equipment via a target access node of the communication system, the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node;

verifying the user equipment using the cryptographic key;~~; and i~~n an instance in which the ~~non-access-stratum~~ first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering, initiating via the mobility management node,

set up of a signaling interface with the target access node;

sending a second message to the user equipment via the target access node, the second message acknowledging the radio link failure; and retrieving buffered data associated with the data transfer over the control plane

~~while maintaining the non-access stratum security context previously established between the user equipment and the mobility management node, the radio link for the user equipment through a target access node of the communication system~~,

wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node.

In an aspect, there is provided an apparatus for recovering a radio link, the apparatus comprising:

one or more processors; and

one or more memories storing program instructions which, when executed by the one or more processors, cause the apparatus at least to:

establish, in a communication system, a non-access stratum security context between user equipment and the apparatus;

receive, at the apparatus, within the non-access stratum security context previously established between the user equipment and the apparatus, a ~~non-access stratum~~first message from the user equipment via a target access node of the communication system, the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node; verify the user equipment using the cryptographic key; ~~and~~

in an instance in which the ~~non-access stratum~~first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, initiate set up of a signaling interface with the target access node;

send a second message to the user equipment via ~~enable recovering of the radio link for the user equipment through~~ the target access node of the communication system, the second message acknowledging the radio link failure~~using the non-access stratum security context previously established between the user equipment and the apparatus,~~ and retrieve buffered data associated with the data transfer over the control plane.

wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the apparatus.

In an aspect, there is provided a non-transitory computer-readable storage medium for recovering a radio link, the non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to:establish, in a communication system, a non-access stratum security context

between user equipment and a mobility management node of the communication system;

receive, at the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node of the communication system, a ~~non-access-stratum~~first message from the user equipment via a target access node of the communication system, the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node; verify the user equipment using the cryptographic key;~~and~~

in an instance in which the ~~non-access-stratum~~first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, initiate set up of a signaling interface with the target access node;

send a second message to the user equipment via ~~recover, via the mobility management node, while maintaining the non-access stratum security context previously established between the user equipment and the mobility management node, the radio link for the user equipment through~~ the target access node of the communication system, and

retrieve buffered data associated with the data transfer over the control plan ~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node~~.

In an aspect, there is provided a method for recovering a radio link, the method comprising:

establishing, between user equipment and a mobility management node of a communication system, via a source access node of the communication system, a non-access stratum security context; ~~and~~ in an instance in which a radio link failure occurs between the user equipment and the source access node of the communication system during a data transfer operation over a control plane, initiating recovery of the radio link for the user equipment, through a target access node of the communication system, by sending a ~~non-access-stratum~~first message from the user equipment to the mobility management node of the communication system through the target access node, the non-access stratum message indicating that the radio link failure has occurred,

wherein the first ~~non-access-stratum~~ message is ~~integrity~~ protected using a~~n integrity~~

cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node.;

after the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node, receiving, from the target access node, a second message acknowledging the radio link failure.

In an aspect, there is provided an apparatus for recovering a radio link, the apparatus comprising: one or more processors; and

one or more memories storing program instructions which, when executed by the one or more processors, cause the apparatus at least to:

establish, between the apparatus and a mobility management node of a communication system, via a source access node of the communication system, a non-access stratum security context; and

in an instance in which a radio link failure occurs between the apparatus and the source access node of the communication system during a data transfer operation over a control plane, initiate recovery of the radio link for the apparatus, through a target access node of the communication system, by the apparatus send ing a non access stratumfirst message to the mobility management node of the communication system through the target access node, the non access stratumfirst message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within or associated with the non-access stratum security context previously established between the user equipment and the mobility management node; and

wherein the non access stratum message is integrity protected using an integrity key associated with the non access stratum security context previously established between the apparatus and the mobility management nodeafter the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

In an aspect, there is provided a non-transitory computer-readable storage medium for recovering a radio link, the non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to:

establish, between user equipment and a mobility management node of a communication system, via a source access node of the communication system, a non-access

stratum security context; ~~and~~

in an instance in which a radio link failure occurs between the user equipment and the source access node of the communication system during a data transfer operation over a control plane, ~~initiate recovery of the radio link for the user equipment, through a target access node of the communication system, by~~ send~~ing~~ a ~~non-access-stratum~~first message from the user equipment to the mobility management node of the communication system through a ~~the~~ target access node of the communication system, the ~~non-access-stratum~~first message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within or associated with the non-access stratum security context previously established between the user equipment and the mobility management node; and

after the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

~~wherein the non-access-stratum message is integrity protected using an integrity key associated with the non-access-stratum security context previously established between the user equipment and the mobility management node.~~

In an aspect, method comprising:

in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via a mobility management node of the communication system using a non-access stratum security context previously established between the user equipment and the mobility management node, wherein recovering the radio link further comprises receiving, at the mobility management node, a first ~~non-access-stratum~~ message from the user equipment, wherein the first ~~non-access-stratum~~ message indicates that the user equipment has experienced the radio link failure with the source access node, and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said recovering the radio link further comprises:

verifying, at the mobility management node, the user equipment using the cryptographic key;

initiating, at the mobility management node, set up of a signaling interface with the target access node;

sending, from the mobility management node, a second ~~non-access stratum~~ message to the user equipment through the target access node; and

retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node. Advantageously, in illustrative embodiments, secure radio link recovery is achieved with no new context set up to protect the link between the given user equipment and the target access node, only the non-access stratum security context between the given user equipment and the mobility management node and its related cryptographic keys are used. For the sake of key separation, new keys may be computed using existing non-access stratum security parameters or non-access stratum message counts either in the uplink or in the downlink. In an aspect, there is provided an apparatus comprising:

a network node in a communication system, the network node being configured to function as a mobility management entity, wherein the network node is configured to establish a non-access stratum security context between a user equipment and the mobility management entity, and, in response to a radio link failure occurring between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, enable recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via the mobility management entity using the non-access stratum security context previously established between the user equipment and the mobility management entity,

wherein the mobility management node is configured to enable recovering the radio link in response to the mobility management node receiving, from the user equipment, a first message indicating that the user equipment has experienced the radio link failure with the source access node, the first message being protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said enabling recovery of the radio link further comprises:

verifying, at the mobility management node, the user equipment using the cryptographic key;

initiating, at the mobility management node, set up of a signaling interface with the target access node;

sending, from the mobility management node, a second message to the user

equipment through the target access node; and

retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node. In aspect, there is provided a method comprising:

in a communication system, establishing, between a user equipment and a mobility management node of the communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a first message to the mobility management node of the communication system through the target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, wherein the first message indicates that the user equipment has experienced the radio link failure with the source access node and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said recovering the radio link further comprises:

receiving, at the user equipment, from the mobility management node, through the target access node of the communication system, a second message providing an acknowledgement of the radio link failure by the target access node, the second message being received within the non-access stratum security context previously established between the user equipment and the mobility management node for data transfer operations over said control plane. In an aspect, there is provided an apparatus comprising:

a user equipment configured for communication with a mobility management node of a communication system, the user equipment being configured to:

establish, between a user equipment and a mobility management node of the communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, enable recovery of the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a first message to the mobility management node of the communication system through the target access node using the non-access stratum security

context previously established between the user equipment and the mobility management node, wherein the first message indicates that the user equipment has experienced the radio link failure with the source access node and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said enabling recovery of the radio link further comprises:

receiving, at the user equipment, from the mobility management node, through the target access node of the communication system, a second message providing an acknowledgement of the radio link failure by the target access node, the second message being received within the non-access stratum security context previously established between the user equipment and the mobility management node for data transfer operations over said control plane.

## CLAIMS

What is claimed is:

1. A method for recovering a radio link, the method comprising:

establishing, in a communication system, a non-access stratum security context between user equipment and a mobility management node of the communication system; and

~~in response to~~ receiving a first message indicating a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~recovering,~~ wherein at least a portion of the first message is protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node;

verifying, using the mobility management node, the user equipment using the cryptographic key;

initiating, via the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node, ~~the~~ a radio link for the user equipment through a target access node of the communication system by initiating set up of a signaling interface with the target access node and sending a second message to the user equipment through the target access node; and~~,~~

~~wherein the mobility management node comprises a processor and memory configured to enable the radio link recovery~~

retrieving, by the mobility management node, buffered data associated with the data transfer over the control plane.

~~2. The method of claim 1, wherein recovering the radio link further comprises receiving, at the mobility management node, a first non-access stratum message from the user equipment.~~

~~3. The method of claim 2, wherein the first non-access stratum message indicates that the user equipment has experienced the radio link failure with the source access node, and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node.~~

~~4. The method of claim 3, wherein recovering the radio link further comprises:~~

~~verifying, at the mobility management node, the user equipment using the cryptographic key;~~

~~initiating, at the mobility management node, set up of a signaling interface with the target access node;~~

~~sending, from the mobility management node, a second non-access stratum message to the user equipment through the target access node; and~~

~~retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node.~~

~~5~~2. The method of claim 1, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

~~6. The method of claim 1, further comprising:~~

~~receiving, at the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node of the communication system, a non-access stratum message from the user equipment.~~

~~7. The method of claim 6, further comprising:~~

~~in an instance in which the non-access stratum message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering, via the mobility management node, while maintaining the non-access stratum security context previously established between the user equipment and the mobility management node, the radio link for the user equipment through a target access node of the communication system.~~

~~8. The method of claim 7, wherein the non-access stratum message is integrity protected using a cryptographic key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node or at least a portion of the non-access stratum message is encrypted using the cryptographic key previously created in association with the non-access stratum security~~

~~context previously established between the user equipment and the mobility management node.~~

3~~9~~. The method of claim 1~~8~~, wherein the cryptographic key comprises an integrity key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

4~~10~~. The method of claim 1~~8~~, wherein the cryptographic key is derived using an uplink message count or a downlink message count.

~~11. The method of claim 4, wherein the non-access stratum message and the second non-access stratum message are encrypted using the cryptographic key created from the non-access stratum security context previously established between the user equipment and the mobility management node.~~

5~~12~~. A non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to perform the method of claim 1.

6~~13~~. An apparatus configured for recovering a radio link, the apparatus comprising:

a network node comprising a processor and memory, the network node being configured to function as a mobility management node of a communication system and to be in communication with user equipment and one or more access nodes of the communication system, wherein the network node is further configured to at least:

establish, in the communication system, a non-access stratum security context between the user equipment and the network node; ~~and~~

~~in response to~~ receive a first message indicating a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, wherein at least a portion of the first message is protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node;

verify the user equipment using the cryptographic key;

~~enable recovering~~initiate, within the non-access stratum security context previously established between the user equipment and the network node, ~~the~~ a radio link for

the user equipment through a target access node of the communication system by initiating set up of a signaling interface with the target access node and sending a second message to the user equipment through the target access node; and

retrieve buffered data associated with the data transfer over the control plane.

7. The apparatus of claim 6, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

8. The apparatus of claim 6, wherein the cryptographic key comprises an integrity key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

9. The apparatus of claim 6, wherein the cryptographic key is derived using an uplink message count or a downlink message count.

10~~14~~. A method for recovering a radio link, the method comprising:

establishing, between user equipment and a mobility management node of a communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~initiating recovery of the radio link through a target access node of the communication system, by~~ sending a ~~non-access stratum~~ first message from the user equipment to the mobility management node of the communication system through ~~the~~ a target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, the first ~~non-access stratum~~ message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node~~,~~

~~wherein the user equipment comprises a processor and memory configured to initiate the radio link recovery~~; and

after the mobility management node verifies the user equipment using the cryptographic key and initiates setup of a signaling interface with the target access node,

receiving, from the target access node, a second message acknowledging the radio link failure.

~~15. The method of claim 14, wherein the non-access stratum message is protected using a cryptographic key previously created in association with the non-access stratum security context between the user equipment and the mobility management node.~~

~~16. The method of claim 15, further comprising:~~

~~receiving, at the user equipment, from the mobility management node, via the target access node, a second non-access stratum message.~~

11~~17~~. The method of claim 10~~14~~, wherein the communication system comprises a Narrow Band Internet of Things (NB--IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

12~~18~~. The method of claim 10~~15~~, wherein the cryptographic key comprises an integrity key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

13~~19~~. The method of claim 10~~18~~, wherein the cryptographic key is derived using an uplink message count or a downlink message count.

14~~20~~. The method of claim 10~~16~~, wherein at least one of the ~~non-access stratum~~ first message and the second ~~non-access stratum~~ message is integrity protected using the cryptographic key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node, or at least a portion of the ~~non-access stratum~~ first message or the second ~~non-access stratum~~ message is encrypted using the cryptographic key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

15~~21~~. A non-transitory computer-readable storage medium having embodied therein executable program code that, when executed by a processor, causes the processor to perform the method of claim 10~~14~~.

16~~22~~. An apparatus configured for recovering a radio link, the apparatus comprising:

a processor; and

a memory storing program codes, wherein the memory and program codes are configured, with the processor, to cause the apparatus ~~is configured~~ to at least:

establish, between the apparatus and a mobility management node of a communication system, a non-access security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~initiating recovery of the radio link through a target access node of the communication system, by~~ send a ~~non-access stratum~~ first message from the user equipment to the mobility management node of the communication system through ~~the~~ a target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, the first ~~non-access stratum~~ message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within the non-access stratum security context previously established between the user equipment and the mobility management node~~,~~

~~wherein the user equipment comprises a processor and memory configured to initiate the radio link recovery~~; and

after the mobility management node verifies the user equipment using the cryptographic key and initiates setup of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

17. The apparatus of claim 16, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

18. The apparatus of claim 16, wherein the cryptographic key comprises an integrity key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

19. The apparatus of claim 16, wherein the cryptographic key is derived using an uplink message count or a downlink message count.

20. The apparatus of claim 16, wherein at least one of the first message and the second message is integrity protected using the cryptographic key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node, or at least a portion of the first message or the second message is encrypted using the cryptographic key previously created in association with the non-access stratum security context previously established between the user equipment and the mobility management node.

21~~23~~. A method for recovering a radio link, the method comprising:

establishing, in a communication system, a non-access stratum security context between user equipment and a mobility management node of the communication system;

receiving, at the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node of the communication system, a ~~non-access stratum~~ first message from the user equipment via a target access node of the communication system, the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node; ~~and~~

verifying the user equipment using the cryptographic key;

in an instance in which the ~~non-access stratum~~ first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, ~~recovering~~initiating, via the mobility management node, set up of a signaling interface with the target access node;

sending a second message to the user equipment via the target access node, the second message acknowledging the radio link failure; and

~~while maintaining the non-access stratum security context previously established between the user equipment and the mobility management node, the radio link for the user equipment through a target access node of the communication system,~~retrieving buffered data associated with the data transfer over the control plane

~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node~~.

224. The method of claim 2321, wherein the cryptographic key ~~integrity key~~ is generated using at least an uplink message count or a downlink message count.

~~25. The method of claim 23, further comprising:~~

~~verifying, at the mobility management node, using the integrity key, an identify of the user equipment.~~

~~26. The method of claim 25, further comprising:~~

~~initiating, at the mobility management node, set up of a signaling interface with the target access node.~~

~~27. The method of claim 26, further comprising:~~

~~sending, from the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management node of the communication system, a second non-access stratum message to the user equipment through the target access node, the second non-access stratum message being integrity protected using the integrity key created from the non-access stratum security context previously established between the user equipment and the mobility management node.~~

~~28. The method of claim 27, wherein the second non-access stratum message comprises an indication that the mobility management node acknowledges that the radio link failure has occurred between the user equipment and the source access node.~~

2923. The method of claim 2821, wherein the second ~~non-access stratum~~ message comprises data associated with the data transfer.

3024. The method of claim 2923, wherein the data is at least one of previous buffered data and new data.

3125. The method of claim 2923, wherein the data is encrypted by an encryption key created during establishment of the non-access stratum security context previously established between the user equipment and the mobility management node.

~~32~~26. The method of claim ~~31~~25, wherein the encryption key comprises a non-access stratum encryption key.

~~33~~27. The method of claim ~~25~~21, further comprising:

retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node.

~~34~~28. The method of claim ~~23~~21, wherein the radio link failure is detected by the user equipment.

~~35~~29. The method of claim ~~23~~21, wherein the radio link failure is detected by the source access node.

~~36. The method of claim 23, wherein an access stratum security context is not established between the user equipment and the source access node.~~

30~~37~~. The method of claim ~~23~~21, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

31~~38~~. The method of claim ~~23~~21, wherein the source access node and the target access node each comprise a base station distinct from the mobility management node of the communication system.

~~39. The method of claim 23, wherein the non-access stratum message comprises at least a portion of a non-access stratum message count.~~

32~~40~~. The method of claim 31~~39~~, wherein the ~~non-access stratum~~ first message comprises a radio resource control connection re-establishment request from the user equipment and is received from the user equipment via the target access node, and wherein the ~~non-access stratum~~ first message comprises a request that the mobility management node authenticates the radio resource control connection re-establishment request from the user equipment based at least upon ~~said~~ at least a ~~portion of the~~ non-access stratum ~~message~~ count.

~~41. The method of claim 40, further comprising:~~

~~estimating, using said at least a portion of the non-access stratum message count, the non-access stratum message count.~~

33~~42~~. The method of claim 31~~41~~, further comprising:

in an instance in which the mobility management node receives ~~said non-access stratum~~ the first message comprising said radio resource control connection re-establishment request and said request that the mobility management node authenticates the radio resource connection re-establishment request, authenticating, using the mobility management node, the radio resource control connection re-establishment request received from the user equipment based on at least one of: the non-access stratum ~~message~~ count, an identifier associated with the target access node, or the integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node.

34~~43~~. The method of claim ~~23~~21, wherein the target access node is a different access node than the source access node.

~~44. The method of claim 23, wherein the data transfer operation is carried out using control plane CIoT evolved packet system (EPS) optimization.~~

35~~45~~. An apparatus for recovering a radio link, the apparatus comprising:

one or more processors; and

one or more memories storing program instructions which, when executed by the one or more processors, cause the apparatus at least to:

establish, in a communication system, a non-access stratum security context between user equipment and the apparatus;

receive, at the apparatus, within the non-access stratum security context previously established between the user equipment and the apparatus, a ~~non-access stratum~~ first message from the user equipment via a target access node of the communication system , the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node; ~~and~~

verify the user equipment using the cryptographic key;

in an instance in which the ~~non-access stratum~~ first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a

source access node of the communication system during a data transfer operation over a control plane, initiate set up of a signaling interface with the target access node;

send a second message to the user equipment via ~~enable recovering of the radio link for the user equipment through~~ the target access node of the communication system, the second message acknowledging the radio link failure~~using the non-access stratum security context previously established between the user equipment and the apparatus,~~; and

~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the apparatus.~~

retrieve buffered data associated with the data transfer over the control plane.

3646. The apparatus of claim 345, wherein the integrity key is generated using at least an uplink message count or a downlink message count.

~~47. The apparatus of claim 45, wherein the program instructions, when executed by the one or more processors, further cause the apparatus at least to:~~

~~verify, using the integrity key, an identify of the user equipment.~~

~~48. The apparatus of claim 47, wherein the program instructions, when executed by the one or more processors, further cause the apparatus at least to:~~

~~initiate set up of a signaling interface with the target access node.~~

~~49. The apparatus of claim 48, wherein the program instructions, when executed by the one or more processors, further cause the apparatus at least to:~~

~~send, within the non-access stratum security context previously established between the user equipment and the apparatus, a second non-access stratum message to the user equipment through the target access node, the second non-access stratum message being integrity protected using the integrity key created from the non-access stratum security context previously established between the user equipment and the apparatus.~~

~~50. The apparatus of claim 49, wherein the second non-access stratum message comprises an indication that the apparatus acknowledges that the radio link failure has occurred between the user equipment and the source access node.~~

37~~51~~. The apparatus of claim 35~~50~~, wherein the second ~~non-access stratum~~ message comprises data associated with the data transfer.

38~~52~~. The apparatus of claim 37~~51~~, wherein the data is at least one of previous buffered data or new data.

39~~53~~. The apparatus of claim 37~~51~~, wherein the data is encrypted by ~~an encryption~~ the cryptographic key created during establishment of the non-access stratum security context previously established between the user equipment and the apparatus.

40~~54~~. The apparatus of claim 39~~53~~, wherein the ~~encryption~~ cryptographic key comprises a non-access stratum encryption key.

~~55. The apparatus of claim 47, wherein the program instructions, when executed by the one or more processors, further cause the apparatus at least to:~~

~~retrieve buffered data associated with the data transfer from the source access node.~~

41~~56~~. The apparatus of claim ~~45~~35, wherein the radio link failure is detected by the user equipment.

~~57~~42. The apparatus of claim ~~45~~35, wherein the radio link failure is detected by the source access node.

~~58. The apparatus of claim 45, wherein an access stratum security context is not established between the user equipment and the source access node.~~

43~~59~~. The apparatus of claim ~~45~~35, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

~~60~~44. The apparatus of claim ~~45~~35, wherein the source access node and the target access node each comprise a base station distinct from the apparatus.

~~61. The apparatus of claim 45, wherein the non-access stratum message comprises at least a portion of a non-access stratum message count.~~

~~62~~45. The apparatus of claim ~~61~~31, wherein the ~~non-access stratum~~ first message comprises a radio resource control connection re-establishment request from the user equipment and is received from the user equipment via the target access node, and wherein the ~~non-access stratum~~ first message comprises a request that the apparatus authenticates the radio resource control connection re-establishment request from the user equipment based at least upon ~~said~~ at least a ~~portion of the~~ non-access stratum ~~message~~ count.

~~63. The apparatus of claim 62, further comprising:~~

~~estimating, using said at least a portion of the non-access stratum message count, the non-access stratum message count.~~

~~64~~46. The apparatus of claim ~~63~~45, further comprising:

in an instance in which the apparatus receives ~~said non-access stratum~~ the first message comprising said radio resource control connection re-establishment request and said request that the apparatus authenticates the radio resource connection re-establishment request, authenticating the radio resource control connection re-establishment request received from the user equipment based on at least one of: the non-access stratum ~~message~~ count, an identifier associated with the target access node, or the integrity key associated with the non-access stratum security context previously established between the user equipment and the apparatus.

~~65~~47. The apparatus of claim ~~45~~35, wherein the target access node is a different access node than the source access node.

~~66. The apparatus of claim 45, wherein the data transfer operation is carried out using control plane CIoT evolved packet system (EPS) optimization.~~

~~67~~48. A non-transitory computer-readable storage medium for recovering a radio link, the non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to:

establish, in a communication system, a non-access stratum security context between user equipment and a mobility management node of the communication system;

receive, at the mobility management node, within the non-access stratum security context previously established between the user equipment and the mobility management

node of the communication system, a ~~non-access stratum~~ first message from the user equipment via a target access node of the communication system, the first message being protected using a cryptographic key associated with the non-access stratum security context previously established between the user equipment and the mobility management node; ~~and~~

verify the user equipment using the cryptographic key;

in an instance in which the ~~non-access stratum~~ first message received from the user equipment indicates a radio link failure has occurred between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, initiate set up of a signaling interface with the target access node;

send a second message to the user equipment via ~~recover, via the mobility management node, while maintaining the non-access stratum security context previously established between the user equipment and the mobility management node, the radio link for the user equipment through~~ the target access node of the communication system~~,~~; and

~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node.~~

retrieve buffered data associated with the data transfer over the control plane.

49~~68~~. A method for recovering a radio link, the method comprising:

establishing, between user equipment and a mobility management node of a communication system, via a source access node of the communication system, a non-access stratum security context; ~~and~~

in an instance in which a radio link failure occurs between the user equipment and the source access node of the communication system during a data transfer operation over a control plane, initiating recovery of the radio link for the user equipment, through a target access node of the communication system, by sending a ~~non-access stratum~~ first message from the user equipment to the mobility management node of the communication system through the target access node, the ~~non-access stratum~~ first message indicating that the radio link failure has occurred,

wherein the ~~non-access stratum~~ first message is ~~integrity~~ protected using a~~n~~ cryptographic ~~integrity~~ key associated with the non-access stratum security context previously established between the user equipment and the mobility management node~~.~~;

after the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node,

receiving, from the target access node, a second message acknowledging the radio link failure.

~~69. The method of claim 68, wherein the non-access stratum message comprises at least a portion of a non-access stratum message count.~~

~~70~~50. The method of claim ~~69~~49, further comprising:

~~generating, using at least the non-access stratum message count, said at least a portion of the non-access stratum message count; and~~

including ~~said~~ at least a ~~portion of the~~ non-access stratum ~~message~~ count in the ~~non-access stratum~~ first message.

~~71~~51. The method of claim ~~68~~49, wherein the ~~non-access stratum~~ first message comprises a radio resource control connection re-establishment request.

~~72~~52. The method of claim ~~69~~49, wherein the ~~non-access stratum~~ first message comprises a request that the mobility management node authenticate the radio resource control connection re-establishment request.

~~73~~53. The method of claim ~~67~~49, wherein the target access node is a different access node than the source access node.

~~74~~54. The method of claim ~~67~~49, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, wherein the apparatus comprises cellular IoT (CIoT) user equipment~~, and wherein the data transfer operation is carried out using control plane CIoT evolved packet system (EPS) optimization~~.

~~75~~55. An apparatus for recovering a radio link, the apparatus comprising:

one or more processors; and

one or more memories storing program instructions which, when executed by the one or more processors, cause the apparatus at least to:

establish, between the apparatus and a mobility management node of a communication system, via a source access node of the communication system, a non-access stratum security context;~~ and~~

in an instance in which a radio link failure occurs between the apparatus and the source access node of the communication system during a data transfer operation over a

control plane, ~~initiate recovery of the radio link for the apparatus, through a target access node of the communication system, by the apparatus~~ send~~ing~~ a ~~non-access stratum~~ first message to the mobility management node of the communication system through the target access node, the ~~non-access stratum~~ first message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within or associated with the non-access stratum security context previously established between the user equipment and the mobility management node; and

~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the apparatus and the mobility management node.~~

after the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

~~76. The apparatus of claim 75, wherein the non-access stratum message comprises at least a portion of a non-access stratum message count.~~

~~77~~56. The apparatus of claim ~~76~~55, wherein the program instructions, when executed by the one or more processors, further cause the apparatus at least to:

~~generate, using at least the non-access stratum message count, said at least a portion of the non-access stratum message count; and~~

include ~~said~~ at least a ~~portion of the~~ non-access stratum ~~message~~ count in the ~~non-access stratum~~ first message.

~~78~~57. The apparatus of claim ~~76~~55, wherein the ~~non-access stratum~~ first message comprises a radio resource control connection re-establishment request.

~~79~~58. The apparatus of claim ~~78~~55, wherein the ~~non-access stratum~~ first message comprises a request that the mobility management node authenticate the radio resource control connection re-establishment request.

~~80~~59. The apparatus of claim ~~75~~55, wherein the target access node is a different access node than the source access node.

~~81~~60. The apparatus of claim ~~75~~55, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, wherein the apparatus comprises cellular IoT

(CIoT) user equipment~~, and wherein the data transfer operation is carried out using control plane CIoT evolved packet system (EPS) optimization~~.

~~82~~61. A non-transitory computer-readable storage medium for recovering a radio link, the non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to:

establish, between user equipment and a mobility management node of a communication system, via a source access node of the communication system, a non-access stratum security context;~~ and~~

in an instance in which a radio link failure occurs between the user equipment and the source access node of the communication system during a data transfer operation over a control plane, ~~initiate recovery of the radio link for the user equipment, through a target access node of the communication system, by~~ send~~ing~~ a ~~non-access stratum~~ first message from the user equipment to the mobility management node of the communication system through ~~the~~ a target access node of the communication system, the ~~non-access stratum~~ first message indicating that the radio link failure has occurred, at least a portion of the first message being protected using a cryptographic key created within or associated with the non-access stratum security context previously established between the user equipment and the mobility management node; and

~~wherein the non-access stratum message is integrity protected using an integrity key associated with the non-access stratum security context previously established between the user equipment and the mobility management node.~~

after the mobility management node verifies the user equipment using the cryptographic key and initiates set up of a signaling interface with the target access node, receive, from the target access node, a second message acknowledging the radio link failure.

~~83~~62. A method comprising:

in a communication system, in response to a radio link failure between a user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via a mobility management node of the communication system using a non-access stratum security context previously established between the user equipment and the mobility management node, wherein recovering the radio link further comprises receiving, at the mobility management node, a first ~~non-access stratum~~ message from the user equipment,

wherein the first ~~non-access stratum~~ message indicates that the user equipment has experienced the radio link failure with the source access node, and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said recovering the radio link further comprises:

verifying, at the mobility management node, the user equipment using the cryptographic key;

initiating, at the mobility management node, set up of a signaling interface with the target access node;

sending, from the mobility management node, a second ~~non-access stratum~~ message to the user equipment through the target access node; and

retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node.

~~84~~63. The method of claim ~~83~~62, wherein the communication system comprises a Narrow Band Internet of Things (NB-IoT) network, and further wherein the user equipment comprises cellular IoT (CIoT) user equipment.

~~85~~64. An article of manufacture comprising a non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to perform the method of claim ~~83~~62.

~~86~~65. An apparatus comprising:

a network node in a communication system, the network node being configured to function as a mobility management entity, wherein the network node is configured to establish a non-access stratum security context between a user equipment and the mobility management entity, and, in response to a radio link failure occurring between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, enable recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is enabled via the mobility management entity using the non-access stratum security context previously established between the user equipment and the mobility management entity,

wherein the mobility management node is configured to enable recovering the radio link in response to the mobility management node receiving, from the user equipment, a first

~~non-access stratum~~ message indicating that the user equipment has experienced the radio link failure with the source access node, the first ~~non-access stratum~~ message being protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said enabling recovery of the radio link further comprises:

verifying, at the mobility management node, the user equipment using the cryptographic key;

initiating, at the mobility management node, set up of a signaling interface with the target access node;

sending, from the mobility management node, a second ~~non-access stratum~~ message to the user equipment through the target access node; and

retrieving, by the mobility management node, buffered data associated with the data transfer from the source access node.

~~87~~66. A method comprising:

in a communication system, establishing, between a user equipment and a mobility management node of the communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, recovering the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a first ~~non-access stratum~~ message to the mobility management node of the communication system through the target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, wherein the first ~~non-access stratum~~ message indicates that the user equipment has experienced the radio link failure with the source access node and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said recovering the radio link further comprises:

receiving, at the user equipment, from the mobility management node, through the target access node of the communication system, a second ~~non-access stratum~~ message providing an acknowledgement of the radio link failure by the target access node, the second message being received within ~~information regarding the target access node and confirming that~~ the non-access stratum security context previously established between the user

equipment and the mobility management node ~~has been maintained~~ for data transfer operations over said control plane.

~~88~~67. An article of manufacture comprising a non-transitory computer-readable storage medium having embodied therein executable program code that when executed by a processor causes the processor to perform the method of claim ~~87~~66.

~~89~~68. An apparatus comprising:

a user equipment configured for communication with a mobility management node of a communication system, the user equipment being configured to:

establish, between a user equipment and a mobility management node of the communication system, a non-access stratum security context; and

in response to a radio link failure between the user equipment and a source access node of the communication system during a data transfer operation over a control plane, enable recovery of the radio link for the user equipment through a target access node of the communication system, wherein the radio link recovery is initiated by the user equipment by sending a first ~~non-access stratum~~ message to the mobility management node of the communication system through the target access node using the non-access stratum security context previously established between the user equipment and the mobility management node, wherein the first ~~non-access stratum~~ message indicates that the user equipment has experienced the radio link failure with the source access node and is protected using a cryptographic key created from the non-access stratum security context between the user equipment and the mobility management node, and wherein said enabling recovery of the radio link further comprises:

receiving, at the user equipment, from the mobility management node, through the target access node of the communication system, a second ~~non-access stratum~~ message providing an acknowledgement of the radio link failure by the target access node, the second message being received within ~~information regarding the target access node and confirming that~~ the non-access stratum security context previously established between the user equipment and the mobility management node ~~has been maintained~~ for data transfer operations over said control plane.