network types including 3GPP access and non-3GPP access can be supported via a common access network and core network interfaces. A Non-3GPP Access Network (N3AN) is considered as a 5G Access Network and part of the 5G System (5GS).

[0006] For untrusted non-3GPP access, a N3G access node N3IWF provides termination of signaling interfaces for control-plane and user-plane respectively, same as an NG-RAN node. Thus, 5G capable UEs can access 5G core network by connecting to Non-3GPP Access Network as a 5G Access Network via the N3IWF. The N3IWF relays uplink and downlink control-plane signaling between the UE and AMF, such that the UE has a direct control plane signaling connection towards the AMF. In addition, the N3IWF provides user plane connection between the UE and UPF for the PDU sessions over a non-3GPP access network.

[0007] When a UE is registered to the 5G core over both 3GPP access and non-3GPP access networks, multiple Non-Access Stratum (NAS) connections can be active at the same time. The UE can be registered in the same PLMN or different PLMN. If the UE is accessing one PLMN over one type of access (e.g. 3GPP access) and accessing another PLMN over the other type of access (e.g. non-3GPP access), then different primary authentications are performed. After registration, the NAS connections serve different AMFs utilizing different security contexts. However, if the UE requests registration in the same serving network over different types of access networks, a common 5G NAS security context is created during the registration procedure over the first access type, and all NAS connections are served by the same AMF.

[0008] Currently, for 3GPP access, it is assumed that the NAS connection identifier is "0". For non-3GPP access, it is assumed that the NAS connection identifier is "1". A problem arises when additional non-3GPP access network types are added in future releases, e.g. trusted WLAN access, wireline access, MuLteFire access, etc. These different types of non-3GPP access networks would each need to establish separate NAS connections. However, the currently there is only the one NAS connection identifier of “1” for NAS connections over the different types of non-3GPP access networks.

[0009] Therefore, a need exists to provide a system and method that supports NAS connections over a plurality of different types of non-3GPP access networks. Other needs and benefits are also provided with embodiments described herein.

Summary

[0009a] In an embodiment ~~aspect~~, there is an apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and

the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:

generate a request for registration to a serving network over an access network;

receive a registration reject message, wherein the registration reject message indicates that the serving network is not authorized by a home network of the apparatus; and

in response to receiving the registration reject message indicating that the serving network is not authorized by the home network of the apparatus, enter a deregistered state such that the apparatus is configured to request registration to another serving network.

[0009b] In an embodiment~~aspect~~, there is an apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:

receive an authentication request for a user equipment requesting access to a serving network, wherein the authentication request includes an identifier of the serving network and a subscriber identity;

determine whether the serving network is authorized; and

in an instance in which the serving network is not authorized, generate an authentication response, wherein the authentication response indicates that the serving network is not authorized by a core network associated with the apparatus.

[0009c] In an embodiment~~aspect~~, there is an apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:

communicate with a core network via a selected type of access network; and

construct a subscription concealed identifier used to identify the apparatus during communication with the core network and the selected type of access network, the subscription concealed identifier including at least:

a subscription permanent identifier format type value corresponding to one of a plurality of subscription permanent identifier format types, the subscription permanent identifier format type value being associated with a subscription permanent identifier,

a protection scheme identifier corresponding to one of a plurality of protection schemes preconfigured for the subscription permanent identifier, and

a scheme output derived from the subscription permanent identifier using one of the protection schemes preconfigured for the subscription permanent identifier.

[0009d] In an embodiment~~aspect~~, there is an apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:

receive, from user equipment, via a selected type of access network, a subscription concealed identifier, the subscription concealed identifier including at least:

a subscription permanent identifier format type value corresponding to one of a plurality of subscription permanent identifier format types, the subscription permanent identifier format type value being associated with a subscription permanent identifier,

a protection scheme identifier corresponding to one of a plurality of protection schemes preconfigured for the subscription permanent identifier, and

a scheme output derived from the subscription permanent identifier using one of the protection schemes preconfigured for the subscription permanent identifier; and

identify the user equipment, during communication with the user equipment via the selected type of access network, based at least on the subscription concealed identifier. In an aspect, there is provided a user equipment (UE) comprising: at least one processor; and at least one memory including computer program instructions, wherein the at least one memory and the computer program instructions are configured to, with the at least one processor, cause the UE at least to:establish a non-access stratum (NAS) connection between the UE and a serving public land mobile network (PLMN) over a first non-third-generation partnership project (non-3GPP) access network, the first non-3GPP access network being an untrusted non-3GPP access network, the NAS connection being associated with a NAS connection identifier;

generate a request for registration to the serving PLMN over a second non-3GPP access network to establish a second NAS connection between the UE and the serving PLMN, the second non-3GPP access network having an access network type different than that of the first non-3GPP access network, the request for registration comprising said NAS connection identifier;

receive a registration reject message, wherein the registration reject message comprises a fifth-generation mobility management (5GMM) cause code or a cause information element (IE) that indicates that the request for registration to the serving PLMN over the second non-

3GPP access network is not allowed by a home PLMN of the UE-because a new NAS connection and a new NAS connection identifier are needed to establish the second NAS connection between the UE and the serving PLMN via the second non-3GPP access network; and n response to receiving the registration reject message, cause the UE to enter a 5GMM-DEREGISTERED state and reset a registration attempt counter at the UE.In an aspect, there is provided a method comprising:establishing a non-access stratum (NAS) connection between a user equipment (UE) and a serving public land mobile network (PLMN) over a first non-third-generation partnership project (non-3GPP) access network, the first non-3GPP access network being an untrusted non-3GPP access network, the NAS connection being associated with a NAS connection identifier; generating, at the UE, a request for registration to the serving PLMN over a second non-3GPP access network to establish a second NAS connection between the UE and the serving PLMN, the second non-3GPP access network having an access network type different than that of the first non-3GPP access network, the request for registration comprising said NAS connection identifier; receiving, at the UE, a registration reject message, wherein the registration reject message comprises a fifth-generation mobility management (5GMM) cause code or a cause information element (IE) that indicates that the request for registration to the serving PLMN over the second non-3GPP access network is not allowed by a home PLMN of the UE because a new NAS connection and a new NAS connection identifier are needed to establish the second NAS connection between the UE and the serving PLMN over the second non-3GPP access network; and

in response to receiving the registration reject message, causing the UE to enter a 5GMM-DEREGISTERED state and reset a registration attempt counter at the UE

CLAIMS

1. ~~An apparatus~~ A user equipment (UE) comprising:

at least one processor; and

at least one memory including computer program instructions, wherein the at least one memory and the computer program instructions are configured to, with the at least one processor, cause the UE ~~apparatus~~ at least to:

establish a non-access stratum (NAS) connection between the UE and a serving public land mobile network (PLMN) over a first non-third-generation partnership project (non-3GPP) access network, the first non-3GPP access network being an untrusted non-3GPP access network, the NAS connection being associated with a NAS connection identifier;

generate a request for registration to ~~a~~ the serving PLMN ~~network~~ over a~~n~~ second non-3GPP access network to establish a second NAS connection between the UE and the serving PLMN, the second non-3GPP access network having an access network type different than that of the first non-3GPP access network, the request for registration comprising said NAS connection identifier;

receive a registration reject message, wherein the registration reject message comprises a fifth-generation mobility management (5GMM) cause code or a cause information element (IE) that indicates that the request for registration to the serving PLMN ~~network~~ over the second non-3GPP access network is not allowed ~~authorized~~ by a home PLMN ~~network~~ of the UE ~~apparatus~~ because a new NAS connection and a new NAS connection identifier are needed to establish the second NAS connection between the UE and the serving PLMN via the second non-3GPP access network; and

in response to receiving the registration reject message, ~~indicating that the serving network is not authorized by the home network of the apparatus,~~ cause the UE to enter a 5GMM-DEREGISTERED ~~deregistered~~ state and reset a registration attempt counter at the UE ~~such that the apparatus is configured to request registration to another serving network~~.

2. The ~~apparatus~~ UE of claim 1, ~~wherein the registration reject message includes a cause information element,~~ wherein the cause IE ~~information element~~ includes a value indicative of that the home PLMN of the UE does not allow multiple requests for registration with the serving ~~network~~ PLMN to be made over multiple non-3GPP access networks having different non-3GPP access network types~~is not authorized by the home network of the apparatus~~.

3. The UE ~~apparatus~~ of claim 1, wherein the at least one memory and the computer program instructions are further configured to, with the at least one processor, cause the UE at least ~~is further configured~~ to:

abort the request for registration ~~with~~ to the serving PLMN ~~network~~ over the second non-3GPP access network~~;~~

~~store an identity of the serving network in a list of unauthorized serving networks~~.

4. The UE ~~apparatus~~ of claim 3, wherein the at least one memory and the computer program instructions are further configured to, with the at least one processor, cause the UE at least to: ~~is further configured to~~

select ~~said~~ another serving PLMN ~~network for~~ to which to request registration over the second non-3GPP access network.

~~5. The apparatus of claim 1, wherein the registration reject message indicates that the serving network is not authorized, by the home network of the apparatus, for third generation partnership project (3GPP) access to the serving network.~~

5~~6~~. The UE ~~apparatus~~ of claim 1, wherein the at least one memory and the computer program instructions are further configured to, with the at least one processor, cause the UE at least ~~is further configured~~ to:

~~in response to receiving the registration reject message indicating that the serving network is not authorized by the home network of the apparatus,~~ set a fifth generation system (5GS) update status at the UE to 5U2 NOT UPDATED.

~~7. An apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:~~

~~receive an authentication request for a user equipment requesting access to a serving network, wherein the authentication request includes an identifier of the serving network and a subscriber identity;~~

~~determine whether the serving network is authorized; and~~

~~in an instance in which the serving network is not authorized, generate an authentication response, wherein the authentication response indicates that the serving network is not authorized by a core network associated with the apparatus.~~

~~8. The apparatus of claim 7, wherein the authentication response includes a cause information element, wherein the cause information element includes a value indicative that the serving network is not authorized by the core network.~~

~~9. An apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:~~

~~communicate with a core network via a selected type of access network; and~~

~~construct a subscription concealed identifier used to identify the apparatus during communication with the core network and the selected type of access network, the subscription concealed identifier including at least:~~

~~a subscription permanent identifier format type value corresponding to one of a plurality of subscription permanent identifier format types, the subscription permanent identifier format type value being associated with a subscription permanent identifier,~~

~~a protection scheme identifier corresponding to one of a plurality of protection schemes preconfigured for the subscription permanent identifier, and~~

~~a scheme output derived from the subscription permanent identifier using one of the protection schemes preconfigured for the subscription permanent identifier.~~

10. The apparatus of claim 9, wherein the subscription permanent identifier comprises one of: an international mobile subscriber identity (IMSI) or network specific identifier type, the corresponding subscription permanent identifier format type value thereby allowing for identification of the subscriber identifier format type from among IMSI or network specific identifier types.

11. The apparatus of claim 9, wherein the subscription concealed identifier is transmitted to the core network as a mobile identity parameter with a type of identity field indicating a subscription concealed identifier identity type.

12. The apparatus of claim 11, wherein the mobile identity parameter comprises a fifth generation system (5GS) mobile identity parameter, and the subscription concealed identifier (SUCI) identity type comprises a SUCI identity type.

13. The apparatus of claim 12, wherein the subscription permanent identifier format type value of the subscription concealed identifier is encoded in a subscription permanent identifier (SUPI) format field of the 5GS mobile identity parameter.

14. An apparatus comprising at least one processor and at least one memory including computer program instructions, the at least one memory and the computer program instructions configured to, with the at least one processor, cause the apparatus at least to:

receive, from user equipment, via a selected type of access network, a subscription concealed identifier, the subscription concealed identifier including at least:

a subscription permanent identifier format type value corresponding to one of a plurality of subscription permanent identifier format types, the subscription permanent identifier format type value being associated with a subscription permanent identifier,

a protection scheme identifier corresponding to one of a plurality of protection schemes preconfigured for the subscription permanent identifier, and

a scheme output derived from the subscription permanent identifier using one of the protection schemes preconfigured for the subscription permanent identifier; and

identify the user equipment, during communication with the user equipment via the selected type of access network, based at least on the subscription concealed identifier.

~~15. The apparatus of claim 14, wherein the subscription permanent identifier comprises one of: an international mobile subscriber identity (IMSI) or network specific identifier type, the corresponding subscription permanent identifier format type value thereby allowing for identification of the subscriber identifier format type from among IMSI or network specific identifier types.~~

~~16. The apparatus of claim 15, wherein the at least one memory and the computer program instructions are configured to, with the at least one processor, cause the apparatus at least to:~~

~~identify, based at least upon the corresponding subscription permanent identifier format type value, the subscriber identifier format type from among IMSI or network specific identifier types.~~

~~17. The apparatus of claim 14, wherein the subscription concealed identifier is received by the apparatus as a mobile identity parameter with a type of identity field indicating a subscription concealed identifier identity type.~~

~~18. The apparatus of claim 17, wherein the mobile identity parameter comprises a fifth generation system (5GS) mobile identity parameter, and the subscription concealed identifier (SUCI) identity type comprises a SUCI identity type.~~

~~19. The apparatus of claim 18, wherein the subscription permanent identifier format type value of the subscription concealed identifier is encoded in a subscription permanent identifier (SUPI) format field of the 5GS mobile identity parameter.~~

6. A method comprising:

establishing a non-access stratum (NAS) connection between a user equipment (UE) and a serving public land mobile network (PLMN) over a first non-third-generation partnership project (non-3GPP) access network, the first non-3GPP access network being an untrusted non-3GPP access network, the NAS connection being associated with a NAS connection identifier;

generating, at the UE, a request for registration to the serving PLMN over a second non-3GPP access network to establish a second NAS connection between the UE and the serving PLMN, the second non-3GPP access network having an access network type different than that of the first non-3GPP access network, the request for registration comprising said NAS connection identifier;

receiving, at the UE, a registration reject message, wherein the registration reject message comprises a fifth-generation mobility management (5GMM) cause code or a cause information element (IE) that indicates that the request for registration to the serving PLMN over the second non-3GPP access network is not allowed by a home PLMN of the UE because a new NAS connection and a new NAS connection identifier are needed to establish the second NAS connection between the UE and the serving PLMN over the second non-3GPP access network; and

in response to receiving the registration reject message, causing the UE to enter a 5GMM-DEREGISTERED state and reset a registration attempt counter at the UE.

7. The method of claim 6, wherein the cause IE includes a value indicative of that the home PLMN of the UE does not allow multiple requests for registration with the serving PLMN to be made over multiple non-3GPP access networks having different non-3GPP access network types.

8. The method of claim 6, further comprising:

aborting registration with the serving PLMN over the second non-3GPP access network.

9. The method of claim 8, further comprising:

selecting, at the UE, another serving PLMN to which to request registration over the second non-3GPP access network.

10. The method of claim 6, further comprising:

setting a fifth-generation system (5GS) update status at the UE to 5U2 NOT UPDATED.