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(54) **AUTHENTICATION IN DEVICE TO DEVICE DISCOVERY**

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H04W 12/04	(2006.01)

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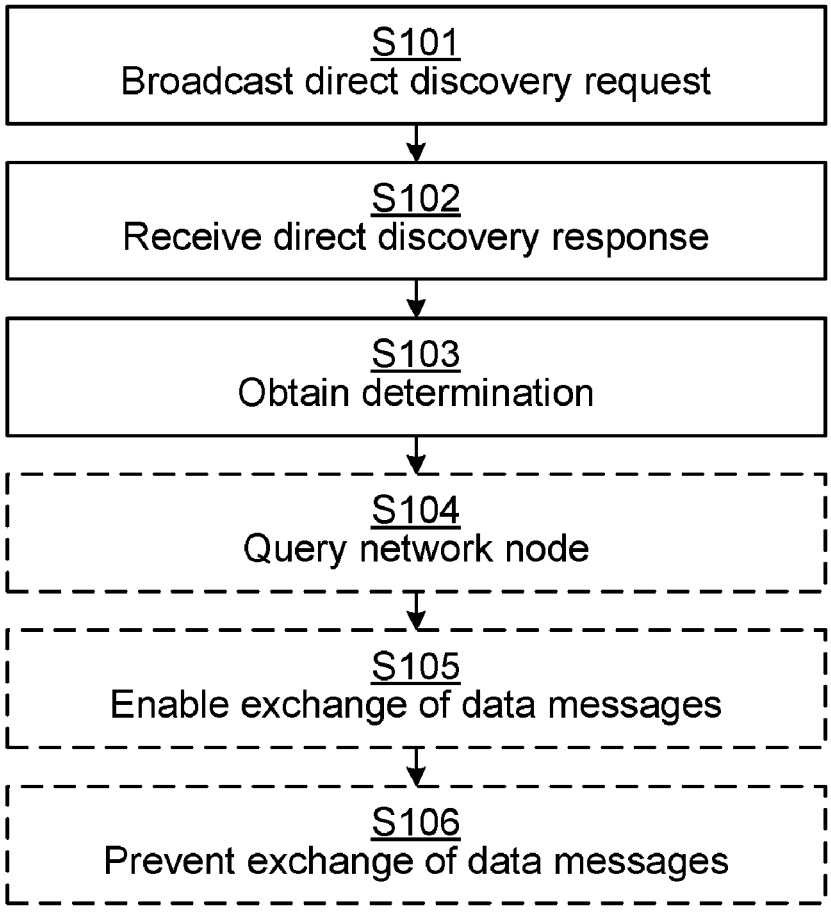
(57) **ABSTRACT**

There is provided a method for authentication in device to device discovery. A method performed by a Discoverer device, comprises broadcasting a direct discovery request, receiving a direct discovery response from a Discoveree device, the direct discovery response comprising a first token, and obtaining a determination of whether the first



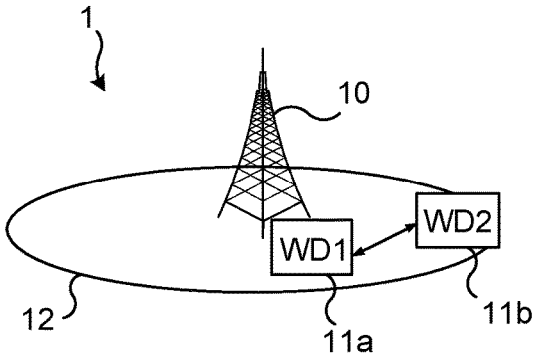

1
10
WD2
WD1
12
11a
11b

Fig. 1

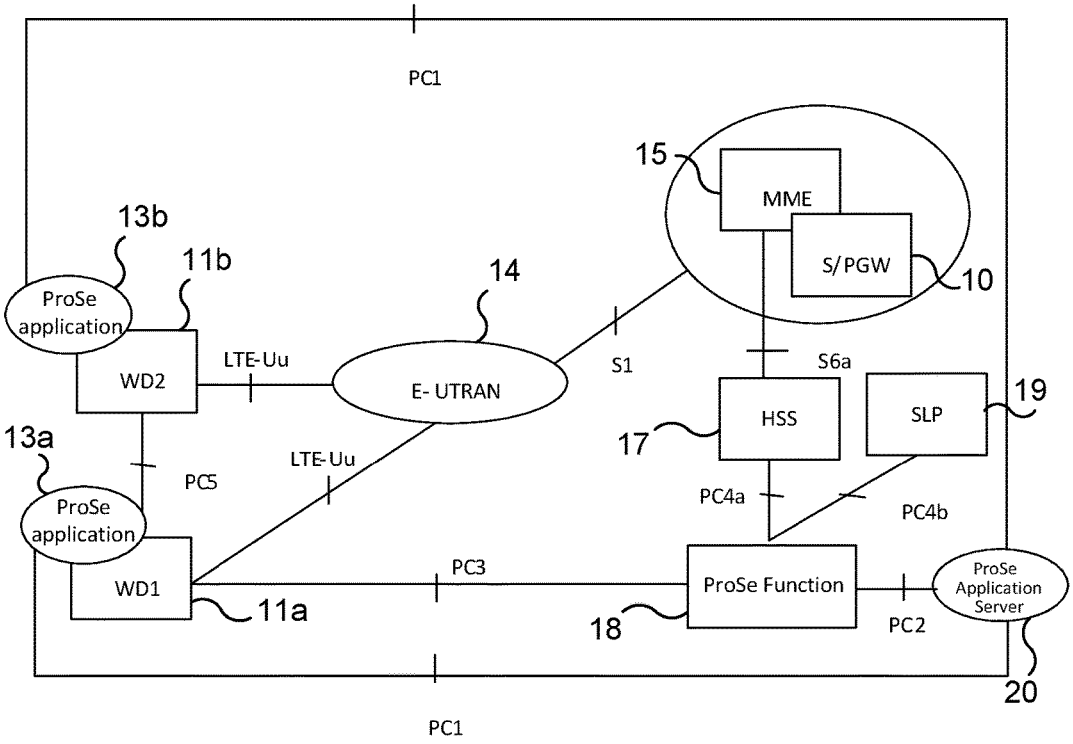

PC1
15
MME
S/PGW
10
13b
11b
14
ProSe application
WD2
LTE-Uu
E- UTRAN
S1
S6a
HSS
SLP
19
17
13a
PC5
LTE-Uu
ProSe application
PC4a
PC4b
WD1
PC3
ProSe Function
ProSe Application Server
11a
18
PC2
20
PC1

Fig. 2

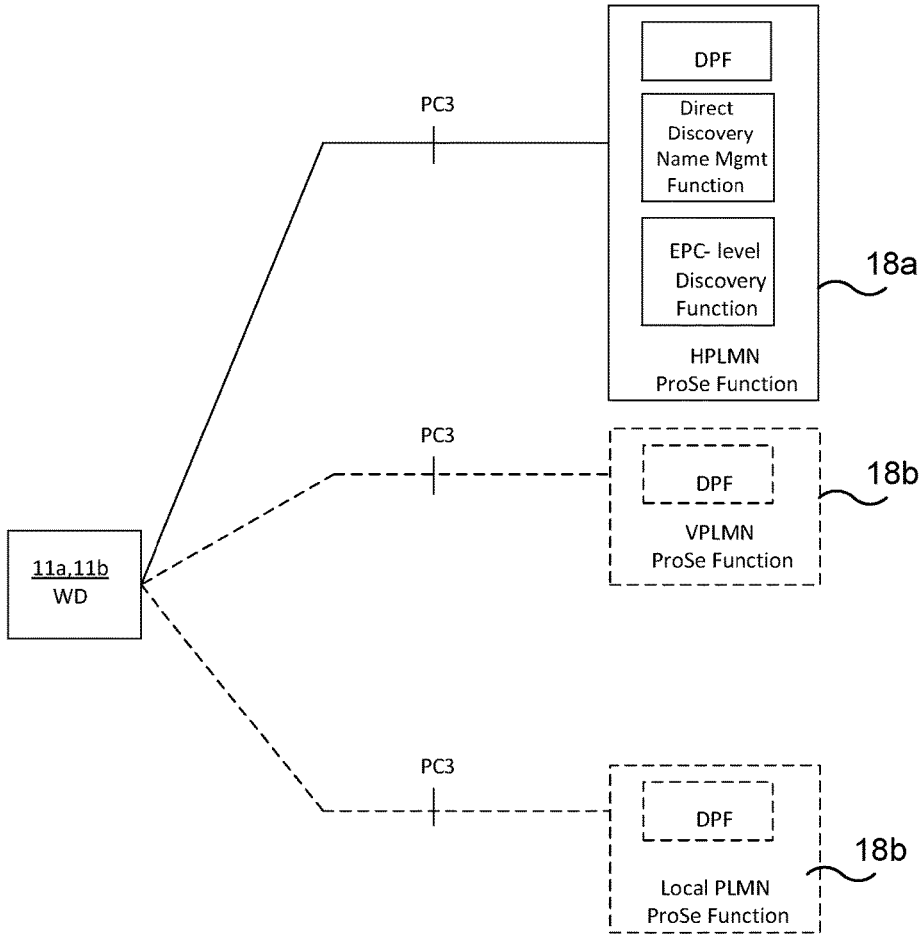

DPF
Direct Discovery Name Mgmt Function
EPC- level Discovery Function
HPLMN ProSe Function
18a
PC3
PC3
DPF
VPLMN ProSe Function
18b
11a,11b WD
PC3
DPF
Local PLMN ProSe Function
18b

Fig. 3

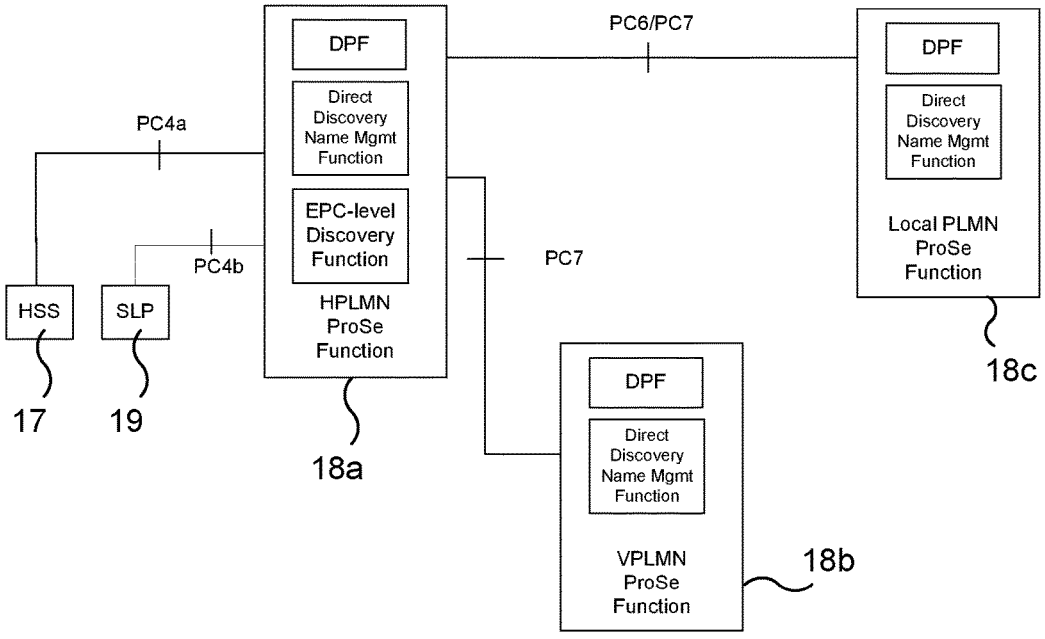

DPF
Direct Discovery Name Mgmt Function
EPC-level Discovery Function
HPLMN ProSe Function
18a
PC4a
PC4b
HSS
SLP
17
19
PC6/PC7
PC7
DPF
Direct Discovery Name Mgmt Function
Local PLMN ProSe Function
18c
DPF
Direct Discovery Name Mgmt Function
VPLMN ProSe Function
18b

Fig. 4

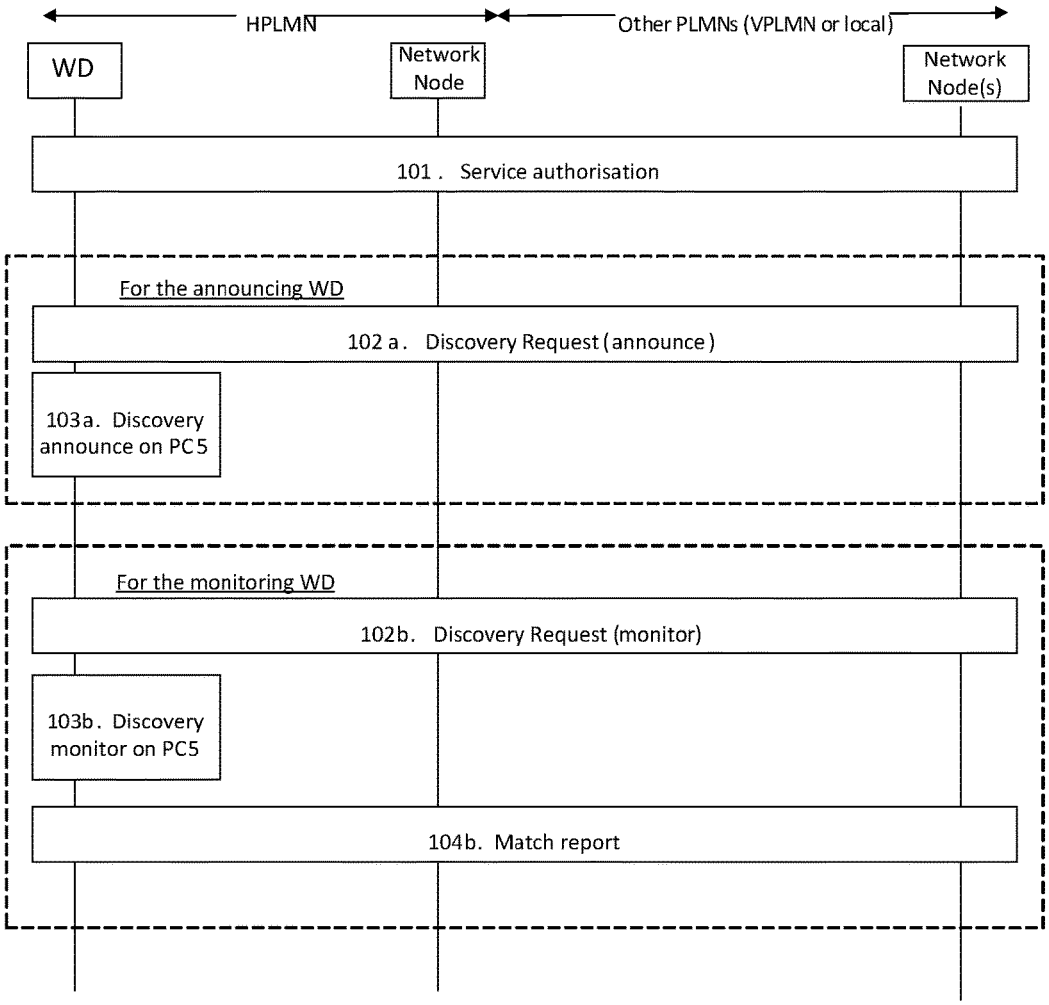

HPLMN
Other PLMNs (VPLMN or local)
WD
Network Node
Network Node(s)
101 . Service authorisation
For the announcing WD
102 a . Discovery Request (announce)
103a. Discovery announce on PC5
For the monitoring WD
102b. Discovery Request (monitor)
103b. Discovery monitor on PC5
104b. Match report

Fig. 5

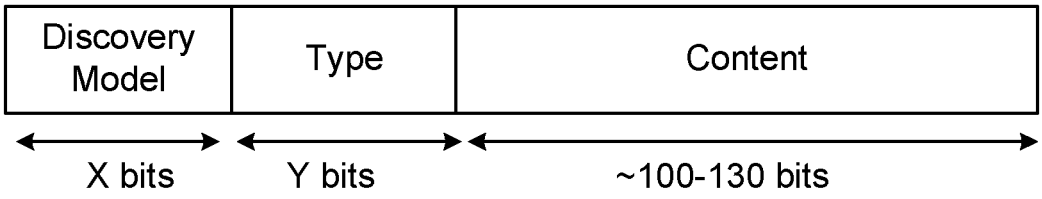

Discovery Model
Type
Content
X bits
Y bits
~100-130 bits

Fig. 6

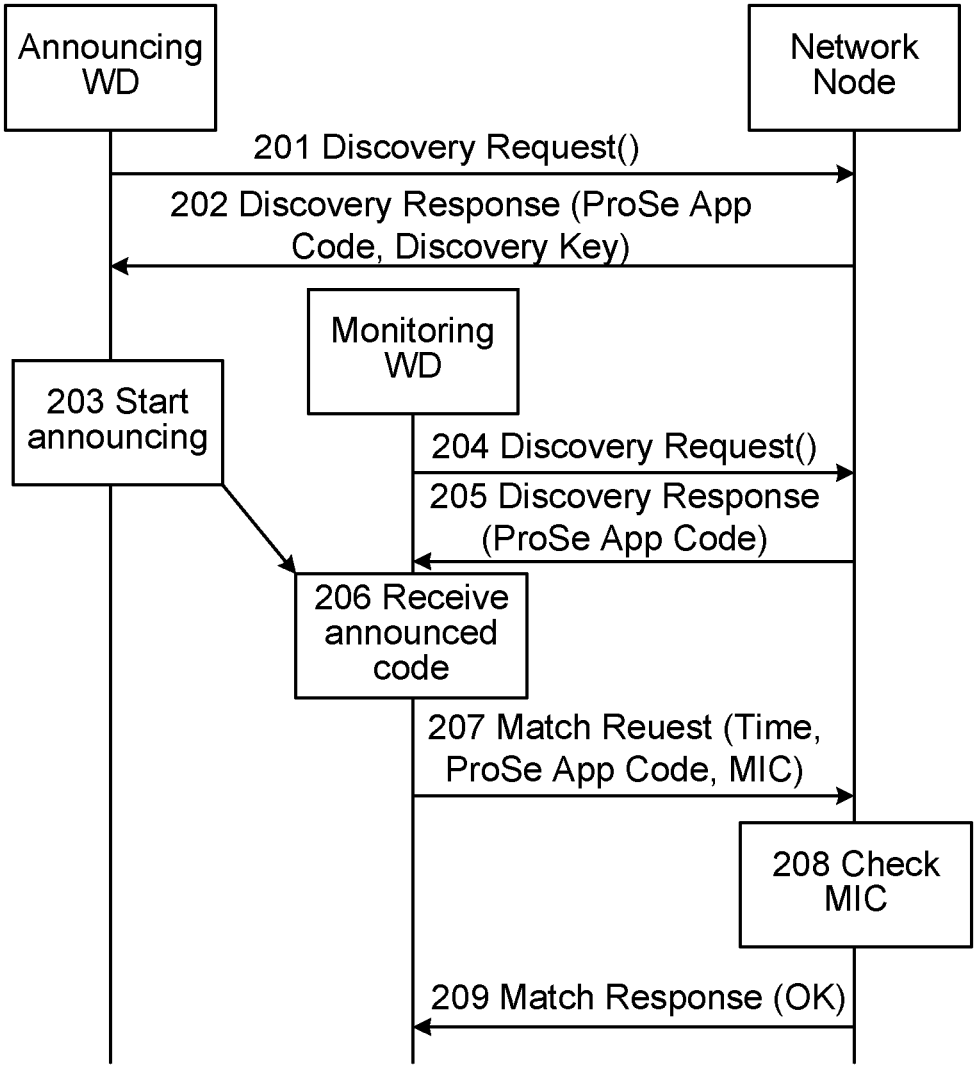

Announcing WD
Network Node
201 Discovery Request()
202 Discovery Response (ProSe App Code, Discovery Key)
Monitoring WD
203 Start announcing
204 Discovery Request()
205 Discovery Response (ProSe App Code)
206 Receive announced code
207 Match Reuest (Time, ProSe App Code, MIC)
208 Check MIC
209 Match Response (OK)

Fig. 7

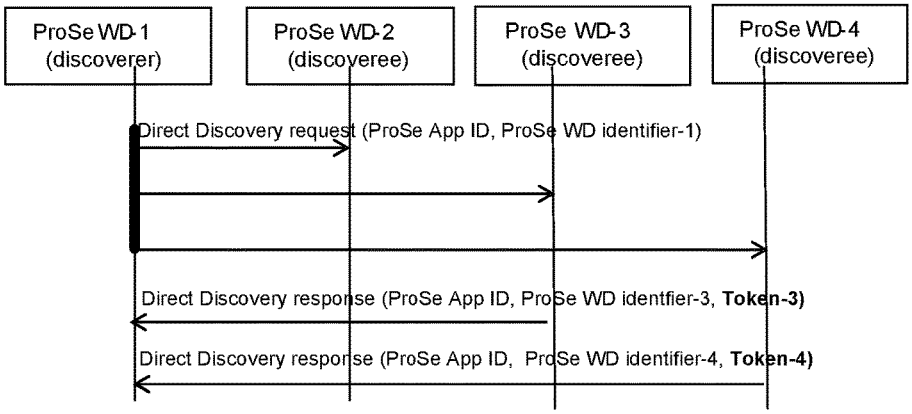

ProSe WD-1 (discoverer)
ProSe WD-2 (discoveree)
ProSe WD-3 (discoveree)
ProSe WD-4 (discoveree)
Direct Discovery request (ProSe App ID, ProSe WD identifier-1)
Direct Discovery response (ProSe App ID, ProSe WD identfier-3, Token-3)
Direct Discovery response (ProSe App ID, ProSe WD identifier-4, Token-4)

Fig. 8

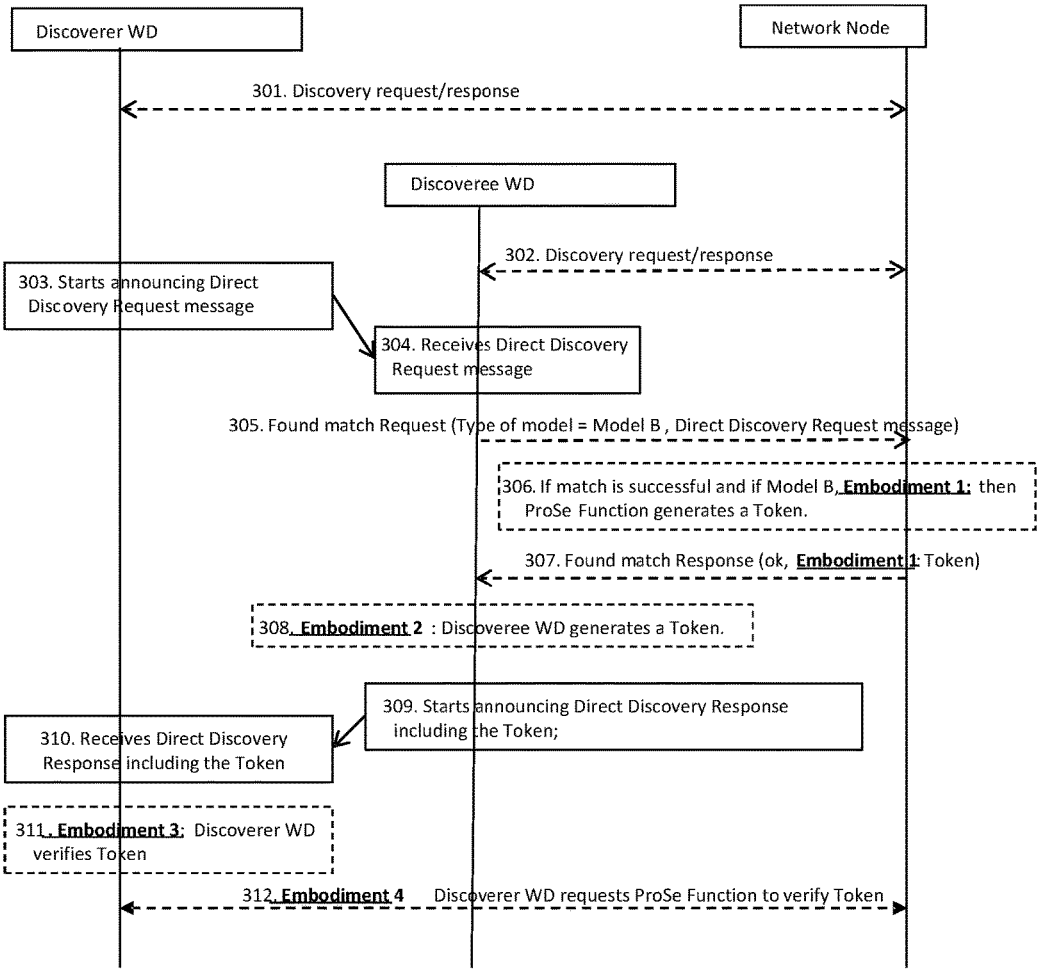

Discoverer WD
Network Node
301. Discovery request/response
Discoveree WD
302. Discovery request/response
303. Starts announcing Direct Discovery Request message
304. Receives Direct Discovery Request message
305. Found match Request (Type of model = Model B , Direct Discovery Request message)
306. If match is successful and if Model B, Embodiment 1: then ProSe Function generates a Token.
307. Found match Response (ok, Embodiment 1: Token)
308. Embodiment 2 : Discoveree WD generates a Token.
309. Starts announcing Direct Discovery Response including the Token;
310. Receives Direct Discovery Response including the Token
311. Embodiment 3: Discoverer WD verifies Token
312. Embodiment 4 Discoverer WD requests ProSe Function to verify Token

Fig. 9

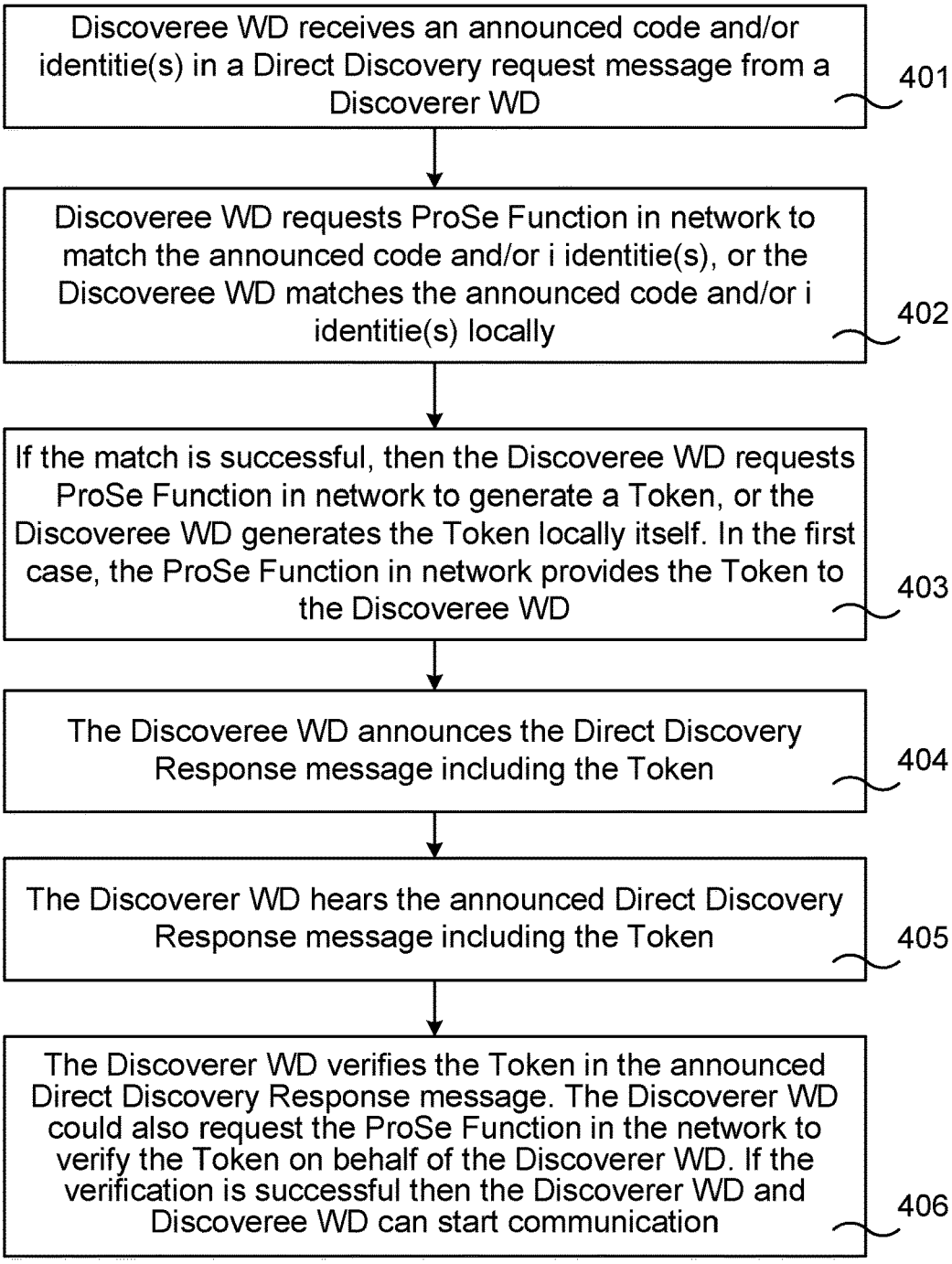

Discoveree WD receives an announced code and/or identitie(s) in a Direct Discovery request message from a Discoverer WD
401
Discoveree WD requests ProSe Function in network to match the announced code and/or i identitie(s), or the Discoveree WD matches the announced code and/or i identitie(s) locally
402
If the match is successful, then the Discoveree WD requests ProSe Function in network to generate a Token, or the Discoveree WD generates the Token locally itself. In the first case, the ProSe Function in network provides the Token to the Discoveree WD
403
The Discoveree WD announces the Direct Discovery Response message including the Token
404
The Discoverer WD hears the announced Direct Discovery Response message including the Token
405
The Discoverer WD verifies the Token in the announced Direct Discovery Response message. The Discoverer WD could also request the ProSe Function in the network to verify the Token on behalf of the Discoverer WD. If the verification is successful then the Discoverer WD and Discoveree WD can start communication
406

Fig. 10

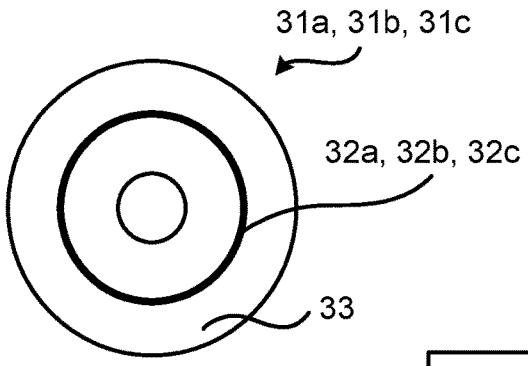


Fig. 11

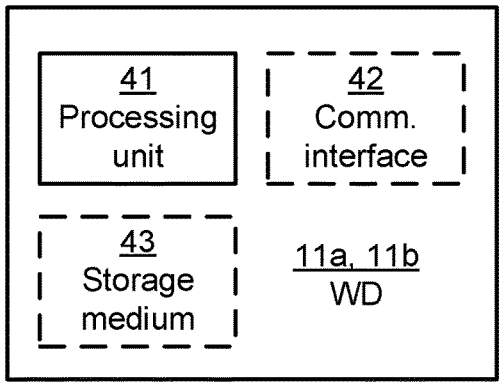


Fig. 12

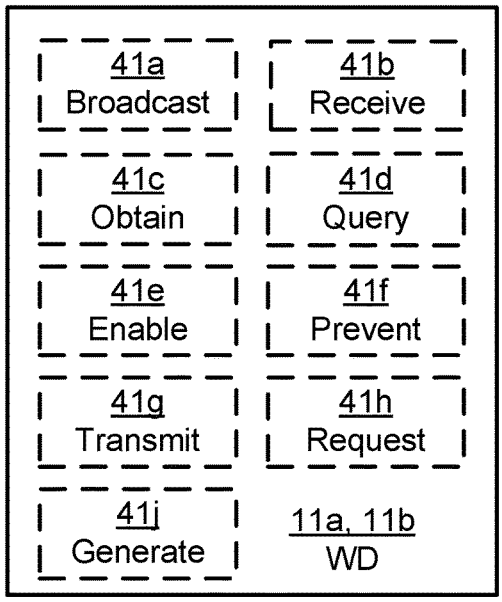


Fig. 13

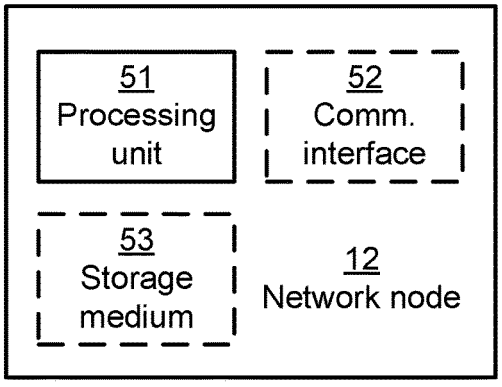


Fig. 14

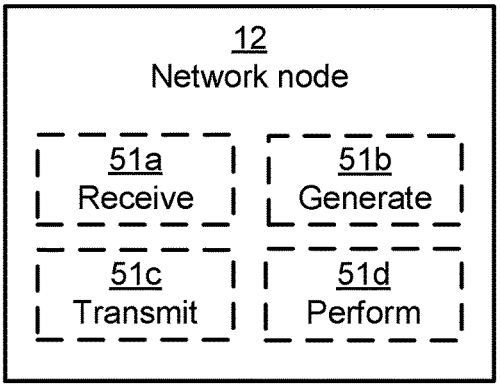


Fig. 15

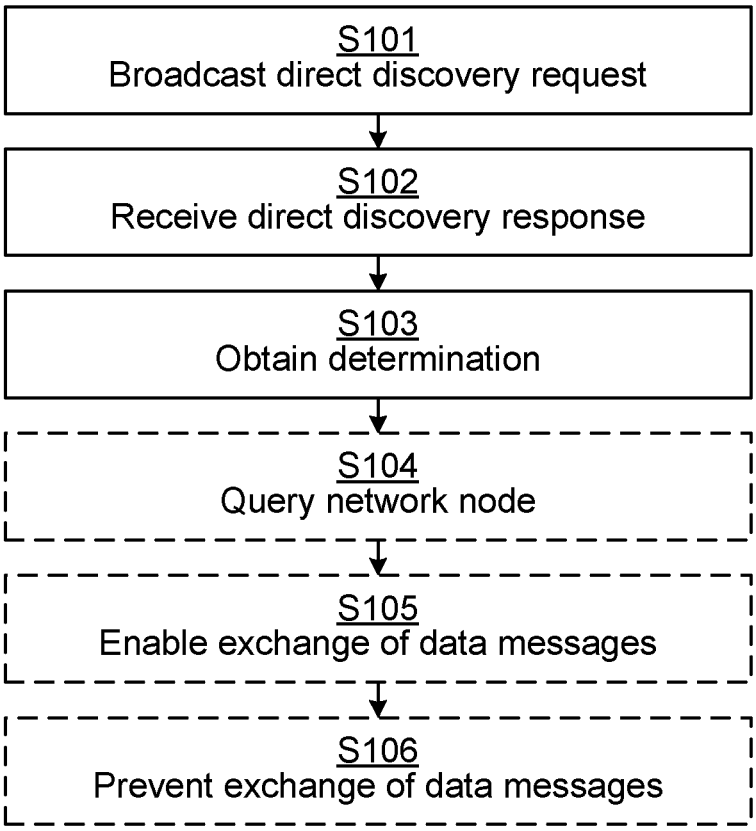

S101
Broadcast direct discovery request
S102
Receive direct discovery response
S103
Obtain determination
S104
Query network node
S105
Enable exchange of data messages
S106
Prevent exchange of data messages

Fig. 16

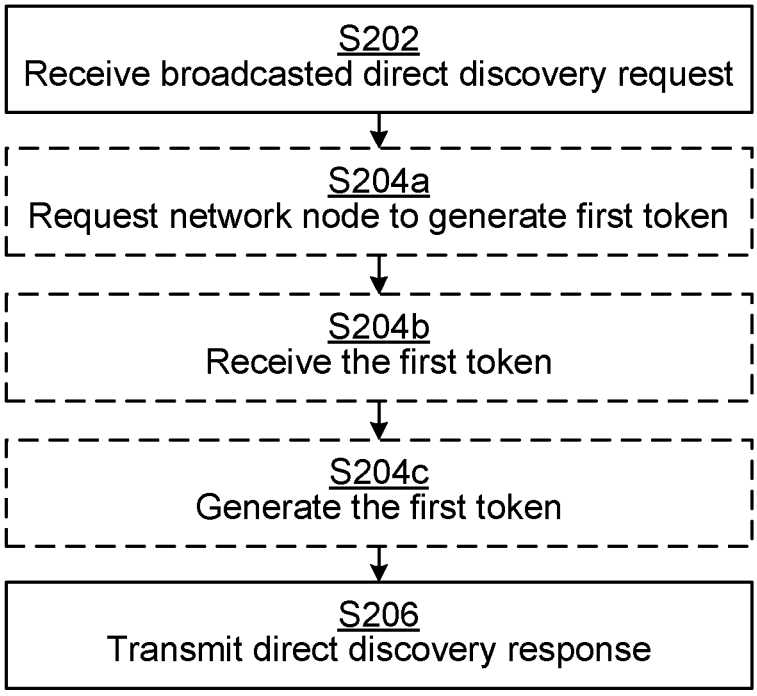

S202
Receive broadcasted direct discovery request
S204a
Request network node to generate first token
S204b
Receive the first token
S204c
Generate the first token
S206
Transmit direct discovery response

Fig. 17

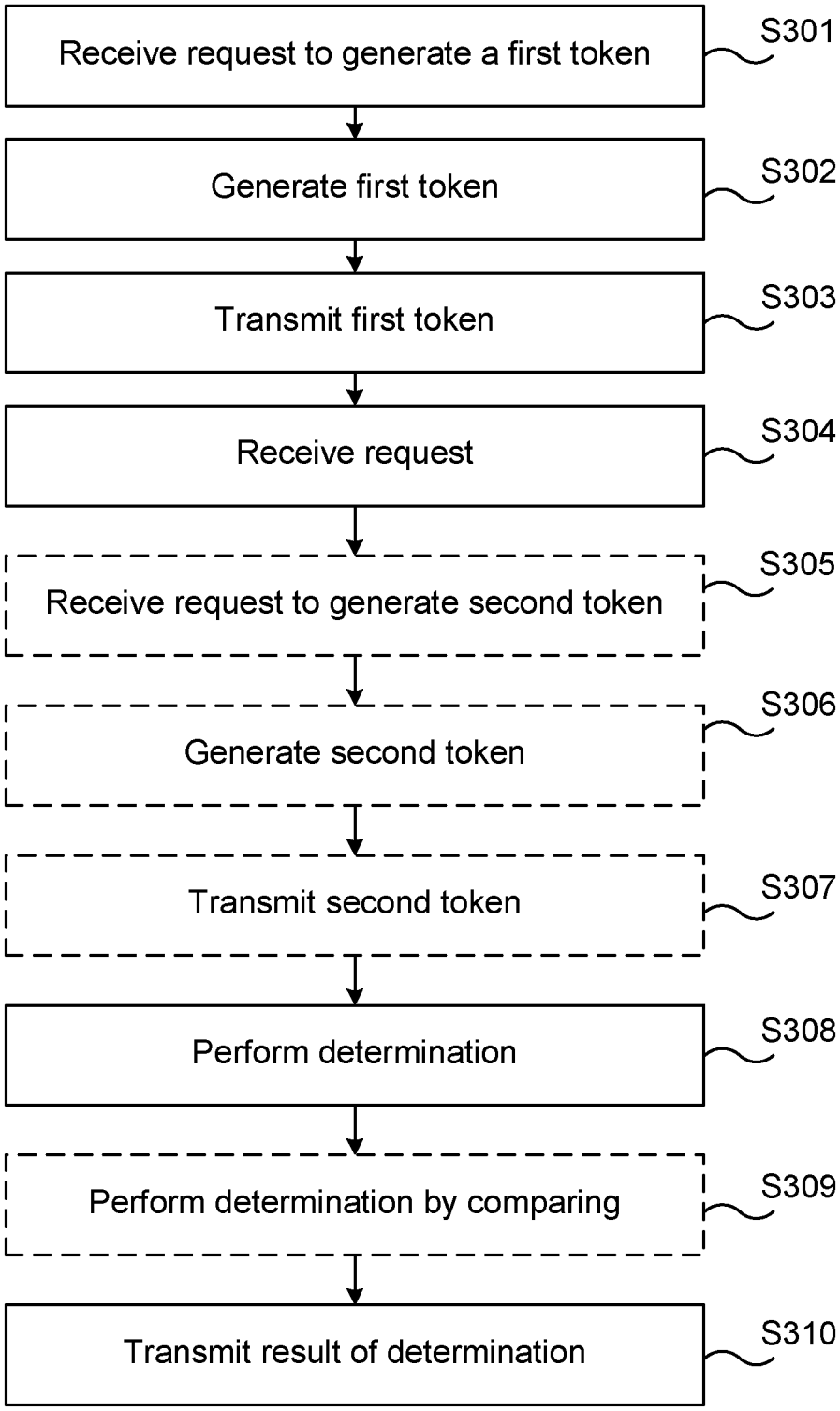

Receive request to generate a first token
S301
Generate first token
S302
Transmit first token
S303
Receive request
S304
Receive request to generate second token
S305
Generate second token
S306
Transmit second token
S307
Perform determination
S308
Perform determination by comparing
S309
Transmit result of determination
S310

Fig. 18

AUTHENTICATION IN DEVICE TO DEVICE DISCOVERY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 14/437,662 (published as US 20160302062), which has a section 371 date of Apr. 22, 2015 and which is the national stage of international patent application no. PCT/SE2015/050250, filed on Mar. 5, 2015, which claims priority to U.S. provisional patent application No. 61/968,725, filed on Mar. 21, 2014. The above identified applications and publication are incorporated by this reference.

TECHNICAL FIELD

[0002] Embodiments presented herein relate to authentication, and particularly to methods, wireless devices, a network node, computer programs, and a computer program product for authentication in device to device discovery.

BACKGROUND

[0003] In communications networks, there is always a challenge to obtain good performance and capacity for a given communications protocol, its parameters and the physical environment in which the communications network is deployed.

[0004] Proximity services (hereinafter ProSe) have recently been made available in communications networks. In general terms, proximity services are services that can be provided by some 3rd Generation Partnership Project (3GPP) communications networks based on wireless devices (hereinafter WDs) being in proximity to each other. One of these services is ProSe Discovery. The ProSe service is described in 3GPP TS 22.278 'Technical Specification Group Services and System Aspects; Service requirements for the Evolved Packet System (EPS) (Release 12)'—V12.4.0, Section: 7A.0A.1 and 3GPP TS 23.303 'Technical Specification Group Services and System Aspects; Proximity based Services; Stage 2 (Release 12)'—V0.2.1, Sections: 4.2, 5.3.2, 5.3.3.

[0005] ProSe Discovery identifies that ProSe-enabled WDs are in proximity of each other, using Evolved Universal Terrestrial Radio Access (E-UTRA), with or without the Evolved Universal Terrestrial Radio Access Network (E-UTRAN), or the Evolved Packet Core (EPC) network when permission, authorisation and proximity criteria are fulfilled. The proximity criteria can be configured by the operator.

[0006] In general terms, the ProSe Function comprises three main sub-functions that perform different roles depending on the ProSe feature. The Direct Discovery Name Management Function is one of the sub-functions.

[0007] The Direct Discovery Name Management Function is used for open Prose Direct Discovery to allocate and process the mapping of ProSe Applications identities or identifiers and ProSe Application Codes used in ProSe Direct Discovery. It uses ProSe related subscriber data stored in the Home Subscriber Server (HSS) for authorisation for each discovery request. It also provides the WD with the necessary security material in order to protect discovery messages transmitted over the air.

[0008] In order to perform device to device ProSe a Discoverer WD transmits information (such as a direct discovery request message) about other WDs that it would like to receive responses from. This approach may be regarded as querying "who is there/are you there". For example the transmitted information may be about a ProSe Application Identifier corresponding to a group and the members of the same group who listen and are interested in the same application (the ProSe Application Identifier) may respond to the Discoverer WD who then for example can start communication with the Group member(s), and so on.

[0009] When a Discoveree WD listens to Direct Discovery Request messages (e.g., on broadcast channels) and discovers a code or an identifier that the Discoveree WD is interested in, then the Discoveree WD replies by announcing a Direct Discovery Response message.

[0010] However, when the Discoverer WD receives the Direct Discovery Response message, it is today not possible for the Discoverer WD to be able to determine whether the responding WD is a genuine WD, i.e., a WD authorized to respond to the Direct Discovery request message or not. It could happen that a false Discoveree WD could fool the Discoverer WD that the false Discoveree WD is a genuine Discoveree WD which is currently located in proximity of the Discoverer WD. Also replay attacks where, for example, a false Discoveree WD is replaying genuine Direct Discovery response messages may occur. Such issues are not described in 3GPP TR 33.833 'Technical Specification Group Services and System Aspects Study on security issues to support Proximity Services (Release 12)'—V0.4.0, section 6.2.5.

[0011] Hence, there is a need for secure device to device discovery.

SUMMARY

[0012] An object of embodiments herein is to provide secure device to device discovery.

[0013] According to a first aspect there is presented a method for authentication in device to device discovery. The method is performed by a Discoverer device. The method comprises broadcasting a direct discovery request. The method comprises receiving a direct discovery response from a Discoveree device, the direct discovery response comprising a first token. The method comprises obtaining a determination of whether the first token was generated for the Discoveree device or not.

[0014] Advantageously this provides secure device to device discovery.

[0015] Advantageously, this enables the Discoverer WD to know that the Discoveree WD is genuine and that the Direct Discovery Response message is not replayed by a false WD.

[0016] According to embodiments the determination comprises querying a network node to determine whether the first token was generated for the Discoveree device or not.

[0017] Advantageously, this enables the Discoverer WD to know that the Discoveree WD is authorized by the ProSe Function in the network to respond to the announced Direct Discovery Request message.

[0018] If two identities are broadcasted in Direct Discovery Response message, for example a ProSe Application Identifier together with a ProSe WD Identifier of the Discoveree WD, then the ProSe WD Identifier of the Discoveree WD could be encrypted but the ProSe Application Identifier

could be sent in clear text. This could be achieved if the Direct Discovery Response message is supporting partial encryption.

[0019] If two identities are broadcasted in the Direct Discovery Request message, for example a ProSe Application Identifier together with a ProSe WD Identifier of Discoverer WD, then the ProSe WD Identifier of the Discoverer WD could be encrypted but the ProSe Application Identifier could be sent in clear text. This could be achieved if the Direct Discovery Request message is supporting partial encryption.

[0020] According to a second aspect there is presented a wireless device for authentication in device to device discovery. The wireless device comprises a processing unit and a non-transitory computer readable storage medium, the non-transitory computer readable storage medium comprising instructions executable by the processing unit. The wireless device is operative to perform a method according to the first aspect.

[0021] According to a third aspect there is presented a computer program for authentication in device to device discovery, the computer program comprising computer program code which, when run on a wireless device, causes the wireless device to perform a method according to the first aspect.

[0022] According to a fourth aspect there is presented a method for authentication in device to device discovery. The method is performed by a Discoveree device. The method comprises receiving a broadcasted direct discovery request from a Discoverer device. The method comprises transmitting a direct discovery response to the Discoverer device, the direct discovery response comprising a first token.

[0023] According to a fifth aspect there is presented a wireless device for authentication in device to device discovery. The wireless device comprises a processing unit and a non-transitory computer readable storage medium, the non-transitory computer readable storage medium comprising instructions executable by the processing unit. The wireless device is operative to perform a method according to the fourth aspect.

[0024] According to a sixth aspect there is presented a computer program for authentication in device to device discovery, the computer program comprising computer program code which, when run on a wireless device, causes the wireless device to perform a method according to the fourth aspect.

[0025] According to a seventh aspect there is presented a method for authentication in device to device discovery. The method is performed by a network node. The method comprises receiving a request to generate a first token from a Discoveree device. The method comprises generating the first token. The method comprises transmitting the first token to the Discoveree device. The method comprises receiving a request from a Discoverer device to determine whether the first token was generated for the Discoveree device or not. The method comprises performing a determination of whether the first token was generated for the Discoveree device or not. The method comprises transmitting a result thereof to the Discoverer device.

[0026] According to an eight aspect there is presented a network node for authentication in device to device discovery. The network node comprises a processing unit and a non-transitory computer readable storage medium, the non-transitory computer readable storage medium comprising instructions executable by the processing unit. The network node is operative to perform a method according to the seventh aspect.

[0027] According to a ninth aspect there is presented a computer program for authentication in device to device discovery, the computer program comprising computer program code which, when run on a network node, causes the network node to perform a method according to the seventh aspect.

[0028] According to a tenth aspect there is presented a computer program product comprising a computer program according to at least one of the third aspect, the sixth aspect, and the ninth aspect and a computer readable means on which the at least one computer program is stored. The computer readable means may be non-transitory computer readable means.

[0029] It is to be noted that any feature of the first, second, third, fourth, fifth, sixth, seventh, eight, ninth, and tenth aspects may be applied to any other aspect, wherever appropriate. Likewise, any advantage of the first aspect may equally apply to the second, third, fourth, fifth, sixth, seventh, eight, ninth, and/or tenth aspect, respectively, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

[0030] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The inventive concept is now described, by way of example, with reference to the accompanying drawings.

[0032] FIG. **1** schematically illustrates a scenario for device to device ProSe according to embodiments.

[0033] FIG. **2** schematically illustrates a high level view of a non-roaming architecture for a communications network according to embodiments.

[0034] FIG. **3** schematically illustrates the WD-to-ProSe Function Interfaces according to embodiments.

[0035] FIG. **4** schematically illustrates ProSe Function Interfaces according to embodiments.

[0036] FIGS. **5**, **7**, **8**, and **9** are signalling flow diagrams according to embodiments.

[0037] FIG. **6** schematically illustrates an example protocol format for direct discovery messages according to embodiments.

[0038] FIGS. **10**, **16**, **17**, and **18** are flowcharts of methods according to embodiments.

[0039] FIG. **11** shows one example of a computer program product comprising computer readable means according to an embodiment.

[0040] FIG. **12** schematically illustrates functional units of a wireless device according to an embodiment.

[0041] FIG. **13** schematically illustrates functional modules of a wireless device according to an embodiment.

[0042] FIG. **14** schematically illustrates functional units of a network node according to an embodiment.

[0043] FIG. **15** schematically illustrates functional modules of a network node according to an embodiment.

DETAILED DESCRIPTION

[0044] The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the inventive concept are shown. This inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. Like numbers refer to like elements throughout the description. Any step or feature illustrated by dashed lines should be regarded as optional.

[0045] FIG. **1** schematically illustrates a scenario **1** for device to device ProSe where WD1 **11***a* and WD2 **11***b* are located within coverage of a cell **12** served by a network node **10**. When WD1 has a role of transmission, WD1 sends discovery message and WD2 receives it. WD1 and WD2 may change their transmission and reception role. The transmission from WD1 may be received by one or more WDs like WD2.

[0046] Commonly, the use of ProSe Discovery must be authorised by the operator, and the authorisation can be on a "per WD" basis, or a "per WD per application" basis. An authorised application may interact with the ProSe Discovery feature to request the use of certain ProSe Discovery preferences.

[0047] In general terms, the network controls the use of E-UTRAN resources used for ProSe Discovery for a ProSe-enabled WD served by E-UTRAN.

[0048] In general terms, ProSe Discovery may be used as a standalone process (i.e. it is not necessarily followed by ProSe Communication) or as an enabler for other services.

[0049] FIG. **2** schematically illustrates a high level view of a non-roaming architecture for a communications network where embodiments presented herein may be applied. In FIG. **2**, WD1 **11***a* and WD2 **11***b* use a subscription of the same PLMN. The communications network of FIG. **2** comprises an E-UTRAN **14**. The communications network of FIG. **2** additionally comprises a number of functional nodes; HSS **17** is a Home Subscriber Server, MME **15** is a Mobility Management Entity, S/PGW **16** is a Serving Gateway and/or a Packet Data Network Gateway, and SLP **19** is a SUPL Location Platform (where SUPL is short for Secure User Plane Location). These functional nodes and their functionality are as such known in the art and a detailed description thereof is therefore omitted. The communications network of FIG. **2** further comprises a ProSe Function **18**, and a ProSe Application Server **20**. FIG. **2** also schematically illustrates some logical network interfaces; PC1, LTE-Uu, PC5, S1, PC3, S6a, PC4a, PC4b, and PC2 enabling communications between elements of the communications network and/or the wireless devices **11***a*, **11***b*. As schematically illustrated in FIG. **2** each wireless device **11***a*, **11***b* is associated with a ProSe application **13***a*, **13***b*.

[0050] FIG. **3** schematically illustrates the WD-to-ProSe Function Interfaces for each sub-function in the ProSe function. The ProSe Function may be regarded as the logical function that is used for network related actions required for ProSe. The ProSe Function may play different roles for each of the features of ProSe. Particularly, the wireless devices **11***a*, **11***b* have a PC3 interface to a HPLMN ProSE Function **18***a*, a VPLMN ProSe Function **18***b*, and a Local PLMN ProSE Fuction **18***c*. In some embodiments the ProSe Function **18***b* and the Local PLMN ProSE Fuction **18***c* are optional. The ProSe Function consists of main sub-functions that perform different roles depending on the ProSe feature. The Direct Provisioning Function (DPF) is used to provision the UE with necessary parameters in order to use ProSe Direct Discovery and ProSe Direct Communication. It is used to provision the UE's with PLMN specific parameters that allow the UE to use ProSe in this specific PLMN. Direct Discovery Name Management Function is used for open ProSe Direct Discovery to allocate and process the mapping of ProSe Application IDs and ProSe Application Codes used in ProSe Direct Discovery. It uses ProSe related subscriber data stored in HSS for authorization for each discovery request. It also provides the UE with necessary security material in order to protect discovery messages transmitted over the air.

[0051] FIG. **4** schematically illustrates ProSe Function Interfaces PC4a, PC4b, PC6, and PC7 to other network elements and PLMNs, where DPF is a Direct Provisioning Function. PC4a is used to provide subscription information in order to authorise access for ProSe Direct Discovery and ProSe Direct Communication on a per PLMN basis. PC6 is used between the ProSe Function in the HPLMN and the ProSe Function in a Local PLMN (ProSe Direct Discovery). With ProSe Direct Discovery this interface is used for HPLMN control of ProSe service authorization. It is also used to authorise ProSe Direct Discovery requests, retrieve the Discovery Filter(s) corresponding ProSe Application ID name(s) and translate the ProSe Application Code to the ProSe Application ID Name. PC7 is used between the ProSe Function in the HPLMN and the ProSe Function in the VPLMN. It is used for HPLMN control of ProSe service authorization. It is also used to authorise ProSe Direct Discovery requests, retrieve the Discovery Filter(s) corresponding ProSe Application ID name(s) and translate the ProSe Application Code to the ProSe Application ID Name.

[0052] The ProSe discovery procedure is described in 3GPP TS 23.303 'Technical Specification Group Services and System Aspects; Proximity based Services; Stage 2 (Release 12)'—V0.2.1, Sections: 4.2, 5.3.2, 5.3.3.

[0053] ProSe Direct Discovery may be provided as a standalone service enabler that for example may use information from the discovered WD for certain applications in the WD that are permitted to use this information e.g., "find a taxi nearby", "find me a coffee shop", etc. Additionally, for example depending on the information obtained, ProSe Direct Discovery may be used for subsequent actions e.g., to initiate ProSe Direct Communication.

[0054] Examples of two models for ProSe Direct Discovery will now be presented. The first is termed Model A and the second Model B.

[0055] Model A ("I am here"): This model generally defines two roles for the ProSe-enabled WDs that are participating in ProSe Direct Discovery. An Announcing WD is the WD that announces certain information that could be used by WDs in proximity that have permission to discover. A Monitoring WD is the WD that monitors certain information of interest in proximity of Announcing WDs. In this model the Announcing WD may broadcast discovery

messages at pre-defined discovery intervals and the Monitoring WDs that are interested in these messages read them and process them.

[0056] The overall procedure for ProSe Direct Discovery in Model A will now be disclosed in more detail with reference to the signalling flow diagram of FIG. **5**. The overall procedure for ProSe Direct Discovery is described as follows in 3GPP TS 23.303 'Technical Specification Group Services and System Aspects; Proximity based Services; Stage 2 (Release 12)'—V0.2.1, Sections: 4.2, 5.3.2, 5.3.3 for Model A.

[0057] Step **101**. Service authorisation for ProSe direct services is performed for ProSe Direct Discovery.

[0058] If the WD is authorized to announce:

[0059] Step **102***a*. When the Announcing WD is triggered to announce then it sends a discovery request for announcing to the ProSe Function in the home public land mobile network (HPLMN) of the Announcing WD.

[0060] Step **103***a*. If the request is successful and is provided with ProSe Application Code then the Announcing WD starts announcing on the PC5 interface.

[0061] If the Monitoring WD is authorized to monitor:

[0062] Step **102***b*. When the Monitoring WD is triggered to monitor, it sends a discovery request for monitoring to the ProSe.

[0063] Step **103***b*. If the request is successful and the Monitoring WD is provided with a Discovery Filter consisting of ProSe Application Code(s) or mask(s) it starts monitoring for these ProSe Application Codes on the PC5 interface.

[0064] Step **104***b*. When the Monitoring WD detects that one or more ProSe Application Code(s) that match the filter, it reports the ProSe Application Code(s) to the ProSe Function.

[0065] Model B ("who is there?"/"are you there?"): This model generally defines two roles for the ProSe-enabled WDs that are participating in ProSe Direct Discovery. The Discoverer WD transmits a request containing certain information about what it is interested to discover. The Discoveree WD receives the request message can respond with some information related to the request of the Discoverer WD. The Discoverer WD may thus transmit information about other WDs that it would like to receive responses from. The transmitted information may be about a ProSe Application Identifier corresponding to a group and the members of the group may thus respond.

[0066] No signaling flow for Model B has yet been approved to be included into 3GPP TS 23.303 'Technical Specification Group Services and System Aspects; Proximity based Services; Stage 2 (Release 12)'—V0.2.1, Sections: 4.2, 5.3.2, 5.3.3. However, the following model for ProSe Direct Discovery Model B has been included into 3GPP TR 23.703 'Technical Specification Group Services and System Aspects; Study on architecture enhancements to support Proximity-based Services (ProSe); (Release 12)'—V1.1.0, Sections 6.1.1.2.3.3. It is noted that this is one example of how the format for the Direct Discovery message could look like.

[0067] An example protocol format for direct discovery messages in the context of this proposal is presented in FIG. **6**.

[0068] A Discovery Model field may indicate whether the message is for Model A ("I am here"), or Model B ("who is there"/"are you there").

[0069] A Type field may indicate whether the ProSe Identifier is a ProSe WD Identifier, and whether it is used for Open Discovery or Restricted Discovery.

[0070] A Content field may for example indicate at least one of the following (for example with the Type field set to 1): the ProSe WD Identifier or ProSe Group Identifier, (for example with the Type field set to 2): the ProSe Application Identifier, and (for example with the Type field set to 3): the ProSe Application Identifier and ProSe WD Identifier.

[0071] In general terms, if the WD or application is configured to support Model B discovery, it may announce a discovery message, for example indicating in the "Discovery model" field "Model B (request)" and carrying the Identities as described above.

[0072] For example, when the Type field is set to 3, the discovery message may comprise the ProSe Application Identifier in addition to the ProSe WD Identifier. In this case each of the recipient(s) of this message may respond with a discovery message with for example the "Discovery model" field set to "Model B (response)" and which message comprises the ProSe WD Identifier and/or the ProSe Application Identifier that was included in the request at the next discovery interval (if required based on the protocol design).

[0073] Alternatively, if the WD or application may support discovery using "Model A", the WD may announce a discovery message for example indicating in the "Discovery model" field "Model A" and the ProSe Application Identifier of its own.

[0074] If the Type field is set to "2" then the ProSe Application Identifier may be comprised in the content of the message.

[0075] If the Type field is set to "3" then the ProSe Application Identifier and ProSe WD Identifier may be comprised in the content of the message.

[0076] The Type filed may in these cases also be used in order to assist the processing of open or restricted discovery messages by the access stratum.

[0077] Some security aspects for the ProSe Discovery procedure will be summarized next.

[0078] A security solution has been provided for the ProSe Discovery procedure in 'Solution #2.5: Security for discovery with network checking' in 3GPP TR 33.833 'Technical Specification Group Services and System Aspects Study on security issues to support Proximity Services (Release 12)'—V0.4.0, section 6.2.5. This suggestion applies to 'Model A'. This suggestion is described below in this section.

[0079] In Model A the announced code is integrity protected as shows in the signalling flow diagram of FIG. **7**. It is assumed that there is a "time value" parameter available to both the WDs. The possible multiple ProSe Functions have also been collapsed into one logical element as it does not affect the security here, so in effect the signalling flow diagram represents both the Announcing WD and Monitoring WD being in their home network.

[0080] Step **201**. The Announcing WD transmits a Discovery Request message to the ProSe Function in order to be allowed to announce code on that PLMN.

[0081] Step **202**. The ProSe function returns the ProSe App Code that the announcing WD can announce and a Discovery Key associated with it. The ProSe Function stores the Discovery Key with the ProSe App Code.

[0082] Step **203**. The Announcing WD starts announcing. In each slot that it announces, the Announcing WD calcu-

lates a Message Integrity Code (MIC) to append to the ProSe App Code, so that the announced code becomes the ProSe App Code plus the MIC. The MIC is generally calculated using the key derivation function (KDF) described in 3GPP TS 33.220 'Technical Specification Group Services and System Aspects; Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA) (Release 12)'—V12.1.0, section Annex B with the Discovery Key as the key and the "time value" parameter and the ProSe App Code as the other inputs.

[0083] Step **204**. The Monitoring WD transmits a Discovery Request message to the ProSe Function in order to get the ProSe App Code that it wants to listen for.

[0084] Step **205**. The ProSe Function returns the ProSe App Code.

[0085] Step **206**. The Monitoring WD listens for announced codes that contain a ProSe App Code that it is interested in.

[0086] Step **207**. On hearing such an announced code, the Monitoring WD transmits a Match Request message to the ProSe function containing the 'time value' parameter related to the slot it heard the announcement in and the announced code, i.e. the ProSe App Code and the MIC.

[0087] Step **208**. The ProSe Function checks if the MIC is valid. The relevant Discovery Key is found using the ProSe App Code.

[0088] Step **209**. The ProSe Function returns an acknowledgement that the integrity check has passed to the Monitoring WD.

[0089] As noted above, in Model B the Discoverer WD transmits information (such as a direct discovery request message) about other WDs that it would like to receive responses from. When the Discoveree WD listens to Direct Discovery Request messages (e.g., on broadcast channels) and discovers a code or an identifier that the Discoveree WD is interested in, then the Discoveree WD replies by announcing a Direct Discovery Response message. However, when the Discoverer WD receives the Direct Discovery Response message, it is today not possible for the Discoverer WD to be able to determine whether the responding WD is a genuine WD, i.e., a WD authorized to respond to the Direct Discovery request message or not. It could happen that a false Discoveree WD could fool the Discoverer WD that the false Discoveree WD is a genuine Discoveree WD which is currently located in proximity of the Discoverer WD. Also replay attacks where, for example, a false Discoveree WD is replaying genuine Direct Discovery response messages may occur. Such issues are not described in 3GPP TR 33.833 'Technical Specification Group Services and System Aspects Study on security issues to support Proximity Services (Release 12)'—V0.4.0, section 6.2.5.

[0090] The embodiments disclosed herein relate to secure device to device discovery, and particularly to authentication in device to device discovery. In order to obtain authentication in device to device discovery there is provided a wireless device acting either as a Discoverer WD or a Discoveree WD, a network node, methods performed by the Discoverer WD, the Discoveree WD, and the network node, and computer programs comprising code, for example in the form of computer program products, that when run on the wireless device and/or the network node causes the wireless device and/or the network node to perform the methods.

[0091] FIG. **12** schematically illustrates, in terms of a number of functional units, the components of a wireless device acting either as a Discoverer WD **11***a* or a Discoveree WD **11***b* according to an embodiment. The wireless device may be configured to run a ProSe application **13***a*, **13***b*. A processing unit **41** is provided using any combination of one or more of a suitable central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), application specific integrated circuit (ASIC), field programmable gate arrays (FPGA) etc., capable of executing software instructions stored in a computer program product **31***a*, **31***b* (as in FIG. **11**), e.g. in the form of a storage medium **43**. Thus the processing unit **41** is thereby arranged to execute methods as herein disclosed. The storage medium **43** may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory. The wireless device further comprises a communications interface **42** for communications with a further wireless device and a network node **12**. As such the communications interface **42** may comprise one or more transmitters and receivers, comprising analogue and digital components and a suitable number of antennae for radio communications. The processing unit **42** controls the general operation of the wireless device e.g. by sending data and control signals to the communications interface **42** and the storage medium **43**, by receiving data and reports from the communications interface **42**, and by retrieving data and instructions from the storage medium **43**. Other components, as well as the related functionality, of the wireless device are omitted in order not to obscure the concepts presented herein.

[0092] FIG. **13** schematically illustrates, in terms of a number of functional modules, the components of a wireless device acting either as a Discoverer WD **11***a* or a Discoveree WD **11***b* according to an embodiment. The wireless device of FIG. **13** comprises a number of functional modules, such as any of a broadcast module **41***a*, a receive module **41***b*, an obtain module **41***c*, a query module **41***d*, an enable module **41***e*, a prevent module **41***f*, a transmit module **41***g*, a request module **41***h*, and a generate module **41***j*. The functionality of each functional module **41***a-j* will be further disclosed below in the context of which the functional modules **41***a-j* may be used. In general terms, each functional module **41***a-j* may be implemented in hardware or in software. The processing unit **41** may thus be arranged to from the storage medium **43** fetch instructions as provided by a functional module **41***a-j* and to execute these instructions, thereby performing any steps as will be disclosed hereinafter.

[0093] FIG. **14** schematically illustrates, in terms of a number of functional units, the components of a network node **12** according to an embodiment. The network node may implement the functionality of at least one of the ProSe Function **18** and the ProSe application server **20**. A processing unit **51** is provided using any combination of one or more of a suitable central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), application specific integrated circuit (ASIC), field programmable gate arrays (FPGA) etc., capable of executing software instructions stored in a computer program product **31***c* (as in FIG. **11**), e.g. in the form of a storage medium **53**. Thus the processing unit **51** is thereby arranged to execute methods as herein disclosed. The storage medium **53** may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted

memory. The network node further comprises a communications interface **52** for communications with another network node, and at least one wireless device, for example a wireless device acting as a Discoverer WD and a wireless device acting as a Discoveree WD. As such the communications interface **52** may comprise one or more transmitters and receivers, comprising analogue and digital components and a suitable number of antennae for radio communications. The processing unit **51** controls the general operation of the network node e.g. by sending data and control signals to the communications interface **52** and the storage medium **53**, by receiving data and reports from the communications interface **52**, and by retrieving data and instructions from the storage medium **53**. Other components, as well as the related functionality, of the network node are omitted in order not to obscure the concepts presented herein.

[0094] FIG. **15** schematically illustrates, in terms of a number of functional modules, the components of a network node **12** according to an embodiment. The network node of FIG. **15** comprises a number of functional modules, such as any of a receive module **51***a*, a generate module **51***b*, a transmit module **51***c*, and a perform module **51***d*. The functionality of each functional module **5***a-d* will be further disclosed below in the context of which the functional modules **51***a-d* may be used. In general terms, each functional module **51***a-d* may be implemented in hardware or in software. The processing unit **51** may thus be arranged to from the storage medium **53** fetch instructions as provided by a functional module **51***a-d* and to execute these instructions, thereby performing any steps as will be disclosed hereinafter.

[0095] FIGS. **10**, **16**, **17**, and **18** are flow chart illustrating embodiments of methods for authentication in device to device discovery. The methods of FIGS. **10** and **16** are performed by the wireless device acting as a Discoverer WD. The methods of FIGS. **10** and **17** are performed by the wireless device acting as a Discoveree WD. The methods of FIGS. **10** and **18** are performed by the network node.

[0096] The methods are advantageously provided as computer programs **32***a*, **32***b*, **32***c*. FIG. **11** shows one example of a computer program product **31***a*, **31***b*, **31***c* comprising computer readable means **33**. On this computer readable means **33**, at least one computer program **32***a*, **32***b*, **32***c* can be stored, which at least one computer program **32***a*, **32***b*, **32***c* can cause the processing units **41**, **51** and thereto operatively coupled entities and devices, such as the communications interfaces **42**, **52** and the storage medium **43**, **53**, to execute methods according to embodiments described herein. The at least one computer program **32***a*, **32***b*, **32***c* and/or computer program products **31***a*, **31***b*, **31***c* may thus provide means for performing any steps as herein disclosed.

[0097] In the example of FIG. **11**, the computer program product **31***a*, **31***b*, **31***c* is illustrated as an optical disc, such as a CD (compact disc) or a DVD (digital versatile disc) or a Blu-Ray disc. The computer program product **31***a*, **31***b*, **31***c* could also be embodied as a memory, such as a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM), or an electrically erasable programmable read-only memory (EEPROM) and more particularly as a non-volatile storage medium of a device in an external memory such as a USB (Universal Serial Bus) memory. Thus, while the computer programs **32***a*, **32***b*, **32***c* are here schematically shown as a track on the depicted optical disk, the computer programs **32***a*, **32***b*, **32***c* can be stored in any way which is suitable for the computer program product **31***a*, **31***b*, **31***c*.

[0098] Reference is now made to FIG. **16** illustrating a method for authentication in device to device discovery as performed by a Discoverer device according to an embodiment.

[0099] According to some embodiments the Discoverer device is configured to, in a step **S101**, broadcast a direct discovery request. According to some embodiments the Discoverer device is configured to, in a step **S102**, receive a direct discovery response from a Discoveree device. The direct discovery response comprises a first token.

[0100] Thus, when the Discoverer WD wishes to discover other WDs (Discoveree WDs) in its vicinity, it broadcasts a Direct Discovery Request message. The Discoveree WD(s) process the Direct Discovery Request message and based on the information in the Direct Discovery Request message the Discoveree WDs may decide to respond with a Direct Discovery Response message.

[0101] When the Discoverer WD receives the Direct Discovery Response message, then the Discoverer WD may need to ensure that the Discoveree WD is genuine and that the Discovery response message is not replayed by a false WD, and the Discoverer WD, and/or may need to ensure that the Discoveree WD is authorized by the ProSe Function in the network to respond to the announced Discovery request message.

[0102] According to herein disclosed embodiments a Token (a first token) is included in the Direct Discovery Response message from the Discoveree WDs to the Discoverer WD. According to some embodiments the Discoverer device is configured to, in a step **S103**, obtain a determination of whether the first token was generated for the Discoveree device or not.

[0103] FIG. **8** schematically illustrates a signalling flow diagram for authentication in device to device discovery involving one Discoverer WD1 and three Discoveree WD2, WD3, WD4, where Discoveree WD3 and WD4 respond to an announced Discovery request message from the Discoverer WD1 with respective identifiers and Tokens. In the example in FIG. **8**, the Model B ("who is there"/"are you there") is used. The Discoverer WD transmits a ProSe Application ID and its identity in the Direct Discovery Request message. When the Discoveree WD2 or Discoveree WD3 or Discoveree WD4 listens to the Direct Discovery Request messages and discovers a ProSe Application ID that the Discoveree WD is interested in, then the Discoveree WD replies by announcing a Direct Discovery Response message. In order for the Discoverer WD to determine whether the responding WD is a genuine WD, the responding Discoveree WD includes a Token together with the ProSe Application ID and the identifier of the responding Discoveree WD.

[0104] Reference is now continued to FIG. **16**.

[0105] The Discoverer device may optionally be configured to, in a step **S105**, and if determined that the first token was generated for the Discoveree device, enable exchange of data messages in direct communication with the Discoveree device.

[0106] The Discoverer device may optionally be configured to, in a step **S106**, and if determined that the first token was not generated for the Discoveree device, prevent exchange of data messages in direct communication with the Discoveree device.

[0107] There may be different ways relating to which device to generate the Token. For example the first token may be generated by a network node. The ProSe Function in the network may thus determine a Token which it provides to the Discoveree WD. The Discoveree WD then includes the Token to the Discoverer WD in Direct Discovery Response message. For example the first token may be generated by the Discoveree device. The Discoveree WD may thus generate the Token itself. The Discoveree WD then includes the Token in the Discovery response message back to the Discoverer WD in Direct Discovery Response message.

[0108] As noted above, the Discoverer WD receives the Direct Discovery Response message. The Discoverer WD needs to check the Token included in the Direct Discovery Response message.

[0109] The check of the Token may comprise determining a Token (a second token) for the Discoverer WD in the same way as for the Discoveree WD. The second token may be generated by a network node. The second token may be generated by the Discoverer device.

[0110] The Token for the Discoverer WD may be compared to the Token received in the Direct Discovery Response message. Hence the determination may comprise comparing the first token of the Discoveree WD to a second token of the Discoverer device.

[0111] If the two Tokens are equal then the Direct Discovery Response message is genuine. If the two Tokens are equal then the Discoverer WD knows that the Direct Discovery Response message is genuine which means that the Discoveree WD is genuine and authorized to respond and the Direct Discovery Response message is not a replayed Direct Discovery Response message.

[0112] There may be different ways relating to which device to compare the Tokens. The determination may be generated by the Discoverer device. The Discoverer WD may thus generate its own Token and compare it with the broadcasted Token in the Discovery response message. Alternatively the generation of the determination may comprise the Discoverer device to, in an optional step **S104**, query a network node to decide whether the first token was generated for the Discoveree device or not. The Discoverer WD may thus request the ProSe Function in the network to determine the Token of the Discoverer WD and compare the two Tokens on behalf of the Discoveree WD. The ProSe Function in the network then informs the Discoverer WD if the check of the Token was successful.

[0113] Encryption may be applied to at least one of the direct discovery response and the direct discovery request. Details thereof will now be disclosed in turn.

[0114] In general terms, a Token would not provide privacy to broadcasted identifiers in the Direct Discovery Response message, particularly not in Model B. Privacy could be provided by supporting encryption of the identifier (s).

[0115] For example, the direct discovery response may comprise at least two broadcasted identifiers, one of which is encrypted. Thus, if there are two broadcasted identifier(s) in the Direct Discovery Response message, for example a ProSe Application Identifier and a ProSe WD Identifier of the Discoveree WD, then it may be possible to encrypt the ProSe WD Identifier of the Discoveree WD, since the Discoverer WD may be able to filter out the Direct Discovery Response messages it is interested in by monitoring the ProSe Application Identifier.

[0116] For example, the direct discovery request may comprise at least two broadcasted identifiers, one of which is encrypted. Thus, if there are two or more broadcasted identifier(s) in the Direct Discovery Request message, for example a ProSe Application Identifier and a ProSe WD Identifier of the Discoverer WD, then it may be possible to encrypt the ProSe WD Identifier of the Discoverer WD, since the Discoveree WD may be able to filter out the Direct Discovery Request messages it is interested in by monitoring the ProSe Application Identifier which it is interested in.

[0117] Reference is now made to FIG. **17** illustrating a method for authentication in device to device discovery as performed by a Discoveree device according to an embodiment.

[0118] According to some embodiments the Discoveree device is configured to, in a step **S202**, receive a broadcasted direct discovery request from a Discoverer device. According to some embodiments the Discoveree device is configured to, in a step **S206**, transmit a direct discovery response to the Discoverer device. The direct discovery response comprises a first token.

[0119] The Discoveree device may optionally be configured to, in a step **S204***a*, request a network node to generate the first token. The Discoveree device may then be configured to, in a step **S204***b*, receiving the first token from the network node prior to transmitting the direct discovery response. Alternatively the Discoveree device may optionally be configured to, in a step **S204***c*, generate the first token prior to transmitting the direct discovery response.

[0120] Reference is now made to FIG. **18** illustrating a method for authentication in device to device discovery as performed by a network node according to an embodiment.

[0121] According to some embodiments the network node is configured to, in a step **S301**, receive a request to generate a first token from a Discoveree device. According to some embodiments the network node is configured to, in a step **S302**, generate the first token. According to some embodiments the network node is configured to, in a step **S303**, transmit the first token to the Discoveree device. According to some embodiments the network node is configured to, in a step **S304**, receive a request from a Discoverer device to determine whether the first token was generated for the Discoveree device or not. According to some embodiments the network node is configured to, in a step **S308**, perform a determination of whether the first token was generated for the Discoveree device or not. According to some embodiments the network node is configured to, in a step **S310**, transmit a result thereof to the Discoverer device.

[0122] The network node may optionally be configured to, in a step **S305**, receive a request to generate a second token from the Discoverer device. The network node may optionally be configured to, in a step **S306**, generate the second token. The network node may optionally be configured to, in a step **S309**, performing the determination by comparing the first token to the second token. The network node may optionally be configured to, in a step **S307**, transmit the second token to the Discoverer device.

[0123] Particular details of the first (and optionally the second token) will now be disclosed in more detail. However, as the skilled person understands, these are just

examples of tokens which may be readily used for authentication in device to device discovery as disclosed herein.

[0124] Based on the Direct Discovery Request message format as for example described in 3GPP TR 23.703 'Technical Specification Group Services and System Aspects; Study on architecture enhancements to support Proximity-based Services (ProSe); (Release 12)'—V1.1.0, Section 6.1.1.2.3.3, it may be assumed that the Direct Discovery Request message in Model B for example could indicate any of the combinations of identifiers presented in Table 1.

TABLE 1

Examples of identifiers in Direct Discovery Request messages in Model B
1) ProSe WD Identifier of Discoveree WD
2) ProSe Group Identifier of the group of Discoveree WDs
3) ProSe Application Identifier
4) ProSe Application Code
5) ProSe Application Identifier and ProSe WD Identifier of Discoverer WD
6) ProSe Application Code and ProSe WD Identifier of Discoverer WD
7) ProSe Application Identifier and ProSe Group Identifier of the group of Discoverer WD and Discoveree WDs
8) ProSe Application Code and ProSe Group Identifier of the group of Discoverer WD and Discoveree WDs

[0125] According to items 1), 2), 3), and 4) in Table 1 the identifier of the Discoverer WD (i.e., the ProSe WD Identifier of Discoverer WD) is not broadcasted.

[0126] According to items 5), and 6) in Table 1 the identifier of the Discoverer WD (i.e., the ProSe WD identifier of Discoverer WD) is broadcasted.

[0127] According to item 4) in Table 1 the Discoveree WD may check with the ProSe Function in the network whether the broadcasted ProSe Application Code (ProSe App Code) origins from an authorized Discoverer WD and also find out the identifier of the Discoverer WD from the ProSe Function in the network.

[0128] The format for the Direct Discovery Response message in Model B is not described in any 3GPP specification. Without loss of generality it is assumed that the Direct Discovery Response message for example may indicate any of the following combinations of identities presented in Table 2.

TABLE 2

Examples of identities included in Direct Discovery Response message in Model B
1) ProSe WD Identifier of Discoveree WD
2a) ProSe Group member Identifier of the Discoveree WD
2b) ProSe WD Identifier of Discoveree WD
3a) ProSe Application Identifier and ProSe WD Identifier of Discoveree WD
3b) ProSe Application Identifier and ProSe Group member Identifier of Discoveree WD
4a) ProSe Application Code and ProSe WD Identifier of Discoveree WD
4b) ProSe Application Code and ProSe Group member Identifier of Discoveree WD
5) ProSe Application Identifier and ProSe WD Identifier of Discoveree WD
6) ProSe Application Code and ProSe WD Identifier of Discoveree WD
7) ProSe Application Identifier and ProSe Group member Identifier of the Discoveree WD
8) ProSe Application Code and ProSe Group member Identifier of the Discoveree WD

[0129] The token may comprise a message authentication code (MAC). The MAC may be a function of any combination of a First parameter, a Second parameter, a Third parameter, and a Fourth parameter.

[0130] One purpose of the First parameter may be to provide a freshness indication. Examples of parameters which could provide this include, but are not limited to, a ProSe App Code, a time stamp, a time value, a counter value. The ProSe App Code could for example provide freshness in a time window. The ProSe App Code may be generated by the ProSe function in the network and may have an associated validity timer. When the validity timer expires then the ProSe App Code is no longer valid. Any freshness indication may be initialized upon generation of the token.

[0131] One purpose of the Second parameter may be to make it difficult to forge tokens. Examples of parameters which could be used for the Second parameter include, but are not limited to, a Discovery security key, a Group security key, and any security key shared between Discoverer WD and Discoveree WD. The Discovery security key may be shared by the Discoverer WD and the ProSe function in the network; or the Discovery key may be shared by the Discoverer WD and the Discoveree WD. The Group key may be shared by all the Group members part of the same Group.

[0132] One purpose of the Third parameter may be to make the token unique per Discoveree WD. Examples of parameters which could be used for the Third parameter include, but are not limited to a Discoveree WD identifier as ProSe WD identifier, a Discoveree WD identifier as ProSe Group member identifier, a group member within a Group identified by a Group identifier, and any other Discoveree WD identifier.

[0133] One purpose of the Fourth parameter may be to map the Direct Discovery Response to the Direct Discovery Request. Some examples of the Fourth parameter will be provided next. The ProSe App Code included in the Direct Discovery Request message. Note that if the ProSe App Code has been used as the First parameter then it may not be needed to be included twice. The ProSe Group identifier included in the Direct Discovery Request message. The ProSe Application Identifier included in the Direct Discovery Request message. Any combination of ProSe Application identifier and ProSe Group identifier. Any combination of ProSe App Code and ProSe Group identifier. Any other identifier included in the Direct Discovery Request message.

[0134] Particular embodiments relating to authentication in device to device discovery will now be disclosed in more detail.

[0135] Further details of Direct Discovery Response messages will now be disclosed. It is without loss of generality assumed that Model B is used and that a Discoveree WD listens to broadcasted Direct Discovery Request messages announcing a code and/or identifier(s). In general terms, when the Discoveree WD is hearing a code or identifier in

the message which it is interested in, it is assumed that the Discoveree WD would like to respond back to the Discoverer WD with a Direct Discovery Response message including a Token.

[0136] According to embodiments (hereinafter denoted Embodiment 1) the Discoveree WD contacts the ProSe Function in the network, requesting the ProSe function to check whether the Direct Discovery Request message is broadcasted by an authorized Discoverer WD. If the ProSe Function in the network determines that the Discoverer WD is genuine, and determines that the Discoveree WD is allowed to respond to the Direct Discovery Request message, then the ProSe Function generates a Token by using a shared security key (for example a Discovery security key, a Group security key or any other security key) which the ProSe Function in the network shares with the Discoverer WD. The Token may comprise a MAC determined over a defined number of parameters, known by the ProSe Function in the network and also known by the Discoverer WD. The Token may be generated in many different ways, for example as described above. The ProSe Function in the network provides the Token to the Discoveree WD. The Discoveree WD broadcasts the Direct Discovery Response message including the Token. The Discoverer WD hears the Direct Discovery Response message including the Token.

[0137] There are at least two different variants of how the Discoverer WD continues when it hears the Direct Discovery Response message including the Token, which it is interested in.

[0138] According to embodiments (hereinafter denoted Embodiment 2) the Discoveree WD checks whether the Direct Discovery Request message is broadcasted by an authorized Discoverer WD. If the Discoveree WD determines that the Discoverer WD is genuine, then the Discoveree WD generates a Token by using a shared security key which the Discoveree WD shares with the Discoverer WD. The Token may comprise a MAC determined over a defined number of parameters, known by the Discoveree WD and also known by the Discoverer WD. The Token may be generated in many different ways, for example as described above. The Discoveree WD broadcasts the Direct Discovery Response message including the Token. The Discoverer WD hears the Direct Discovery Response message including the Token.

[0139] There are at least two different variants of how the Discoverer WD continues when it hears the Direct Discovery Response message including the Token, which it is interested in.

[0140] According to embodiments (hereinafter denoted Embodiment 3) the Discoverer WD determines the MAC over a defined number of parameters (for example the same parameters as used by the ProSe Function in the network), and the Discoverer WD compares the calculated MAC with the MAC in the Token. If the both MAC's are equal, then the Discoverer WD knows that the Discoveree WD transmitting the Direct Discovery Response message is genuine and authorized by the ProSe Function in the network to respond to the original Direct Discovery request message. The Discoverer WD knows now that the Discoveree WD is within proximity, and may take any appropriate action e.g., initiate direct communication with the Discoveree WD.

[0141] According to embodiments (hereinafter denoted Embodiment 4) the Discoverer WD requests the ProSe Function in the network to verify the Token by forwarding the Direct Discovery response message including the Token to the ProSe Function in the network. The ProSe Function in the network determines the MAC over a defined number of parameters (for example the same parameters as used by the ProSe Function in the network when determining the Token on behalf of the Discoveree WD). The ProSe Function in the network then compares the calculated MAC with the MAC in the Token. If the both MACs are equal, then the ProSe Function in the network knows that the Discoveree WD transmitting the Direct Discovery Response message is genuine and authorized by the ProSe Function in the network to respond to the original Direct Discovery Request message. The ProSe Function in the network informs the Discoverer WD that the Discoveree WD is genuine. The Discoverer WD knows now that the Discoveree WD is within proximity, and may take any appropriate action e.g., initiate direct communication with the Discoveree WD.

[0142] A detailed signaling flow diagram based on Embodiment 1, 2, 3, and 4 is provided in FIG. **9** and comprises steps as will be discussed below. Reference is also made to the flowchart of FIG. **10** based on Embodiment 1, 2, 3, and 4.

[0143] First Optional step (not illustrated in the figure): A shared security key, for example a Discovery key or Group key, may be pre-configured or provisioned in the Discoverer WD.

[0144] Second Optional step (not illustrated in the figure): A shared security key, for example a Discovery key or Group key, may be pre-configured or provisioned in the Discoveree WD.

[0145] Step **301**. Optional step: The Discoverer WD may transmit a Discovery Request message to the ProSe Function in order to request to be allowed to announce one or more identifiers/codes on that PLMN. The ProSe function may return the Discovery Response message (containing for example a ProSe App Code or an application Identifier or any other identifier) that the Discoverer WD is allowed to announce and may also include an associated security key (for example a Discovery Key, a Group Key or some other security key). The ProSe Function may store the Discovery Key together with the Discovery Request message.

[0146] Step **302**. Optional step: The Discoveree WD transmits a Discovery Request message to the ProSe Function in the network in order to obtain a code and/or identifier(s) that it wants to listen for. The ProSe Function in the network returns the code and/or identifier(s) to the Discoveree WD.

[0147] Step **303**. The Discoverer WD starts announcing (broadcasting) the Direct Discovery Request message.

[0148] Step **304**. The Discoveree WD listens for announced (broadcasted) information that comprises a code and/or identifier(s) that the Discoveree WD is interested in.

[0149] Now either steps **305**, **306**, **307**, **309**, **310**; or steps **305**, **306**, **307** (except for Embodiment 1), **308**, **309**, **310**; or steps **308**, **309**, **310** take place.

[0150] Step **305**. Upon hearing such an announced code or identifier, the Discoveree WD sends a Found Match Request message to the ProSe function with the Direct Discovery Request message comprising the code and/or identifier(s). The Discoveree WD may also transmit an indication that it wants to use, for example, Model B and announces (broadcasts) a Direct Discovery Response message.

[0151] Step **306**. The ProSe Function in the network verifies the received code and/or identifier(s). If the verification is successful, then, according to Embodiment 1, the

ProSe Function in the network generates a Token using a security key (for example a Discovery Key, a Group Key or some other security key).

[0152] Step **307**. The ProSe Function informs the Discoveree WD that the match of the Direct Discovery Request message was successful. The ProSe Function, according to Embodiment 1, provides the Token to the Discoveree WD.

[0153] Step **308**. Upon hearing such an announced code or identifier in step **304**, the Discoveree WD, according to Embodiment 2, verifies the received code and/or identifier(s) and if verification is successful, then the Discoveree WD generates a Token; or if the ProSe Function in in step **307** informs the Discoveree WD that the match of the Direct Discovery Request message was successful, then the Discoveree WD, according to Embodiment 2, generates a Token.

[0154] Step **309**. The Discoveree WD starts to announce (broadcast) the Direct Discovery Response message comprising the Token.

[0155] Step **310**. The Discoverer WD listens for Direct Discovery Response messages and receives the Direct Discovery Response message including the Token which it is interested in.

[0156] Now either step **311** or **312** takes place.

[0157] Step **311**. The Discoverer WD, according to Embodiment 3, verifies the Token using the shared secret key (for example a Discovery key or a group key or some other security key). If the verification is successful then the Discoverer WD knows that the Discoveree WD is within proximity.

[0158] Step **312**. The Discoverer WD, according to Embodiments 4, forwards the Token to the ProSe Function in the network. The ProSe Function in the network verifies the Token using the shared secret key (for example a Discovery key or a group key or some other security key). If the verification is successful then the ProSe Function knows that the Discoveree WD is genuine and within proximity. The ProSe Function in the network informs the Discoverer WD. Discoverer WD knows now that the Discoveree WD is within proximity.

[0159] Particular reference is now made to the flowchart of FIG. **10**.

[0160] Step **401**. The Discoveree WD receives an announced code and/or identitie(s) in a Direct Discovery request message from a Discoverer UE.

[0161] Step **402**. The Discoveree WD requests ProSe Function in the network to match the announced code and/or identitie(s), or the Discoveree WD matches the announced code and/or identitie(s) locally.

[0162] Step **403**. If the match is successful, then the Discoveree WD requests ProSe Function in the network to generate a Token, or the Discoveree WD generates the Token locally itself. In the first case, the ProSe Function in the network provides the Token to the Discoveree WD.

[0163] Step **404**. The Discoveree WD announces the Direct Discovery Response message including the Token.

[0164] Step **405**. The Discoverer WD hears the announced Direct Discovery Response message including the Token.

[0165] Step **406**. The Discoverer WD verifies the Token in the announced Direct Discovery Response message. The Discoverer WD could also request the ProSe Function in the network to verify the Token on behalf of the Discoverer WD. If the verification is successful then the Discoverer WD and Discoveree WD can start communication.

[0166] If the Token comprises a freshness value which the Discoverer WD in step **311** is not able to verify itself, then Discoverer WD may request the ProSe Function in the network to check the freshness value in step **312**.

[0167] Further details of encryption of identities in Direct Discovery Response messages will now be disclosed.

[0168] According to embodiments (hereinafter denoted Embodiment 5), if there, for example in Model B, are two broadcasted identifiers in the Direct Discovery Response message, for example a ProSe Application Identifier and a ProSe WD Identifier of the Discoveree WD, then it may be possible to encrypt the ProSe WD Identifier of the Discoveree WD, since the Discoverer WD may be enabled to filter out the Direct Discovery Response messages it is interested in by monitoring the ProSe Application Identifier which it is interested in. The ProSe Application Identifier would then be sent in clear text. Table 3 summarizes examples of broadcasted identifiers included in a Direct Discovery Response message.

TABLE 3

Examples of two broadcasted identities included in a Direct Discovery Response message

Discovery Model = Model B (Direct Discovery Response)	ProSe Application Identifier or ProSe App Code	Encrypted ProSe WD Identifier of Discoveree WD or Encrypted Group member identifier of Discoveree WD	Token (MAC)

[0169] Partial encryption of the Direct Discovery Response message would imply that Discoverer WD interested in a ProSe Application Identifier would need to decrypt the ProSe WD Identifier of Discoveree WD or Group member identifier of Discoveree WD in order to find out who has responded to the Direct Discovery Request message which Discoverer WD originally broadcasted.

[0170] If the Direct Discovery Response message only comprises one identifier as a ProSe WD identifier of the Discoveree WD or a Group member identifier of the Discoveree WD, also this identifier may be encrypted. It may be possible for the Discoverer WD to decrypt all broadcasted Direct Discovery Response messages it listens to, as the Discoverer WD then may not be able to filter out the Direct Discovery Response messages the Discoverer WD is interested in.

[0171] If it is assumed that partial encryption cannot be provided, the identifiers may not be broadcast in clear text and instead some temporary identifier allocated by the ProSe Function in the network may be temporarily broadcast.

[0172] Further details of encryption of identities in Direct Discovery Request messages will now be disclosed.

[0173] According to embodiments (hereinafter denoted Embodiment 6), if there, for example in Model B, are two broadcasted identifiers in the Direct Discovery Request message, for example a ProSe Application Identifier and a ProSe WD Identifier of the Discoverer WD, then it may be possible to encrypt the ProSe WD Identifier of the Discoverer WD, since the Discoveree WD may be enabled to filter out the Direct Discovery Request messages it is interested in by monitoring the ProSe Application Identifier. The ProSe Application Identifier may then be transmitted in clear text.

Table 4 summarizes examples of broadcasted identifiers included in a Direct Discovery Request message.

TABLE 4

Examples of two broadcasted identities included in a Direct Discovery Request message

Discovery Model = Model B (Direct Discovery Request)	ProSe Application Identifier or ProSe App Code	Encrypted ProSe WD Identifier of Discoverer WD or Encrypted Group Identifier	Token or MAC

[0174] Partial encryption of the Direct Discovery Request message would imply that Discoveree WDs interested in a ProSe Application Identifier would need to 1) decrypt the Group Identifier in order to find out whether the Direct Discovery Request message is addressed to them; or 2) decrypt the ProSe WD Identifier of Discoverer WD in order to find out what Discoverer WD transmitted the discovery request.

[0175] If the Direct Discovery Request message only comprises one identifier as a ProSe Application Identifier or a ProSe Application Code or Group Identifier, also this identifier may be encrypted. It may be possible for the Discoveree WD to decrypt all broadcasted Direct Discovery Request messages it listens to, as the Discoveree WD then may not be able to filter out the Direct Discovery Request messages the Discoveree WD is interested in.

[0176] The inventive concept has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended patent claims. For example, although referring to Model B, the embodiments disclosed herein are also applicable, mutatis mutandis, to Model A.

1. A method for device authorization in device to device discovery, the method being performed by a discoverer device, comprising:

broadcasting, by the discoverer device, a direct discovery request, the direct discovery request comprising an application identifier;

the discoverer device receiving a direct discovery response transmitted by a discoveree device, wherein the direct discovery response comprises: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, and further wherein the discoveree device transmitted the direct discovery response as a result of the discoveree device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request; and

the discoverer device using the first token to verify that the discoveree device is authorized to respond to the direct discovery request.

2. The method according to claim **1**, wherein the first token is generated by a network node.

3. The method according to claim **1**, wherein the first token is generated by the discoveree device.

4. The method according to claim **1**, wherein using the first token to verify that the discoveree device is authorized to respond to the direct discovery request comprises comparing the first token to a second token.

5. The method according to claim **4**, wherein the second token is generated by a network node.

6. The method according to claim **4**, wherein the second token is generated by the discoverer device.

7. The method according to claim **4**, wherein the comparing is performed by the discoverer device.

8. The method according to claim **1**, wherein using the first token to verify that the discoveree device is authorized to respond to the direct discovery request comprises:

the discoverer device querying a network node to decide whether the first token was generated for the discoveree device.

9. The method according to claim **1**, wherein the direct discovery response comprises the first token, an application identifier, and an encrypted discoveree device identifier, said discoveree device identifier identifying the discoveree device.

10. The method according to claim **9**, wherein the direct discovery request comprises the application identifier and an encrypted discoverer device identifier, said discoverer device identifier identifying the discoverer device.

11. The method according to claim **10**, wherein using the first token to verify that the discoveree device is authorized to respond to the direct discovery request comprises determining whether a second token matches the first token, wherein the second token is generated using the application identifier, a security key, and the discoveree device identifier.

12. The method according to claim **1**, further comprising:

prior to broadcasting the direct discovery request, the discoverer device transmitting to a network node a discovery request message requesting permission to announce an application identifier on a Public Land Mobile Network (PLMN); and

the discoverer device receiving a discovery response message transmitted by the network node, the discovery response message comprising: i) an application identifier that the network node has determined may be announced by the discoverer device and ii) a security key, wherein

the direct discover request broadcasted by the discoverer device comprises the application identifier that was included in the discovery response message transmitted by the network device,

the direct discovery response transmitted by the discoveree device also comprises the application identifier, and

the step of using the first token to verify that the discoveree device is authorized to respond to the direct discovery request comprises the discoverer device using the security key to generate a second token and discoverer device comparing the second token with the first token to determine whether the tokens are equal.

13. The method according to claim **1**, wherein the generation of the first token comprises using any of a discovery security key, a group security key, and a security key shared between discoverer device and the discoveree device.

14. The method according to claim **13**, wherein the discovery security key is shared by the discoverer device and a network node, wherein the discovery key is shared by

the discoverer device and the discoveree device, and wherein the group key is shared by all group members part of the same group.

15. A method for authentication in device to device discovery, the method being performed by a discoveree device, comprising:

receiving, at the discoveree device, a broadcasted direct discovery request transmitted by a discoverer device, the direct discovery request comprising an application identifier; and

transmitting, by the discoveree device, a direct discovery response to the discoverer device, the direct discovery response comprising: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, wherein

the discoveree device transmits the direct discovery response to the discoverer device as a result of the discoveree device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request.

16. The method according to claim **15**, further comprising:

requesting a network node to generate the first token; and

receiving the first token from the network node prior to transmitting the direct discovery response.

17. The method according to claim **15**, further comprising:

generating the first token prior to transmitting the direct discovery response.

18. A wireless device for authentication in device to device discovery, the wireless device comprising a processing unit and a non-transitory computer readable storage medium, said non-transitory computer readable storage medium comprising instructions executable by said processing unit whereby said wireless device is operative to:

broadcast a direct discovery request, the direct discovery request comprising an application identifier;

receive a direct discovery response transmitted by a discoveree device, wherein the direct discovery response comprises: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, and further wherein the discoveree device transmitted the direct discovery response as a result of the discoveree device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request; and

use the first token to verify that the discoveree device is authorized to respond to the direct discovery request.

19. A wireless device for authentication in device to device discovery, the wireless device comprising a processing unit and a non-transitory computer readable storage medium, said non-transitory computer readable storage medium comprising instructions executable by said processing unit whereby said wireless device is operative to:

receive a broadcasted direct discovery request transmitted by a discoverer device, the direct discovery request comprising an application identifier; and

transmit a direct discovery response to the discoverer device, the direct discovery response comprising: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, wherein

the wireless device is configured such that the wireless device transmits the direct discovery response to the discoverer device as a result of the wireless device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request.

20. A computer program product comprising a non-transitory computer readable medium storing a computer program for authentication in device to device discovery, the computer program comprising computer code which, when run on a wireless device, causes the wireless device to:

broadcast a direct discovery request, the direct discovery request comprising an application identifier;

receive a direct discovery response transmitted by a discoveree device, wherein the direct discovery response comprises: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, and further wherein the discoveree device transmitted the direct discovery response as a result of the discoveree device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request; and

use the first token to verify that the discoveree device is authorized to respond to the direct discovery request.

21. A computer program product comprising a non-transitory computer readable medium storing a computer program for authentication in device to device discovery, the computer program comprising computer code which, when run on a wireless device, causes the wireless device to:

receive a broadcasted direct discovery request transmitted by a discoverer device, the direct discovery request comprising an application identifier; and

transmit a direct discovery response to the discoverer device, the direct discovery response comprising: i) the application identifier, ii) a discoveree device identifier or an encrypted version thereof, and iii) a first token for verifying that the discoveree device is authorized to respond to the direct discovery request, wherein

the computer program is configured such that the wireless device transmits the direct discovery response to the discoverer device as a result of the wireless device receiving the direct discovery request and determining, based on the application identifier included in the direct discovery request, to respond to the direct discovery request.

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