**3GPP TSG- Meeting # *C3-232163r1***

**Bratislava, Slovakia, 22nd May – 26th May 2023 (Revision of C3-231552)**

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| *CR-Form-v12.2* |
| **CHANGE REQUEST** |
|  |
|  | **29.552** | **CR** | **0045** | **rev** | **3** | **Current version:** | **18.0.0** |  |
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| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* |
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| ***Proposed change affects:*** | UICC apps |  | ME |  | Radio Access Network |  | Core Network | **X** |

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|  |
| ***Title:***  | Procedures for Federated Learning among Multiple NWDAFs in 5GC |
|  |  |
| ***Source to WG:*** |  |
| ***Source to TSG:*** | CT3 |
|  |  |
| ***Work item code:*** | eNA\_Ph3 |  | ***Date:*** |  |
|  |  |  |  |  |
| ***Category:*** | **B** |  | ***Release:*** |  |
|  | *Use one of the following categories:****F*** *(correction)****A*** *(mirror corresponding to a change in an earlier release)****B*** *(addition of feature),* ***C*** *(functional modification of feature)****D*** *(editorial modification)*Detailed explanations of the above categories canbe found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | *Use one of the following releases:Rel-8 (Release 8)Rel-9 (Release 9)Rel-10 (Release 10)Rel-11 (Release 11)…Rel-16 (Release 16)Rel-17 (Release 17)Rel-18 (Release 18)Rel-19 (Release 19)* |
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| ***Reason for change:*** | In clause 6.2C.2 of TS 23.288, procedures are added to support Federated Learning among multiple NWDAFs in 5GC.This CR introduces the following procedures related to Federated Learning among multiple NWDAFs:* General procedure for Federated Learning among multiple NWDAF instances, which corresponds to clause 6.2C.2.2 of TS 23.288.
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| ***Summary of change:*** | The following changes are made:* Added the abbreviation for "Federated Learning" to clause 3.3.
* Added new clauses (5.10, 5.10.1, 5.10.2, 5.10.2.1) for the description and procedures related to Federated Learning among multiple NWDAFs in 5GC.
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| ***Consequences if not approved:*** | Misalignment with stage 2. No support of Federated Learning among multiple NWDAFs in 5GC. |
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| ***Clauses affected:*** | 3.3, 5.10(new), 5.10.1(new), 5.10.2(new), 5.10.2.1(new) |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** | **X** |  |  Other core specifications  | TS 23.288 CR 0765 |
| ***affected:*** |  | **X** |  Test specifications | TS/TR ... CR ...  |
| ***(show related CRs)*** |  | **X** |  O&M Specifications | TS/TR ... CR ...  |
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| ***Other comments:*** |  |
|  |  |
| ***This CR's revision history:*** | The changes made upon the previous version include:* Use the latest updated TS 29.552 as base
* Add/remove changes to the procedures in clause 5.10.2 according to the latest updated TS 23.288
* Remove detail parameters in the request/response messages of the procedures
* Update the cover page

CT3#128:The changes made upon the previous version include:* Updated the Figure 5.10.2.1-1 by adding detail service operation flows to steps 0, 1, 4, 6, 7, 10, and 11.
* Updated steps 0, 1, 4, 6, 7, 10, and 11 for the FL general procedure by adding descriptions for Nnwdaf\_MLModelProvision service, Nnwdaf\_MLModelTraining service and Nnwdaf\_MLModelTrainingInfo service.
* Removed the EN: “The services (i.e. Nnwdaf\_MLModelTraining, Nnwdaf\_MLModelTrainingInfo) in steps 1, 4 and 7 will be updated in the Figure 5.10.2.2-1 and to be aligned based on stage 2 requirements.”
* Added an EN: “How the Nnwdaf\_MLModelTrainingInfo service be used in steps 0e-0f, 1c-1d, 4c-4d, 6ae-6af, 6be-6bf, 7c-7d, and 10e-10f is FFS and will be updated.”
* Removed the EN: “Whether more FL related procedures are in the scope of CT3 is FFS and will align with stage 2 requirements.”
* Changed “Server NWDAF” and “Client NWDAF” to “FL Server NWDAF” and “FL Client NWDAF” to align with the terminology in stage 2.
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**Additional discussion(if needed):**

**Proposed changes:**

\*\*\* 1st Change \*\*\*

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

ADRF Analytics Data Repository Function

AF Application Function

AMF Access and Mobility Management Function

AnLF Analytics Logical Function

DCCF Data Collection Coordination Function

FL Federated Learning

MFAF Messaging Framework Adaptor Function

MDT Minimization of Drive Tests

ML Machine Learning

MTLF Model Training Logical Function

NEF Network Exposure Function

NRF Network Repository Function

NSACF Network Slice Admission Control Function

NWDAF Network Data Analytics Function

PCF Policy Control Function

SMF Session Management Function

UDM Unified Data Management

\*\*\* 2nd Change \*\*\*

## 5.10 Federated Learning among Multiple NWDAFs

### 5.10.1 General

The NWDAF containing MTLF can leverage Federated Learning (FL) technique to train an ML model. To apply FL technique for ML model training, there is no need for input data transfer (e.g. centralized into one NWDAF) but only need for cooperation among multiple NWDAFs (MTLF) distributed in different areas, i.e. sharing of ML model(s) and of the learning results among multiple NWDAFs (MTLF).

\*\*\* 3rd Change \*\*\*

### 5.10.2 Procedures related to Federated Learning

#### 5.10.2.1 General Procedure for Federated Learning among Multiple NWDAF Instances

This procedure is used by the NWDAF containing MTLF (FL Server NWDAF) to trigger FL among multiple NWDAF instances, by the multiple NWDAF containing MTLF (the FL Server NWDAF and FL Client NWDAF(s)) to execute Federated Learning in FL execution phase.



Figure 5.10.2.1-1: General procedure for FL among Multiple NWDAF

0a-0b. To send a request for ML model analytics events subscription to the NWDAF containing MTLF (the FL Server NWDAF), the NWDAF service consumer (NWDAF containing AnLF) invokes the Nnwdaf\_MLModelProvision\_Subscribe service operation by sending an HTTP POST request targeting the resource "NWDAF ML Model Provision Subscriptions".

 The FL Server NWDAF responses to the Nnwdaf\_MLModelProvision\_Subscribe service operation. Upon receipt of the HTTP POST request, if the subscription is accepted to be created, the FL Server NWDAF responds to the NWDAF service consumer with “201 Created”, and the URI of the created subscription is included in the Location header field. Details are described in clause 4.5.2.2 of 3GPP TS 29.520 [5].

0c-0d. To send a request for ML model training events subscription to the FL Server NWDAF, the NWDAF service consumer (NWDAF containing MTLF) may invoke the Nnwdaf\_MLModelTraining\_Subscribe service operation by sending an HTTP POST request targeting the resource "NWDAF ML Model Training Subscriptions".

 The FL Server NWDAF responses to the Nnwdaf\_MLModelTraining\_Subscribe request. Upon the receipt of the HTTP POST request, if the subscription is accepted to be created, the FL Server NWDAF responds to the NWDAF service consumer with "201 Created", and the URI of the created subscription is included in the Location header field. Details are described in clause 4.6.2.2 of 3GPP TS 29.520 [5].

0e-0f. The NWDAF service consumer (NWDAF containing MTLF) may invoke the Nnwdaf\_MLModelTrainingInfo\_Request service operation to send a request for ML model training events to the FL Server NWDAF.

Editor’s Note: How the Nnwdaf\_MLModelTrainingInfo service be used in steps 0e-0f, 1c-1d, 4c-4d, 6ae-6af, 6be-6bf, 7c-7d, and 10e-10f is FFS.

NOTE 1: The requested accuracy level can be used to indicate the target ML model accuracy of the training process, and the FL Server NWDAF may stop the training process when the ML model accuracy threshold is achieved during the training process.

 If the consumer (i.e. the NWDAF containing AnLF) provides the time when the ML model is needed, the FL Server NWDAF can take this information into account to decide the maximum response time for its FL Client NWDAFs.

1a-1b. To request the selected NWDAF containing MTLF (the FL Client NWDAF) to perform the local model training, the FL Server NWDAF may invoke Nnwdaf\_MLModelTraining\_Subscribe service operation by sending an HTTP POST request targeting the resource "NWDAF ML Model Training Subscriptions". The FL Client NWDAF responses to the Nnwdaf\_MLModelTraining\_Subscribe service operation with an HTTP "201 Created" status code to the FL Server NWDAF, as defined in clause 4.6.2.2 of 3GPP TS 29.520 [5].

1c-1d. The FL Server NWDAF may invoke Nnwdaf\_MLModelTrainingInfo\_Request service operation to request the selected FL Client NWDAF to perform the local model training.

2a-2b. To subscribe to notification (or to modify subscriptions to notifications) of data events from the data source NF, each FL Client NWDAF may invoke the Nnf\_EventExposure\_Subscribe service operation by sending an HTTP POST (or PUT, for modification) request targeting the resource representing event exposure subscriptions of that NF.

 The data source NF responds to the Nnf\_EventExposure\_Subscribe service operation. Upon receipt of the HTTP POST request, if the subscription is accepted to be created, the NF responds to the FL Client NWDAF with "201 Created", and the URI of the created subscription is included in the Location header field.

3a-3b. If the data source NF observes the subscribed event(s), the NF invokes the Nnf\_EventExposure\_Notify service operation to report the event(s) by sending an HTTP POST request.

 On success, the FL Client NWDAF sends an HTTP “204 No Content” response to the NF.

4. During FL training process, each FL Client NWDAF further trains the retrieved ML model from the FL Server NWDAF based on its own/collected data, and reports interim local ML model information to the FL Server NWDAF. Each FL Client NWDAF also computes local model metric and reports it to the FL Server NWDAF. The ML model information are exchanged between the FL Client NWDAF(s) and the FL Server NWDAF during the FL training process.

4a-4b. To report the ML model training information, the FL Client NWDAF may invoke Nnwdaf\_MLModelTraining\_Notify service operation as defined in clause 4.6.2.4 of 3GPP TS 29.520 [5]. The FL Server NWDAF stores the notification and responds to the Nnwdaf\_MLModelTraining\_Notify service operation with an HTTP "204 No Content" status code to the FL Client NWDAF.

4c-4d. The FL Client NWDAF may invoke Nnwdaf\_MLModelTrainingInfo\_Response service operation to report the ML model training information.

* If the FL Client NWDAF is not able to complete the training of the interim local ML model within the maximum response time provided by the FL Server NWDAF, the FL Client NWDAF notifies the FL Server NWDAF on the delay event with proper cause information before the maximum response time elapses.

4e. [Optional] If FL Server NWDAF receives notification that the FL Client NWDAF is not able to complete the training within the maximum response time, the FL Server NWDAF may send to the FL Client NWDAF an extended maximum response time by invoking Nnwdaf\_MLModelTraining\_Subscribe or Nnwdaf\_MLModelTrainingInfo\_Request service operation, before which the FL Client NWDAF shall report the interim local ML model information to the FL Server NWDAF. Otherwise, the FL Server NWDAF may indicate FL Client NWDAF to skip reporting for this iteration.

5. The FL Server NWDAF aggregates all the local ML model information retrieved at step 4, to update the global ML model. The FL Server NWDAF may also compute the global model metric.

- If the FL Server NWDAF provides the maximum response time for the FL Client NWDAFs to provide the interim local ML model information in step 1, the FL Server NWDAF decides either to wait for the FL Client NWDAFs which have not yet provided their interim local ML model within the maximum response time or aggregates only the retrieved local ML model information instances to update global ML model. The FL Server NWDAF makes this decision, considering the notification from the FL Client NWDAF or, if the notification is not received, based on local configuration.

6a. [Optional] Based on the NWDAF service consumer request, the FL Server NWDAF updates the training status (e.g., global model metric) to the NWDAF service consumer periodically or dynamically when some pre-determined status is achieved.

6aa-6ab. To report the ML model training information, the FL Server NWDAF invokes Nnwdaf\_MLModelProvision\_Notify service operation as defined in clause 4.5.2.4 of 3GPP TS 29.520 [5]. The NWDAF service consumer stores the notification and responds to the Nnwdaf\_MLModelProvision\_Notify service operation with an HTTP "204 No Content" status code to the FL Server NWDAF.

6ac-6ad. The FL Server NWDAF invokes Nnwdaf\_MLModelTraining\_Notify service operation as defined in clause 4.6.2.4 of 3GPP TS 29.520 [5] to report the ML model training information. The NWDAF service consumer stores the notification and responds to the Nnwdaf\_MLModelTraining\_Notify service operation with an HTTP "204 No Content" status code to the FL Server NWDAF.

6ae-6af. The FL Server NWDAF invokes Nnwdaf\_MLModelTrainingInfo\_Response service operation to report the ML model training information.

6b. [Optional] The NWDAF service consumer decides whether the current model can fulfil the requirement. The NWDAF service consumer modifies subscription (stops or continues the training process) according to the NWDAF service consumer decision.

6ba. To modify the existing subscription, the NWDAF service consumer invokes Nnwdaf\_MLModelProvision\_Subscribe service operation by sending an HTTP PUT request with Resource URI of the resource "Individual NWDAF ML Model Provision Subscription". The FL Server NWDAF responds to the NWDAF service consumer with an HTTP "200 OK" or "204 No Content" status code, as defined in clause 4.5.2.2.3 of 3GPP TS 29.520 [5].

6bb. The NWDAF service consumer invokes Nnwdaf\_MLModelTraining\_Subscribe service operation to modify the existing subscription by sending an HTTP PUT request or an HTTP PATCH request with Resource URI of the resource "Individual NWDAF ML Model Training Subscription". The FL Server NWDAF responds to the NWDAF service consumer with an HTTP "200 OK" or "204 No Content" status code, as defined in clauses 4.6.2.2.3 and 4.6.2.2.4 of 3GPP TS 29.520 [5].

6cb. The NWDAF service consumer invokes Nnwdaf\_MLModelTrainingInfo\_Request service operation to modify the existing subscription.

6c. [Optional] According to the request from the NWDAF service consumer, the FL Server NWDAF updates or terminates the current FL training process.

7. If the FL procedure continues, the FL Server NWDAF sends the aggregated ML model information to each FL Client NWDAF for next round model training.

7a. To modify the existing subscription, the FL Server NWDAF invokes Nnwdaf\_MLModelTraining\_Subscribe service operation by sending an HTTP PUT request or an HTTP PATCH request with Resource URI of the resource "Individual NWDAF ML Model Training Subscription". The FL Client NWDAF responds to the FL Server NWDAF an HTTP "200 OK" or "204 No Content" status code, as defined in clauses 4.6.2.2.3 and 4.6.2.2.4 of 3GPP TS 29.520 [5].

7b. The FL Server NWDAF invokes Nnwdaf\_MLModelTrainingInfo\_Request service operation to modify the existing subscription.

8. Each FL Client NWDAF updates its own ML model based on the aggregated ML model information distributed by the FL Server NWDAF at step 7.

NOTE 2: The steps 4-8 should be repeated until the training termination condition (e.g. maximum number of iterations, or the result of loss function is lower than a threshold) is reached.

9a-9b. To unsubscribe to the notifications of data events from the data source NF, the FL Client NWDAF invokes the Nnf\_EventExposure\_Unsubscribe service operation by sending an HTTP DELETE request targeting the resource that represents the previously created individual event exposure subscription.

 The data source NF responds to the Nnf\_EventExposure\_Unsubscribe service operation. If the subscription deletion is accepted, the NF responds with "204 No Content".

10. If the FL Server NWDAF determines that the subscribed ML model information is available, the FL Server NWDAF may invoke the Nnwdaf\_MLModelProvision\_Notify service operation or the Nnwdaf\_MLModelTraining\_Notify service operation to report the ML model information by sending an HTTP POST request to the NWDAF service consumer identified by the notification URI received during the creation/modification of the subscriptions. The NWDAF service consumer responds to the FL Server NWDAF with an HTTP "204 No Content" message.

 If the FL Server NWDAF determines that the subscribed ML model information is available, the FL Server NWDAF may invoke the MLModelTrainingInfo\_Response service operation to report the ML model information.

11a-11b. To unsubscribe from the notification(s) of the ML model information, the NWDAF service consumer invokes the Nnwdaf\_MLModelProvision\_Unsubscribe service operation by sending an HTTP DELETE request, which targets the resource "Individual NWDAF ML Model Provision Subscription", to the FL Server NWDAF, as defined in clause 4.5.2.3 of 3GPP TS 29.520 [5].

 If the request is accepted, the FL Server NWDAF deletes the subscription and responds to the NWDAF service consumer with an HTTP "204 No Content" message.

11c-11d. To unsubscribe from the notification(s) of the ML model information, the NWDAF service consumer invokes the Nnwdaf\_MLModelTraining\_Unsubscribe service operation by sending an HTTP DELETE request, which targets the resource "Individual NWDAF ML Model Training Subscription", to the FL Server NWDAF, as defined in clause 4.6.2.3 of 3GPP TS 29.520 [5].

 If the request is accepted, the FL Server NWDAF deletes the subscription and responds to the NWDAF service consumer with an HTTP "204 No Content" message.

\*\*\* End of Changes \*\*\*