**3GPP TSG- Meeting # *S2-2411626***

**18th – 22nd November, 2024, Orlando, US (Revision of S2-2411194)**

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| *CR-Form-v12.3* |
| **CHANGE REQUEST** |
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|  |  | **CR** |  **1134** | **rev** | **14** | **Current version:** |  |  |
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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:***  | General training procedure for Vertical Federated Learning between NWDAF(s) and AF(s) |
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| ***Source to WG:*** | China Mobile, CATT, ZTE, OPPO, China Telecom, ETRI, Huawei, HiSilicon, Nokia, Futurewei, Samsung |
| ***Source to TSG:*** | SA2 |
|  |  |
| ***Work item code:*** |  |  | ***Date:*** | 07 |
|  |  |  |  |  |
| ***Category:*** |  |  | ***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-17 (Release 17)Rel-18 (Release 18)Rel-19 (Release 19) Rel-20 (Release 20)* |
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| ***Reason for change:*** | The paper adding procedure of Vertical Federated Learning when NWDAF is acting as VFL server.//////////////////////////////////////////////////////////////////////////////////////////////////////1. The following two ENs are suggested to be removed. Because if dynamical reselection, addition, or removal of VFL client occurs, it means the training procedure will stop and the VFL model will have to be re-trained after performing sample and feature alignment with the new members of VFL, which obviously introduces much complex considering R19 time limitation and could be left to the next release.Editor’s Note: Whether and how to maintain a Vertical Federation Learning process including dynamical reselection, addition, or removal of VFL Client NWDAF(s) is FFS.Editor’s Note: the following is FFS. The VFL server determines with which VFL Client(s) to continue the VFL. The VFL server may provide to the VFL clients any sample ID(s) if changed.2. The EN below can be removed by replacing “backward local ML model training information” with “intermediate model training information” based on the offline discussion.Editor’s Note: It is FFS if the term “backward local ML model training information” needs to be changed into “intermediate results”. |
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| ***Summary of change:*** | Adding new clause for procedure of Vertical Federated Learning when NWDAF is acting as VFL serverRemoved 3 ENs. |
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| ***Consequences if not approved:*** | VFL training procedure not specified. |
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| ***Clauses affected:*** | 6.2H.2.3 (new), 6.2H.2.3.1 (new) |
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|  | **Y** | **N** |  |  |
| ***Other specs*** |  | **X** |  Other core specifications  | TS/TR ... CR ...  |
| ***affected:*** |  | **X** |  Test specifications | TS/TR ... CR ...  |
| ***(show related CRs)*** |  | **X** |  O&M Specifications | TS/TR ... CR ...  |
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| ***Other comments:*** | CRs shall be implemented in the following order:CR 1198, CR 1246, CR1235, CR1208, CR1134 |
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| ***This CR's revision history:*** |  |

>>>>BEGINNING OF CHANGES<<<<

#### 6.2H.2.3 Training Procedure for Vertical Federated Learning

##### 6.2H.2.3.1 Training Procedure for Vertical Federated Learning when NWDAF is acting as VFL server

The figure 6.2H.2.3.1-1 below shows the training procedure for Vertical Federated Learning when NWDAF is acting as VFL server.

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Figure 6.2H.2.3.1-1Training procedure for Vertical Federated Learning when NWDAF is acting as VFL server

Editor’s Note: Further extensions are needed to show the interaction between consumer and VFL server. For example, how the consumer (i.e., NWDAF containing AnLF) sends a subscription request to VFL server.

Editor's Note: How the NEF assists the VFL training process as well as whether the service operations going via NEF is using the existing or new service operation are FFS.

Editor’s Note: The details of the services in the procedure and whether VFL Training Start Flag is needed are FFS.

Editor’s Note: It is FFS whether sample/feature information is required to be provided in each training.

Editor´s Note: Whether and how to include interoperability information in the VFL training procedure is FFS.

Editor’s Note: Terminology will be aligned in the future.

0. OPTIONAL If the first NWDAF containing both AnLF and MTLF and can be the VFL server, then step 0 is skipped.

If the first NWDAF is an NWDAF only containing AnLF and does not have a model, it sends a subscription request for a model to NWDAF containing MTLF using Nnwdaf\_MLModelProvision\_Subscribe including Analytics ID, optionally Target of Analytics Reporting = e.g. UE IDs.

Editor’s note: the following case (steps 0a and 0b) is FFS and shall be removed if trusted AF is to not be included in this clause. If NWDAF containing MTLF does not have a model and realizes it cannot be VFL server, the NWDAF sends a subscription request for a model to VFL server AF using Naf\_VFLOperation\_Subscribe including Analytics ID, optionally Notification target set to the first NWDAF, optionally Target of Analytics Reporting = e.g. UE IDs.

 If decision is triggered on request from an NWDAF, the NWDAF containing MTLF sends in the service subscription response that no model will be available to download.

Either based on the information received, operator policy or internal configuration, VFL server decides to initiate VFL inference procedure with VFL clients.

1. The NWDAF acting as VFL server determines the VFL clients that participate in VFL procedure in the VFL clients discovery and preparation phase as described in the clause 6.2H.2.1 and clause 6.2H.2.2.

NOTE: VFL Server determines to perform VFL training based on the internal trigger or local configuration.

The steps 2-6 are repeated until the training termination condition is reached.

2. To start VFL training, the VFL server allocates VFL correlation ID. The VFL server sends a request to start the VFL training to each of the selected VFL clients. The VFL server NWDAF sends a Nnwdaf\_MLModelTraining\_Subscribe or Nnwdaf\_MLModelTrainingInfo\_Request to the selected NWDAF clients(s) and Naf\_VFLTraining\_Subscribe or Naf\_VFLTrainingInfo\_Request to the selected AF clients(s). The request includes VFL correlation ID, VFL capability type (VFL Client) Analytics ID, Vendor-specific Feature ID, applicable samples optional the analytic filter information.The request may also include maximum response time(i.e. the maximum time between VFL clients receive backward local model information and send back intermediate training result).

If a VFL client is an untrusted AF, NWDAF as VFL server sends the VFL training request to the AF via NEF, the NEF may translate the analytic filter information if needed, e.g. TAIs into geographical area.

Editor´s Note: Analytics ID and Vendor-specific Feature ID might already have been indicated in the preparation phase and are then no longer required

 If the VFL procedure continues in subsequent iterations, the VFL server sends a request for a new VFL training iteration containing the intermediate model training information to each of the VFL clients for next round of VFL training.The intermediate training information may also include training checkpoint information which indicates VFL clients to either save the current model status or restart the training from a previous model status. The VFL server may also request re-start of training from a previously agreed checkpoint with the clients if there has been a change of availability in the samples (e.g., UEs) used by the clients.

NOTE: The initial local models for VFL clients may be provisioned by the VFL server by methods outside the scope of 3GPP.

Editor´s Note: Additional Parameters to be provided in the request are FFS.

Editor´s Note: It is FFS whether and how the local ML model is obtained by VFL Client in VFL training process.

Editor’s Note: It is FFS which service is used between VFL server and VFL clients for VFL training.

3. [Optional] Each VFL client collects its local data by using the current mechanism if the VFL client has no local data already available.

4. During VFL training procedure, each VFL client further trains the local ML model associated with the same VFL Correlation ID based on their own collected or available data and when applicable (e.g., after the first round of training) based on possible intermediate model training information distributed by the VFL server in the previous training iteration, and computes and reports the client intermediate training result of the local ML model to the VFL server. VFL client(s) may also report a change in the samples it is working with by including the missing sample ID(s) in intermediate training result.

Editor´s note: The following is FFS and may depend on the service design: When the clients reports the client intermediate training result, it also includes the corresponding VFL correlation ID.

5. The VFL server may collect the local data and generate its own local intermediate training result. The NWDAF acting as VFL Server computes the intermediate model training information (e.g. gradient information or loss information) based on the client intermediate training result received in step 4 taking into account the supported Features by each VFL client, its own local intermediate results and the label. The intermediate model training information is used for updating the models of VFL clients. Different intermediate model training information may be computed for different VFL clients, respectively.

 The VFL server may also compute the ML model metric (e.g. ML model accuracy) based on all the intermediate training result received from VFL clients and the label.

Editor’s Note: Whether weight of feature is computed by VFL server is FFS.

Editor’s Note: Whether VFL server and VFL clients share feature information is FFS.

6. [Optional] The NWDAF acting as VFL server evaluates (e.g., based on the convergence of a loss function or loss value, the pre-set iteration number is reached) whether VFL Training process converged. If not, the NWDAF acting as a VFL Server determines another round of VFL training is required and repeats step 2 - 6. If yes, it determines the VFL Training is completed. In this case, the VFL Server terminates the current VFL training process via step 7.

The VFL training termination decision may be also made as follows:

Based on the consumer request, the VFL server sends VFL status report to the consumer. The status report may include model metric (e.g. ML model accuracy).

Editor’s Note: The content of the VFL status report is FFS.

Editor’s Note: Whether VFL server sending convergence report to the VFL client and what is convergence report are FFS

The consumer decides whether the current model can fulfil the requirement, e.g. ML model metric is satisfactory for the consumer and determines to stop or continue the training process. The consumer continues the training process or stops the training process.

Based on the subscription request sent from the consumer, the VFL server updates or terminates the current VFL training process.

7. The VFL server sends VFL training termination message to VFL Client if it decides to terminate the VFL training process. The VFL Server and each VFL Client, stores the VFL correlation ID and latest information related to their locally trained Models.The VFL Sever (i.e. NWDAF) and VFL Client (i.e. NWDAF and trusted AF) may optionally store the latest ML Model information to ADRF.

NOTE X: The VFL correlation ID is used later for inference.

Editor’s Note: Whether VFL Training termination Flag in the termination message is required will be determined after we decide the service operation used in VFL training process.

NOTE Y: The VFL server and VFL client need to locally maintain the mapping relationship between ML Model ID and VFL correlation ID locally if they stores the ML Model information to ADRF after VFL training process.

NOTE 1: If untrusted AF is involved in VFL Clients, the message between NWDAF acting as VFL Server and the untrusted AF is via NEF.

>>>>END OF CHANGES<<<<