## 

## 5.2 NWDAF Discovery and Selection

The NWDAF service consumer selects an NWDAF that supports requested analytics information and required analytics capabilities and/or requested ML Model Information by using the NWDAF discovery principles defined in clause 6.3.13 of TS 23.501 [2].

Different deployments may require different discovery and selection parameters. Different ways to perform discovery and selection mechanisms depend on different types of analytics/data (NF related analytics/data and UE related analytics/data). NF related refers to analytics/data that do not require a SUPI nor group of SUPIs (e.g. NF load analytics). UE related refers to analytics/data that requires SUPI or group of SUPIs (e.g. UE mobility analytics).

In order to discover an NWDAF containing AnLF using the NRF:

- If the analytics is related to NF(s) and the NWDAF service consumer (other than an NWDAF) cannot provide an Area of Interest for the requested data analytics, the NWDAF service consumer may select an NWDAF with large serving area from the candidate NWDAFs from discovery response. Alternatively, in case the consumer receives NWDAF(s) with aggregation capability, the consumer preferably selects an NWDAF with aggregation capability with large serving area.

NOTE 1: If the selected NWDAF cannot provide the requested data analytics, e.g. due to the NF(s) to be contacted being out of serving area of the NWDAF, the selected NWDAF might reject the analytics request/subscription or it might query the NRF with the service area of the NF to be contacted to determine another target NWDAF.

- If the analytics is related to UE(s) and the NWDAF service consumer (other than an NWDAF) cannot provide an Area of Interest for the requested data analytics, the NWDAF service consumer may select an NWDAF with large serving area from the candidate NWDAFs from discovery response. Alternatively, in case the consumer receives NWDAF(s) with aggregation capability, the consumer preferably selects an NWDAF with aggregation capability with large serving area.

NOTE 2: If a selected NWDAF cannot provide analytics for the requested UE(s) (e.g. the NWDAF serves a different serving area), the selected NWDAF might reject the analytics request/subscription or it might determine the AMF serving the UE as specified in clause 6.2.2.1, request UE location information from the AMF and query the NRF with the tracking area where the UE is located to discover another target NWDAF serving the area where the UE(s) is located.

- If the analytics are related to UE(s) and if NWDAF instances indicate weights for TAIs in their NF profile (see clause 6.3.13 of TS 23.501 [2]), the NWDAF service consumer may use the weights for TAIs to decide which NWDAF to select.

- If the NWDAF service consumer needs to discover an NWDAF containing an AnLF with analytics accuracy checking capability, the consumer may query NRF providing also the analytics accuracy checking capability in the discovery request.

- If the NWDAF service consumer needs to discover an NWDAF containing AnLF which can use the Model provided by the specific NWDAF containing MTLF (e.g., in case of analytics context transfer), the consumer should discover the NWDAF(s) whose vendor ID is in the ML Model Interoperability indicator of the NWDAF containing MTLF.

If the NWDAF service consumer needs to discover an NWDAF that is able to collect data from particular data sources identified by their NF Set IDs or NF types or to collect data from particular NWDAF Serving Area, the consumer may query NRF providing the NF Set IDs or NF types or Area of Interest in the discovery request.

NOTE 3: The NF Set ID or NF Type of a data source serving a particular UE, can be determined as indicated in Table 5A.2-1.

In order to discover an NWDAF that has registered in UDM for a given UE:

- NWDAF service consumers or other NWDAFs interested in UE related data or analytics, if supported, may make a query to UDM to discover an NWDAF instance that is already serving the given UE.

If an NWDAF service consumer needs to discover NWDAFs with data collection exposure capability, the NWDAF service consumer may discover via NRF the NWDAF(s) that provide the Nnwdaf\_DataManagement service and their associated NF type of data sources or their associated NF Set ID of data sources or NWDAF Serving Area information as defined in clause 6.3.13 of TS 23.501 [2].

In order to discover an NWDAF containing MTLF via NRF:

- When one or more trained ML Models are available for one or more Analytics ID(s) the NWDAF containing MTLF shall include the Analytics ID(s) that is(are) supported per service in the registration towards NRF. The NWDAF containing MTLF may wait to register in NRF the above services until at least one trained model is available. The NWDAF containing MTLF may provide to the NRF a list of Analytics IDs corresponding to the trained ML Models and possibly the ML Model Filter Information for the trained ML Model per Analytics ID(s), if available. In this Release of the specification, only the S-NSSAI(s) and Area(s) of Interest from the ML Model Filter Information for the trained ML Model per Analytics ID(s) may be registered into the NRF during the NWDAF containing MTLF registration. If the NWDAF containing MTLF supports ML Model interoperability, the NWDAF containing MTLF includes, in the registration to the NRF, an ML Model Interoperability indicator for each Analytics ID.

Editor's note: How to indicate supporting model training for the LMF-based AI/ML positioning as defined in TS 23.273 [39] by the MTLF to NRF, e.g., using a specific analytics ID or a new indication is FFS.

Editor's note: For model training for LMF-based AI/ML positioning, whether Positioning case information (e.g. Uplink/downlink, or case 2b, 3b) can be included in NF profile as an optional parameter is FFS.

- The ML Model Interoperability indicator comprises a list of NWDAF providers (vendors) that are allowed to retrieve ML Models from this NWDAF containing MTLF. It also indicates that the NWDAF containing MTLF supports the interoperable ML Models requested by the NWDAFs from the vendors in the list.

NOTE 4: The S-NSSAI(s) and Area(s) of Interest from the ML Model Filter Information are within the indicated S-NSSAI and NWDAF Serving Area information in the NF profile of the NWDAF containing MTLF, respectively.

- During the discovery of NWDAF containing MTLF, a consumer (e.g. an NWDAF containing AnLF, an NWDAF containing MTLF as FL server or FL client) may include in the request the target NF type (i.e. NWDAF), the Analytics ID(s), the S-NSSAI(s), Area(s) of Interest of the Trained ML Model required and Vendor ID. The NRF returns one or more candidate instances of NWDAF containing MTLF to the NF consumer and each candidate instance of NWDAF containing MTLF includes the Analytics ID(s), possibly the ML Model Filter Information for the available trained ML Models and ML Model Interoperability indicator, if available.

- If the NWDAF service consumer needs to discover an NWDAF containing an MTLF with ML Model accuracy checking capability, the consumer may query NRF also providing the ML Model accuracy checking capability in the discovery request.

In order to discover an NWDAF containing MTLF with Horizontal Federated Learning (HFL) capability via NRF, in addition to the procedures described above for discovering NWDAF containing MTLF:

- An NWDAF containing MTLF supporting HFL as a server shall additionally include FL capability type (i.e. HFL server), and may include Time interval supporting HFL as HFL capability information during the registration in NRF.

- An NWDAF containing MTLF supporting HFL as a client shall additionally include FL capability type (i.e. HFL client), and may include Time interval supporting HFL as HFL capability information during the registration in NRF, and it may also include, NF type(s) and NWDAF Serving Area information and/or NF set ID(s) of the data source(s) where data can be collected as input for local model training.

NOTE 5: An NWDAF containing MTLF may indicate to support both HFL server and HFL client in the HFL capability for specific Analytics ID. The FL capability type only applies for HFL but continues to be termed FL capability type to maintain backward compatibility with previous releases where only HFL was supported but the term FL capability type was used

- During the discovery of NWDAF containing MTLF as HFL server, a consumer (e.g. a NWDAF containing MTLF) may include in the request the FL capability type as HFL server and may include Time Period of Interest and ML Model Filter information for the trained ML Model(s) per Analytics ID(s), if available. The NRF returns one or more NF profiles of candidate instances of NWDAF satisfying the query parameters.

- During the discovery of NWDAF containing MTLF as HFL client, a consumer (e.g. an HFL server) may include in the request FL capability type as FL client and may include Time Period of Interest, a list of NF type(s) and/or NF set ID(s) of the data source(s). The NRF returns one or more NF profiles of candidate instances of NWDAF satisfying the query parameters.

NOTE 6: The service consumer to discover an NWDAF containing MTLF with HFL capability is limited to NWDAF containing MTLF in this Release.

A PCF may learn which NWDAFs being used by AMF, SMF and UPF for a specific UE, via signalling described in clause 4.16 of TS 23.502 [3]. This enables a PCF to select the same NWDAF instance that is already being used for a specific UE.

In the roaming architecture, the NWDAF with roaming exchange capability (RE-NWDAF) to request analytics or input data is discovered via the NRF. A consumer in the same PLMN as the RE-NWDAF discovers the RE-NWDAF(s) by querying for NWDAF(s) where the roaming exchange capability is indicated in its (their) NF profile. A consumer in a peer PLMN (i.e. RE-NWDAF) discovers the RE-NWDAF(s) by querying for NWDAF(s) in the target PLMN that is (are) supporting the specific services defined for roaming. A RE-NWDAF discovers the RE-NWDAF(s) in a different PLMN (i.e. HPLMN or VPLMN) using the procedure defined in clause 4.17.5 (if delegated discovery is not used) or clause 4.17.10 (if delegated discovery is used) of TS 23.502 [3], where the detailed parameters are determined based on the analytics request or subscription from the consumer 5GC NF, operator policy, user consent and/or local configuration.

In order to support VFL training and inference, the NWDAF shall include its VFL capability information per supported Analytics ID during registering to NRF. The VFL capability information includes VFL capability type (i.e. VFL server or VFL client or both) and Time interval supporting VFL if available. To discover NWDAF supporting VFL from NRF, the consumer should consider the VFL capability information, the detailed procedure and parameters of NWDAF registration and discovery for VFL are as defined in clause 6.2H.2.1.

Editor’s Note：Whether NWDAF as VFL server registers to NRF with VFL capability information is needed is FFS.

Editor's note: Whether the VFL Interoperability information (e.g. type of supported VFL training method(s), vendor information, and feature related information) needs to be part of the NF profile registered in NRF is FFS.

Editor’s note: It is FFS whether and how to enhance the discovery of VFL client that can do VFL with the VFL server.

Editor's note: Details of ML Model handling, supported features, Feature alignment are FFS.

5.4 Vertical Federated Learning (VFL)

Vertical Federated learning is a machine learning technique working without exchanging/sharing of local data set, while maintaining some level of coordination amongst VFL participants, when training and inference are performed on local ML Models, wherein the local data set in different VFL Participant for local model training have different feature spaces for the same samples (e.g. UE IDs). Vertical Federated Learning may involve multiple NWDAFs and AFs.

For Vertical Federated Learning, there may be one NWDAF or one AF acting as a VFL server and one or multiple NWDAF(s) and/or one or multiple AF(s) acting as VFL Client(s). Vertical Federated Learning is available among NWDAFs within a single PLMN or between an AF and NWDAF(s) in a single PLMN.

The main functionalities of VFL server and VFL client include:

**VFL server:**

- An NWDAF or trusted AF acting as VFL server discovers and selects VFL client(s) (NWDAF(s) and/or AF(s)) to participate in a VFL procedure.

NOTE: When an untrusted AF is acting as VFL server, NEF discovers and selects VFL client NWDAFs, then the AF determines final set of VFL clients.

* requests VFL clients to do local ML model training for an Analytic ID, it assigns VFL correlation ID, and it requests to report intermediate results.

- optionally locally trains ML Model with the available local data set.

- combines intermediate results from VFL client(s) and computes intermediate training results (e.g. gradient information, loss information) for updating its own local ML Model and the ML Models of VFL clients during the VFL training process and sends the intermediate training results towards VFL clients involved in the joint VFL training process. VFL server can send and receive separate message for each client.

NOTE: NEF forwards the message from/to NWDAF to/from untrusted AF.

- It initiates the VFL inference process using VFL correlation ID.

- It combines local inference result from VFL clients and generates the final VFL inference result.

- It may send the final VFL inference result to the consumer.

**VFL client:**

- locally trains ML Model with the available local data set, which includes the data that may not be allowed to be shared with other VFL clients due to e.g. data privacy, data security, data access rights.

- computes the intermediate results for their local ML Models involved in the VFL training and provide reports with the intermediate results to the AF or NWDAF acting as VFL server.

- performs inference based on the local model and local data and provides inference results to VFL server.

Vertical Federated Learning includes the following procedures:

* Registration of the NF profile including a list of VFL related information to NRF. Registration of the NWDAF profile to NRF is described in clause 5.2. For an untrusted AF, the NEF registers based on configuration at the NRF within its NF profile information about the AF as specified in clause 6.2.2.3 and includes as part of the information about the AF an VFL capability information. The procedure for registration and discovery of VFL server and VFL client is described in clause 6.2H.2.1.

Editor’s Note: Whether and how change of samples during a VFL training is supported is FFS.

Editor's note: Terminology will be aligned to clause 6.2H.2 in future meeting.

Editor's note: Detailed references to clause 6.2H.2 will be added in future meeting.

Editor's note: Whether and how to provide initial model from VFL server to VFL clients based on VFL client request is FFS.

Editor's note: Details regarding features alignment functionality or whether the functionality needs to be specified are FFS.

Editor's note: Accuracy monitoring in VFL when VFL server is NWDAF is FFS.

Editor's note: For an NWDAF impacts of the split into AnLF and MTLF are FFS.

5.X AF Discovery and Selection for VFL

The AF discovery and selection is defined in the clause 6.3.25, TS 23.501 [2]. In addition to support VFL training and inference, the following factors may be considered for AF discovery and selection:

- VFL capability information per supported AnalyticsID, which includes:

- VFL capability type (i.e. VFL client)

- optional Time interval supporting VFL.

A trusted AF registers the above factor in NRF, for an untrusted AF the NEF is configured via OAM to register this factor into NRF. For the discovery of a trusted AF or untrusted AF, the consumer may select an AF instance considering the above factor. The detailed procedure and parameters of AF registration and discovery for VFL are as defined in clause 6.2H.2.1.

Editor’s Note：Whether AF as VFL server registers to NRF with VFL capability information is needed is FFS.

6.2G Void

6.2G.1 Void

6.2G.2 Void

6.2G.2.1 Void

6.2H Vertical Federated Learning among NWDAFs and AFs

6.2H.1 General

This clause specifies procedures for Vertical Federated learning where AFs and NWDAF can can either act as VFL servers or VFL clients. Procedures for registration and discovery, for VFL training preparation, for VFL training, and for VFL inference are covered.

Both the VFL server and VFL client store the VFL model after finishing the VFL training process and use the same VFL local model to perform the VFL inference later based on the VFL correlation ID. The differences between the VFL training and inference are that for the inference there is no check of the labels, nor any server intermediate results are sent and as such only client intermediate results are sent to the server.

Editor's note: This clause needs to be update to include the description of the subclauses for NWDAF or AF as the server case.

### 6.2H.2 Procedures

#### 6.2H.2.1 Registration and Discovery procedure for Vertical Federated Learning

##### 6.2H.2.1.1 Registration and Discovery procedure for Vertical Federated Learning when NWDAF is acting as the VFL server



Figure 6.2H.2.1.1-1: Registration and Discovery procedure for Vertical Federated Learning when NWDAF is acting as VFL server and NWDAF(s) and/or AF(s) are the VFL clients

Steps 1 to 3 are the NWDAF and AF Registration procedures when the VFL server is NWDAF.

1a. VFL Server NWDAF registers to NRF with its NF profile, which includes NF Type (i.e. NWDAF type), Analytics ID(s), service area if available and VFL capability information per analytics ID. The VFL capability information includes VFL capability type (i.e. VFL server) and optional Time interval supporting VFL.

1b. NWDAF as VFL client registers to NRF with its NF profile, which includes NF Type (i.e. NWDAF type), analytics ID(s), service area if available and VFL capability information per analytics ID. The VFL capability information includes VFL capability type (i.e. VFL client). and optional Time interval supporting VFL.

1c. When untrusted AF as VFL client, it shall register to the NEF via OAM configuration: Analyics ID(s) and its VFL capability information per supported analytics ID. The AF’s VFL capability information includes VFL capability type (i.e. VFL client) and optional Time interval supporting VFL. Then NEF updates NEF profile to NRF including associated AF ID and AF’s VFL capability information.

1d. When trusted AF as VFL client, it registers to NRF with its NF profile, which includes NF Type (i.e. AF type), analytics ID(s), service area if available and VFL capability information per analytics ID. The VFL capability information includes VFL capability type (i.e. VFL client) and optional Time interval supporting VFL.

2. The NRF receives the registrations from VFL server and VFL client(s), and stores their NF profile.

3. The NRF sends registration response to VFL server and VFL client(s).

Steps 4 to 6 are the NWDAF and AF Discovery procedures when the VFL server is NWDAF.

4-6. NWDAF as the VFL server determines that the ML Model requires VFL based on operator policy, Analytics ID, and Service Area.

NOTE: Step 4 in Figure 6.2H.2.1-1 may be triggered at the VFL Server NWDAF by VFL server NWDAF itself or a request from a consumer.

If the NWDAF can not perform as VFL Server, it first discovers and selects another VFL Server NWDAF from NRF by invoking the Nnrf\_NFDiscovery\_Request service operation. The following criteria might be used: Analytics ID, VFL capability type as VFL server, Time Period of Interest, and optional Service Area.

Once the VFL Server NWDAF is determined, the VFL Server NWDAF discovers other NWDAF(s) and/or AF(s) as VFL Client from NRF by invoking the Nnrf\_NFDiscovery\_Request service operation. The following criteria might be used: NF type (i.e. NWDAF type, AF type, or NEF type), Analytics ID, VFL capability type (i.e.VFL client), Time Period of Interest and and optional Service Area.

##### 6.2H.2.1.2 Registration and Discovery procedure for Vertical Federated Learning when AF is acting as the VFL server

The procedure below shows registration and discovery for VFL training and inference when the AF is the AF server, the AF can be trusted or untrused one. There can be multiple NWDAFs as VFL clients.

Editor´s note: The following is FFS: a deployment scenario that can also be agreed between operator and application service provider is when untrusted AF is the VFL server and only one NWDAF will be the VFL client. In such case the VFL Server can be configured to go directly to preparation procedure in clause 6.2H.2.2.



Steps 1 to 3 are the NWDAF and AF Registration procedures when the VFL server is AF.

Editor’s Note：Whether a discovery of an AF acting as VFL server is required and how it can be done is FFS.

1. Same as the step 1b, in clause 6.2H.2.1, NWDAF as VFL client registers to NRF with its NF profile. The NWDAF registers with the analytics IDs it supports.

NOTE x: The AF can use unstandardized values of the analytics ID. The unstandardized values can be used by the AF as the VFL server to intiate the VFL training VFL inference and need to be supported by NWDAFs acting as VFL clients. It is the operator´s responsibility to guarantee that unstndardized analytics ID values within a PLMN are unique.

2-3. Same as the steps 2-3, in clause 6.2H.2.1.

Steps 4-10 are the NWDAF Discovery procedures when the VFL server is an untrusted AF.

4. If untrusted AF acting as the VFL server, it determines that VFL operations are required and the NWDAF(s) as VFL client(s) are required. The AF sends a discovery request for the VFL client(s) to the NEF and provides selection criteria: analytics ID, required NF type (i.e. NWDAF type), VFL capability type (i.e. FL client), Time Period of Interest and optional Service Area.

Editor's note: Whether additional selection criteria are required is FFS (e.g. vendor information and feature related information).

5. The NEF checks based on configured policies whether the AF is entitled to request a VFL client for the analytics ID.

6-7. The NEF discovers VFL client (i.e. NWDAF) on behalf of the AF from the NRF by invoking the Nnrf\_NFDiscovery\_Request using the selection criteria provided by the AF as defined in step 4.

Editor’s note: It is FFS, whether NEF should perform VFL NWDAF selection (or shortlisting) or it should only discover NWDAF client candidates without any further selection.

8. The NEF selects an NWDAFs capable as acting as VFL clients and matching the received selection criteria. The NEF anonymizes NWDAF instances ID(s) and assigns temporary NWDAF ID(s) for each selected NWDAF intance as VFL client. The NEF stores the temporary NWDAF ID(s) together with information how to reach the NWDAFs

9. The NEF sends the temporary NWDAF ID(s) to the untrusted AF.

10. The AF stores the received temporary VFL client ID and uses it subsequent interactions with the NEF to indicate the target VFL client.

Editor's note: Which services are used in step 4 and step 9 are FFS.

Editor's note: How to subsequently handles the Temporary NWDAF ID (e.g. removing and possibly notifying the update of Temporary NWDAF IDs) is FFS.

Steps 11-12 are the NWDAF Discovery procedures when the VFL server is an trusted AF.

11. If the AF as the VFL server is a trusted one, it discovers NWDAF(s) as VFL Client from NRF by invoking the Nnrf\_NFDiscovery\_Request service operation. The following criteria might be used by the trusted AF: Analytics ID, required NF type (i.e. NWDAF type), VFL capability type as VFL client, Time Period of Interest and Service Area.

Editor's note: Whether additional selection criteria are required is FFS (e.g. vendor information and feature related information).

12. The NRF returns one or more NWDAF intances as VFL Client to the AF.

#### 6.2H.2.2 Preparation procedure for Vertical Federated Learning

6.2H.2.2.0 General

Preparation procedure is used to check if the VFL Client(s) can meet the ML Model training requirement. The procedure includes the negotiation, between server and client(s) to enable interoperability, sample alignment and optionally feature alignment.

NOTE 1: Features can be non-specified, privacy protected and in this case feature alignment is a simple alignment using info registered in NRF, e.g. data sources info or proprietary Feature ID).

Editor´s note: Possible refinement of the selection of features during the preparation phase is FFS.

NOTE 2: Vertical Federated Learning preparation procedure can be skipped if the VFL Server can decide which VFL Client(s) support the VFL procedure to be performed, e.g. based on local configuration.

6.2H.2.2.1 Preparation procedure for Vertical Federated Learning when NWDAF is the VFL Server

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**Figure 6.2H.2.2-1: Preparation procedure for Vertical Federated Learning when NWDAF is the VFL Server**

Editor's note: Whether the VFL Interoperability information (e.g. type of supported VFL training method(s)) needs to be part of the NF profile registered in NRF is FFS.

Editor´s Note: Whether the sample IDs are included as part of the MLModelTraining or a separate Nnwdaf service is defined is FFS.

Editor´s Note: The preparation procedure when an untrustrd AF is part of the procedure is FFS.

Editor´s note: For UEs as samples, additional discussion is needed on whether UE needs to be registerd or not.

1. The VFL Server sends a Federated Learning preparation request to each of the VFL Client(s), using Nnwdaf\_MLModelTraining\_Subscribe or Nnwdaf\_MLModelTrainingInfo\_Request service with the ML Preparation Flag. The Server may add a list of sample IDs, Analytics ID and optionally Feature ID.

2. Each VFL Client checks if it can meet the ML Model training requirement. If it cannot meet the requirements for any reason, it may decide which requirements it can agree to.

Editor´s note: Clarifications which parameters are regarded as requirements and can be modified by the VFL client is required

3. Each VFL Client invokes Nnwdaf\_MLModelTraining\_Notify or Nnwdaf\_MLModelTraining\_Subscribe response or Nnwdaf\_MLModelTrainingInfo\_Request response service operation to indicate to the VFL Server whether it accepts the requirements, whether it requests new requirements or whether it will not join. The client includes the requirements it can accept or may add a reason if it cannot join the FL process.

If the notify or response includes new requested requirements, procedure from step 1 is repeated.

Editor´s note: It is ffs whether the VFL client can only reduce the requirements (e.g. samples) or also add new requirements. It is also ffs whether step 1 needs to be repeated if requirements have been reduced by the VFL client.

4. The VFL Server NWDAF determines the VFL Client(s) to be involved in the FL procedures based on the information received in step 6 in Figure 6.2H.2.1-1 (if performed) and other information received in step 3 (if available).

6.2H.2.2.2 Preparation procedure for Vertical Federated Learning when the AF as the VFL server

This clause specifies the preparation (including sample alignment) procedure for AF-initiated VFL scenarios between AF and NWDAF(s) within a single PLMN.

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**Figure 6.2H.2.2-1: Preparation procedure for Vertical Federated Learning when AF is the VFL Server**

Editor´s Note: Whether the sample IDs are included as part of the MLModelTraining or a separate Nnwdaf service is defined is FFS.

* 1. The AF as VFL server sends VFL preparation request to the candidate VFL client(s) with the ML Preparation Flag to check if the VFL client(s) can meet the ML Model training requirement (e.g. Analytics ID, Sample alignment requirement, VFL Availability time requirement (time span needed for the VFL process), etc.). Sample alignment requirement includes a list of sample IDs targeted for VFL training as defined by the AF.

Editor´s note: It is ffs whether .the VFL server sends a separate message for each VFL client towards the NEF. Usage of temporary NWDAF IDs needs to be added.

* 1. The NEF maps the external UE IDs (e.g. GPSIs) to the internal UE IDs (e.g. SUPIs). The NEF may send VFL preparation request to each candidate VFL client using Nnwdaf\_MLModelTraining\_Subscribe or Nnwdaf\_MLModelTrainingInfo\_Request service when multiple candidate VFL clients are involved with the same information as provided in step 1 in 6.2H.2.2.1.

Editor’s Note: Whether to extend the existing ML Preparation Flag for reuse or introduce a new flag dedicated for VFL preparation is FFS.

Editor's note: Whether to use ML Model interoperability information or introduce new identifiers for interoperability among NWDAF and AFs is FFS.

Editor’s Note: The specific service name for the untrusted AF case is FFS.

* 1. Same as step 1 in 6.2H.2.2-1.
  2. Same as step 2 in 6.2H.2.2-1.
  3. Same as step 3 in 6.2H.2.2-1.
  4. When multiple candidate VFL clients are involved, the NEF may aggregate the response from each candidate VFL client and send a VFL Preparation response message to the untrusted AF.

#### 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: 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: 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.

Editor’s Note: It is FFS if the term “backward local ML model training information” needs to be changed into “intermediate results”.

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).

If the VFL procedure continues in subsequent iterations, the VFL server sends a request for a new VFL training iteration containing the backward local ML model training information to each of the VFL clients for next round of VFL training.

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 based on possible backward local ML 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.

Editor’s note: The report may include ID(s) of sample(s) corresponding to the 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 backward local ML model training information (e.g. gradient information or loss information) based on the client intermediate training result received in step 4, its own local intermediate results and the label. The backward local ML model training information is used for updating the models of VFL clients. Different backward local ML 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.

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

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

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

Editor’s Note: Whether VFL Training termination Flag in the termination message is required is FFS.

Editor’s Note: Possible procedures to be executed at the end of the VFL training (to terminate a training session and to store/handle trained models) are FFS.

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.

6.2H.2.3.2 Vertical Federated Learning (VFL) training procedures with AF as VFL server

Editor's note: It is ffs whether to shift the trusted AF as server case to the NWDAF as server case. However, it would need to be considered that the trusted AF only interacts with NWDAFs as clients.

Editor's note: Where the same messages appear in NWDAF as server and AF as server callflows, the description should be replaced by cross-references.

Editor´s note: The callflow should be compared with the NWDAF as server callflow to have the same steps where applicable

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Figure 6.2H.2.3.2-1: VFL model training with AF as VFL server

1. The AF acting as VFL training server assigns a unique VFL Correlation ID.

Steps 2 to 7 are repeated until the MTLF acting as VFL training server determines that the training is complete.

2. For each NWDAF VFL client, the AF acting as VFL training server sends a request to start a VFL training iteration. It includes the VFL Correlation ID. It also includes the intermediate results if step 2 is repeated. An untrusted AF identifies the VFL client using the temporary NWDAF ID assigned in the discovery procedure (see Clause 6.2H.2.1.1) and sends the request to the NEF. A trusted AF includes Analytics ID.

Editor's note: Additional parameters, e.g. to indicate features and samples, are FFS. More clarifications about the intermediate results might be required; if loss information and gradient information is contained in intermediate results is FFS.

3a. For an unstrusted AF: The NEF looks up information about VFL client stored in the discovery procedure (see Clause 6.2H.2.1.1). It forwards the request to the VFL client and includes the stored selection criteria. If the message in step 2a contains external identifiers, the NEF maps them to internal identifiers.

Editor's note: It is ffs whether the NEF stores selection criteria received during discovery and includes them in subsequent messages or if the AF needs to provide related parameters.

4. If intermediate results were received in step 2 or 3a, each NWDAF/MTLF acting as VFL client updates the own local VFL model based on the received intermediate results.  
Each NWDAF/MTLF acting as VFL client collects input data, and calculates own intermediate results based on the input data and the own local VFL model.

Editor's note: It is ffs whether the NWDAF as VFL client also uses the collected input data to update its model.

5a. Each NWDAF/MTLF as VFL training client sends the intermediate results to the VFL server AF. For an untrusted AF, the NWDAF/MTLF sends the message via the NEF.

6a For an unstrusted AF: For each NWDAF/MTLF as VFL training client, the NEF forwards the intermediate results to the AF

7. The AF acting as VFL server updates the own model based on the received intermediate results. The AF may in addition collect own input data and also use those data to update the model. For each VFL client, it determines intermediate results based on the updated model and provides those intermediate results to the VFL clients in the request to start the next training iteration (step 2).

8. Once the AF acting as VFL server determines that the trained model is sufficiently stable to terminate the training, it informs each VFL clients that the VFL training is completed. An untrusted AF sends the message via NEF.

Editor's note: It is ffs whether intermedite results can be included in step 8..

9a. For an unstrusted AF: The NEF looks up stored information about VFL client and selection criteria. It forwards the request to the VFL client and includes the stored selection criteria.

Editor's note: Which services are used between VFL server, NEF and VFL client is FFS and message names need to be confirmed.

Editor's note: Terminology should be alligned related among VFL related descriptions, in particular related to intermediate results and VFL model correlation ID.

Editor's note: The NEF procedures need to be confirmed.

10. The AF acting as VFL server and the NWDAFs acting as VFL clients store their trained models along with the VFL correlation ID.

6.2H.2.4 Inference procedure for vertical federated learning

6.2H.2.4.1 Inference procedure for vertical federated learning when NWDAF is acting as VFL server

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**Figure 6.2H.2.4.2-1: Inference procedure for vertical federated learning when NWDAF is acting as VFL server**

Editor's note: If any of the Consumer, Server and clients are untrusted AF(s), how the NEF assists the VFL inference process, and whether the existing or new NEF service should be invoked are FFS.

0. For an NWDAF as a VFL server, the analytics consumer NF sends an Analytics request/subscribe (Analytics ID, Target of Analytics Reporting= e.g., UE IDs, Analytics Reporting Information=Analytics target period)) to NWDAF containing AnLF by invoking a Nnwdaf\_AnalyticsInfo\_Request or a Nnwdaf\_AnalyticsSubscription\_Subscribe.

1. If the NWDAF containing AnLF can be the VFL server to generate the VFL inference results for the requested analytics ID, then step 1 is skipped.

If the NWDAF containing AnLF can not generate the analytics output, the NWDAF containing AnLF determines the VFL Server for the requested analtyics, sends a subscription request to VFL server NWDAF using Nnwdaf\_AnalyticsInfo\_Request or Nnwdaf\_AnalyticsSubscription\_Subscribe including Analytics ID, Target of Analytics Reporting = e.g., UE IDs.

Editor's note: Whether the case that the AnLF can not generathe the analytics output but can determines the VFL server for the requested analytics is exist is FFS. Whether and how such NWDAF is capable to determine the NWDAF as VFL server is FFS.

2. Based on the information received in the step 0 or 1, VFL server decides to initiate the VFL inference procedure with the VFL clients. VFL Server selects clients(s) using information stored in the VFL training process. The server may select some or no clients, e.g., depending on their contribution to the training result and the current status of the client.

If the VFL server is NWDAF and the VFL client(s) are NWDAF(s), VFL server NWDAF sends a VFL Inference request/subscription to the VFL clients including the UE IDs, VFL correlation ID to indicate the VFL client which previously well-trained VFL local model associated with this ID will be used.

Editor's note: It is FFS additional parameters are needed to send from the VFL server to VFL client.

Editor's note: It is FFS how the origin of analytics results can be traced and explained if not all clients participate and results are not satisfying.

When the VFL server is NWDAF and the VFL client(s) are AF(s), VFL server NWDAF sends a VFL Inference request/subscription to the VFL clients which includes the UE ID(s), the VFL correlation ID to indicate the VFL client which previously well-trained VFL local model associated with this ID will be used. If the AF is untrusted, the VFL server NWDAF sends the request to the NEF, and NEF forwards the request to the untrusted AF.

Editor's note: Which service is used between the VFL server and VFL client is FFS.

3. Each VFL Client collects its local data by using the current mechanism if the VFL Client does not have local data available already.

4. Based on the VFL correlation ID, each VFL Client determines the VFL local model to generate the intermediate local inference results.

Editor's note: Whether VFL client may also provide local intermediate inference results to other VFL client is FFS.

5. VFL Client sends the client intermediate local inference results to the VFL server including the VFL correlation ID.

The intermediate local inference results, which are sent from the VFL Client to the VFL Server during the VFL inference process, are the information for the VFL Server to combine and generate the VFL inference results.

Editor's note: It is FFS additional parameters are needed to send from the VFL client to VFL server.

If the VFL server used an inference subscription in step 2, step 5 may be repeated.

6. The VFL server may collects its local data and generate the intermediate local inference results. The VFL Server combines all the intermediate local inference results to generate the VFL inference results based on the VFL correlation ID. The VFL server takes into account the participation of each VFL client during the ML training process and the importance of the intermediate results when generates the combined inference output.

Editor's note: The details on how the VFL server monitoring the accuracy of the VFL is FFS.

7. If the NWDAF is the VFL server, the VFL server sends Nnwdaf\_AnalyticsInfo\_Response or Nnwdaf\_AnalyticsSubscription\_Notify to the consumer (i.e NWDAF containing AnLF) including the VFL inference results.

8. The NWDAF containing AnLF provides the analytics output to the analytics consumer NF based on the VFL inference results by means of either Nnwdaf\_AnalyticsInfo\_Response or Nnwdaf\_AnalyticsSubscription\_Notify, depending on the service used in step 0.

6.2H.2.4.2 Inference procedure for vertical federated learning with AF as VFL server

Editor's note: It is ffs whether to shift the trusted AF as server case to the NWDAF as server case. However, it would need to be considered that the trusted AF only interacts with NWDAFs as clients. It also needs to be considered that the interfence trigger may be different

Editor's note: Where the same messages appear in NWDAF as server and AF as server callflows, the description should be replaced by cross-references.

Editor´s note: The callflow should be compared with the NWDAF as server callflow to have the same steps where applicable

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**Figure 6.2H.2.4.2-1: inference procedure for vertical federated learning with AF as VFL server.**

1. The inference procedure may be triggered by internal service logic of the AF acting as VFL server, or by a request or subscription for information from a 5GC entity, for instance for service experience information.

2. For an unstrusted AF: The NEF forwards the request or subscription for information to the AF.

Editor's note: Whether and how a 5GC NF can send a request to trigger the VFL server AF to perform inference is FFS. Whether the AF event exposure service can be reused is FFS

3. AF acting as VFL server decides to initiate the VFL inference procedure with the VFL clients and for each client sends an inference request or subscription to the NEF including the Target of Analytics Reporting (e.g. UE ID(s)), possible analytics filters (see clause 6.1.3), and VFL correlation ID. An untrusted AF includes the temporary NWDAF ID obtained in the discovery procedure (see Clause 6.2H.2.1.1) and sends the request to the NEF. A trusted AF includes the Analytics ID and sends the request to the NWDAF.

Editor's note: Additional parameters, e.g. to indicate features, are FFS.

4a. For an unstrusted AF: The NEF looks up stored information about VFL client during in the discovery procedure (see Clause 6.2H.2.1.1). It forwards the request to the VFL client and includes the stored selection criteria. If the message in step 3a contains external identifiers, the NEF maps them to internal identifiers.

Editor's note: It is ffs whether the NEF stores selection criteria received during discovery and includes them in subsequent messages or if the AF needs to provide related parameters.

5. Each VFL Client collects its local data if the VFL Client does not have local data already available.

6. Based on the VFL correlation ID, each VFL Client determines the VFL local model to generate the intermediate local inference results and generates intermediate local inference results using the VFL local model.

Editor's note: Whether the VFL client needs to retrieve stored local models is FFS.

7. Each VFL Client sends the intermediate local inference results to the NEF. The VFL Client may in addition include validity period, confidence, and Client Analytics Metadata Information (see clause 6.1.3).

8a. For an unstrusted AF: For each VFL client, the NEF forwards the inference result to the VFL server.

If the VFL server used an inference subscription in step 3, step 5 to 8 may be repeated.

9. The AF acting as VFL server may collect own local data and generate own intermediate local inference results. The VFL Server aggregates all the intermediate local inference results to generate the VFL inference results.

10. If the inference was triggered by a request or subscription for information from a 5GC entity in step 1, the AF may report results derived by the inference process to the 5GC entity.

11a. For an unstrusted AF: The NEF forwards the reported results to the 5GC

Editor's note: The NEF procedures need to be confirmed.