**3GPP SA WG2 Meeting #162 S2-2404210**

**Changsha, April 15 – April 19, 2024**

**Source: vivo, Huawei, HiSilicon, Tencent, Tencent Cloud, Ericsson?**

**Title: KI#2: New Solution –** **Vertical Federated Learning**

**Document for: Approval**

**Agenda Item: 19.15**

**Work Item / Release:** **FS\_AIML\_CN / Rel-19**

*Abstract of the contribution: This contribution proposes a solution for KI#2 to support Vertical Federated Learning.*

# 1 Discussion

As indicated in KI#2: 5GC Support for Vertical Federated Learning, the following aspects need to be studied:

- Whether and how the existing NF discovery and selection needs to be enhanced.

- Whether and how ML Model training and/or inference related procedures need to be enhanced to support VFL.

- Whether and how to do performance monitoring for the ML model trained via VFL.

- Whether and how to provide ML Models to the participants in the VFL training process.

- How to support sample and feature alignment among the participating network entities when performing VFL.

Use Case #4 and #5 describe the different scenarios for VFL in 5GC: VFL among NWDAF (mainly described in UC#4) and VFL between NWDAF and AF (mainly described in UC#5).

There are two different scenarios between NWDAF and AF to perform VFL procedures:

1. NWDAF triggers VFL procedure acting as the VFL server, with one or more AFs acting as VFL client(s);
2. AF triggers VFL procedure acting as the VFL server, with one or more NWDAFs acting as VFL client(s)

This paper proposes a solution for the above scenarios.

# 2. Proposal

It is proposed to add the following contents to TR 23.700-84.

Start of Change

# 6 Solutions

## 6.0 Mapping of Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues and Use Cases

|  |  |  |
| --- | --- | --- |
|  | Key Issues | Use cases (optional) |
| Solutions | <Key Issue #1> | <Key Issue #2> | <use case #4> | <use case #5> |
| 6.X |  | x | x | x |
|  |  |  |  |  |

Next Change (all new text)

## 6.X Solution #X: Vertical Federated Learning between NWDAF and AF

### 6.X.1 Description

This solution is for Key Issue#2: 5GC Support for Vertical Federated Learning.

This solution describes how to enable ML Model training and inference using VFL as following

Editor´s Note: How to do performance monitoring for the ML model trained via VFL is FFS.

Editor´s Note: Whether and how to provide ML Models to the participants in the VFL training process.

If an ML model needs to be trained on local data set(s) from data source(s) (e.g. NF and AF), which have different feature spaces for the same samples (e.g. UE IDs), and some data cannot be obtained by the model training logic function directly from data source, (e.g., sample ID(s), raw data from AF(s) cannot be obtained and shared due to data privacy, data security issue), then Vertical Federated Learning mechanism can be used to train the ML model. Additionally, a VFL joint model training is also applicable when the training entities are not able to share their ML models (e.g., or due to multi-vendor NWDAFs) nor the input data for training the ML models can be shared (e.g., due to privacy).

The VFL joint model training is characterized by at least two ML models, each associated with different training entities (i.e., one Active VFL Participant and at least one Passive VFL participant). The Active VFL participant trains its own model together with the ML model owned by the Passive VFL Participant, where both ML Models have the same model objective (e.g., are being trained to predict the same output – such as service experience), but these two ML models are different from each other (i.e., have an overall different set of ML features – an input data type associated with some statistical processing).

The proposed solution considers the existence of VFL entities that can assume the following roles: VFL Server (acting as Active VFL Participant as defined in Clause 3.1) and VFL Client (s) (acting as Passive VFL Participant as defined in Clause 3.1).

The NF Entities considered in the solutions comprises the scenarios highlighted in Clause 5.1:

- VFL among NWDAFs: related to Use Case #4

- VFL between Active NWDAF and AF(s): related to Use Case #5

- VFL between Active AF and NWDAF(s): related to Use Case #5

Editor’s Note: Whether multiple NWDAF(s) can be involved when Active AF initiated the VFL is FFS.

The followingprinciples apply in this solution:

- NWDAFs and AFs are enhanced with the VFL Capability, which defines that such entities are able to perform VFL processes such as VFL joint model training and/or VFL inference.

- Entities with a VFL Capability store the VFL capability information at NRF, enabling the discovery and search of such entities when necessary, e.g., during VFL participant determination.

- At least 2 ML Models are associated with an VFL Model training process, where for a single VFL model training process there exist a unique identifier (VFL task correlation ID) that enables the identification and association with the ML Model identifiers of the participants in the VFL joint model training process.

NOTE: The name of the unique identifier is to be decided during conclusion phase.

- Each VFL enabled NF has the VFL related configuration, that defines the allowed and/or restricted parameters that can be considered by the NF for executing a VFL joint model training and VFL inference. The VFL related configuration may be per analytics ID:

- supported VFL Roles (Active Participant/VFL Server, Passive Participant/ VFL Client);

- VFL Interoperability indicator and information, e.g., to identify vendors that can be involved in the same VFL task (in case of VFL among NWDAFs); and/or AFs that can participate in the same VFL task. Additionally, it can also define VFL-specific information, e.g., VFL model type information (e.g., linear regression, neural network).

NOTE: The details of VFL Interoperability Information is not specified since it is either vendor specific information or it is AF-Mobile Network specific information, and is agreed between vendors or between AF owners and operators.

There are two different scenarios between NWDAF and AF to perform VFL procedure

1. NWDAF triggers VFL procedure acting as the VFL server, with one or more AFs acting as VFL client(s);

Note: In this scenario, VFL client(s) can also involve one or more NWDAFs.

1. AF triggers VFL procedure acting as the VFL server, with one or more NWDAFs acting as VFL client(s)

For scenario a), the NWDAF needs to select one or more AF instances from NRF to participate the VFL procedure, before that the AF(s) should register its VFL related capability into NRF via NEF. The NRF will return one or more AF instance IDs to the NWDAF. The detailed procedure is described in clause 6.x.2.1.1.

For scenario b), the AF needs to select one or more NWDAF instances from NRF via NEF to participate the VFL procedure, before that the NWDAF(s) should register its VFL related capability into NRF. The NRF will return one or more NWDAF instance IDs to NEF. If the NEF directly exposes the NWDAF instance ID to AF (especially untrusted AF), then there may be security risk for operator due to leakage of network element information. Thus, in this case, the NEF needs to hide the NWDAF instance ID by transforming it to a temporary NWDAF ID. The detailed procedure is described in clause 6.x.2.1.2.

For scenario a), NWDAF triggers VFL training procedure with the selected AF(s). Before the VFL training iteration execution, the NWDAF interacts with the AF(s) to prepare for the Vertical Federated Learning procedure, in this preparation procedure samples of training data should be selected and aligned between AF(s) and NWDAF. The detailed procedure of VFL training is described in clause 6.x.2.2.1.

For scenario b), AF triggers VFL training procedure with the selected NWDAF(s). Before the VFL training iteration execution, the AF interacts with the NWDAF(s) to prepare for the Vertical Federated Learning procedure, in this preparation procedure samples of training data should be selected and aligned between AF and NWDAF(s). The detailed procedure of VFL training is described in clause 6.x.2.2.2.

For scenario a), due to the ML model was trained between NWDAF and AF(s) in a jointly distributed manner, the NWDAF can trigger joint VFL inference procedure only with the selected AF(s) which participated in the VFL training procedure. The detailed procedure of the joint VFL inference for scenario a) is described in clause 6.x.2.4.1.

For scenario b), due to the ML model was trained between AF and NWDAF(s) in a jointly distributed manner, the AF can trigger joint VFL inference procedure only with the selected NWDAF(s) which participated in the VFL training procedure. The detailed procedure of the joint VFL inference for scenario b) is described in clause 6.x.2.4.2.

### 6.X.2 Procedures

#### 6.x.2.1 Discovery and selection of VFL clients

##### 6.x.2.1.0 VFL capabilities within NF profile

The VFL server and VFL clients such as the AF or the NEF (on behalf of the AF) or the NWDAF registers its VFL capabilities into NRF:

* VFL capability information, whether the AF or NWDAF can act as a VFL Server or VFL Client or both. (MANDATORY).
* If VFL capability information indicates that the AF or NWDAF can perform VFL then the AF or NWDAF provide the list of Analytics IDs that can train. Per Analytics ID the NF provides:

- (Optional) VFL training method (e.g. neural networks, etc).

- Dimensionality of the intermediate results (e.g. number of samples and number of nodes)

-

- (Optional). The list of supported features spaces.

- Time interval supporting VFL.

- Other parameters that are listed in clause 6.2A.2 in TS 23.288,

Editor's note: Whether changes or additional parameters are needed in the VFL profile is FFS.

##### 6.x.2.1.1 Discovery and selection of AF(s) if NWDAF as the VFL server



Figure 6.x.2.1.1-1: Registration and discovery of AF(s) for VFL

1-3. The AF registers its NF profile as defined in clause 5.2.7.2.2 of TS 23.502 [3], with the difference it includes the Supported VFL capability information as defined in clause 6.x.2.1.0 .

NOTE: the untrusted AF could register indirectly via NEF.

4-5. The consumer (e.g. NWDAF acts as VFL server) is to discover the AF(s) supporting VFL via the NRF by invoking the Nnrf\_NFDiscovery\_Request (including required NF type (e.g. AF type), required VFL capability information) service operation. The NRF notifies the consumer with one or more AF instances IDs. The required VFL capability information is as defined in clause 6.x.2.1.0 .

##### 6.x.2.1.2 Discovery and selection of NWDAF(s) if AF as the VFL server



Figure 6.x.2.1.2-1: Registration and discovery of NWDAF for VFL

1-3. The NWDAF registers its NF profile as defined in clause 5.2.7.2.2 of TS 23.502 [3], with the difference it includes the Supported VFL capability information as defined in clause 6.x.2.1.0 .

4-8. The consumer (e.g. AF acts as VFL server) is to discover the NWDAF supporting VFL via the NEF by invoking a VFL clients discovery service including required NF type (e.g. NWDAF type), required VFL capability information. The required VFL capability information may include required VFL capability type (i.e. VFL client), Time period of Interest.

The NEF interacts with the NRF by invoking the Nnrf\_NFDiscovery\_Request including required NF type, required VFL capability information. The NRF notifies the NEF with one or more NWDAF instances.

The NEF anonymizes NWDAF instances ID(s) into temporary NWDAF ID(s) and returns the temporary NWDAF ID(s) to the AF.

Editor’s Note: Whether temporary NWDAF ID(s) is needed and feasible is FFS.

#### 6.x.2.2 VFL training procedure between NWDAF and AF

The following principles are defined for the VFL Joint ML Model training procedures:

- If AF is involved in the VFL Joint ML Model training process, it is assumed that such AF is capable to perform model training.

- If NEF is required for the interaction with 3rd party AFs, NEF services are extended in order to properly support the exchange of information between AF and NWDAFs performing the VFL training/inferencing

##### 6.x.2.2.1 VFL training procedure if NWDAF acts as the VFL server



Figure 6.x.2.2.1-1: VFL training procedure when NWDAF acts as the VFL server

1. If an ML model needs to be trained on local data set(s) from data source(s) (e.g. NF and AF), which have different feature spaces for the same samples (e.g. UE IDs), the NWDAF as the VFL server determines to use Vertical Federated Learning mechanism if some data cannot be obtained directly from data source AF(s) (e.g. due to data privacy, data security).
2. The NWDAF selects AF(s) to participate the Vertical Federated Learning procedure by discovering from the NRF, as described in clause 6.x.2.1.1.

**Vertical Federated Learning preparation procedure:**

3a-3f. The NWDAF starts samples alignment procedure with AF(s) via NEF with VFL Training Preparation Information, and then it will obtain common sample ID(s) for the VFL task from NEF, which are determined by the NEF comparing sample ID(s) from NWDAF and AF(s).

 The VFL Training Preparation Information may comprises:

* VFL Preparation Phase Start Flag: defining the preparation phase for the VFL training is to be executed;
* VFL Preparation Phase Conclusion Flag: defining the preparation phase for the VFL training is finished;
* Indication of VFL capability type to be performed by the NF receiving the VFL Training Preparation Indication;
* VFL Training Information (e.g., dimensionality, category of output: discrete value, e.g. related to classification algorithms; or real value, e.g., regression algorithms, the maximum response time for every training iteration of the VFL process)
* analytics ID;
* VFL task correlation ID;
* sample ID(s) selected by NWDAF;
* feature spaces information selected by NWDAF;

NOTE: The NWDAF determines the VFL Training Preparation Phase is completed and provides to the AF(s) via NEF the VFL Training Preparation Information comprising: the VFL Preparation Phase Conclusion Flag and VFL task correlation ID. Each VFL participant store the mapping of their local VFL related information to the VFL task correlation ID.

**Vertical Federated Learning execution procedure:**

4. To start VFL training procedure, The NWDAF sends VFL training request to NEF including analytics ID, the VFL task correlation ID, , VFL Training Start Phase Flag and AF instance ID(s) selected in step 2. The VFL Training Start Phase Flag indicates to start the joint model training.

5. The NEF transfers the VFL training request to each AF.

6a. Based on local data set, each AF does local model training for the VFL task and generates intermediate result base on it.

6b-6c. Each AF sends the intermediate result (i.e., Passive VFL ML Model Output Reporting) to The NWDAF via NEF

6d. The NWDAF compiles the intermediate results from AF(s) and its own intermediate result calculated with its local model to calculate the loss function value. And it determines whether the VFL training is converged or reaches the convergence requirement.

6e-6f. The NWDAF returns the intermediate result to corresponding AF via NEF.

Step 6a-6f will be repeated until the VFL training procedure is finished.The NWDAF sends a notification that the ML Model is trained to AF(s) including the Analytics ID, and the indication that the ML Model is trained.

##### 6.x.2.2.2 VFL training procedure if AF acts as the VFL server



Figure 6.x.2.2.2-1: VFL training procedure when AF acts as the VFL server

1. If the ML model needs to be trained on local data set(s) from data source(s) (e.g. NF and AF), which have different feature spaces for the same samples (e.g. UE IDs), AF as the VFL server determines to use Vertical Federated Learning mechanism if some data cannot be obtained directly from data source NWDAF(s) (e.g. due to data privacy, data security).
2. The AF selects NWDAF(s) to participate the Vertical Federated Learning procedure by discovering from the NEF and NRF, as described in clause 6.x.2.1.2.

Editor’s Note: Whether multiple NWDAF(s) can be involved when Active AF initiated the VFL is FFS.

**Vertical Federated Learning preparation procedure:**

3a-3f. The AF starts samples alignment procedure with NWDAF(s) via NEF with, VFL Training Preparation Information , and then it will obtain common sample ID(s) for the VFL task from NEF, which are determined by the NEF comparing sample ID(s) from AF and NWDAF(s).

 The VFL Training Preparation Information may comprises:

* VFL Preparation Phase Start Flag: defining the preparation phase for the VFL training is to be executed;
* VFL Preparation Phase Conclusion Flag: defining the preparation phase for the VFL training is finished;
* Indication of VFL capability type to be performed by the NF receiving the VFL Training Preparation Indication;
* VFL Training Information (e.g., dimensionality, category of output: discrete value, e.g. related to classification algorithms; or real value, e.g., regression algorithms, the maximum response time for every training iteration of the VFL process);
* analytics ID,
* VFL task correlation ID,
* AF instance ID(s),
* sample ID(s) selected by NWDAF;
* feature spaces information selected by NWDAF;
* temporary NWDAF ID(s) as defined in 6.x.2.1.2

NOTE: The AF determines the VFL Training Preparation Phase is completed and provides to the NWDAF(s) the VFL Training Preparation Information comprising: the VFL Preparation Phase Conclusion Flag and VFL task correlation ID. Each VFL participant store the mapping of their local VFL related information to the VFL task correlation ID.

**Vertical Federated Learning execution procedure:**

4. To start VFL training procedure, the AF sends VFL training request to NEF including analytics ID, the VFL task correlation ID, , VFL Training Start Phase Flag and temporary NWDAF ID(s) selected in step 2. The VFL Training Start Phase Flag indicates to start the joint model training.

5. The NEF transfers the VFL training request to each NWDAF.

6a. Based on local data set, each NWDAF does local model training for the VFL task and generates intermediate result base on it.

6b-6c. Each NWDAF sends the intermediate result (i.e., Passive VFL ML Model Output Reporting) to the AF via NEF

6d. The AF compiles the intermediate results from NWDAF(s) and its own intermediate result calculated with its local model to calculate the loss function value. And it determines whether the VFL training is converged or reaches the convergence requirement.

6e-6f. The AF return the intermediate result to corresponding NWDAF via NEF with temporary NWDAF ID(s).

Step 6a-6f will be repeated until the VFL training procedure is finished. The AF sends a notification that the ML Model is trained to NWDAF(s) including the Analytics ID, and the indication that the ML Model is trained.

#### 6.x.2.3 VFL training procedure among NWDAFs

The following principles are defined for the VFL Joint ML Model training procedures:

- An NWDAF (VFL Server) with VFL Capability for performing VFL ML Training can initiate the process VFL joint Training Process.

NOTE 1: The procedures illustrated in 6.x.2.3-1 show the NWDAF (VFL Server), i.e., Active VFL Participant, initiating the VFL Joint ML Model Training but does not preclude the Passive Participants (VFL Clients) for initiating the VFL Joint ML Model Training.

- An NWDAF (VFL Server) is able to coordinate the VFL training process among the VFL participants for a VFL Joint ML Model Training Process (i.e., associated with a VFL task correlation ID).



Figure 6.X.2.1.1: VFL Joint Model Training with Active NWDAF and Passive NWDAFs

1. The NWDAF (VFL Server) identifies the need to start a VFL process. The VFL Server is capable to discover the other NWDAFs (VFL Clients) for performing VFL joint ML Model training. Based on the VFL related configurations available at such NF and the information about the discovered participants, the VFL Server determines the VFL Participant Information required for the VFL joint model training to be executed.

NOTE: The procedure defined in 6.x.2.1.2 is used for the discovery and selection of the VFL participants.

**Vertical Federated Learning preparation procedure:**

2. Based on the VFL related configuration and VFL Participant Information, the VFL Server determines the VFL Training Preparation Information. The VFL Server sends to each of the VFL Client the VFL Training Preparation Information. The VFL Training Preparation Information may comprises:

* VFL Preparation Phase Start Flag: defining the preparation phase for the VFL training is to be executed;
* VFL Preparation Phase Conclusion Flag: defining the preparation phase for the VFL training is finished;
* Indication of VFL capability type to be performed by the NF receiving the VFL Training Preparation Indication;
* VFL Training Information (e.g., dimensionality, category of output: discrete value, e.g. related to classification algorithms; or real value, e.g., regression algorithms, the maximum response time for every training iteration of the VFL process);
* VFL task correlation ID;
* analytics ID;
* sample ID(s);
* feature spaces information

3. Each VFL Client based on the received VFL Training Preparation Information and the VFL related configuration locally available, determines whether it can associate its training process of a local ML model to the VFL joint model training process with the requested requirements and alignment information comprised in the VFL Training Preparation Information.

4. In case the requested preparation can be performed, the VFL Client sends to the VFL Server a response with a confirmation, otherwise it sends a response with a rejection.

5. The VFL Server determines the VFL Training Preparation Phase is completed and provides to the VFl Client(s) the VFL Training Preparation Information comprising: the VFL Preparation Phase Conclusion Flag and VFL task correlation ID.

6. (a,b) Each VFL participant store the mapping of their local VFL related information to the VFL task correlation ID.

**Vertical Federated Learning execution procedure:**

7. When the VFL Server determines that the VFL joint model training should start, the VFL Server provides to the VFL Client(s) the following information: analytics ID, the VFL task correlation ID, , VFL Training Start Phase Flag (a flag indicating to start the joint model training)

8. (a,b) The VFl Server and the VFL Client(s) start the training of their local ML model (i.e., Active ML Model at the VFL Server and the Passive ML Model(s) at the VFL Client (s)) associated with the VFL task correlation ID and with the information received during the VFL Preparation Phase.

The VFL Server and the VFL Client(s) each execute one round of training process to generate, respectively the Active VFL ML Model Output Reporting and Passive VFL ML Model Output Reporting.

NOTE: The data used by VFL Server and the VFL Client is collected as per alignment information defined in the preparation phase.

9. (a,b) The VFL Client provides the Passive VFL ML Model Output Reporting to the VFL Server, which comprise the intermediate results of the model training round.

10. The VFL server compiles the intermediate results from VFL clients(s) and its own intermediate result calculated with its local model to calculate the loss function value.

11. The VFL Server provides to the VFL Client(s) the intermediate result.

12. The VFL Server determines that the joint model training is completed.

NOTE 2: The Steps 6 to 9 are repeated executed until the VFL Server determines the performance of the jointly trained models is enough to stop the training (e.g., loss function value is converged).

13. The VFL Server provides to the VFL Clients the VFL Training Conclusion information comprising: the VFL Training Conclusion Flag and VFL task correlation ID.

14. (a,b) Each VFL participant, stores the latest information about their locally trained Models (i.e., Active VFL ML Model Information and Passive VFL ML Model Information) associated with the VFL task correlation ID.

#### 6.x.2.4 VFL inference procedure between NWDAF and AF

##### 6.x.2.4.1 VFL inference procedure if NWDAF acts as the VFL server



Figure 6.x.2.4.1-1: VFL inference procedure when NWDAF acts as the VFL server

1. To obtain analytics, the NF consumer sends analytics info request to NWDAF with analytics ID, Target of Analytics Reporting and analytics filter.

Editor’s Note: Whether the NWDAF is the NWDAF acted as VFL sever in VFL model training procedure or another NWDAF containing AnLF is FFS.

2. For the analytics info request, if the NWDAF as the VFL server decides to do inference based on the ML model jointly trained via VFL mechanism, it determines the VFL task correlation ID, and corresponding AF instance ID(s), which participated in the VFL training procedure to jointly train the ML model.

3-4. The NWDAF sends VFL inference request to corresponding AF(s) via NEF a VFL Inference Request, containing: a flag that indicates the passive participants to start to perform VFL model inference, the VFL task correlation ID, corresponding AF instance ID(s), analytics ID, and VFL inference timing information that indicates the time aspects for the sample alignment and may include:

- Data timestamp(s): indicates one or more timestamps at which the inference data for VFL inference process is collected.

- Data time window(s): indicates one or more time windows at which the inference data for VFL inference process is collected.

- VFL Inference trigger: indicates the condition for triggering the model inference. For example, the passive participant will collect data and perform model inference when UE reaches a certain area.

5. Each AF generates intermediated result based on local input data using the trained local model corresponding to the VFL task correlation ID.

6-7. Each AF sends the intermediated result to the NWDAF as the VFL server via NEF. The NWDAF may also include an Inference ID corresponding to the local inference result. The Inference ID is used to identify the order of inference results, and can be used by the active participant to associate the local inference results of different passive participants. For example, the Inference ID may be a timestamp of the inference data, or a sequence number generated in the chronological order of the inference results.

8. The NWDAF as the VFL server aggregates the intermediated result from each AF(s).

9. the NWDAF sends analytics info response to the NF consumer with the generated final result.

NOTE: Any privacy preserving method for sharing intermediate results is to be defined by SA3.

##### 6.x.2.3.2 VFL inference procedure if AF acts as the coordinator



Figure 6.x.2.4.2-1: VFL inference procedure when AF acts as the VFL server

1. To obtain analytics, the NF consumer sends analytics info request to AF with analytics ID, Target of Analytics Reporting and analytics filter.

2. For the analytics info request, if the AF as the VFL server decides to do inference based on the ML model jointly trained via VFL mechanism, it determines the VFL task correlation ID, and corresponding temporary NWDAF instance ID(s), which participated in the VFL training procedure to jointly train the ML model.

Editor’s Note: Whether multiple NWDAF(s) can be involved when Active AF initiated the VFL is FFS.

3-4. The AF sends VFL inference request to corresponding NWDAF(s) via NEF a VFL Inference Request, containing: a flag that indicates the passive participants to start to perform VFL model inference, the VFL task correlation ID, corresponding temporary NWDAF ID(s), analytics ID, and VFL inference timing information that indicates the time aspects for the sample alignment and may include:

- Data timestamp(s): indicates one or more timestamps at which the inference data for VFL inference process is collected.

- Data time window(s): indicates one or more time windows at which the inference data for VFL inference process is collected.

- VFL Inference trigger: indicates the condition for triggering the model inference. For example, the passive participant will collect data and perform model inference when UE reaches a certain area.

5. Each NWDAF generates intermediated result based on local input data using the trained local model corresponding to the VFL task correlation ID.

6-7. Each NWDAF sends the intermediated result to the AF as the VFL server via NEF with the temporary NWDAF ID(s). The NWDAF may also include an Inference ID corresponding to the local inference result. The Inference ID is used to identify the order of inference results, and can be used by the active participant to associate the local inference results of different passive participants. For example, the Inference ID may be a timestamp of the inference data, or a sequence number generated in the chronological order of the inference results.

8. The AF as the VFL server aggregates the intermediated result from each NWDAF(s).

9. the AF sends analytics info response to the NF consumer with the generated final result.

Editor’s Note: It is FFS if AF can directly offer analytics or not.

NOTE: Any privacy preserving method for sharing intermediate results is to be defined by SA3.

#### 6.x.2.5 VFL inference procedure among NWDAFs

Figure 6.x.2.5-1 illustrated the procedure for analytics subscription at an NWDAF with an Active participant role (i.e., VFL Server) and the generation of the analytics output based on VFL inference process.

NOTE: The procedure in Figure 6.x.2.5-1 supports the Use Case #4.

The proposed procedure for VFL inference is based on the following principles:

- The VFL process executed for analytics generation is transparent to the Analytics Consumer.

- NWDAF is the entity that determines whether VFL inference process is applicable to a subscription/request from an Analytics Consumer.



Figure 6.x.2.5-1: VFL Joint inference among NWDAFs

1. The Analytics Consumer discover the appropriated NWDAF (VFL Server) to subscribe or request an analytics.

2. The NWDAF (VFL Server) determines that VFL inference should be performed and identifies it has the VFL Active Role for a VFL inference process associated with a VFL task correlation ID. The NWDAF with Active VFL Participant Role (VFL Server) determines the VFL Participants, i.e., further NWDAFs) for the VFL process associated with a VFL task correlation ID.

4. The VFL Server provides to the determined VFL Clients (i.e., Passive NWDAF(s)) a VFL Inference Request, containing: a flag that indicates the passive participants to start to perform VFL model inference, the VFL task correlation ID, analytics ID, and VFL inference timing information that indicates the time aspects for the sample alignment and may include:

- Data timestamp(s): indicates one or more timestamps at which the inference data for VFL inference process is collected.

- Data time window(s): indicates one or more time windows at which the inference data for VFL inference process is collected.

- VFL Inference trigger: indicates the condition for triggering the model inference. For example, the passive participant will collect data and perform model inference when UE reaches a certain area.

5. (a,b) Each participant uses the received VFL task correlation ID to determine the appropriated ML Model to be associated with the VFL Inference process and based on the data of the specified time to generate the local VFL Output Reporting (i.e., the Active VFL Output Reporting and the Passive VFL Output Reporting).

6. Each VFL Client sends the local inference result to the VFL Server including, and may also include an Inference ID corresponding to the local inference result. The Inference ID is used to identify the order of inference results, and can be used by the active participant to associate the local inference results of different passive participants. For example, the Inference ID may be a timestamp of the inference data, or a sequence number generated in the chronological order of the inference results.

7. The VFL Server aggregates the local inference result from the different VFL Clients to generate the final analytics output result.

8. The VFL Server sends to the Analytics consumer the analytics notification with the final analytics output result.

NOTE: Any privacy preserving method for sharing intermediate results is to be defined by SA3.

### 6.X.3 Impacts on services, entities and interfaces

NWDAF:

- Determine to use Vertical Federated Learning mechanism to train ML model if some features cannot be obtained directly from data producer AF;

- Discover and select AF to participate the Vertical Federated Learning procedure;

- Interact with AF(s) to perform VFL training and VFL inference;

AF:

- Determine to use Vertical Federated Learning mechanism to train ML model if some features cannot be obtained directly from data producer NWDAF;

- Discover and select NWDAF(s) from NW to participate the Vertical Federated Learning procedure, which is indicated by temporary NWDAF ID(s)

- Interact with NWDAF(s) to perform VFL training and VFL inference;

NEF:

* Discover NWDAF(s) as the VFL clients for AF to participate the VFL training, and indicate it to AF using temporary NWDAF ID(s).

End of Changes