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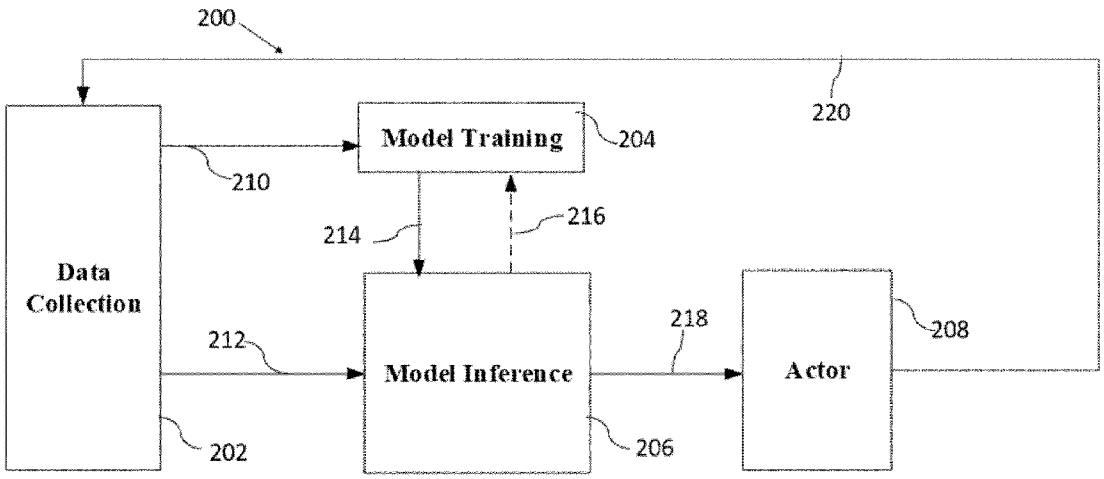

FIG. 2

(57) Abstract: The application relates to managing such machine learning models. In examples of the disclosure a User Equipment (UE) is configured to receive a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model. The UE can then perform the training and/or validating of the machine learning model using the received instructions and prepare a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

WO 2024/027915 A1

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TITLE

Managing Machine Learning Models

TECHNOLOGICAL FIELD

Examples of the disclosure relate to managing machine learning models. Some relate to managing machine learning models in communication networks.

BACKGROUND

Machine learning models can be used in communication networks to perform a variety of suitable tasks. For example, they can be used to assist with decisions relating to handover such as predicting which cell a UE should handover to, predicting when a UE should handover, predicting UE's trajectory information, and/or any other suitable decisions and/or information.

BRIEF SUMMARY

According to various, but not necessarily all, examples of the disclosure there is provided a User Equipment (UE) comprising means for:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

The first message may comprise at least one of:

an indication of parameters to be used for training the machine learning model;

an indication of training rules to be used for training the machine learning model;

an indication of validation rules to be used for validating the machine learning model;

an indication of an exit condition for the validation process of the machine learning model.

The rules to be used for the machine learning model may be configured to control one or more outcomes of the machine learning model to an outcome preferred by the network.

The means may be for determining if the validation of the machine learning model has been successful.

The second message may comprise an indication of whether or not the validation of the machine learning model has been successful

The means may be for receiving a third message from the network wherein the third message comprises instructions indicating how the UE should proceed with the trained machine learning model for inference.

The third message may be received in instances where the second message indicates that the validation of the machine learning has been successful.

The third message may comprise at least one of:

an indication of parameters to be used for the trained machine learning model during inference;

an indication of inference rules to be used by the machine learning model during inference;

an indication of a timer for inference by the machine learning model;

an indication of an accuracy level for revalidation of the trained machine learning model;

an indication of a validation threshold for the trained machine learning model.

The means may be for enabling the UE to be configured into a non-machine learning mode if the validation of the machine learning model is not executed successfully.

The means may be for receiving an updated first message from the network wherein the updated first message comprises updated instructions indicating how the UE should perform training and/or validation of the machine learning model.

The updated first message may be received in instances where the second message indicates that the validation of the machine learning model has not been successful.

According to various, but not necessarily all, examples of the disclosure there is provided a method comprising:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

According to various, but not necessarily all, examples of the disclosure there is provided a computer program comprising computer program instructions that, when executed by processing circuitry, cause:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

According to various, but not necessarily all, examples of the disclosure there is provided a network apparatus comprising means for:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

The means may be for enabling further control of the machine learning model based on the indicated outcome of the training and/or validation of the machine learning model by the UE.

The first message may comprise at least one of:

an indication of parameters to be used for training the machine learning model;

an indication of training rules to be used for training the machine learning model;

an indication of validation rules to be used for validating the machine learning model;

an indication of an exit condition for the validation process of the machine learning model.

The rules to be used for the machine learning model may be configured to control one or more outcomes of the machine learning model to an outcome preferred by the network.

The second message may comprise an indication of whether or not the validation of the machine learning model has been successful

The means may be for enabling a third message to be sent to the UE wherein the third message comprises instructions indicating how the UE should proceed with the trained machine learning model for inference wherein the third message is sent in instances where the second message indicates that the validation of the machine learning model has been successful.

The third message may comprise at least one of:

an indication of parameters to be used for the trained machine learning model during inference;

an indication of inference rules to be used by the machine learning model during inference;

an indication of a timer for inference by the machine learning model;

an indication of an accuracy level for revalidation of the trained machine learning model;

an indication of a validation threshold for the trained machine learning model.

The means may be for controlling the UE to be configured into a non-machine learning mode if the validation of the machine learning model is not executed successfully.

The means may be for updating the instructions indicating how the UE should perform training and/or validation of a machine learning model in response to one or more messages from the UE and enabling the updated instructions to be sent to the UE.

The instructions indicating how the UE should perform training and/or validation may be updated in response to receiving a second message that indicates that the validation of the machine learning by the UE has not been successful.

According to various, but not necessarily all, examples of the disclosure there is provided a method comprising:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

According to various, but not necessarily all, examples of the disclosure there is provided a computer program comprising computer program instructions that, when executed by processing circuitry, cause;

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

While the above examples of the disclosure and optional features are described separately, it is to be understood that their provision in all possible combinations and permutations is contained within the disclosure. It is to be understood that various examples of the disclosure can comprise any or all of the features described in respect of other examples of the disclosure, and vice versa. Also, it is to be appreciated that any one or more or all of the features, in any combination, may be implemented by/comprised in/performable by an apparatus, a method, and/or computer program instructions as desired, and as appropriate.

BRIEF DESCRIPTION

Some examples will now be described with reference to the accompanying drawings in which:

FIG. 1 shows an example network;

FIG. 2 shows an example functional framework;

FIGS. 3A and 3B show example methods;

FIG. 4 shows an example method;

FIG. 5 shows an example signaling chart; and

FIG. 6 shows an example controller.

The figures are not necessarily to scale. Certain features and views of the figures can be shown schematically or exaggerated in scale in the interest of clarity and conciseness. For example, the dimensions of some elements in the figures can be exaggerated relative to other elements to aid explication. Corresponding reference numerals are used in the figures to designate corresponding features. For clarity, all reference numerals are not necessarily displayed in all figures.

DEFINITIONS

AMF	Access and Mobility Management Function
gNB	NR base station
NR	New Radio
O-RAN	Open-Radio Access Network
RAN	Radio Access Network
RSRP	Reference Signal Received Power
SIM	Subscriber Identity Module
UE	User Equipment
UL	Uplink
ULSRS	Uplink Sounding Reference Signal
UPF	User Plane Function

DETAILED DESCRIPTION

Fig. 1 illustrates an example of a network 100 comprising a plurality of network entities including terminal apparatus 110, node apparatus 120 and one or more network apparatus 130. The terminal apparatus 110 and node apparatus 120 communicate with each other. The one or more network apparatus 130 communicate with the access nodes 120. In some examples the one or more network apparatus 130 communicate with the terminal apparatus 110.

The one or more network apparatus 130 can, in some examples, communicate with each other. The one or more node apparatus 120 can, in some examples, communicate with each other.

The network 100 can be a cellular network comprising a plurality of cells 122 each served by a node apparatus 120. In this example, the interface between the terminal apparatus 110 and a node apparatus 120 defining a cell 122 is a wireless interface 124.

The node apparatus 120 comprises one or more cellular radio transceivers. The terminal apparatus 110 comprises one or more cellular radio transceivers.

In the example illustrated the cellular network 100 is a third generation Partnership Project (3GPP) network in which the terminal apparatus 110 are user equipment (UE) and the node apparatus 120 can be access nodes such as base stations.

The term 'user equipment' is used to designate mobile equipment comprising a smart card for authentication/encryption etc such as a Subscriber Identity Module (SIM). In some examples the term 'user equipment' is used to designate mobile equipment comprising circuitry embedded as part of the user equipment for authentication/ encryption such as software SIM.

The node apparatus 120 can be any suitable base station. A base station is an access node. It can be a network element responsible for radio transmission and reception in one or more cells to or from the UE 110. The node apparatus 120 can be a network element in a Radio Access Network (RAN), an Open-Radio Access Network (O-RAN) or any other suitable type of network.

The network apparatus 130 can be part of a core network. The network apparatus 130 can be configured to mange functions relating to connectivity for the UEs 110. For example, the network apparatus 130 can be configured to manage functions such as connectivity, mobility, authentication, authorization and/or other suitable functions. In some examples the network apparatus 130 can comprise an Access and Mobility management Function (AMF) and/or a User Plane Function (UPF) or any other suitable entities.

In the example of Fig. 1 the network apparatus 130 is shown as a single entity. In some examples the network apparatus 130 could be distributed across a plurality of entities. For example, the network apparatus 130 could be cloud based or distributed in any other suitable manner.

The network 100 can be a 4G or 5G network, for example. It can for example be a New Radio (NR) network that uses gNB or eNB as access nodes 120. New Radio is the 3GPP name for 5G technology. In such cases the node apparatus 120 can comprise gNodeBs (gNBs) 120 configured to provide user plane and control plane protocol

terminations towards the UE 110 and/or to perform any other suitable functions. The gNBs 120 are interconnected with each other by means of an X2/Xn interface 126. The gNBs are also connected by means of the N2 interface 128 to the network apparatus 130. The gNBs can be connected to an AMF or any other suitable network apparatus 130. Other types of networks and interfaces could be used in other examples. Other types of network could comprise next generation mobile and communication network, for example, a 6G network.

In some examples the network 100 can make use of machine learning models. For instance the machine learning models could be used to implement processes such as predicting cells for handover, beam selection for transmission and/or reception, and/or any other suitable processes.

Examples of the disclosure relate to managing such machine learning models. In examples of the disclosure the machine learning model can be implemented by the UE 110 but can be, at least partially, controlled by the network apparatus 130. Enabling the network apparatus 130 to maintain some control over the machine learning model implemented by the UE 110 can provide the technical effect of keeping the performance of the machine learning model at the UE 110 consistent with the requirements of the network 100. This can prevent the UE 110 from becoming biased towards outcomes that are not desirable or preferred by the network 100.

Fig. 2 shows an example functional framework 200 that can be used for RAN intelligence. The functional framework 200 makes use of machine learning models. The functional framework 200 could be implemented within networks 100 such as the network of Fig. 1.

In the example of Fig. 2 the functional framework 200 comprises a data collection block 202, a machine learning model training block 204, a machine learning model inference block 206 and an actor block 208. Other blocks, and/or arrangements of the blocks could be used in examples of the disclosure.

The data collection block 202 is configured to collect data to be used by the machine learning model. The data collected by the data collection block 202 can be used as

inputs for the machine learning model. The data collected by the data collection block 202 can be used by the machine learning model for training and/or inference.

The data collected by the data collection block 202 can comprise measurements from UEs 110, measurements from other network entities, feedback 220 from an actor block 208 output from a machine learning model, and/or any other suitable data.

The data collection block 202 can be configured to provide different outputs comprising different types of data. In the example of Fig. 2 the data collection block 202 provides an output comprising training data 210. The training data 210 is provided as an input to the machine learning model training block 204. In the example of Fig. 2 the data collection block 202 also provides an output comprising inference data 212. The inference data 212 is provided as an input to the machine learning model inference block 206.

The data provided by the data collection block 202 can be provided in any suitable format. The data provided by the data collection block 202 need not be provided in a format specific to the machine learning model. For example, processes such as data pre-processing and cleaning, formatting, transforming, or other suitable processes, need not be carried out by the data collection block 202. These processes could be carried out by other blocks in the framework 200.

The machine learning model training block 204 is configured to perform training and validation of the machine learning model. The validation can comprise the testing and/or generation of performance metrics of the machine learning model.

The machine learning model training block 204 is configured to receive the training data 210 as an input. In some examples the machine learning model training block 204 can be configured to perform processes that prepare the training data for use by the machine learning model. The process could comprise data pre-processing and cleaning, formatting, transforming, or other suitable processes.

The machine learning model training block 204 is configured to provide a model deployment output 214. The model deployment output 214 can be used to deploy a

trained and validated machine learning model to the machine learning model inference block 206 or to deliver an updated machine learning model to the machine learning model inference block 206. The machine learning model training block 204 can also receive performance feedback 216 from the machine learning model inference block 206. The performance feedback 216 can comprise information relating to the performance of the machine learning model during an inference process.

The machine learning model inference block 206 is configured to perform inference using the machine learning model. The machine learning model inference block 206 can be configured to use a machine learning model to process data collected by the data collection block 202 to provide an output 218. The output 218 can comprise a prediction or a decision.

The machine learning model inference block 206 is configured to receive the inference data 212 as an input. In some examples the machine learning model inference block 206 can be configured to perform processes that prepare the inference data for use by the machine learning model. The process could comprise data pre-processing and cleaning, formatting, transforming, or other suitable processes.

The machine learning model inference block 206 can also provide performance feedback 216 to the machine learning model training block 204.

The output 218 of the machine learning model inference block 206 is provided to the actor block 208. The actor block can be configured to perform or trigger action based on the output 218 of the machine learning model inference block 206. The actor block 208 can perform the functions itself and/or can trigger other entities to perform the actions.

The actor block 208 can provide feedback 220 as an output. The feedback 220 can be provided to the data collection block 202. The feedback can comprise Information that can be used to derive training data, inference data or to monitor the performance of the machine learning model and its impact to the network 100. The performance of the machine learning model can be monitored by updating of key performance indicators and performance counters.

In examples of this disclosure the machine learning model can comprise a trainable model such as a neural network (such as, but not limited to, convolutional neural network, Long Short Term Memory (LSTM)) or any other suitable type of trainable model. The term "Machine Learning Model" refers to any kind of artificial intelligence (AI), intelligent or other method that is trainable or tuneable using data. The machine learning model can comprise a computer program. The machine learning model can be trained to perform a task, such as predicting which base station to hand over to, without being explicitly programmed to perform that task. The machine learning model can be configured to learn from experience E with respect to some class of tasks T and performance measure P if its performance at tasks in T, as measured by P, improves with experience E. In these examples the machine learning model can learn from previous channel metrics and configurations that were undertaken for the same or similar channel conditions. The machine learning model can also be a trainable computer program. Other types of machine learning models could be used in other examples.

Any suitable process can be used to train the machine learning model. The training of the machine learning model can be performed using real world/or simulation data. In some examples, the real world data that is used to train the machine learning model can comprise data that is collected by the UE 110 and/or any other suitable network entity. some examples the output of the machine learning model can be based, at least in part, on simulation data. Examples of real world data in a mobile communication network can comprise the reference signal received power (RSRP) measured by a UE 110 and reported to the network for a set of cell(s) over a period of time. Another example can be the Uplink Sounding Reference Signal (ULSRS) that the network 100 measures due to a UE transmission to determine Uplink (UL) channel quality. Such data can be used as training data to train a machine learning model that learns to predict handovers of mobile UE(s) 110 as they move from one cell to another.

The training data used to train the machine learning model can comprise historical data collected from the network 100 and/or live data collected by the UE 110 and network. The training of the machine learning model can be repeated as appropriate until the machine learning model has attained a sufficient level of stability. The machine

learning model has a sufficient level of stability when fluctuations in the predictions provided by the machine learning model are low enough so that the machine learning model provides consistent responses to test inputs. The stability of the machine learning model can be tested during a validation process.

In some examples the training of the machine learning model can be repeated as appropriate until one or more parameters of the outputs have reached a pre-defined threshold and/or until a predefined accuracy has been attained and/or until any other suitable criteria are satisfied.

The machine learning model can be executed using any suitable apparatus, for example CPU, GPU, ASIC, FPGA, compute-in-memory, analog, or digital, or optical apparatus. It is also possible to execute the machine learning model in apparatus that combine features from any number of these, for instance digital-optical or analog-digital hybrids. In some examples the weights and required computations in these systems can be programmed to correspond to the machine learning model.

Figs. 3A and 3B show methods that can be performed by a UE 110 and a network apparatus or any other suitable entities.

Fig. 3A shows an example method that could be performed by a UE 110. The UE 110 could be in a network 100 as shown in Fig. 1 or any other suitable type of network. In these examples the UE 110 has machine learning capabilities.

The method comprises, at block 300, receiving a first message from a network 100. The first message comprises instructions indicating how the UE 110 should perform training and/or validation of a machine learning model.

The first message can be sent from any suitable entity within the network 100. In some examples the first message can be sent by a network apparatus 130.

The first message can comprise any information that can be used to control the training and/or the validation of the machine learning model at the UE 110. The training of the machine learning model can comprise determining parameters that should be used for

the machine learning model. The validation of the machine learning model can comprise evaluating whether the training has been performed adequately. The validation can comprise using a test data set to determine whether the trained machine learning model generates the expected outcomes with a sufficient level of reliability or could comprise any other suitable evaluation.

In some examples the first message could comprise an indication of parameters to be used for training the machine learning model. The parameters could relate to the internal structure of the machine learning model. For example, if the machine learning model comprises a neural network then the parameters could comprise sampling weights for the input data for the neural network. Other types of machine learning model and/or parameters could be used.

The parameters that are comprised within the first message can comprise learnable parameters that can be adjusted as the machine learning model is trained. The parameters that are comprised within the first message could comprise hyper-parameters that are not adjusted as the machine learning model is trained.

In some examples the first message could comprise an indication of training rules to be used for training the machine learning model. The training rules can comprise instructions that are to be followed by the UE 110 for the training of the machine learning model. The training rules can comprise an indication of how training data should be adjusted, how the parameters should be adjusted, when to stop the training and perform validation, and/or any other suitable rules.

In some examples the first message could comprise an indication of validation rules to be used for validating the machine learning model. The validation rules can comprise instructions that are to be followed by the UE 110 for the validation of the machine learning model. The validation rules can comprise an indication of the data to be used for validation, where the data to use for validation should be obtained from, when validation should be performed and/or any other suitable rules.

In some examples the first message could comprise an indication of an exit condition for the validation process of the machine learning model. The exit condition comprises

any requirements that can be met to exit the validation process. The exit conditions can comprise a time threshold, a limit on the number of times the validation process can be performed and/or any other suitable condition.

In some examples the rules to be used for the machine learning model are configured to control one or more outcomes of the machine learning model to an outcome preferred by the network 100. For instance, the training rules and/or the validation rules could be configured to bias the outcomes of the machine learning model to an outcome preferred by the network 100. As an example, if the machine learning model is used to predict a cell to use for handover then the training rules that the network 100 sends to the UE 110 can be biased towards a particular cell or set of cells, or could be biased against a particular cell or set of cells or beams within a given cell or set of cells. This control could help the network 100 manage flexible load distribution across cells/beams or perform any other suitable function such as efficient resource scheduling for enabling better power savings.

At block 302 the method comprises training and/or validating the machine learning model using the received instructions.

The UE 110 can be configured to determine if the validation of the machine learning model has been successful. The requirements for determining whether the validation has been successful can be received by the UE 110 in the first message. The requirements for determining whether the validation has been successful can comprise a required accuracy level for the outcomes of the machine learning model being met, a time threshold expiring, and/or any other suitable requirement.

At block 304 the method comprises preparing a second message to be sent to the network 100. The message can be transmitted from the UE 110 to the network 100.

The second message comprises information indicating an outcome of the training and/or validation of the machine learning model. In some examples the second message comprises an indication of whether or not the validation of the machine learning model has been successful.

The method shown in Fig. 3A shows how the training and/or validation of the machine learning model UE 110 can be controlled, at least partially, by the network 100. In some examples the UE 110 can also be configured so that the network 100 can, at least partially, control the inference process of the machine learning model at the UE 110. The inference process can be performed after validation of the machine learning model has been successful. In examples of the disclosure the inference process can be performed after the network 100 receives validation feedback from the UE 110.

To enable the network 100 to, at least partially, control the inference process of the machine learning model at the UE 110 the UE 110 can be configured to receive a third message from the network 100. The third message can comprise instructions indicating how the UE 110 should proceed with the trained machine learning model for inference.

The third message can be received in instances where the second message, that is sent by the UE 110, indicates that the validation of the machine learning has been successful. For example, the second message could indicate that the required level of accuracy has been achieved. In such cases the third message could be received in response to an indication that the validation has been successful.

The third message can be sent from any suitable entity within the network 100. In some examples the third message can be sent from a network apparatus 130. The third message can be sent from the same network apparatus 130 that sent the first message.

The third message can comprise any information that can be used to control the inference of the machine learning model at the UE 110. The inference can comprise processing obtained data to obtain one or more outputs. The outputs can be used to determine an action to be taken by the UE 110 and/or the network 100.

In some examples the third message can comprise an indication of parameters to be used for the trained machine learning model during inference. The parameters can comprise an indication of the machine learning model that is to be used, a required

accuracy of the outputs of the machine learning model and/or any other suitable parameter.

In some examples the third message can comprise an indication of inference rules to be used by the machine learning model during inference. The inference rules can comprise instructions that are to be followed by the UE 110 for the inference of the machine learning model. The inference rules can comprise an indication of the input data that is to be obtained, updated requirements for revalidation of the machine learning model and/or any other suitable rules.

In some examples the third message can comprise an indication of a timer for inference by the machine learning model. The timer can set a time limit for which the machine learning model is considered to be valid. The timer can take into account changes external to the UE 110. For instance, the environment around the UE 110 could be changing. The changes in the environment could be changes in the position of the UE 110 and/or changes in the positions of other UEs 110 around the UE 110.

In some examples the third message can comprise an indication of an accuracy level for revalidation of the trained machine learning model. For instance, the inference rules can instruct that revalidation of the machine learning model is performed by the UE 110 so that if the accuracy level of the machine learning model drops below the required threshold then this could be reported back to the network 100. The accuracy level of the machine learning model could change due to changes in the environment of the UE 110 and/or any other suitable factor.

In some examples the third message can comprise an indication of a validation threshold for the trained machine learning model. The validation threshold can comprise a time limit, an accuracy requirement and/or any other suitable validation requirements.

In some cases the validation of the machine learning model might not be successful. For instance, the required level of accuracy might not be attained by the machine learning model or the time threshold could be exceeded before the required level of accuracy is attained. In such cases the UE 110 could be configured into a non-

machine learning mode if the validation of the machine learning model is not executed successfully. The switch from the machine learning mode of operation to a non-machine learning mode of operation can be controlled, at least partially, by the network 100. For instance, the UE 110 can receive a message from the network 100 indicating that the UE 110 is to switch from the machine learning mode of operation to a non-machine learning mode of operation.

In some cases, if the validation of the machine learning model is not successful, then the UE 110 can be configured to update the training and/or validation process. For instance, the UE 110 can be configured to receive an updated first message from the network 100. The updated first message can comprise updated instructions indicating how the UE 110 should perform training and/or validation of the machine learning model. For example, the updated first message could comprise updated training rules, updated validation rules and/or any other suitable information. The updated instructions can enable adjustments to the training and/or validation of the machine learning model to be implemented. The updated first message can be received in instances where the second message indicates that the validation of the machine learning model has not been successful.

Fig. 3B shows a method corresponding to the method of Fig. 3A. The example method of Fig. 3B could be performed by a network apparatus 130. The network apparatus 130 could be any suitable apparatus that is configured to control functions of the network 100. The network apparatus 130 can be a single entity as shown in Fig.1 or could be distributed over a plurality of different entities.

The method comprises, at block 306, enabling a first message to be sent to a UE 110. The first message can be sent from the network apparatus 130 to the UE 110 via any suitable means. For example, a baste station 120 or other access node could be used to transmit the first message from the network 100 to the UE 110.

The first message comprises instructions indicating how the UE 110 should perform training and/or validation of a machine learning model. The instructions indicating how the UE 110 should perform training and/or validation can be as described above and/or can comprise any other suitable instructions.

The method comprises, at block 308, receiving a second message. The second message can originate from the UE 110. The second message can be sent from the UE 110 to the network apparatus 130 via any suitable means.

The second message can comprise information indicating an outcome of the training and/or validation of the machine learning model by the UE 110. The information indicating an outcome of the training and/or validation of the machine learning model by the UE 110 can be as described above and/or can comprise any other suitable information.

The method shown in Fig. 3B shows how the network apparatus 130 can, at least partially, control the training and/or validation of the machine learning model by the UE 110. In some examples the network apparatus 130 can also be configured so that the network apparatus 130 can, at least partially, control the inference process of the machine learning model at the UE 110. For instance, the network apparatus 130 can be configured to enable further control of the machine learning model based on the indicated outcome of the training and/or validation of the machine learning model by the UE 110.

In some examples the network apparatus 130 can be configured to enable a third message to be sent to the UE 110 to enable the network apparatus 130 to, at least partially, control the inference process of the machine learning model at the UE 110. The third message can comprise instructions indicating how the UE 110 should proceed with the trained machine learning model for inference. The third message is sent in instances where the second message indicates that the validation of the machine learning model has been successful.

In some examples the validation of the machine learning model might not be successful. In such cases the second message can comprise an indication that the validation of the machine learning model has not been successful.

If the second message indicates that the validation of the machine learning model has not been successful then, in some cases the network apparatus 130 can send a

message to the UE 110 indicating that the UE 110 is to switch from the machine learning mode of operation to a non-machine learning mode of operation. The UE 110 can then be reconfigured into a non-machine learning mode of operation based on the information in the message.

In some cases, if the validation of the machine learning model is not successful, then the network apparatus 103 can update the training and/or validation process that is to be used by the UE 110. For instance, the network apparatus 103 can be configured to send an updated first message to the UE 110. The updated first message can comprise updated instructions indicating how the UE 110 should perform training and/or validation of the machine learning model. For example, the updated first message could comprise updated training rules, updated validation rules and/or any other suitable information. The updated instructions can enable adjustments to the training and/or validation of the machine learning model to be implemented. The updated first message can be sent in instances where the second message indicates that the validation of the machine learning model has not been successful.

Fig. 4 shows an example method according to examples of the disclosure. The method could be implemented by a UE 110 or any other suitable entity with a network 100.

At block 400 a machine learning model is selected. In some examples the UE 110 can have capabilities to run different machine learning models.

The UE 110 can be configured in either a non-machine learning mode or a machine learning mode. In the example of Fig. 4 the UE 110 is configured in the non-machine learning mode at block 402 or configured in the machine learning mode at block 406. Whether or not the UE 110 is configured in the machine learning mode or the non-machine learning mode can be controlled by the network 100. For instance the network 100 can send one or more messages to the UE 110 indicating whether the UE 110 should be configured in the machine learning mode or the non-machine learning mode.

If the UE 110 is configured in the non-machine learning mode then the UE 110 does not perform any machine learning assisted operations. The operations that are

performed by the UE 110 can be implemented using any suitable processes that do not involve machine learning.

In the non-machine learning mode the UE 110 can be configured to collect data that can be reported to other network entities to enable the other network entities to perform machine learning operations. In the non-machine learning mode the UE 110 would not process the collected data to make decisions or predict an outcome.

In the example of Fig. 4 the method comprises, at block 404, making measurements and reporting the outcome of these measurements to the network 100. The measurements that are made by the UE 110 can comprise measurements relating to one or more metrics of the environment in which the UE 110 is located. For example, the measurements could comprise Reference Signal Received Power (RSRP) measurements, or any other suitable type of measurements.

Once the measurements have been reported to the network 100 the network 100 can then use the data from the measurements to make a decision or predict an outcome. The network 100 could use machine learning models or any other suitable process to do this.

If the UE 110 is configured in the machine learning mode then the UE 110 can perform machine learning assisted operations. In the machine learning mode the UE 110 can be configured to collect data and process the collected data using a machine learning model to make decisions or predict an outcome. The machine learning assisted operations can be controlled, at least partially, by the network 100.

In the example of Fig. 4 the method comprises, at block 408, the UE 110 making measurements and save the data collected from the measurements for use in machine learning operations. The measurements can comprise measurements relating to one or more metrics of the environment in which the UE 110 is located. For example, the measurements could comprise Reference Signal Received Power (RSRP) measurements, or any other suitable type of measurements.

At block 410 it is determined whether or not enough data has been collected. The amount of data that is needed can be determined by the network 100. For instance, the network 100 can indicate to the UE 110 the type and/or quantity of data that is needed to perform the machine learning operations. The network 100 could indicate this information to the UE 110 in a first message as shown in Figs. 3A and 3B or by any other suitable means.

If it is determined that enough data has not been collected then the method returns to block 408 and further measurements are made by the UE 110.

If it is determined that enough data has been collected then the method proceeds to block 412 where training and validation of the machine learning model are performed. The training and validation can be performed by the UE 110 in accordance with rules and policies that are set by the network 100. The network 100 can inform the UE 110 of these rules and policies in a first message as shown in Figs. 3A and 3B. The first message could be sent when the machine learning mode is selected or could be sent at any other suitable occasion.

If the validation of the machine learning model determines that the machine learning model is valid, then the method proceeds to block 414 and the machine learning model is used by the UE 110 for inference.

The inference can be performed by the UE 110 in accordance with rules and policies that are set by the network 100. The network 100 can inform the UE 110 of the rules and policies that are to be used for the inference by sending a message to the UE 110. The message could be sent in response to an indication from the UE 110 that the validation of the machine learning model has been successful or could be sent at any other suitable occasion.

The method also comprises, at block 416, performing inference validation. The inference validation can evaluate whether or not the machine learning model is still valid during the inference phase. The rules and policies for determining whether or not the machine learning model is still valid during the inference phase can also be set

by the network 100. These can be communicated from the network 100 to the UE 110 in any suitable message.

If, at block 416, is determined that the machine learning model is not valid then the method proceeds to block 418 and the network policy is followed. The machine learning model can be determined not to be valid during the training phase at block 412 or during the inference phase at block 416. In such cases an indication that the machine learning model is not valid can be sent from the UE 110 to the network 100 and the network 100 can make a decision on how to proceed based on the network policy.

In this example the network policy can either require that the UE 110 reverts to a non-machine learning mode or that the machine learning policy and/or rules are updated. If the network policy requires that the UE 110 reverts to a non- machine learning mode then the method proceeds to block 402 and the non-machine learning mode is implemented.

If the network policy requires that the machine learning policy and/or rules are updated then the method proceeds to block 406 and the machine learning mode is implemented again but with updated rules and/or polices. To enable the machine learning to be updated the network 100 can send a message to the UE 110 indicating the new policies and rules for the training and validation of the machine learning model.

Fig. 5 shows an example signaling chart that could be used in some examples of the disclosure. In this example the signals are exchanged between a UE 110 and the network 100. The signals could be exchanged between a UE 110 and any suitable part of the network 100 such as a network apparatus 130.

In this signal chart it is assumed that the relevant information about the UE 110 has been obtained by the network 100. That is, the network 100 has pre-acquired knowledge about the UE 110. This knowledge could comprise the model type of the UE 110, the machine learning capabilities of the UE 110 or any other suitable information.

At block 500 the network 100 sends a first message 500 to the UE 110. The first message comprises instructions indicating how the UE 110 should perform training and/or validation of the machine learning model. The instructions can comprise sampling weights for data for the machine learning model and/or any other suitable rules or instructions. In some examples the weights for the machine learning model can be biased towards a particular outcome. For instance, if the machine learning model is being used for predicting a handover the sampling weights for the input data can be biased towards a preferred cell or beam for load balancing purposes. Other biases could be used in other examples. Other reasons might be used for biasing or controlling the outcomes of the machine learning model.

In the example of Fig. 5 the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model but doesn't comprise any data to be used for the training and/or validation. In this example the UE 110 is trusted to use its own data for the training and/or validation. The UE 110 can obtain the data for the training and/or validation by performing measurements and/or by any other suitable means.

At block 502 the UE 110 performs the training of the machine learning model. The training of the machine learning model is performed using the data collected by the UE 110 and the rules and policies provided by the network 100 in the first message. The training of the machine learning model can comprise determining sampling weights for the input data or other parameters that should be used for the machine learning model. The network 100 does not perform any of the training of the machine learning model beyond providing the rules and policies.

At block 504 the validation of the machine learning model is performed. The validation of the machine learning model can comprise evaluating whether the training has been performed adequately. The validation can comprise using a test data set to determine whether the trained machine learning model generates the expected outcomes with a sufficient level of reliability or could comprise any other suitable evaluation.

The validation is performed by the UE 110 in accordance with the rules and policies that have been provided by network 100. The network 100 does not perform any of the validation of the machine learning model beyond providing the rules and policies. For example, the network 100 can indicate an accuracy level that is to be attained by the machine learning model but the UE 110 determines whether that accuracy level is attained. The accuracy level could be a percentage such as 95% or could comprise any other metric.

If the validation is not passed then the method proceeds to block 506 and the UE 110 counts how may iterations of the training and validation have been performed by the UE 110. The network 100 can indicate a threshold number of iterations that are to be performed. This indicates a maximum number of iterations that are to be performed before the training and validation process is exited. Other exit conditions for exiting the validation phase could be used in other examples, for example a time threshold could be used instead of a count of the number of iterations. The exit conditions can be sent from the network 100 to the UE 110 in the first message at block 500 or in any other suitable message.

If it is determined, at block 506, that the threshold number of iterations has not been reached then the method returns to block 502 and the training and validation is repeated.

If it is determined, at block 506, that the threshold number of iterations has been reached then, at block 508 the UE 110 sends a message to the network 100. The message that is sent to the network 100 at block 508 can be a second message. The second message indicates the outcome of the validation. In this case it indicates that the validation has not been successful.

At block 510 the network 100 sends another message to the UE 110. The another message can be sent in response to the second message received at block 508 that indicates that the validation has not been successful. In this example the another message is an updated first message. The updated first message can comprise updated instructions indicating how the UE 110 should perform training and/or validation of the machine learning model. For example, the updated first message

could comprise updated training rules, updated validation rules, an updated accuracy level for the validation and/or any other suitable information.

At block 512 the UE 110 receives the updated training and/or validation rules from the network 100. The updated rules and policy can indicate whether or not the UE 110 is to continue in the machine learning mode. After the updated training and/or validation rules have been received the method proceeds to block 532 and the UE 110 determines, based on the information in the updated message, whether or not the UE 110 is stay in machine learning mode or if the UE 110 is to switch to non-machine learning mode. If the updated message indicates that the UE 110 is to stay in the machine learning mode then the method returns to block 502 and the training and validation is repeated using the updated rules and policies. If the updated message indicates that the UE 110 is to switch to the non-machine learning mode then the method proceeds to block 534 and UE 110 stops using the machine learning model.

In the example of Fig. 5 the network 100 can decide whether or not the UE 110 is to continue in the machine learning mode or if it should be switched to the non-machine learning mode. For example, if the validation shows that the accuracy level of the machine learning model is close to the required level then the network 100 could decide that the UE 110 is to continue in the machine learning mode with adjusted parameters. The adjusted parameters could be changes to the sampling weights of input data of the machine learning model, changes to the required accuracy levels and/or any other suitable metrics. If the validation shows that the accuracy level of the machine learning model is not close to the required level then the network 100 could decide that it is unlikely that a sufficient level of accuracy can be attained by the UE 110 and can decide to switch the UE 110 into non-machine learning mode.

If, at block 504 the validation is passed then the method proceeds to block 514 and the UE 110 sends a message to the network 100. The message that is sent to the network 100 at block 514 can be a second message. The second message indicates the outcome of the validation. In this case it indicates that the validation has been successful.

After receiving the message indicating that the validation has been successful the network 100 prepares inference rules at block 516. The inference rules can comprise instructions that are to be followed by the UE 110 during an inference phase of the machine learning model. The inference rules can comprise an indication of the input data that is to be obtained, requirements for revalidation of the machine learning model and/or any other suitable rules. The inference rules can be prepared based on validation feedback that is received in the message at block 514.

At block 518 the network 100 sends a message to the UE 110. The message comprises an indication of the inference rules. The message can be a third message as described previously or could be any other suitable message.

At block 520 the UE 110 uses the trained machine learning model to perform inference. In the example of Fig. 5 the UE 110 uses data collected by the UE 110 to perform the inference. The UE 110 can use the rules and policies provided by the network 100 to perform the inference. In some examples the UE 110 could also use data collected from other network entities to perform the inference.

During inference the UE 110 can use the machine learning model to process input data to provide an output. The output can be used to predict an outcome or make a decision. The output can be used to control an actor within the UE 110 and/or to control an actor within the network 100. For example, the inference could be used to predict a cell to use for handover, for beam selection, or for any other suitable purpose.

Validation is also performed during the inference phase at block 520. The validation performed during the inference phase can be used to evaluate whether or not the machine learning model is still valid. The validity of the machine learning model could change due to changes in the environment around the UE 110 and/or because of any other suitable factor. In some examples the validation performed during inference can comprise determining whether the machine learning model is attaining a required level of accuracy or meeting some other metric. In some examples the validation performed during inference could comprise determining if some external criteria has been met, for example it could be determining whether or not a time threshold has been reached. The time threshold could be set by the network 100. The time threshold could be

indicated to the UE 110 in the message sent at block 518 or could be indicated using any other suitable means.

If, at block 522, it is determined that the machine learning model is still valid then, the method returns to bock 520 and inference continues.

If, at block 522, it is determined that the machine learning model is not valid or the inference timer expired then, the method proceeds to block 524 and a message is sent from the UE 110 to the network 100. The message indicates that the machine learning model is no longer valid. In some examples the message can also indicate why the machine learning model is no longer valid.

After receiving the message indicating that the machine learning model is no longer valid the network 100 prepares updated training and/or validation rules at block 526. The updated training and/or validation rules can comprise instructions that are to be followed by the UE 110 during a new training and validation phase of the machine learning model. The updated training and/or validation rules can comprise updates to the updated training and/or validation rules that were send in the first message at block 500 and/or could be new training and/or validation rules.

At block 528 the updated training and/or validation rules are sent from the network 100 to the UE 110.

At block 530 the UE receives the updated training and/or validation rules from the network 100. At block 532 the UE 110 determines, based on the information in the updated training and/or validation rules, whether or not the UE 110 is stay in machine learning mode or if the UE 110 is to switch to non-machine learning mode. If the updated message indicates that the UE 110 is to stay in the machine learning mode then the method returns to block 502 and the training and validation is repeated using the updated rules and policies. If the updated message indicates that the UE 110 is to switch to the non-machine learning mode then the method proceeds to block 534 and UE 110 stops using the machine learning model.

Variations to the signaling chart could be used in examples of the disclosure. For instance, in some cases the network 100 could make a decision to switch the UE 110 out of the machine learning mode even if the machine learning model is determined to be valid. As an example, a UE 110 could be making optimal, or substantially optimal, decisions but these could be causing high levels of interference to neighboring network entities. In this case the network policy can require that the UE switches to the non-machine learning to reduce the interference with the other network entities.

The methods and processes described may be applied to achieve technical effects such as enabling the network 100 to manage the training and validation phase at the UE 110. The examples of the disclosure can also enable the network to control the inference phase of the machine learning model at the UE 110. This provides the benefit of enabling the UE 110 to perform the machine learning operations. This can be beneficial because it enables the UE 110 to collect and process the data itself which might be more efficient. However, in examples of the disclosure the network 100 retains a sufficient level of control over the machine learning operations which can reduce problems such as the UE 110 causing interference by making decisions that negatively affect other entities within the network or making decisions that may lead for a degradation of the performance of UE 110 or making decisions that may lead to a degradation of network performance. Decisions that could lead to a degradation of performance of the UE 110 or the network 100 could be making a handover too early, making a handover too late, handing over to the wrong target or any other relevant errors.

Fig. 6 illustrates an example of a controller 600. The controller 600 could be provided within an apparatus such as a UE 110 or a network apparatus. Implementation of a controller 600 may be as controller circuitry. The controller 600 may be implemented in hardware alone, have certain aspects in software including firmware alone or can be a combination of hardware and software (including firmware).

As illustrated in Fig. 6 the controller 600 can be implemented using instructions that enable hardware functionality, for example, by using executable instructions of a computer program 606 in a general-purpose or special-purpose processor 602 that

may be stored on a computer readable storage medium (disk, memory etc.) to be executed by such a processor 602.

The processor 602 is configured to read from and write to the memory 604. The processor 602 may also comprise an output interface via which data and/or commands are output by the processor 602 and an input interface via which data and/or commands are input to the processor 602.

The memory 604 stores a computer program 606 comprising computer program instructions (computer program code) that controls the operation of the apparatus when loaded into the processor 602. The computer program instructions, of the computer program 606, provide the logic and routines that enables the apparatus to perform the methods illustrated in the Figs. The processor 602 by reading the memory 604 is able to load and execute the computer program 606.

In examples where the controller 600 is provided within a UE 110 the controller 600 therefore comprises: at least one processor 602; and at least one memory 604 including computer program code 606, the at least one memory 604 storing instructions that, when executed by the at least one processor 602, cause a UE 110 at least to perform:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

In examples where the controller 600 is provided within a network apparatus the controller 600 therefore comprises: at least one processor 602; and at least one memory 604 including computer program code 606, the at least one memory 604 storing instructions that, when executed by the at least one processor 602, cause a network apparatus at least to perform:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

The computer program 606 may arrive at the apparatus or network apparatus via any suitable delivery mechanism 608. The delivery mechanism 608 may be, for example, a machine readable medium, a computer-readable medium, a non-transitory computer-readable storage medium, a computer program product, a memory device, a record medium such as a Compact Disc Read-Only Memory (CD-ROM) or a Digital Versatile Disc (DVD) or a solid-state memory, an article of manufacture that comprises or tangibly embodies the computer program 606. The delivery mechanism may be a signal configured to reliably transfer the computer program 606. The apparatus may propagate or transmit the computer program 606 as a computer data signal.

The computer program 606 can comprise computer program instructions for causing a UE 110 to perform at least the following or for performing at least the following:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

The computer program 606 can comprise computer program instructions for causing a network apparatus to perform at least the following or for performing at least the following:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

The computer program instructions may be comprised in a computer program, a non-transitory computer readable medium, a computer program product, a machine readable medium. In some but not necessarily all examples, the computer program instructions may be distributed over more than one computer program.

Although the memory 604 is illustrated as a single component/circuitry it may be implemented as one or more separate components/circuitry some or all of which may be integrated/removable and/or may provide permanent/semi-permanent/ dynamic/cached storage.

Although the processor 602 is illustrated as a single component/circuitry it may be implemented as one or more separate components/circuitry some or all of which may be integrated/removable. The processor 602 may be a single core or multi-core processor.

References to 'computer-readable storage medium', 'computer program product', 'tangibly embodied computer program' etc. or a 'controller', 'computer', 'processor' etc. should be understood to encompass not only computers having different architectures such as single /multi- processor architectures and sequential (Von Neumann)/parallel architectures but also specialized circuits such as field-programmable gate arrays (FPGA), application specific circuits (ASIC), signal processing devices and other processing circuitry. References to computer program, instructions, code etc. should be understood to encompass software for a programmable processor or firmware such as, for example, the programmable content of a hardware device whether instructions for a processor, or configuration settings for a fixed-function device, gate array or programmable logic device etc.

As used in this application, the term 'circuitry' may refer to one or more or all of the following:

(a) hardware-only circuitry implementations (such as implementations in only analog and/or digital circuitry) and

(b) combinations of hardware circuits and software, such as (as applicable):

(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and

(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions and

(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g. firmware) for operation, but the software may not be present when it is not needed for operation.

This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit for a mobile device or a similar integrated circuit in a server, a cellular network device, or other computing or network device.

The stages illustrated in Figs. 2 to 5 can represent steps in a method and/or sections of code in the computer program 606. The illustration of a particular order to the blocks does not necessarily imply that there is a required or preferred order for the blocks and the order and arrangement of the block may be varied. Furthermore, it can be possible for some blocks to be omitted.

Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

The term ‘comprise’ is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use ‘comprise’ with an exclusive meaning then it will be made clear in the context by referring to “comprising only one...” or by using “consisting”.

In this description, the wording 'connect', 'couple' and 'communication' and their derivatives mean operationally connected/coupled/in communication. It should be appreciated that any number or combination of intervening components can exist (including no intervening components), so as to provide direct or indirect connection/coupling/communication. Any such intervening components can include hardware and/or software components.

As used herein, the term "determine/determining" (and grammatical variants thereof) can include, not least: calculating, computing, processing, deriving, measuring, investigating, identifying, looking up (for example, looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (for example, receiving information), accessing (for example, accessing data in a memory), obtaining and the like. Also, " determine/determining" can include resolving, selecting, choosing, establishing, and the like.

In this description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example.

Although examples have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the claims.

Features described in the preceding description may be used in combinations other than the combinations explicitly described above.

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not.

The term 'a', 'an' or 'the' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising a/an/the Y indicates that X may comprise only one Y or may comprise more than one Y unless the context clearly indicates the contrary. If it is intended to use 'a', 'an' or 'the' with an exclusive meaning then it will be made clear in the context. In some circumstances the use of 'at least one' or 'one or more' may be used to emphasis an inclusive meaning but the absence of these terms should not be taken to infer any exclusive meaning.

The presence of a feature (or combination of features) in a claim is a reference to that feature or (combination of features) itself and also to features that achieve substantially the same technical effect (equivalent features). The equivalent features include, for example, features that are variants and achieve substantially the same result in substantially the same way. The equivalent features include, for example, features that perform substantially the same function, in substantially the same way to achieve substantially the same result.

In this description, reference has been made to various examples using adjectives or adjectival phrases to describe characteristics of the examples. Such a description of a characteristic in relation to an example indicates that the characteristic is present in some examples exactly as described and is present in other examples substantially as described.

The above description describes some examples of the present disclosure however those of ordinary skill in the art will be aware of possible alternative structures and method features which offer equivalent functionality to the specific examples of such

structures and features described herein above and which for the sake of brevity and clarity have been omitted from the above description. Nonetheless, the above description should be read as implicitly including reference to such alternative structures and method features which provide equivalent functionality unless such alternative structures or method features are explicitly excluded in the above description of the examples of the present disclosure.

Whilst endeavoring in the foregoing specification to draw attention to those features believed to be of importance it should be understood that the Applicant may seek protection via the claims in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not emphasis has been placed thereon.

I/we claim:

CLAIMS

1. A User Equipment (UE) comprising means for:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

2. A UE as claimed in claim 1 wherein the first message comprises at least one of:

an indication of parameters to be used for training the machine learning model;

an indication of training rules to be used for training the machine learning model;

an indication of validation rules to be used for validating the machine learning model;

an indication of an exit condition for the validation process of the machine learning model.

3. A UE as claimed in claim 2 wherein the rules to be used for the machine learning model are configured to control one or more outcomes of the machine learning model to an outcome preferred by the network.

4. A UE as claimed in any preceding claim wherein the means are for determining if the validation of the machine learning model has been successful.

5. A UE as claimed in any preceding claim wherein the second message comprises an indication of whether or not the validation of the machine learning model has been successful

6. A UE as claimed in any preceding claim wherein the means are for receiving a third message from the network wherein the third message comprises instructions indicating how the UE should proceed with the trained machine learning model for inference.

7. A UE as claimed in claim 6 wherein the third message is received in instances where the second message indicates that the validation of the machine learning has been successful.

8. A UE as claimed in any of claims 6 to 7 wherein the third message comprises at least one of:

an indication of parameters to be used for the trained machine learning model during inference;

an indication of inference rules to be used by the machine learning model during inference;

an indication of a timer for inference by the machine learning model;

an indication of an accuracy level for revalidation of the trained machine learning model;

an indication of a validation threshold for the trained machine learning model.

9. A UE as claimed in any preceding claim wherein the means are for enabling the UE to be configured into a non-machine learning mode if the validation of the machine learning model is not executed successfully.

10. A UE as claimed in any preceding claim wherein the means are for receiving an updated first message from the network wherein the updated first message comprises updated instructions indicating how the UE should perform training and/or validation of the machine learning model.

11. A UE as claimed in claim 10 wherein the updated first message is received in instances where the second message indicates that the validation of the machine learning model has not been successful.

12. A method comprising:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

13. A computer program comprising computer program instructions that, when executed by processing circuitry, cause:

receiving a first message from a network wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model;

training and/or validating the machine learning model using the received instructions; and

preparing a second message to be sent to the network wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model.

14. A network apparatus comprising means for:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

15. A network apparatus as claimed in claim 14 wherein the means are for enabling further control of the machine learning model based on the indicated outcome of the training and/or validation of the machine learning model by the UE.

16. A network apparatus as claimed in any of claims 14 to 15 wherein the first message comprises at least one of:

an indication of parameters to be used for training the machine learning model;

an indication of training rules to be used for training the machine learning model;

an indication of validation rules to be used for validating the machine learning model;

an indication of an exit condition for the validation process of the machine learning model.

17. A network apparatus as claimed in any of claims 14 to 16 wherein the means are for enabling a third message to be sent to the UE wherein the third message comprises instructions indicating how the UE should proceed with the trained machine learning model for inference wherein the third message is sent in instances where the second message indicates that the validation of the machine learning model has been successful.

18. A network apparatus as claimed in claim 17 wherein the third message comprises at least one of:

an indication of parameters to be used for the trained machine learning model during inference;

an indication of inference rules to be used by the machine learning model during inference;

an indication of a timer for inference by the machine learning model;

an indication of an accuracy level for revalidation of the trained machine learning model;

an indication of a validation threshold for the trained machine learning model.

19. A method comprising:

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

20. A computer program comprising computer program instructions that, when executed by processing circuitry, cause;

enabling a first message to be sent to a UE wherein the first message comprises instructions indicating how the UE should perform training and/or validation of a machine learning model; and

receiving a second message from the UE wherein the second message comprises information indicating an outcome of the training and/or validation of the machine learning model by the UE.

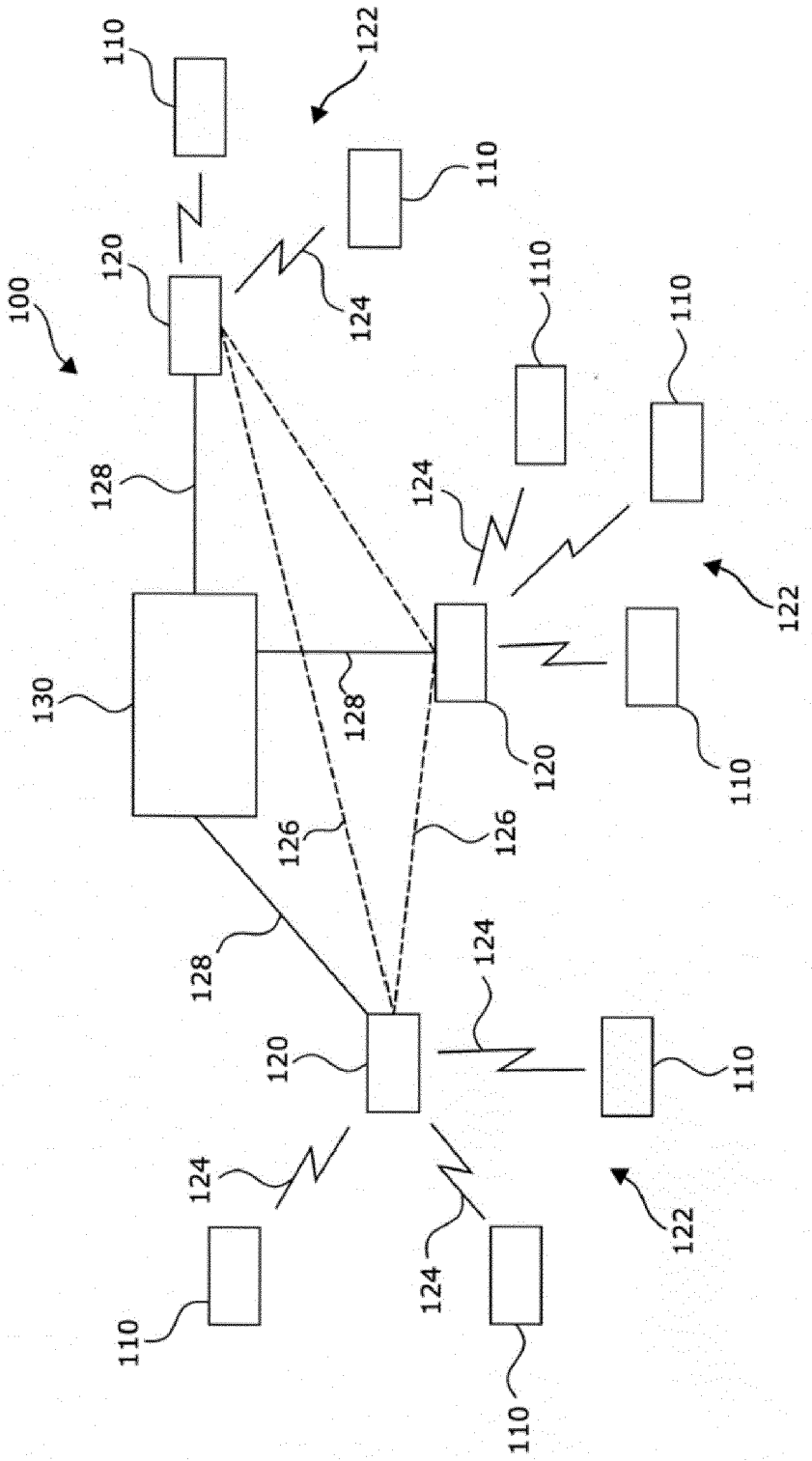

FIG. 1

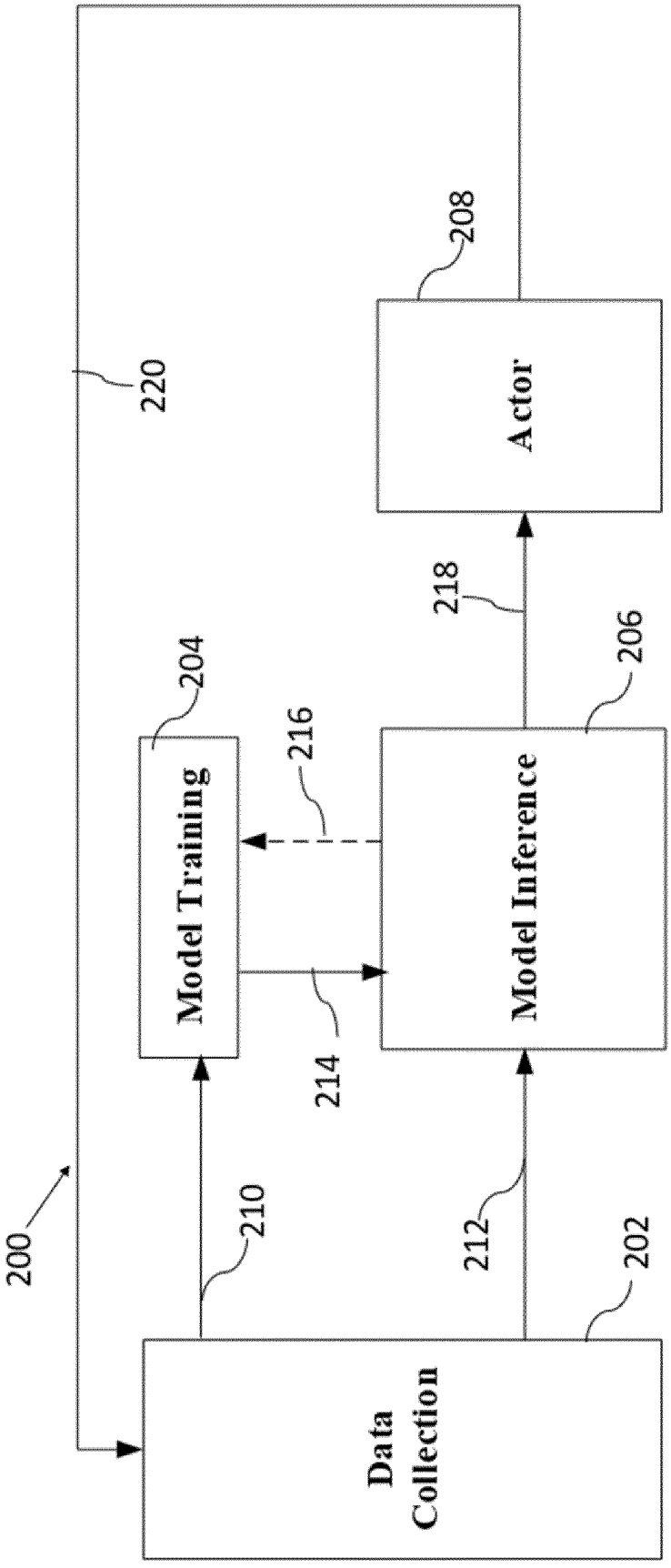
200
202
Data Collection
204
Model Training
206
Model Inference
208
Actor
210
212
214
216
218
220

FIG. 2

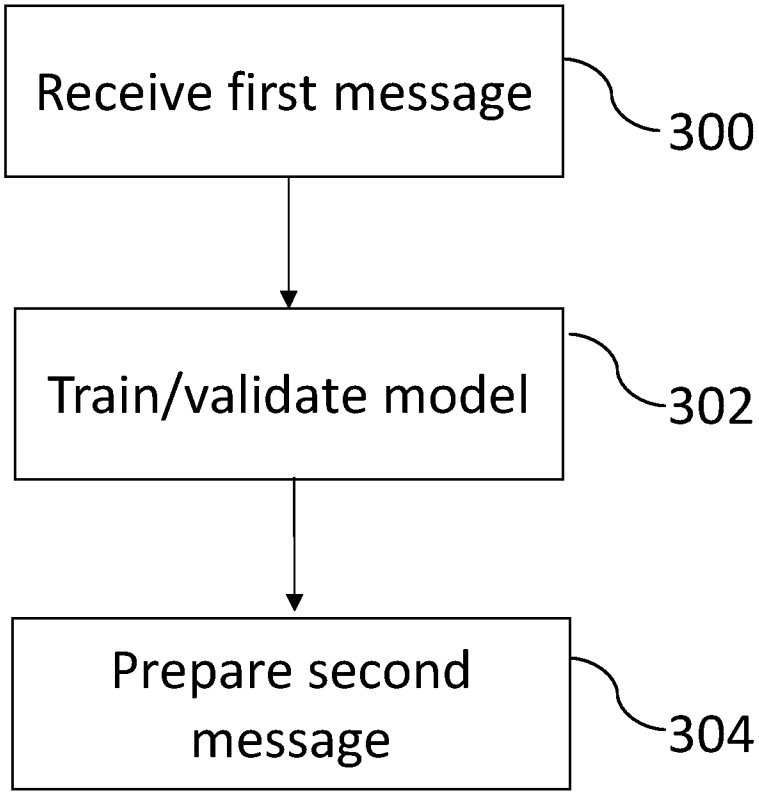
Receive first message
300
Train/validate model
302
Prepare second message
304

FIG. 3A

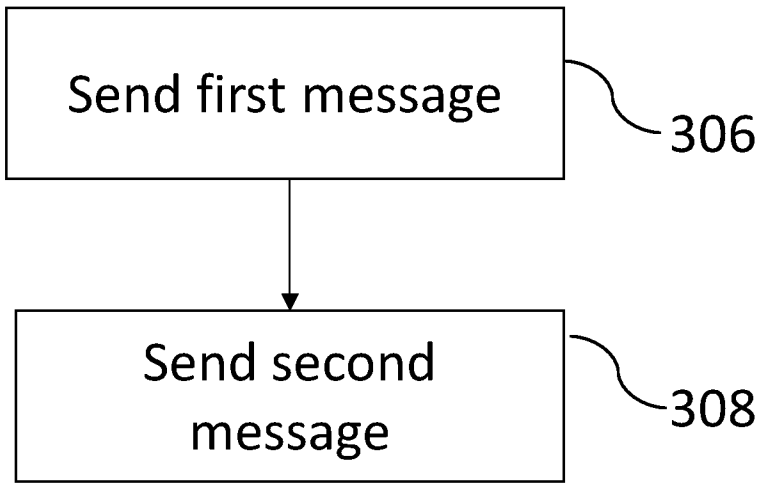
Send first message
306
Send second message
308

FIG. 3B

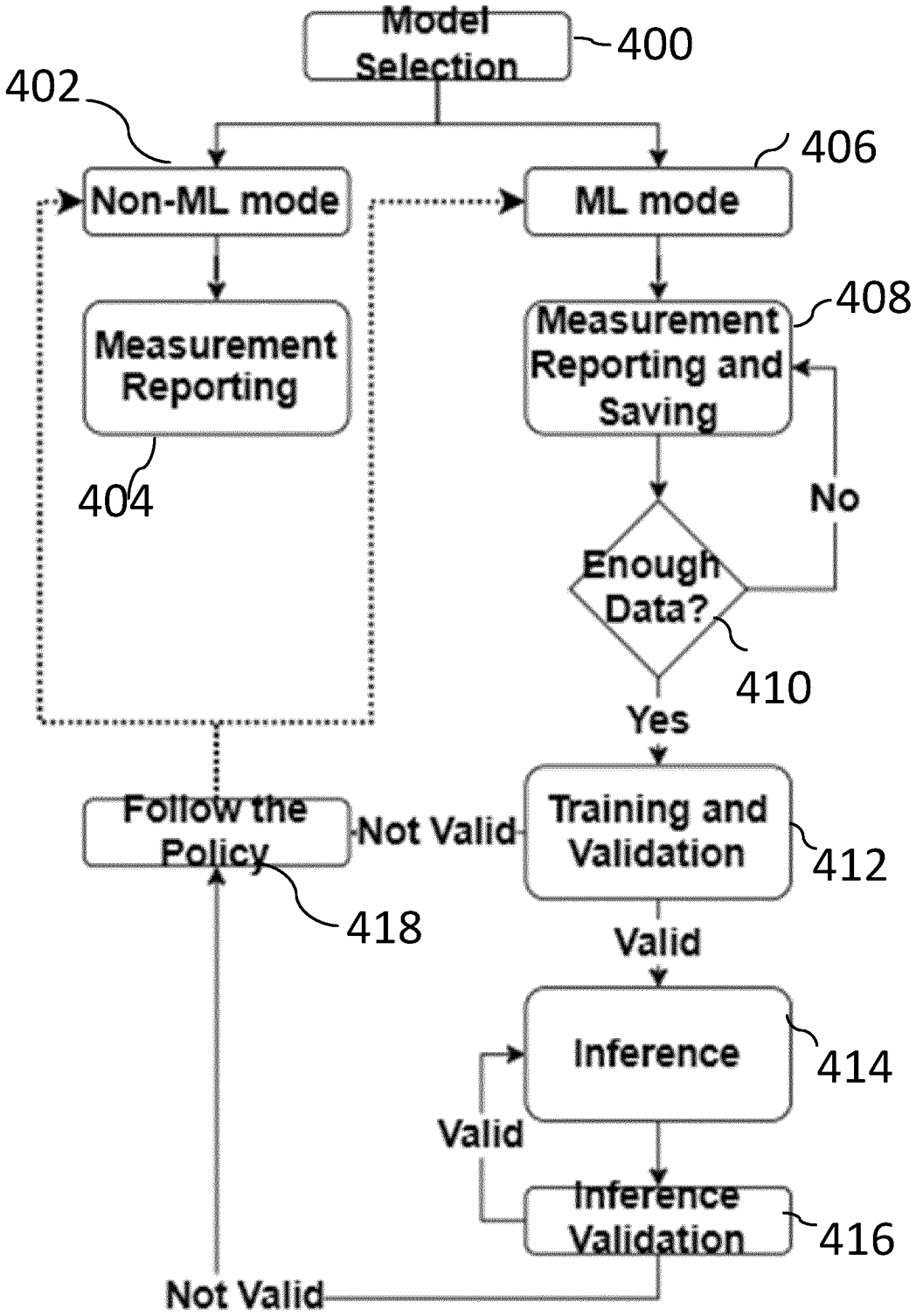
Model Selection
400
402
406
Non-ML mode
ML mode
Measurement Reporting
404
Measurement Reporting and Saving
408
No
Enough Data?
410
Yes
Follow the Policy
Not Valid
Training and Validation
412
418
Valid
Inference
414
Valid
Inference Validation
416
Not Valid

FIG. 4

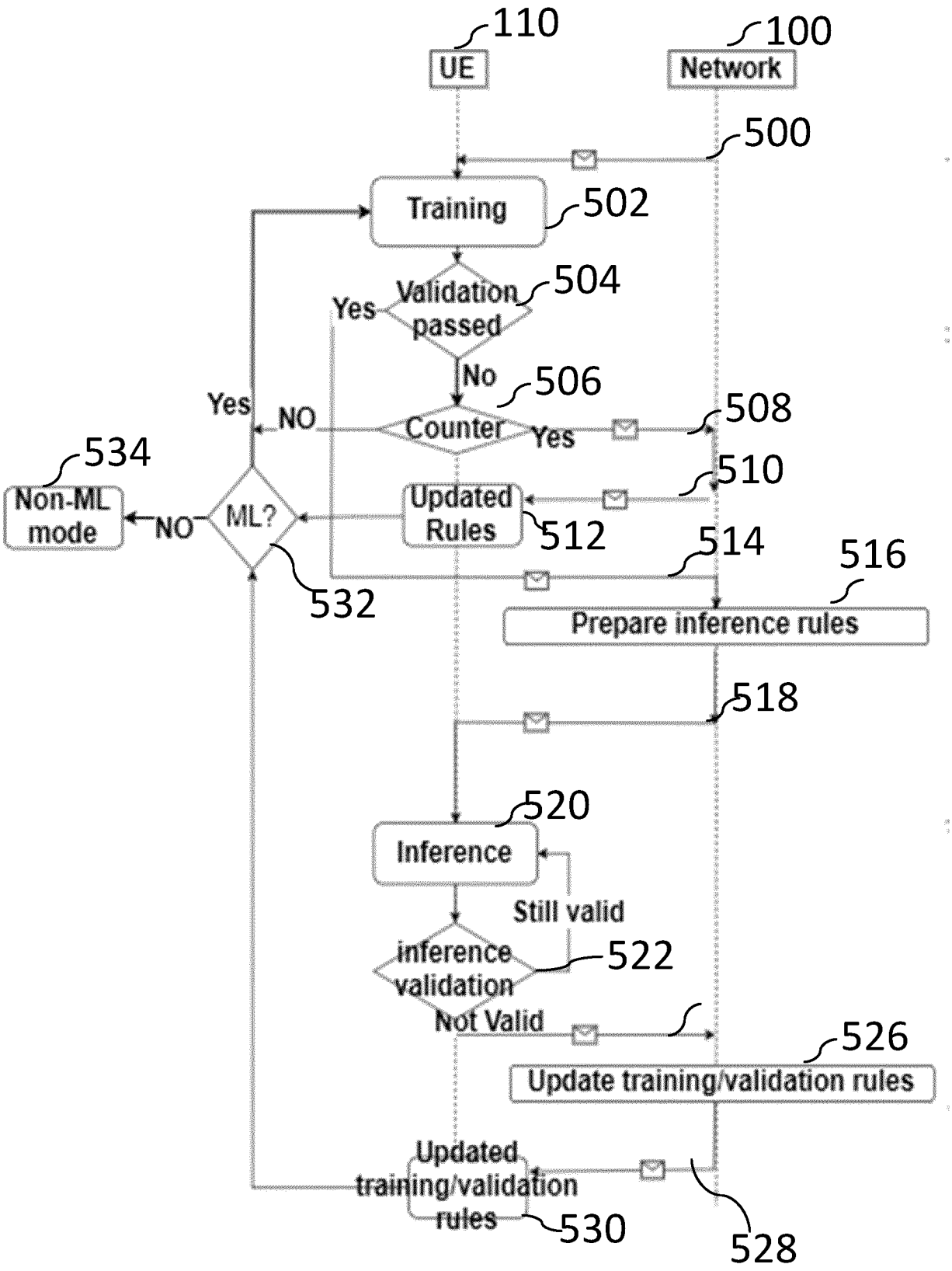
110
UE
100
Network
500
Training
502
Validation passed
504
Yes
No
506
Counter
Yes
NO
Yes
508
534
Non-ML mode
NO
ML?
Updated Rules
512
510
514
516
532
Prepare inference rules
518
520
Inference
Still valid
inference validation
522
Not Valid
526
Update training/validation rules
Updated training/validation rules
530
528

FIG. 5

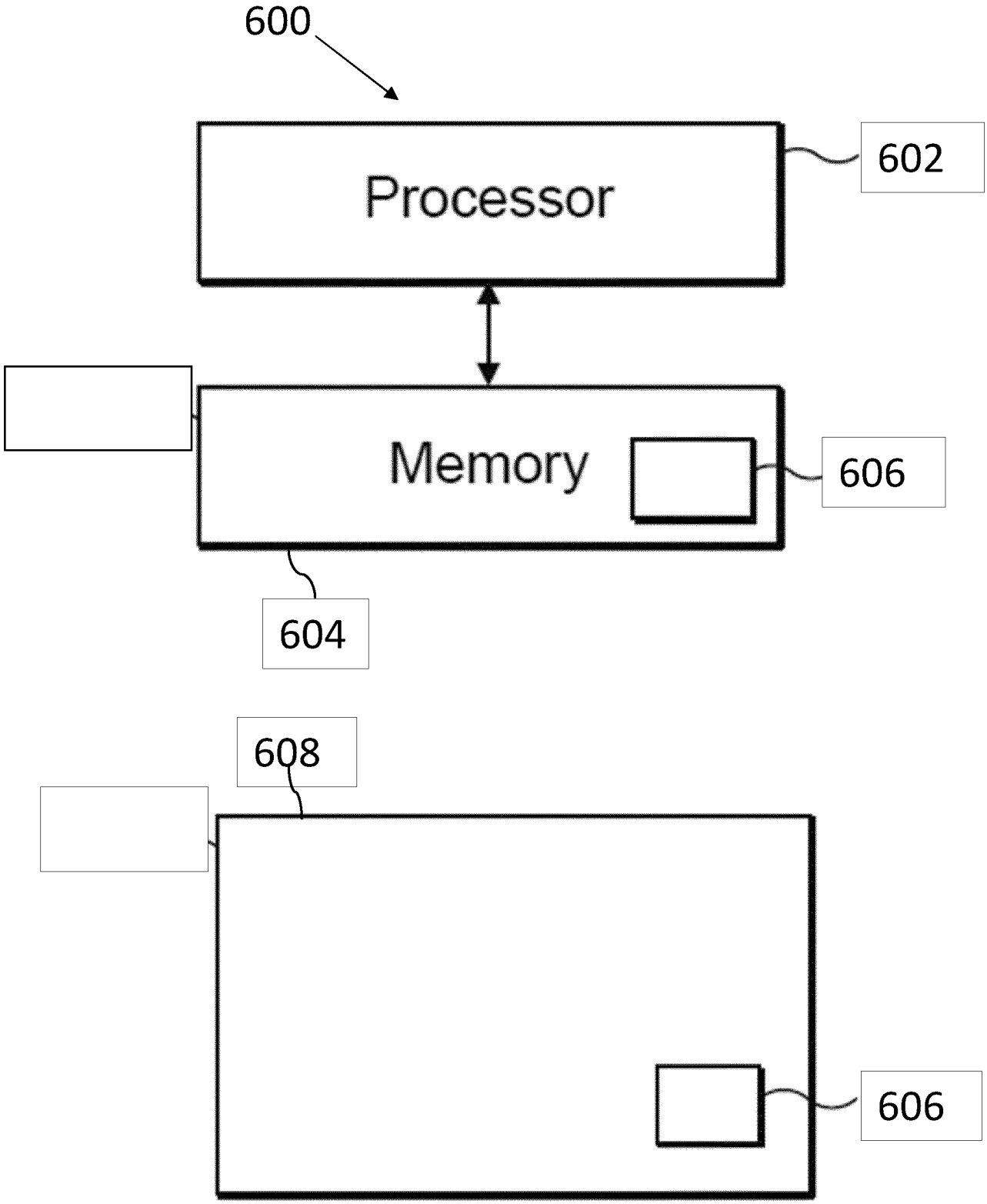

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/071903

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L41/0803 H04L41/16 H04L41/042
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOKIA SHANGHAI BELL ET AL: "Use case on shared AI/ML model monitoring", 3GPP DRAFT; S1-210209R4, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. SA WG1, no. Electronic Meeting; 20210222 - 20210304 15 March 2021 (2021-03-15), XP051987031, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_sa/WG1_Serv/TSGS1_93e_Electronic_Meeting/Docs_revised_number/S1-210209r4.zip S1-210209r4-Use_case_AI_ML_shared_model_sharing.docx [retrieved on 2021-03-15] the whole document -/--	1-20

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 March 2023	16/03/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ceccarini, Giulio

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 9 503 466 B2 (CISCO TECH INC [US]) 22 November 2016 (2016-11-22) column 11, line 50 - column 14, line 17 column 15, line 40 - column 17, line 18; claims; figures	1-20
X	RAKUTEN MOBILE INC: "AI/ML Model Life Cycle Management", 3GPP DRAFT; R1-2205065, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. e-Meeting; 20220509 - 20220520 29 April 2022 (2022-04-29), XP052203911, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205065.zip R1-2205065 AIML Model Life Cycle Management.doc [retrieved on 2022-04-29] the whole document	1-20
X	SONY: "Consideration on common AI/ML framework", 3GPP DRAFT; R1-2203728, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. e-Meeting; 20220509 - 20220520 29 April 2022 (2022-04-29), XP052153145, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203728.zip R1-2203728.docx [retrieved on 2022-04-29] the whole document	1-20

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RAKUTEN MOBILE INC: "Consideration on UE processing capability for AI/ML utilization", 3GPP DRAFT; R1-2205067, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. e-Meeting; 20220509 - 20220520 29 April 2022 (2022-04-29), XP052203913, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205067.zip R1-2205067_RMI_AIML_UEcap_r5.doc [retrieved on 2022-04-29] -----	1-20
A	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Management and orchestration; Study on Artificial Intelligence / Machine Learning (AI/ML) management (Release 18)", 3GPP STANDARD; TECHNICAL REPORT; 3GPP TS 28.908, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , no. V0.3.0 8 July 2022 (2022-07-08), pages 1-20, XP052183687, Retrieved from the Internet: URL:https://ftp.3gpp.org/Specs/archive/28_series/28.908/28908-030.zip 28908-030.docx [retrieved on 2022-07-08] the whole document -----	1-20

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2022/071903

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 9503466 B2	22-11-2016	US 2015193693 A1	09-07-2015
		US 2015193696 A1	09-07-2015
		US 2015193697 A1	09-07-2015
		US 2015195145 A1	09-07-2015
		US 2015195146 A1	09-07-2015
		US 2015195296 A1	09-07-2015