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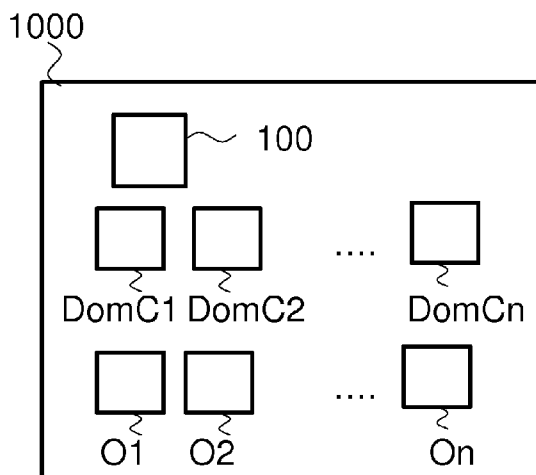


FIG. 3

(57) Abstract: A system (100) for dynamic orchestra-
tion is provided, the system configured to be used for
embedding a virtual network into a physical infra-
structure, the system comprising: a decision compo-
nent (DC) which is configured to evaluate a perform-
ance of at least one orchestrator ($O_1, O_2, \dots, O_n$) based
on at least one parameter ($P_1, P_2, \dots, P_n$), and which
is configured to settle on a recomposing of the orches-
trator ($O_1, O_2, \dots, O_n$) based on the evaluated perform-
ance and, which is configured to provide a recompos-
ing signal ($RS_1, RS_2, \dots, RS_n$) when the recomposing
is settled; and a recomposing component (RC) which
is configured to execute the recomposing of the orches-
trator ($O_1, O_2, \dots, O_n$) when the recomposing signal
($RS_1, RS_2, \dots, RS_n$) is received.

SYSTEM AND METHOD FOR DYNAMIC ORCHESTRATION

5

TECHNICAL FIELD

The present application relates to the field of embedding virtual network appliances into virtualized or physical substrates. In particular the present application relates to a system and a
10 method system for dynamic orchestration.

BACKGROUND

The term “embedding” refers to the allocation of virtualized network functions and respective
15 resources including network resources over possibly physical or virtual network and compute environments. Embedding virtual network appliances into virtualized or physical substrates requires a set of network components responsible for deciding where that embedding will be performed, storing the decision in a database and furthermore managing the creation and maintenance of the correct performance of those components.

20

The term “orchestration” as used by the present invention may describe the automated arrangement, coordination, and management of complex computer systems, middleware, and services or any kind of network management or operation and includes the embedding of virtualized network functions.

25

With increasing number of physical resources, virtual appliances or the number of requests for mapping the performance of the orchestrator is bound to decrease significantly or the requirements for quicker solutions bound to increase. With increasing physical resources the average time taken to calculate the optimal embedding increases exponentially. The problems
30 arise due to static treatment of orchestration requests. This renders those solutions slow, inefficient and prone to errors in various cases.

Every orchestrating component orchestrates a set of “domain controllers”. A domain controller can be any kind of control entity in the infrastructure. This includes as examples in the present

world entities, such as OpenFlow controllers, cloud management systems, hypervisors, lower layer orchestrators and so on.

5 The following patents describe work that is similar to this patent but does not affect the innovativeness of this patent.

US 2003/0167295 A1 describes a method, a system and a computer program to balance the computational and network load in networked computers using self-replicating programs, so-called symbionts. The method presented therein reduces hotspots by encapsulating a resource
10 in a symbiont, and having a user access that symbiont through programs that host symbionts, referred to as hosts. Our definition of self-replicating orchestrators is much different from that of self-replicating programs for load balancing.

US 7,636,916 B2 describes copy operations in a data storage system. A host device directs that
15 a volume of customer data be stored through one of two virtual storage servers on media in an associated library. An initiating controller queues a request to copy the volume to a second library. An initiating controller queues a request to copy the volume to a second library. If the request is not processed by the initiating controller within a predetermined period, the initiating controller broadcasts the copy request to other controllers, each of which queues the request.
20 The patent uses broadcasting of the request to achieve determined processing times which is different from replicating control and management structures for the network.

SUMMARY AND DESCRIPTION

25 It is the objective of the invention to provide an improved technique for realizing dynamic orchestration.

This objective of dynamism is achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

30

According to a first aspect, a system for dynamic orchestration is provided, the system configured to be used for embedding a virtual network into a physical infrastructure, the system comprising: a decision component (DC) which is configured to evaluate a performance of at least one orchestrator or a performance of a domain controller (DomC) or a performance of

orchestrated infrastructure, based on at least one parameter, and which is configured to settle on a recomposing of the at least one orchestrator based on the evaluated performance and, which is configured to provide a first recomposing signal when the recomposing is settled; and a recomposing component (RC) which is configured to execute the recomposing of the at least one orchestrator when a second recomposing signal is received.

Therefore the present invention advantageously provides that a physical resource of the physical infrastructure is associated to at least one domain controller and a domain controller is associated to at least one orchestrator. Based on the performance feedback this association can be changed by the decision component, e.g. setting a decision, and the recomposing component, e.g. performing a merging or a splitting or any transformation in composition. To do this the recomposing component can create and/or delete existing orchestrators and/or domain controllers and copy the relevant information of the existing orchestrators.

The present invention may apply to future carrier networks that need to be able to scale to a vast plurality of nodes, interconnect a vast plurality of devices, and, especially, provide support for the diversified requirements of carrier grade next-generation services.

In a first possible implementation form of the system according to the first aspect, the recomposing component is configured to execute the recomposing by assigning or reassigning at least one domain controller (DC) to the at least one orchestrator. This advantageously provides a reduction in time by automatic expansion and reduction of the domain controllers.

In a second possible implementation form of the system according to the first aspect as such or according to the first implementation form of the first aspect, the decision component is configured to evaluate the performance based on a size of a physical infrastructure of the embedded virtual network, a number of domain controllers (DomCs) assigned to the orchestrator, a topology of the physical infrastructure, or a performance parameter of the physical infrastructure as the at least one parameter. This advantageously provides an improved performance of the dynamic orchestration.

In a third possible implementation form of the system according to the first aspect as such or according to the any of the preceding implementation forms of the first aspect, the decision

component (DC) is configured to settle on a splitting of the orchestrator based on the evaluated performance and wherein the decision component (DC) is configured to provide a first splitting signal as the first recomposing signal when the splitting is settled, wherein the recomposing component (RC) is configured to execute a splitting of the orchestrator when a second splitting signal as the second recomposing signal is received. This advantageously provides an enhanced embedding of a virtual network into a physical infrastructure.

In a fourth possible implementation form of the system according to the third preceding implementation form of the first aspect, the recomposing component (RC) is configured to execute the splitting of the orchestrator by allocating resources for installing a new orchestrator and wherein the recomposing component (RC) is configured to allocate at least one domain controller of the at least one orchestrator to the new orchestrator. This advantageously provides an improved performance of the dynamic orchestration.

In a fifth possible implementation form of the system according to the first aspect as such or according to the any of the preceding implementation forms of the first aspect, the decision component (DC) is further configured to settle on a merging of at least two orchestrators based on the evaluated performance and wherein the decision component (DC) is configured to provide a first merging signal as the first recomposing signal when the merging is settled and wherein the recomposing component (RC) is configured to execute a merging of the at least two orchestrators when a second merging signal as the second recomposing signal is received. This advantageously provides an adjusted recomposing of the virtual network.

In a sixth possible implementation form of the system according to the fifth preceding implementation form of the first aspect, the recomposing component (RC) is configured to execute the merging of the at least two orchestrators by allocating resources for the merged orchestrator and wherein the recomposing component (RC) is configured to allocate at least one domain controller to the merged orchestrator. This advantageously provides an adjusted recomposing of the virtual network.

In a seventh possible implementation form of the system according to the first aspect as such or according to any of the preceding implementation forms of the first aspect, the recomposing component is configured to execute the merging of the at least two orchestrators by allocating

resources for the merged orchestrator, wherein the recomposing component is configured to allocate at least one domain controller to the merged orchestrator. This advantageously provides an improved performance of the dynamic orchestration.

- 5 In an eighth possible implementation form of the system according to the first aspect as such or according to any of the preceding implementation forms of the first aspect, the recomposing component is configured to install the merged orchestrator by reconfiguring the at least one domain controller to be allocated to the merged orchestrator. This advantageously provides an enhanced embedding of a virtual network into a physical infrastructure.

10

According to a second aspect, the invention relates to a computer system for embedding a virtual network into a physical infrastructure comprising: a domain controller, an orchestrator and a system for dynamic orchestration according to the first aspect as such or according to any of the preceding implementation forms of the first aspect.

15

In a first possible implementation form of the computer system according to the second aspect, the computer system is configured to be used in a carrier grade telecommunication or in a computer network. This advantageously provides that the system can be used in next-generation networks.

20

According to a third aspect, the invention relates to a method for dynamic orchestration for embedding a virtual network into a physical infrastructure, the method comprising: evaluating a performance of at least one orchestrator based on at least one parameter; settling on a recomposing of the orchestrators based on the evaluated performance; providing a first
25 recomposing signal, when the recomposing is settled; and executing the recomposing of the orchestrator when a second recomposing signal is received. This advantageously provides an improved performance of the dynamic orchestration.

30

In a first possible implementation form of the method according to the third aspect, the step of settling on a recomposing of the orchestrator comprises a splitting of the orchestrator and wherein a first splitting signal is provided as the first recomposing signal when the splitting is settled and wherein a splitting of the orchestrator is executed when a second splitting signal as

the second recomposing signal is received. This advantageously provides an adjusted recomposing of the virtual network.

In a second possible implementation form of the method according to the third aspect or according to the first possible implementation form of the method according to the third aspect, the step of evaluating the performance of the at least one orchestrator comprises determining whether a failure of at least one domain controller or of at least one orchestrator or of an communication channel is present. This advantageously provides an enhanced embedding of a virtual network into a physical infrastructure.

In a third possible implementation form of the method according to the third aspect as such or according to the any of the preceding implementation forms of the third aspect, the step of settling on a recomposing of the orchestrators comprises a merging of at least two orchestrators based on the evaluated performance and wherein a first merging signal is provided as the first recomposing signal, when the merging is settled and wherein the merging of the at least two orchestrators is executed when the a second merging signal as the second recomposing signal is received. This advantageously provides an enhanced embedding of a virtual network into a physical infrastructure.

In a fourth possible implementation form of the method according to the third possible implementation form of the method, the at least two orchestrators process one application and after the merging of the at least two orchestrators, one orchestrator processes the one application. This advantageously provides an efficient merging interface.

In a fifth possible implementation form of the method according to the third aspect as such or according to the any of the preceding implementation forms of the third aspect, the step of settling on a recomposing of the orchestrators comprises a copying of at least one orchestrator, wherein a copying signal is provided as the recomposing signal, when the copying is settled and wherein a copying of at least one orchestrator is executed when the copying signal is received. This advantageously provides that the components of the orchestrator can independently of each other create multiple copies of themselves.

In a sixth possible implementation form of the method according to the fifth possible implementation form, after the copying of the at least one orchestrator, two orchestrators may process one application. This advantageously provides an improved performance of the dynamic orchestration.

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In a seventh possible implementation form of the method according to the fifth possible implementation form of the method, after the copying of the at least one orchestrator, at least one domain controller is moved to another orchestrator and a performance of a controlee of at least one domain controller is improved. This advantageously provides an improved performance of the dynamic orchestration.

10

According to a fourth aspect, the invention relates to a decision component for dynamic orchestration in a system for embedding a virtual network into a physical infrastructure according to the first aspect as such or according to any of the preceding implementation forms of the first aspect.

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According to a fifth aspect, the invention relates to a recomposing component (RC) for dynamic orchestration in a system for embedding a virtual network into a physical infrastructure according to the first aspect as such or according to any of the preceding implementation forms of the first aspect.

20

The methods, systems and devices described herein may be implemented as software in a Digital Signal Processor, DSP, in a micro-controller or in any other side-processor or as hardware circuit within an application specific integrated circuit, ASIC or in a field-programmable gate array which is an integrated circuit designed to be configured by a customer or a designer after manufacturing – hence "field-programmable".

25

The invention can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations thereof, e.g. in available hardware of conventional mobile devices or in new hardware dedicated for processing the methods described herein.

30

These and other aspects of the present invention will become apparent from and be elucidated with reference to the embodiments described hereinafter. A more complete appreciation of the

present invention and the attendant advantages thereof will be more clearly understood with reference to the following schematic drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

5

Further embodiments of the invention will be described with respect to the following figures, in which:

10 Fig. 1 shows a schematic diagram of a system for dynamic orchestration according to one embodiment of the present invention;

Fig. 2 shows a schematic diagram of a flowchart diagram of a method for dynamic orchestration for embedding a virtual network into a physical infrastructure according to an embodiment of the invention;

15

Fig. 3 shows a schematic diagram of a computer system for embedding a virtual network into a physical infrastructure according to one embodiment of the present invention;

20 Fig. 4 shows a schematic diagram of a dynamic creation of new orchestration to manage load according to one embodiment of the present invention;

Fig. 5 shows a schematic diagram of a flowchart of decision for rearrangement for embedding a virtual network into a physical infrastructure according to one embodiment of the present invention;

25

Fig. 6 shows a schematic diagram of the functioning of the decision component according to one embodiment of the present invention;

30 Fig. 7 shows a schematic diagram of the functioning of the recomposing component according to one embodiment of the present invention;

Fig. 8 shows a schematic diagram of a sequence diagram for copying and moving according to one embodiment of the present invention; and

Fig. 9 shows a schematic diagram of a sequence diagram for two orchestrators to one orchestrator merged according to one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

5

In the associated figures, identical reference signs denote identical or at least equivalent elements, parts, units or steps. In addition, it should be noted that all of the accompanying drawings are not to scale.

10 The technical solutions in the embodiments of the present invention are described clearly and completely in the following with detailed reference to the accompanying drawings in the embodiments of the present invention.

The present invention advantageously provides an orchestrator responsible for the management
15 and mapping of virtual resources over physical resources via north bound interfaces of the domain controllers. The configurations of the said physical resources are controlled usually remotely by domain controllers. Examples of domain controllers include OpenFlow, OF, controllers, cloud managers, data center managers.

20 The present invention advantageously provides an orchestrator that can recompose itself when a given threshold in the physical size or virtual network, abbreviated vnet, request queue length is reached. In essence, replication implies the direct or indirect movement of data and configurations relating to at least one of the domain controllers under the control of one orchestrating entity to another orchestrating entity or creating a copy of the same data and
25 configurations, with the purpose of reassigning control of the said domain controller's physical and or virtual resources to a new orchestrator.

The present invention may solve the problem in that the components of the orchestrator can independent of each other i) create multiple copies (or any other recomposing) of themselves
30 ii) calculate which part of the network under their control has to be moved to which new copy (or any other recomposing) and iii) move the identified part of network there. The new copy (or any other recomposing) can be anywhere, even a thread or a process on the same machine, for instance.

According to an exemplary embodiment of the present invention, all these steps can be independent of each other, for example, the moving the network to new orchestrator can be done with pre-existing orchestrators. For the case of merging, the following steps may be performed: i) identify the networks that should be merged under which orchestrator ii) move
5 the networks there iii) uninstall release the resources of remaining empty orchestrators.

The present invention is intended to provide a solution enabled by the fact that in a dynamic virtualized environment the orchestrator can be recomposed, for instance copied, in part or whole, dynamically and assigned to a new resource. The present invention provides that the
10 orchestrator may become a client of itself.

The present invention advantageously makes use of decision components and recomposing components along with the moving or merging or any other recomposing procedures, like for instance splitting. The decision components and the recomposing components are logical or
15 virtual network components and can be collocated or implemented in one component (even within the orchestrator) or may share some functionality such as embedding with the orchestrator.

The term “recomposing” or “to recompose” as used by the present invention can be any kind of change or of transforming or of altering the composition or the structure or the hierarchy or
20 the topology network entities, in particular, of the orchestration components in relation to the domain controllers.

The term “virtual network embedding” or “embedding” as used by the present invention may describe the efficient embedding of virtual networks with resource constraints into a substrate
25 network.

The term “splitting” or “to split” as used by the present invention may describe any dividing or copying of entities, resulting in a modified composition or structure or hierarchy or topology of
30 network entities, in particular, of the orchestration components in relation to the domain controllers.

The present invention may apply to future carrier networks that need to be able to scale to a vast plurality of nodes, interconnect a vast plurality of devices, and, especially, provide support for the diversified requirements of carrier grade next-generation services.

- 5 The present invention may provide that as a recomposing a merging can be done by distributing controllers across multiple orchestrators as well as that multiple orchestrators can merge onto multiple orchestrators, for instance, 5 to 3, or 3 to 2, or 4 to 2, or 8 to 3 or any other pair of numbers, also a merging of 2 to 1, or 3 to 1 or any higher number to 1 may be possible.
- 10 The present invention may provide that as a recomposing a splitting can be done by distributing multiple controllers across multiple orchestrators as well as that one or multiple orchestrators can split into multiple orchestrators, for instance, 3 to 5, or 2 to 3, or 2 to 4, or 3 to 8 or any other pair of numbers.
- 15 The present invention may apply to domain controllers such as OpenFlow, OF, controllers, cloud managers, data centre managers which may copy themselves or move the controlees (physical resources) under the control of newer domain controllers. Similarly, an increase in network traffic lookups from OF switches may require the OF switches to copy some of the switches under its control to another OF controller.
- 20 Domain controllers can also be other orchestrators. Orchestrators can move domain controllers or other orchestrators under their control. For instance, any controllee (managed) may be copied into another virtualized controller (manager) to improve overall performance. For example, the present invention may advantageously allow increasing lower layer orchestrators that can create
- 25 a new higher layer orchestrator.

The present invention may also apply to other scenarios such as controller failure (orchestrator failure) where the failing orchestrator can be replicated to ensure continued performance of the network.

- 30 The present invention may apply that the copied orchestrator can be another thread/process of the same orchestrating application or another application in the same resource.

The present invention may apply to an example in which the orchestrator to copy itself creates a request of a newer control network which is then handled by itself (or another orchestrator).

Apparently, the described embodiments are only some embodiments of the present invention, rather than all embodiments. Based on the described embodiments of the present invention, all other embodiments obtained by persons of ordinary skill in the art without making any creative effort shall fall within the protection scope of the present invention.

Fig. 1 shows a schematic diagram of a system for dynamic orchestration according to one embodiment of the present invention.

Fig. 1 shows an embodiment of a system 100 for dynamic orchestration, the system configured to be used for embedding a virtual network into a physical infrastructure, the system comprising: a decision component DC and a recomposing component RC.

The decision component DC is configured to evaluate a performance of at least one orchestrator $O_1, O_2, \dots, O_n$ based on at least one parameter $P_1, P_2, \dots, P_n$.

The decision component DC is configured to settle on a recomposing of the orchestrator $O_1, O_2, \dots, O_n$ based on the evaluated performance and is configured to provide a recomposing signal $RS_1, RS_2, \dots, RS_n$ when the recomposing is settled.

The recomposing component RC is configured to execute the recomposing of the orchestrator $O_1, O_2, \dots, O_n$ when the recomposing signal $RS_1, RS_2, \dots, RS_n$ is received.

Fig. 2 shows a schematic diagram of a flowchart diagram of a method for dynamic orchestration for embedding a virtual network into a physical infrastructure according to an embodiment of the invention.

As a first step of the method, evaluating S1 a performance of at least one orchestrator $O_1, O_2, \dots, O_n$ based on at least one parameter $P_1, P_2, \dots, P_n$ is conducted.

As a second step of the method, settling S2 on a recomposing of the orchestrator $O_1, O_2, \dots, O_n$ based on the evaluated performance is conducted.

As a third step of the method, providing S3 a recomposing signal $RS_1, RS_2, \dots, RS_n$, when the recomposing is settled, is conducted.

- 5 As a fourth step of the method, executing S4 the recomposing of the orchestrator $O_1, O_2, \dots, O_n$ when the recomposing signal $RS_1, RS_2, \dots, RS_n$ is received is conducted.

Fig. 3 shows a schematic diagram of a computer system for embedding a virtual network into a physical infrastructure according to one embodiment of the present invention.

10

The computer system 1000 for embedding a virtual network into a physical infrastructure may comprise a domain controller $DomC_1, DomC_2, \dots, DomC_n$, an orchestrator $O_1, O_2, \dots, O_n$ and a system 100 for dynamic orchestration, wherein the system is configured to be used for embedding a virtual network into a physical infrastructure.

15

Fig. 4 shows a schematic diagram of a dynamic creation of new orchestration to manage load according to one embodiment of the present invention.

Fig. 4 shows a schematic diagram of splitting, wherein an orchestrator can replicate itself when
20 a given threshold in the physical size or vnet request queue length is reached.

The domain controllers $DomC_{1-9}$ are originally assigned to Orchestrator O_1 .

According to an exemplary embodiment of the present invention, the decision component DC
25 is configured to settle on a splitting of the orchestrator O_1 into O_1 and O_2 . The splitting of the orchestrator O_1 is executed by the recomposing component RC when the splitting signal is received.

According to the decision, the domain controllers $DomC_1, DomC_2, DomC_3, DomC_4$, and
30 $DomC_5$ are assigned to orchestrator O_1 , the domain controllers $DomC_6, DomC_7, DomC_8$, and $DomC_9$ are assigned to orchestrator O_2 . The two orchestrators O_1, O_2 are separated by the domain border DB. This dynamic creation of new orchestration is performed and executed by the recomposing component RC in order to manage load of the two orchestrators O_1, O_2 .

Fig. 5 shows a schematic diagram of a flowchart of decision for rearrangement for embedding a virtual network into a physical infrastructure according to one embodiment of the present invention.

5

The decision component DC is responsible for making the decision to split the orchestrator or not. Based on the recommendation of the decision component DC, informing the orchestrator to ask the recomposing component RC to execute to splitting by transmitting the recomposing signal $RS_1, RS_2, \dots, RS_n$.

10

The orchestrator $O_1, \dots, O_n$ may periodically report various performance parameters to the decision component DC based on which the decision component DC can recommend to orchestrator to split or not or to merge or to perform any kind of recomposing. These recommendations may be based on an algorithm that can be influenced by administrator settings of various values.

15

The parameters $P_1, P_2, \dots, P_n$ that the decision component DC will consider, in other words the parameter $P_1, P_2, \dots, P_n$ that the decision component DC will use for evaluating a performance of at least one orchestrator $O_1, O_2, \dots, O_n$ may include for instance:

20

- Size of the physical infrastructure, i.e. the physical network or any controllers
- Topology of the network, for instance, including geographic locations
- Virtual networks embedded
- Network characterizing parameters (delay in control plane, number of new connection requests, migrating virtual machine states, abbreviated vms)

25

The parameter $P_1, P_2, \dots, P_n$ can be a parameter of a domain controller $DomC_1, \dots, DomC_n$ or a parameter of an orchestrator $O_1, O_2, \dots, O_n$.

30

The decision component DC may work by either periodically polling the orchestrator for statistics on various parameters $P_1, P_2, \dots, P_n$ or the orchestrator $O_1, O_2, \dots, O_n$ may report those parameters $P_1, P_2, \dots, P_n$ to the decision component DC periodically.

The decision component DC may review the parameters of operation of every domain controller DomC₁, ..., DomC_n under the corresponding orchestrator O₁, O₂, ..., O_n, see Fig. 5, are within the operation limits of the control network as specified by the vendor or the administrator of the network.

5

For instance, the performance of an orchestrator O₁, O₂, ..., O_n may be evaluated or measured by reviewing the parameters P₁, P₂, ..., P_n of operation of the domain controllers DomC₁, ..., DomC_n under the orchestrator O₁, O₂, ..., O_n. The decision component DC may periodically evaluate or measure performance parameters P₁, P₂, ..., P_n of the domain controllers DomC₁,
10 ..., DomC_n under the orchestrator O₁, O₂, ..., O_n.

The decision component DC may prepare a list of all the domain controllers DomC₁, ..., DomC_n that don't meet the parameters P₁, P₂, ..., P_n and reports them to the orchestrator – supposing the domain controllers DomC₁, ..., DomC_n belong to the same orchestrator – with a
15 recommendation to move those domain controllers DomC₁, ..., DomC_n to another orchestrator O₁, ..., O_n. For instance, moving domain controllers DomC₁, ..., DomC_n to another orchestrator O₁, ..., O_n helps to reduce the load of an orchestrator.

Fig. 6 shows a schematic diagram of the functioning of the decision component according to
20 one embodiment of the present invention.

In step S10, a statistics report for at least one domain controller DomC₁ from an orchestrator O₁ may be performed. The orchestrator O₁ may periodically report various performance parameters to the decision component DC based on which the decision component DC can
25 recommend to orchestrator O₁ to split or not.

In step S11, an evaluation whether the domain controllers DomC₁, ..., DomC_n meet an admin provided threshold value may be performed. This advantageously ensures that the load faced by an orchestrating component may be limited.

30

If yes, an confirmation may be send to the orchestrator O₁, ..., O_n.

If no, in step S12, a list of domain controllers DomC₁, ..., DomC_n not meeting the threshold may be generated and the list may be send to an orchestrator O₁, ..., O_n and splitting or any

other recomposing operation may be recommended. Based on the recomposing decision a list of domain controllers is sent to the new orchestrator responsible for them.

Fig. 7 shows a schematic diagram of the functioning of the recomposing component according to one embodiment of the present invention.

The recomposing component RC is responsible for executing the decision recommended by the decision component DC for the orchestrator $O_1, \dots, O_n$. The recomposing component RC can co-exist with decision component DC. The recomposing component RC may find the resource to install the new orchestrator or may assign the split of the network to the new orchestrator.

The recomposing component RC may configure control channels, may transfer information of existing networks vnets or may reconfigure physical controllers and vnets to report to new orchestrator O_1 .

In step S20, an initializing may be performed and a list of all domain controllers $DomC_1, \dots, DomC_n$ to move from an orchestrator $O_1, \dots, O_n$ will be transmitted.

In step S21, a search for existing orchestrators $O_1, \dots, O_n$ per domain controllers $DomC_1, \dots, DomC_n$ which meet the threshold value may be performed.

In step S22, an evaluation whether all domain controllers $DomC_1, \dots, DomC_n$ found a new orchestrator $O_1, \dots, O_n$ may be performed.

If yes, the method will continue with performing step S25.

If no, in step S23, finding one or more empty resource satisfying a threshold requirement for the remaining domain controllers $DomC_1, \dots, DomC_n$ may be performed. If there are domain controllers $DomC_1, \dots, DomC_n$ that cannot be matched to any orchestrator $O_1, \dots, O_n$ then one or multiple new empty resources may be located that can best satisfy the constraints of an orchestrator controller relationship.

In step S24, a copying or a splitting of the orchestrator O_1 may be performed. In other words, a recomposing may be performed.

In step S25, a transfer of intended domain controllers DomC₁, ..., DomC_n to a new orchestrator O₂ may be performed.

5 In step S26, a de-initializing may be performed.

A de-initializing may comprise a re-adjusting of constraints or threshold requirement that can be placed by the vendor and/or enhanced by the administrator or the applications using the domain controllers DomC₁, ..., DomC_n.

10

Fig. 8 shows a schematic diagram of a sequence diagram for copying and moving according to one embodiment of the present invention.

Fig. 8 shows the functions of the orchestrator together with the recomposing component RC for copying to a new empty resource and moving domain controllers. The steps in Fig. 8 are explained as follows:

15

1) The orchestrator O₁ receives the decision to split some domain controllers from its domain that do not satisfy the predetermined/preconfigured requirements.

20

2) The orchestrator O₁ provides the list of such domain controllers to the recomposing component RC, and other relevant information that it may inquire for.

3) The recomposing component RC runs a splitting algorithm deciding individually or as parts which domain controllers should be migrated where. Any splitting algorithm maybe used.

25

4) A) Information is provided to the orchestrator to move the domain controllers to various orchestrators; and/or

B) A new resource location is identified to install an orchestration component and a copy procedure to move the identified domain controllers to the new orchestrator is initiated.

30

5) The old orchestrator O_1 determines if some service-level agreement, SLA, or contractual agreements are compromised as a result of the move of the various domain controllers and takes necessary measures to reconfigure the virtual networks to conform to those requirements.

5 6) The different orchestrators are contacted by the recomposing component RC asking them to take on the responsibilities of the respective domain controllers and copy their states from the old orchestrator.

7) Further relevant information of the virtual networks hosted on the resources controlled
10 by those domain controllers maybe requested by the new orchestrator O_2 to the old orchestrator O_1 .

8) The old orchestrator replies supplying such information. This interface may also be proactive from the old orchestrator.

15

9) The old orchestrator O_1 then can ask and/or configure the respective domain controllers $DomC_1$ to report to the new orchestrator.

10) The copy of the domain controllers $DomC_1$ to the new orchestrator O_2 is completed and
20 standard operation between the domain controllers $DomC_1$ and new orchestrator O_2 follows.

Fig. 9 shows a schematic diagram of a sequence diagram for two orchestrators merged into one orchestrator according to one embodiment of the present invention.

25 Fig. 9 shows the functions of the orchestrator together with the recomposing component RC for merging two orchestrators to one. When merging two orchestrators to one, for instance, the two orchestrators O_1 , O_2 may process one application and after the merging of the two orchestrators O_1 , O_2 , one orchestrator O_1 may processes the same application. The processing of the same application can comprise a thread or a process of the same orchestrating application.

30

The same procedure can also cover multiple orchestrators to multiple orchestrator convergence (n to $n-x$ where $x \geq 0$). The steps in the Fig. 9 are explained as follows:

- 1) Multiple orchestrators may receive the decision to merge some domain controllers DomC₁, ..., DomC_n from their domain primarily because there are far too many orchestrators idle.
- 5 2) The orchestrator O₁ provides the list of all its domain controllers DomC₁, ..., DomC_n to the recomposing component RC, and other relevant information that it may inquire for.
- 3) The recomposing component RC runs the merging algorithm deciding individually or as parts which domain controllers DomC₁, ..., DomC_n should be migrated where. Any
10 algorithm may be used such.
- 4) The information is provided to the orchestrator to move all its the domain controllers to various orchestrators and to a specific (could be newly created Figure 8 step 4B) orchestrator to accept all those domain controllers.
15
- 5) The different old orchestrators O₁ are contacted by the new orchestrator O₂ asking them to provide details of their respective domain controllers DomC₁, ..., DomC_n and copy their states over.
- 20 6) Relevant information of the virtual networks hosted on the resources controlled by those domain controllers is provided by the old orchestrator(s) O₁ to the new orchestrator O₂. This interface may also be proactive from the old orchestrator O₁.
- 7) The old orchestrator O₁ then can ask/configure the respective domain controllers to
25 report to the new orchestrator O₂.
- 8) The domain controllers DomC₁, ..., DomC_n independent of the previous steps may also seek to authorize the move to the new orchestrator O₂.
- 30 9) In response to the authorization request the old orchestrator O₁ may authorize or deny the move.
- 10) A) the old orchestrator O₁ may request the recomposing component RC to undeploy itself since has no more domain controllers to manage.

B) the copy of the domain controllers DomC₁, ..., DomC_n to the new orchestrator O₂ is completed and standard operation between the domain controllers DomC₁, ..., DomC_n and new orchestrator O₂ follows.

- 5 11) The recomposing component RC may undeploy the orchestrator that has no underlying domain controllers releasing a new empty resource container.

From the foregoing, it will be apparent to those skilled in the art that a variety of methods, systems, computer programs on recording media, and the like, are provided.

10

The present disclosure also supports a computer program product including computer executable code or computer executable instructions that, when executed, causes at least one computer to execute the performing and computing steps described herein.

- 15 Many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the above teachings. Of course, those skilled in the art readily recognize that there are numerous applications of the invention beyond those described herein.

20 While the present invention has been described with reference to one or more particular embodiments, those skilled in the art recognize that many changes may be made thereto without departing from the scope of the present invention. It is therefore to be understood that within the scope of the appended claims and their equivalents, the inventions may be practiced otherwise than as specifically described herein.

- 25 In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims.

30 The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. A computer program may be stored or distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

PATENT CLAIMS

5 1. A system (100) for dynamic orchestration, the system configured to be used for embedding a virtual network into a physical infrastructure, the system comprising:

10 - a decision component (DC) which is configured to evaluate a performance of at least one orchestrator or a performance of a domain controller (DomC) or a performance of orchestrated infrastructure, based on at least one parameter ($P_1, P_2, \dots, P_n$), and which is configured to settle on a recomposing of the at least one orchestrator based on the evaluated performance and, which is configured to provide a first recomposing signal when the recomposing is settled; and

15 - a recomposing component (RC) which is configured to execute the recomposing of the at least one orchestrator when a second recomposing signal is received.

20 2. The system (100) according to claim 1, wherein the recomposing component (RC) is configured to execute the recomposing by assigning or reassigning at least one domain controller (DC) to the at least one orchestrator.

25 3. The system (100) according to one of the claims 1 and 2, wherein the decision component (DC) is configured to evaluate the performance based on a size of a physical infrastructure of the embedded virtual network, a number of domain controllers (DomCs) assigned to the orchestrator, a topology of the physical infrastructure, or a performance parameter of the physical infrastructure as the at least one parameter.

30 4. The system (100) according to one of claims 1 to 3, wherein the decision component (DC) is configured to settle on a splitting of the orchestrator based on the evaluated performance and wherein the decision component (DC) is configured to

provide a first splitting signal as the first recomposing signal when the splitting is settled, wherein the recomposing component (RC) is configured to execute a splitting of the orchestrator when a second splitting signal as the second recomposing signal is received.

5 5. The system (100) according to claim 4,

wherein the recomposing component (RC) is configured to execute the splitting of the orchestrator by allocating resources for installing a new orchestrator and wherein the recomposing component (RC) is configured to allocate at least one domain controller of the at
10 least one orchestrator to the new orchestrator.

6. The system (100) according to one of claims 1 to 5,

wherein the decision component (DC) is further configured to settle on a merging of at least
15 two orchestrators based on the evaluated performance and wherein the decision component (DC) is configured to provide a first merging signal as the first recomposing signal when the merging is settled and wherein the recomposing component (RC) is configured to execute a merging of the at least two orchestrators when a second merging signal as the second recomposing signal is received.

20

7. The system (100) according to claim 6,

wherein the recomposing component (RC) is configured to execute the merging of the at least two orchestrators by allocating resources for the merged orchestrator and wherein the
25 recomposing component (RC) is configured to allocate at least one domain controller to the merged orchestrator.

8. A decision component (DC) for dynamic orchestration in a system for embedding a virtual network into a physical infrastructure according to any one of claims 1 to 7.

30

9. A recomposing component (RC) for dynamic orchestration in a system for embedding a virtual network into a physical infrastructure according to any one of claims 1 to 7.

10. Computer system (1000) for embedding a virtual network into a physical infrastructure comprising:

- a domain controller;
- an orchestrator; and
- a system (100) for dynamic orchestration according to one of claims 1 to 7.

11. The computer system (1000) according to claim 10, wherein the computer system (1000) is configured to be used in a carrier grade telecommunication or in a computer network.

12. A method for dynamic orchestration for embedding a virtual network into a physical infrastructure, the method comprising:

- evaluating (S1) a performance of at least one orchestrator based on at least one parameter;
- settling (S2) on a recomposing of the orchestrators based on the evaluated performance;
- providing (S3) a first recomposing signal, when the recomposing is settled; and
- executing (S4) the recomposing of the orchestrator when a second recomposing signal is received.

13. The method according to claim 12,

wherein the step of settling (S2) on a recomposing of the orchestrator comprises a splitting of the orchestrator and wherein a first splitting signal is provided as the first recomposing signal when the splitting is settled and wherein a splitting of the orchestrator is executed when a second splitting signal as the second recomposing signal is received.

14. The method according to one of the claims 12 to 13,

wherein the step of evaluating (S1) the performance of the at least one orchestrator comprises determining whether a failure of at least one domain controller or of at least one orchestrator or of an communication channel is present.

15. The method according to claim 12,

wherein the step of settling (S2) on a recomposing of the orchestrators comprises a merging of at least two orchestrators based on the evaluated performance and wherein a first merging signal is provided as the first recomposing signal, when the merging is settled and wherein the merging of the at least two orchestrators is executed when the a second merging signal as the second
5 recomposing signal is received.

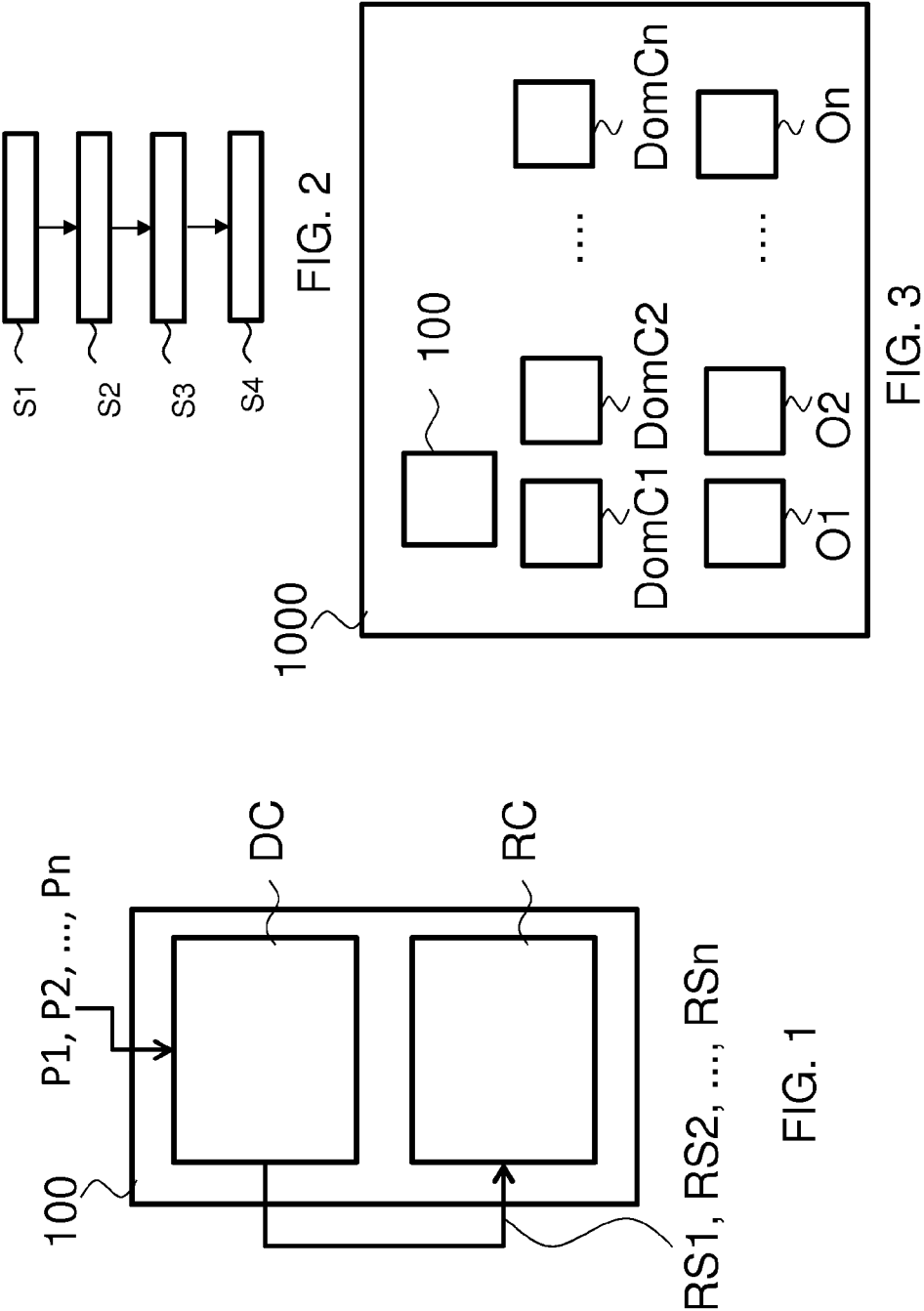


FIG. 1

FIG. 2

FIG. 3

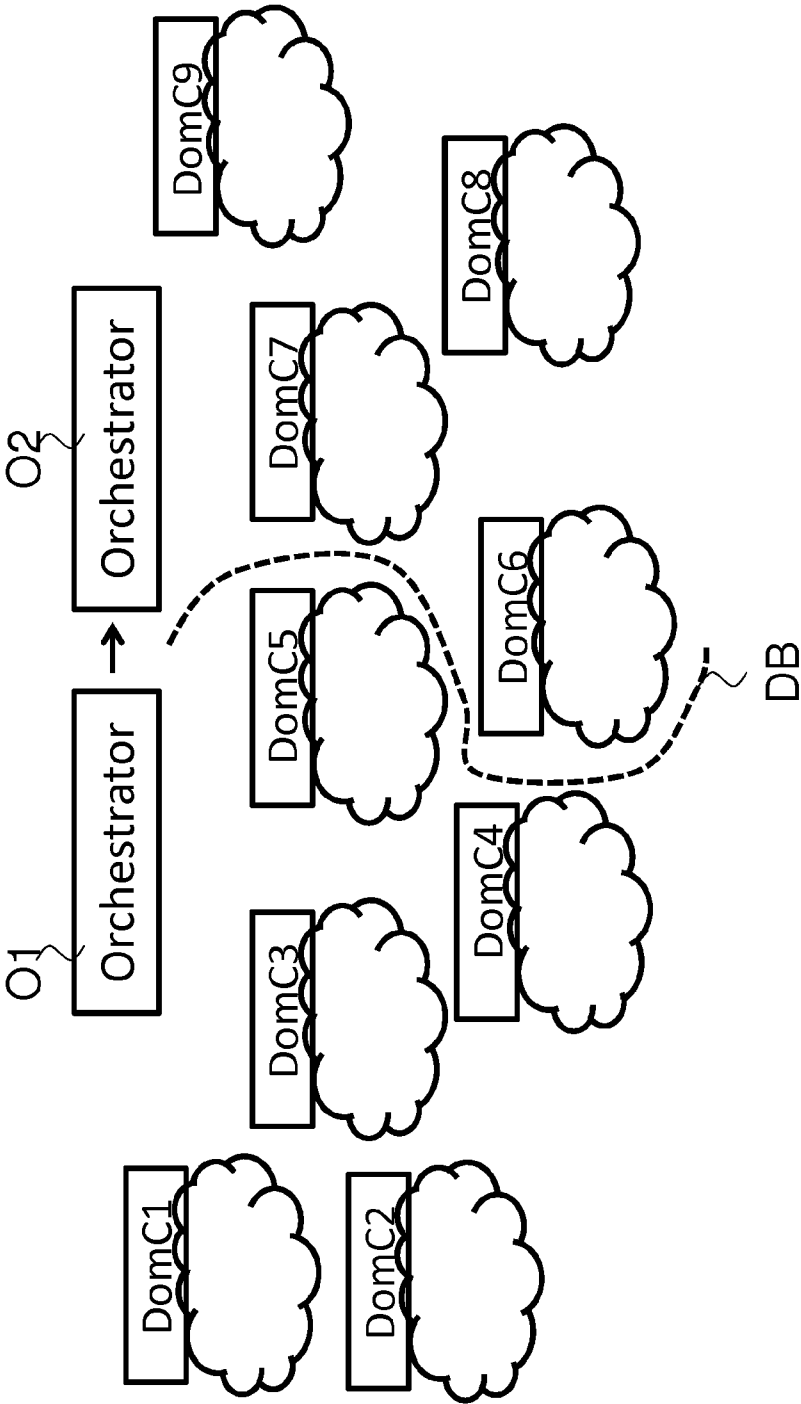


FIG. 4

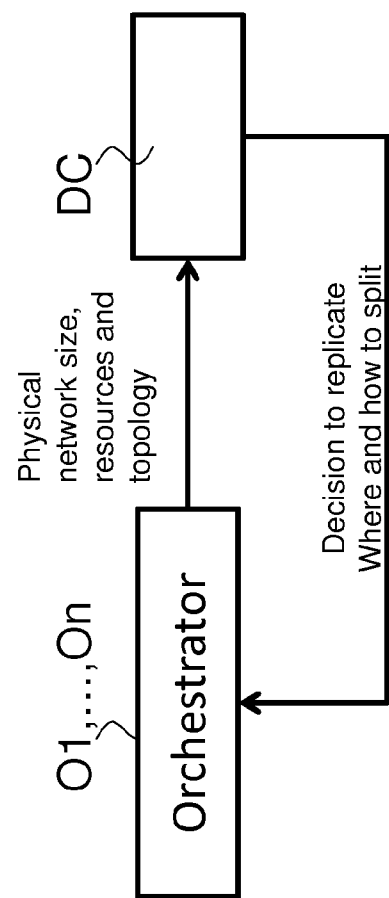


FIG. 5

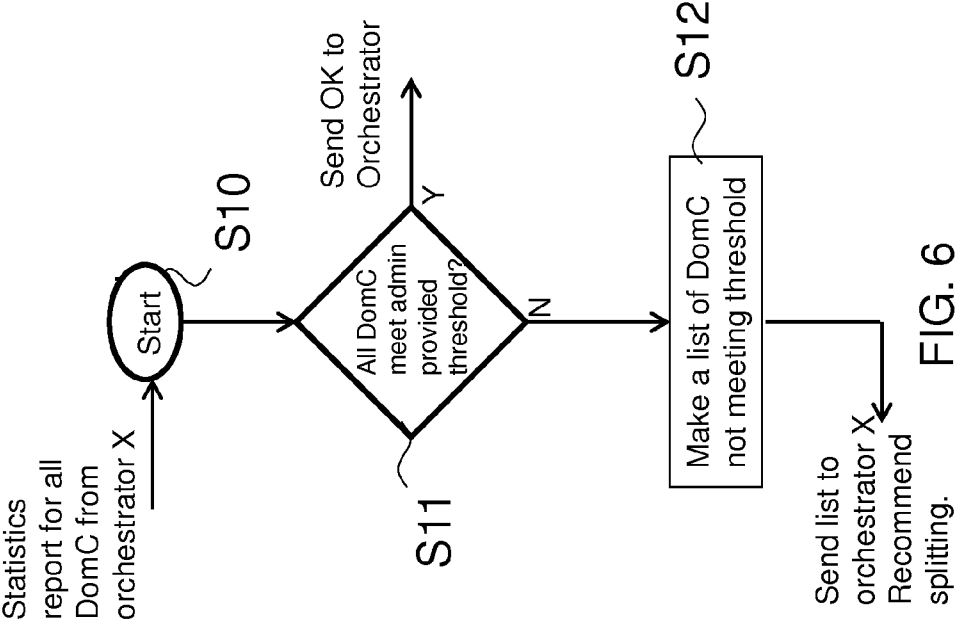
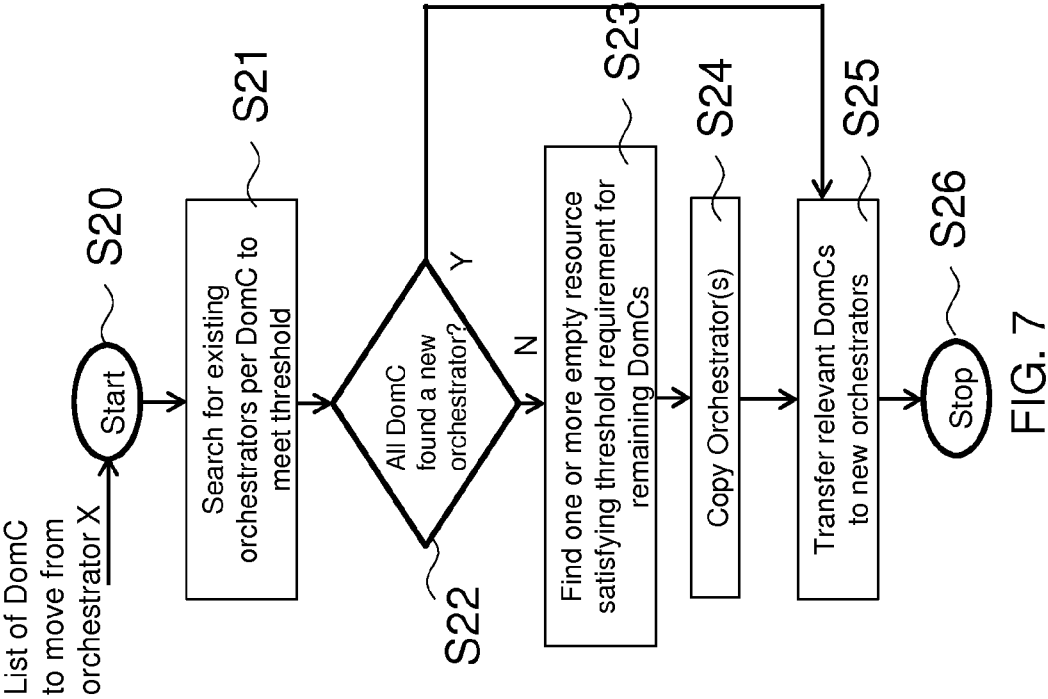


FIG. 6



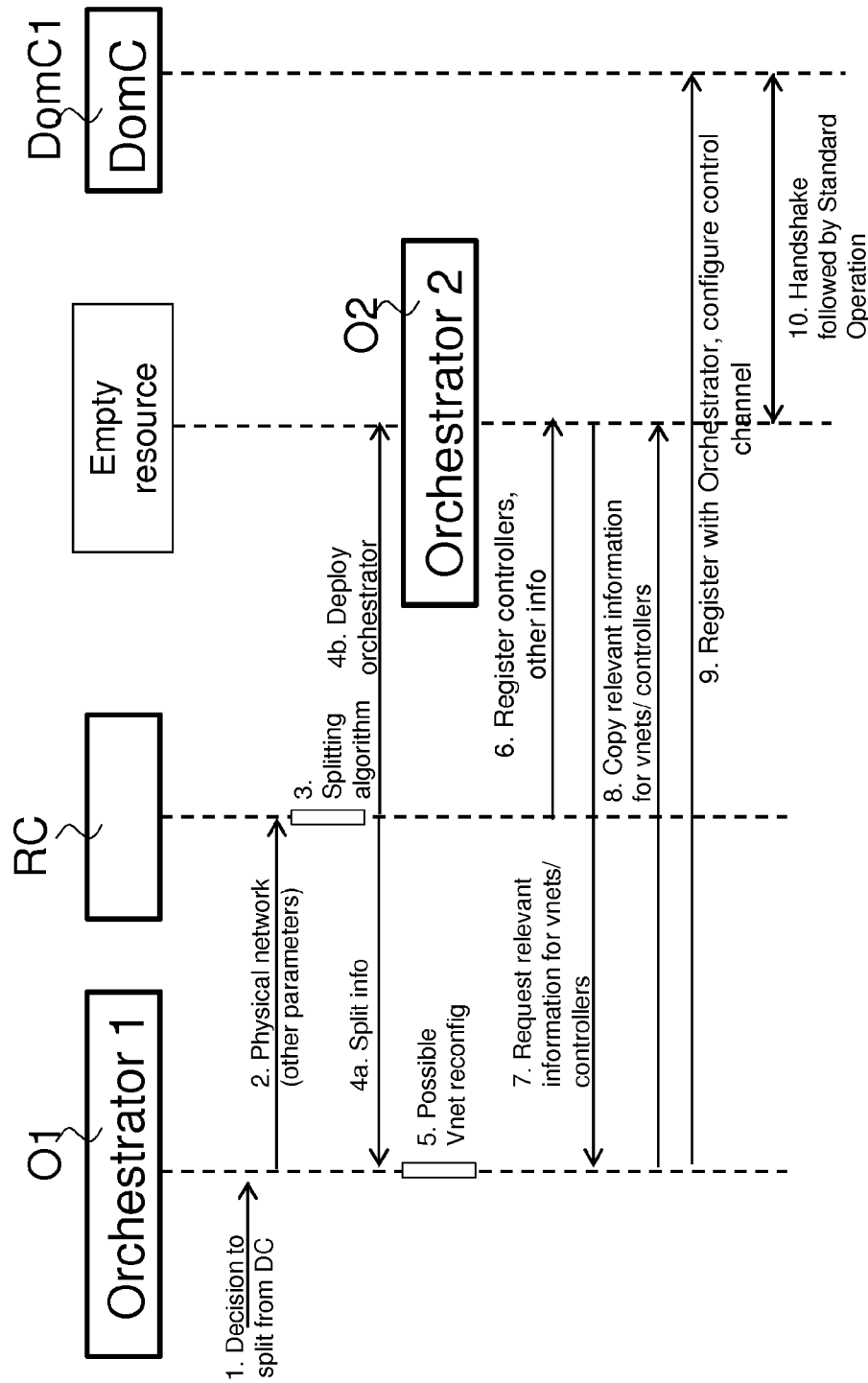


FIG. 8

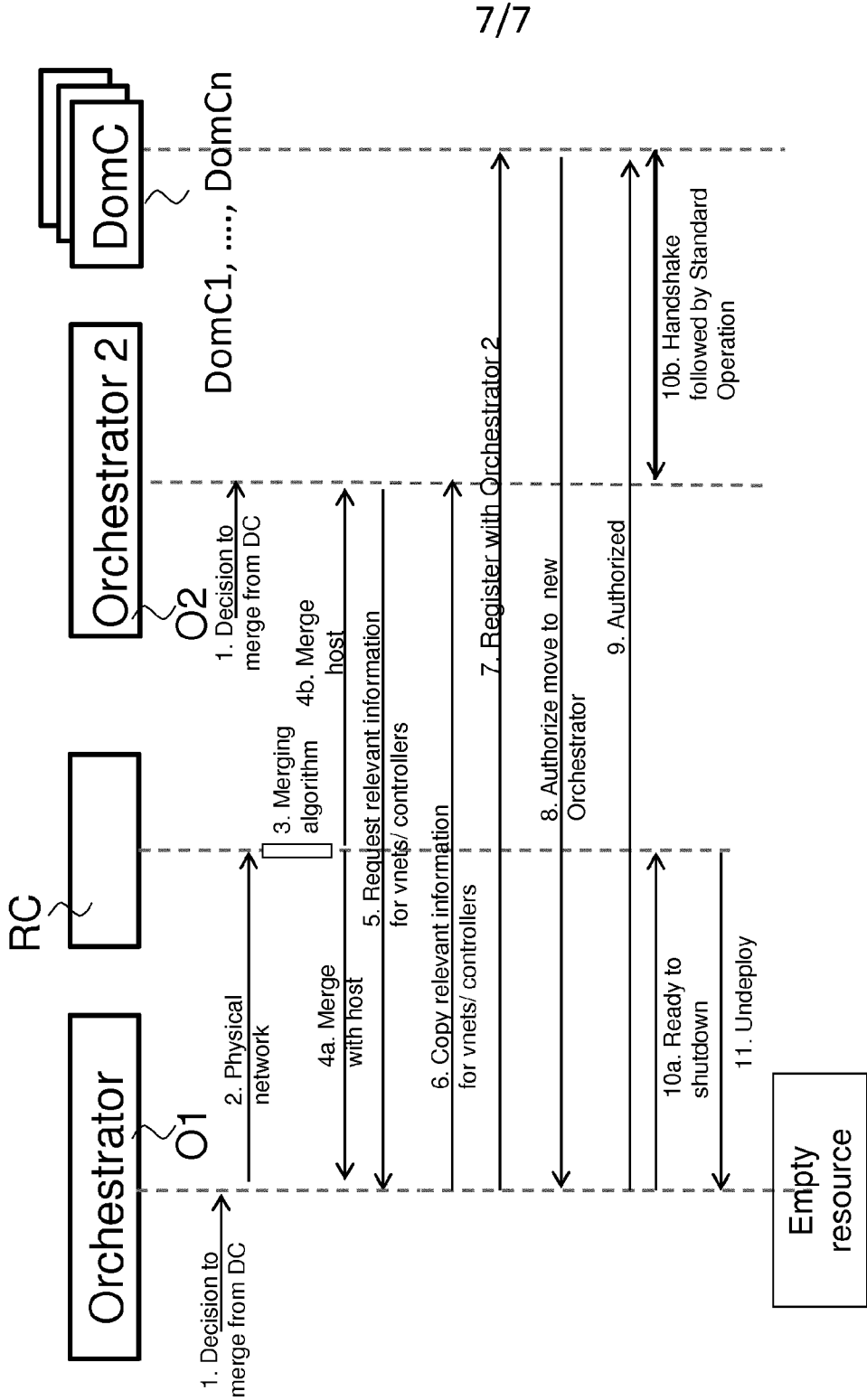


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/050464

A. CLASSIFICATION OF SUBJECT MATTER INV. H04L12/24 G06F9/50 H04L29/06 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) G06F 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 <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>US 2006/136928 A1 (CRAWFORD ISOM L JR [US] ET AL) 22 June 2006 (2006-06-22) figure 1 paragraphs [0005], [0006], [0014] - [0021], [0023] - [0025], [0028] - [0030], [0032] - [0035] -----</td> <td>1-15</td> </tr> <tr> <td>X</td> <td>US 2011/314520 A1 (OLSZEWSKI MARCIN [US] ET AL) 22 December 2011 (2011-12-22) paragraphs [0015], [0016], [0021], [0035], [0037] - [0040], [0054], [0055], [0059] -----</td> <td>1-15</td> </tr> <tr> <td>A</td> <td>US 2012/297249 A1 (YANG FAN [CN] ET AL) 22 November 2012 (2012-11-22) paragraphs [0038], [0063], [0064] ----- -/-</td> <td>1-15</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 2006/136928 A1 (CRAWFORD ISOM L JR [US] ET AL) 22 June 2006 (2006-06-22) figure 1 paragraphs [0005], [0006], [0014] - [0021], [0023] - [0025], [0028] - [0030], [0032] - [0035] -----	1-15	X	US 2011/314520 A1 (OLSZEWSKI MARCIN [US] ET AL) 22 December 2011 (2011-12-22) paragraphs [0015], [0016], [0021], [0035], [0037] - [0040], [0054], [0055], [0059] -----	1-15	A	US 2012/297249 A1 (YANG FAN [CN] ET AL) 22 November 2012 (2012-11-22) paragraphs [0038], [0063], [0064] ----- -/-	1-15
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X	US 2006/136928 A1 (CRAWFORD ISOM L JR [US] ET AL) 22 June 2006 (2006-06-22) figure 1 paragraphs [0005], [0006], [0014] - [0021], [0023] - [0025], [0028] - [0030], [0032] - [0035] -----	1-15												
X	US 2011/314520 A1 (OLSZEWSKI MARCIN [US] ET AL) 22 December 2011 (2011-12-22) paragraphs [0015], [0016], [0021], [0035], [0037] - [0040], [0054], [0055], [0059] -----	1-15												
A	US 2012/297249 A1 (YANG FAN [CN] ET AL) 22 November 2012 (2012-11-22) paragraphs [0038], [0063], [0064] ----- -/-	1-15												
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Date of the actual completion of the international search		Date of mailing of the international search report												
29 September 2015		08/10/2015												
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Balevic, Ana												

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/050464

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/138816 A1 (KUO RICHARD [US] ET AL) 30 May 2013 (2013-05-30) paragraphs [0011] - [0012], [0020] - [0023], [0029], [0032], [0040] -----	1-15
A	US 2006/167674 A1 (LOISEY CHRISTOPHE [US] ET AL) 27 July 2006 (2006-07-27) paragraph [0050] - paragraph [0054] -----	1-15
A	WO 2011/087584 A2 (MICROSOFT CORP [US]) 21 July 2011 (2011-07-21) paragraphs [0003], [0019], [0031] - [0032], [0038] - [0046] -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/050464

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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