

# Change and Impact Analysis of Multi-tenant Service Networks

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## 1 Types of Changes and Impacts

A change can occur at each element of the multi-tenant service network. A given change to an element can further cause changes to that element and/or other elements as *direct consequential* impacts of the change.

### 1.1 Service Layer.

The changes at the service layer includes the addition, removal, and update of services, their capabilities, their interaction relationships, the regulations on interactions, and the improvement or degradation of the performance of capabilities. The dependencies among these elements can also be altered, for example, control relations among capabilities.

A new service (to be used) requires a node, and a set of links to represent the expected relationships between the new service and the relevant existing services in the service network. A new service also introduces new service capabilities. The removal of an existing service makes the related node and links invalid as they represent a nonexistent service and some nonexistent relationships, respectively. An update to a used service can involve capability and service relationship changes.

A new service relationship between two services, which is relevant to the achievement of the goals of the service network, requires a link between the relevant nodes to represent the service relationship. A link becomes obsolete if the underlying service relationship becomes non-existence (terminated) or irrelevant to the service network. A new interaction (to be used) between two services requires a new interaction term in the corresponding link. A non-existent (removed) or unused interaction makes the relevant interaction term obsolete. An update to a service interaction can include the changes to the format of the message/information exchanged, and the direction of the interaction.

To use a new service capability of a service, the corresponding node needs a task to represent the capability. The removal of a used capability makes the related task invalid because it represents a non-existence capability. A change

to the provided-required relationships between used capabilities can affect the dependencies among the relevant tasks, which are captured by linking tasks via interaction terms. The modifications to used capabilities (e.g., merging capabilities) can result in the same types of changes to the relevant tasks. To use or realize a capability, services need to interact with each other, and thus a capability change can result in service relationship changes. A change to a control relation between used capabilities can affect the conditions (event patterns) of the regulation rules that execute the relevant tasks.

A new regulation decision requires new regulation rules at a subset of the regulation enforcement points (REP) in the service network. The selection of a REP depends on the scope of the regulation decision, which can be an incoming interaction(s), the provision of a capability, an outgoing interaction(s), and one or more interactions in transit (between two or more services). The REP for an outgoing interaction is the routing REP at the node for the service that initiates the interaction. The REP for an incoming service interaction and the capability provision is the synchronization REP at the role for the service that receives the interaction. The REP for interactions between two services is the pass-through REP at the link that connects the nodes for the two services. The REPs for interactions between more than two services is the coordinated pass-through REP, and a pass-through REP for each service pair.

The removal of a regulation decision makes the corresponding regulation rules obsolete and potentially erroneous, as they can add unwanted restrictions. The update of a regulation decision can have the combined impacts of the removal of the existing decision and the addition of the new decision.

The changed performance (response time and throughput) of a capability can trigger changes to the regulation rules that control the request of the capability. The service network provider may need to prevent the negative impacts of a degraded performance, and to utilize an improved performance. To cope with the degraded performance of a capability, three common types of solutions can be used: 1) admission control of request messages to the relevant capability, 2) selection of an alternative capability or the same capability from a different (potentially new) service, and 3) skipping the capability if it is optional. To utilize the improved performance of a capability, the degree of sharing of the capability can be increased by regulating the relevant capability request traffic (e.g., increasing request rates), and/or by sharing the capability with additional tenants (VSNs). Each of these solutions require selecting alternative paths in the service network or conditioning the service network traffic, which can be done via the regulation rules at the routing and synchronization REPs.

## 1.2 Service Network Layer.

The topology and the regulation structure of a service network can be changed. The deployment and un-deployment of a service network design creates and remove the topology. A topology can be altered by adding or removing nodes and links. The modifications to a node and a link involves adding, removing, and modifying tasks and interaction terms, respectively. The linkage between tasks

and interaction terms can also be altered. The regulation enforcement points (REPs) are created and removed as the corresponding placeholder elements (node, link, and service network) are created and removed, respectively. The modifications to a REP include the addition, removal, and update of regulation rules and regulation table entries. The implementations of regulation functions can also be added, removed, or updated.

A new node generally needs one or more tasks, and the endpoint reference of the service that it represents. It also needs to be linked to some other nodes so that the service can interact them to request or provide capabilities (or tasks). The removal of a node also removes its tasks, and makes its links dangling elements. An update to the service endpoint reference of a node replaces the service that the node represents. A removed endpoint reference makes the realizations of the tasks of the node nonexistent.

A task depends on and/or initiates interactions. Hence, a new task may need one or more (existing or new) interaction terms as its inputs and outputs. It also needs synchronization REP rules to synchronize incoming interactions and execute the task, and routing REP rules to route the task response message (or to initiate outgoing interactions). The removal of a task can make the relevant interaction terms and regulation rules obsolete. An update to the inputs and outputs of a task can have the similar impacts of a new task and a removed task.

A new link between two nodes in the service network connects the two roles architecturally. It may need one or more interaction terms to be used (consumed or initiated) by some tasks in the two nodes. A removal of a link also removes its interaction terms, and the linkage between the corresponding two nodes. A new interaction term may be used by some existing tasks by including the references to it in their inputs and/or outputs. It also needs regulation rules at the pass-through REP of the link to process the relevant interaction message. A removal of an interaction term makes its usage by the related tasks invalid (dangling references), and the relevant regulation rules obsolete.

A new regulation rule (of any REP type) uses a subset of (existing and new) regulation functions as its action(s). In general, the conditions of a synchronization rule or coordinated pass-through rule use events, that of a routing rule is a message from a service or user, and that of a pass-through rule is an node-node interaction message. The removal of a regulation rule can make some regulation functions unused. An update to a regulation rule can have the similar impacts of adding a new rule and removing an existing rule.

A new synchronization rule requires a set of pass-through rules to analyze the interaction messages to be synchronized and generate the events, which are conditions of the rules. A synchronization rule at a given node also requires a set of routing rules at the relevant source nodes to initiate the interactions to be synchronized. The removal of a synchronization rule can make the relevant pass-through and routing rules obsolete. Similarly, the addition and removal of a routing rule may require the addition or removal of some pass-through rules and synchronization rules. A new pass-through rule generally introduces new service

network events, which are to be consumed by some (new or existing) synchronization rules at the destination role, and coordinated pass-through regulation rules. The removal of a pass-through rule requires the removal of or updating the conditions of the rules that depend on the events generated by it as they will not be activated. The addition or removal of a coordinated pass-through rule requires the addition or removal of the rules that generates the events consumed by it.

A regulation rule at a given REP may have some other rules that must be executed before or after its execution. These dependencies are captured through the conditions of the rules, and the underlying rule engine determines the activation of such rules. Thus, the addition, removal, and update of a regulation rule can modify the dependencies between the existing rules in the same REP. In particular, the removal or update of a rule can prevent the activation of some rules at the same REP.

A new regulation mechanism may be used by a set of regulation rules. It may produce or consume service network events. The removal of a regulation mechanism makes the rules that use it invalid as they depend on a non-existent mechanism. An update to the underlying implementation of a mechanism can change the regulation behaviors of the mechanism and the regulation rules that use the mechanism.

A new regulation (at a given REP) that needs to be used by business processes in the VSNs of some tenants may require new entries (mapping from `vsn,process` to the rules) or update to some existing entries in the regulation tables at the REP. Thus, the removal of a regulation rule may require the removal or update of some regulation table entries.

### 1.3 Virtual Service Network Layer.

The changes at the VSN layer include the addition, removal, and update of VSNs and their processes. As a process is a service network path, represented as a set of regulation table entries, the VSN layer changes generally include regulation table entry changes. A VSN needs to include one or more processes, which in turn require new entries in the regulation tables at the REPs along the service network path of the process. The removal of a VSN requires that of its processes, which in turn the removal of the relevant table entries.