VMware vCloud Architecture Toolkit
Cloud Bursting

Version 3.0

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VMware, Inc.
3401 Hillview Ave
Palo Alto, CA 94304
www.vmware.com

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1. Overview

Cloud bursting is the act of dynamically leveraging off-premise private or public compute resources in response to an increase in demand. *Auto scaling* is the act of dynamically adding local resources to a service in response to an increase in demand. Cloud bursting and auto scaling are *bursting modes* that can be triggered by an increase in demand. The resources consumed during cloud bursting or auto scaling are not explicitly dedicated to the service and are deallocated when the increase in workload normalizes.

Cloud bursting is an advanced topic that is rapidly evolving. This guide examines design guidelines, theory, and early technical insights developed to help address emerging use cases related to building an auto scaling infrastructure. The focus of this guide is specifically on the infrastructure components of auto scaling, and the document does not address the application and end-user layer implications of an auto scaling infrastructure.

1.1 The Auto Scaling Process

Auto scaling or cloud bursting allows the infrastructure to consume resources when they are needed and return them to the pool of available resources when they are not. This serves the end user by providing the following benefits:

- Automatic response to performance or capacity incidents.
- Reduced service delivery cost.
- Reduced outages due to human error.

The automatic or dynamic scaling of an application requires that the infrastructure provide the following components:

- Monitoring.
- Orchestration.
- A programmable API-driven infrastructure.

Each of these components can be implemented using various technologies, all providing the same function for each component. The implementation used determines how the auto scaling process is triggered and carried out, but the end result is the same. The goal of the system is to allow the application or service to autonomously remain within compliance of a service level agreement (SLA). If necessary additional resources are added to remain in compliance and meet increased demand.

1.2 Open Loop and Closed Loop Implementation Models

The dynamic Infrastructure as a Service (IaaS) infrastructure can be thought of in terms of two implementation models—*Open Loop* or *Closed Loop*. Regardless of the approach, a monitoring system is required to track the critical metrics used to trigger a scale out event and instruct the orchestrator to perform the scaling task.

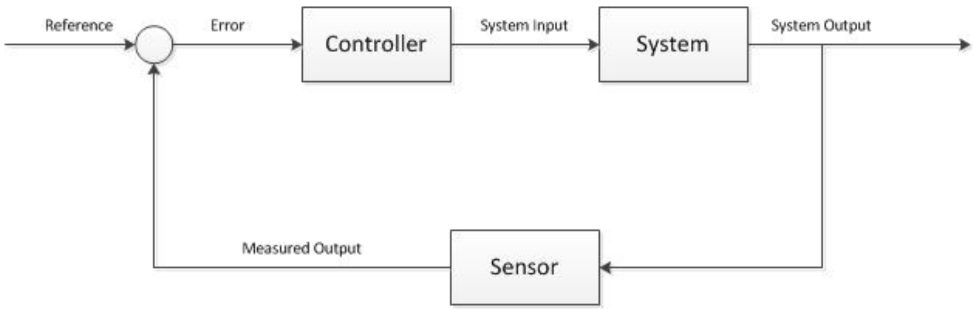
1.2.1 Closed Loop Systems

Closed loop control systems are those that provide feedback of the actual state of the system and compare it to the desired state of the system in order to adjust the system.

1.2.1.1. Control Theory

The closed loop control system is a system where the actual behavior of the system is sensed and then fed back to the controller and mixed with the *reference* or desired state of the system to adjust the system to its desired state. The objective of the control system is to calculate solutions for the proper corrective action to the system so that it can hold the set point (reference) and not oscillate around it.

Figure 1. Closed Loop Control System



1.2.1.2. Closed Loop Dynamic IaaS

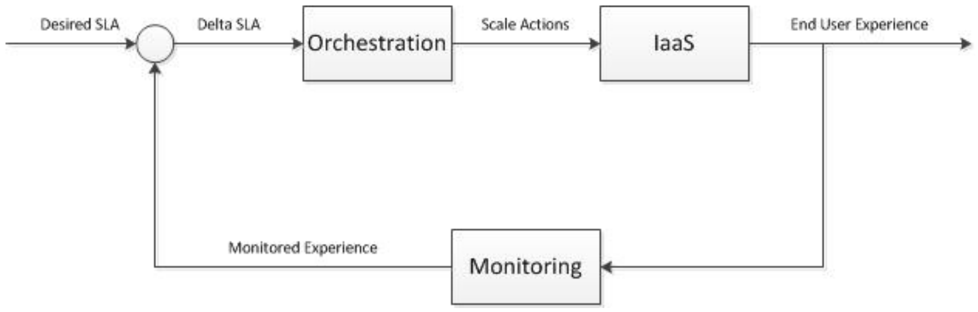
When a scale out triggering event occurs, the input parameter that triggers the event is monitored around its set point. The system increases and decreases capacity on demand to stay as close to the set point for the triggering parameter as possible.

With closed loop systems, we can evaluate the system around the set point using a PID control algorithm or similar control scheme. A simpler approach, such as *hysteresis*, can be very effective and can be implemented with less complexity and tuning.

Hysteresis is the dependence of a system not only on its current state but also on its past state. For example, a thermostat controlling a heater may turn the heater on when the temperature drops below A degrees, but not turn it off until the temperature rises above B degrees.

An example of a closed loop dynamic IaaS system is one where the infrastructure is constantly monitoring the end-user experience. When an end-user experience measure drops below a desired threshold, for example, transactions taking > n milliseconds, the controller scales out the environment to compensate. The experience is checked with the new resources, and if it still is below the desired state, it continues to scale out the service. When the transaction time drops below the desired *n* milliseconds, the controller scales back the environment to reduce the resources consumed and continues to monitor whether the user experience is within the acceptable range.

Figure 2. Closed Loop Dynamic IaaS



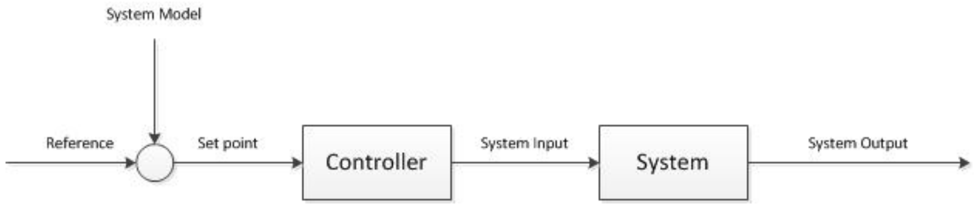
1.2.2 Open Loop Systems

Open loop control systems are those that do not provide feedback of the actual state of the system in order to adjust the system.

1.2.2.1. Control Theory

The open loop control system is a non-feedback system where the control input to the system is determined using only the current state of the system and a model of the system. There is no feedback used to determine if the system is achieving the desired output based on the reference input or set point. The system does not observe itself to correct itself and, as such, is more prone to errors and cannot compensate for disturbances to the system.

Figure 3. Open Loop Control System



1.2.2.2. Open Loop Dynamic IaaS

When a scale out triggering event occurs, the infrastructure expands its capacity through the appropriate bursting mode, either auto scaling or cloud bursting.

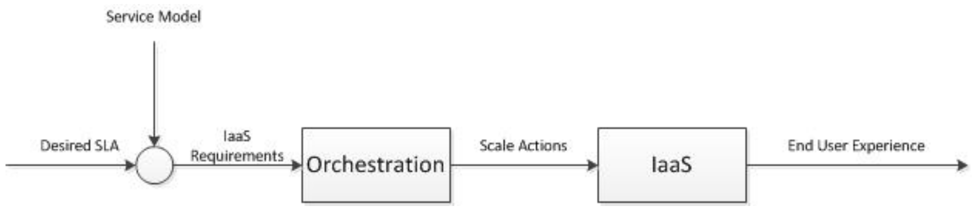
There is no feedback in the system from the usage of the new capacity to tightly control the amount of resources added or decommissioned from the service based on real world service utilization. A model of the service is used to determine the appropriate scaling activities.

For example, a basic model of our service says that for every 100 active sessions we require one virtual machine in our web tier to provide a 100ms transaction time. Capacity planning data tells us that we need to support 1000 active sessions during weekdays and 250 active sessions on weekends.

During the weekdays the environment scales to 10 virtual machines in the web tier (1000 sessions/100 sessions per virtual machine), and on weekends it scales to three virtual machines in the web tier (250 sessions).

The model describes how many virtual machines per 100 sessions, but it does not account for rogue sessions that might consume significantly more resources than the typical session. It also does not account for transient spikes in resource consumption that might occur, causing our 100 sessions per virtual machine model to be incorrect. In this scenario, the open loop control method does not account for the real-world state of the system, and the end-user experience degrades.

Figure 4. Open Loop Dynamic IaaS



1.2.3 Closed Loop Versus Open Loop

Open loop systems have many disadvantages due to their lack of feedback from the system. With feedback in a closed loop system, we can more closely manage the state of the system relative to desired goals, such as staying within an SLA or providing an appropriate end-user experience. Closed loop systems provide several advantages over open loop systems:

- Disturbance rejection from unforeseen increases in user load.
- Predictable performance with uncertain service models when a user does not know exactly how the service scales relative to user workload.
- Improved reference tracking where resource allocation can closely track what is needed to provide SLA compliance without overprovisioning.

Closed loop systems are recommended because of these benefits.

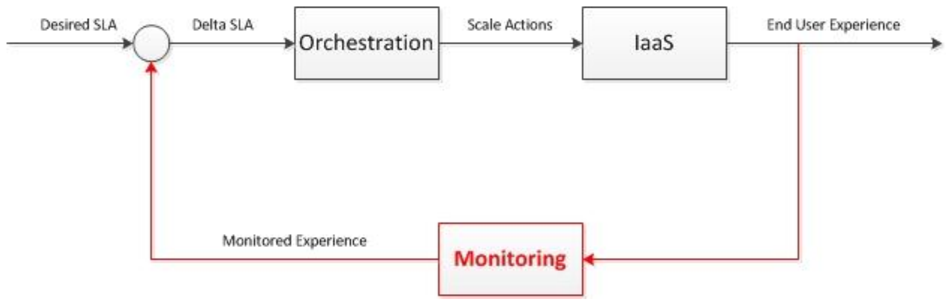
2. Sensing (Monitoring) the Service State

To implement our control system, we need the ability to sense (monitor) the state of the service.

2.1 Monitoring Approaches

Polled monitoring and *stream monitoring* are both approaches to monitoring the service state. The following figure shows a typical monitoring process.

Figure 5. Monitoring Process



The observable service state is critical in implementing an effective, dynamic IaaS architecture. *Observability* is related to the possibility of observing, through measurement, the state of the service. If we don't have a way of understanding what the service is providing to the end users, we cannot dynamically react to that state. The fidelity of the monitoring is important, as monitoring provides the information that makes it possible for the system to respond.

2.1.1 Polled Monitoring

Polled monitoring is where the application performing the monitoring task is querying the service at a set interval and evaluating the state of the service at that moment in time. Polled monitoring is relatively simple to implement and typically far less costly than real-time or stream monitoring in terms of both overhead and dollars. Though simpler and less costly than stream monitoring, polled monitoring has the following issues:

- Potentially long event detection periods.
- Missed events (architecture dependent).

If we have a polled monitoring solution with an interval of five minutes (300 seconds), the worst case response time to an event is 300 seconds—the worst case response time is the polling interval. This is the response time to determine something has to be done and includes the time the system takes to actually respond to the event in addition to the up to 300 seconds it took to detect the event.

2.1.2 Stream Monitoring

Stream monitoring is where we passively monitor the service by "listening" to streams of data between the application and the end user or components of the application. This is typically done at the network packet layer and introduces little to no overhead on the service itself. Stream monitoring provides benefits over polled monitoring. Every session is observed as it occurs and, therefore, events should not go unnoticed. However, stream monitoring is typically far more complex and costly than polled monitoring.

Though it provides the benefits of real-time visibility, stream monitoring has the following issues:

- Increased complexity and cost.
- It is application specific and not supported by all applications.

2.1.3 Derived Metrics

Derived metrics include composite metrics and forecast metrics.

2.1.3.1. Composite Metrics

Whether using polled, stream, or a combination of both monitoring techniques to observe the system, more fidelity can be provided to the results by creating macro metrics that are a function of a number of metrics to derive a composite metric that describes the system state.

2.1.3.2. Forecast Metrics

By using simple or complex statistical and signal analysis techniques, we can take the data from our polled, streamed, or derived metrics and predict what the future metrics might be. This enables us to provide data to our controller to make decisions ahead of the event occurrence. We can proactively take action on the system to reduce the chance of end-user impact due to slow controller response.

2.1.4 Monitoring Criteria

When we monitor the delivered service to understand its current behavior, and when we need to scale out or scale back, we can do so across several main categories. Each category has its own benefits and drawbacks relative to one another. The ideal system considers metrics from multiple sources to make the best decisions regarding how to adapt the system to provide the desired service level for the end user. The following table describes each category of monitoring criteria.

Table 1. Monitoring Criteria Categories

Category	Description	Example
Infrastructure	Utilization of specific infrastructure resources such as: • CPU or memory utilization. • Disk latency and bandwidth. • Any metric that describes the health or utilization of the infrastructure.	CPU utilization > 80% on web tier virtual machines.
Application	Consumption of application-specific resources such as active sessions.	Active sessions per web server > 200.
End User (Real)	The response time of a live user transaction exceeds acceptable levels. Measured from the perspective of real users. Can be real time.	• Load time on a specific object > 250ms • Page latency > 100ms.
End User (Synthetic)	The response time of a synthetic user transaction. Measured by executing synthetic transactions against application.	• Load time on a specific object > 250ms. • Complete synthetic session > 5s.

2.1.5 End-User Monitoring

Of all of the metrics that are generated by a service at all layers, *end-user experience* is a single metric that we can take as an overall indicator of service health. If the end-user experience falls below a given threshold as dictated by an SLA, there is not sufficient capacity in the service to deliver the required SLA, and capacity should be added.

Taking this approach, we can monitor the service and use this measure as a trigger for the scaling out and back of our dynamic infrastructure. Whenever the end-user experience falls below a threshold, capacity is added, and as the measure increases above our threshold we decrease capacity. Increasing and decreasing capacity are equally important. We do not want to over-spend on infrastructure to provide a service that exceeds our SLA beyond where it provides business value based on the cost.

The drawback of using only an end-user monitoring approach is that this tells us only that we have a problem with the performance for our end users. It does not give our system any information as to where the problem is or what is causing the problem. To create a truly intelligent dynamic IaaS service, we need to consider end-user experience as our key performance indicator (KPI), but infrastructure and application metrics provide the causal analysis data.

2.1.6 Infrastructure and Application Monitoring: Causal Analysis

When creating a dynamic infrastructure, end-user experience is almost always the most important KPI. For example, if CPU utilization on our virtual machines is constantly around 90%, it means we are efficiently using our paid resources. As long as the end-user experience is where it should be, high CPU or memory usage are not critical metrics. This is the target in our control model. We want to drive our resource consumption on a given virtual machine as high as possible without requiring additional virtual machines, as long as end-user experience stays where it should.

When the KPI falls outside of what we consider to be an acceptable value, this indicates that we need to investigate a scaling event. This does not explicitly mean we have a scaling out-worthy incident. It could be an actual problem causing the KPI degradation rather than a capacity issue.

We need to perform a causal analysis on the environment to determine whether or not we should scale or if we should trigger a fault alert and have someone intervene.

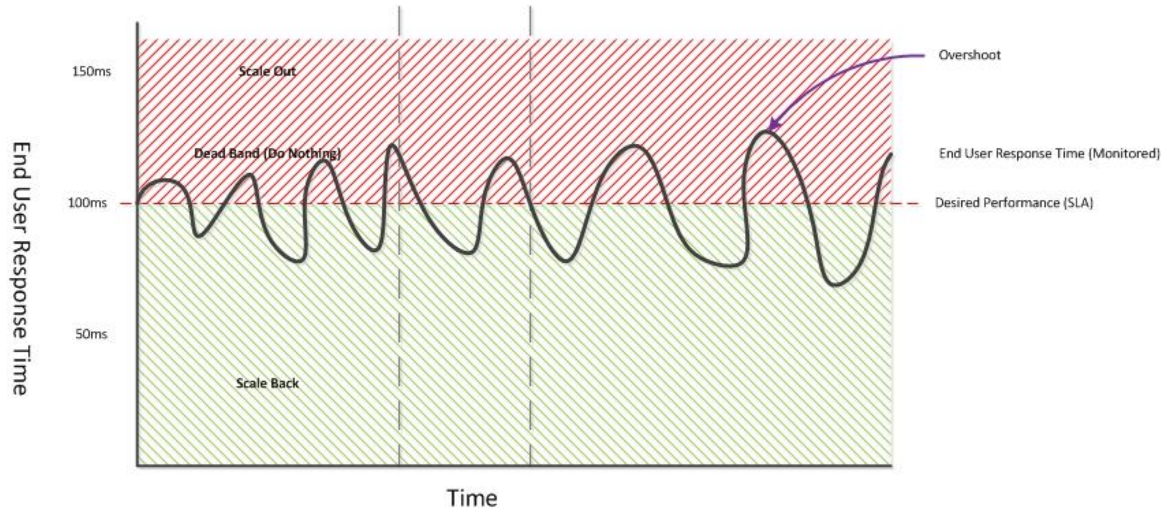
2.1.7 Triggering the Scale Event

Scaling can be uncontrolled, controlled, or controlled with hysteresis.

2.1.7.1. Uncontrolled Scaling

When triggering a scale event, we cannot decide to increase capacity when our threshold exceeds or falls below the set point. This results in a *Ping-Pong* effect, where the infrastructure is constantly scaling out and scaling back as it seeks the set point for our triggering metric. Depending on the instability of the system, this can result in significant *overshoot* while seeking the set point, where the system increasingly overprovisions resources and then decreases them back and forth, resulting in an ever-increasing problem. The following figure provides an illustration of uncontrolled scaling.

Figure 6. Uncontrolled Scaling

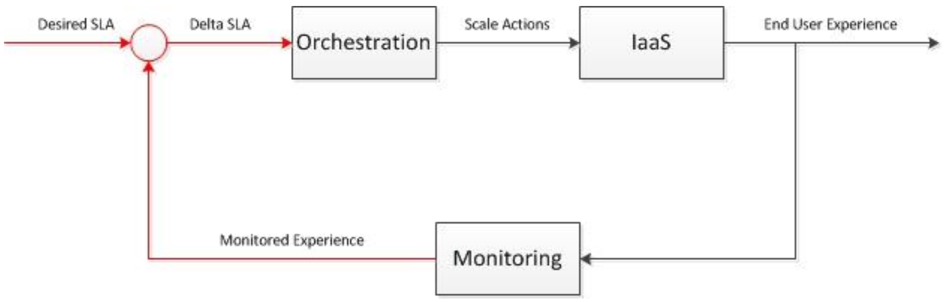


This constant expansion and contraction of resources with today's technology places an undesirable load on the infrastructure and can ultimately result in further degradation of the service.

2.1.7.2. Controlled Scaling

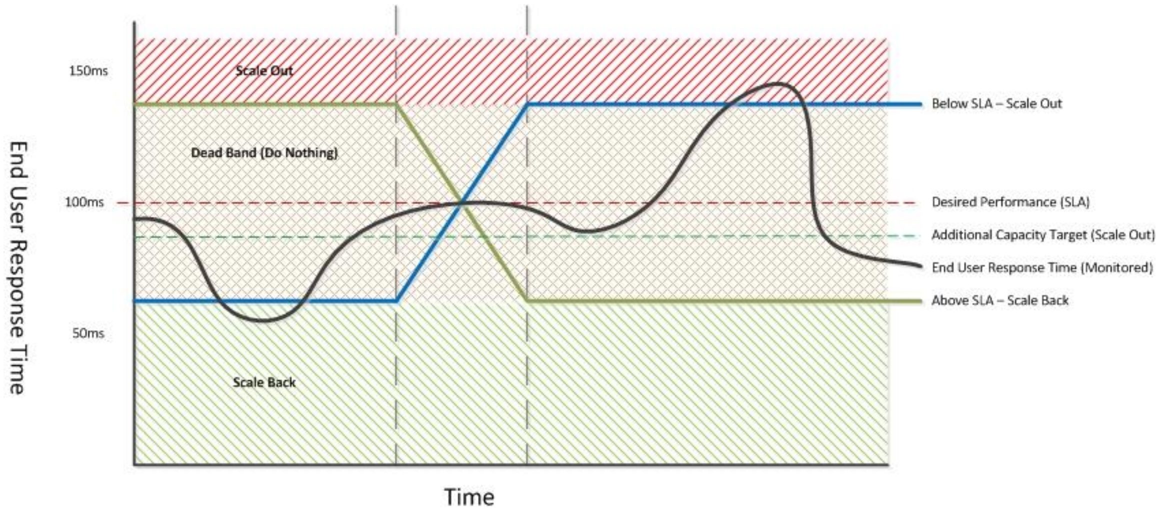
The scaling process needs to be controlled to provide the overall stability of the application and its underlying infrastructure.

Figure 7. Scaling Controller



The monitoring information, in conjunction with the desired performance of the system (set point), needs to be controlled by the overall system in order to prevent the constant seeking of the set point. This allows the infrastructure to operate more efficiently and in a far more stable manner. The simplest control scheme to introduce to the dynamic IaaS is to add hysteresis to the system.

Figure 8. Controlled Scaling Using Hysteresis



With this method of control, instead of aggressively seeking the set point for our end-user experience, we create a band around it. Action is taken only when the performance falls outside of this band.

In the above example, as our end user experience improves in the form of decreased response time, we start to provide higher service quality then we really need, and are consuming too much capacity. This results in spending too much on the service, so we scale back the resources required to get as close as possible to our desired SLA (set point). When response time increases and we have a reduction in service quality, we scale out when we reach our SLA scale out threshold and add resources to bring the service level to our set point.

We might choose to bring our service level slightly above or below the desired set point based on our understanding of the service, how it responds to additional resources, and the cause of the increase itself.

By creating a dead band within the scaling model, we allow the service performance to fluctuate about the set point and not aggressively seek it, which can result in the Ping-Pong effect.

3. Orchestration (Infrastructure Scaling)

The task of scaling the infrastructure is performed by the service orchestrator. The orchestrator of the service is responsible for executing the scaling task after it has been identified as necessary by the monitoring party. When scaling our infrastructure, we need to understand what to scale and how to scale it.

3.1 Scaling Localization

When scaling our dynamic infrastructure, we need to know where to scale. Depending on the complexity and architecture of the application service, there are several approaches to scaling.

- Fixed scaling – Scale where the bottlenecks typically occur.
- Scale everything – Scale out the entire environment with each scale event.
- Intelligent scaling – Scale where the resources are needed.

Table 2. Scaling Modality Benefits and Drawbacks

Scaling Mode	Benefits	Drawbacks
Fixed Scaling.	Simplicity.	• Can create bottlenecks in other areas of the service. • Bottlenecks not within the fixed scaling components are not addressed. • Scaling might not address the problem, and if not managed properly, this can result in a runaway scaling event.
Scale Everything.	Simplicity.	• Can result in overprovisioning in certain tiers of the service. • Can be far more time consuming during the orchestration phase of scaling out. • Can be more complicated than a fixed scaling approach due to database configuration and synchronization challenges.

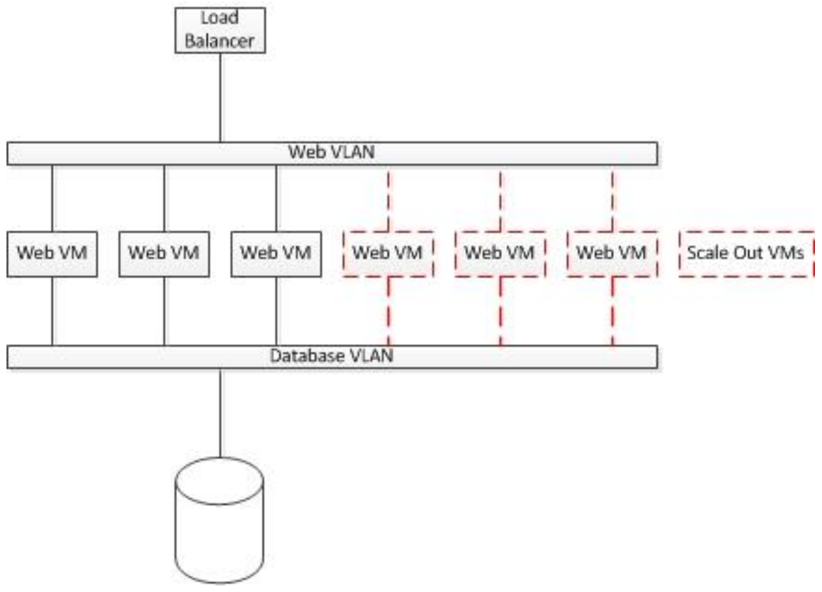
Intelligent Scaling.	• Adds capacity where it is needed every time. • Scaling out across tiers and components dynamically avoids creating new bottlenecks. • Excess capacity is not added where it is not required.	Complexity.

In the context of scaling, the scale remediation can scale out, scale up, or a combination of both depending on the level of complexity within the system. Make scaling design decisions based on prior knowledge of the application or services scaling characteristics.

3.1.1 Fixed Scaling

In the fixed scaling mode in a two-tier web application (with n-web servers and a database server), we add additional web servers to the environment as user load increases. For the scaling model, we assume that the database is infinitely scalable to support the increase in web servers. We scale the database server as a separate exercise and address it outside of our automated scaling.

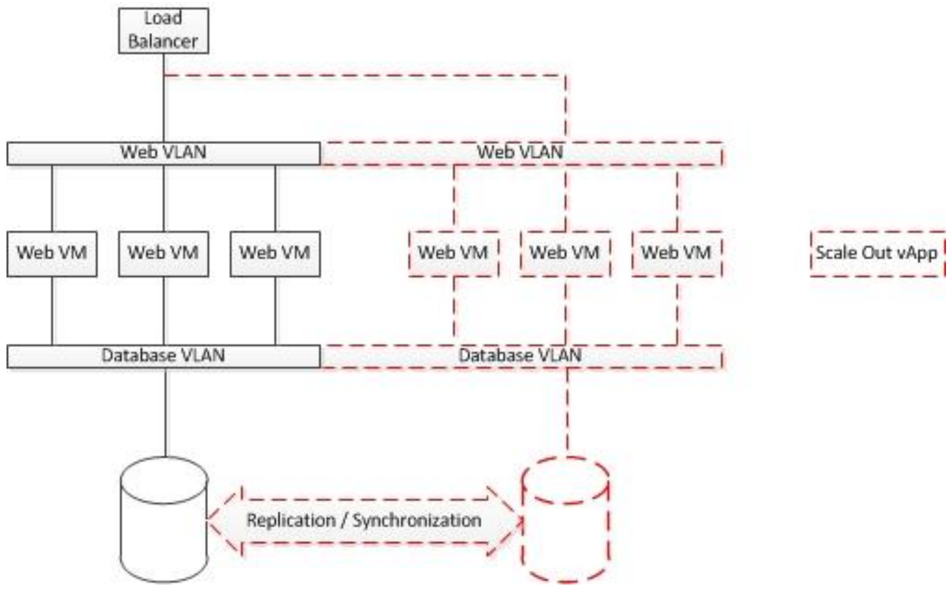
Figure 7. Fixed Scaling



3.1.2 Scale Everything

In the two-tier web application, rather than considering the database as an infinite resource, we more closely size the database to the number of web servers within the initial deployment architecture. We then scale the entire environment whenever a scale out event occurs. This maintains database resource alignment with the web server resources that are placing load on the database. In a scale everything model, we replicate our entire application service.

Figure 8. Scale Everything

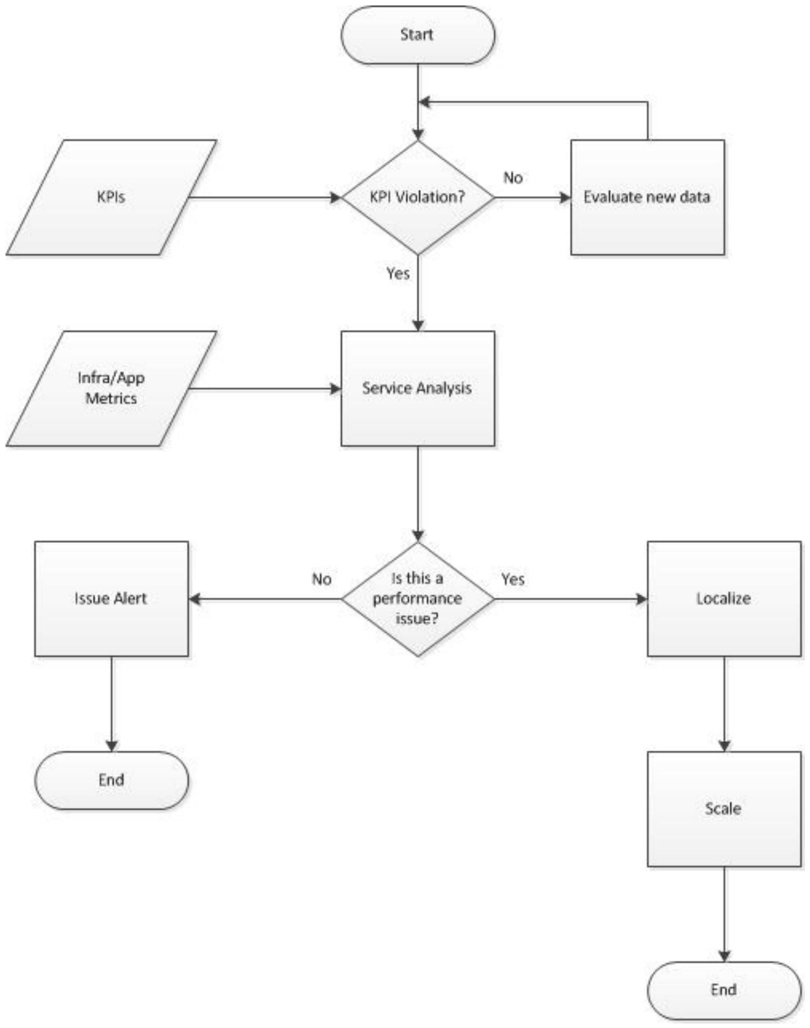


3.1.3 Intelligent Scaling

Intelligent scaling eliminates the drawbacks of both the fixed and scale everything dynamic infrastructure. This comes with the cost of complexity within the system itself. An infrastructure that performs intelligent scaling must consider the current state of all the components within the system in order to identify what components are responsible for the degradation of our KPI or where the service is currently over-provisioned. The system has to monitor our KPI (set point) as well as the details of the system itself (infrastructure and application monitoring).

When a KPI event occurs, the system performs an analysis to determine next steps.

Figure 9. Intelligent Scaling Flowchart



The decision flowchart for intelligent scaling has to perform the following tasks:

1. Identify a KPI violation.
2. Determine if the violation is caused by an infrastructure performance/capacity issue.
3. Localize the performance/capacity issue.
4. Issue the appropriate scaling request and scale.

3.1.3.1. Identify a KPI Violation

The identification of a KPI violation is common requirement of all the scale out modes, however in all other modes, the violation triggers the scaling event. In the intelligent scaling model, the KPI violation triggers a second phase analysis or causal analysis to determine the reason for the KPI violation.

3.1.3.2. Determine KPI Violation Cause

To determine the KPI violation root cause and whether nor not we need to scale our service, analyze the infrastructure and application metrics. This can be done using techniques such as:

- Trend analysis.
- Historical or baseline comparison.
- Pattern matching.

The analysis should result in one of two outcomes. The violation is performance- or capacity-related, or it is related to a problem with the service. In the case of a problem with the service, an alert is issued, and there should be no further action on the part of the scaling tasks.

If the analysis determines that the root cause is a bottleneck or overprovisioning, the next task is to localize the cause.

3.1.3.3. Localize the Cause

During the localization phase, the service metrics are further analyzed to identify the root cause of the capacity issue. We identify within what tier we need additional resources and what type of resource those should be.

Do we require the following:

- Additional web servers?
- More database throughput?

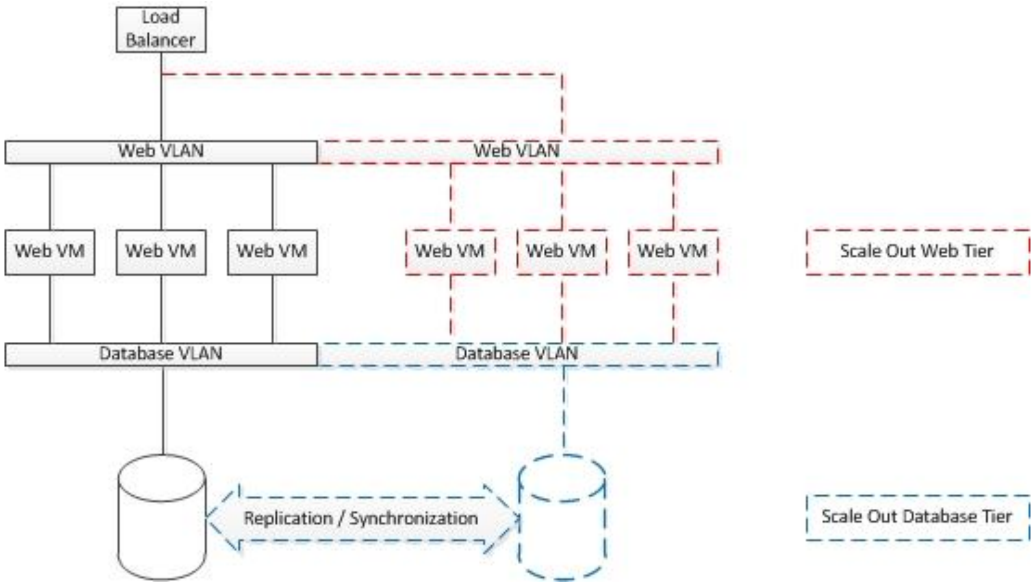
We identify the location of the capacity issue by using techniques such as:

- Correlation.
- Anomaly detection.

3.1.3.4. Issue the Scaling Request

After the system knows there is a performance or capacity-related issue and where the issue is located, it can issue a scaling request to the orchestrator to resolve the issue. The solution might be to add additional web servers or another database node to a cluster. It might also remove capacity from the service to bring costs back in line.

Figure 10. Intelligent Scaling



3.2 Scaling Orchestration

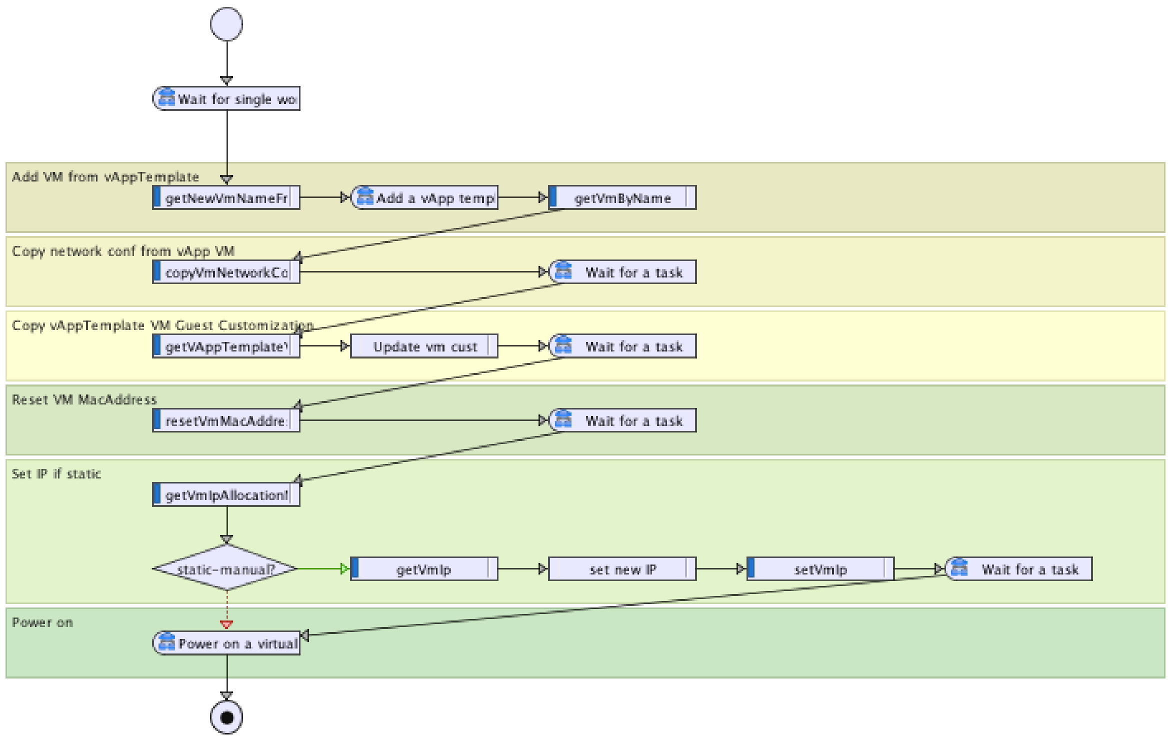
Application infrastructure scaling requires the orchestration of multiple changes to the application and underlying infrastructure. This is performed by the orchestration engine within the dynamic infrastructure.

3.2.1 Foundational Requirements

All scaling activities have a fundamental set of required tasks to scale any application.

- Scaling management.
- Adding/removing resources.
  - Connectivity.
  - Customization.
  - Starting/stopping.

Figure 11. Scaling Resources Workflow



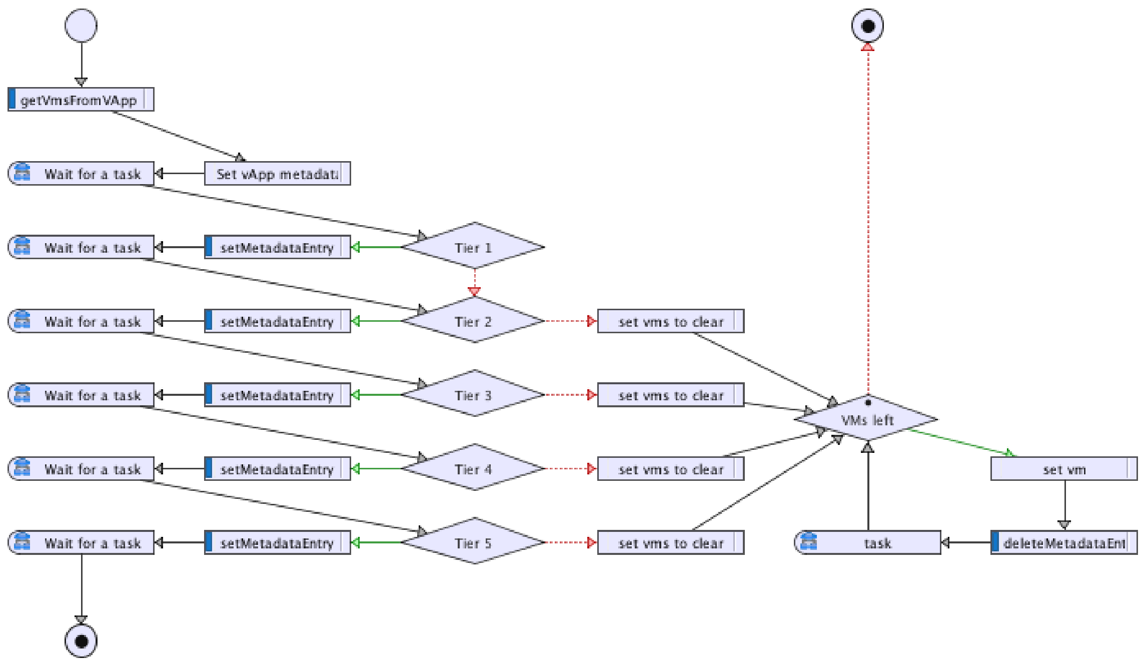
3.2.2 Scaling Management

When scaling out, the orchestration of the scaling process needs to not only configure the resources, but to also manage the scaling task. This includes activities such as:

- Verifying available capacity prior to consuming additional resources.
- Coordinating or restricting parallel scaling activities on the same application.

Generally, scaling activities should be serialized to avoid issues that can arise from the parallel execution. For example, in a parallel operation you must manage name and IP assignment across tasks to prevent duplicate names or IP addresses from being assigned to the new resources. Additionally, parallel deployment across tiers can result in over-shooting the KPI goal, resulting in the immediate triggering of a scale back activity. Parallel scaling can be implemented, but due to the complexity, it should be implemented after serial scaling has proven stable.

Figure 12. Scaling Management



The scaling management process is driven by directives contained within the application metadata itself or by information contained within the scaling workflow. In this example several directives are contained as XML data within the OVF descriptor.

```
  <ns2:Property ns2:value="4" ns2:userConfigurable="true"
ns2:type="string" ns2:key="autoscaleMinTier1Instances">

    <ns2:Label/>

    <ns2:Description>Minimum number of instances for tier 1
VMs</ns2:Description>

  </ns2:Property>
```

3.2.3 Adding/Removing Resources

When adding resources, we need to identify whether they are new or existing resources and what needs to be done with the resources.

3.2.3.1. Adding Resources

- In the *fixed scaling model*, the same type of resource is always added to the service, such as additional web servers. This information can be a configuration parameter to the orchestration workflow that is set in advance by the administrator.
- In the *scale everything* model, it is the application itself that scales out, and we require the location of the application in the service catalog from which it is derived.
- With *intelligent scaling*, the localization process identifies the resource to be scaled and passes that information to the orchestration workflow to scale that component. Depending on the application requirements, the scaling workflow might be generic enough to address all components of the application as a single workflow responsible for the scaling execution.

Due to the application complexities at each layer (web, business logic, data) a separate workflow is developed for scaling each component of the service and addressing the configuration.

3.2.3.2. Connectivity

To use the newly added resources the peripheral networking components must be configured. When auto scaling a service, the consumption of the new resources should be transparent to the user. For this reason it is required that access pathways be automatically updated with the appropriate configuration changes so that resources can be consumed.

Configuration updates might be required for the following:

- Local load balancing.
- Global load balancing.
- Firewalls.
- Authentication.
- VPN gateways.