dynamic networks, real-time operations and the need for active inventory
<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>executive summary</td>
</tr>
<tr>
<td>05</td>
<td>dynamic networks, real-time operations and the need for active inventory</td>
</tr>
<tr>
<td>07</td>
<td>the anatomy of dynamic services: an example</td>
</tr>
<tr>
<td>09</td>
<td>active inventory and live topology – what exactly are they?</td>
</tr>
<tr>
<td>10</td>
<td>infrastructure-aware mano</td>
</tr>
<tr>
<td>11</td>
<td>getting there; the hybrid path</td>
</tr>
</tbody>
</table>

in summary
executive summary

This paper lays the groundwork to fully understand the dramatic impact on operations that we believe will result from dynamic, virtualized (and hybrid) networks. It is intended as an easy-to-consume look at the specific topic of active inventory and live topology.

We believe that “active inventory and live topology” are crucial “shared resources” for next generation hybrid network operations. The terms “active” and “live” indicate that these are living, changing databases that reflect the dynamic nature of virtualized networks, maintaining a current view of both the infrastructure in place, its utilization by virtualized functions and flows, and the topology of services across that infrastructure.

This paper focuses on the business value to be derived from active inventory and live topology – it will be of interest to network operations teams. A comprehensive active inventory framework such as is described in this paper, is now available in open source. It is an integral part of the Linux Foundation’s Open Network Automation Platform (ONAP), that was formed by merging open source ECOMP (co-created by AT&T and Amdocs) and Open-O in February 2017. Now global providers can benefit from a holistic approach to NFV and SDN automation, including the important operational aspects of an active inventory, in open source as part of the ONAP project.

Virtualization – aside from its inherent attractiveness as a simplified network technology, promises to dramatically lower a wide range of costs, both CAPEX and OPEX, with profound implications for how network businesses can and should be run. Beyond simple cost reduction, virtualization also promises speed and agility that can benefit revenues, business models, service availability and therefore customer satisfaction.

In this report we look at the many operational changes in virtualized networks that make them highly dynamic and flexible. We next look at how operations must change to derive full business benefit from that technical flexibility. Finally, we look specifically at one critical enabler – active inventory / live topology, and how it supports changes across the process spectrum. Active inventory is truly one of the most critical of the common enablers of flexible, dynamic operations on virtualized and hybrid networks.

In short, what are active inventory and live topology and why are they critical? Active inventory is a dynamic, real-time view of network infrastructure and its status – recognizing the constantly changing nature of this underlying capacity. Live topology represents “services” including customer-facing, network-facing and complex VNFs – superimposed on that network infrastructure. With network virtualization, VNFs and services move dynamically – to automatically scale and optimize the use of costly capacity as traffic conditions change and self-heal as the inevitable failures or maintenance actions occur. To accurately support operational processes and minimize fallout, inventory must be 100% up-to-date, reflecting the latest locations and configurations. This data is used multiple times, from order validation through automatic healing. And, in the end, this dynamism is what drives both agility and cost reductions.
dynamic networks, real-time operations and the need for active inventory

**Business drivers for change**

Virtualization is the emerging network technology of our time. It promises agility, reduced costs, hardware consolidation and other attractive benefits. Yet its largest value – according to our analysis in "The Economics of Virtualized Networks" is delivered through operational changes that drive down OPEX and increase both revenues and margins. We believe that vastly larger per-action OPEX reductions are possible in categories such as trouble isolation, service or network function restoration, activation/provisioning and new product-offer innovation. In some cases the OPEX reductions exceed 90% as automation is implemented. These reductions, however, depend on entirely new processes, a high degree of automation, and in fact a re-thinking of management processes. Without significant rethinking of operations and OSS assumptions, neither set of financial and operational benefits can be fully realized. This paper discusses one of the critical underlying technologies in this operational transformation – active inventory.

We have illustrated the economic benefits that virtualization brings to service providers’ operations if automation is applied to key operations in which labor is both inefficient and unable to meet the expectations (e.g.: on demand, seamless operation, instant scaling) of customers using cloud-based services. Figure 1 depicts the expected change in the cost curve (after automation). If communications and media providers transform their operational infrastructure, we make the case for a significant payback in terms of lower cost operations. Using virtualization, it will be far cheaper, in some cases close to zero, to set up, scale, heal or repair a service. Similarly, it may be for the first time feasible to "groom" traffic and services dynamically so that capacity left idle by one service supports the peak traffic of another.

Some key take-aways to figure 1 include:

- CAPEX falls as an absolute number, but GROWS modestly as a percentage of revenue
- OPEX falls as both an absolute figure and as a percentage of total cost
  - note: taken together these mean that the industry is substituting capital for labor – which is exactly the long term trend of productivity improvement in all industries
- Net cost per activity falls, for virtualized plant, to near zero
- Net profit margins improve as a direct result of efficiency gains and automation  

![Figure 1: Changing Cost Curve for communications and media providers applying operational changes in a cloud service network](image-url)
Figure 2 provides another perspective on the impact of virtualization; this time as applied to infrastructure utilization and the opportunity for dynamic resource allocation. Network traffic peak-to-average ratios often exceed 5:1, resulting in utilization rates as low as 20% or 30% in networks of today. Future networks that implement automation methods will be capable of dynamic grooming, resulting in enormous CAPEX savings.

Finally, low unit operational costs can drive new revenues. In the past it has often not been economically feasible to create (for example) new services “on demand”, to create large numbers of product offers tailored to niches, or to enter into some complex and demanding partner/wholesale business models. But SDN, NFV and XaaS change those costs significantly, and this drives new revenue opportunities, and allows the industry to better capture value – expanding margins.

Figure 2: Network Traffic utilization measured by hourly consumption

The goal of the operational changes we will discuss for the remainder of this paper is to realize all of those OPEX savings, revenue opportunities, and CAPEX savings.
the anatomy of dynamic services: an example

In order to understand all the ways that networks and operations become dynamic – and therefore understand the business and technical demand for active inventory – let’s walk through the majority of a product’s lifecycle, from ordering through repair or scaling, and points along the way.

Before we begin, let’s address the question that is likely on many readers’ minds: “how many traditional inventory tasks go away in a virtualized environment?” Our opinion: none; however the specific demands placed on inventory changes, driven in particular by the constantly changing, dynamic nature of virtualized services and network functions.

We will begin with a product that has already been created, all the operations processes defined, and the resulting model placed in the enterprise catalog. This also implies that all component services are defined in orchestration (service and network/resource), and that the operations logic (fulfillment, testing, etc.) is defined in associated DevOps – or we hope so.

**Step#1 – Order Negotiation:** Note that we don’t call this “order capture”. It will no longer be a one-way process in which a user provides ordering data to the communications and media provider. Rather, a customer interacts with a portal, which is driven by a catalog. Order negotiation will be contextual: as the customer makes product selection choices, new options are presented and other options, which are no longer relevant, will be removed. For example, if the customer chooses a vFirewall option, firewall parameters must be presented.

As the order progresses, not only must the order make logical sense, but also the process must check with inventory to see if the service can be accommodated. Inventory based validation is already a service fulfillment best practice today, but in a virtual world there is a unique challenge: resources are constantly being added and consumed in near real time. Consequently it is imperative to ensure that both the capability and capacity constraints exist in the network and in the data center, in the location(s) needed, at order time – not at some time in the past. This is one case of the dynamic network complicating the ordering process, and requiring a near real-time inventory that is 100% up-to-date. Note that active inventory must not only be fast (near real time), but it also must receive near real-time updates (probably from orchestration) as resources are consumed via new orders and re-arrangements.
Step #2 – Order Fulfillment: Once complete, the order must be fulfilled (instantiated). In a physical world, it is likely that specific physical resources (ports, line cards, etc.) are selected – and tentatively reserved – during ordering. In a virtual or hybrid network, many service-resource mappings are made at the time of fulfillment, based on 1) policy rules that define the product’s requirements, and 2) available resources (locations) where they can be instantiated, with valid resources provided by active inventory. Once again, we can see that underlying resources are constantly being used (fulfillment, scaling, healing) and released; therefore inventory must have an up-to-date view of available capacity, along with the salient characteristics of those underlying resources.

Step #3 – Service Assurance: Once the order is fulfilled, and the customer is using the service, we must monitor it, identify problems, and correlate underlying resources with services and ultimately with the products and customers that depend on those resources. The complication, as always in virtualized environments, is that the products and services do not necessarily remain in one place, dependent on known and constant resources: they may move. Two important (and closely related) concepts in virtualized networks are auto-scaling and auto-healing. Another concept is improved capacity utilization, realized by shifting services among resources (for example, to replace corporate firewall capacity with consumer STB capacity at night). 1 In both cases the result is the same: the service may not be running on the same resources it was when originally fulfilled. To support assurance processes, it is critical that the service topology be “live” (beginning to see a pattern?) – meaning that its mapping to resource inventory must be updated each and every time such a location change is made. It is worth noting that in a truly cloud-native environment there may be many individual changes associated with a single VNF.

Step #4 – Automated Healing and Scaling: Step 4 builds on the same capabilities and principles to achieve business benefits not available today – specifically automated self-healing and scaling. Automated healing and scaling utilize various OSS/MANO systems to perform “continuous, context-aware fulfillment” – reacting rapidly to failures and traffic demands. This, in turn requires those same OSS/MANO systems to consume inventory data in near real time to support the functions necessary to achieve a dynamic order to assurance lifecycle.

As “add, change, and remove” requests are initiated, automated orchestration methods will reconfigure resources to meet the necessary NF and service requirements. In addition, optimal performance of the network will be impacted by weather, power, component failures, catastrophic link failure (fiber cuts), often without warning. To combat these unfortunate realities, dynamic, context-aware healing and scaling will inevitably transform today’s business practices (which often depend on manual task components) towards automation to meet these short time frames, and vastly higher number of actions. As a direct consequence, automated healing and scaling in the hybrid virtualized network will shift the minimum responsiveness requirement for inventory systems from being relatively static, to being near real-time, federated, and active.

As we see from the four process steps above, inventory remains an essential part of virtualized and hybrid infrastructure. Its roles – in validation, fulfillment, testing, assurance and automated life-cycle management (healing, scaling, decommissioning) are consistent with historical roles for inventory. Implementation details and the requirements placed on inventory however, are significantly affected by the dynamic nature of virtualized networks: a) inventory must be in the update path as NF and service rearrangements occur; and b) it must operate in the time-frame necessary and support the vastly higher transaction load. We will address one final impact; that of hybrid operation later in this paper.

---

1 In this paper we will use TMF terminology such that all customer-facing commercial services are called products, the pre-packaged components that make them up are called services, and the underlying network or IT capabilities are called resources. So when we say product, we might mean “mobile service plan” or “enterprise VPN with Firewall.”

2 While virtualization eases some requirements on inventory (since it can be instantiated on demand), there are still requirements for available NFV-I, capacity and congestion must be confirmed, and in some cases, specialized NFV-I may be required.

3 We pragmatically define NRT as “sufficiently fast to avoid out of date inventory” This requirement will vary depending on the case, and will undoubtedly become more stringent over time.

4 These requirements are defined in service characteristics, stored in both VNF (MANO) models and service catalog models, and implemented by policies.
active inventory and live topology – what exactly are they?

Hopefully, we have adequately made the case that inventory and topology must become dynamic. Next, we will investigate in more detail what components and capabilities are needed today, and (in the following section) why federation is useful both to break-down technology silos, and smooth the evolution from existing systems and methods. We will note up front that there are several different physical implementations possible – but at this time we will simplify by focussing on the “what?” rather than the “where and how?”, both of which may vary based on deployed systems, and other choices you make as you evolve your network.

We believe that active inventory and live topology are the premier shared resources for next generation hybrid network operations. The terms “active” and “live” indicate that these are living, changing databases that reflect the dynamic nature of virtualized networks, maintaining a current view of both the infrastructure in place, its utilization by virtualized functions and flows, and the topology of services across that infrastructure. The following characterize what we believe is necessary for success. Active inventory should be:

**Characteristics of next-generation “active inventory”**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Shared Resource</td>
<td>A resource shared among (but not limited to) fulfillment, assurance and capacity management processes. It is important that data is not duplicated – since that inevitably leads to inconsistent data, and errors. Note that this also means that the performance and scaleability (as noted below) must meet the requirements to serve all those processes simultaneously.</td>
</tr>
<tr>
<td>Near-real-time</td>
<td>Providing responses in the same time frame in which the operation must be completed (which varies by operation), such that there is no perceptible delay to customer interactions, instantiations, or auto-heals/scales.</td>
</tr>
<tr>
<td>Highly Scaleable (transaction volumes)</td>
<td>Since the number of active inventory transactions maybe many times higher than in traditional inventory systems.</td>
</tr>
<tr>
<td>Highly Available</td>
<td>Since inventory is in the critical path of orders, fulfillment, healing, scaling and rearrangements – most of which are becoming automated. If inventory is down, dynamic network operations may be down. Note: the same applies to the core orchestration software and method.</td>
</tr>
<tr>
<td>Federated</td>
<td>Meaning that it acts as a &quot;clearinghouse&quot; for other sources of inventory data. The active inventory must understand that reference data may be in more than one place, and perform near-real-time queries sufficient to validate an order, understand dependencies, or identify free and appropriate resources for assignment and instantiation. In this capacity, active inventory becomes the clearinghouse for all necessary inventory data, regardless of the original source (which may in fact be the network itself).</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Concurrent with federation, the end-state solution must support both virtualized and non-virtualized infrastructure seamlessly. This is critical to overall agility, and essential due to the long evolution period to fully virtualized networks.</td>
</tr>
</tbody>
</table>

Collectively, these characteristics define a structure that can support highly flexible, real-time and interactive operations. Those operations can enable on-demand services, automated and pro-active scaling and healing, and near-real-time fulfillment – all benefits both in terms of cost reduction, but also in terms of customer satisfaction and, ultimately, market share and revenues.

Communications and media providers, suppliers and industry bodies (e.g.: ETSI) have been working toward new operational concepts based on flexible, common methods and closed-loop automation. Initially, this position (which breaks down well established process silos) was at best new, at worst controversial. We are happy to note that those ideas are becoming accepted practice both among leading software suppliers, and implicitly in work underway in ETSI and TMF (ETSI GANA, ETSI auto-healing, TMF ZOOM and related work). As closed loop automation becomes a reality, the dynamic demands on inventory will rise, demanding ever more active and federated architectures.
At this juncture, it is worth discussing an advanced inventory concept which we believe will be increasingly important, especially as the industry supports higher performance VNFs: this concept is "Infrastructure aware instantiation". Unlike the hyperscale-IT cloud, telecom network loads often have strict performance demands, and many of them skew toward packet processing. High Availability (HA) configurations, and low-latency database access (typically fast reads, but occasionally, as in prepaid or OCS, the more difficult writes).

Many VNFs may have no special requirements, and can be placed on any infrastructure. Others, however, may require specialized hardware acceleration, access to ultra-fast memory (e.g.: remote-DMA type schemes), or have unusual proximity requirements (diversity for availability, co-location for low latency, etc.). Active inventory must be sufficiently aware of these capabilities in order to support the most intelligent location of VNF (and their constituent micro-services) workloads, and also make the best use of scarce resources.
getting there; the hybrid path

Up to this point, we have looked at operations in a virtualized world and asked “how will it differ, specifically with respect to inventory-intensive operations?” Now, we will look at the practical issue of transitioning from where we are today (primarily physical, static networks) to a virtualized world.

Transition requirements are heavily influenced by the expected duration and timeframe over which virtualization will replace more traditional technologies in networks. Appledore Research Group estimates that the transition to a “fully” virtualized world will take roughly another 15 years. Moreover, that same forecast shows that only a portion of all communications and media provider capital can realistically be virtualized. This means that the industry will operate in a hybrid world containing both virtualized and physical resources for most of our current planning horizon.

We strongly believe that future operations should be built to achieve virtual-network-like agility under all possible conditions – fully virtual, hybrid and even when existing physical technology is primarily employed. This is a realistic goal – dynamic path routing can be achieved before the advent of full SDN, as many PNFs may be remotely configured, and XaaS responds well to “on demand”. In addition, customer operations on mobile networks (which are shared, dynamically allocated resources) could be far more agile than today’s OSS and BSS enable. Therefore, despite the long road to a purely virtualized world, an opportunity exists to transform operations, costs and agility starting today.

While a full discussion of inventory evolution is beyond the scope of this paper, a few key concepts are clear. First, communications and media providers should look to add a federation layer to logically unify existing inventory silos (note plural) with new, near-real-time active inventory and live topology resources. Second, communications and media providers can largely allow existing inventory to operate with its existing performance: so long as we “cap” these to existing resource types. Because older inventory systems need only support (older) semi-static resource types, their lower update rates and traditional load/discovery methods should continue to perform adequately within the context of a federated environment led by modern “active” inventory.

Most importantly however, new, federated and active inventory must have the ability to return status and values across resource types, breaking down silos and allowing agile creation of network- and customer-facing services across the necessary spectrum of inventory. In this way we can a) minimize project costs and risks, b) allow older systems to begin a natural sunset path c) support near-real-time operations without drastic changes to existing systems or methods, and d) effect increased agility not only on new virtual technology, but across large parts of hybrid technology as well. In this way we can focus on agility and operational improvements immediately, and allow technology replacement to continue at its own pace – while communications and media providers reap immediate benefits.

in summary

Our industry is entering an exciting time, in which the inherent flexibility of virtualized networks promises lower costs, higher agility, exciting service options – and even improved performance and robustness of underlying networks – all at the same time. However, these benefits depend on re-thought operations processes, and re-architected “OSS” and “BSS”. We hope that this paper illustrates the dramatic impact that virtualization will have on inventory, and provides a high-level view of how inventory and topology must evolve. Further, we see inventory strengthening its role as “shared resource” to many processes, becoming real-time and interactive, and being sufficiently intelligent to abstract data from myriad sources and present the necessary information to the querying process.

When implemented properly, active inventory can also simplify communications and media providers’ OSS architectures, by providing a common point of interaction, reducing duplication, and therefore reducing the burden of ongoing integration and maintenance across disparate sources of data. We applaud those that are innovating in active, federated inventory solutions, and encourage communications and media providers to take this opportunity to truly design the inventory process they have always needed and wanted.
about amdocs

Amdocs is a leading software & services provider to the world’s most successful communications and media companies. As our customers reinvent themselves, we enable their digital and network transformation through innovative solutions, delivery expertise and intelligent operations.

Amdocs and its 25,000 employees serve customers in over 85 countries. Listed on the NASDAQ Global Select Market, Amdocs had revenue of $3.7 billion in fiscal 2016.

www.amdocs.com