Network Auto Discovery and Reconciliation: The bedrock of effective network inventory management

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Maintaining an accurate record of network inventory is essential for supporting and enabling operational processes and automation. To achieve this, accuracy is essential – changes in the network need to be reflected in the inventory system. How can this be achieved? Reconciliation from all network systems to the network inventory solution is the answer – you can't maintain accuracy without this core process.

Communications networks are made up of a complex, ever-evolving mix of assets ranging from physical and virtual elements to IT systems and beyond. These are usually sourced from multiple vendors, they operate across different domains, and involve different generations of technology working alongside each other. As such, they present a basic challenge to operators that's easy to understand: how do you manage everything in an operationally effective and efficient way?

To ensure that you can, all these resources must communicate seamlessly with the processes that co-ordinate service delivery (and sometimes also with each other). This is because any combination may be required as part of the same service chain, so the operator must be fully aware of their performance and status at any time. In simple terms, there's an inventory of resources that must be managed and, moreover, managed dynamically.

The Inventory Management System is the reconciliation "hub"

Doing this is primarily the responsibility of the Inventory Management System (IMS). This should contain an accurate record of all network resources and assets. By consolidating all such records into a centralized platform, disparate silos can be eliminated. In addition, a single repository of all relevant information can then be accessible to any other process that needs such data.

So, if operators want their networks to perform optimally, the IMS is critical.

It yields the insights and information which allow numerous important questions to be answered and issues to be flagged up and resolved in areas including:

- **Network Operations**
- **Network Planning**
- **Service Orchestration**
- **Service Assurance**
- **Network Design and Build**
- **New Integrations and Deployments**
- **Performance and KPI monitoring**

…and others. But if things change in the network, then the record of assets in the IMS will no longer be accurate or reliable – introducing friction into operations. In this paper, we'll explore how the IMS can be kept up to date, ensuring accuracy – reconciliation.

Nothing is static

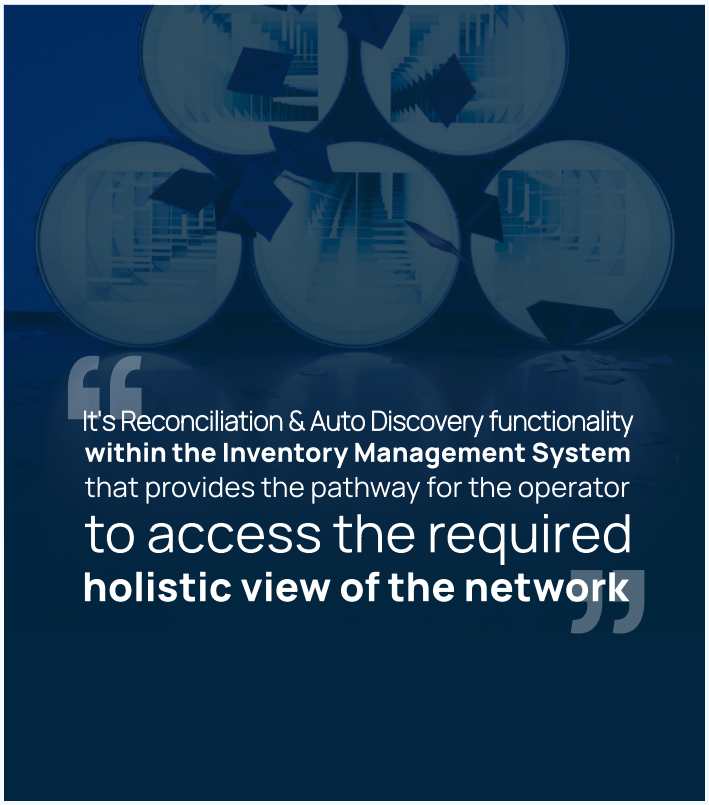
Changes in the network are a constant. Operators have to stay on top of them, and integrate them to create an accurate, reconciled, and up to date view of their resources and operations.

To put matters into perspective, networks aren't static. Of course, this merely adds to the challenge of managing everything the operator already has. New elements must be added – new routers, new racks, new cables; the status of others will change; new services will be delivered to different customers; and so on.

Often, old assets and resources need to be taken out of service – yet still included in the overall inventory because in some cases elements may remain in the network, but with an inactive status.

Likewise, when a new fiber connection is added, it may be not just the physical route but also the service that needs to be put in place. Or, an existing connection might be upgraded – with more capacity, adding a new L3 VPN, or something else, for example. So, change is a given – and it's constant.

These are just headline examples of why inventory management can present a considerable challenge.



Outlining the **complexity**

- In WDM deployments, operators must be able to both view and manage the relationship between the different elements that support the individual wavelengths over which data is transported. A continual awareness of these elements is required. This includes – but is not limited to:
  - Fibers and fiber locations
  - WDM equipment
  - Shelves, cards and pluggables
  - Physical connections
  - Logical connections (OMS, OCH, ODU)
  - Client connections
  - Relationships with other networks and domains, such as MPLS, mobile, and more
  - All aspects of service delivery
  - Service descriptions
  - Customer identity and status

  Without such an awareness – and without a dynamic IMS – it would be impossible to optimize network performance.

- **In FTTH/PON networks, components, and processes** (including active network registration, passive networks registration, geographical information (GIS), Physical Network Inventory registration, Logical Network Inventory registration, relationships to other networks, such as MPLS, and more) **must be understood and tracked individually**. Commercial success depends on these being managed and reconciled, again by the IMS.

- **Many operators manage MPLS and IP networks without an NMS**, which means that network engineers need direct access to the network equipment (NEs). For obvious security reasons, this is not best practice, especially when we consider the many recent cases of security breaches and criminal hacks. In addition, for **planning purposes it is also not ideal**, as network planners may not have access to the NEs. So, when the inventory is not up to date, planners need to go to the operations team to ask for the current situation before being able to plan something new. With MPLS and IP network reconciliation such security and planning issues can be mitigated.

- Some inventory management systems, such as VC4-IMS, can create a true digital twin of the actual network, allowing the whole organization to view the MPLS and IP networks through a "proxy". With this functionality, there is no need for direct access to the NEs. This point also applies when an NMS is used. **VC4-IMS limits NMS access, avoiding the risks of allowing too many technicians to access the NMS directly.**

- **Service Activation/Provisioning of any new service means multiple usage records are created** by different network components, as well as records from the control platform managing end-user communications. All this information is necessary for optimal network management and service delivery, but it must be captured and correlated. Furthermore, the **rapid increase in data volumes makes it an even bigger challenge** to do so. Without a dynamic IMS, end user expectations could not be met.

- Deploying new fiber routes and connections to a new neighborhood or to the fiber core network means that **physical infrastructure needs to be aligned with new service orders** from different properties as customers take up the new connectivity options – triggering new work orders and ensuring that related processes, such as billing, are also activated.

Reconciliation is **key**

What must be reconciled must first be discovered. Information must be both accurate and timely.

It's reconciliation (and auto discovery) functionality within the Inventory Management System that provides the pathway for the operator to access the required holistic view of the network described above, to deploy new components more rapidly, to more effectively leverage network data, and to enhance network design and build. In other words, to keep ahead of any changes to the network and the deployed assets, physical or otherwise.

Central to reconciliation is the process of synchronization, which ensures that all the performance data sourced from components within the network is accurate and synchronized with the greater whole.

This is challenging to achieve because, during operations, data constantly changes, so the network alters across multiple dimensions: status, resource allocation, etc. on a continual basis. This problem is compounded as more systems are deployed.

In addition, each network may be managed by a Network Management System (NMS), or Element Management System (EMS). Equally, however, it's possible that either or both are absent - which means that direct access to the Network Elements (NEs) is required. Each NMS, EMS or NE will also be vendor and version specific.

Network upgrades happen all the time and equipment vendors are continuously evolving their platforms. To make matters even more complex, all these platforms are connected to others. But, on its own, the network doesn't 'know' how these are all interconnected – in other words, these critical relationships may not be accurately understood.

That matters, because any given service requires the support of a chain of such elements – so multiple NEs are involved in each network or customer service.

> "VC4-IMS is equipped with an **advanced reconciliation process** that ensures that all network changes can be captured"

To make sense of this and to understand these relationships, it is the Network Inventory System that should hold a map of all such network connections, so that it can provide an end-to-end view of all the network services and the infrastructure over which they are delivered.

Synchronization is the key to keeping up with where things stand at any given moment. It's how the Network Inventory System can stay updated, ensuring that the big picture is available, showing all network and equipment relationships.

It may occur on a scheduled basis or ad hoc – but the Network Inventory System should retain the view of the network and preserve previous versions, so that the current view can be compared with earlier ones and check for discrepancies when necessary so the operators can discover gaps and close them if required.

Reconciliation: a definition and an understanding of the process

Understanding the complexity of the data to be reconciled highlights the scope of the process and the challenges it presents.

Reconciliation then, as we've established, is essential for effective inventory management and synchronization, so it's worth defining it in at least simple terms.

We can understand it as:

> *"The process of obtaining all data related to changes (additions, removals, and operations) in the network."*

It is an ongoing activity because, as we've seen, changes are constantly happening, so to maintain the necessary degree of operational awareness, the operator must scan for and retrieve related data.

This (data) is sourced from multiple levels ranging from the NMS or EMS, if present, as well as to every type of equipment that is (or might be) deployed.

VC4-IMS: built for advanced reconciliation

VC4-IMS is equipped with an advanced reconciliation process that ensures that all network changes can be captured, so that consistency and accuracy are maintained. The reconciliation process itself works broadly as follows:

- Connecting to the Network Management System, the reconciliation process will extract data held within it and initially store it in the same format as the original source file, generally doing this via an API. This is a complicated process, given that for different vendors or different types of networks, formats are not consistent with each other.
- Each equipment vendor technology will have its own Northbound interface (NBI), which allows external platforms to connect and interrogate them. Each NMS and EMS software version may also have different NBI versions and different output formats. For these reasons, VC4-IMS supports different types of adapters and versions of adapters, ensuring compatibility with the widest possible range of NMS and EMS platforms. Some examples of frequently used methods are:
    - Restful API, T-API
    - TMF CORBA
    - MTOSI
    - TL1
    - XML based interfaces
    - CLI (SSH)
    - SNMP
    - Flat files (txt, csv)
    - Vendor proprietary interfaces
    - Database to database connections

- Once ingested via the NBI, the reconciliation process will then store the captured data, ideally in its current format to ensure accuracy and consistency.
- Next, crucially, the data will be normalized to a standard VC4-IMS format so that the actual process of reconciliation can take place with the network inventory data.
- At this point, the reconciliation process uses different database schemas, one for each vendor NMS/NE interface, so that the master inventory data set is not affected.
- Different reconcile options are available to allow the operator to determine what to include in any specific reconciliation sub-process. Thus, the user always retains 100% control over what is being reconciled.
- The reconciliation process will identify new "things" in the network, for instance nodes, cards, or ports, thus allowing customers to choose whether to bring them into service or not, as well as changes to existing objects and assets.
- In some instances, customers prefer manual control and don't require automatic object creation. Meanwhile, others want full synchronization from the NMS/EMS or NEs to the inventory, which requires auto-creation and auto-deletion.
- The reconciliation options and all recorded discrepancies between the live network and inventory are available in a dedicated Reconcile Form. In the case of VC4-IMS, customers using this Reconcile Form can easily identify discrepancies and enable corrections.

> "The bottom line is that it's **complicated and** the required data must be assembled from all **possible sources** overcoming the limitations of the deployed systems and the available interfaces"

Reconciliation: in action

Every network is unique, and reconciliation must be tailored to the network in question. There are many important considerations.

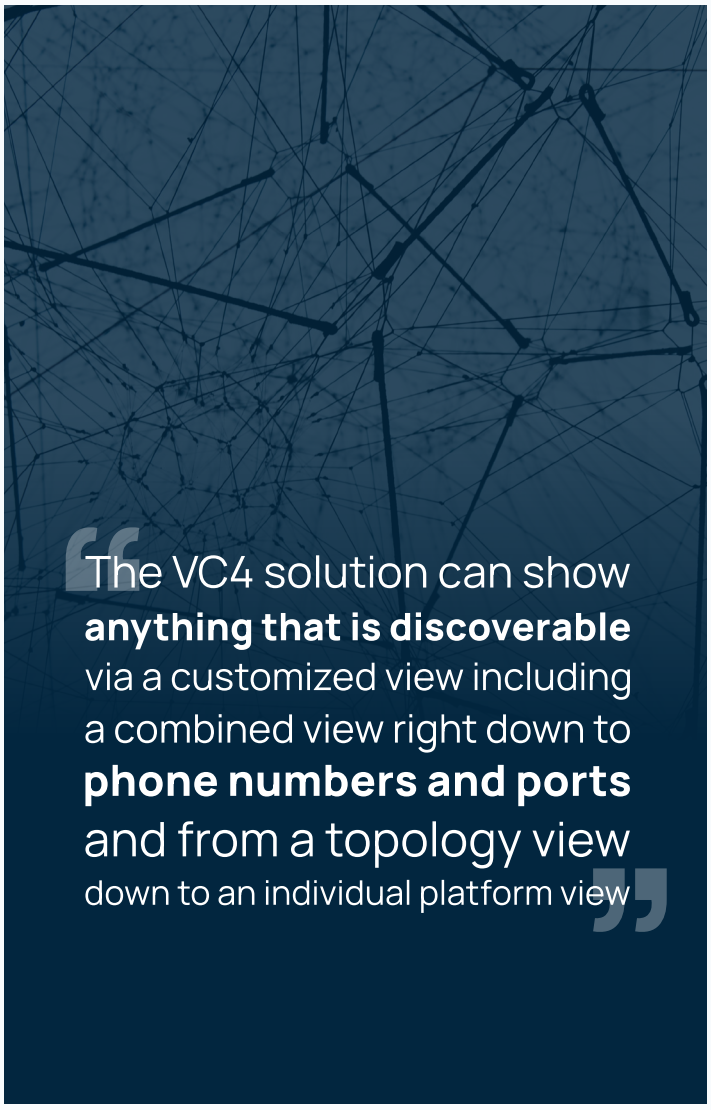
As the functional description above suggests, the foundation of reconciliation depends on the completeness of the data discovered via the network interfaces. When there is an NMS, often it will provide all, or most, of the data needed. However, this is not always the case. Some Network Management System Northbound interfaces (NBI) are not capable of providing all necessary information. As a general rule, the older the NMS version, the less data will be available. It is also often heavily dependent on the type of network.

For example, transmission network NMSs are usually capable of providing the most data. On the other hand, most vendor DSL and GPON network NBIs are more limited and often slow. In such cases, VC4 can enrich the data using other methods to collect the missing information – for example by connecting to the Network Elements via CLI (SSH) or using other available NBIs.

Some EMS platforms offer only limited data for retrieval. In this case, direct connection to the NEs is a useful alternative. However, this means that VC4-IMS scripts need to enrich that data to obtain the end-to-end network topology. That's because NEs don't hold real connection data, only relations (neighbor commands), tags and comments.

Another thing to consider is the license provided by the NMS vendor for the NBIs exposed. In many cases, the vendor only exposes such interfaces for additional license fees. Further, some older equipment may only offer relatively limited NBIs – which may mean that an upgrade to the NMS might be necessary, resulting in further costs.

The bottom line is that it's complicated and the required data must be assembled from all possible sources, overcoming the limitations of the deployed systems and the available interfaces.



Reconciliation step-by-step

Let's assume we've mastered the above and we have collected a complete record of the entire network equipment and network topology (end to end connectivity within the network technology). This record of the current (live) network data can now be compared with the data already held in the inventory system to check for accuracy. A number of specific steps are involved in this reconciliation process:

Discovery & Reconciliation

As described above, raw data is collected from the NMS, EMS, and/or NEs and normalized to be reconcilable. Here, each element of the collected data drawn from an inventory item (such as equipment, shelf, card, port, connection, and so on) is given a unique identifier that creates a relationship between its name in the IMS and its identity in the NMS/EMS/NE, as appropriate.

The IMS can then query and compare the data in the reconcilable tables with the data that's stored in its own database. When the data doesn't match and there's a reconciliation problem, either the IMS auto-discover process automatically corrects the error in the IMS database, or the IMS creates a reconcile form for the operator to handle as it wishes. Either way, anomalies are swiftly addressed and resolved.

Automatic Reconciliation

This process automatically corrects data in the IMS database when necessary. For instance, when there is new equipment or new connections in the network that are not yet in the IMS – incorrect serial numbers in the IMS database, or new hardware software versions, for example. The operator can decide which components are automatically discovered or reported when issues arise.

Equipment Discovery

This procedure collects equipment information (such as name, type, parameters, card names, slot positions, etc.). The information collected can be configured to the operators' requirements. There can be unavoidable issues here if an element or system doesn't provide all the required information automatically, but as explained earlier, such issues can be mitigated by VC4.

> **The VC4 solution**
> enables operators to take control
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Port discovery

This is the automatic process for discovery of equipment ports. Most ports are related to cards or SFP/XFPs, but there could also be fixed, logical or virtual ports. Any mismatch will be discovered and presented on the screen. VC4-IMS will follow vendor equipment specifications to automatically ensure the correct port naming and settings.

Physical connection discovery

Discovery of physical connections depends on the availability of network data. Generally, this can be sourced from the NMS which, in many cases, holds information about the full network topology. As a rule, northbound interfaces (for example, CORBA or REST APIs, as we discussed) provide the required physical connection details. If there is no NMS, the required information can be sourced directly from the NE. In this case, specific commands (e.g., neighbor commands or similar) are used to obtain information regarding the physical connections from one node to another.

Logical connection and service discovery

This, too, is heavily reliant on the availability of network data that can be sourced from the NMS or NEs. Different vendor equipment types will have their own command sets to retrieve the logical connections and services data. It's not only the logical or service information that is important, but also how these connections or services are routed through the network and through which channels – for instance, VLAN IDs or similar.

Other network objects

Other network objects, such as IP addresses, telephone numbers, VRFs and Bridge Domains can also be retrieved from live networks. Such data collection follows a similar process to that described above – first, discovery from the network, then synchronization with the inventory data. Discrepancy reports can be made available: for example, duplicated IP addresses, duplicated VRF names, incorrect VRF names, phone numbers that are assigned to the network but not in VC4-IMS, and many more.

To summarize, reconciliation and auto discovery work together to deliver a clear, usable, and, most importantly, accurate end-to-end picture that is invaluable for network engineers, planners, and other key operatives. It allows them to view an up-to-date topology map, do quick fault correlation, and achieve faster service delivery. Operators can't navigate their networks effectively without the information that reconciliation provides, making sure that the IMS is up to date at all times.

Reconciliation: by VC4

Functional considerations in a reconciliation solution. What should you expect?

VC4-IMS provides these rich reconciliation capabilities. VC4-IMS is a complete inventory management solution that's optimized for all networks. Some examples include:

- WDM/OTN
- MPLS/IP
- SD-WAN/SDN
- Ethernet
- xPON
- xDSL
- SDH/SONET
- Microwave
- Mobile Core and RAN (2G, 3G, 4G, 5G)
- Voice/VoIP
- Wi-Fi
- VSAT

This enables operators to take control of their data, eliminating silos and providing a single view of all assets and relationships – that is updated to maintain accuracy.

The VC4 solution can show anything that is discoverable via a customized view including a combined view right down to phone numbers and ports, and from a topology view down to an individual platform view.

VC4-IMS: built for advanced reconciliation

VC4-IMS delivers unique advantages in the critical area of reconciliation including:

- The comprehensive nature of the interfaces it supports. Without a fully comprehensive view, operators may not have full visibility of their complete topology – for instance, only the physical view might be visible.
- Extensive data enrichment functionality. Where required for specific networks, VC4-IMS can enrich the source data. For example, if the WDM NMS doesn't have the end-to-end-view, the reconciliation solution can correlate with other data to create the full picture by stitching connections together to see how they are run, end-to-end – e.g., MPLS and VLAN.
- Reconciliation spans both core and access – so the operator can associate core services with the access nodes (e.g., VLAN ID) and know which nodes are associated with each customer allowing services to be mapped to them.
- Keeping pace with new interfaces as they emerge, utilizing more than 160 unique adaptors with ongoing, continuous investment in tracking.

VC4-IMS: built for any generation of technology

The solution can also be enhanced in combination with complementary partner solutions. Some examples of these include:

Network Compliance

- Check all your devices to ensure they comply to the standards.
  - Does each device configuration comply with the current global and vendor specific security standards?
  - Are your company's business and network rules applied in all devices?
- Ensure all configurations are consistent and up-to-date.
- Avoid security breaches

Service Orchestration

- Automate service delivery
- Provision services in the network automatically

Network Monitoring/ Fault Handling

- Collect alarm and performance data
- Correlate PM and FM data
- Create alarms and trouble tickets in VC4-IMS
- Perform impact analysis directly in VC4-IMS
- Root cause analysis

Track configuration changes

- Have visibility of all configuration changes that happen in device configurations.
- Complete overview of all historical changes and easy search functions.

Backups

- Make backups of device configurations every time there is a configuration change.

Supporting any generation of technology, VC4-IMS helps operators to plan new investments more efficiently and seamlessly integrate operations, end-to-end.

By bringing all data together, VC4-IMS is the foundation of operational excellence, providing:

- a complete, up-to-date overview of all network assets;
- insight to drive optimization and performance;
- integration to business processes;
- frictionless automation and service delivery;
- enhanced KPIs, costs management and financial performance; and
- accurate, timely reconciliation to keep ahead of dynamic network changes.

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