Digital Network Twin: Setting a Foundation for Innovation

Leveraging Equipment Identity Best Practices to Establish a Broadband Network Digital Twin

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1. Introduction

Cable operators are pursuing a network evolution – one that leverages existing DOCSIS® infrastructure, which in some areas has been deployed for more than 20 years. The number of permutations of network gear that has been cycled through any given operators' plant could be high, and the complexity could be tough to quantify. It poses a challenge, but also an opportunity, to drive innovation in how network planning, management, and upgrades will be handled in the future.

This paper covers an approach to inventorying broadband network components in a way that creates the foundation for a true digital twin of the cable network and the enablement of future innovation.

2. Cable Network Digital Twin: Foundation for Innovation

Cable operators all have software solutions for network design, construction, maintenance and management. Most already have a mechanism to digitally represent their networks, including the components, their relationships, and how they come together to deliver service to end customers. These, in their current forms, can be considered a digital twin. Yet despite these existing solutions, field operations and network management remain labor- and capital-intensive activities that operators must perform. We see true digital network twin capabilities as a way of unlocking untapped potential and innovation. While there might be future innovation potential, this paper will focus on four tangible, near-term use cases that are possible with a network digital twin: As-Is Plant Maps, Proactive Plant Maintenance & Failure Trending, Supply Chain Tracking, and Technician Accuracy, Efficiency, and Experience.

2.1. Precise, As-Is Plant Maps

A design map for cable networks is the beginning of the network evolution journey, but too often this reference guide is used as the source of truth. It will tell you an optical node is on the 300 block of an urban area, but what it doesn't tell you is that the 300 block did not have a suitable pole to hang the enclosure, therefore the optical node is on the 400 block.

One city block is not a huge issue for the operations of the plant because Radio Frequency (RF) levels were set to accommodate the different distances than what was designed. But it could significantly impact plant maintenance. What if it's snowing in upstate New York? Or there is a torrential downpour in Georgia? Or when there is a customer outage impacting an entire service group and the node enclosure is not located where the map indicated?

Location matters not only to the business but also to the technicians who keep the network operable and connected day in and day out. While one block may not seem significant in case of an issue, over thousands of miles of access network, this could become a time demand for technicians. Not only does the error create a potentially undesirable experience for field technicians, but it also could cost the business time and resources.

While a design map serves a role in the development and deployment of network components, a precise, as-is plant map could provide benefits immediately and in the future. Knowing exactly what is deployed and its precise location could improve a wide range of factors including mean time to recovery, plant analytics, future plant improvements, plant walkouts, and more.

2.2. Proactive Plant Maintenance & Failure Trending

Today, the access network for many operators could be compared to a web of roads connecting homes to the highway. Just as there are multiple components on the road - such as stoplights, stop signs, yield signs, and speed limit signs - that assist in smooth and safe travel to the highway, the access network comprises numerous components that assist in efficient and reliable connectivity. But what happens when a stoplight, or in the case of access networks, an amplifier fails?

By unlocking the ability to know where all network components are located, their exact model number, manufacturer, and other unique characteristics, network operators have the ability to apply advanced plant analytics, including proactive plant maintenance and failure trend analysis. While this information already exists, it does not live in a single, integrated, and federated dataset that can be leveraged for these advanced analytics. Model number might live in an engineering playbook, while manufactured date lives in a vendor's database, while installed date lives in a workforce management tool – and there is no way to accurately bring that together because there is no unique identifier that is reliable enough for such broad use cases (more on this later).

Allowing operators to predict and address potential failures, such as an amplifier failing or a tap reaching its end of life, before they occur could ensure reliable service and improved network performance. Without the ability to capture a digital twin of the network, operators will continue to react to failures within their respective plants. By pushing towards a digital twin that captures precise location and detailed component information, operators have the ability to conduct proactive plant maintenance and failure trending. Just as road signs guide drivers safely to their destinations, a proactive analytics solution could enable the access network to operate smoothly and efficiently, paving the way for a robust and reliable connectivity infrastructure.

2.3. Supply Chain Tracking

Many of the challenges being solved by creating a network digital twin through better identity and inventory methods have been solved in other industries, or even in other parts of the cable operator's business. When thinking about supply chain tracking, we should learn from the world of customer premises equipment (CPE) ordering, tracking, and installation. Across the industry, it is common practice to be able to identify and track a single CPE unit from the original equipment manufacturer (OEM) to the shipping partner to the warehouse to a technician's truck to a customer's home. This could be a $200 piece of equipment and there is highly precise tracking throughout its lifecycle. Should we not apply the same rigor to a full station node or amplifier potentially worth thousands of dollars?

Within operators' networks, specifically the outside plant and access network, component leakage has always been a challenge to find and address. Given the sheer number of components required to evolve cable networks, it is likely that many operators are negatively impacted by component leakage yet identifying it has been challenging. However, by adopting equipment identity best practices, as other parts of our industry have, operators could be enabled to regain control over their networks and components.

In early 2024, the Indian Department of Telecommunications was called upon to address an unprecedented surge in the theft of telecommunications equipment[1]. Operators within the region had noticed that large volumes of radio units and other components were being stolen from their plants. This type of theft is even common in North America. Although not specifically noted in the case in India, it is likely that these providers were unable to identify stolen components as theirs or their competitors'.

Theft comes in many forms and is not always as explicit as the case mentioned above. Many operators utilize expansive supply chain networks that involve the exchange of network components at many points. Although most of the time these supply chains run smoothly and are not hindered by leakage, that does not mean it does not exist. With the introduction of an industry-standard for unique component identification, operators can start to mature the way in which network components are tracked throughout their lifecycle. Once a component has been shipped, operators will quickly know which components were sent to them and should be accounted for within their network. An industry standard for unique component identification will not inherently fix leakage, but it can at the very least provide far greater visibility into the supply chain process and identify challenges or risks that exist.

2.4. Tech Efficiency, Accuracy + Tech Experience (AR/VR)

Capturing more data on the broadband network will have an impact on how operators manage and maintain these networks. These benefits are not hard to imagine. It is important, though, to not lose sight of how operators can improve the experience for their technicians who interact with the network daily. If you talk to a technician who has several years of experience, they will likely be able to tell you where a plant map differs from an actual component location, or which makes/models/types of components give them the most trouble. Getting this institutional knowledge into a digital tool that can scale is what the digital network twin could do. But if they already know this information, what is the benefit to them? There are benefits to be gained by even the most experienced technicians.

2.4.1. Tech Efficiency + Accuracy

Imagine, as a technician, for every job assigned to you, your workforce application shows you which components might be impacted, the make and model of those components, when those components were installed, the input and output RF levels at the time of install, and the exact location. You now know which components you might need in case there is a failure. You can be prepared with those components, instead of going to the job site only to find out you don't actually have what you need to replace. Maybe you know one of those components fails often in certain situations. You are now able to start troubleshooting before you even get to the site, making your time there spent fixing rather than diagnosing. Or even further, you know there was commercial power work in that exact location last week, so you can be prepared for potential power impacts.

The goal of a digital twin is not to replace the valuable knowledge of technicians. Rather, it will help to utilize, at scale, the experience technicians have from years working and maintaining the plant. It gives them a tool to apply their knowledge more efficiently, while making job planning and upgrades even more accurate.

2.4.2. Tech Experience (AR/VR)

A technician's job is physically demanding and requires a high level of attention to detail given the nature of the work. Checking a simple issue could require a technician to block part of a street from traffic or put on their harness and go up in a bucket truck. As we imagine what is possible in the future and what innovative solutions can be applied to the cable plant, the application of augmented reality (AR) or even virtual reality (VR), in combination with a digital network twin is an interesting proposition. A technician could be equipped with the tools to investigate smaller, more common issues without even leaving their truck. Armed with precise location and component details, an advanced image recognition application could tell a technician all the internal modules of an optical node by simply looking at it from the street. While this is simply a potential use case, it shows the power of this data set as you start applying it to other emerging technologies.

3. Digital Network Twin: A Promise Unfullfilled

Digital twins are not new. In fact, the digital twin concept was at its "peak of inflated expectations" in 2018 according to Gartner's Hype Cycle for Emerging Technologies. This publication predicted digital twins would reach a "plateau of productivity" in 5-10 years. Fast forward to 2024 (6 years later) and the cable operator industry has yet to apply this to their networks, but there is hope on the horizon. Why has it taken until now to be talking about true operational deployment and benefit? One hypothesis is the lack of reliable data.

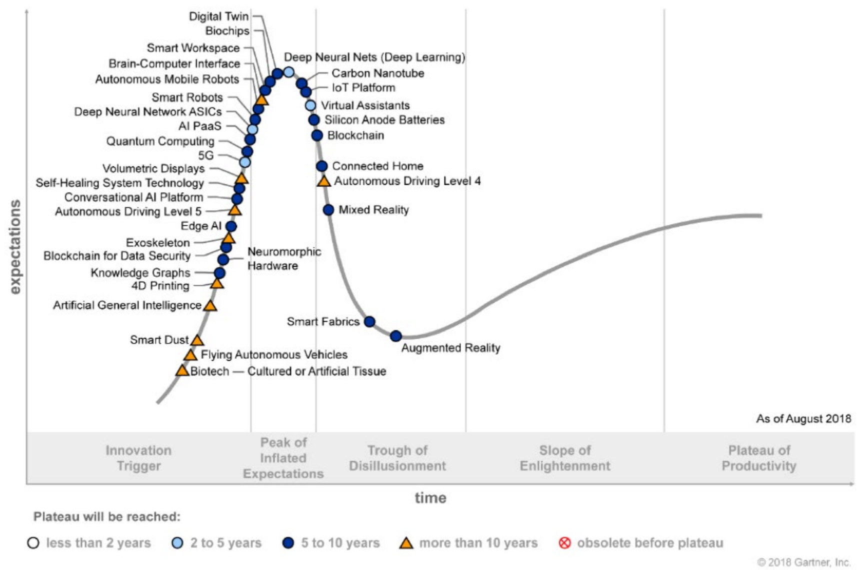

Figure 1 – Hype Cycle for Emerging Technologies, 2018

To capture the benefit of a digital twin, an organization needs to have a very clear, precise, and reliable picture of the physical deployment in which they wish to digitally replicate. The "digital" is only as reliable as the data it ingests on the physical. Anyone can create a digital twin, but the value is derived from the level of accuracy and precision of that digital twin. As we put this into context for cable operators, a digital twin is only as valuable as the information an organization has on its entire cable plant, from national data centers, to hub sites, to the access network. A large portion of this network, primarily data centers and facilities, are discoverable, meaning they have an IP address and can be identified uniquely. While by no means easy to digitally replicate, the data at least exists to some degree. The digital twin concept becomes more of an ideal vs reality when trying to accurately maintain data on non-discoverable network elements. How can you reliably create a digital record of a component when you have no digital record of what it is, when it was installed, its status, or even its exact location?

The cable operator industry has invested time and energy trying to answer this question, and through partnership and collaboration, has identified a rather simple approach that is tackling this very problem. The solution is an industry aligned unique identification standard and a more robust asset tag that allows for the efficient capture of complex data points.

4. Broadband Component QR Code Specification

Today, network components, specifically in the outside plant, are delivered and installed without uniform serialization or unique naming characteristics applied across all types of components (e.g., Media Access Control [MAC] addresses do not apply to all network components). Additionally, most network components either lack any type of serialized label or are affixed with a label unique to the vendor, used solely for internal vendor tracking.

Following collaboration across the cable industry, and leveraging existing industry aligned practices for specific components, significant progress has been made towards the alignment and standardization of tagging and serializing network components. This new industry specification, SCTE 292 2024[2], focuses on three key areas: unique identification via the Broadband Equipment Identity (BEID), standardized asset tags with consistent quick response (QR) codes and embedded syntax, and the sharing of more robust component level information via advanced shipping notices. The standard was designed to be future proof, allowing for additions and modifications over time, and while the initial scope of the specification focuses on access network components, it was designed to be easily applied to other areas of the network.

4.1. Broadband Equipment Identity (BEID)

Unique identifiers exist today in many forms across the cable operator ecosystem. The challenge with existing unique identifiers in the cable plant is the population to which their uniqueness can be guaranteed. Within the four walls of a vendor's operation, uniqueness is usually guaranteed with serial numbers. Given the number of vendors, component types, and sheer volume of components manufactured, uniqueness becomes harder to guarantee unless you align everyone on a standard syntax. This was the impetus for the creation of the BEID.

The Vehicle Identification Number (VIN) and the International Mobile Equipment Identity (IMEI) serve as critical unique identifiers, enabling precise tracking and authentication of vehicles and mobile devices respectively, while providing detailed insights into the specific attributes and origins of each component. Similarly, the BEID aims to serve as an industry standard in telecommunications, offering unique identification and delivering specific attributes for component identification. Each BEID is constructed in a standardized manner, as outlined in the specification, including a combination of vendor code, device type code, manufacture year code, and an additional seven-digit alphanumeric component ID created by each vendor. Figure 2 below illustrates this construct.

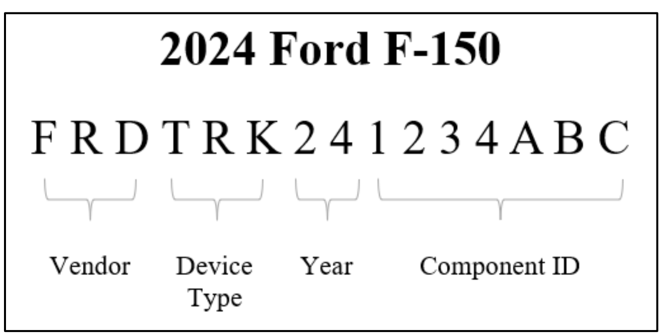

Figure 2 – Broadband Equipment Identity Syntax Example

It is not easy to establish a standard where standardization never existed before. Cable operators understand serial numbering and other identifiers are critical for ongoing business processes, beyond just the need of cable operators. The BEID is meant to be an industry standard, that is incremental to existing identifiers used by vendors. The hope is this will increase the adoption curve, at which time, expansion of the uses and applications for the BEID will be possible. For now, the “small” task of being the single unique identifier across the industry to enable more robust inventorying systems and the creation of a true digital network twin will do.

4.2. Asset Tag

Implementing a labeling solution that provides unique component identity is important, but alone still leaves an operational burden to efficiently capture that information. A key to the long-term success and impact of this specification is the ability to easily, without significant investment in new equipment or tools, capture the information about the component. To enable this seamless data capture, each component will be affixed with a label that has, among other things, a QR code with component specific information.

The labels and QR codes were designed to accommodate a wide range of placement situations and external environments. There are 4 “minimum” size labels given the variability in component size, available surface area, and environmental exposure. Figure 4 shows the 4 label sizes and design layouts.

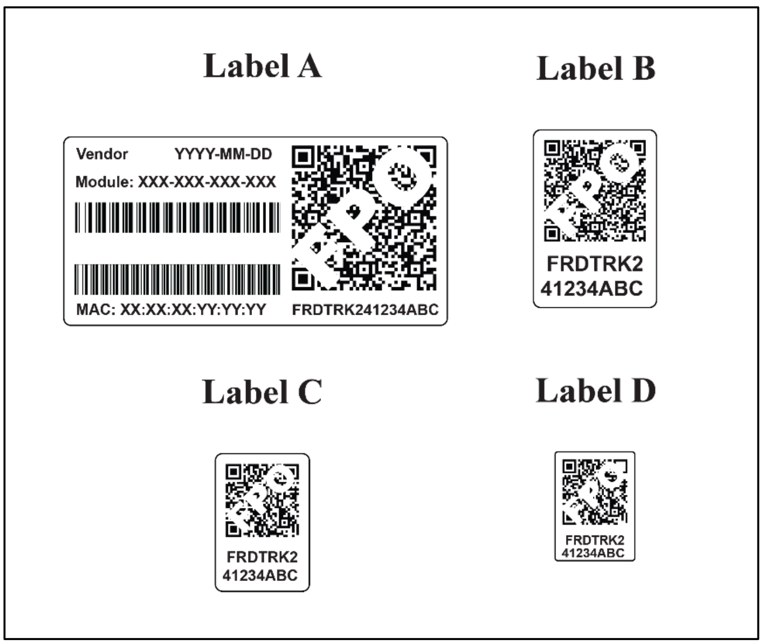

Figure 3 – Asset Tags A – D by Size

Along with standard label sizes, materials, etc. the new specification also defines the syntax and data that should be embedded with the QR code itself. From an operational perspective, it was important to align on a standard QR code syntax and definitions for how to populate the fields. This allows every operator the ability to build scalable solutions without the need for custom development or development cycles in the future to accommodate vendor level changes. Table 1 and 2 below show the fields required and information needed to be provided for both variations of the QR code syntax.

Table 1 - Field ID Definitions and Criteria for QR code Labels A & B

Field ID	Definition	Information Provided	Characters
DT	Device Type[1]	<device type code>	3[1]
DM	Device MAC/EUI[2]	<device MAC address – EUI-48 or EUI-64 bit>	16 (max)
VN	Vendor[1]	<vendor code>	3[1]
SN	Serial Number[2]	<device serial number>	16 (max)
MN	Model Number[2]	<device model, product, or part number>	35 (max)
HW	Hardware Revision[2]	<device HW rev number>	8 (max)
ID	Broadband Equipment Identity (BEID)[1,2]	<Broadband Equipment Identity (BEID)>	15

1. Device Type Codes and Vendor Codes are defined and maintained as part of this new specification to ensure consistency.
2. Vendor developed, managed, and assigned.

Table 2 - Field ID Definitions and Criteria for QR code Labels C & D

Field ID	Definition	Information Provided	Characters
MN	Model Number[1]	< device model, product, or part number >	35 (max)
ID	Broadband Equipment Identity (BEID)[1,2]	<Broadband Equipment Identity (BEID)>[3]	15

1. Device Type Codes and Vendor Codes are defined and maintained as part of this new specification to ensure consistency.
2. Vendor developed, managed, and assigned.

5. Conclusion

The cable operator industry has long wanted to have better visibility into the entire broadband network, but without standardization across the ecosystem, it was somewhat out of reach. With the creation of this new industry standard unique identity and asset tag, operators now have the means to capture and inventory outside plant network components like never before. This piece of data might be what is needed to capture the promised productivity from the digital twin capabilities and enable next generation network planning, design, maintenance, and upgrade solutions. The hope is we, as an industry, do not let this network upgrade pass us by without laying the foundation for innovation for our industry.

Abbreviations

AR	Augmented Reality
VR	Virtual Reality
RF	radio frequency
CPE	customer premise equipment
OEM	original equipment manufacturer
MAC	media access control
QR	quick response
BEID	Broadband Equipment Identity
VIN	Vehicle Identification Number
IMEI	International Mobile Equipment Identity

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