Augmented Reality and Artificial Intelligence Approaches for Inventory Synchronization

A Technical Paper prepared for SCTE by

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1. Introduction

Network operators understand that an increasing number of discrepancies between their network and inventory databases can lead to (1) greater service fallout rates, (2) impact to customer experience and (3) potential significant loss of revenue from dissatisfied customers. While networks are evolving toward more "addressable" (e.g., discoverable) devices, there is still a significant amount of resource elements in the network that are non-addressable (e.g., patch panels, fibers) thus requiring manual tracking in databases. Furthermore, most existing inventory systems either do not, or cannot, stay in lockstep with the "as-is" state of the network and continue to impose on network operators a significant amount of error-prone manual tasks. While network-to-inventory "manual audits" can provide a snap-shot update in time, each audit can cost network operators millions of dollars in consulting/staff costs and expenses they can no longer afford. And, with networks and services evolving quickly to keep up with customer demand this only increases the number of yearly audits needed to stay up to date with the network. As a result, network operators find it increasingly difficult to reconcile their physical network with their network inventory databases leading to (1) increasing number of discrepancies that is no longer manageable through traditional manual corrective means; and (2) generating an increasing amount of stranded assets that may no longer generate revenue to the network operator while still consuming space, power, and HVAC expenses.

In this paper, we will describe an architecture that uses augmented reality (AR) and artificial intelligence (AI) [1] as part of a planned network maintenance or upgrade to reconcile the physical network with planned inventory. We propose a new inventory architecture in which AR is used to capture images of network devices, seamlessly and unobtrusively, in the field during regular maintenance tasks, which are then analyzed using AI to update the inventory. It will also describe how technicians are assisted in verifying that a task was performed correctly. Visual examples will show, in tutorial style, how the technologies blend together.

2. Present Mode of Operations

The operations context in which we introduce the new inventory architecture begins with an operator planning changes to the physical network, as part of end-to-end service setup, and dispatches technicians to implement the change at a central office (CO). The technician will most likely have a workforce order (WFO) describing the changes; specifically, the order may require the technician to connect fiber "Z" to

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Port “2” of a patch panel to complete connectivity, as illustrated in

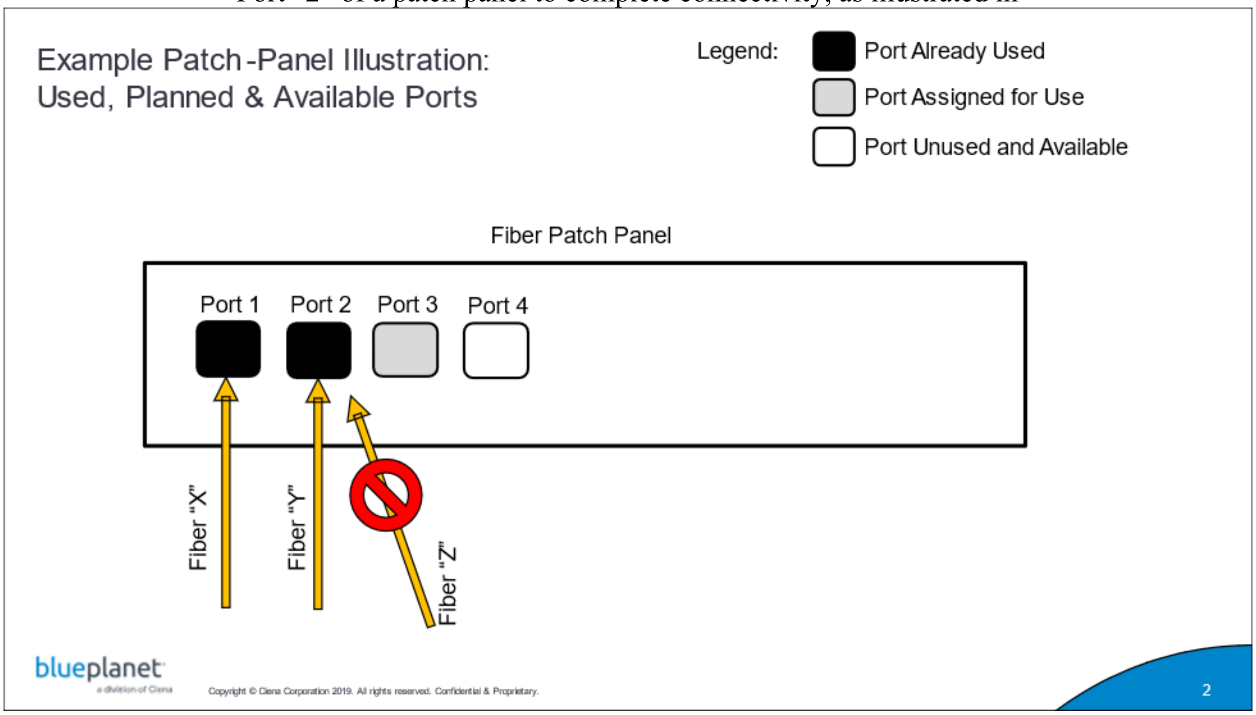

Figure 1. The problem begins that although the network operator planning team may have designed the end-to-end service based on inventory data showing port “2” available, the reality (“as-is” state) of the network shows that an existing fiber is already consuming this assigned port. Although this network discrepancy may have originated in different ways – e.g., terminated service but fiber not removed, previous workorder task assigned fiber “Y” to the wrong port, poor documented updates back into inventory… – the result is the dispatched technician will need to make a choice:

(1) Perform an ad-hoc change to the task, or
(2) Delay the task until the inventory and physical network match.

For most network operators, option (2) of first reconciling inventory with the network to then generate a new design and workorder for service introduces such delay and impact as to certainly jeopardize customer business, so option (1) becomes the de facto approach – Do what is necessary to deliver customer service now, update systems as best as possible later.

Present mode of operations (PMO) shows that network operators will define decision protocols for the technician to assist in option (1). For example, often the technician will not know if there is live traffic on the offending fiber (Fiber “Y”) consuming port “2” eliminating the possibility of disconnecting the fiber to release the port. As a result, a decision protocol may guide the technician that in case a port defined in the workorder is already consumed, select the next available port on the panel, say port "3" in

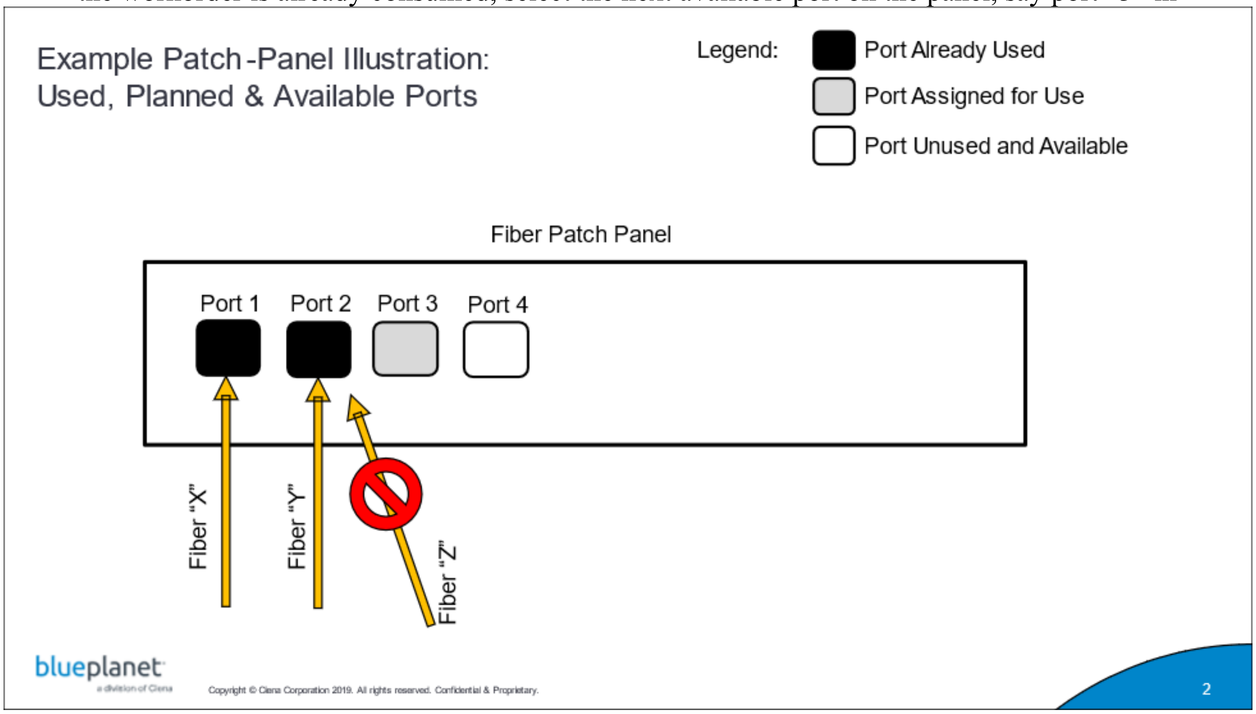

Figure 1, and document back to the planning team the newly selected port. What the technician will not know, and workforce order will not capture, is that port "3" may already be planned in inventory and assigned for another service to be connected in the field at a later time, making port "4" the next unused and viable port for service. This approach exacerbates the out-of-sync inventory problem and works against their efforts to plan network updates.

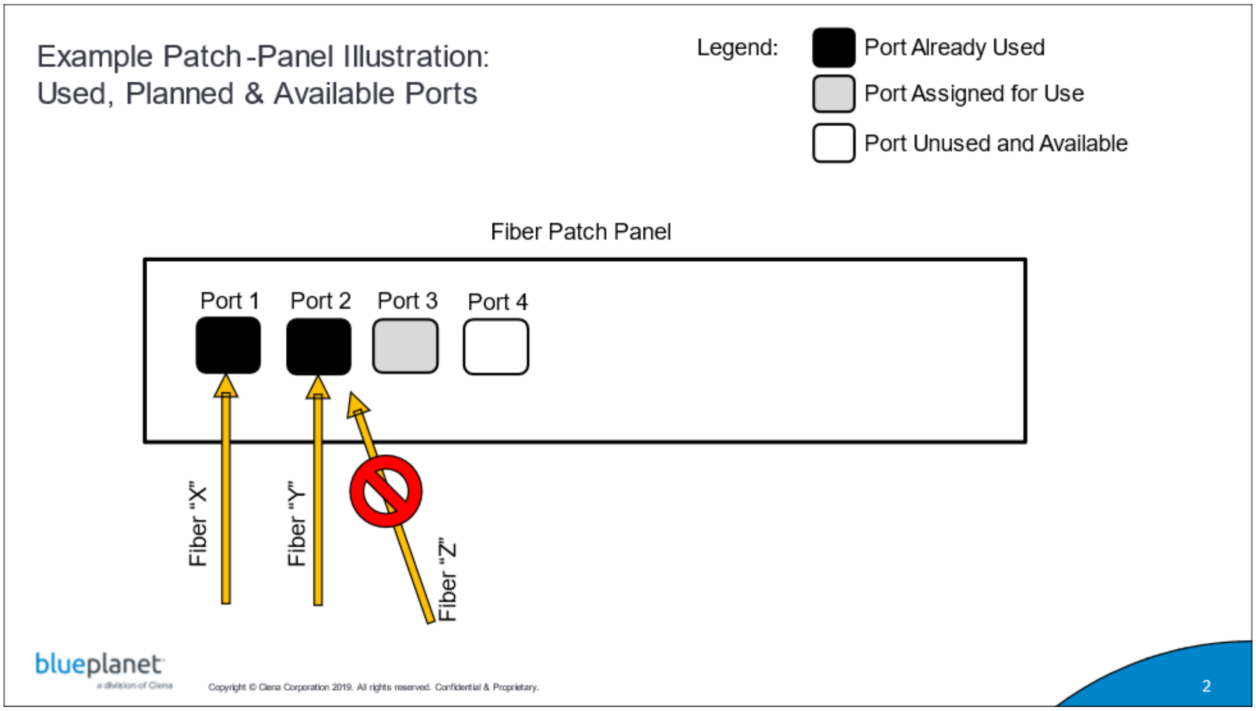

Figure 1: Patch Panel Illustration

Instead, what if we can use AR with physical visual devices such as phones, tablets, or "smart glasses" to superimpose real time digital records over the visuals of physical reality to guide operations and technicians to first time right service delivery [2]. And, if we can use AI with image processing and deep neural networks for object detection and image segmentation to convert physical reality into digital records ("as-is" network view) that can rapidly resolve discrepancies. Operators have a growing interest in using image capture, recognition, and AI [3] [4] to digitize inventory and track physical network assets while exposing any discrepancies in the network.

3. AR and AI for Inventory Synchronization

The first step in our proposed architecture approach is to enable the technician to quickly take stock of the "as-is" state of the resource elements and then compare with planned equipment for alignment before engaging any changes. Figure 2, provides an example network device as we would see in a CO, the device has several ports in use and cables dropping from the used connections. Here, some ports are used and cables that connect to the port overlap and sometimes cover available ports. The approach to capture and digitize the current port usage will need to determine which ports are used and which are available underneath the mesh of cables.

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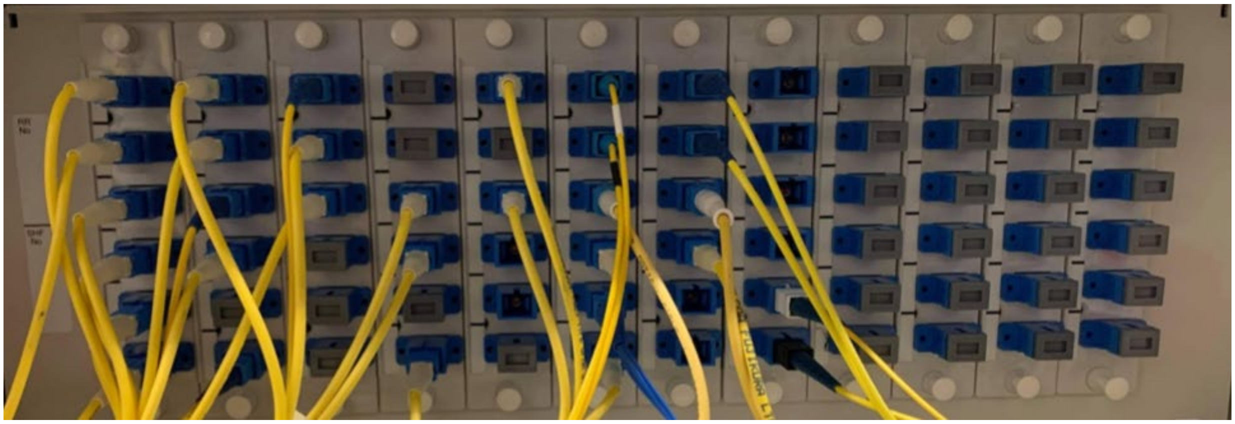

Figure 2: Example Network Device

For this we introduce the use of augmented reality (AR) combined with smart device enabling the technician to capture and digitize the target equipment as shown in Figure 3. The technician would aim the smart device camera toward the network device and ensure it fits within the boundary of digitization border of the application.

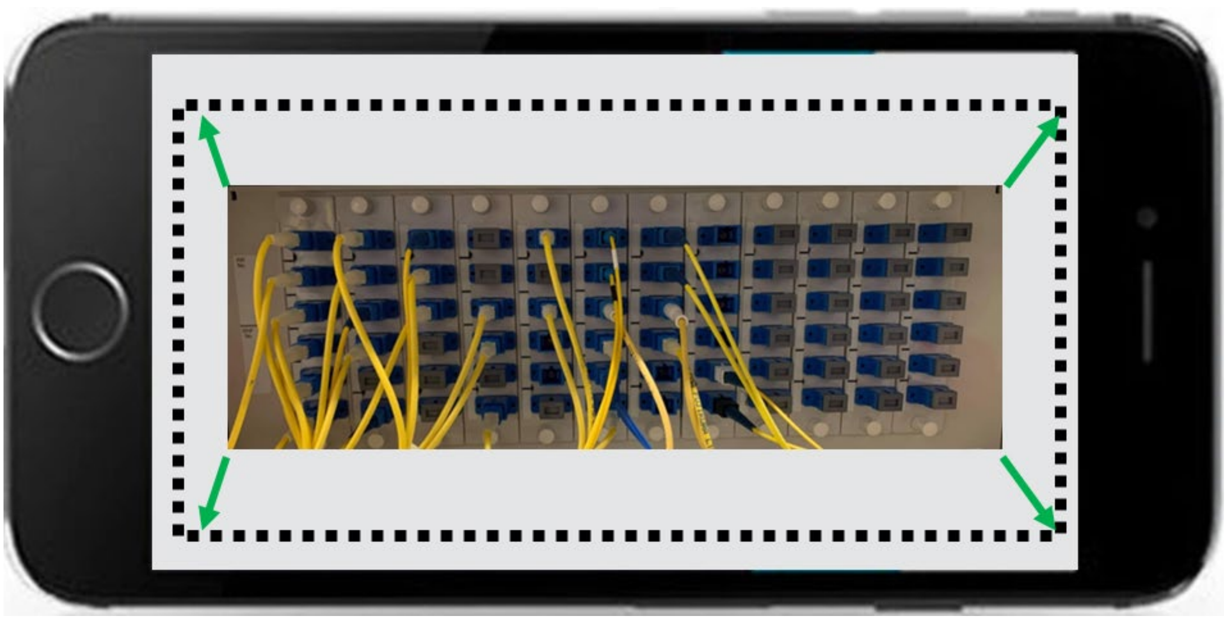

Figure 3: Device Capture with Augmented Reality

Because a single frontal picture would certainly not take a clear enough picture of ports through the cables, the augmented reality application would guide the technician to pivot the smart device in direction of the arrows shown on screen so the smart device can collect a series of picture or video from different angles creating a rich multi-perspective recording of the device before automatically closing the camera

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indicating the capture process is complete. This image capture process would take less than a minute of the overall technician's time and have negligeable impact on his task schedule. The image capture has a dual purpose:

A) Digitize the "as-is" state of the device to be compared with the planned view of the device in inventory database and identify any potential discrepancies.
B) Become the reference image to guide the technician on the device tasks ahead.

Before we can identify any potential discrepancies, the digitized device must first be identified so the system knows what to compare with and what device to present back to the technician as operational guidance in next step tasks. For this, when the smart device captures the device image, it can also capture the device bar code, and/or the unique ID (combination of location, floor, shelf, etc.) many network operators stamp on devices today, and/or the physical characteristics of the device itself. The latter part means comparing the physical layout of the digitized device with digital reference pictures/models from device vendors themselves. When combining the above vectors of identifications with GIS (Geographic Information System) location the AI function can present back to the technician through their smart device an accurate determination of the network device discovered. In absence of enough identification vectors the smart device will ask the technician to enter a known ID code for the device to finalize selection.

The next step is for the image technology tied to digital image capture to determine what ports are used or available for use. This is done by extracting the features of the ports (used and available) and comparing them to models of available ports and computing their likely association to either available or used, as illustrated in Figure 4. This is where the importance of having created a stream of images or video by pivoting the smart device camera around the network device is key. As the image processing computes the likelihood across different image perspectives some ports will show consistently 100% available (green) or 100% used (red), while many of the ports that were "hidden" by cabling may be computed to higher accuracy as each perspective reinforces either "used" or "available". For ports that are not resolved as either 100% used or available, the smart device can allow the technician to "pinch-zoom" on the area of the device image they will work on and enable the technician to confirm by touch (yes/no) if the port is consumed or not. It is important to note that as technicians continue to take image captures over time as they work on the device the movement of cables, changes in connection and exposure to different angles will create an increasing accurate perspective of the as-is state of the device and phase out any potential differences across image captures.

Figure 4: Digital Image Map

At this point the resulting discovered digital image map is ready for comparison with inventory database to create a discrepancy map that will guide the network operator to correct and reconcile inventory to the network. The discrepancy map would list all the objects in database that do not match with the digital image map with associated probability based on the accuracy of the digital map. The network operator can take the discrepancy of highest to lowest probability and initiate reconciliation processes to correct discrepancies in future in-field work, or directly guide the technician on location to make the correction if in the

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technician's remit. An example can be a cable is occupying a port that the inventory systems know the service was terminated and cable should have been removed but not completed by the last technician. By continually feeding image captures of network devices as changes are implemented the imaging technology and underlying AI engine creates a more accurate view of discrepancies and their associated probabilities. This enables the network operator to focus on correcting the discrepancies of greatest value to the business, all while the technicians continue their daily work orders with the addition of image capture.

While the AI system computes and updates the digital image map and probabilities of discrepancies continuously, the technician is guided in his workorder operations through the smart device without delay. Let's take the original example in

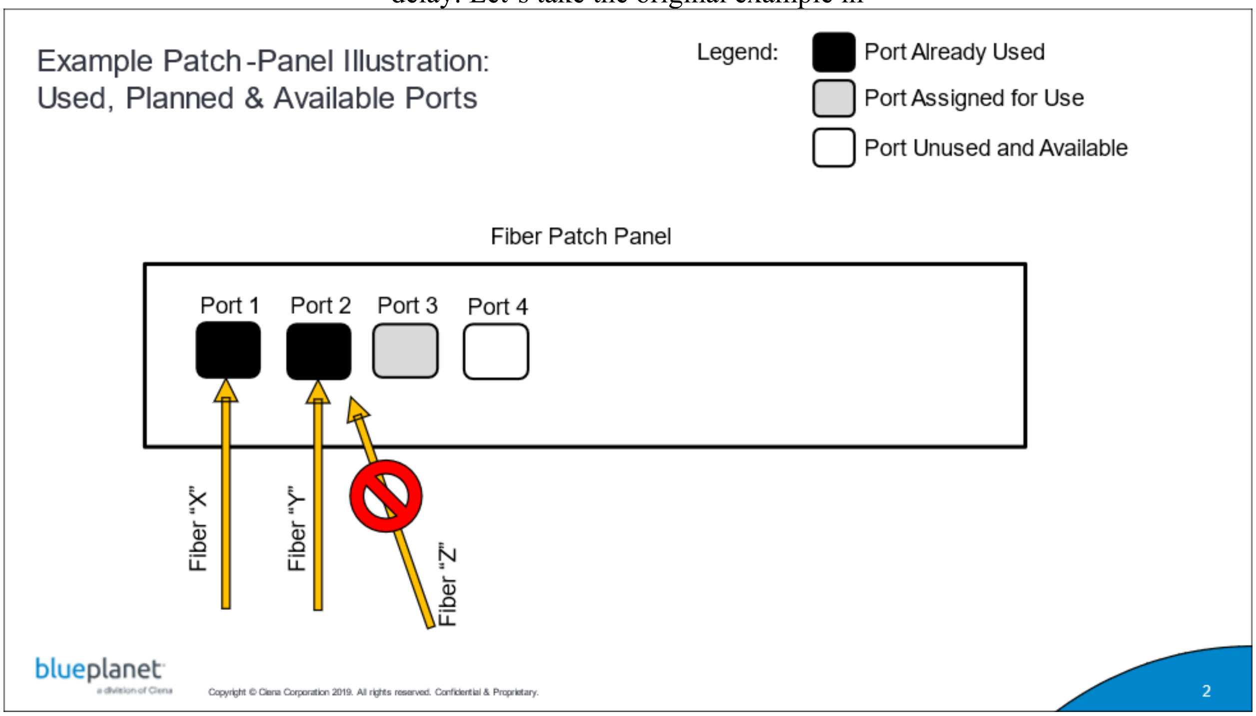

Figure 1: The technician has a workorder to connect a fiber cable to complete an end-to-end service. The workorder indicates that fiber "Z" should go to port "2" but the port is already used. Although the technician may have a protocol in place indicating he should use the next "available" port, the selection of the port will benefit from a guided operations approach from the combined AR/AI system. Because port "3" is already assigned for future service in the inventory database, the smart device will guide the technician to connect the fiber to port "4" as illustrated in Figure 5.

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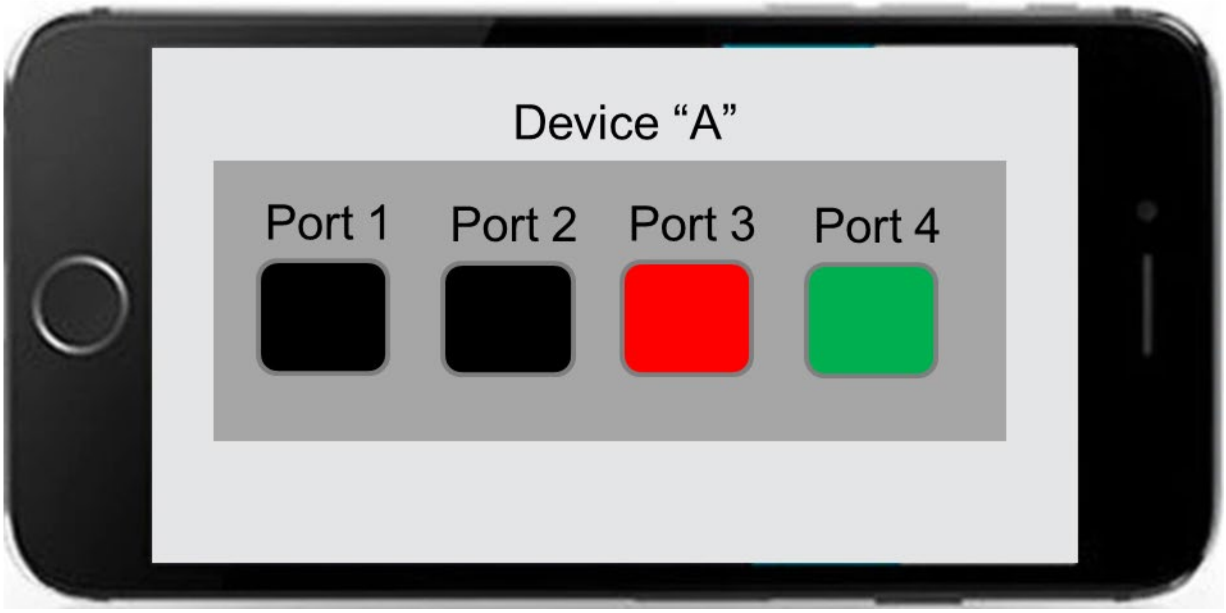

Figure 5: Guided Operations - Connections

Once the fiber connection is completed, the technician will capture another image of the device in its current "as-is" state which will update the inventory database with the new connection and can include communication to the planning team that an update to the original plan was required to complete the task.

The proposed architecture that captures the above AR and AI technology and guided operations can be illustrated as in Figure 6. At the heart of the architecture is the federation of data that that brings together under a common normalized information model, the following:

- Network operator defined device template used to model and identify the equipment to be analyzed for discrepancies.
- The Inventory "as-planned" view of the device to compare with the digital image map for discrepancies.
- The digital image map of the network device, generated by the imaging technology, from the captured smart device video/pictures.
- The federated data can also include vendor defined device templates that may be more accurate/complete than inventory models and when combined with GIS data enables very accurate determination of network devices across a wide range of resources in inventory.

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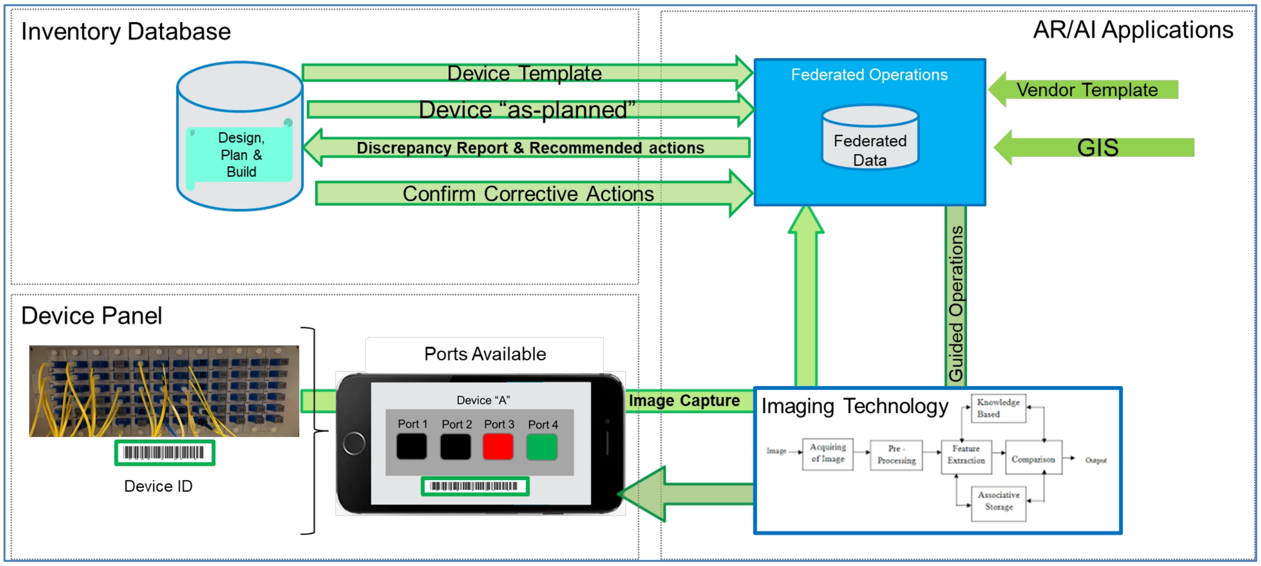

Figure 6: Proposed AR/AI based Architecture

Discrepancy detection rules are applied across the federated data to generate discrepancy reports where each discrepancy is mapped from highest to lowest level of accuracy and associated recommended action for remediation. Here the network operator can choose to either tabulate a series of reports into a dedicated workorder where a technician can be dispatched at a prescribed time and location to correct these discrepancies, or, the architecture allows the guided operations (as shown in Figure 6) where the corrective action is communicated back to the technician through the smart device and corrected in flight. Both approaches enable the network operator to achieve increased inventory and network synchronization (INS) toward eliminating device discrepancies that can impact their customer, their business, and their competitiveness in the market.

4. Future Mode of Operations

The AR/AI architecture presented in this paper is a proposed future mode of operations (FMO) to enable network operators in stopping and reversing the proliferation of network discrepancies that impact their business today. In this future mode of operations, the technicians in the field use readily available image capture tools like smart phones and/or tablets combined with existing AR software to provide a constant feed (crowd sourcing) of "as-is" state of devices as a constant stream of data complementing any traditional discovery process to keep the inventory database in lockstep with the network. The imaging technology and associated AI that creates the digital device map, and federated data infrastructure, can be cloud-based making the approach scalable to different business needs. Communications across image capture tools, imaging technology, federated data and Inventory databases can be achieved through open APIs for greater ease of integration. The result of this proposed architecture is to finally close, in as real-time as possible, the inventory and network synchronization loop that has eluded the industry for so long.

It is important to note that while the example used in this paper describes an approach to resolving discrepancies related to fiber connection, this same architecture can be used in wider context, for example:

- Equipment upgrade: Upgrading card, shelf, or device where the image technology is used to map the existing device to be upgraded against the new device characteristics to guide and confirm toward a successful upgrade.

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- Initial equipment discovery: The digital image captured by the technician and resulting digital device map generated through AI can be quickly mapped to vendor templates that trigger the creation of accurate device object entries in inventory without lengthy or costly audit processes in the field.

Although the proposed architecture provides a promising approach to inventory and network synchronization, this future mode of operations would also need to fit within the following operational considerations:

- Recording devices: Not all network operators allow recording devices to capture network information. The off the shelf devices and software proposed with this architecture would need to be authorized on premises.
- Workforce: A technician's contracted responsibilities may not allow for the additional task of capturing images/video as part of workorder flow.
- Secure data/connection: The processing of images/video in the cloud would mean secure connection and possibly encryption between network operator and federated data.
- Inventory database access: Many existing and legacy inventory systems in network operators may not allow direct access to inventory data and could require multiple data exports that would be ingested into a federated environment.

5. Conclusion

This paper has proposed an AR and AI architecture approach to inventory synchronization. The approach shows that with off the shelf smart devices and the use of AR a technician can capture a rich set of multi-angle images/video data in very short time and effort that can be used by AI to quickly identify the device and generate an accurate digital image map for discrepancy detection between network and inventory. We also described how conversely AI and data federation can provide the technician, through AR, a guided operations approach to completing a workorder task without compounding network discrepancies and even correcting in real-time previously reported discrepancies. The proposed architecture can be either on-prem or cloud-based depending on the business needs of the network operator. The architecture approach applies to the connectivity example presented in this paper but also in wider context of device/equipment upgrade and maintenance. And the approach can be used as an initial network discovery and inventory setup method for network operators wanting to populate their new inventory system with a current view of network devices in the field.

Abbreviations

AR	augmented reality
AI	artificial intelligence
PMO	present mode of operations
CO	central office
WFO	workforce order
INS	inventory network synchronization
FMO	future mode of operations

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