WHITE PAPER

How to Achieve Greater Rail Availability through Smoother Configuration

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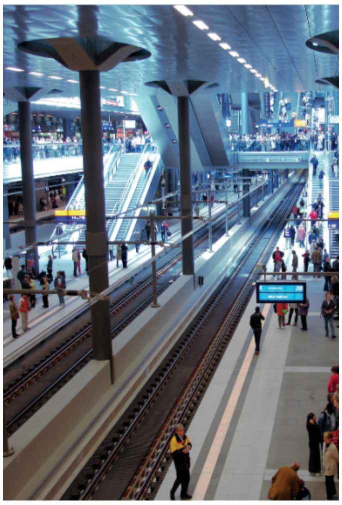
Abstract

When deploying Ethernet technologies, manual configuration is too time-consuming and automatic configuration is too random for rail networks. As a result, making automatic configuration more deterministic by improving on the capabilities of DHCP offers railway operators an ideal solution for physical topology learning. In physical topology learning, the server is always aware of the topological location of the network devices on the network, and so network devices will always be assigned the same IP address as long as they are connected to the same location.

Overview



Now that IP Ethernet technology has transformed networking for many different rail applications, it's time for railway system builders and operators to explore how to maximize the benefits of working with this at-times unfamiliar technology and minimize the costs. Ethernet technology certainly has the potential to deliver dramatic benefits by making railway systems more safe, efficient, and flexible. Ethernet networks are easy to expand, cost-effective to operate, and support sufficient bandwidth.

But the novelty of Ethernet in railway systems and unfamiliarity with this technology can make it difficult to fully realize these benefits. In order for any system to work well in a rail context, it must achieve very high availability. Put simply, the trains must run on time, which means that none of the train systems that run on the Ethernet network can experience substantial downtime.

A Spotlight on Availability

Rail systems follow standard reliability engineering principles by using the RAMS metric: Reliability, Availability, Maintainability, and Safety. Of these four metrics, Availability, also known as the mission capable rate, can be considered a cornerstone. Trains achieve safety in part by ensuring the constant availability of their safety and control systems, and highly available systems make it possible for the trains to deliver more consistent service.

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Availability can be expressed with the following formula:

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Availability = Estimated Uptime / (Estimated Uptime + Estimated Downtime)
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Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) are quantitative estimates of uptime and downtime, respectively, so another way to express the above equation is:

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Availability = MTBF / (MTBF + MTTR)
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Looking at this formula, we can immediately see that availability can in some sense be described as a function of both reliability (MTBF) and maintainability (MTTR). Clearly, availability can be improved by increasing MTBF. This is something that is already well-understood by most rail operators, and immediately makes sense: by using more reliable products, the system will improve its availability. However the second value is sometimes overlooked: MTTR. It is worth pointing out that availability also improves when we decrease MTTR.

In other words, for a system to be truly optimized for high availability, it must be very reliable (high MTBF) and also very easy to maintain (low MTTR). Ultimately, even if a system has an extraordinarily high MTBF value, it cannot be said to have truly optimized availability if it takes an unacceptably long time to recover when service interruptions do occur.

What the Availability Formula Means for Rail

In creating communications networks, rail integrators and operators already understand the important role of availability, and work to achieve high reliability/MTBF in order to support that ultimate goal. However, the second half of that equation, maintainability/MTTR, represents an untapped potential strategy to further optimize system availability. This is especially true in the rail market because rail operators and their front-line maintenance staff are not yet very familiar with operating Ethernet networks. Network maintenance tasks that might only be mild inconveniences in a conventional enterprise setting can become major operational roadblocks in a rail setting. Thus, by making everyday maintenance procedures more streamlined, efficient, and error-free, rail system integrators can dramatically improve the overall availability of the rail operations.

One Common Maintenance Task: IP Configuration

In an Ethernet network, every Ethernet device has an IP address that is used to identify it to the rest of the network. Every time a device is attached to the network, it needs to set an IP address. This is also true when an existing network device is swapped for a replacement device, as frequently occurs in train maintenance depots: the replacement device will need an IP address. Traditionally, Ethernet devices will be assigned an IP address either manually by an administrator, or automatically by a central server. Both of these approaches present maintenance issues in rail systems, and thus adversely affect availability. Let’s examine each in turn.

Automatic IP Assignment: Ethernet networks can use Dynamic Host Configuration Protocol (DHCP) to automatically assign an IP address to network devices. The newly connected device is a DHCP client and will send a broadcast query on boot up. Upon receiving this query, the DHCP server will assign an available IP address to the device. This procedure eliminates any need for manual IP configuration.

However, DHCP also has its limitations. The DHCP server is comparatively indiscriminate in assigning IP addresses, because DHCP only provides limited mechanisms for deciding which IP address to assign. Generally speaking, a DHCP server will simply give the newly connected device the next available IP address. This is acceptable in enterprise networks, as devices on such networks are generally capable of identifying themselves on higher layers of the network. For example, Bill's laptop can always identify itself to the network as "BillsLaptop" on the application layer regardless of what its current IP address on that network is. Applications running on this network will know to look for "BillsLaptop," and not a specific IP address, when they need to send a communication to that machine.

However, this is not the case for rail applications and devices. In rail networks and applications, IP addresses are used as the unique identifier. This means that when devices are replaced, rebooted, or swapped, the IP address attached to the same location must remain the same, or else the application will have no idea how to communicate. DHCP is unable to achieve this consistency. If you boot up the same device on a DHCP network in different locations, you may receive different IP addresses.

Manual IP Assignment: Because it is comparatively indiscriminate, DHCP is rarely used for networks that need to be more specific about which IP addresses are assigned to which devices. The alternative is to forgo the convenience of automatic IP assignment for more laborious, but more precise, manual IP assignment. Typically, administrators can manually assign an IP address to a network device by connecting to that device through a serial, Telnet, or web console.

Such a procedure may be feasible when there is a limited number of devices, or when the devices only need to be configured once. Neither is the case in rail networks. In rail networks, there could be tens of network devices just in a single train car, multiplied by the number of cars in a consist, amounting to hundreds of network devices in one system. Each of these devices would need to be assigned a specific IP address every time the system reboots, and also every time a device is replaced. Maintenance time for such a process would be nearly unworkable, especially when one considers that in rail operations, maintenance engineers are rarely also IP networking experts. In addition to the sheer workload, the potential for manual error further erodes MTTR when using manual IP configuration.

Manual IP assignment can be made somewhat easier through a configuration dongle that stores configuration information, typically on a USB device. When the device boots up, it will be assigned an IP address through the dongle. The administrator only needs to attach the right dongle to the device. This is an improvement on completely manual configuration, but has its own limitations. Each dongle can only store one configuration, so a unique dongle is needed for each network device. Again, the number of devices involved, and the frequency with which they need to be assigned IP addresses, makes this approach one that adversely affects availability. This is just considering the case of replacement, not even swapping.

Automatic IP Assignment that Works for Rail: Physical Topology Learning

So, if manual configuration is too time-consuming and automatic configuration is too random for rail networks, how can rail operators improve their availability? The solution is to make automatic configuration more deterministic by improving on the capabilities of DHCP. For rail, the ideal solution is physical topology learning. In physical topology learning, the server is always aware of the topological location of the network devices on the network, and so network devices will always be assigned the same IP as long as they are connected to the same location. For example, the IP camera connected to the second port on the second switch on the network will always be assigned the same IP address by the server. That IP address can then be used as the unique identifier for "Camera 2, Car 2" on the system.

By adding physical topology learning, rail operators can achieve the convenience of automatic IP configuration, with the precision and determinism of manual IP configuration, thus improving the availability of their overall system. All the network devices will keep the same IP address because they will always be connected to the same topological location on the network. Similarly, any replacement devices will always be assigned the same IP address of the device they are replacing, because they too will be connected to the same location on the network.

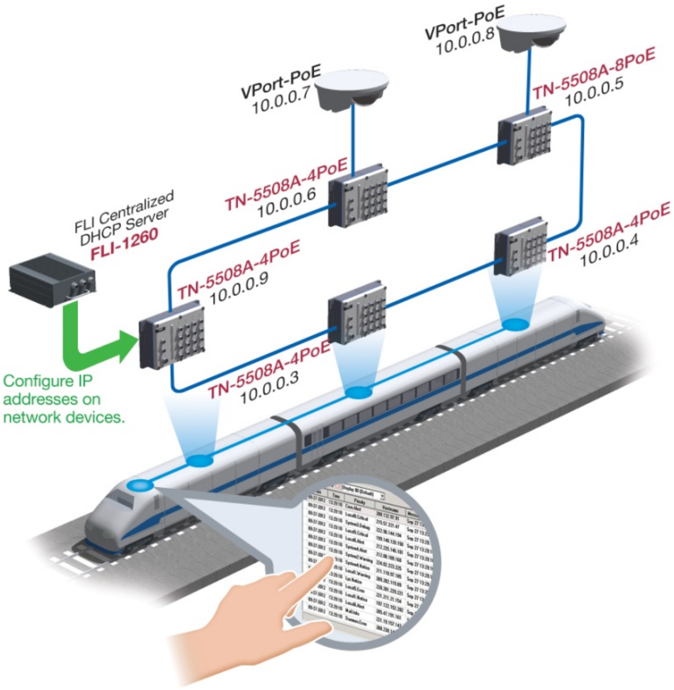
DHCP already possesses limited information about the physical attachment of DHCP clients, through a function known as DHCP option 82. However, option 82 is of limited utility for rail, because it is only able to identify the physical location of network devices, and is unable to physically locate switches. In car swapping, this is even worse. In this case, the option 82 ID attached to the switches could actually lead to massive mis-configuration. Again, in enterprise systems most end devices will be able to identify themselves on the application layer, such as "BillsLaptop." By failing to physically locate these devices, option 82 is an incomplete solution for rail networks.

Flexible, Location-Based, Intelligent (FLI) Technology

Moxa's FLI is a convenient auto-configuration technology that automates common configuration tasks while remaining highly deterministic. A FLI server extends the reach of option 82 so that even end devices will be able to identify their physical topological location to the server. This allows the server to consistently deliver the same IP address to the IP devices deployed in the same location. Camera 2 in car 2 will always be assigned exactly the same IP address, even after it's been rebooted or replaced.

What's more, a FLI configuration is able to send network devices their device configurations the same way, not just IP address. For example, camera 2 in car 2 will also always be assigned the same camera privacy mask settings.

FLI technology gives rail operators the convenience of an automatic configuration system, without compromising on consistency or determinism. This reduces maintenance time substantially by reducing maintenance workload and minimizing maintenance errors. Furthermore, with FLI, the entire network configuration is centralized in a central location. This makes it much easier to reconfigure the entire network, as the entire network can be reconfigured from a single location instead of individually reconfiguring each individual device.



Maximizing the Value of Ethernet Technology in Rail by Accurately Automating Configuration

Automating the time-consuming network setting and device configuration for network devices delivers dramatic dividends for rail networks. Plug-and-play Ethernet devices are a paradigm shift for rolling stock operations that reduces MTTR and increases overall availability, with benefits that can be seen throughout all phases of railway system deployment.

Installation: Faster IP assignment makes it easier to mass-deploy many network devices in a new train system. It is a highly scalable solution, so whether the network needs ten or a hundred devices, the manufacturer only needs to configure a single device: the auto-configuration server.

Commissioning: Mass configuration changes means that during sub-systems testing and verification, changes and tweaks to the system can be made without significant downtime. The network does not need to be reset, device by device, for every new iteration of testing. Faster testing ultimately translates into a much accelerated and less costly commissioning stage.

Maintenance: During live operations, front line maintenance personnel can simply swap out a faulty device. Now, a sophisticated understanding of Ethernet networking is not required to perform these common maintenance tasks. This prevents a single point of failure from causing significant network downtime, and optimizes the system availability.

Moxa's exclusive Auto-Configuration technology is included on selected Moxa TN series switches and will be expanded to cover other devices in Moxa's product portfolio, including Ethernet switches, IP cameras, embedded systems, 802.11 access points, serial device servers, and I/O devices. Find out more about how to maximize the value of Ethernet technology in rolling stock by visiting www.moxa.com/rail.