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CONTROLLED ONBOARDING OF DEVICES IN A HIERARCHICAL TOPOLOGY THROUGH DETERMINISTIC IP ASSIGNMENT

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ABSTRACT

Techniques are presented herein that support the controlled onboarding of switches that are arranged in a daisy chain or hierarchical topology. Aspects of the presented techniques support a deterministic Dynamic Host Configuration Protocol (DHCP)-based Internet Protocol (IP) address assignment based on the location of a client or device, thus making possible, and allowing the necessary control for, a hop-by-hop DHCP assignment paradigm. Further aspects of the presented techniques leverage elements of a zero-touch provisioning (ZTP) process in support of the onboarding of devices in a hierarchical topology.

DETAILED DESCRIPTION

In the case of a device or client that employs a local Dynamic Host Configuration Protocol (DHCP) server, the location of the local area network (LAN) of the DHCP client, and whether the client is directly connected or is multiple hops away, is never used during the assignment of an Internet Protocol (IP) address lease. This makes it impossible to achieve the controlled onboarding of switches that are arranged in a daisy chain or hierarchical topology.

Such an impediment may impact a number of different scenarios where a deterministic IP address assignment and a day-0 configuration are required, including a controlled day-0 onboarding operation using an external zero-touch provisioning (ZTP) server, a recovery following a power failure, or after a random software upgrade or power-on operation.

For example, in a hierarchical topology (such as a local area network (LAN) automation network comprising a seed device (such as one or more core switches) and some number of riser switches (such as fixed-configuration, Gigabit Ethernet switches that provide enterprise-class Layer 2 access)), it is not possible to deterministically control the day-0 or ZTP onboarding of the riser switches. Such an inability flows from the reality that the riser switches may boot in a random order and, after booting, may begin broadcasting DHCP discover (DHCPDISCOVER) messages. Under such an arrangement, it is possible that the seed device (that is acting as a DHCP server) could process the DHCP discover packets of one or more riser switches which are multiple hops away. This breaks the deterministic DHCP IP address assignment process and, consequently, the onboarding process.

To address the above-described limitation, techniques are presented herein that support the controlled onboarding of switches that are arranged in a daisy chain or hierarchical topology.

Figure 1, below, presents elements of an exemplary workflow (depicting aspects of a DHCP assignment and onboarding process) that is possible according to the techniques presented herein and which is reflective of the above discussion.

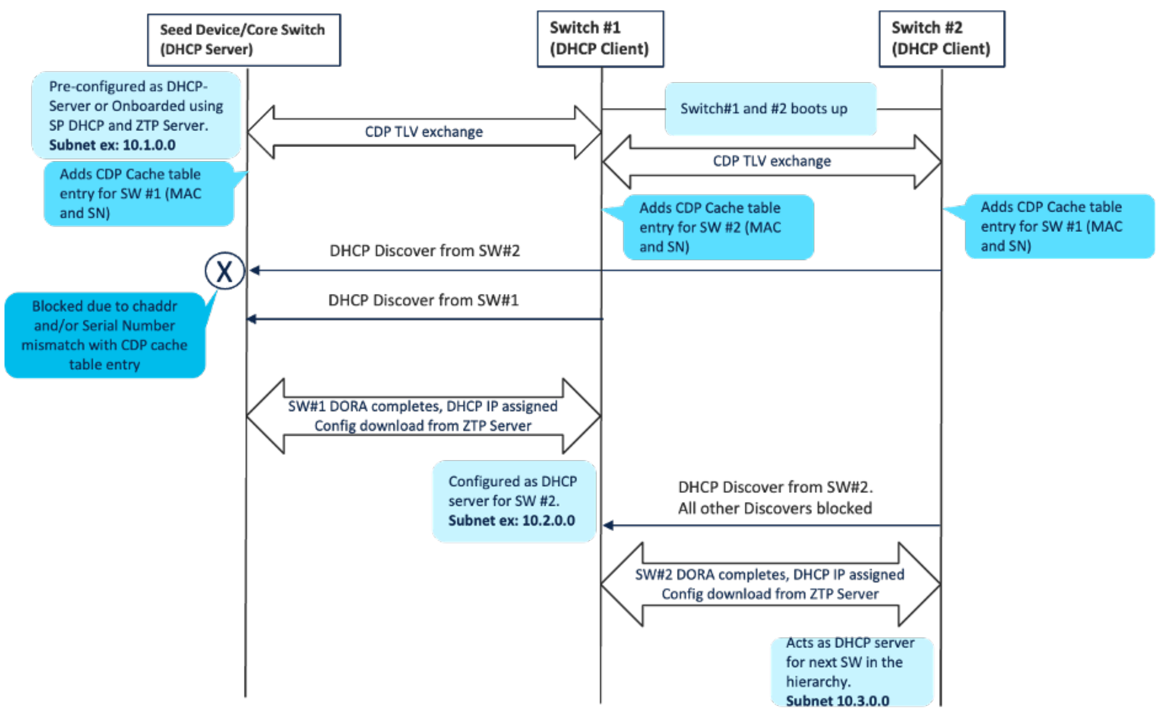

Figure 1: Exemplary Workflow

As depicted in Figure 1, above, the presented techniques employ either a custom data link layer protocol (CDP) or the Link Layer Discovery Protocol (LLDP) data link layer protocol to identify whether a device that is requesting a DHCP-assigned IP address is or isn’t a next-hop neighbor. Information about the neighbor (such as its media access control (MAC) address and serial number) may then be used to selectively restrict a DHCP assignment.

According to the presented techniques, a DHCP server may employ a unique identifier from a DHCP packet (such as, for example, a client hardware address (chaddr) field, a serial number, or a MAC address sent in option-61 (optionally, a 'Vendor-Identifying Vendor Class option' option code 124 can be used to send the MAC address)) and compare that value against an identifier (e.g., a MAC address, a serial number, or both values) that is stored in a CDP or LLDP cache table. In the event of a match, the DHCP Discover, Offer, Request, Acknowledgement (DORA) process may be allowed and the device may receive a DHCP-assigned IP address lease following the successful completion of the DORA process. If there is no match, then the client is located one or more hops away and the DHCP discover (request) message may be ignored.

Figure 2, below, presents elements of one use case (encompassing the controlled onboarding of devices in a hierarchical network) that is possible under the presented techniques.

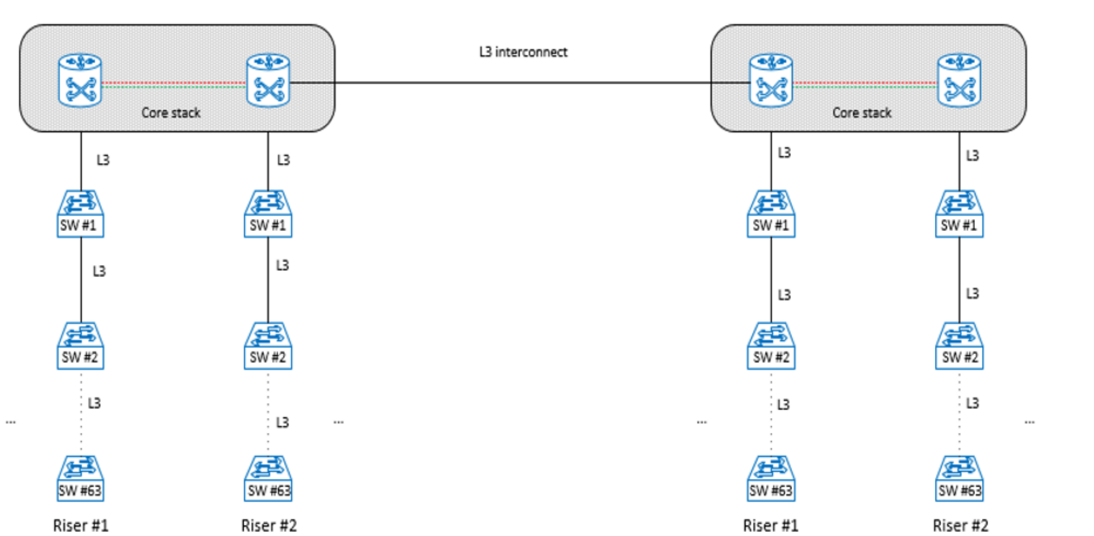

Figure 2: Typical LAN Automation Network

When considering the different steps that the presented techniques may complete during the onboarding of a core switch and any associated riser switches, the exemplary arrangement that is presented in Figure 2, above, can serve as a helpful guide.

During a first step, the core switch stacks may be configured as DHCP servers and they may be either onboarded as part of a ZTP day-0 mechanism or preconfigured. Each core stack may be connected to some number of risers, which are in essence multiple chains of switches as shown in Figure 2, above.

Next, during the installation process each of the riser switches may boot, either randomly or at the same time, with no initial configuration (i.e., each switch possesses no startup configuration information). Initially, the above-described process results in a large Layer 2 topology with each switch being part of a VLAN1.

Then, each of the riser switches may begin broadcasting a DHCP discover message on VLAN1. The core switch (as a DHCP server) may determine the origin of a DHCP discover message by validating it against CDP or LLDP table entries to identify the directly-connected devices and restrict an IP address assignment to only those devices.

Later, after receiving an IP address from a DHCP server, each riser switch may request start-up configuration information from a ZTP server, which may provide a configuration file based on the IP address that is allocated to it. The received configuration information may also start a DHCP server on the riser switch, which may then provide an IP address assignment for the next (i.e., lower) switch in the hierarchical chain.

The above-described process may continue until each riser switch has received an IP address and its configuration information. In such a way, a deterministic IP address assignment and ZTP-based configuration deployment may be consistently achieved.

The techniques presented herein may be further understood through an illustrative example that expands on the use case that was described and illustrated above. That example encompasses two core switches (that reside in a group), six riser switches (that reside in two separate chains of switches), and a ZTP server. Figure 3, below, depicts such an arrangement.

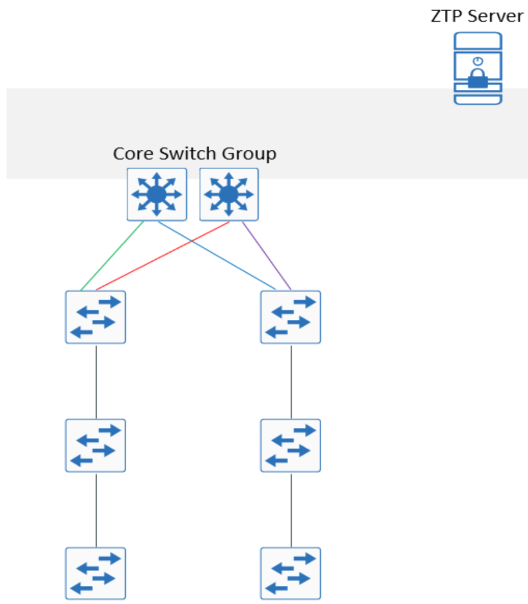

Figure 3: Illustrative Arrangement

Figure 4, below, illustrates elements of a first step during which the members of the core switch group complete a boot process using appropriate configuration information that is supplied through either the ZTP server or a Universal Serial Bus (USB)-based memory stick.

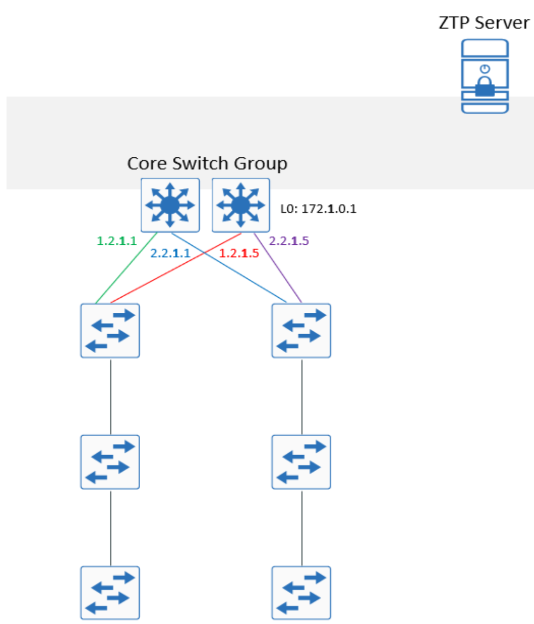

Figure 4: First Step

Figure 5, below, illustrates elements of a second step during which the first riser switch in each riser switch chain receives an IP address from the DHCP server that is configured locally on the core switch group.

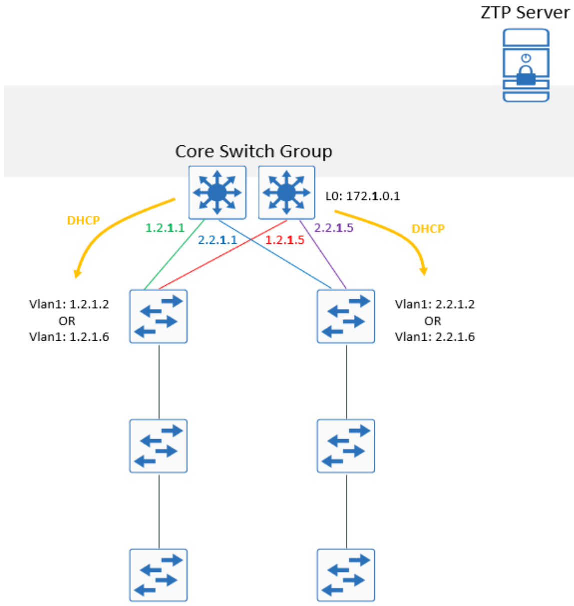

Figure 5: Second Step

Figure 6, below, illustrates elements of a third step during which the first riser switch in each chain receives configuration information from the ZTP server.

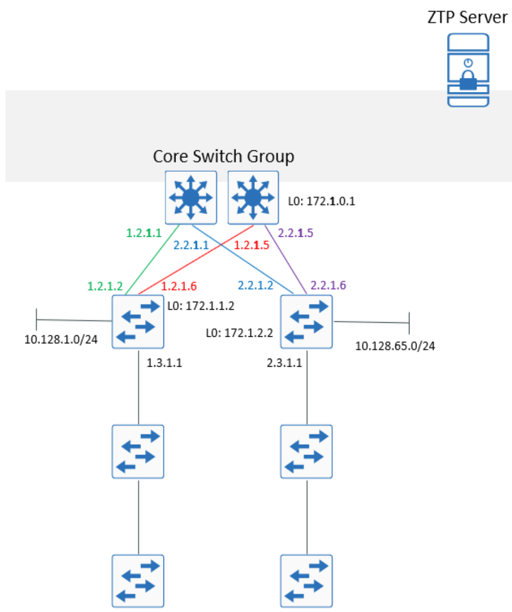

Figure 6: Third Step

Figure 7, below, illustrates elements of a fourth step during which the second riser switch in each chain receives an IP address from the DHCP server that is configured locally on the previous switch (i.e., on the first riser switch in each chain).

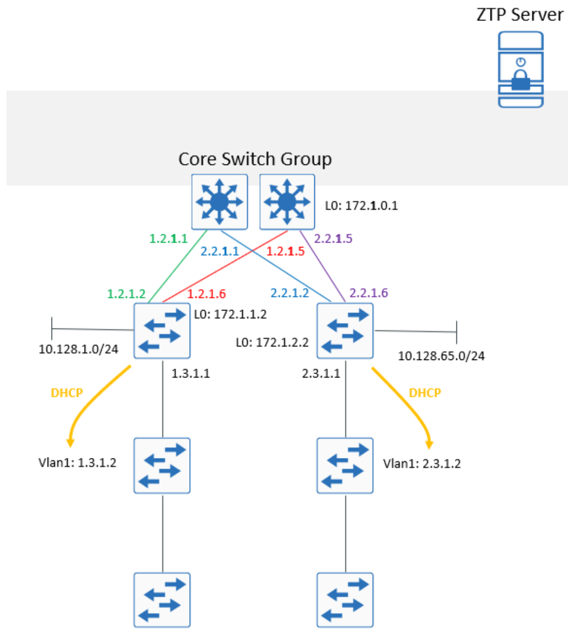

Figure 7: Fourth Step

Figure 8, below, illustrates elements of a fifth step during which the second riser switch in each chain receives configuration information from the ZTP server.

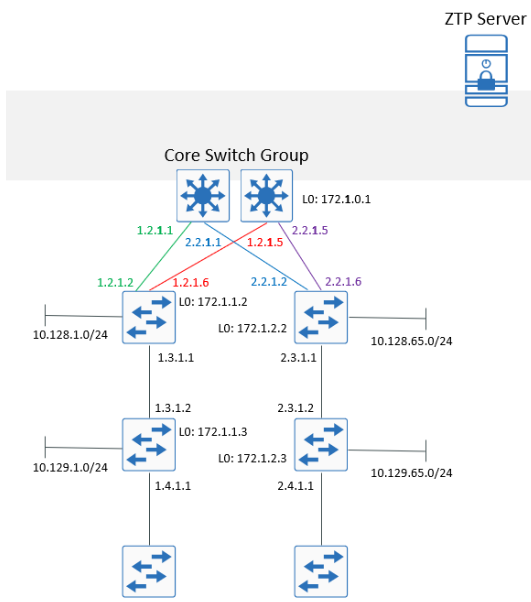

Figure 8: Fifth Step

Figure 9, below, illustrates elements of a sixth step during which the third riser switch in each chain receives an IP address from the DHCP server that is configured locally on the previous switch (i.e., on the second riser switch in each chain).

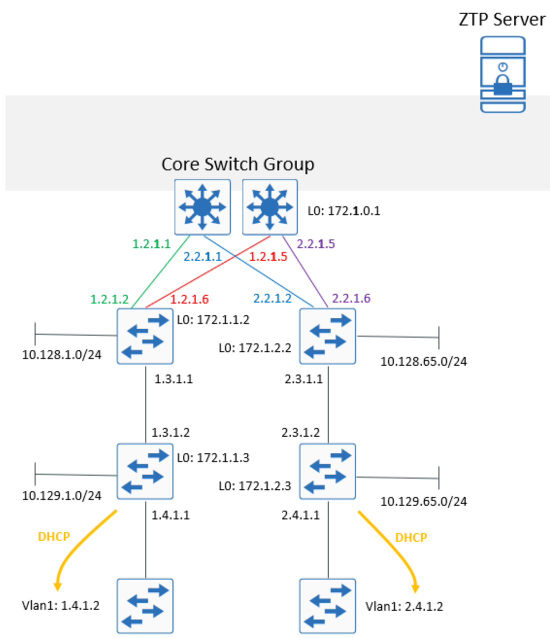

Figure 9: Sixth Step

Figure 10, below, illustrates elements of a seventh, and final, step during which the third riser switch in each chain receives configuration information from the ZTP Server.

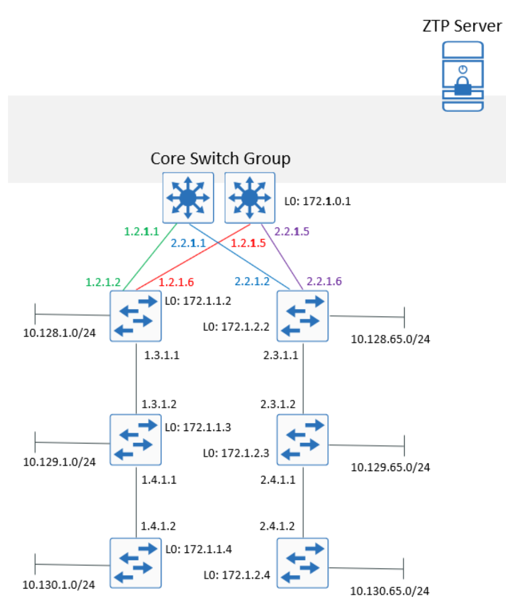

Figure 10: Seventh Step

Through the above-described steps, a deterministic IP address assignment and ZTP-based configuration deployment may be consistently achieved.

In summary, techniques have been presented herein that support the controlled onboarding of switches that are arranged in a daisy chain or hierarchical topology, thus addressing one of the critical issues that customers encounter when using a ZTP process in multi-tier networks. Aspects of the presented techniques support a deterministic DHCP-based IP address assignment based on the location of a client or device, thus making possible, and allowing the necessary control for, a hop-by-hop DHCP assignment paradigm. Further aspects of the presented techniques leverage elements of a ZTP process in support of the onboarding of devices in a hierarchical topology.