Optimizing Subnet Interconnections with Industrial Layer 3 Switches

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It is well known that the open standard multi-layer TCP/IP networking structure governs network traffic on the Internet and millions of LANs and subnets around the world. TCP/IP is often described in terms of the following five layers:

	Layer Name	Protocols
Layer 5	Application	HTTP
Layer 4	Transport	TCP, UDP
Layer 3	Routing	IP
Layer 2	Switching	Ethernet
Layer 1	Interface	RJ45, CAT5

The topic of this paper is what is referred to in the market as a "layer 3 switch," which as we can see from the above table resides in the routing layer. Over the past decade or so, products that direct networking traffic have evolved into a fairly stable hierarchy. Generally speaking, layer 2 switches (which for obvious reasons reside in the switching layer) connect network hosts together to form a subnet, layer 3 switches connect two or more subnets to form a LAN, and routers connect LANs to each other or connect LANs to the Internet.

What is a Layer 2 Switch?

Layer 2 switches evolved from the Ethernet hubs used with the original coaxial-type Ethernet LANs. Since the original Ethernet was set up as one big collision domain using CSMA/CD to direct

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traffic, there was a need to break the Ethernet LANs into smaller, more manageable collision domains. In essence, a layer 2 switch combines several NICs (network interface cards) into one device to allow network administrators to divide the LAN up into collision domains.

Layer 2 switches use the MAC address of network hosts to distinguish one host from another. Since MAC addresses are hardwired into the NIC, layer 2 switches use hardware to process network traffic. For this reason, layer 2 switches can manage traffic very quickly. In addition, switches keep a record of which MAC address is connected to which switch port, and then use this information to determine which switch port a packet is sent to.

Layer 2 switches are used to combine several NICs into one subnet.

In fact, the situation is somewhat more complicated. Large LANs are generally further subdivided into subnets, with a NIC's subnet address used to define which subnet the NIC belongs to. One consequence of this is that since layer 2 switches use MAC addresses to direct traffic, a layer 2 switch cannot be used to connect from one subnet to another.

What is a Router?

The main purpose of a router is to form a WAN (wide area network) by enabling communication between two or more LANs, or to connect LANs to the Internet. Present day routers can be extremely complex (and extremely expensive), and involve multiple CPUs, ASICs, and different connectors for connecting to different types of communication media.

Routers use IP addresses to direct traffic, and consequently function on layer 3 of the 5-layer TCP/IP networking model. One of the distinguishing factors of lower-end routers is that they use specialized software running on general purpose CPUs, and for this reason, operate somewhat slower than might be needed for high bandwidth networks.

What is a Layer 3 Switch?

A layer 3 switch combines the best of both worlds by using

hardware to optimize IP switching. In a very real sense, software originally used in a router is hardwired into one or more ASICs (application specific integrated circuits) to form the brains of the layer 3 switch. By basing the bulk of the layer 3 switch's operation on hardware instead of software, layer 3 switches can operate at a much faster rate.

The 802.1Q VLAN of a Layer 2 switch allows network operators to configure and maintain networks more efficiently, but connecting from one VLAN to another requires using traditional layer 3 routers. Both routers and layer 3 switches use routing protocols and routing tables to determine the best path. However, compared to software-based routers, layer 3 switches are faster and less expensive due to the built-in switching hardware.

Layer 3 switches are used to combine several subnets into one LAN.

As we mentioned above, layer 2 switches are used to combine several NICs into one subnet. So what about layer 3 switches? Since layer 3 switches use IP addresses to direct traffic, they can be used to combine several subnets into one LAN. In fact, layer 3 switches provide network administrators with a choice of routing options, including Static Routing, Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and Dynamic Routing.

Side-by-side Comparison of Layer 3 Switches and Routers

As mentioned in the previous section, a layer 3 switch is a high-performance network device used to combine several subnets into a LAN. In some respects, layer 3 switches do not differ that much from routers, in the sense that layer 3 switches support the same routing protocols as network routers do, and routing decisions are based on the IP addresses of the source and destination.

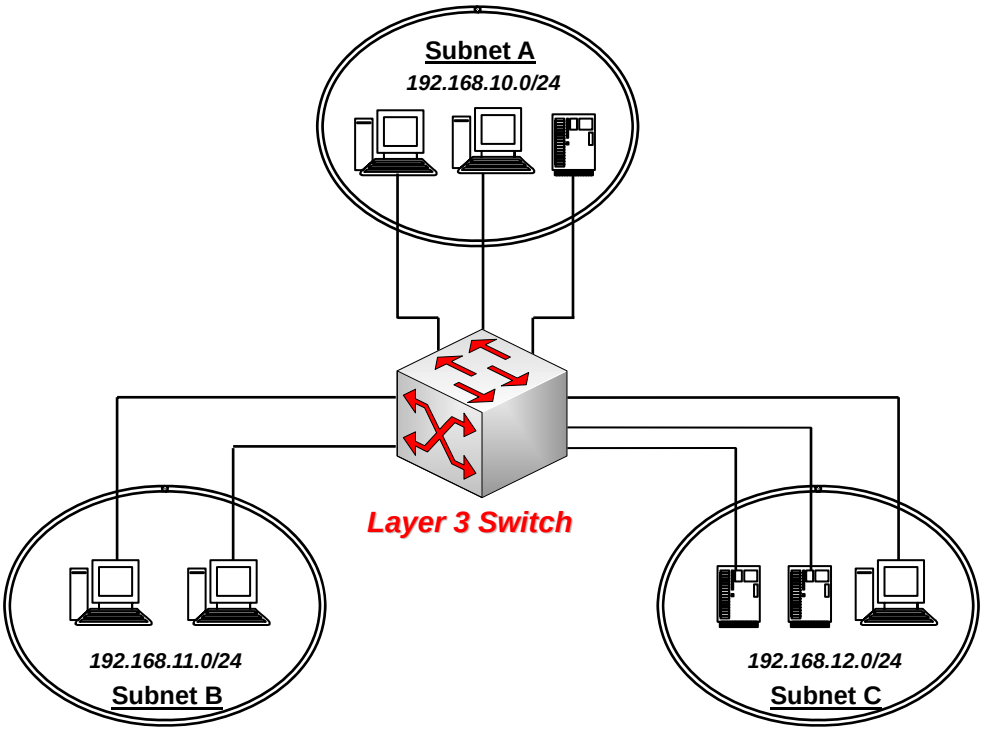
Routers are software-based, whereas layer 3 switches are hardware-based.

Layer 3 switches were developed to provide better performance than routers when used to build up large LANs. The major difference between layer 3 switches and routers used for this purpose is the way the switch or router processes

information. For routers, software running on general purpose CPUs is used to process data, whereas for layer 3 switches, the packet switching software is hardwired into a number of application-specific integrated circuits (ASICs). Simply put, a router is software-based, and a layer 3 switch is hardware-based, which gives layer 3 switches a big speed advantage over the typical router.

Simple Network Topology that Uses a Layer 3 Switch

The basic topology of a LAN made up of a number of subnets is easy to illustrate. In the following figure, Subnet A is a class C subnet with IP addresses of the form 192.168.10.x, Subnet B is a class C subnet with IP addresses of the form 192.168.11.x, and Subnet C is a class C subnet with IP addresses of the form 192.168.12.x. Note that each class C subnet can support 255 IP addresses.



In the figure, we show a layer 3 switch connected to switches and hosts from the three subnets. Since the layer 3 switch uses IP addresses to direct traffic, it is capable of transmitting packets from any network host on the LAN to any other

network host on the LAN.

Why Industry is Adopting Layer 3 Switches

More and more applications, such as networks for subways and tunnels, are installing layer 3 switches, since commercial grade products are not reliable enough. There are the three major issues to consider when selecting an industrial layer 3 switch.

Rugged Design

- *Dual DC power inputs for power redundancy*
  Redundancy is one of the most important factors for many industrial information systems, particularly since more types of industrial equipment now come with an Ethernet interface. Unlike the “comfortable” environment of office automation, control systems used for industrial automation must be able to withstand harsh environmental conditions. For this reason, a basic redundancy requirement for control systems is that every part of the communication network should be connected to a backup power supply in case of a power outage. The backup power supply takes over as soon as the electricity fails, minimizing the possibility of damage caused by the system shutting down.
- *Wider operating temperature*
  The operating temperature range of a device is another key issue for industrial products. In fact, some industrial applications require products that are guaranteed to operate in a wider temperature range. For these types of applications, it is important to look for products that do not use a built-in fan, since products with fans tend to have a lower MTBF (meantime between failures).
- *IP30 protection*
  Unlike commercial environments, equipment used in industrial environments could incur unexpected damage from external factors. If you use a general purpose device in an industrial environment, you will need to add an extra protection box to prevent the device from being damaged. For this reason, using devices with a rugged design is a key

factor for industrial applications.

Higher reliability with fan-less design

People in industry look at either the MTBF (meantime between failures) or warranty period of a product to gauge the product's reliability. However, since the MTBF for many products is not readily available, it is more common to use the warranty period as the determiner. Whereas general purpose devices tend to be warranted for only 1 or 2 years, the warranty period for products used in industrial applications should be at least 3 to 5 years to ensure the reliability of the system, and to reduce the probability that devices will need to be changed frequently.

Communication Redundancy

"Communication Redundancy" is now one of the most important aspects of industrial automation networks, and ring topologies are ideal for setting up hierarchical structures consisting of multiple levels. For example, Moxa's Turbo Ring has gained notoriety in recent years since it gives system administrators a convenient means of setting up a versatile but stable Ethernet network, and sports a recovery time of only a few milliseconds.

Summary

In this paper we gave a brief introduction to layer 2 switches, routers, and layer 3 switches, and discussed how these three networking products are used. A simple yet accurate description is that layer 2 switches connect network hosts to form a subnet, layer 3 switches connect subnets to form a LAN, and routers connect LANs to each other or connect LANs to the Internet. We also pointed out that industrial-grade layer 3 switches are in great demand for networks used in mines and tunnels. When deciding which industrial-grade layer 3 switch to purchase, system integrators should insist on switches with a rugged design that includes dual DC power inputs, wider operation temperatures, and IP30 protection. In addition, it is important to insist on switches that do not use fans, and that

support millisecond level communication redundancy.