Cisco Nexus 3548 - Active Buffer Monitoring

White Paper

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Contents

What You Will Learn

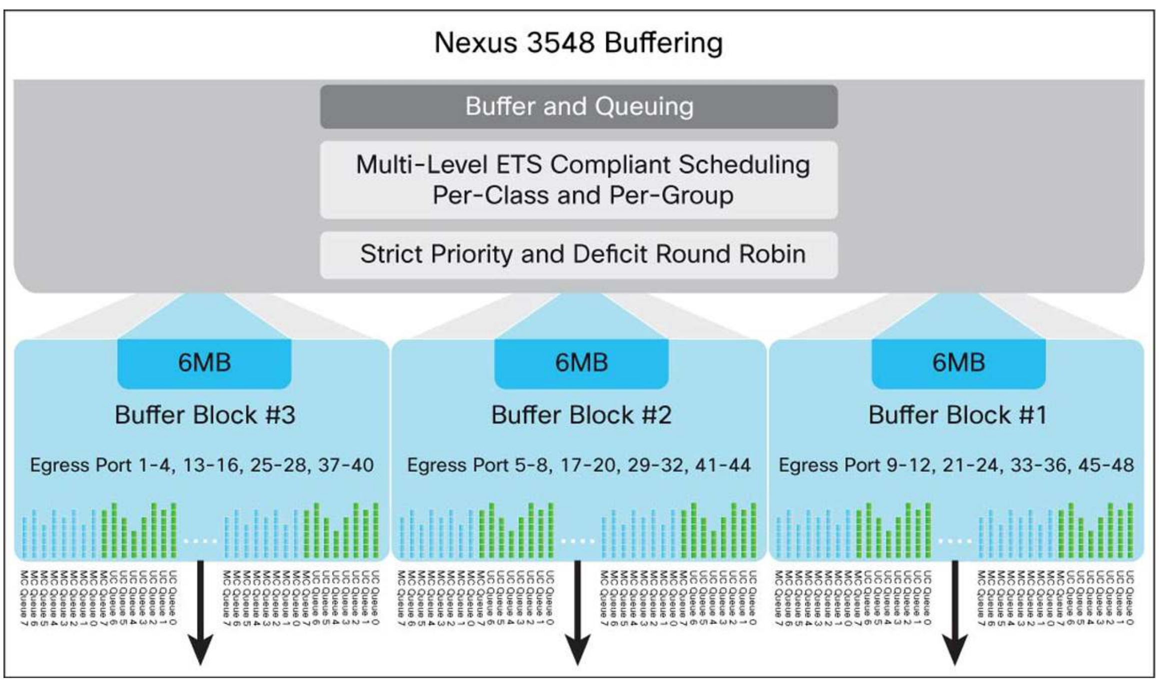
The Cisco Nexus 3500 platform contains the innovative Algorithm Boost (or Algo Boost) technology. Algo Boost technology, built into the switch application specific integrated circuit (ASIC), allows the Nexus 3548 to achieve exceptional Layer 2 and Layer 3 switching latencies of less than 200 nanoseconds (ns). In addition, Algo boost brings an industry-leading innovation for performance analytics called active buffer monitoring.

Nexus 3548 is a cut-through switch, enabling line rate throughput with reduced need for buffering as compared to a store and forward architecture. However, any practical production network experiences congestion due to a variety of conditions including but not limited to many-to-one flows, speed mismatches, and bursty traffic. This congestion can have a serious impact on the latency of packets traveling through the switch, as queued packets must wait for the buffer to clear before they can be transmitted. For instance, a burst of 1.2MB would introduce latencies of over 1 millisecond - 5,000 times the nominal latency of the Nexus 3548! Today's switches don't adequately inform administrators about the presence of congestion, the time when congestion occurred or how long congestion was present, leaving them blind to address the conditions causing sub-optimal performance. Active buffer monitoring is an advanced analytic framework that solves this challenge. This document covers this feature in more details.

Nexus 3548 Architecture Overview

Before going into more detail on the advanced buffer monitoring feature, a brief overview on Nexus 3548 architecture is needed. Nexus 3548 uses a Switch-on-Chip (SoC) architecture specially designed to provide ultra-low latency through the switch. The SoC contains shared buffer architecture with a total of 18MBytes of buffer. Internally, it is divided into three 6MB memory blocks, with each block serving 16 individual ports (Figure 1). For optimal performance a percentage of the buffer is statically reserved for each physical port and the remaining buffer is shared among all ports within the allocated block to be used during periods of congestion. More details on the Cisco Nexus 3548 switch architecture can be found at [Nexus 3548 Architecture Whitepaper].

Figure 1. Nexus 3548 Buffer Architecture



Active Buffer Monitoring - Need for It

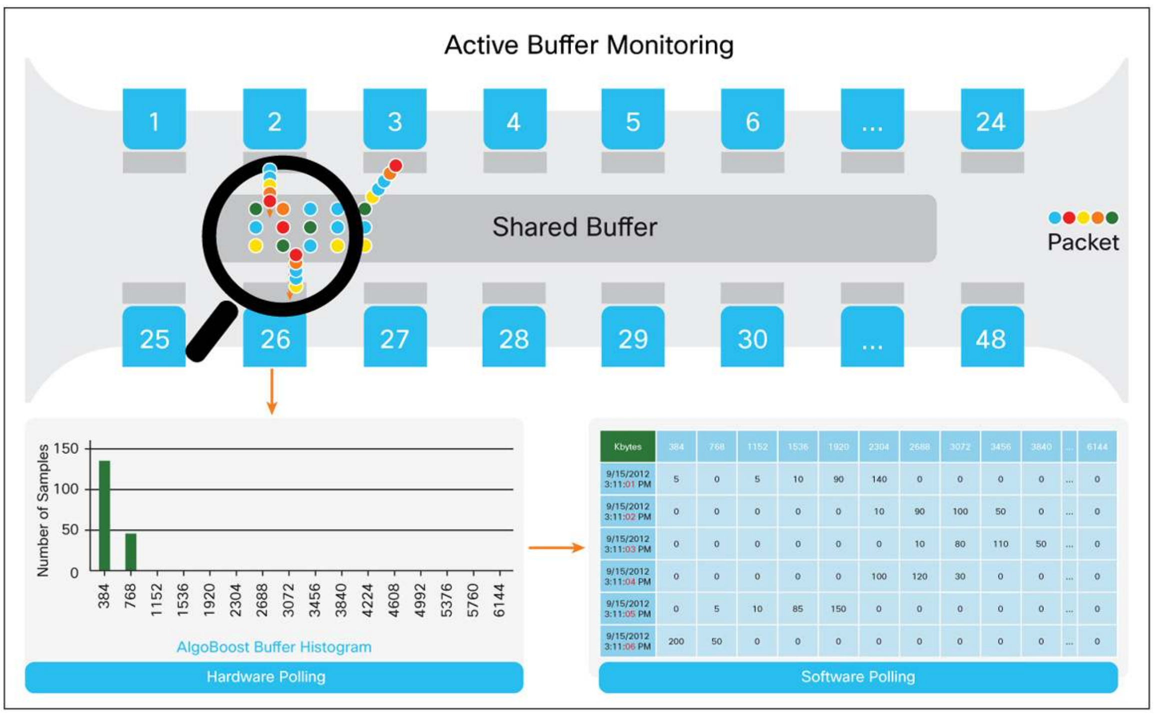
Active buffer monitoring provides granular buffer occupancy data providing better insight into possible hot-spots of congestion. In contrast to previous buffer monitoring technologies that provide utilization snapshots and watermarks, active buffer monitoring provides rich buffer histograms per port illustrating the percentage of time switch buffers were empty, fully occupied, or anywhere in between, with up to ten nanosecond granularity.

This feature helps network administrators to:

- Proactively act on the network congestion which could impact the performance of the network, latency or packet drops
- Go back in time to understand and correlate the network events using this granular buffer monitoring data
- Understand historical trending and identifying patterns of application traffic flow

Active Buffer Monitoring - Implementation

Figure 2. Active Buffer Monitoring



Active buffer monitoring feature has 2 modes of operation:

- **Unicast Mode:** In this mode, the Nexus 3548 switching ASIC monitors and maintains buffer histogram for total buffer utilization per buffer block and unicast buffer utilization for all 48 ports.
- **Multicast Mode:** In this mode, the Nexus 3548 switching ASIC monitors and maintains buffer histogram for total buffer utilization per buffer block and multicast buffer utilization per buffer block.

The active buffer monitoring feature implementation has two types of polling interval - hardware and software. Each works together as described below in detail:

- Each buffer histogram has 18 bucket counters spanning across the memory block. Each bucket corresponds to equal-size ranges of buffer utilization e.g. (0-384KB), (385KB-768Kb), and so on (Figure 3 shows all buffer ranges).
- The Nexus 3548 switching ASIC polls the total buffer utilization and unicast buffer utilization for all ports every 4 milliseconds (by default). This polling interval is configurable and can be as low as 10 nanoseconds.
- Based on the buffer utilization observed for each HW polling interval, the corresponding histogram bucket counter incremented. For example: if port "ethernet 1/4" is consuming 500KB of buffer, bucket #2 (385-768KB) counter for the port is incremented.
- Each buffer histogram counter is 8 bits wide. This means it can go up to a maximum value of 255. In order to avoid counter overflow, by default, the Nexus 3548 hardware polling interval is set to 4 milliseconds and the software polling interval is set to 1 second. At this software polling interval, the histogram data is downloaded to system memory.
- NX-OS software maintains these histogram counters in the memory for last 60 minutes with 1-second granularity.
- As a backup, after every hour NX-OS copies buffer histogram data from system memory to the bootflash.

Active Buffer Monitoring - Data Access and Collection

In order to help network administrators proactively identify and rectify sources of network congestion, NX-OS includes the following options to access and consume the buffer histogram data:

- Device Console: Buffer histogram can be directly accessed from the device console, in real time, using show commands. This allows administrators to access the last 1 hour of data in the system memory (refer to the demonstration section for exact commands and output).
- On-switch scripting interface: NX-OS python scripting/feature scheduler can be used to copy the data to the server regularly to have the historic data.
- Switch file system: The previous 1 hour of histogram data can be accessed from the switch bootflash. Effectively, the switch maintains 2 hours of buffer histogram data, with the most recent hour in system memory and second hour in the bootflash. This allows network management stations to periodically download historic data via lightweight file transfer protocols like FTP.
- XML interface: All active buffer monitoring CLIs have XML equivalents, allowing network management stations to automate the collection of this data at any interval desired.

Furthermore, NX-OS can notify the administrator with a syslog message when the buffer occupancy exceeds a configured threshold (see configuration section for command to set the threshold).

Active Buffer Monitoring - Configuration

Active Buffer Monitoring feature can be enabled/disabled using the command as shown below. By default this feature is disabled.

```
[no] hardware profile buffer monitor  (unicast|multicast)
```

The following commands can be used to show the buffer occupancy histogram and to clear the buffer monitoring data:

```
show hardware profile buffer monitor (summary|brief|details|interface|output-
buffer|multicast)

clear hardware profile buffer monitor
```

The following command can be used to set the buffer utilization syslog threshold and hardware polling interval:

```
hardware profile buffer monitor (unicast|multicast) [threshold <threshold-value>]

          hardware profile buffer monitor (unicast|multicast) [sampling
<Interval in nsec>]
```

Active Buffer Monitoring - Demonstration

The following demonstration illustrates the unicast mode of active buffer monitoring by introducing temporary congestion in a simulated network with the default hardware polling interval of 4 milliseconds. Next, it looks at the data to answer the following questions:

- What ports were congested?
- When was the congestion introduced?
- What is the buffer utilization during the congestion?
- How long did the congestion last?

Figure 3. Active Buffer Monitoring Brief Output

```
Nexus3548# show hardware profile buffer monitor brief
Brief CLI issued at: 09/10/2012 22:15:34
                     Maximum buffer utilization detected
                   1sec     5sec    60sec     5min      1hr
                  -----    -----    -----    -----    -----
Buffer Block 1      0KB      0KB      0KB      0KB      0KB

Total Shared Buffer Available = 5049 Kbytes
Class Threshold Limit = 4845 Kbytes
------------------------------------------------------------
Ethernet1/45        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/48        0KB      0KB      0KB      0KB      0KB
Ethernet1/21        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/24        0KB      0KB      0KB      0KB      0KB
Ethernet1/9         0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/12        0KB      0KB      0KB      0KB      0KB
Ethernet1/33        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/36        0KB      0KB      0KB      0KB      0KB
============================================================
Buffer Block 2      0KB      0KB      0KB      0KB      0KB

Total Shared Buffer Available = 5799 Kbytes
Class Threshold Limit = 5598 Kbytes
------------------------------------------------------------
Ethernet1/17        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/20        0KB      0KB      0KB      0KB      0KB
Ethernet1/5         0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/8         0KB      0KB      0KB      0KB      0KB
Ethernet1/41        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/44        0KB      0KB      0KB      0KB      0KB
Ethernet1/29        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/32        0KB      0KB      0KB      0KB      0KB
============================================================
Buffer Block 3   2304KB   3072KB   3072KB   3072KB   3072KB

Total Shared Buffer Available = 5799 Kbytes
Class Threshold Limit = 5598 Kbytes
------------------------------------------------------------
Ethernet1/13        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/16        0KB      0KB      0KB      0KB      0KB
Ethernet1/37        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/40        0KB      0KB      0KB      0KB      0KB
Ethernet1/25        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/28        0KB      0KB      0KB      0KB      0KB
Ethernet1/1         0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/4      2304KB   3072KB   3072KB   3072KB   3072KB

Nexus3548#
```

Figure 3 shows the brief buffer occupancy output for every 6MB buffer block and all individual ports. As shown, it indicates maximum buffer utilization seen for a variety of intervals - 1 second, 5 seconds, 1 minute, 5 minute, and 1 hour. This data can be used to identify what ports or buffer blocks have been congested and what was the maximum buffer utilization for each.

In the example, ethernet port 1/4 (part of buffer block 3) was congested in last 5 seconds and max buffer utilization reached was 3072KB. No other ports or buffer blocks have seen congestion in the last hour.

Once the network administrator knows which ports have been congested ports, he or she can drill down further per port for more details about the congestion. Figure 4 illustrates the detailed buffer histogram for ethernet port 1/4.

Figure 4. Active Buffer Monitoring Detailed Output

```
Nexus3548#show hardware profile buffer monitor  interface ethernet 1/4 detail
Detail CLI issued at: 09/10/2012 22:15:42
Legend -
384KB  - between   1 and 384KB of shared buffer consumed by port
768KB  - between 385 and 768KB of shared buffer consumed by port
307us  - estimated max time to drain the buffer at 10Gbps
Active Buffer Monitoring for port Ethernet1/4 is: Active
KBytes                 384  768 1152 1536 1920 2304 2688 3072 3456 3840 4224 4608 4992 5376 5760 6144
us @ 10Gbps            307  614  921 1228 1535 1842 2149 2456 2763 3070 3377 3684 3991 4298 4605 4912
                      ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
09/10/2012 22:15:41      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:40      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:39      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:38      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:37     34    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:36    139  111    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:35      0   67  179    4    0    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:34      0    0    0  174   76    0    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:33      0    0    0    0  102  148    0    0    0    0    0    0    0    0    0    0
09/10/2012 22:15:32      0    0    0    0    0   30  178   43    0    0    0    0    0    0    0    0
09/10/2012 22:15:31      0    0    1    0    0    1    0  208    0    0    0    0    0    0    0    0
09/10/2012 22:15:30      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
<snip>
Nexus3548#
```

Figure 4 gives a more granular view of the buffer monitoring for that port. It shows the exact time when congestion occurred, how long it was present, and how highly congested the port was before it cleared. Each row of the output shows one second worth of histogram data for the specified port. Within each line, each column shows the number of hardware polling interval instances where buffer utilization was observed within the corresponding bucket. Since the default hardware polling interval of 4ms was used in this example, the total number of samples adds up to about 250. Reading the specific output in this example, port ethernet 1/4's congestion started at "9/10/2012 22:15:31" and lasted until "9/10/2012 22:15:37". During the 22:15:31 interval, the data indicates the buffer quickly climbed from 0KB to 3072KB, with hardware observing it at 1152KB and 2304KB on the way. Once it reached a utilization of 3072KB, the buffer stayed at this level for approximately 832 milliseconds (208 samples X 4 milliseconds). After this, starting at 22:15:32, the data shows the buffer slowly draining, finally becoming empty at 22:15:37.

This level of detail and analysis can be done on any of the other 47 ports of the switch, or as an aggregate on each of the 3 buffer blocks.

Active Buffer Monitoring - Microburst Detection

The previous example was shown using the default hardware polling interval of 4 milliseconds, which is the highest interval that can be achieved without risking saturation of hardware counters at 255 samples during each 1 second software polling interval. Small microbursts may build up and drain in less than 4ms, requiring a more frequent polling interval to observe. Active buffer monitoring's hardware polling interval can be configured as low as 10 nanoseconds, allowing administrators to choose more rapid polling and 100% microburst detection potentially at the expense of calculating microburst length.

In this example, a microburst is simulated while the active buffer monitoring hardware polling interval was set to 4 microseconds, 1000 times the default frequency. With the active buffer monitoring commands, this example shows administrators how to answer the following questions:

- Which ports saw microbursts?
- At what time did the microburst occur?
- What was the max level of buffer utilization during the microburst?

Figure 5. Active Buffer Monitoring Brief Output

```
Nexus3548#show hardware profile buffer monitor brief
Brief CLI issued at: 09/13/2012 21:31:55

                  Maximum buffer utilization detected
                   1sec     5sec    60sec     5min     1hr
                  ------   ------   ------   ------   ------
Buffer Block 1      0KB      0KB      0KB      0KB     0KB

Total Shared Buffer Available = 5049 Kbytes
Class Threshold Limit = 4845 Kbytes
------------------------------------------------------------
<snip>
============================================================
Buffer Block 2      0KB      0KB      0KB      0KB      0KB

Total Shared Buffer Available = 5799 Kbytes
Class Threshold Limit = 5598 Kbytes
------------------------------------------------------------
<snip>
============================================================
Buffer Block 3      0KB   1152KB   1152KB   1152KB   1152KB

Total Shared Buffer Available = 5799 Kbytes
Class Threshold Limit = 5598 Kbytes
------------------------------------------------------------
Ethernet1/13        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/16        0KB      0KB      0KB      0KB      0KB
Ethernet1/37        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/40        0KB      0KB      0KB      0KB      0KB
Ethernet1/25        0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/28        0KB      0KB      0KB      0KB      0KB
Ethernet1/1         0KB      0KB      0KB      0KB      0KB
<snip>
Ethernet1/4         0KB   1152KB   1152KB   1152KB   1152KB

Nexus3548#
```

From the brief buffer occupancy output in Figure 5, it is clear that there was congestion on the ethernet port 1/4, which is part of buffer block 3. This congestion occurred during the last 5 seconds, but outside of the last 1 second, and the max buffer utilization was 1152 KB. No other ports or buffer blocks have seen congestion in the last hour.

Figure 6. Active Buffer Monitoring Detail Output

```
Nexus3548# show hardware profile buffer monitor interface ethernet 1/4 detail
Detail CLI issued at: 09/13/2012 21:32:01

Legend -
384KB  - between   1 and 384KB of shared buffer consumed by port
768KB  - between 385 and 768KB of shared buffer consumed by port
307us  - estimated max time to drain the buffer at 10Gbps

Active Buffer Monitoring for port Ethernet1/4 is: Active
KBytes                384  768 1152 1536 1920 2304 2688 3072 3456 3840 4224 4608 4992 5376 5760 6144

us @ 10Gbps           307  614  921 1228 1535 1842 2149 2456 2763 3070 3377 3684 3991 4298 4605 4912
                     ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
<snip>
09/13/2012 21:31:52     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
09/13/2012 21:31:51   255  255  255    0    0    0    0    0    0    0    0    0    0    0    0    0
09/13/2012 21:31:50     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

<snip>
Nexus3548#
```

Figure 6 illustrates the detailed buffer histogram data for the ethernet port 1/4. The output shows that a microburst occurred at “9/13/2012 21:31:51”, with the buffer climbing from 0 KB to 1152KB of utilization. Here, since hardware was polling the buffer so frequently, the buffer utilization was observed at each bucket more than 255 times, or for longer than 1 millisecond.

This example attempts to show an extreme case where the buffer is polled so frequently that a short-lived burst is observed 765 times during a 1-second interval. In real-world networks, administrators should tune this value to a value appropriate for the typical congestion seen on their network.

Conclusion

Cisco Nexus 3548’s active buffer monitoring feature provides a rich toolset to administrators, allowing them to observe and study switch buffer data at a level of detail that was never before possible.

For More Information

- Cisco Nexus 3000 Series Switches: http://www.cisco.com/go/nexus3000
- Cisco NX-OS Software: http://www.cisco.com/go/nxos

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