VIRGINIA DOE PILOT PROGRAM FOR BANDWIDTH OPTIMIZATION

PILOT PROGRAM RESULTS

PRESENTED TO:

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SECTION 1: EXECUTIVE SUMMARY

Background

The Virginia Department of Education (VDOE) initiated a statewide pilot to test and measure a new bandwidth optimization technology that directly addresses the growing need for network capacity management in schools. The recent proliferation of tablets, devices and online learning platforms has created an unprecedented strain on school networks, particularly their WiFi infrastructure and WAN circuits. While equipment improvements and bandwidth upgrades have helped solve many of the performance and latency issues facing schools today, the VDOE recognized that an intelligent management of network capacity and throughput was necessary to mitigate future costs and complement existing network resources, with the end-goal of improving the online learning process and experience.

Recognizing that infrastructure improvement and circuit upgrades were often times not enough to address the exponential increase in data throughput produced at schools, the Virginia Department of Education sought out technologies to maximize existing network capacity and optimize utilization of bandwidth resources. A company called CirrusWorks, founded by network operations professionals based in Falls Church, VA, was selected to field-test their "Governor" device and gather performance data from schools throughout the Commonwealth. This report captures those relevant data points and provides analysis based on quantitative outputs and anecdotal response from participating schools.

Pilot Program

In January 2016, CirrusWorks' provided a no-cost 90-day pilot program of The Governor™ device in selected educational venues across the eight regions of Virginia. The process consisted of an open on-line application followed by a technical interview. The objective of the pilot program was to assess the impact of the CirrusWorks Governor™ device to the educational experience – specifically, assessing the Governor's impact to the performance of the school's WiFi infrastructure and bandwidth capacity. The impact of the Governor™ to the educational experience during the pilot program was periodically measured throughout the trial period. Assessments were conducted typically over a two-week basis through both quantitative and qualitative measurements.

Results

The CirrusWorks Governor platform provided measurable Internet bandwidth enhancement to almost every school system in which it was deployed. As expected, the measure of enhancement (Efficiency Quotient) varied based upon: circuit size, user population size and what kinds of content were allowable in each system.

Summary Analysis

1. The CirrusWorks Governor platform provides significant percentage increases over total aggregate traffic throughput in school system configurations where the existing Internet circuit capacity is low relative to the application data demand. The relief provided by the Governor is demonstrable and calculable, delivering an ROI and an improved user QoS and QoE (Quality of Service and Quality of Experience).

2. The CirrusWorks Governor platform provides significant data smoothing for school systems where the Internet access capacity is not fully utilized. The impact of the platform in these environments can be qualified as a cost mitigation and quality assurance to future Internet traffic demands. The results become more evident as the data volumes rise closer to the carrying capacity of the existing Internet access circuit, and as the traffic load spikes increase in size and periodicity.

SECTION 2: ISSUES DRIVING SEARCH FOR BANDWIDTH OPTIMIZATION

"To provide students with the education they need to thrive in a globally connected world, we must find ways to design, fund, acquire, and maintain the infrastructure that will make connectivity a reality for every teacher and student in every classroom."

Office of Education Technology: Future Ready Schools

The way students learn in the classroom has evolved considerably – especially in the use of technology. The introduction of tablets in the classroom and online testing have strained many schools' network infrastructure to their limits. With tight budgets and IT resources, schools have struggled to provide an acceptable level of bandwidth capacity to students and faculty during peak periods, often causing delays in online testing, or making students wait to upload or download assignments in the classroom. Bandwidth congestion and the resultant Internet delays are inhibiting the progress of students and teachers to adopt online learning platforms. Some of the developments facing school IT departments are highlighted below, and these challenges drove the search for new, innovative, and more effective ways to manage the resulting constraints on network capacity and Internet quality of service.

Online Testing, In-Classroom Devices and Video

Online testing, in-classroom tablets and laptops, and video-based curriculum are now firmly rooted in the education experience. Classroom time is precious, page-turn delays during online testing are not an option, and faculty and students do not want to waste time waiting for files to download or videos to stream. More concerning, the inability to perform online testing due to unreliable Internet access and unmanageable demands on network capacity.

Adoption of Cloud-Based Applications

As school systems migrate applications and file storage to the cloud, the amount of simultaneous data transfer has grown exponentially. With data being retrieved and stored outside the education venue, the cost and labor involved in developing and managing a reliable school network continues to rise. This becomes even more acute when multiple school districts pipe data through a centralized hub before accessing the public Internet.

Increasing Reliance on High Performance Internet

New applications, devices and cloud-based systems all depend on high-performance, optimized Internet. The challenge is that the local circuit often falls short. Demand for bandwidth often exceeds available supply – generating localized WAN circuit congestion, packet delays and ultimately poor service quality. Even surplus bandwidth at the WAN layer can be compromised when overwhelming demand at the LAN (on-campus school infrastructure) is not fairly apportioned among competing devices.

Adding Bandwidth Isn't Enough

When congestion and delays are experienced on the Internet, the traditional course of action has been to increase the bandwidth of the WAN circuit. Adding bandwidth is not only expensive, it has proven to be insufficient. In recent years, universities have studied the effects of increasing bandwidth, mostly to find that demand rises to meet the bandwidth and continues until the new circuit is also overwhelmed. Simply opening a bigger pipe does not necessarily solve the problem.

Traditional Packet Shaping is Complex and Expensive

Traditional packet shaping solutions require months to setup and configure – often costing tens of thousands in software and consulting. IT budgets are tight and technical staff generally lack the time and expertise necessary to setup, maintain and continually monitor packet shaping software. As a result, for most schools, traditional WAN optimization or packet shaping solutions are simply out of reach.

Traffic is Encrypted, Uncontrollable and Unpredictable

Users (teachers and students) and their applications are too diverse, and devices are too numerous to effectively manage with static rule sets or policies. More significantly, today's data traffic is mostly encrypted, thwarting efforts to inspect packets and prioritize applications.

VDOE Seeks to Test and Measure Bandwidth Optimization Solutions

Recognizing that infrastructure improvement and circuit upgrades were often times not enough to address the exponential increase in data throughput produced at schools, the Virginia Department of Education sought out technologies to maximize existing network capacity and optimize utilization of bandwidth resources. A company called CirrusWorks, founded by network operations professionals based in Falls Church, VA, was selected to field-test their "Governor" device and gather performance data from schools throughout the Commonwealth. This report captures those relevant data points and provides analysis based on quantitative outputs and anecdotal response from participating schools.

Bandwidth Optimization as a Compliment to Infrastructure and Circuit Upgrades

CirrusWorks' approach to the bandwidth congestion problems facing schools is fundamentally different from traditional traffic shaping technologies, and is specifically designed to complement, or enhance existing network infrastructure and WAN circuits. Rather than over-procuring bandwidth capacity that is only utilized during peak load periods, CirrusWorks arbitrates Internet congestion as it occurs by making the most mathematically efficient decisions possible based purely upon aggregate available bandwidth relative to the traffic behavior and instantaneous data demands of each user. CirrusWorks dynamically reprioritizes traffic without complex static rule sets, requiring little to no configuration, and it eliminates the need to upgrade your link beyond optimal levels of capacity.

CirrusWorks replaces the need to add surplus bandwidth by improving the efficiency of a school's existing circuit capacity. Using predictive analytics that define a user's transmission profile, bandwidth allocation among users is dynamically adjusted allowing the algorithm to momentarily demote users who have a recent history of using large amounts of bandwidth at the expense of others. In turn, traffic that is burstable, transient or transactional in nature will be favored, while heavy traffic is governed by the device (hence, the "Governor" product name), resulting in a higher quality of service for the entire population. The technology does not create more bandwidth, but rather ensures the most efficient allocation of bandwidth capacity among various, uncontrollable users.

SECTION 3: PILOT PROGRAM

PILOT PROGRAM OBJECTIVE

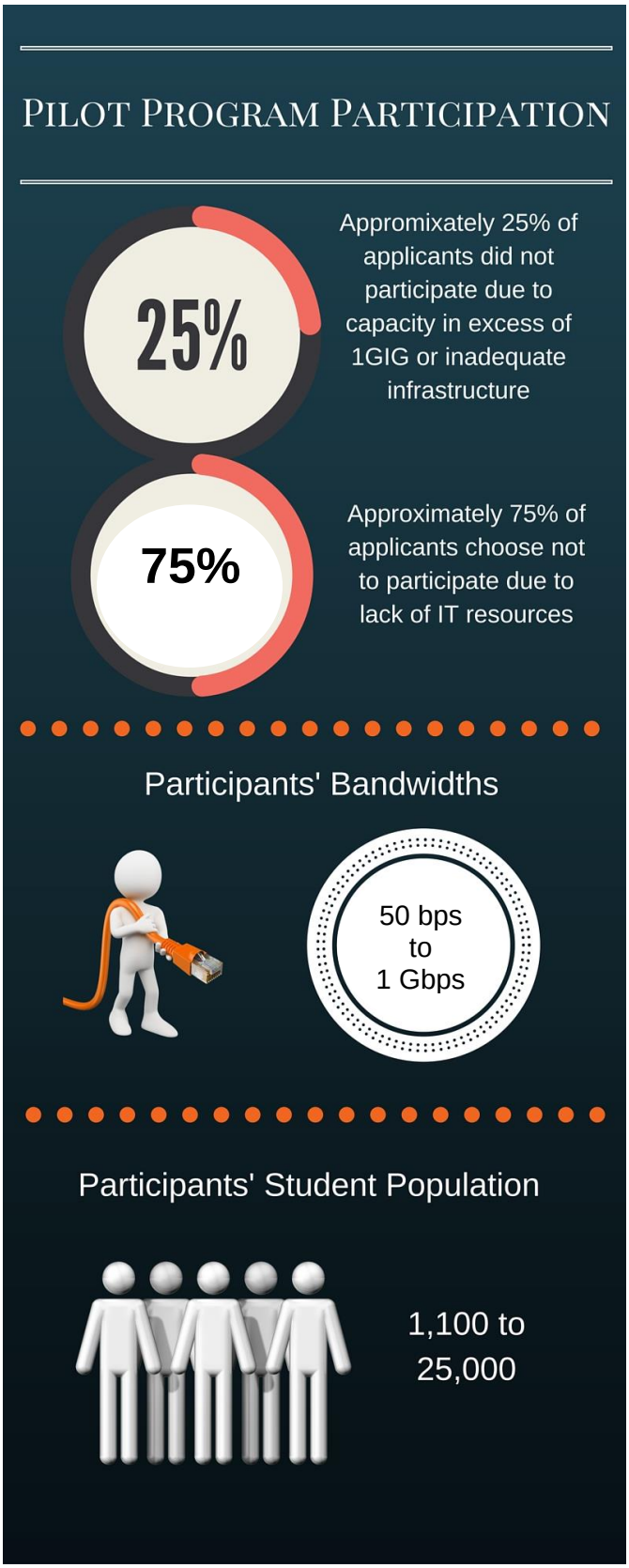
The objective of the pilot program was to assess the impact of the CirrusWorks Governor™ device to the educational experience – specifically, assessing the Governor's impact to the performance of the school's WiFi infrastructure.

PILOT PROGRAM APPLICATION AND SELECTION PROCESS

In collaboration with the Virginia Department of Education, in January 2016 CirrusWorks' provided a no-cost 90-day pilot program of The Governor™ device in selected educational venues across the eight regions of Virginia. The process consisted on an open on-line application followed by a technical interview. The following are the schools who applied to participate in the program:

School District	*# of Students*	*Internet Capacity*
Hampton City	20,000	2GB
Shenandoah County*	6,000	500 mbps
Salem City *	3,721	200/100 mbps
Mathews County*	1,100	100 mbps
Culpepper County	5,000	Not provided
King William County	Not provided	100 mbps
Prince William County	96,000	Dual 2 GB links
Fluvanna County	3,500	200 mbps
Cumberland County	1,400	100 mbps
Middlesex County	1,200	200 mbps
Goochland County	2,500	300 mbps
Orange County	Not provided	Not provided
Giles County*	2,393	50 mbps
Richmond Public Schools*	25,000	1 GB
Virginia Beach	70,000	4 GB
Newport News	Not provided	500 mbps

**Selected for pilot participation.*



PILOT PROGRAM REQUIREMENTS

- ✓ Application submitted online via CirrusWorks, Inc. website (www.cirrrusworks.net)
- ✓ Applicants were required to provide current Internet capacity and student population
- ✓ After application submission, CirrusWorks performed interviews regarding the pilot program administrative and technical requirements prior to selection
- ✓ During participation selection, two limitations were identified:
  - capacity size (current specifications of the Governor product limits to 1Gbps), and
  - lack of internal IT resources to facilitate program requirements
- ✓ Selected participants were required to respond to bi-weekly surveys regarding the Internet Experience during “active” and “non-active” periods of the pilot program

MEASURING THE RESULTS OF PILOT PROGRAM

The impact of the Governor™ to the educational experience during the pilot program was periodically measured throughout the trial period. Assessments were conducted typically over a two-week basis through both quantitative and qualitative measurements.

The first two weeks post installation served as the baseline for measurement. During this period the **governing feature was turned ON** and the device's User Interface collected the state of the circuit's utilization (number of devices, Governing activity and bandwidth requirements) during peak load periods. In addition, qualitative information was gathered through online surveys to capture the "digital learning experience" from both the user and IT support perspectives.

At the end of the first two-week period, the device's governing feature was turned OFF and additional data was collected regarding users governed during this period[1]. Quantitative data was analyzed for the same peak loads of prior periods for week-on-week comparisons. Qualitative measurements were also obtained through an online survey.

The bi-weekly "governing and non-governing" process continued throughout the pilot program. The objective is to ensure the various digital learning activities conducted within the pilot school are captured and assessed in both a "governing" and "non-governing" state – **in effect, empirically demonstrating the impact of the Governor™.**

Timeline and Key Performance Indicators (KPI)

Period 1 – Governor On	Period 2 – Governor Off	KPI
Internet Performance • Devices Governed • Bandwidth Governed • Bandwidth Re-allocated	Internet Performance • Devices Active • Bandwidth Consumed • Bandwidth Outliers	Bandwidth Efficiency (BX) Quotient (%) represents net optimization of circuit capacity during Governing.
User Experience • IT Tickets/Complaints • Survey Results	User Experience • Service Tickets/Complaints • Survey Results	User Experience (UX) Improvement Rate - %

The tables below provide the quantitative and qualitative measurements collected, sources in which the data was obtained to measure the **success of the pilot program**.

Quantitative Measurements Via Governor's User Interface

Measurement	Outcomes
Peak Bandwidth Rate in kilobytes/sec [Mbps]	Maximize throughput
Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices	Pinpoint outliers
Peak Active Device Time and Count	Pinpoint heavy utilization times
Peak Concurrent Governed Devices	Manage outliers
% OF Data Governed (to WAN and to LAN)	Determine quality improvement

[1] The exception to the two-week Governing On/Off assessment was Giles County. This installation was non-optimal due to the current infrastructure limitations. The representative of Giles County chose to keep the Governing active during the entire Pilot timeframe.

Qualitative Measurements Via Online Surveys

Measurement	Outcomes
Trouble Tickets relating to slow/poor internet	Change in trouble tickets
Performance of VOIP, Streaming Video and Online Testing	Performance variance
Impact to throughput performance during peak periods	Performance variance
Overall LAN (WiFi) Network performance	Performance variance

PILOT PROGRAM RESULTS

Quantitative Measurements Via Governor's User Interface

The CirrusWorks Governor platform provided measurable Internet bandwidth enhancement to almost every school system in which it was deployed. As expected, the measure of enhancement (Efficiency Quotient) varied based upon: circuit size, user population size and what kinds of content were allowable in each system.

The below table presents selected quantitative data points collected by school during the Pilot Program. Quantitative data collections by Governing period is provided in Attachment A.

Pilot program participants can be grouped in three major categories:

A. School systems that regularly reach the maximum carrying capacity of their Internet access circuit
B. School systems that occasionally reach the maximum carrying capacity of their Internet access circuit
C. School systems that possess excess Internet access circuit capacity and never fully utilize the bandwidth being purchased

In this study, **Group-A** consist of Mathews County and Giles County. Both systems operate with relatively small total bandwidth and regularly reach the maximum throughput of their existing Internet circuit.

Group-B is the City of Salem. The system occasionally approaches full utilization.

Group-C is Shenandoah County and the City of Richmond. In both these systems, large Internet bandwidth is readily available and remains at least 25% untapped in terms of daily utilization.

Quantitative results for **Group-A** indicate a sustained **throughput improvement of more than 30% in both the upstream and downstream directions**. This is accomplished by the CirrusWorks Governor having reprioritized bulk traffic, demoting that traffic in favor of burst and transactional traffic. This eliminated traffic spikes and congestion as well as minimizing dropped packets both within the school system and on the circuit from the ISP to the school system.

The **Group-B** school saw mixed results, with a **36% downstream (to schools) improvement, but no significant improvement in the upstream direction**. We believe this is a function of this particular system's work load, device count, and generally underutilized (excess) Internet capacity. While the quantitative measure of 36% is in itself significant, the positive impacts of traffic reprioritization may not have been sufficient to clearly differentiate the impact of the Governor platform. As this school system's Internet traffic increases over time, the impact of the CirrusWorks Governor platform would become more obvious.

The **Group-C** school systems had **both the highest and lowest levels of traffic reprioritization (53% and 5% respectively). But both these systems operate with large excess Internet capacity**. In these cases, any qualitative improvements that could be observed by the students or faculty might have been masked by the over excess available Internet capacity.

Quantitative Summary Analysis

3. The CirrusWorks Governor platform provides significant % increases overall traffic throughput in school system configurations where the existing Internet circuit capacity is low relative to the application data demand. The relief provided by the Governor is demonstrable and calculable, delivering an ROI and an improved user QoS and QoE (Quality of Service and Quality of Experience).

4. The CirrusWorks Governor platform provides significant data smoothing for school systems where the Internet access capacity is not fully utilized. The impact of the platform in these environments can be qualified as an insurance policy to future Internet traffic demands. The results become more evident as the data volumes rise closer to the carrying capacity of the existing Internet access circuit, and as the traffic load spikes increase in size and periodicity.

	Salem	Mathews	Giles	Shenandoah	Richmond (City of)
SCHOOL IT DEMOGRAPHICS					
Circuit Size [Mbps]	300	100	50	500	1000
OBSERVATIONS					
Total Observation Days	40	42	20	42	17
Governing "ON" Days	21	23	20	23	12
Governing "OFF" Days	19	19	0	19	5
SCHOOL DEVICES OBSERVED					
Devices Observed (IP count per 24hrs)	4,463	1,438	1,576	4,575	29,932
AX Concurrent Active Devices (2min Samples)	978	414	515	1,343	3,444
WAN BANDWIDTH (To Internet)					
Peak Rate - Governing ON [Mbps]	83	50	40	82	159
Peak Rate Governing OFF [Mbps]	86	37	n/a	58	158
Percentage Data Governed (deprioritized)	20%	20%	11%	21%	4%
Percentage WAN Traffic Expedited	80%	80%	89%	79%	96%
LAN BANDWIDTH (To Schools)					
Peak Rate - Governing ON [Mbps]	228	127	77	336	775
Peak Rate Governing OFF [Mbps]	167	92	n/a	219	738
Percentage Data Governed (deprioritized)	7%	19%	7%	10%	1%
Percentage LAN Traffic Expedited	93%	81%	93%	90%	99%
GOVERNING ACTIVITY SESSIONS					
Average # Daily Governed Devices	796	705	811	1,287	1,048
Average of Peak Concurrent Governences	8	8	12	18	6
Percentage Device Pop. Deprioritized	1%	2%	2%	1%	0%
PEAK LOAD TRAFFIC QUALITY IMPROVEMENT					
To Internet [% of Peak Load]	-3%	33%	30% est	40%	1%
To Schools [% of Peak Load]	36%	38%	30% est	53%	5%
To Internet [Expressed in Mbps]	(10)	33	15 est	201	8
To Schools [Expressed in Mbps]	108	38	15 est	267	51

Qualitative Measurements Via Online Surveys

Surveys were conducted on a bi-weekly basis and at the end of the pilot program. The purpose of the surveys was to collect qualitative measurements on the Governor's impact to the "Internet experience."

During the pilot program, only 2 of the 5 participants submitted surveys. At the end of the program, a final survey was summited by 100% of the participants. The final survey responses have been included as an integral part of this report to ensure results included input from all of the pilot participants.

In all cases, the participants found the Governor product **installation and setup** relatively **straightforward**. **No on-site assistance** was required during the installation.

40% of the population reported **decreased trouble tickets** associated with Internet performance during when Governing was active.

60% of the participants experienced **improved performance** during applications such as **software updates and video streaming.**

60% of the participants reported **improved overall Internet performance**.

School	Data STATS	2/5/2016	2/19/2016	3/4/2016	3/18/2016	4/8/2016 END OF PILOT
Salem City Schools	Governing	OFF	ON	OFF	ON	ON
	Peak Bankdwidth Rate in kilobytes/sec [Mbps]	1/28: WAN 18,000[140][13:06] 2/5: LAN 24,720 [193][14:35]	2/12: WAN 15,678[122][11:51] 2/12: LAN 24,951 [195][11:25]	3/1: WAN 16,917[132][11:55] 3/3: LAN 34,053 [266][11:29]	3/10: WAN 15,637[122][16:24] 3/10: LAN 37,311 [291][13:20]	3/24: WAN 15,346[120][15:02] 3/23: LAN 36,758 [287][12:53]
	Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices	1/29: 4524/OFF/971	2/11: 4662/931/944	2/24: 4846/OFF/1075	3/08: 4691/399/891	3/22: 4585/1006
	Peak Bridge Packet Rates (packets/sec, WAN and LAN combined)	2/2: 44,803	2/12: WAN: 21,776 2/18: LAN: 24,539 2/12: COMBINED: 45,888	3/3: 52,157	3/11: WAN: 23,808 3/10: LAN: 31,783 3/11: COMBINED: 53,600	3/24: WAN: 21,565 3/23: LAN: 30,269 3/24: COMBINED: 50,518
	% OF Data Governed (to WAN and to LAN)	OFF	2/11: WAN: 36% 2/11: LAN: 8%	OFF	3/20: WAN: 22% 3/14: LAN: 11%	3/22: WAN: 24% 3/23: LAN: 08%
	% of Data Govered at Max Level	OFF	2/11: WAN 11.5% 2/18: LAN 2.1%	OFF	3/10: WAN 8.9% 3/15: LAN 2.9%	3/22: WAN 7.5% 3/23: LAN 1.9%
Mathews County Public Schools	Governing	OFF	ON	OFF	ON	ON
	Peak Bankdwidth Rate in kilobytes/sec [Mbps]	1/29: WAN 10,000[78][8:45] 1/26: LAN 11,900[93][11:03]	2/19: WAN 10,342[80][14:56] 2/09: LAN 12,296 [96][09:30]	2/23: WAN 8351[65][15:32] 2/29: LAN 12,205[95][12:15]	3/16: WAN 12,009[94][09:04] 3/09: LAN 14,766 [115][8:57]	4/07: WAN 11,664[91][14:54] 4/07: LAN 12,575 [98][8:23]
	Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices	2/4: 2179/OFF/681	2/19: 1653/691/630	3/3: 1773/OFF/534	3/14: 2327/852/721	3/24: 2561/667/
	Peak Bridge Packet Rates (packets/sec, WAN and LAN combined)	1/29: 18,746	2/12: WAN: 9,089 2/09: LAN: 11,789 2/09: COMBINED: 19,905	2/25: 18,005	3/16: WAN: 10373 3/09: LAN: 11,059 3/14: COMBINED: 20,005	4/07: WAN: 13142 4/07: LAN: 12,326 4/07: COMBINED: 25,077
	% OF Data Governed (to WAN and to LAN)	OFF	2/12: WAN: 27% 2/09: LAN: 30%	OFF	3/16: WAN: 49% 3/08: LAN: 25%	4/07: WAN: 59% 4/06: LAN: 31%
	% of Data Govered at Max Level	OFF	2/12: WAN 13.7% 2/09: LAN 9.5%	OFF	3/16: WAN 18.6% 3/08: LAN 9.0%	4/07: WAN 44.7% 4/06: LAN 14.7%
Shenandoah County Public Schools	Governing	ON	ON	OFF	ON	ON
	Peak Bankdwidth Rate in kilobytes/sec [Mbps]	2/3/16 WAN 10300[80][8:53] 2/2/16 LAN 43800[342][13:40]	2/09: WAN 11,377[89][09:31] 2/19: LAN 47,741 [373][08:34]	2/25: WAN 12,212[95][19:16] 2/24: LAN 53,126[415][9:01]	3/15: WAN 12,293[96][19:16] 3/08: LAN 55,382 [433][14:13]	3/23: WAN 12,358[97][19:16] 3/24: LAN 52,518 [410][14:32]
	Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices	2/1: 5819/1294/1852	2/12: 5662/1246/1660	2/25: 6345/OFF/1705	3/17: 6165/1104/1740	3/21: 6007/1149/
	Peak Bridge Packet Rates (packets/sec, WAN and LAN combined)	2/5: WAN 23,851 2/2: LAN 34,826	2/08: WAN: 23,808 2/17: LAN: 37,626 2/19: COMBINED: 61,005	2/26: 76,280	3/14: WAN: 26,737 3/08: LAN: 42,949 3/08: COMBINED: 65,907	3/29: WAN: 29,299 3/29: LAN: 44,892 3/29: COMBINED: 74,191
	% OF Data Governed (to WAN and to LAN)	2/5: WAN 22% 2/2: LAN 32%	2/19: WAN: 29% 2/19: LAN: 10%	OFF	3/07: WAN: 47% 3/08: LAN: 15%	3/24: WAN: 31% 3/24: LAN: 08%
	% of Data Govered at Max Level	2/5: WAN 8.1% 2/2: LAN 10.0%	2/09: WAN 9.6% 2/19: LAN 2.3%	OFF	3/07: WAN 13.9% 3/08: LAN 4.7%	3/24: WAN 09.5% 3/22: LAN 2.2%

School	*Data STATS*	2/5/2016	2/19/2016	3/4/2016	3/18/2016	4/8/2016 END OF PILOT
Giles Review	*Governing*	*Not Installed*	*Not Installed*	ON	ON	ON
	Peak Bankdwidth Rate in kilobytes/sec [Mbps]			2/25: WAN 10,369[81][11:42] 2/25: LAN 14,900 [116][10:54]	3/16: WAN 6,134[48][14:54] 3/18: LAN 13,940 [109][13:17]	4/05: WAN 4,466[35][13:31] 4/04: LAN 13,268 [104][09:38]
	Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices			2/23: 2003/778/588	3/10: 1671/803/548	3/29: 1764/999/
	Peak Bridge Packet Rates (packets/sec, WAN and LAN combined)			2/25: COMBINED: 17296	3/11: WAN: 7,381 3/11: LAN: 12,287 3/11: COMBINED: 19,608	4/06: WAN: 8,179 4/04: LAN: 10,027 4/04: COMBINED: 15,491
	% OF Data Governed (to WAN and to LAN)			2/25: WAN: 22% 2/23: LAN: 8%	3/14: WAN: 13% 3/14: LAN: 9%	4/05: WAN: 13% 4/01: LAN: 10%
	% of Data Govered at Max Level			2/25: WAN 11.7% 2/25: LAN 1.1%	3/16: WAN 5.0% 3/16: LAN 1.5%	3/29: WAN 3.6% 4/01: LAN 2.1%
Richmond	*Governing*	*Not Installed*	*Not Installed*	ON	ON	ON
	Peak Bankdwidth Rate in kilobytes/sec [Mbps]			2/23: WAN 35,266[276][08:08] 2/26: LAN 109,202 [853][10:47]	3/17: WAN 19,558[153][10:31] 3/15: LAN 108,818 [850][10:29]	3/22: WAN 24,923[195] [08:49] 3/25: LAN 117,376 [917[10:43]
	Peak Monitored Device Population/Governed Devices/MAX Concurrent Active Devices			2/25: 32772/876/3635	3/17: 33584/1104/3729	4/07: 34072/1023/
	Peak Active Device Time and Count			2/23: 14:40/6	3/11: 14:06/8	
	Peak Concurrent Governed Devices					
	Peak Bridge Packet Rates (packets/sec, WAN and LAN combined)			2/26: COMBINED: 146731	3/17: WAN: 57,975 3/17: LAN: 91,069 3/17: COMBINED: 149,044	3/25: WAN: 68,911 3/25: LAN: 98,466 3/25: COMBINED: 167,335
	% OF Data Governed (to WAN and to LAN)			2/26: WAN: 27% 2/25: LAN: 3%	3/14: WAN: 28% 3/11: LAN: 13%	4/05: WAN: 28% 3/22: LAN: 04%
	% of Data Govered at Max Level			2/26: WAN 8.8% 2/24: LAN 0.8%	3/11: WAN 8.7% 3/11: LAN 3.7%	4/05: WAN 6.4% 4/04: LAN 0.7%

APPENDIX B - QUALITATIVE SURVEYS BY PARTICIPANT

School: *Question*	Salem City Schools Response	Mathews High Schools, Thomas Hunter Middle School, Lee-Jackson Elementary School Response	Shenandoah County Public Schools Response	Giles County Response	Richmond City Public Schools Response
Please provide feedback on the installation and setup of the Governor Product:	Installation and setup was straight forward. There were some gateway detection issues, but those were specific to our perimeter topology and were quickly resolved by manual configuration.	Installation and setup was challanging. There was an issue that was never solved and blamed on the way our network was set up. We did not want to pay a network engineer to figure this out. Otherwise the set-up was simple. FROM CIRRUS WORKS REPORTS ..."Monitored device counts are skewed due to anomalous IP source addresses originating from the LAN. This is IP spoofing, and arrives in bursts during various periods throughout the school day. These bogus devices contribute to elevated concurrent monitored device counts, and watered down percentage of devices governed.	Installation and setup was straight forward	Installation and setup was straight forward	Installation and setup was straight forward
During the pilot period when Governing was active, trouble tickets relating to slow/poor internet performance:	Remained the same from non-Governing periods	Remained the same from non-Governing periods	Decreased during Governing periods	Decreased during Governing periods	Remained the same from non-Governing periods
During the pilot periods when Governing was active, performance of the following were:	VOIP: No impact identified Streaming Video: No Impact identified Online Testing: No Impact identified Software Updates: No Impact identified	VOIP: No impact identified Streaming Video: No Impact identified Online Testing: No Impact identified Software Updates: Improved	VOIP: No impact identified Streaming Video: Improved Online Testing: No Impact identified Software Updates: No Impact identified	VOIP: No impact identified Streaming Video: Improved Online Testing: No Impact identified Software Updates: Improved	VOIP: No impact identified Streaming Video: No Impact identified Online Testing: No Impact identified Software Updates: No Impact identified
During the pilot period when Governing was active, the impact to throughput performance during peak periods were	Anecdotal evidence suggests there was little discernible change. Our throughput graphs seemed to show longer lasting periods of saturation than usual. The data I am seeing suggests that throughput bursting capability offered by our ISP may have been undermined. On my end, I observed slower downloads of large files even after schools closed (low overall utilization). High consumption should be okay as long as it is not interfering with others. I am unsure how to go about meeting this desire while ensuring that users cannot be disruptive during peak hours, but it is an observation.	Performance improved. The ONLY time there was a noticeable improvement was during the updates times. This improvement was very signficant.	Performance Improved.	Performance Improved. Specifically with Windows Updates.	No difference experienced
Overall LAN (WiFi) network performance?	We experienced WiFi problems between Feb. 26 and March 2 that required intervention of engineers. This may have skewed our results some. Otherwise, LAN performance was amiable.	Improved. The ONLY time there was a noticeable improvement was during the updates times. This improvement was very signficant.	Performance Improved.	Performance Improved.	No difference experienced

APPENDIX B - QUALITATIVE SURVEYS BY PARTICIPANT – CONTINUED

School:	Salem City Schools	Mathews High Schools, Thomas Hunter Middle School, Lee-Jackson Elementary School	Shenandoah County Public Schools	Giles County	Richmond City Public Schools
Question	Response	Response	Response	Response	Response
Please provide any additional comments regarding the overall end user Internet experience during the Governing active periods.	It was evident that our users were prevented from monopolizing the connection. However, we were unable to discern a noteworthy change in quality of experience. We also increased our bandwidth from 200 Mbps to 300 Mbps starting the week of March 6, so the effectiveness may well have been muted by this change. While other districts experience internet bandwidth saturation for the majority of the day, we only see a few periods (15 - 30 minutes each) of saturation per day. The difference may be more pronounced in divisions that have provisioned fewer resources per student.	Other than the update days things seemed to be the same. Perhaps our system is not over subscribed like other except during updates.	*Respondent skipped this question*	Helped with Windows Updates	no change noted during the pilot
Please provide the frequency of interaction with the product's user interface	Weekly	Weekly	Weekly	Weekly	Weekly
Of the product's UI, what features and tools did you find most helpful?	The Governing Data page is where I spent most of my analysis. We already obtain performance and throughput metrics from an already established monitoring system - PRTG. We collect Netflow data so we can already see which streams account for the majority of the bandwidth used, as well as what percentage each stream occupies. The Governing Data screen served as confirmation that throughput decisions were made on heavy hitters.	Governed devices and number of times governed.	*Respondent skipped this question*	*Respondent skipped this question*	*Respondent skipped this question*
Please share your recommendations on enhancements to the product's UI that you believe would be of value:	My recommendation would be to provide more time frame granularity on the Governing Data page. Seeing data for the whole day can get in your way. When we first setup the appliance, we had mistakenly inverted the cables across the bridge interfaces, so the first day was quickly filled with data indicating that the inverse was governed. Before we could make the determination that swapping the cables cured this issue, we needed to wait a day so that the data would be out of scope. Being able to drill down more granularly might be helpful in that case, as well as day-to-day analysis (acknowledging that you can sort per 3-hour time span).	A easy to use live and historical graphical bandwidth monitor (with downloadable csv data log) couple with a easy to use live and historical graphical bandwidth monitor (with downloadable csv data log) is required. Had I had this I would have been able to see how much bandwidth is being extended/saved by using this device.	*Respondent skipped this question*	I am pleased.	*Respondent skipped this question*
Exit Interview comments:	Did not experience signficant change from on and off Governing periods. School's current capacity is not experiencing oversubscription at this time.	Signficant improvement experienced during software updates. Circuit was not oversubscribed except for when software updates was provided.	Did not experience signficant change from on and off Governing periods. School's current capacity is not experiencing oversubscription at this time.	Signficant improvement experienced during software updates.	*Did not participate in Exit Interview*

APPENDIX C – TECHNICAL ANALYSIS

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