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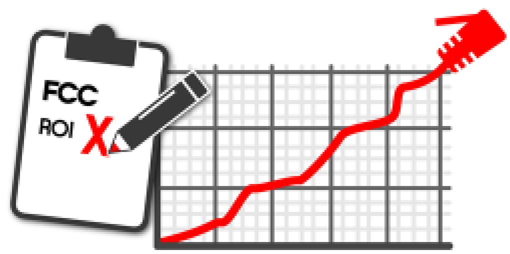
Caching to improve E-Rate ROI

ApplianSys Presentation to the FCC - November 14 2017



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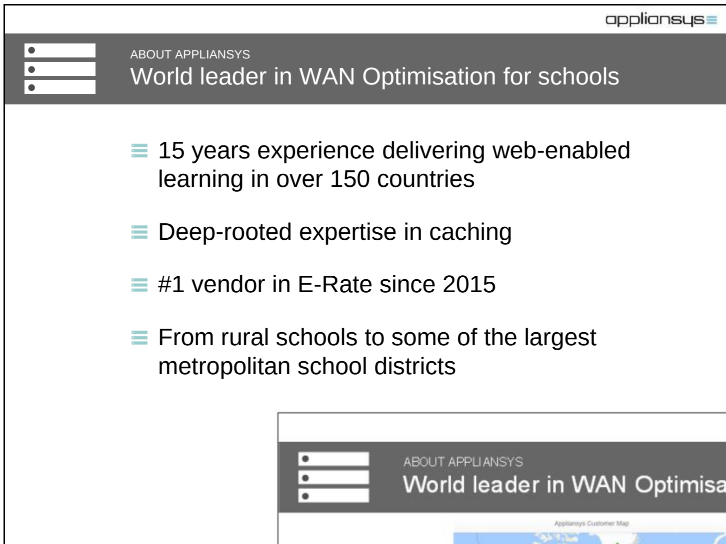

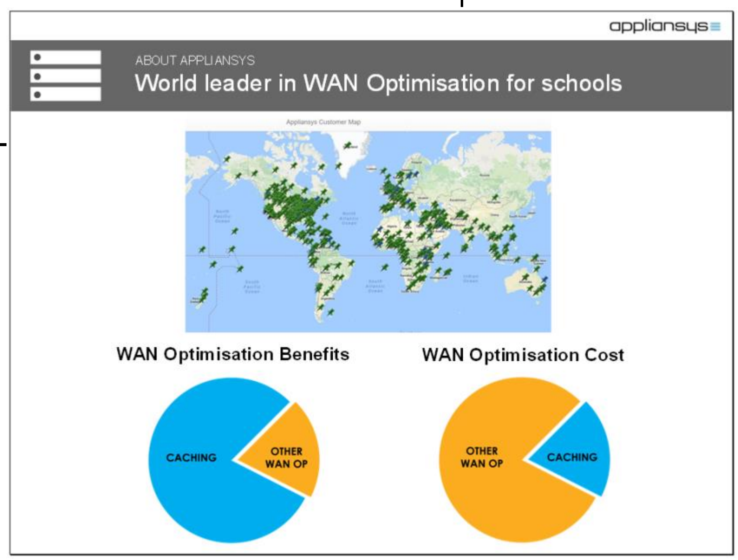

We have developed a range of WAN Optimization capabilities that we can select from in our work with Ministries of Education and corporations – including Compression, Traffic Shaping, De-duplication, Rate Limiting and caching.

Caching – happens to be both the most effective AND the most cost effective method of dealing with the schools use-case.

We estimate in K-12, caching delivers 80% of the value of all the WAN Optimization technologies 'basketed' together, accounting for just 20% of the combined cost.

Our caching appliance, **CACHE**BOX, has been the most widely selected caching solution by far in the E-Rate program since 2015. It is the only schools-focused solution in the sector that handles 'whole school' traffic patterns including HTTPS, software updates, online testing, video and LMS password protected materials.

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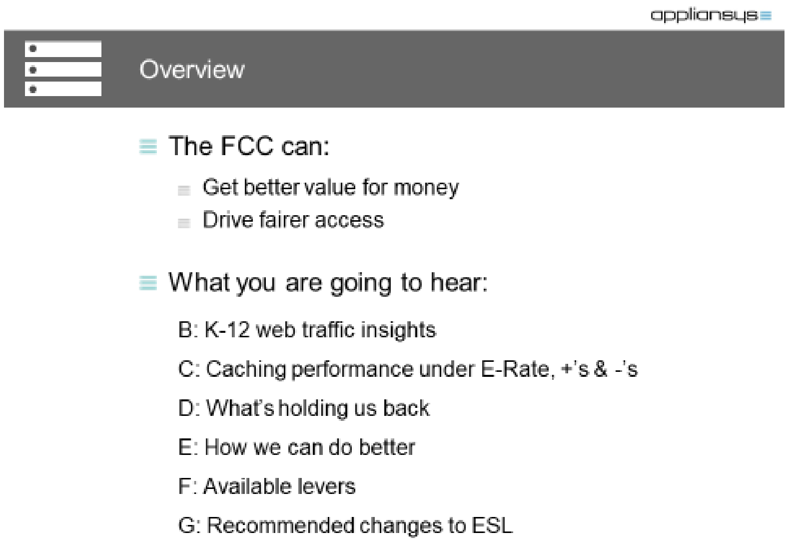

We advocate that the FCC can:

- Leverage more effective bandwidth per dollar
- Address cost-inefficiencies
- Ensure equitable access to digital learning under E-Rate program

We share our observations, analysis and real-world evidence on:

- Why modern K-12 web traffic mandates a re-think of the focus on bandwidth
- How the success of caching in schools is beyond initial expectations
- The factors behind broadband overspend, inequality of digital access and the slow uptake of caching
- Bridging the Digital Divide with better targeting of E-Rate funds
- Specific ways to effect change using the levers of funding, education and targets
- Recommended amendments to the ESL and recent proposals for FY2018 ESL

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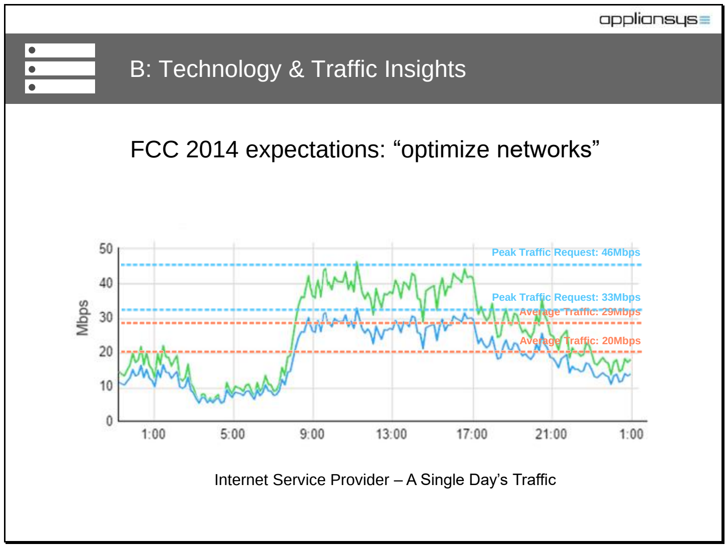

Though it seems intuitive that caching would help schools with insufficient bandwidth, we now have the data that the scale of the benefit is far reaching and considerably larger than many would have expected. And this doesn’t just apply to small rural schools.

Back in 2014, when caching was given eligibility for E-Rate Category 2 funding, the stated aim was broadly to optimize networks to support digital access.

In an enterprise or service provider environment that typically looks like the above chart – a proportion of traffic is served from cached memory. This saves about 20-30% of bandwidth use, and reduces the size of the external connection needed by the same 20-30%.

That’s what caching was understood to do – was expected to do: save a bit of bandwidth and serve, faster, anything that could be cached. For a rural school with 30% less bandwidth than needed, it was hoped that caching might fill that gap.

Mbps = Megabits per second
Gbps = Gigabits per second
(1Gbps = 1000Mbps)

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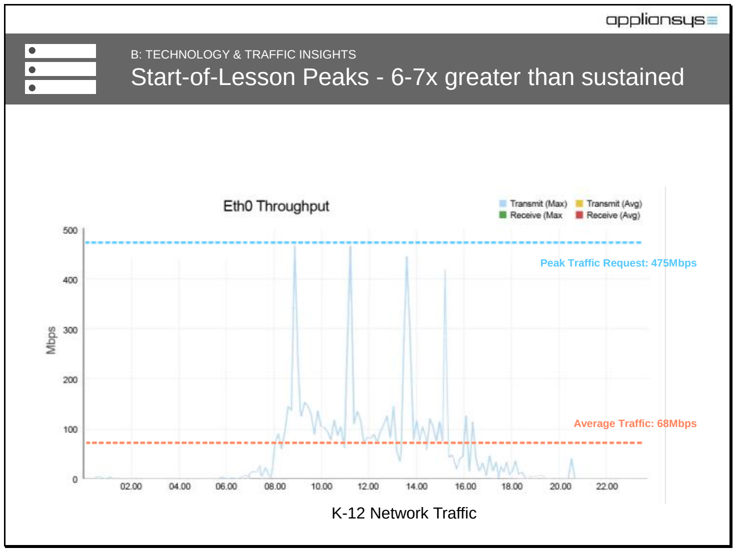

In fact, the traffic pattern in K-12 is fundamentally different, and as a result that’s not the outcome that we see from caching in schools.

K-12 schools have a very spiky traffic profile - with large peaks at the start of each lesson that drop back to a fraction of that demand for the rest of the lesson.

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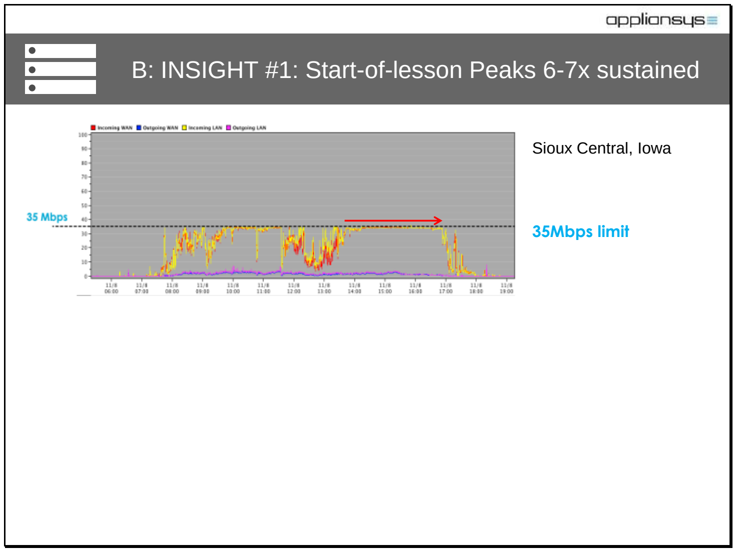

For those 24% of schools that are bandwidth constrained, it is those peaks that cause most damage.

If a school doesn’t have enough bandwidth to meet peak demand then congestion occurs; the Internet connection flat-lines as it did here at Sioux Central in rural Iowa (top graph). Teachers were simply unable to use the 35Mbps Internet for independent, Internet-enabled learning for their 600 students.

(Graphs provided courtesy of AEA - Prairie Lakes)

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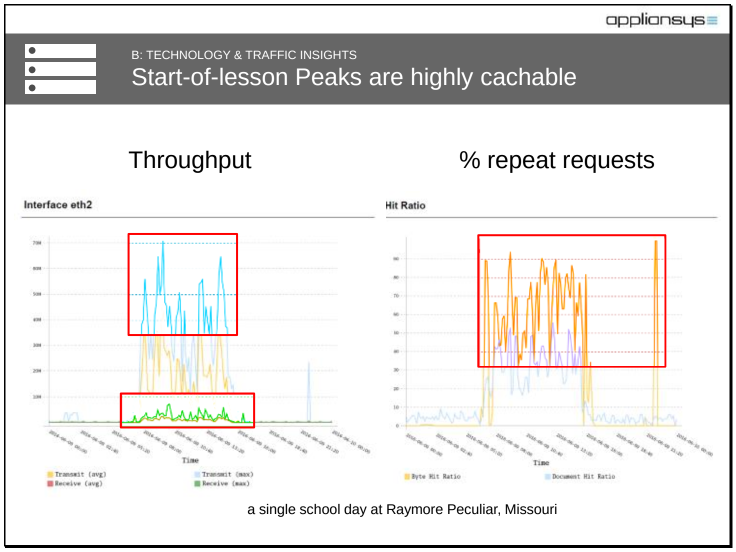

Those start-of-lesson peaks consist largely of repeat requests: whole classes of students all directed to the same content at the same time.

K-12 peaks are delivered very effectively by caching because they consist largely of repeat requests.

Peaks result from whole classes of students all directed to the same content at the same time.

Demand peaks (graph left) correlate closely with cachability (graph right). With the right caching solution, 90% or more of the bandwidth used from that set of repeat requests can be saved.

At Raymore Peculiar school (above left), the incoming Internet (green line at the bottom) is maxing at about 8Mbps of unique traffic, while (in light blue at the top) the demand - including duplicate traffic delivered by the cache - peaks at up to 70Mbps.

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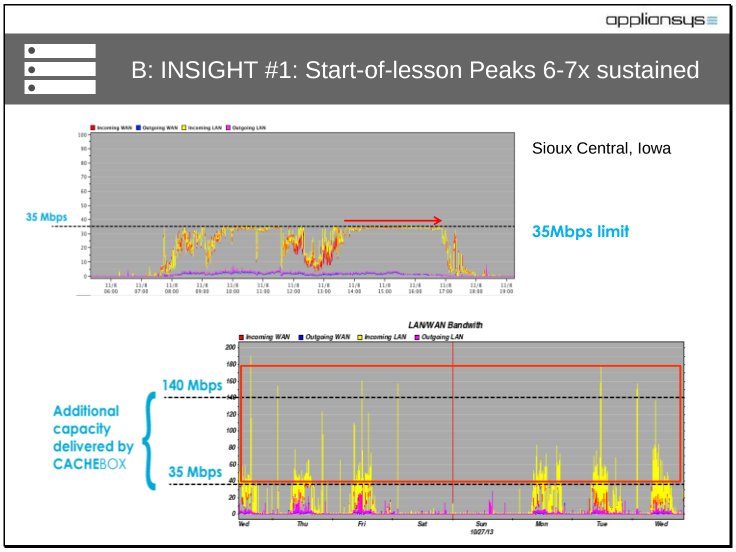

Back at Sioux Central, the district installed a cache which can be seen (bottom graph) responding to those peaks in requests, delivering up to 140Mbps – even towards 200Mbps – on that existing 35Mbps connection.

(Graphs provided courtesy of AEA - Prairie Lakes)

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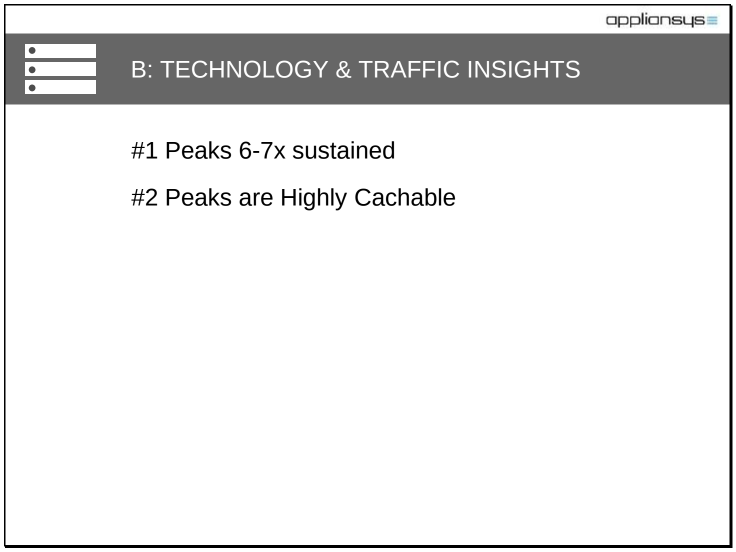

Start-of-lesson peaks are really significant to learning outcomes as their correct handling determines the viability of 1:1 Internet-enabled independent learning.

It is those peaks that define the amount of bandwidth capacity needed to prevent congestion and which result in poor ROI from annual bandwidth upgrades. They also lead to the remarkable impact that caching is having in schools.

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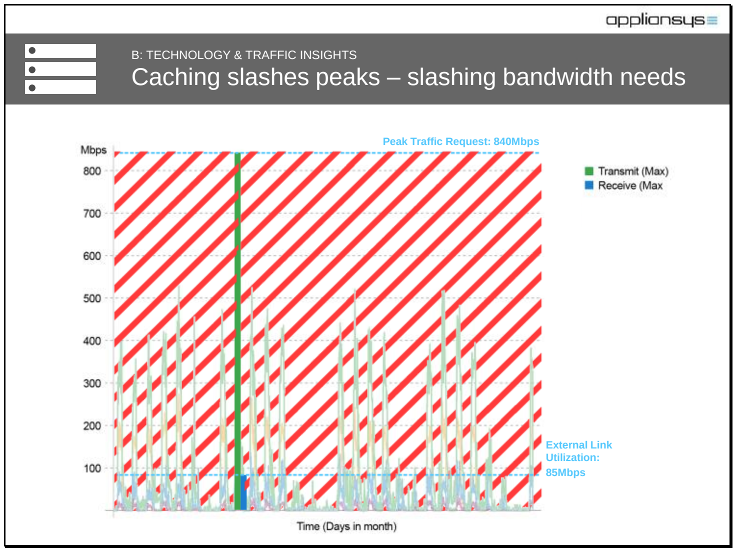

Those peaks in Internet demand are cut right down to size by caching.

St Paul Public Schools in Minnesota have caches in their largest high schools. They each have peaks in demand of around 800, 900, 950Mbps.

The example above is Central High – where green is the demand from the students and staff peaking at over 800Mbps – yet blue is what those users actually draw from the Internet – well below 100Mbps.

So with a cache, only 85Mbps capacity would be needed to deal with such demand spikes.

Without a cache, to meet that demand the school would utilize the bulk of a 1Gbps connection - JUST for those start-of-lesson peaks. In a year from now traffic growth would be expected to exceed the capacity of those 1Gbps links. And yet the majority of that capacity would be unused MOST of the time

The red shaded area, shown above, is the amount of unused capacity each high school would have if it purchased bandwidth to cover those peaks - without caching.

Without caching, this high school and the other 8 in the district would each draw around 1Gbps from the main Internet connection – so 9Gbps of their existing 20Gbps links would be already consumed.

As there are another 60 schools in the district, there wouldn't be enough capacity. Yet, with caching in place those external links are only 30-40% utilized.

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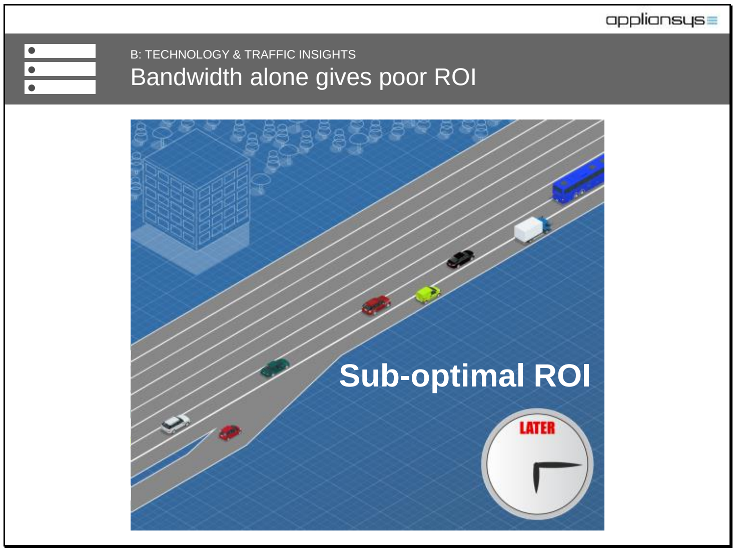

Using the analogy of highway infrastructure and periodic traffic congestion as an example, maintaining enough capacity to deal with enormous peaks that are momentary would mean masses of unused capacity – which somebody somewhere is paying for.

Consequently, it's not a great use of public money.

Bandwidth connectivity to cater for peak capacity demand does not deliver satisfactory ROI in K-12 because of the nature of this peak demand.

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So while Bandwidth alone gives poor ROI in schools because of the nature of those peaks.

The existing approach to connectivity targets compounds that, because it doesn’t take into account the impact of caching and seems - on this analysis - to be completely at odds with value-for-money

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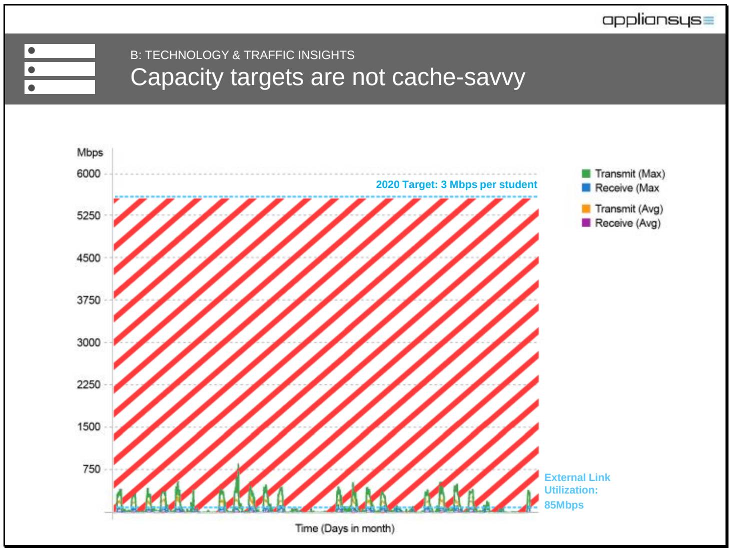

The 1Mbps/student connectivity target for 2018 for this school is drastic against this backdrop of potential waste (red shading).

For a school like this which utilizes caching to deal with peak web-traffic demand, clear that the 2020 /student target of 3Mbps simply don't take that caching into account.

When considering this 2020 target for the same school (shown above, wastage in red shading) the potential for unnecessary costs is immense.

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That existing approach to connectivity targets is also, in part, responsible for the enormous collateral cost in prematurely upgrading other network equipment.

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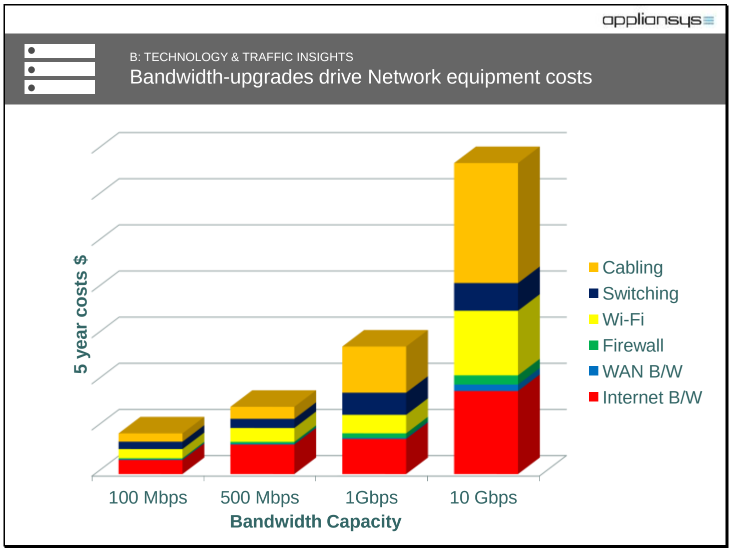

If you allow bandwidth capacity to grow out of control, money isn't just wasted on the cost of the external connection itself.

Many districts opt for caching to avoid a bandwidth increment that will take them over some throughput threshold with their firewall or filter systems - which would then need to be upgraded – the costs involved can be huge at key thresholds such as 100Meg, and 1Gig.

If the next bandwidth capacity upgrade can be delayed by a year or more, those savings are substantial.

The evidence shows that just about every school district in the nation should be able to delay either their currently planned bandwidth increment or the following one, and get another year's life out of their current connection and network investment.

Realised across the nation, that's billions of dollars. And it's not a one-off hit either – caching extracts the most value out of the next increment, and the one after that. Districts that have been using our caches since 2010 like Sioux Central in Iowa and Woodland in Chicago are several increments in to those savings.

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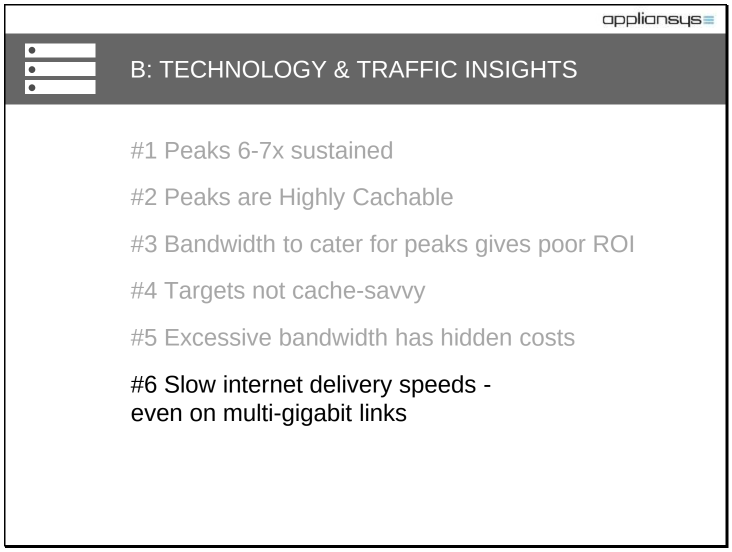

But let's put the cost aside for a moment and focus on functionality — does the annual bandwidth upgrade guarantee schools the snappy and responsive browser performance that modern teaching and learning demands?

The simple answer is no.

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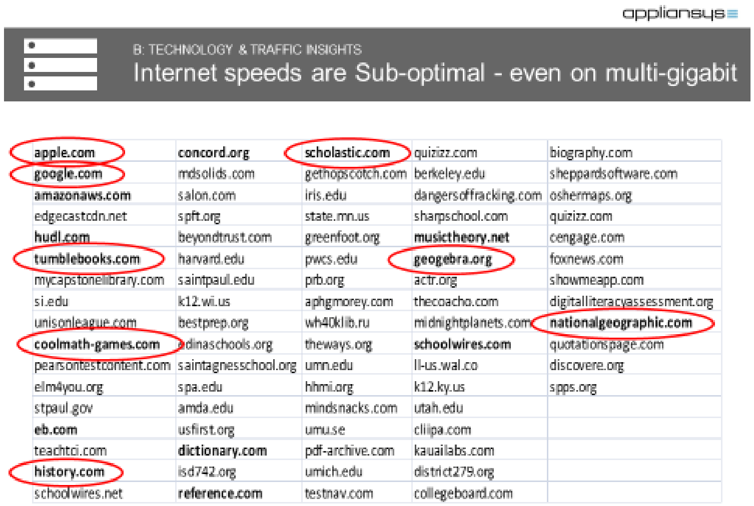

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history.com	isd742.org	umich.edu	district279.org	
schoolwires.net	**reference.com**	testnav.com	collegeboard.com	

Here's the top 80 websites being used in classrooms at Washington High in Minnesota and <u>all of these are accelerated by caching</u> - generally 10-20x faster – even though this is on a multi-gigabit connection

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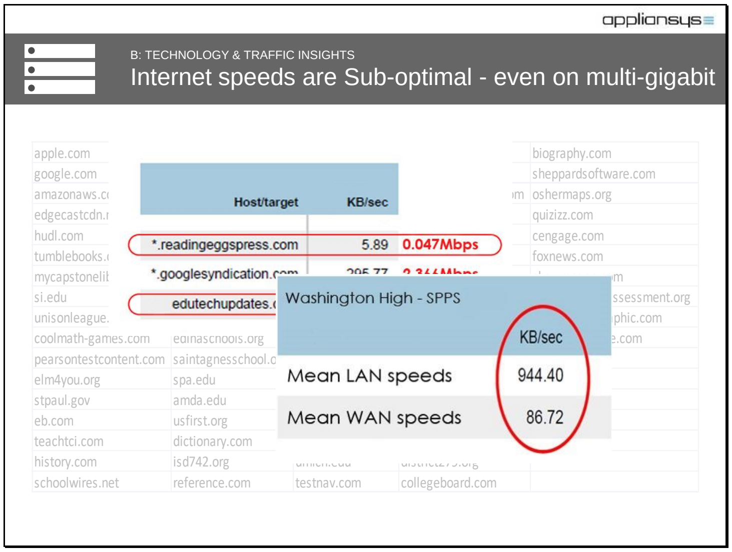

In a single typical high school (Washington High in Minnesota):

- hundreds of Educational sites are accessed in just a single day
- that content arrives at the network edge at a huge variety of speeds – some extremely slow, even when their 10Gbps link is completely underutilized

Caching serves that content at LAN speeds, typically 10-20x faster, often far more, even on a 10Gbps Internet connection

Let’s just put this speed into context - just 3 seconds average page load means you have 5% less time to answer questions in an online arithmetic test than students in a district with lightning fast browser speeds. And accumulated browser wait at those relatively modest levels can account for more than a week of lost teaching & learning time in a high school career.

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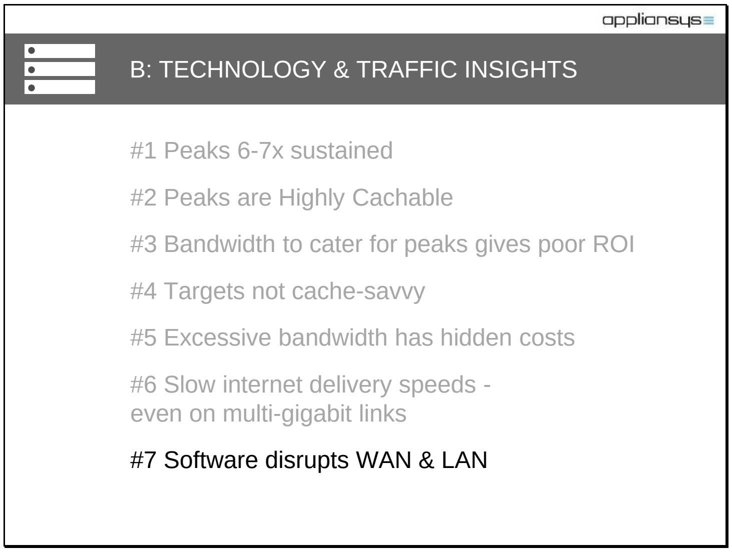

We now have comprehensive data on software downloads that they have emerged over the last decade as a significant driver of bandwidth growth. But they don’t just consume bandwidth; they are also a menace to Wi-Fi networks.

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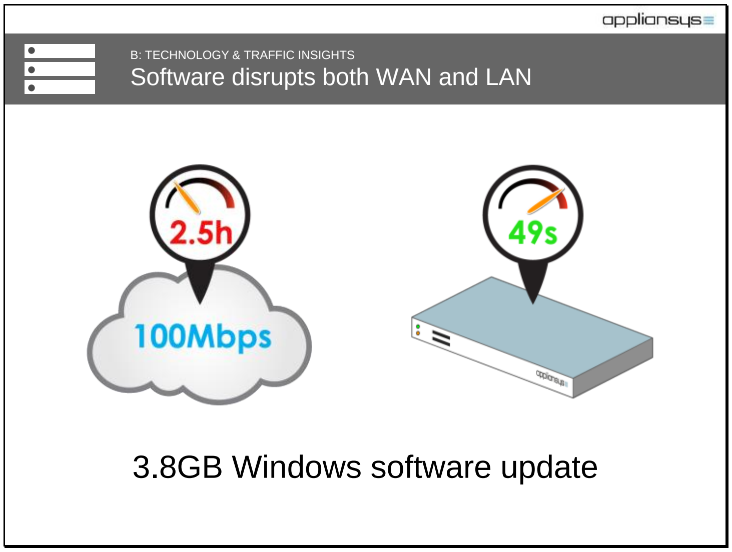

Our data show that this is not just down to their sheer size and number, but also to the slow speeds at which they are delivered – speeds that are slow regardless of how much bandwidth you throw at them.

In networks with appropriate caching, massive objects like multi-gigabyte Windows update files get clear of the LAN in seconds.

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B: TECHNOLOGY & TRAFFIC INSIGHTS

#1 Peaks 6-7x sustained

#2 Peaks are Highly Cachable

#3 Bandwidth to cater for peaks gives poor ROI

#4 Targets not cache-savvy

#5 Excessive bandwidth has hidden costs

#6 Slow internet delivery speeds -
even on multi-gigabit links

#7 Software disrupts WAN & LAN

These insights then, help us to identify the underlying features of caching performance in schools and marshals those outcomes into 4 groups.

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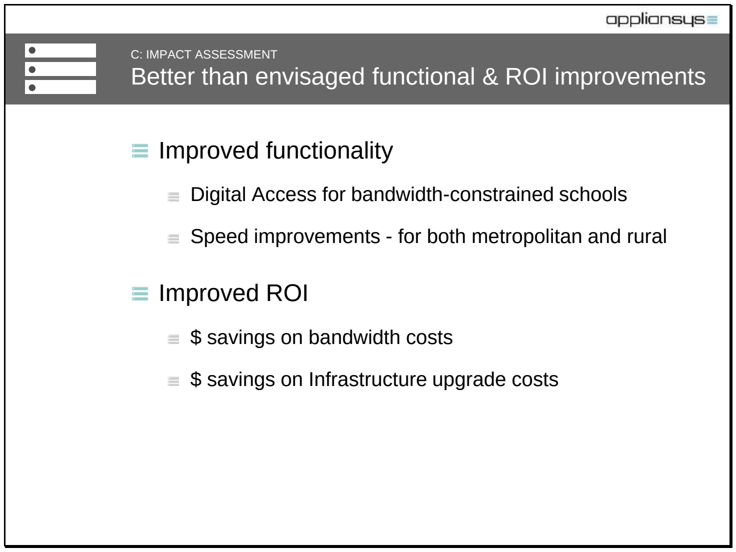

And here are those groups. Two of them are around improving broadband functionality and two capture the key cost savings

We've provided an Appendix at the back this submission in the form of a dossier of case studies that illustrate each of these.

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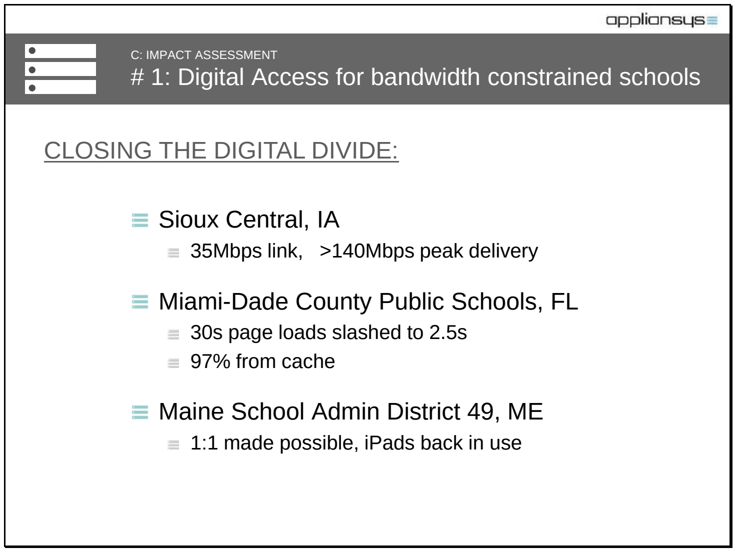

Here’s a short summary of each:
In terms of improved broadband functionality, there are many examples of rural schools where broadband simply didn’t support Internet-enabled independent learning. With the deployment of a cache things were transformed: changing the life-chances of pupils in rural communities at a stroke.

EducationSuperHighway estimates that 24% of students in remote schools across the US are on the wrong side of the Digital Divide.

See Appendix for a detailed dossier of the results of these and other schools.

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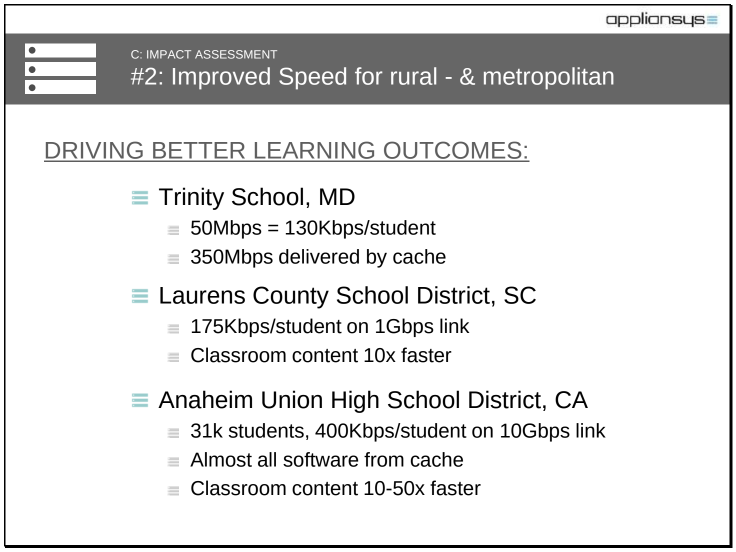

It's not just bandwidth-constrained rural schools that benefit from competitive browser speeds. Those with seemingly high bandwidth capacity like Trinity School in Maryland also gain vastly accelerated content.

More surprising is that even large metropolitan districts like Laurens County, St Paul Public Schools and Anaheim Union on a 10Gbps link are extracting enormous benefit from caching with classroom content between 10 and 50x faster than without.

See Appendix for a detailed dossier of the results of these and other schools.

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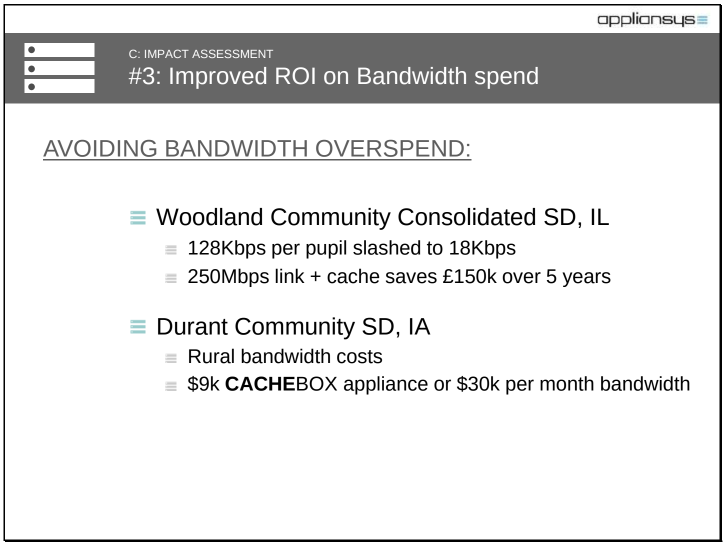

Beyond functionality there is a reduction in costs.

Woodland in Chicago saved more than $100k over 5 years by deploying a cache on their 250Mbps link.

Durant in Idaho deployed a cache instead of a bandwidth upgrade which would have cost $30k/month, 100x more than the cache!

We estimate that most school districts in most states could slash the cost of their local connections, and, on top of that, the State Departments of Education and AEAs could save $millions per year on backbone costs.

See Appendix for a detailed dossier of the results of these and other schools.

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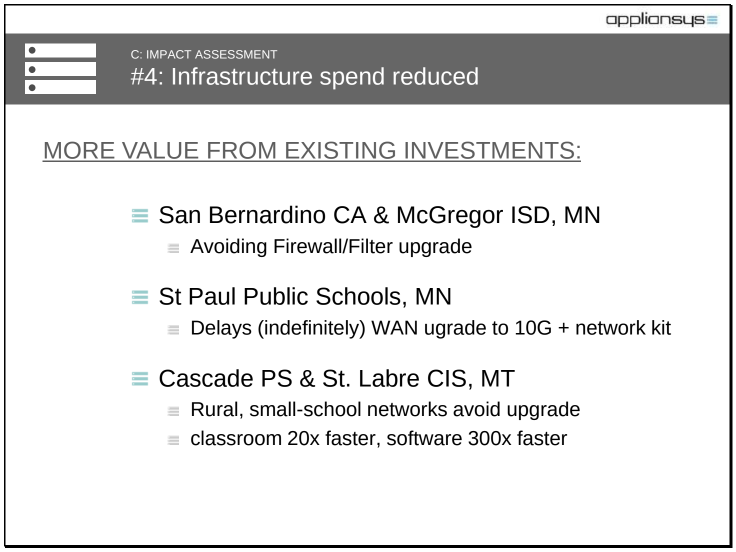

The last group of reported benefits encompass reductions in infrastructure spend as a result of deploying a cache, affecting very large districts like San Bernardino in California and countless smaller districts like McGregor ISD in Minnesota – all avoiding infrastructure and network kit upgrades.

Above the 1Gbps threshold, upgrade costs can be monumental. External connections and network equipment with 10Gbps capability is required, causing phenomenal waste.

At St Paul Public Schools the 1Gbps WAN that looked close to capacity has now had many years of additional life breathed back into it.

At the other end of the spectrum, those rural schools on the wrong side of the digital divide can persist with sub-100Mbps connections for several more years, yet gain cached content delivered at many times that speed.

See Appendix for a detailed dossier of the results of these and other schools.

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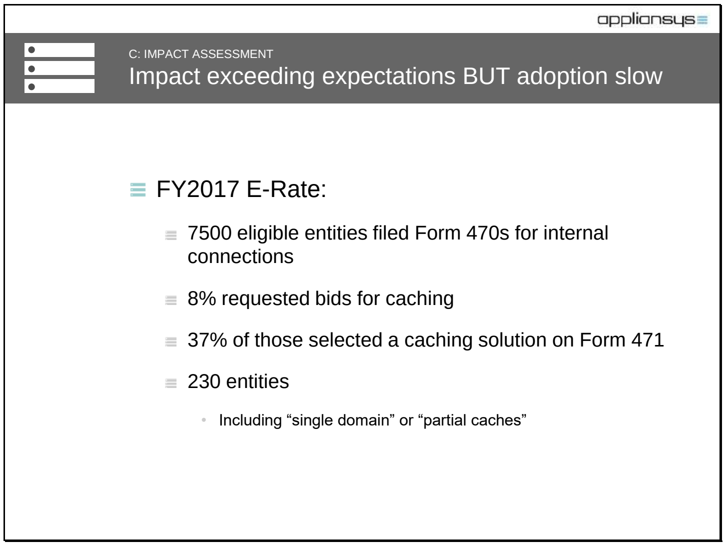

Yet despite the results surprisingly few schools are utilizing E-Rate funding to implement caching.

We estimate that:

- Only about 8% of over 7,500 eligible entities that filed Form 470s then requested bids for caching
- Only 37% of those actually selected a caching solution

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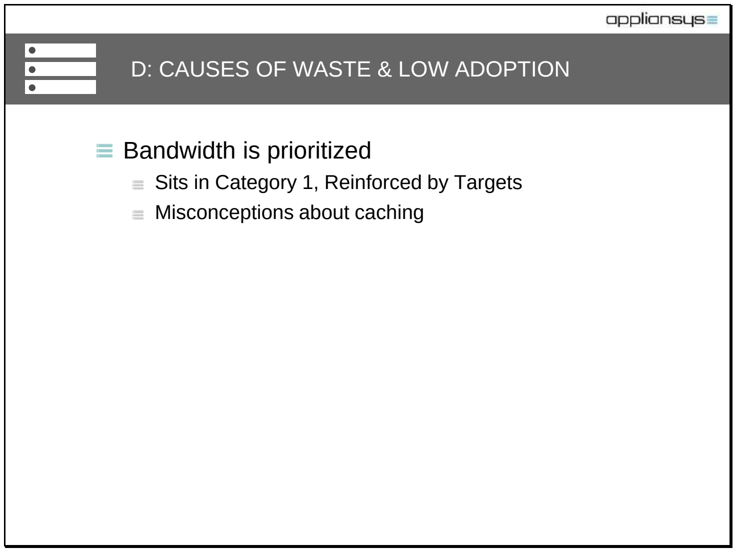

Talking with Technical Directors over the last year at ISTE, TCEA, and regional and state Ed Tech conferences, there are some clear reasons why take-up has been slow:

- To some extent, the odds are stacked in favor of broadband overspend.
- Bandwidth is prioritized – it's in Category 1 – priority 1
- The status quo is reinforced by Connectivity Targets, the efficacy of which, on this analysis, looks to be questionable.
- In addition many schools are unaware of what caching can deliver today.

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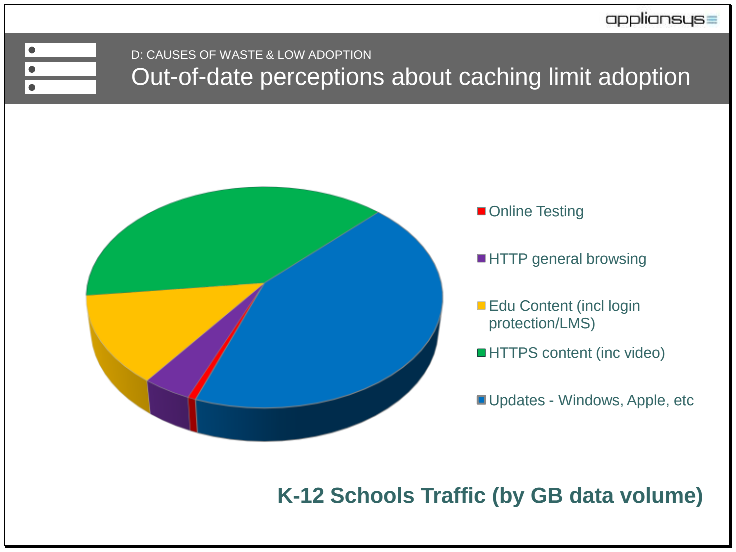

Based on their experience with expensive corporate caches a decade ago some technology teams assume that caching isn't capable of very much, thinking that if it didn't work particularly well back then, it can't possibly do a great job now, with web-traffic immensely more complex today.

They are surprised to hear that a modern cache can handle:

- HTPPS - a principal component of e-learning content
- More complex modern traffic and dynamic content
- LMS 'single sign-on' and other Login-protected materials
- Video and software updates

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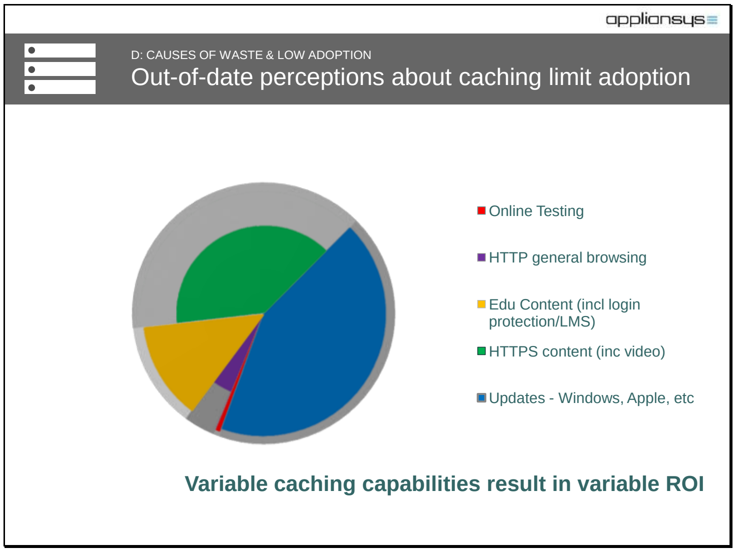

Many materials can be pre-fetched – loaded into memory before they are needed. It's not unusual for 95% or more of educational content, software updates and online testing to be delivered from cache.

That's great news for online testing – with a more flexible and responsive process and potential for massive reduction in expense compared with administering paper tests.

It needs to be remembered though that online testing accounts for a very small proportion of school bandwidth. So, while caching of testing materials is important and welcome in States where it is cacheable, it doesn't make a significant impact on the individual school's overall bandwidth or day-to-day teaching and learning demands.

Similarly a cache that acts only on a single application or website, or a single software type, will need careful ROI consideration to make a sensible comparison with bandwidth capacity, or indeed other caching solutions.

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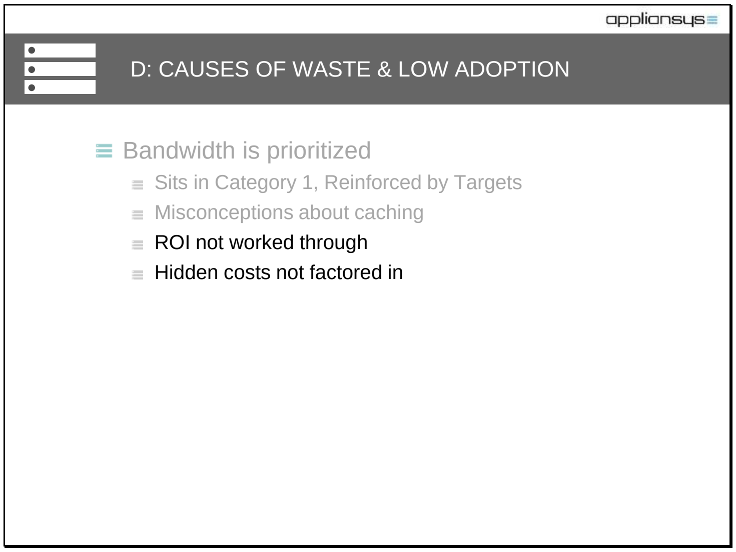

Consequently the ROI of bandwidth purchases is not properly considered: the hidden costs of bandwidth upgrades are discounted or unknown, and the benefits that caching can deliver are not considered.

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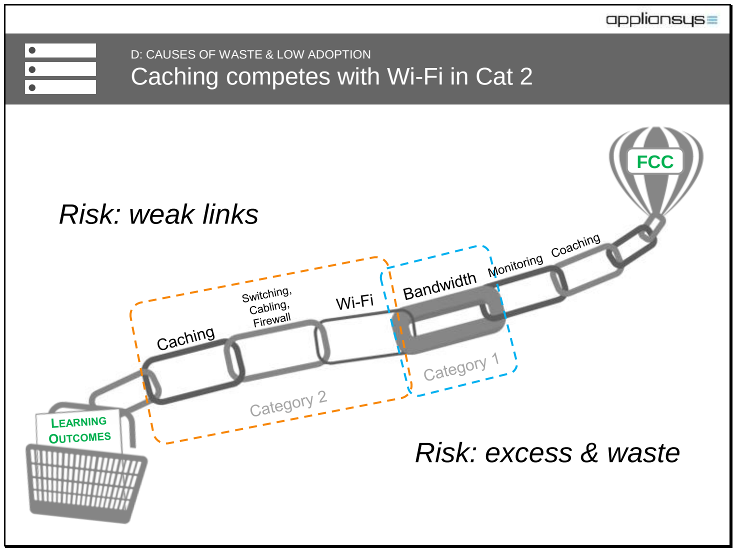

The elements needed to properly support a modern Internet-enabled independent learning environment are described in some detail by the likes of Project RED. And comprehensive, itemized project lists are shared by K12 tech innovators across the US at State Ed-tech conferences.

Because caching competes for funding with Wi-Fi, we risk under-resourcing those network functions, while conversely leaving Bandwidth in its own category risks overspend.

St John County School District in Florida has 32k students spread over 39 schools; the district implemented caching, only to find that the old Wi-Fi setup was then a bottleneck.

More commonly, schools put off caching until they have sorted out their Wi-Fi.

The e-learning network is an interdependent ecosystem; everything needs to be in balance. There's no value in pumping up one link in the chain disproportionately to the others, because it's the weakest link that will define capability limits.

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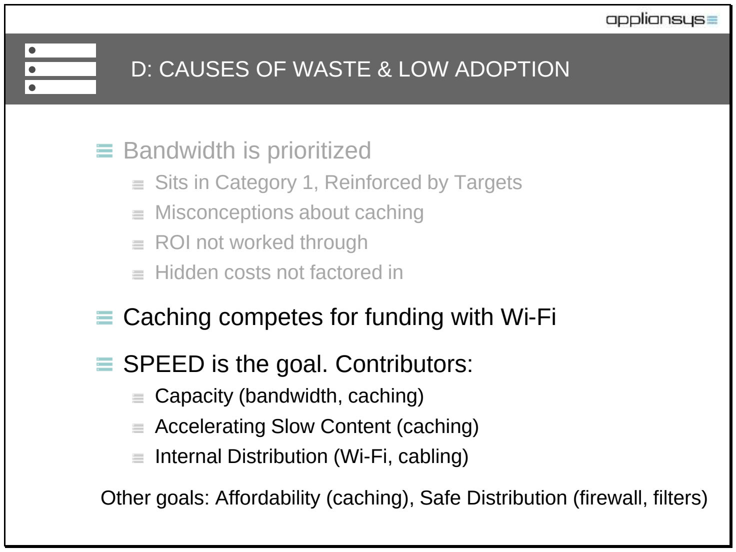

In fact, *capacity* is not the real goal - *classroom browser speed* is.

Capacity is *a contributor* – along with *accelerating slow content* (through caching), and *internal distribution* (through Wi-Fi).

Affordability is another goal and caching is also a key contributor to that. Bandwidth is not.

Meanwhile, excessive bandwidth has no positives.

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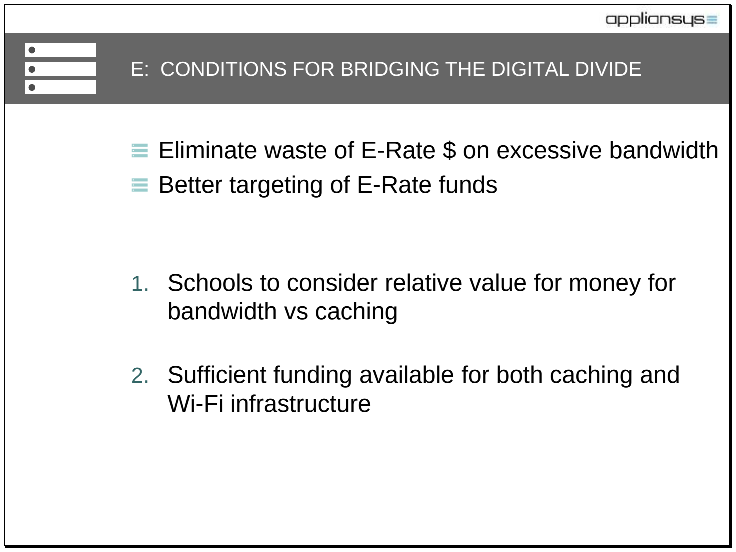

So for caching to properly contribute to closing that Digital Divide, the key outcomes that are needed are firstly for:

- districts to base their bandwidth upgrade decisions on a proper sense of relative value for money.
- funding for caching to be as readily accessible as funds for bandwidth.

We need to ensure that schools can put in place adequate Wi-Fi AND caching, and not be forced to choose between the two.

Competition for funding between bandwidth and caching on the other hand might be a thoroughly constructive development.

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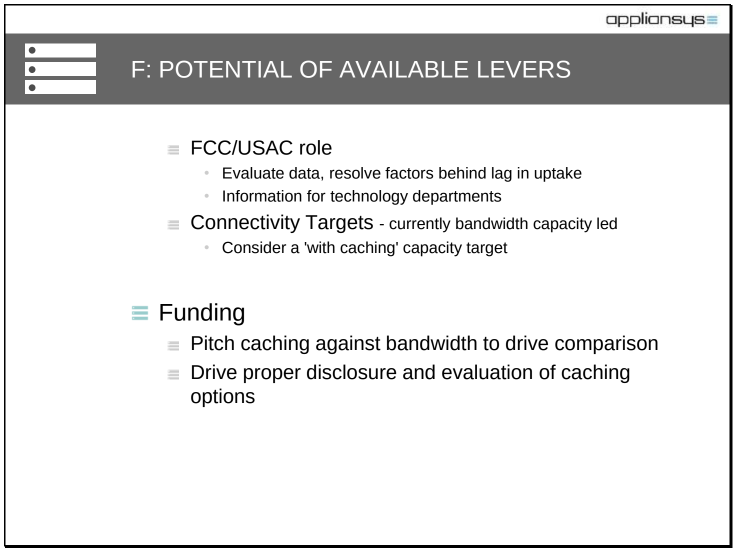

There are potential levers that could be utilized in conjunction with adjustments to funding frameworks, including the dissemination of suitable advice and guidance, in which the FCC and USAC could actively support.

It may be possible to adjust targets and develop a more nuanced approach to the annual bandwidth upgrade cycle.

Our written submission of 21st July 2017 raises questions and makes suggestions regarding this.

Our main focus in this dialogue is Funding.

Currently, there’s a de facto bias towards broadband overspend which we contend could be checked by adjusting Funding frameworks to pitch bandwidth against caching and drive a comparison of ROI in the decision-making process.

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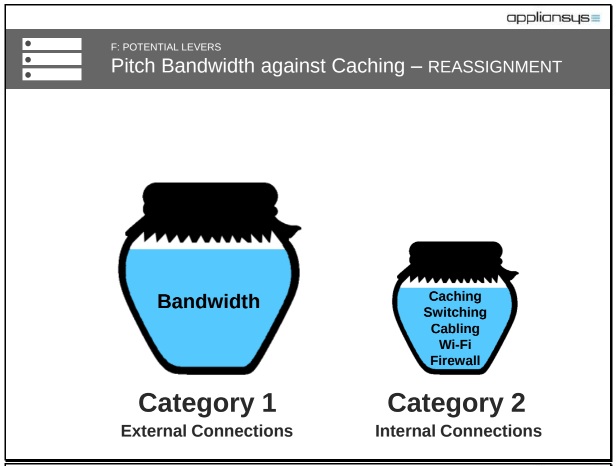
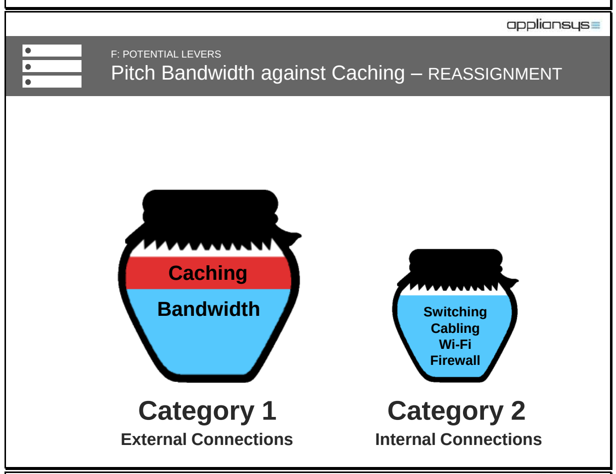
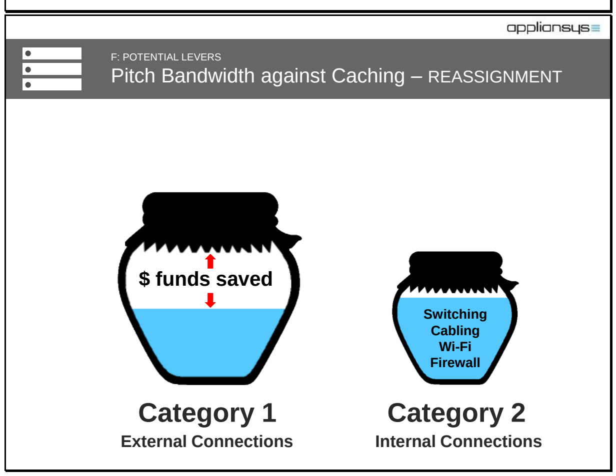
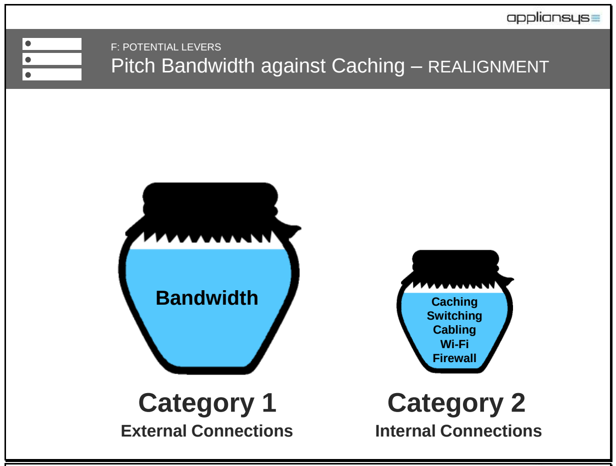


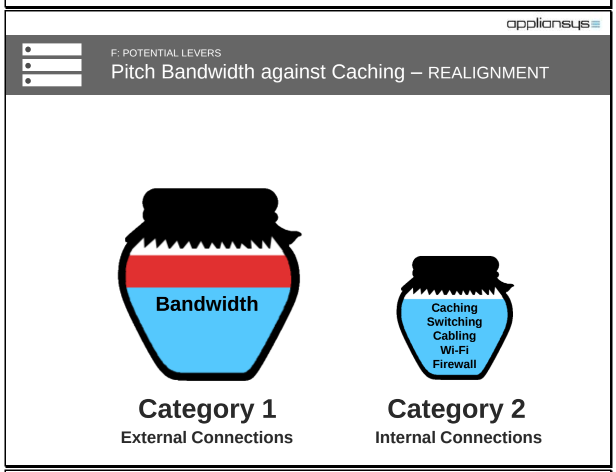


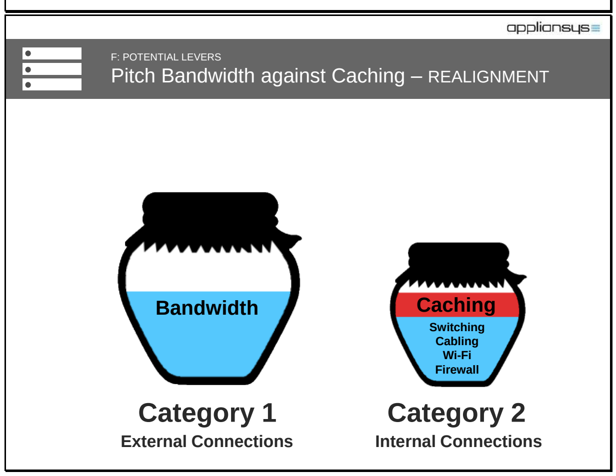


Scenario 1 - Move caching into Category 1 so schools would have to choose between them.

Slide 37







Scenario 2 - Cut Category 1 allocations globally and increase Category 2.

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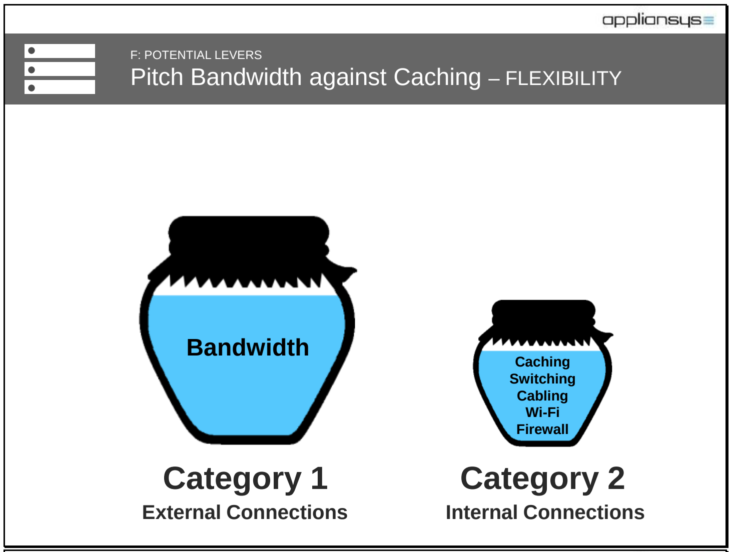

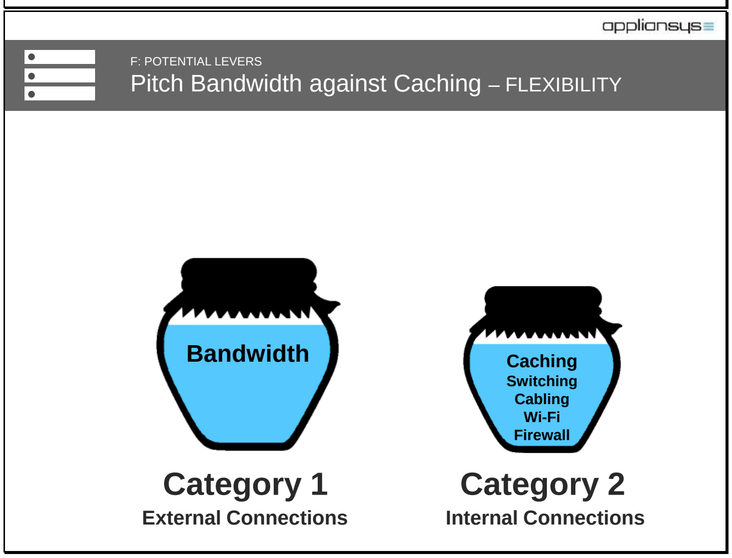

Scenario 3 - Transfer some budget from Category 1 to Category 2 at the individual entity level (if a school chooses to not upgrade their bandwidth you allow them to roll a proportion of that across to their Category 2 allocation)

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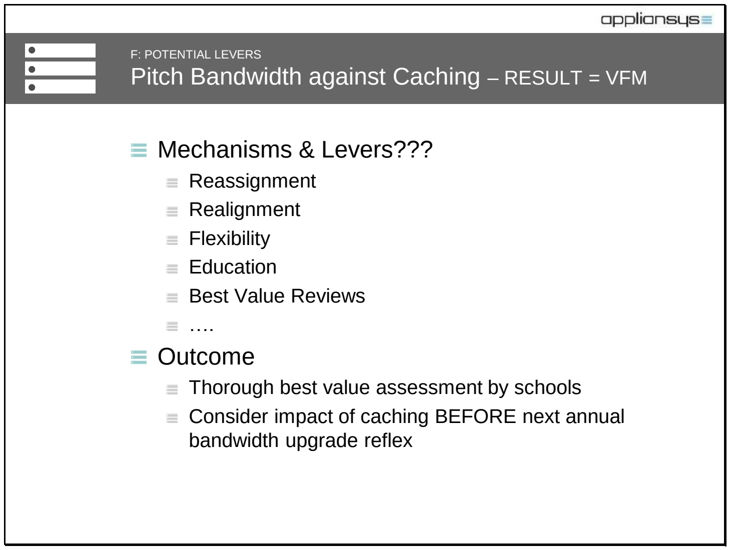

Which possible mechanisms and levers would be the most effective, and that could be achieved in the shortest timeframe is for the Commission to assess.

But with value for money a desirable outcome for the FCC, schools must be encouraged to do a thorough job of calculating best value – making sure that suitable caching technologies have been assessed before any funds are committed to upgrading bandwidth and its supplementary costs.

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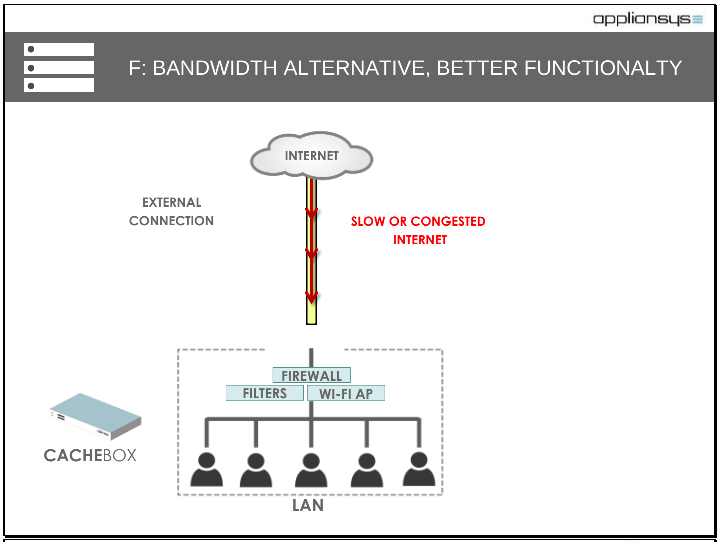
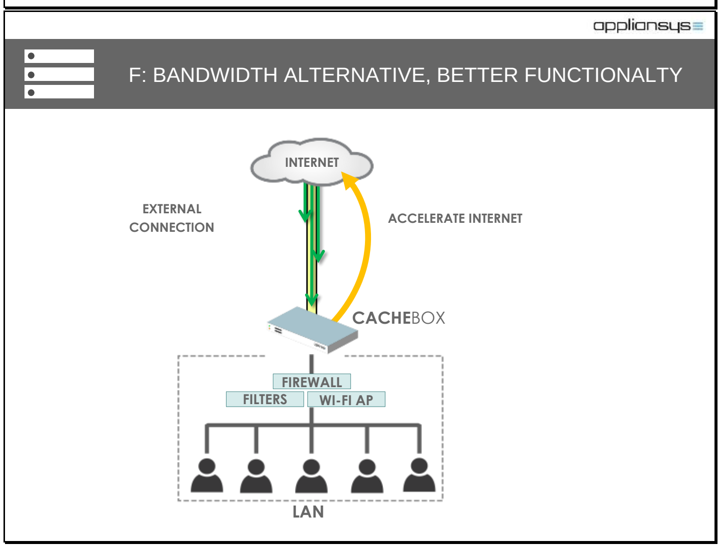




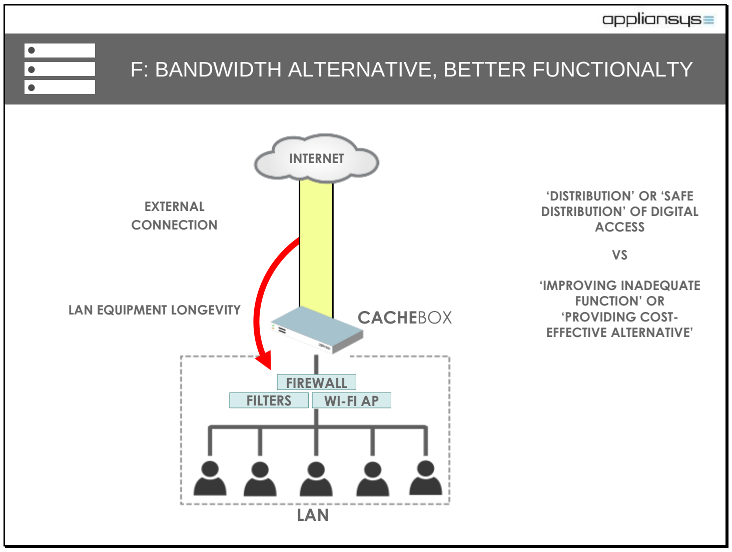
There appears to be reasons in favor of the first of those scenarios – Category 1 eligibility for Caching.

A number of network technologies could lay claim to being “essential” for the correct functioning of External Links and therefore to being considered eligible for Category 1.

But caching has the right credentials for this: Caches do indeed functionally - and usually topologically as well - sit between the external link and on-premises Category 2 LAN equipment.

Their primary functions are:

1. To accelerate slow web-content being requested down the External Connection – improving broadband functionality even on multi-gigabit links.



2. To provide a cost-effective alternative to a bandwidth upgrade – reducing the amount of bandwidth capacity that needs to be maintained.

In so doing caching helps schools to avoid the associated costs of network equipment upgrades.

So - while Wi-Fi and other Category 2 LAN devices either *distribute* or *ensure the safe distribution* of digital access provisioned by Category 1 external connections, caching both *improves the functionality* of existing links and is *a replacement* for a needed increment of bandwidth.

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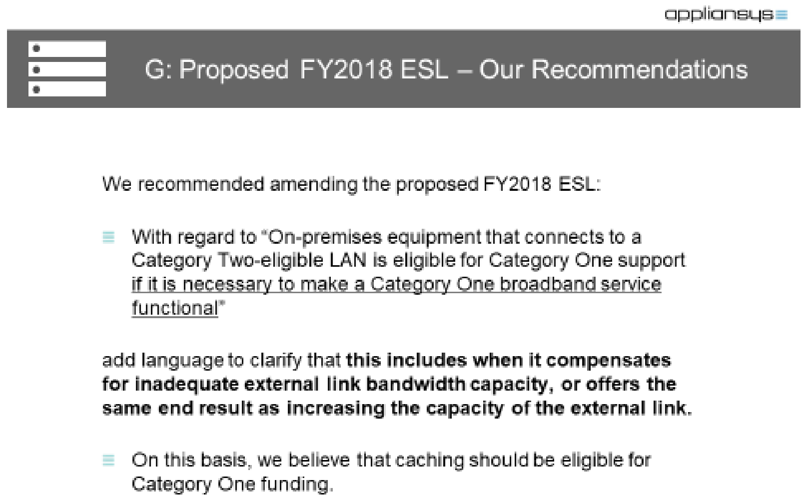

Taking the opportunity offered by the request for comments on the draft FY2018 ESL, we argued that a means to drive better value for money in Erate would be to designate caching as Category1 in order to force schools to do a better job of evaluating broadband spending –

We thought that the clarifications under consideration around mixed eligibility equipment could be the fastest and simplest vehicle for pitching bandwidth up against caching in order to deliver widespread savings and at the same time improve connectivity for rural schools.

We offered a suggestion for additional clarifying language: that Category1 support would be available where the equipment is necessary to make broadband functional, **including where it compensates for inadequate link capacity, or offers the same end result as increasing the capacity of the link.**

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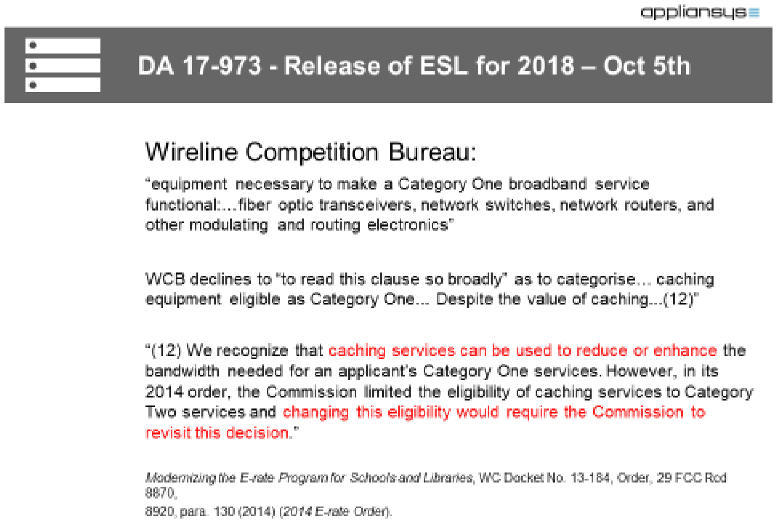

The WCB said that while they recognized that caching services can be used to reduce or enhance external connections, because the Commission had designated caching as Category 2, it was up to the Commission to change that.

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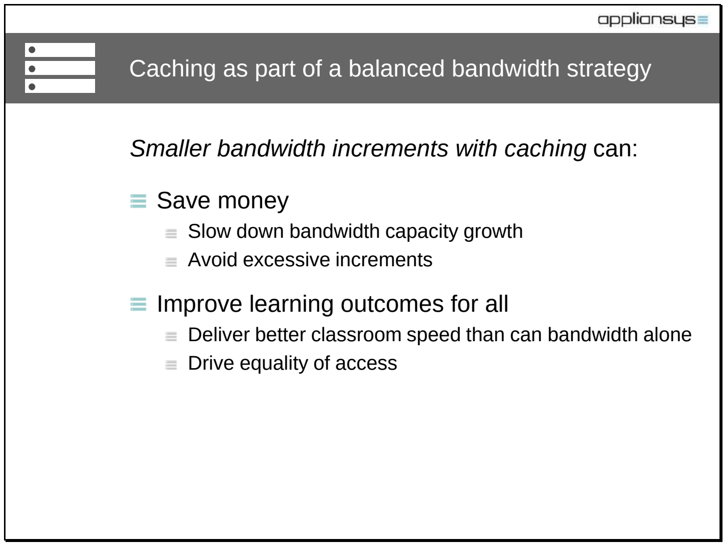

The 2014 Modernization Order was a little hesitant and conceived of ‘potentially’ optimizing networks. In fact it is clear that because of the nature of start of lesson peaks, caching in schools can be a substitution for broadband. And, used in conjunction with moderate bandwidth upgrades, delivers both better ROI and better speeds than broadband-only regimes.

If the FCC and the schools sector can address the challenge, and drive a proper value-for-money assessment of the options before increasing bandwidth, the evidence says that we can close that digital divide, and move on to focus investment on the other priority items that will elevate learning outcomes for our young people.

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APPENDIX for Section C

A dossier of case studies illustrating the 4 key performance and value performance outcomes of caching deployment in K-12:

Improved functionality

- 1: Digital Access for bandwidth constrained schools
- 2: Speed improvements - for both metropolitan and rural

Improved Return on Investment -

- 3: $ savings on bandwidth costs
- 4: $ savings on Infrastructure upgrade costs

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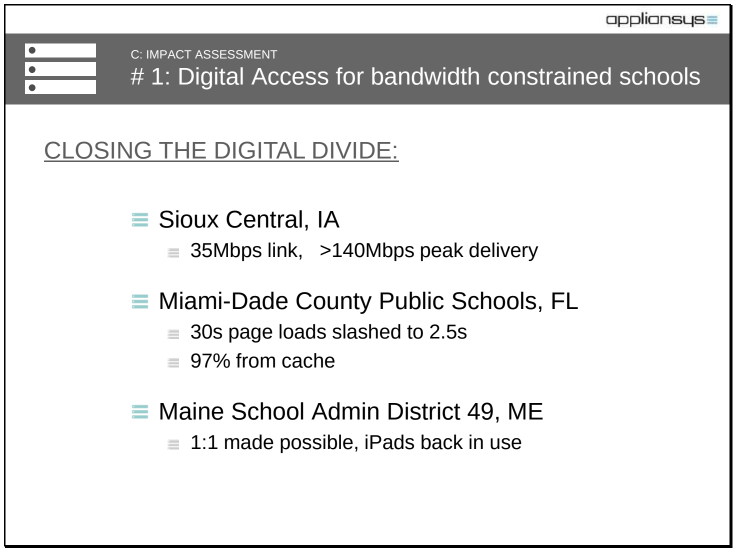

In terms of improved broadband functionality there are many examples right across the country of rural schools where broadband simply didn't support Internet-enabled independent learning.

This was transformed by the deployment of a cache – at a stroke changing the life-chances of pupils in rural communities and remote schools in most States.

(Education Super Highway refers to 24% of all students being on the wrong side of the digital divide.)

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C: Assessment of Impact of Caching in US K-12

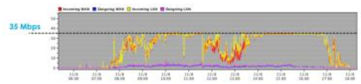
Improved Functionality: Access for Bandwidth constrained

Sioux Central Community SD Profile

613 students | 3 schools | Small, Remote

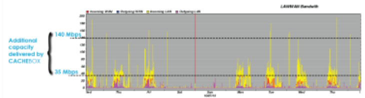
Challenge

- Simultaneous start of lesson video access was too slow in the classroom
- Remote location means bandwidth cost is prohibitive
- Peak traffic demand regularly exceeding 140 Mbps despite existing 35 Mbps connection



Impact of caching

- Serving content locally at LAN speed, drastically slashed load times
- Serving repeat video content from cache enabled peak traffic demand to be handled comfortably



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C: Assessment of Impact of Caching in US K-12

Improved Functionality: Access for Bandwidth constrained

Miami Dade County Public SD Profile

322,000 students | 462 schools | some 4-10Mbps WAN links

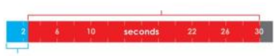
Challenge

- 220 district schools are remote with small external connections
- Constant traffic congestion and latency meant lost learning time reaching many minutes in just a single lesson

Impact of caching

- Serving content locally at LAN speed, drastically slashed load times
- Serving content from cache also freed up precious bandwidth, making the 3% of dynamic content not served from cache also much faster to load.

Caching can help provide equitable access to accelerated e-learning in remote schools.



	Requests	Total Load time
Without Caching	30 requests @ 1 sec each	30 seconds
With CACHEBOX	1 original file @ 1 sec + 29 requests @ 0.05 sec	2.45 seconds

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C: Assessment of Impact of Caching in US K-12

Improved Functionality: Access for Bandwidth constrained

Maine School Administrative District Profile

2,114 students | 6 schools | 95Mbps (former connection)

Challenge

- 1:1 unsuccessful on existing bandwidth link of 95Mbps. Teachers and students had to stop using iPads
- Large file downloads - like software updates – caused internet to become unusable

Impact of caching

- Bandwidth hogs taken off the WAN – cached and served locally
- An average of 42% of content was served from cache for H1/2017, a significant bandwidth saving
- Speed increase spikes of up to 400x for specific content

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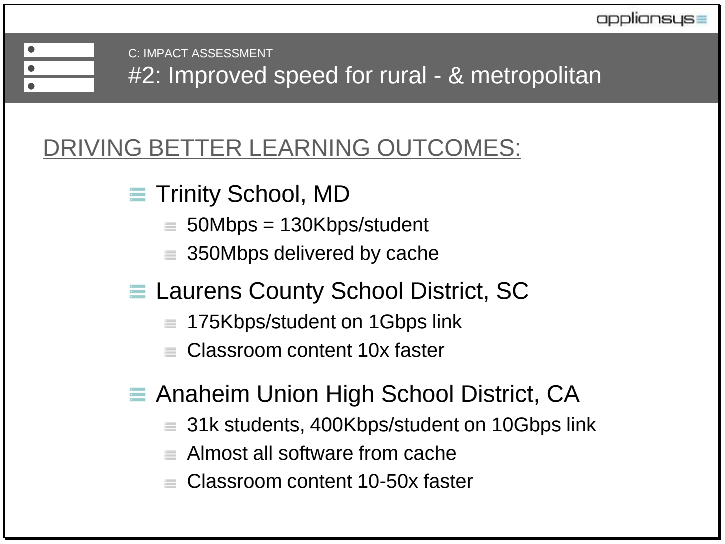

It’s not just bandwidth-constrained rural schools that benefit from competitive browser speeds. Those with seemingly high bandwidth capacity like Trinity School in Maryland get vastly accelerated content too.

What may be even more surprising is that even large metropolitan districts like Laurens County, St Paul Public Schools and Anaheim Union (on a 10Gig link), are extracting enormous benefit from the acceleration that caching provides - with classroom content between 10 and 50 times faster.

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C: Assessment of Impact of Caching in US K-12

Improved Functionality: Speed for rural - & metro

Trinity School, Maryland Profile

382 students | 1 school | 50Mbps connection

Challenge

- 50Mbps Internet connection maxing out most of the day due to students accessing media content on 1:1 iPads, Windows laptops and PCs
- No options for additional bandwidth, reached limit

Impact of caching

- Now getting throughput peaks up to 350-400Mbps from Cache
- Content vastly accelerated
- 'If you have any issues with bandwidth, this is a good product to consider. I would buy it,“ David Godfrey, Trinity School

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C: Assessment of Impact of Caching in US K-12

Improved Functionality: Speed for rural - & metro

Laurens County SD Profile

9 Schools | 5,718 Students | Rural | 1Gbps

Challenge

- 1:1 learning rolled out to each of its 10 schools
- Despite bandwidth upgrade to 1Gbps, content was still slow in the classroom. ‘Coolmath’ access in particular not responsive enough

Impact of caching

- Now caching and serving content over 10x faster on average – and almost 14 times faster for ‘Coolmath’ content.

VOLUME of DATA			
Status	Transfer	% of total	KB/sec
TCP_HIT	302,752.11MB	25.0%	944.40
TCP_MISS	554,805.73MB	45.8%	86.72

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C: Assessment of Impact of Caching in US K-12

Improved Functionality: Speed for rural & metro

Anaheim Union HSD Profile

23,700 students | 20 schools | 10 Gbps connection

Challenge

- Despite a 10Gbps connection critical E-learning content still arrives slowly in classrooms causing delays in learning performance

Impact of caching

- Apex Learning is served 48x faster from cache than from the internet
- SparkNotes is served 35x faster
- PrimaryGames.com is served 27x faster
- HistoryontheNet.com is served 10x faster
- Up to 58% of content monthly is being served from cache

Domain	From Web (Mbps)	From CACHEBOX (Mbps)	Speed increase (times)
*.apexlearning.com	0.97	47.05	48.5
*.sparknotes.com	0.16	5.78	35.8
*.lkqd.net	0.46	16.47	35.8
*.rosettastone.com	1.23	38.22	31.0
*.primarygames.com	1.01	28.18	27.9
*.aeries.com	3.32	51.41	15.5
*.primarygames.com	2.40	29.96	12.5
*.unity3d.com	0.21	2.50	12.1
*.mcafee.com	3.64	42.49	11.7
study.com	0.96	10.62	11.1
*.historyonthenet.com	2.12	22.85	10.8
*.anaheim.net	4.06	39.75	9.8
*.googlevideo.com	6.80	54.69	8.0
*.autodesk.com	6.72	45.53	6.8
*.macromedia.com	9.47	43.84	4.6
*.mhpracticeplusap.com	8.88	31.98	3.6

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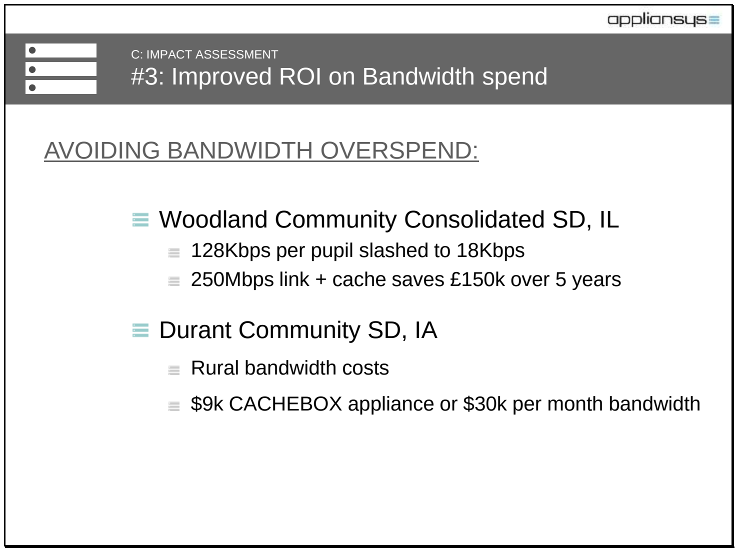

Beyond improved functionality there is a reduction in costs.

Woodland in Chicago saved more than $100k over 5 years by deploying a cache on their 250Mbps link.

Durant in Idaho deployed a cache instead of a bandwidth upgrade which would have cost $30k/month, 100 times more than the caching appliance!

We estimate that most districts in most states could slash the ongoing cost of their connections, even very large school districts could skip a year or more of bandwidth upgrades, and then the State Departments of Education and AEAs could save $m’s/year on backbone costs on top.

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C: Assessment of Impact of Caching in US K-12

Improved ROI: Bandwidth

Woodland SD 50 Profile

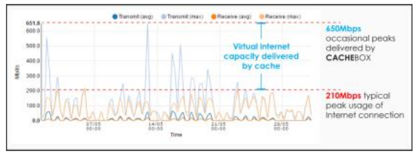
4 Schools | 6,190 Students | Suburban | 250Mbps

Challenge

- With just 250Mbps shared by 6,000+ students, the district was below the FCC's minimum 100 Kbps/student 2016 target. To reach this it needed 370Mbps at an additional $2,000/month
- Additional 360Mbps to reach FCC target: $21,900 per annum for bandwidth that would lie idle most of the month.

Impact of caching

- Woodland's **CACHE**BOX solution costs $7,450 - with expected lifecycle c. 5 years.
- **CACHE**BOX pays for itself in 4 months and saves the district and FCC over $100k in its full lifecycle!



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C: Assessment of Impact of Caching in US K-12

Improved ROI: Bandwidth

Westwood CSD Profile

520 students | 2 schools | 1 Gbps connection

Challenge

- Remote school with an expensive connection ($3,127 per month), high cost per student
- Further upgrading would be an unaffordable and unnecessary option
- Next upgrade step requires 10Gbps-ready infrastructure – new routings, switching, cabling, firewall, Wi-Fi access points...

Impact of caching

- Serving content locally at LAN speed, drastically increased bandwidth capacity, making dynamic content more available.
- Cached content can serve repeat requests while maintaining spare capacity for new content, unlike bandwidth upgrades, where demand will rise to meet capacity.

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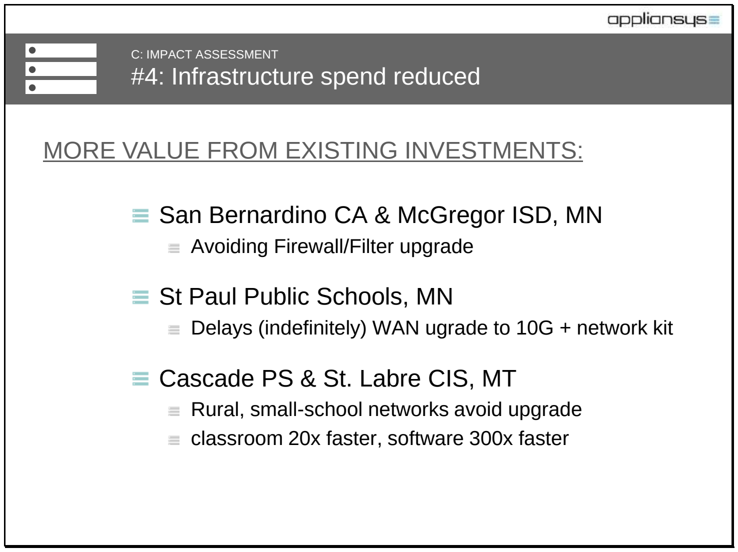

The last group of reported benefits encompasses reductions in infrastructure spend as a result of deploying a cache, affecting very large districts like San Bernardino in California and countless smaller districts like McGregor ISD in Minnesota – all avoiding firewall and filter upgrades.

Some of the more momentous upgrade costs to be avoided or delayed are around the 1Gbps threshold.

External connections and network equipment with 10Gbps capability can be at the root of phenomenal waste.

At St Paul Public Schools their 1Gbps WAN that looked close to capacity now has had many years of additional life breathed back into it.

At the other end of the spectrum, those rural schools on the wrong side of the digital divide can persist with sub-100Mbps connections for several more years yet enjoy cached content delivery at many times that connection speed.

Caching means those 24% of schools can compete in terms of digital access, despite their Little League budgets.

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C: Assessment of Impact of Caching in US K-12

Infrastructure Spend Reduced

Saint Paul Public SD Profile

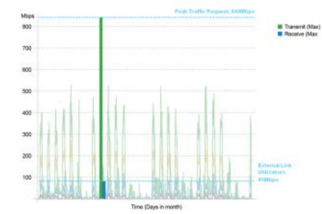
37,000 students | 72 schools | Urban | 500kbps per student

Challenge

- 1Gbps WAN link from High Schools have high utilisation – planning needed for passing through that threshold
- The one-off costs of upgrading WAN links to 72 schools from 1Gbps to 10Gbps is significant
- Content still served at sub-optimal speeds

Impact of caching

- Up to 900Mbps demand peaks slashed to 100-200Mbps
- Classroom content 10-20x faster
- With a **CACHE**BOX solution Saint Paul can continue to **benefit** from its **existing infrastructure investment** and postpone any costly upgrade



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C: Assessment of Impact of Caching in US K-12

Infrastructure Spend Reduced

Cascade Public SD 3 Profile

286 students | 3 schools | 45 Mbps connection

Challenge

- Running 400 devices on 45Mbps
- High cost on bandwidth @ $25k/y
- Upgrading bandwidth would require network kit and infrastructure upgrading

Impact of caching

- Serving content locally enables classroom delivery at 250Mbps
- Windows updates from cache can reach 376Mbps
- Existing infrastructure unchanged, extended lifecycle and increased return on existing investment

Caching is significantly more affordable than an infrastructure upgrade to a school's network, and enables schools to maximise existing investment

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C: Assessment of Impact of Caching in US K-12

Infrastructure Spend Reduced

St. Labre SD Profile

150 students | 1 school | 150 Mbps connection

Challenge

- Remote school with an expensive connection ($2,100 per month)
- Further upgrading would be an unaffordable and unnecessary option

Impact of caching

- **CACHE**BOX solution handles peaks in demand at 280 Mbps
- Traffic from cache is recorded being accelerated 22x faster than form the internet
- Increasing effective capacity saves on higher bandwidth fees and postpones the need for an infrastructure upgrade

Traffic Summary

Bandwidth Total	**9.88 GB**	Average Object Size (direct)	**5.15 KB**
Bandwidth Saved	**5.25 GB**	Average Object Size (from cache)	**58.5 KB**
Bandwidth Savings (%)	**53.09%**	Unique Domains	**1,977**
Requests Total	**991k**	Unique Sources	**288**
Requests Saved	**89.7k**	Average Speed (direct)	**148 KB/s**
Request Savings (%)	**9.05%**	Average Speed (from cache)	**3.33 MB/s**

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C: Assessment of Impact of Caching in US K-12

Infrastructure Spend Reduced

Durant Community SD Profile

673 students | 3 schools | Remote, Rural | 126kbps per student

Challenge

- Simultaneous start of lesson delivery of video and learning content is too slow in the classroom
- Rural location means bandwidth costs are extremely high

Impact of caching

- Content delivered from cache is 5, 8, 20+, even 80 times **faster**
- 700Mbps burstable capacity for a $9k investment in CACHEBOX, costing **$30k per month less than bandwidth!**