CoSN
LEADING EDUCATION INNOVATION

DESIGN GUIDELINES

Smart Education Networks by Design

a CoSN leadership initiative

Guidelines for School System Chief Technology Officers

sponsored by
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CONTENTS

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DESIGN GUIDELINES

Smart Education Networks by Design

Guidelines for School System Chief Technology Officers

> *"We must make our schools an integral part of the broadband and technology transformation — particularly when that same technology can be harnessed to drive empowered, more personalized learning. From digital textbooks that help students visualize and interact with complex concepts, to apps and platforms that adapt to the level of individual student knowledge and help teachers know precisely which lessons or activities are working, this technology is real, it is available, and its capacity to improve education is profound …In a country where we expect free Wi-Fi with our coffee, why shouldn't we have it in our schools?"*
>
> *—President Obama's announcement of ConnectEd, June 6, 2013*

We have a tremendous opportunity to effect significant and positive changes in our classrooms and in the academic lives of our students.

Foreword

We live in an increasingly connected and technology-infused world. In recent years, the proliferation of incredibly powerful and always-connected mobile devices has transformed the way we work, acquire information about the world around us, entertain ourselves and interact with our professional and personal contacts.

Many of today's K-12 students are not far behind. Having grown up in the world of smartphones and the mobile Internet, they approach acquisition and integration of information far differently than students did even just a few short years ago. [1] The trend is worthy of acknowledgment. It is widely accepted that most of the fastest-growing career fields in the U.S. require a mastery of a variety of information technology and communication skills.

Mobile computing technologies, ubiquitous connectivity and cloud-based services have transformed professional, civic and personal lives. If today's children are to be college and career ready, these same technologies should also be an integral part of the learning experiences in K-12 schools and classrooms. Thoughtfully designed and robust networks are critical, with secure access from a mix of devices.

The Smart Education Networks by Design (SEND) initiative will address the challenges faced by school systems by providing school system leaders with the knowledge to wisely invest in educational networks for today and tomorrow.

The initiative will:

- Highlight new and future technologies in all aspects of education network design such as mobile, wireless, broadband, security, safety, identity management, and crisis preparedness.
- Identify best practices in strategic design of networks for education focusing on creating scalable, affordable, reliable and resilient networks for schools and districts.
- Develop vendor neutral resources and tools for school districts to assess the current status, identify long term needs, determine gaps and plan for successful implementation. ■

One-to-one computing, coupled with ubiquitous connectivity promises to transform current approaches to teaching, bring core concepts to life in powerful ways and reinvigorate student engagement. The latest mobile computing devices are capable of enabling highly personalized and targeted curricula, providing integrated learning assessments with immediate feedback, and enabling highly interactive and collaborative learning processes.

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[1] Willingham, Daniel T. "Have Technology and Multitasking Rewired How Students Learn?". *American Educator*, Summer 2010:23. Print

All of these critical ingredients to transforming our education system rely upon the presence of high-performing and highly reliable education networks.

Learning opportunities provided by new well-designed digital learning environments, or innovative time-shifting teaching models, such as flipped classrooms, online courses, or hybrid delivery models are making access to reliable broadband connectivity outside of school as important as it is in school. Learning can no longer be limited to the confines of the classroom or the school day, and neither should access to learning opportunities end when the final bell rings.

As the latest laptops, tablets and smartphones, as well as broadband connectivity become affordable, many U.S. school districts are considering investing in substantial upgrades to their existing IT systems and infrastructure, and exploring build-out of the support structures for extensive 1-to-1 technology deployments, either district-owned, student-owned or a blend.

Design, deployment and ongoing monitoring and maintenance of reliable education networks remain essential to realizing academic gains from 1-to-1 computing, local or remote hosted content, learning management resources, interactive learning simulations or augmented reality environments. Unfortunately, a majority of school districts are not adequately equipped to support these transformative technology programs. According to the CoSN *E-Rate and Broadband Survey 2013,* 57% of districts do not believe their school's wireless networks have the capacity to handle a 1-to-1 deployment today.

Recognizing the need for thoughtful, well-informed planning and effective execution from education IT leaders, CoSN, with financial support from Qualcomm Technologies, Inc., established the Smart Education Networks by Design (SEND) initiative. SEND will assist schools, districts and state boards of education in designing, deploying and maintaining next-generation education networks — critical on-ramps to transformed learning environments. SEND will provide crucial decision guidelines, planning templates, support tools and other resources.

SEND conversation themes include the increasingly significant roles played by:

- 1-to-1 programs
- Bring Your Own Device/Technology (BYOD/T)
- Identity management
- Cloud services
- Data security
- Broadband connectivity in the classroom
- Always connected, 24/7 learning environments
- Mobile broadband connectivity (3G/4G).

***Education networks* encompass any deployment of computer hardware, software, digital content and resources, and local and mobile connectivity services intended to meet the needs of teachers, school administrators, students and parents**. They must be designed and deployed to provide robust, reliable and secure access to designated resources and content by authorized users on approved devices at times and locations that support established learning objectives.

Personal computing technology adoption within education will be successful when that technology is used to support instructional models transformed by anytime, anywhere access to learning content and collaboration, as well as integrated student comprehension assessments and immediate feedback mechanisms. These vital elements require high-performing and highly reliable education networks.

Through SEND and other education technology programs, we have a tremendous opportunity to effect significant and positive changes in our classrooms and in the academic lives of our students. This document is but one aspect of the SEND initiative — to access the SEND CTO Checklist which draws upon the key tenets of these guidelines, as well as other SEND resources, visit http://www.cosn.org/smartednetworks and follow Twitter hashtag #SmartEdNetworks. For the latest updates on other CoSN initiatives visit (www.cosn.org), follow us on Twitter @COSN and like us at http://facebook.com/mycosn CoSN is grateful for Qualcomm Technologies, Inc. (www.qualcomm.com) founding sponsor support.

We hope you find these guidelines and other SEND resources informative and useful.

Information Technology in Schools

Like all segments of the economy, schools use technology in several ways to support their teaching, learning and operational objectives. Rapid development of Information and Communications Technology (ICT) creates substantial opportunity for schools to innovate, to further engage 21st-century learners and to increase operational efficiency.

Ever-increasing digital resources, broadening connectivity, mobile devices and powerful analytical tools are shaping an era of highly personalized, 24/7, anytime, anywhere learning. Increased access, mobility, 1-to-1 and BYOD in schools support personalized learning environments and other instructional methods. Access remains a priority and the direction is clear and persistent: 24/7, ICT-based learning will continue to grow.

Schools are complex, multi-process operating entities. In a digital world, they have been ICT-adopters in many operational aspects, from automation of attendance, scheduling, communications, transportation, etc., to strategic data use for teachers and learners. ICT plays an important role in maximizing efficiencies and providing services. Underlying and enabling all ICT-based programs and processes are education networks.

Already, from smartphones to open-source instructional materials, the educational landscape is changing dramatically. Education networks underlie that change.

Education's adoption

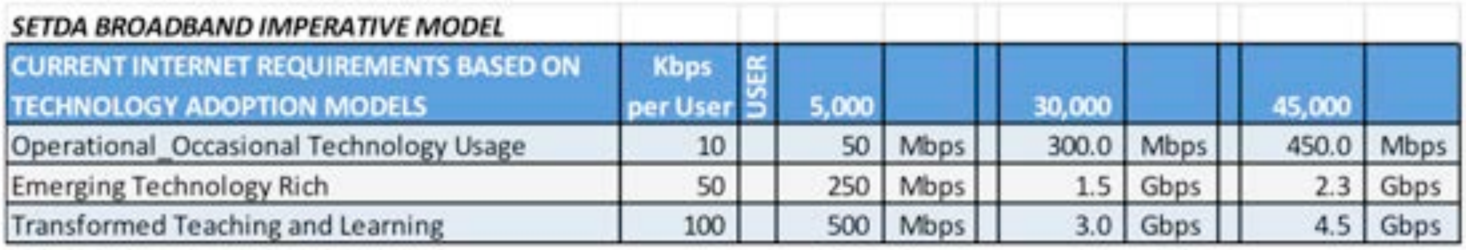
Information and Communications Technology (ICT) is an increasingly important part of the complex fabric of education. In global economies and industries, adoption of timesaving and more effective methods of accomplishing goals has increased productivity and lowered costs — an important foundational benefit of ICT. More importantly, ICT enables *personalized* learning. ICT is also "increasingly recognized as a key source of innovation...This ability to innovate is essential in the current information revolution that is transforming economic and social transactions in our societies." [2] This is true across economic, social and education structures. Teaching and learning processes must embrace innovation to improve learning. Already, from smartphones to open-source instructional materials, the educational landscape is changing dramatically. Education networks underlie that change.

From seemingly ancient dial-in modems to today's always-on Internet of Everything, organizations and societies have been transformed. Advanced technology from the consumer into the enterprise has fundamentally transformed our daily lives and expectations. Digitally-inclined parents, students and future employers challenge educational leaders to deliver real and relevant learning.

To that end, global technology trends impacting education networks include:

[2] 2013 World Economic Forum, *The Global Information Technology Report 2013*, p. v.

> **As schools adopt these technologies for teaching and learning, ...the impact on network and system resources increases exponentially.**



SETDA BROADBAND IMPERATIVE MODEL

CURRENT INTERNET REQUIREMENTS BASED ON TECHNOLOGY ADOPTION MODELS	Kbps per User	USER	5,000		30,000		45,000	
Operational_Occasional Technology Usage	10		50	Mbps	300.0	Mbps	450.0	Mbps
Emerging Technology Rich	50		250	Mbps	1.5	Gbps	2.3	Gbps
Transformed Teaching and Learning	100		500	Mbps	3.0	Gbps	4.5	Gbps

1. Digitization – the mass adoption of connected digital services and the ever-increasing repository of digital content.

2. Consumerization of Information Technology – new information technology emerges first in the consumer market and then spreads into organizations.

3. Ubiquitous Access – Every one of us. Everywhere. Connected.[3]

These trends enable flipped classrooms and hybrid online learning models, and empower collaboration among teachers, learners, parents and the community — fundamentally changing the way our students learn. They also support the SEND design goal of anytime, anywhere learning. Indeed, the Pew Research Center's Internet and American Life Project presents four points about technology's impact on learning:

- Broadband facilitates networked information and networked knowledge
- Mobile connectivity alters learning venues and expectations
- Social media aids peer-to-peer and learning by doing
- New kinds of learners emerge.[4]

As schools adopt these technologies for teaching and learning, as well as additional digital processes for diagnostic assessments that are formative for instruction and come from analyzing data streams generated by learning experiences, the impact on network and system resources increases exponentially. The 2012 SETDA report, "The Broadband Imperative"[5] describes technology adoption on three levels and provides a framework for assessing school bandwidth requirements — and then the associated network and Internet resources based on these adoption levels.

Education technology leaders can use the SETDA tool in determining technology adoption levels of their respective schools. Then they can plan technology resource capacity as they progress through defined adoption levels. The tool can also help schools understand technology usage and resource requirements.

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[3] Internet.org.

[4] http://www.pewinternet.org/About-Us/Our-Research/Use-Policy.aspx

[5] www.setda.org, *The Broadband Imperative*, Framework for Assessing Bandwidth, p. 22.

Documenting current states of technology adoption and identifying opportunities and expected growth patterns is vital in network design.

It is essential that every successful organization or endeavor have a clear and compelling vision, a common mission, and concrete goals.

Schools must build networks that support use of high-bandwidth content by powerful mobile devices (laptops, tablets, smartphones, etc.). Combined with access to digital materials aligned to instructional strategies, a robust, well-designed education network provides unlimited options to assist teachers and students in achieving academic goals.

Documenting current states of technology adoption and identifying opportunities and expected growth patterns is vital in network design. It also helps in planning and instructional strategy. Throughout these guidelines, we have worked to identify the impacts of trends observed in the mobile and computing industries, and provide design models and case studies that build a useful framework for conversation.

Vision, mission, and goals

It is essential that every successful organization or endeavor have a clear and compelling vision, a common mission, and concrete goals. These attributes apply especially in transforming teaching, learning and district operations into a technology-based culture of innovation and efficiency. This transformation is filled with the challenges around change, adaptation, funding, and sometimes breathtaking pace. But it is a transformation of necessity and inevitability with benefits accruing to all.

A necessary and important dynamic in the process of transformation is the establishment of the shared vision, mission, and goals. The involvement of all stakeholders, supported and led by strong leaders, is arguably the most critical factor in the success of the effort. Having broad input and a diversity of informed opinion in a rigorous process of determining the vision, mission, and goals will ensure a robust and durable outcome.

In the process of developing the vision, mission and goals for the district, school leaders must be careful to not overlook formalizing the need for quality network technologies and support mechanisms upon which many of the transformative services will depend. All stakeholders should understand and acknowledge the importance of the network.

Like in all worthy endeavors that are developed and operated, digital transformation and the network underpinning and supporting the transformation must have adequate investment and operating funding. There is simply no alternative.

There are increasing and promising options for technology infrastructure, all of which should be pursued to drive down cost, but there will still be cost to provide and support the network. These costs should be considered as the necessary investment that they truly are.

The relative maturity of component technologies ... make 1-to-1 environments both financially and technically feasible.

24/7 learning

Trends of digitization, consumerization and ubiquitous access have the power to transform the American academic landscape from static, time-constrained one-way industrial-age classroom delivery — to 24/7 access to current content, collaboration and real-world learning. Engaging, relevant and technology-enhanced learning in the classroom and at home is critical to developing lifelong learners.

Digitization enables access to such content. However, it doesn't automatically equate to a digital curriculum or even curriculum-aligned resources. For this, school leaders must develop a strategy and plan — **and the plan must include substantial training and support of teachers and technical staff.** Examples of digital resources include: interactive textbooks, online assessments, proprietary content (Waterford, Pearson Learning, etc.) online courses or MOOCs, and cloud-based tools and resources such as Google Docs or Microsoft Office 365.

Recent consumer technology adoption trends are changing student preferences and expectations; some research also points to a shift in learning styles and abilities.

Components critical to broad-based digital resource adoption include:

- A network design that supports enterprise and cloud-based services and associated ubiquitous access solutions
- Web account provisioning and device-agnostic access solutions
- Device programs that strive to ensure that every student has a capable device and 24/7 access to digital learning environments.

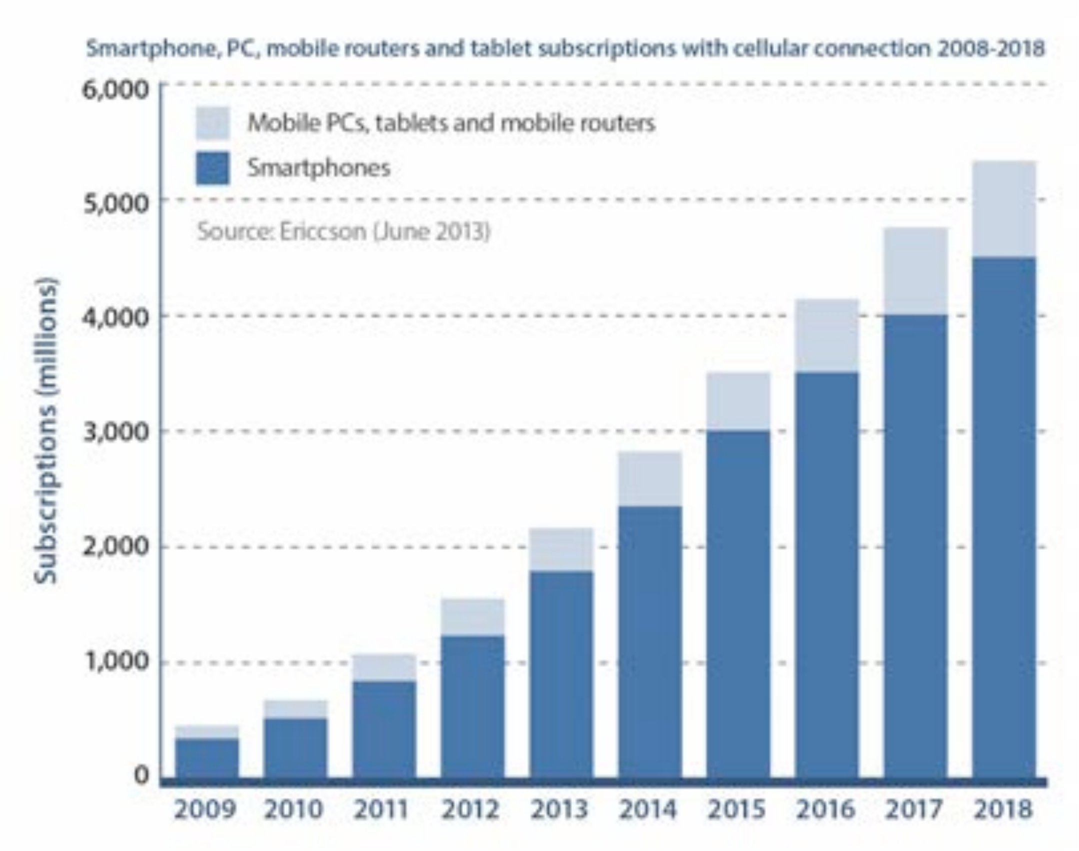
1-to-1 programs and personalized learning environments (PLEs)

The time for 1-to-1 learning technology has arrived. Education networks must support digital resource access across all stakeholders with an assumption of one or more devices per student. Legacy debates on instructional value, cost vs. value, and other concerns have given way to discussions of accessing digital instructional materials such as digital textbooks, building PLEs, and enabling anytime, anywhere learning for all students. The relative maturity of component technologies — digitization of content, widespread adoption of portable/mobile consumer devices, and near ubiquitous broadband connectivity — make 1-to-1 environments both financially and technically feasible. Beyond traditional technology refresh of computers, school networks need to be designed to consider both on- and off-campus connectivity. Therefore, strategies around safely connecting school-owned devices from home, community access points for Internet, and programs to ensure digital equity are all vital

By using school- and student-owned devices at home, the promise of anytime, anywhere, 1-to-1 learning can be realized.

elements of 1-to-1 programs.

On-campus network design models must plan for the impact of 1-to-1 and PLEs on infrastructure resources. Performance specifications should be assessed as part of the transition from previous norms of wired desktops to wireless and mobile end-user devices, especially when upgrading from 100 Mbps to 1 Gbps or faster services.


Smartphone, PC, mobile routers and tablet subscriptions with cellular connection 2008-2018

Source: Ericcson (June 2013)

Another important planning action is to develop an extensive inventory of digital resources and systems, and use service level agreements (SLAs). As 1-to-1 and PLEs grow, so does the mission criticality of their supporting services. Therefore, it is equally critical to understand expected service levels to support the desired classroom experience and design network infrastructure and execute SLAs to support those requirements.

The simultaneous emergence of schools investing in network and mobile technologies and consumer adoption of 3G/4G and Wi-Fi enabled devices creates an opportunity to harmonize these into an effective 24/7 learning model. By using school- and student-owned devices at home, and throughout the community, the promise of anytime, anywhere, 1-to-1 learning can be realized.

Bring Your Own Device/Technology (BYOD/T)

Consumerization, the trend whereby new technologies emerge first in the consumer market and then spread to organizations, is one of the most important design drivers for educational networks

New and advanced technologies are a normal, integral part of student living and learning outside the classroom.

and can be evaluated in two phases. The first is most easily understood and seen in the widespread adoption of Apple's "i" devices and services, though continues with Facebook, Twitter and Instagram. Consumer cloud-based services increase expectations of ubiquitous connectivity via mobile and Wi-Fi networks on a range of personal mobile computing devices including smaller, lighter laptop computers, tablets and smartphones. Growth in consumer mobile devices is expected to continue seemingly unabated. The Ericsson Mobility Report released in June 2013 predicts that the global number of mobile devices will double in the next three years.[6]

The second phase is the infiltration of consumer technology into organizations through waves of BYOD/T programs. This adoption cycle represents a fundamental shift from earlier personal computing models where advanced technologies were first adopted by enterprise buyers and only gradually made their way into consumer hands. Thus, consumer-first end-device designs are potentially less rugged, less consistent in architecture and not enterprise-aware or ready — all obstacles with which to contend. When a consumer product establishes a considerable K-12 or business foothold, pressure mounts for the vendor to make the device more compatible for enterprise management.

New and advanced technologies are a normal, integral part of student living and learning outside the classroom. Naturally, these technologies will migrate into the classroom as students bring their most frequently-used devices onto school grounds. BYOD/T policies and strategies critical to successful learning environments must be developed by the school leadership team so as to inform the design of network infrastructures and systems. **These strategies should be developed in close consultation with teachers, as teachers play a vital role in their effective use. Therefore, IT and administrative leadership must allot ample professional development and instructional planning time.** CoSN has developed a "Leadership for Mobile Learning" initiative to assist CTOs in this important area. Visit: http://www.cosn.org/mobilelead

As always, the network design team should first evaluate stated educational objectives, strategies and policies, and then deploy the technology resources to support those.

Consider these questions in developing a BYOD strategy:

- What is the student population that will utilize BYOD for classroom instruction?
- What are the digital resources that the BYOD will utilize for instruction?

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[6] "A Focus on Efficiency". Internet.org. September 16, 2013 https://fbcdn-dragon-a.akamaihd.net/hphotos-ak-ash3/851590_229753833859617_1129962605_n.pdf

The sole purpose of networks is to help users develop and communicate information in powerful and effective ways.

- What are the technical standards for BYOD to access the resources?
- How will teachers be trained for BYOD instructional usage?
- Is there an adequate wireless device onboarding and resource provisioning infrastructure in place to support BYOD?
- Is the Internet infrastructure ready for a BYOD initiative?

PREPPING FOR PLE, 1-to-1 and BYOD

>> **Whether planning for** a Personalized Learning Environment, 1-to-1 or Bring Your Own Device program, the preparation is similar. All three require strong, on-campus wireless with solid backbone connections to a robust central network and adequate Internet bandwidth. First, build a scalable network *before* trying to implement any one-mobile-device-per-student project. Second, CTOs must involve the curriculum team to ensure the district's curriculum will be adjusted to take advantage of the technology in student hands. Third, provide proper teacher and administrator training at least six months ahead of rollout to students. Lastly, discuss the program with parents, the board and (in some cases) local government entities, businesses, and elected officials who may be able to provide assistance. Soliciting general agreement on the end goal will help keep the programs moving forward when issues arise. http://www.pasadenaisd.org/ ■

—Steve Wentz, Pasadena ISD (TX)

Data and integration

The sole purpose of networks is to help users develop and communicate information in powerful and effective ways. This flow of information at previously unimaginable levels of speed and quantity creates efficiencies in our processes and in learning. *Learning management systems* (LMS) and *student information systems* (SIS) are essential components to the effective operation of schools and to the teaching and learning process. The evolution of these systems into more broadly reaching *content management systems* is challenging networks and information management professionals. As more processes become digital, their integration is paramount to facilitate operational efficiencies and establish the necessary framework for personalized learning. With high-speed communications, robust devices, sophisticated digital content and real-time data — teachers can instruct, assess, remediate and extend learning in unprecedented times, speeds and locations. High-capacity databases with powerful analytical capacity retain system data to inform learners, teachers and school leaders.

These benefits are a mere vision if the networks and communication technologies that will deliver them aren't made reality. Education networks must be smartly designed to realize such potential.

Data itself is essential to understand, but the other essential component when determining capacity is number of users on the network...

Data and Capacity

Data and its movement between and among users is the principal determinant in planning for and developing network capacity. Today's schools face a dual challenge: ever-increasing data rates (media-intensive) and slower, aging networks. CoSN's recent *E-Rate and Broadband Survey 2013* http://www.cosn.org/e-rate-broadband-survey confirms the practical experience of schools: critical capacity needs are at all key points of service, Internet, wireless and LAN/WAN.

Data comes in many forms, from simple email to streaming video. Thus networks must be designed to effectively accommodate transfer of such data and provide a positive user experience. Data itself is essential to understand, but the other essential component when determining capacity is number of users on the network and whether accessing via wired or wireless connections. Together, the number of users and the types of data they are using constitute the aggregate data being transmitted and, implicitly, minimum network capacity.

As a general guideline, CoSN agrees with and supports the recommendation of the State Education Technology Directors Association (SETDA) regarding minimum network capacities detailed later in this document. It is also important to realize that mobile broadband (3G/4G) technologies can substantially add to a school's Internet capacity.

Bandwidth and capacity

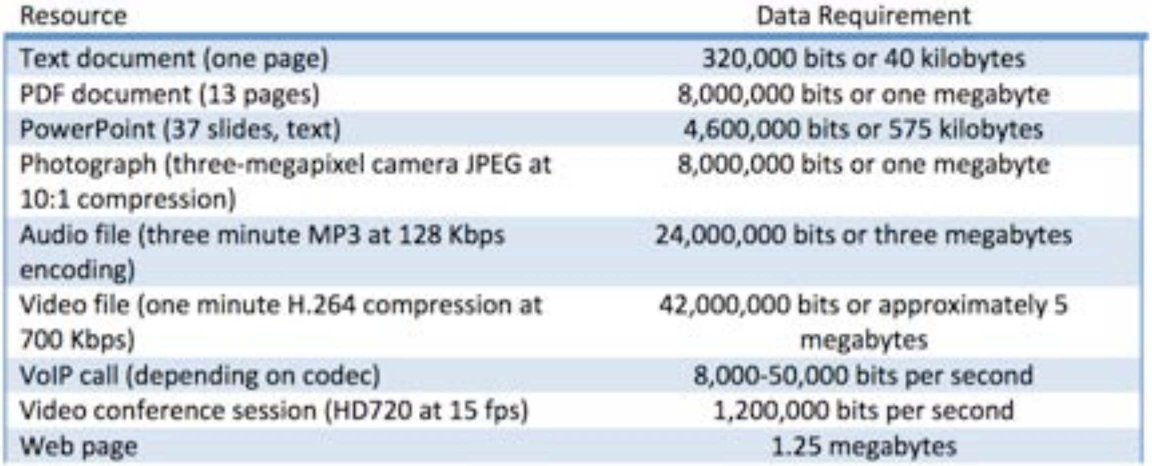
Bandwidth expresses a measure of network capacity. Originally a radio and television term for the size of a communications channel, today bandwidth describes the *pipe-size* used for data flow. Normally expressed in variations of bits per second as in "megabits (a million bits) per second" and, more recently as the technology continues to develop, "gigabits (a billion) per second," the "bits" concept is vital. All performance considerations are a function of bandwidth and it is the *bits* that constitute our data.

A one *giga*bit connection (ports on a switch connecting devices, or an Ethernet adapter in a computer) generally means the speed and capacity of the data flow is one *billion* bits per second. By historical standards, this seems an enormous amount of information to be transported and processed, however, experience demonstrates that it doesn't take much of today's content to consume this capacity. CoSN's recent *E-Rate and Broadband Survey 2013* http://www.cosn.org/e-rate-broadband-survey confirms schools' practical experience — critical capacity needs are at all key points of service, Internet, wireless and LAN/WAN.

Bits and data

All digital media are stored in binary form. This takes many bits to completely define or describe the information to render (present) it to the user. The

School networks nationwide have implemented various forms of Wi-Fi and are in-process on capacity upgrades.



Resource	Data Requirement
Text document (one page)	320,000 bits or 40 kilobytes
PDF document (13 pages)	8,000,000 bits or one megabyte
PowerPoint (37 slides, text)	4,600,000 bits or 575 kilobytes
Photograph (three-megapixel camera JPEG at 10:1 compression)	8,000,000 bits or one megabyte
Audio file (three minute MP3 at 128 Kbps encoding)	24,000,000 bits or three megabytes
Video file (one minute H.264 compression at 700 Kbps)	42,000,000 bits or approximately 5 megabytes
VoIP call (depending on codec)	8,000-50,000 bits per second
Video conference session (HD720 at 15 fps)	1,200,000 bits per second
Web page	1.25 megabytes

number of bits (or 8-bit bytes) needed to represent information types varies widely and depends on many factors. These estimates vary due to the amount of information on a document (words, graphics, etc.) and the quality or resolution of the visual media (photos and video). Some reasonable averages are depicted in the table here.

While they primarily support instruction and learning, **education networks increasingly provide critical support for data analysis, administrative services, security, telephony, and building services such as lighting and HVAC controls**. Thus, data transport and network response requirements must be considered in the design of the network. In particular, "converged" systems — use of a school's digital network to support data in the traditional form *and* voice services (telephony) and video (security and even TV) — are commonly implemented in newer education networks.

Another significant, relevant design trend is Internet web site session growth. A large increase in session count levels has implications for firewalls and content filters. Older architectures and equipment were not designed to support this increase resulting in a diminished or ineffective user experience.

Since 2010, average web page size has nearly doubled. Rampant page bloat may not be news, but that doesn't make new findings any less alarming. According to the HTTP Archive, the average top 1,000 web page is 1246 KB, compared to 828 KB in May 2012 — a 50% growth rate in just one year. [7]

Growth of Internet web page size, including session count, and increase in number of users — helps explain substantial growth in school Internet usage.

Wi-Fi, mobile (3G/4G) and data

Wi-Fi and mobile data (3G/4G) are the two services supporting connected mobile learning. Access to quality connectivity for learners, staff, and whether at school, home or about the community, are

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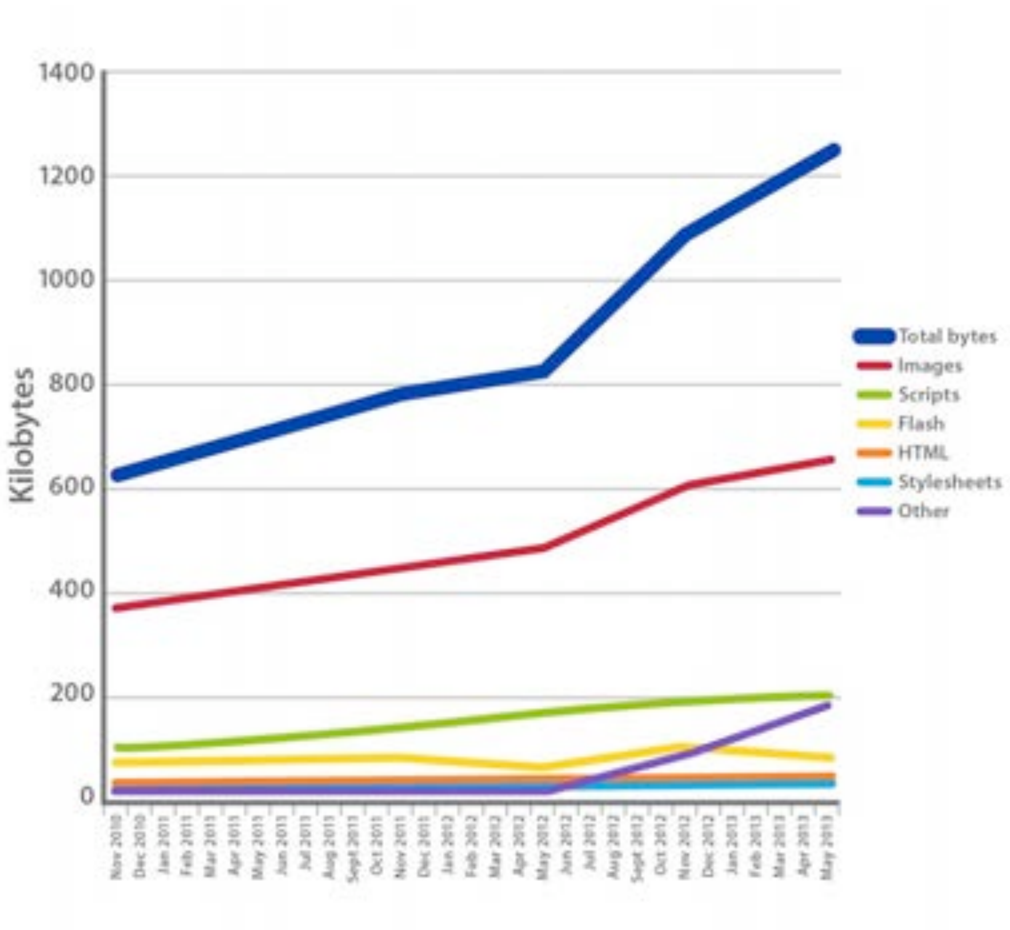
[7] http://www.webperformancetoday.com, June 5, 2013

While they primarily support instruction and learning, education networks increasingly provide critical support for data analysis, administrative services, security …



critically important to the fabric of ubiquitous or anytime-anywhere learning. The capacities of these environments are vital in designing a comfortable user experience. According to CoSN's *E-Rate and Broadband Survey 2013* http://www.cosn.org/e-rate-broadband-survey, "57% of districts do not believe their school's wireless networks have the capacity to handle a 1-to-1 deployment today."

Wi-Fi (802.11x) data capacity

School networks nationwide have implemented various forms of Wi-Fi and are in-process on capacity upgrades. Known by their respective IEEE standards, nominal capacities and some differences are shown on page 16.

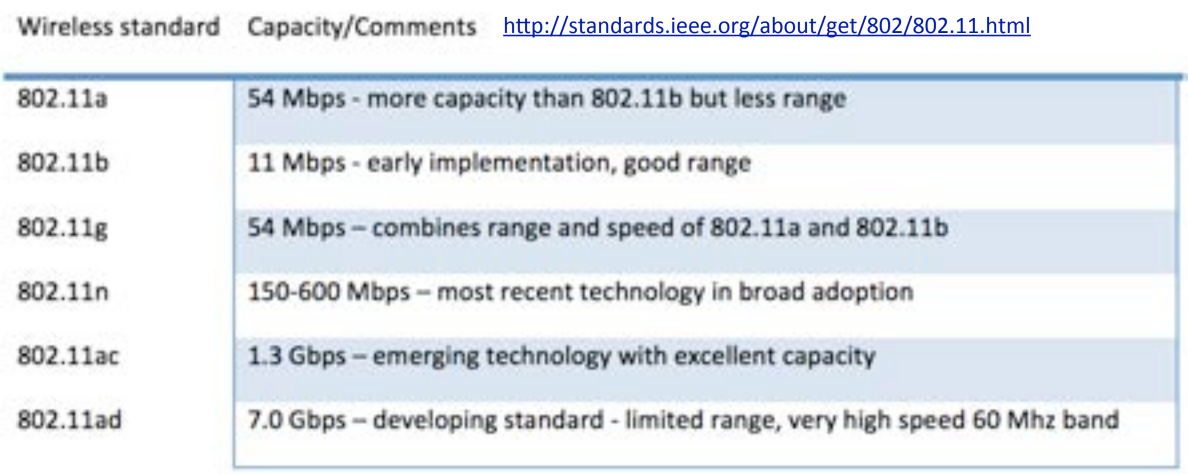
The 802.11ac and recently released 802.11ad standards should prove extremely useful to schools by dramatically improving Wi-Fi network capacity and reliability. These performance improvements are primarily achieved through utilizing the less congested 5GHz spectrum band, and adding intelligent traffic management techniques.

Mobile (3G/4G) data capacity

Consumer mobile (3G/4G) data traffic volumes have increased exponentially in recent years and are expected to continue their dramatic growth rates. Considering the increasing adoption of smartphones and the ever expanding information and entertainment uses these devices are supporting, this is easily understood. Mobile network operators and technology providers are constantly working to make more capacity

The technology industry is constantly upgrading and evolving both the technology itself and network services.

http://standards.ieee.org/about/get/802/802.11.html



Wireless standard	Capacity/Comments
802.11a	54 Mbps - more capacity than 802.11b but less range
802.11b	11 Mbps - early implementation, good range
802.11g	54 Mbps – combines range and speed of 802.11a and 802.11b
802.11n	150-600 Mbps – most recent technology in broad adoption
802.11ac	1.3 Gbps – emerging technology with excellent capacity
802.11ad	7.0 Gbps – developing standard - limited range, very high speed 60 Mhz band

available. With mobile data, the notion of "capacity" can be thought of as a combination of technology and geographic presence.

The technology industry is constantly upgrading and evolving both the technology itself and network services. Both 3G (third generation) and the more recent 4G/LTE (long-term evolution) technologies currently serve the market. The table on the following page (p. 17, top) reflects theoretical speeds of these technologies. As is the case with Wi-Fi, a user's actual experience will vary depending upon on-the-ground conditions.

Current mobile (3G/4G) technologies have proven very effective and reliable in meeting the connectivity needs of most K-12 curricula outside of the classroom. At the end of 2012, 80% of North American residents had 4G/LTE service available to them, frequently from multiple providers. This may increase to 95% of residents by 2019 or possibly earlier.[8]

As a result, mobile broadband services are particularly useful for ensuring consistent 24/7 access when implementing device 'check out' programs and broader 1-to-1 initiatives. While cost of service has been a barrier in the past, mobile operators and education-focused service providers have introduced more flexible, affordable and easily-administered data service plans.

Additionally, mobile technology continues to evolve rapidly. Forthcoming developments that have the potential to address education needs include:

- LTE Advanced – substantially increasing throughput by combining available spectrum allowing denser networks and increasing antenna capacity
- LTE Broadcast – optimizing content distribution over LTE networks using broadcast principles
- Use of LTE in unlicensed spectrum – co-exists with existing Wi-Fi networks while offering extended range, greater capacity and seamless handoff to WANs

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[8] Ericsson Mobility Report, June 2013

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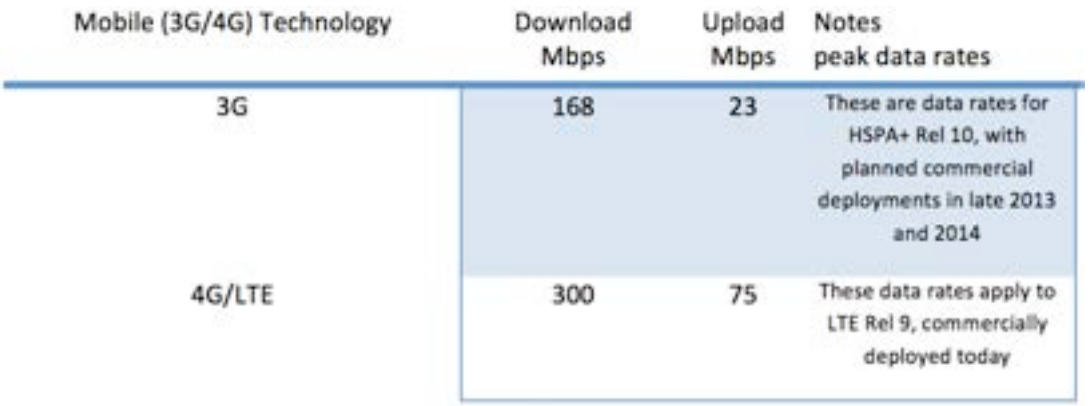


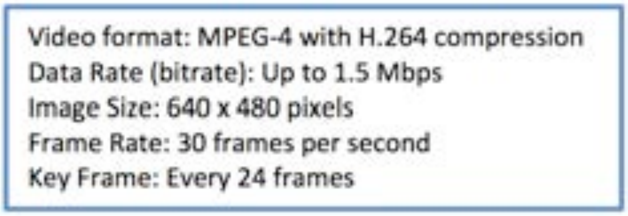
Mobile (3G/4G) Technology	Download Mbps	Upload Mbps	Notes peak data rates
3G	168	23	These are data rates for HSPA+ Rel 10, with planned commercial deployments in late 2013 and 2014
4G/LTE	300	75	These data rates apply to LTE Rel 9, commercially deployed today

- Small cells – capable of significantly boosting indoor capacity, and better managing a large number of concurrently connected devices over LTE and Wi-Fi.

Impact of video file sizes and quality

Previously mentioned examples of the size of various resources are all reasonably manageable by most networks, even wireless networks, with one exception: *video*. Successful use of video in instructional settings at school, home, or in the community depends on the video, the network and the device. Today's devices process and consume digital video, so it is up to the network, wired and wireless, to deliver these files. Content providers are well aware of the importance of mobile in today's consumer and education markets and are making video format and resolution accommodations.

Whether uploaded for sharing or downloaded for consumption by students, video file size and quality is an important consideration. Generally, the better the quality (resolution and bitrate), the larger the file size. To optimize playback in wired and wireless/mobile settings, video *codecs* have long been used. Currently preferred is MPEG-4 with H.264 compression — a robust, international standard with substantial flexibility. Many hosting entities require this for their video content. Below, for example, are the video requirements for Apple's iTunesU service:



Video format: MPEG-4 with H.264 compression
Data Rate (bitrate): Up to 1.5 Mbps
Image Size: 640 x 480 pixels
Frame Rate: 30 frames per second
Key Frame: Every 24 frames

Other service providers and hosting entities have similar recommendations or simply accept source video and then re-encode it using H.264 to optimize for various user environments (wired, wireless, mobile). Technologies such as adaptive streaming also significantly contribute to an easy and effective user experience.

Instructional content

There are a multitude of digital content providers serving the education community. From services

In any project or goal, a good idea is to begin with the end in mind.

such as Apple's iTunesU, TeacherTube, or Google's YouTube, MOOCs from Coursera, edX and Khan Academy — to more proprietary content from learning services companies, as well as district teacher-generated and locally produced instructional video content, the direction is clear: 24/7 digital learning is here to stay. Such services depend heavily upon ubiquitous and reliable network connectivity.

The primary question among network designers is a familiar one – *'Do we have enough bandwidth, both Internet and local?'* The answer depends on the amount of data in these courses, lessons and learning objects that will be supported. This varies by provider, format and student learning time. Khan Academy alone contains thousands of videos, online exercises and other services. Most providers use a combination of HTML content, documents and video in their lessons — with video being the most challenging from a network capacity standpoint.

As a guideline, an estimate of 5 MB per minute of video is a good basis for planning networks. This could be per student or per class, depending on the instructional setting and location (school or home). The transfer medium, wired or wireless, then becomes a vital consideration.

Data requirements calculations

In any project or goal, a good idea is to begin with the end in mind. In network design, "use cases" inform near- and intermediate-term design requirements. Without over generalizing or being simplistic, the goal for the network revolves solely around moving data in whatever volume and speed that is needed, both now and in the future.

In school settings, the classroom remains the dominant location for instruction and learning. Notwithstanding the trends toward flipped classroom models, and 24/7 learning, education network designers must still effectively support the more traditional classroom instruction model, which presents its own spatial and density requirements. Other on-campus settings tend to simply be less-dense variants of the classroom and can be enhanced as needed for BYOD and 1-to-1. Keep in mind that with the introduction of 1-to-1 programs, the *entire school* becomes a learning environment with attending requisite connectivity and capacity needs. As these trends progress, *any* large physical space can suddenly become a high-density use area, such as library media centers, lecture or performance halls, student study areas (inside or outdoors) — and even cafeterias.

Calculating network capacity – students, content and simultaneity

As teachers exercise their various individual and artful styles of teaching, the *scale* at which technology is integrated (both in time used and number of users) ultimately determines network service requirements. Analysis would apply to a given classroom and then

Education network designers must still effectively support the more traditional classroom instruction model, which presents its own spatial and density requirements.

extend throughout the school and district for aggregate school and district estimates.

In calculating these, one approach is to set both high and low utilization bounds in the classroom. In a high-use scenario, perhaps 30 students are actively engaged with technology at any specific time. Content type accessed and devices used ultimately define the requirement. Most static instructional content — HTML pages, text documents (Microsoft Word or Adobe PDFs) — are relatively small in the context of today's baseline networks (100 Mbps – 1 Gbps switched). Video raises the bar with respect to capacity, especially in a wireless setting.

Using a particularly challenging example — all 30 students simultaneously streaming a video at, for example 700 Kbps — the aggregate load on the access point serving these students would be 21,000 Kbps, or 21 Mbps. Adjusted for the inherent capacity loss in Ethernet networks, this level challenges the theoretical capacity of 802.11g technology, but fits comfortably within the capacity of 802.11n devices.

In this scenario, consider the following:

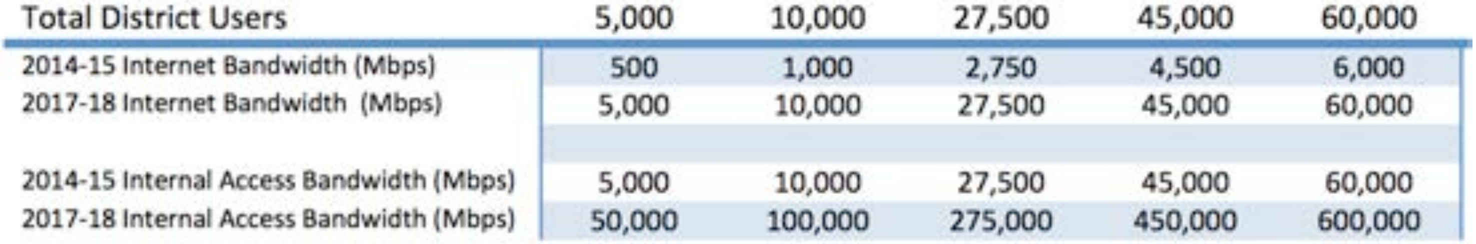
- *The client must have 802.11n capability and can accept streaming.* Depending on the client technology used, capabilities such as buffer size and computing capacity could dramatically affect user experience. In some settings, the presence of any other wireless technology, such as 802.11g could degrade the capacity of the 802.11n access point.
- *The video resolution is standard definition (640x480) at 700 Kbps.* If higher resolutions are needed (such as better SD resolution or an HD stream), then data requirements are increased such that even 802.11n access points could be ineffective.
- *The core (LAN and WAN) network service supporting these wireless sessions is assumed to be sufficient.* Underlying the wireless network is the backbone or core wired network. Today's networks should accommodate this, but there are many design issues and potential capacity limitations, so called *choke points,* which could negatively affect the entire experience.

Although not an exhaustive list, network elements such as switch, wireless controller, access point and Internet capacities (if Internet streamed) all must be designed and scaled accordingly.

School and district capacity

Just as network design must deliver adequate classroom-level services, the same is true at campus and district levels. In earlier discussion on classrooms, the high-use assumption was chosen as the most important scenario — but that scenario could extend to *all* rooms in the school. Depending on the number of rooms in a school, let us say 50

Just as network design must deliver adequate classroom-level services, the same is true at campus and district levels.



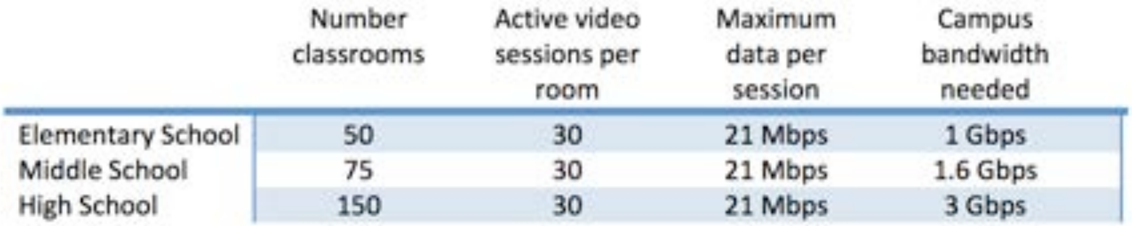
Total District Users	5,000	10,000	27,500	45,000	60,000
2014-15 Internet Bandwidth (Mbps)	500	1,000	2,750	4,500	6,000
2017-18 Internet Bandwidth (Mbps)	5,000	10,000	27,500	45,000	60,000
2014-15 Internal Access Bandwidth (Mbps)	5,000	10,000	27,500	45,000	60,000
2017-18 Internal Access Bandwidth (Mbps)	50,000	100,000	275,000	450,000	600,000

rooms for an elementary school, 75 rooms for a middle school, and 150 rooms in a large high school — the aggregation determines the required capacity for switches and routers. Simply aggregating these utilization levels reveals that (assuming there is sufficient device availability), data rates at the school level are 1 Gbps for the elementary, 1.6 Gbps for a middle school and 3 Gbps for the high school. These levels generally exceed most district infrastructures since 1-Gbps links to schools are common. This challenge is, no doubt, the reason some school districts are deploying 10-Gbps service.

SETDA recommends for 2014-2015 schools have internal capacities of 1 Gbps per 1,000 students and staff — and 100 Mbps per 1,000 students and staff for Internet capacity. For 2017-2018, these recommendations increase *ten-fold* to 10 Gbps and 1 Gbps for internal and Internet capacities respectively. An important and troublesome finding from CoSN's *E-Rate and Broadband Survey 2013* states that "43% of districts indicated that none of their schools can meet the SETDA recommendation…"

Nonetheless, even in the most technologically advanced schools — seldom are *all* students using the *fastest* data and Internet-intensive applications *simultaneously*. Consequently, network managers monitor usage over time and are adept at predicting and calculating peak usage periods, discovering they use considerably less bandwidth than when *all* students are using the *fastest* data and Internet-intensive applications *simultaneously*. Traffic- and packet-shaping applications and devices further help to buffer peak load *without substantial performance loss*. A scaled reference for the SETDA guidelines is presented above.

Additional tools for consideration in network capacity planning are two U.S. initiatives on assessment: the Partnership for Assessment of Readiness for College and



	Number classrooms	Active video sessions per room	Maximum data per session	Campus bandwidth needed
Elementary School	50	30	21 Mbps	1 Gbps
Middle School	75	30	21 Mbps	1.6 Gbps
High School	150	30	21 Mbps	3 Gbps

Even in the most technologically advanced schools — seldom are *all* students using the *fastest* data and Internet-intensive applications *simultaneously*.

Careers (PARCC) and the Smarter Balanced Assessment Consortium. PARCC has published, "Assessment Capacity Planning Tool." A valuable resource, this document is useful in assessment planning. CoSN has also developed resources to assist schools in planning through its "Being Assessment Ready" initiative. http://www.cosn.org/becoming-assessment-ready

It is important to remember that however critical, assessment is but one service that the school's network is supporting. All other services must continue to be supported by the network. Proxy services suggested by assessment providers also offer an effective way of minimizing broadband needs and provide a level of reliability and availability to test takers and administrators. Visit: http://www.parcconline.org/sites/parcc/files/PARCCCapacityPlanningTool_3-5-13_Printablev1.0.pdf

Network Design Considerations

With an informed estimate of the number of services, amount of data, the number of users and their access methods (wired or wireless), a designer has the fundamental variables necessary to begin basic network design. Additional aspects of design include:

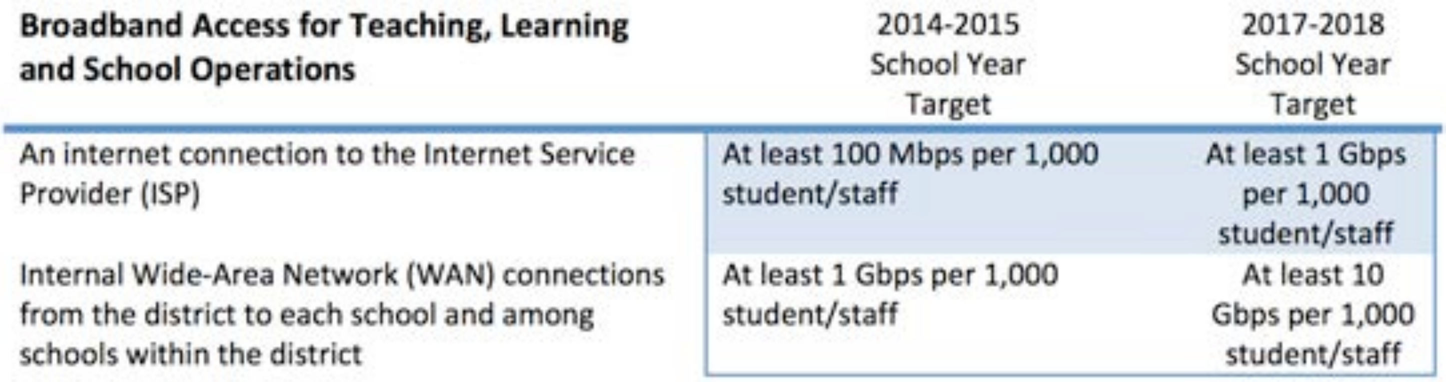
- Security
- Topology
- Addressing schemes (plan for more than one mobile device for some students and staff)
- Resiliency
- Redundancy
- Application needs (quality of service)
- Adaptation to and integration with cloud services
- Virtualization
- Securing and implementing sufficient broadband access — as well as providing for the ongoing network monitoring and management.

From a technology perspective, we live in exciting and dynamic times. Infrastructure is becoming cloud-based, and just as other enterprises are seeking the optimal combination of on-premise and cloud-based services, so too should schools give thoughtful consideration to these services as an effective option for supporting growth or mitigating risk.

Continuing mobile broadband market developments will likely increase school use and integration of such services into network design. Whether in a school-sponsored 1-to-1 or a BYOD program, designing for access and use of services will be critically important.

When designing a network to accommodate the needs of all users, especially in a BYOT/BYOD or 1-to-1 initiative, the old adage 'an ounce of

Assessment is but one service that the school's network is supporting. All other services must continue to be supported by the network.



Broadband Access for Teaching, Learning and School Operations	2014-2015 School Year Target	2017-2018 School Year Target
An internet connection to the Internet Service Provider (ISP)	At least 100 Mbps per 1,000 student/staff	At least 1 Gbps per 1,000 student/staff
Internal Wide-Area Network (WAN) connections from the district to each school and among schools within the district	At least 1 Gbps per 1,000 student/staff	At least 10 Gbps per 1,000 student/staff

prevention is worth a pound of cure' definitely applies. Gone are the days of simply throwing more hardware and infrastructure at the problem and expecting things to work smoothly. This section won't delve into specific pieces of hardware, but one should come away with useful network design considerations, either for totally new environments (greenfields) or to upgrade an existing infrastructure to support wireless. While there is no single best solution to meet every need, the information presented here offers a solid core of considerations and guidelines from which to base decisions.

Performance requirements

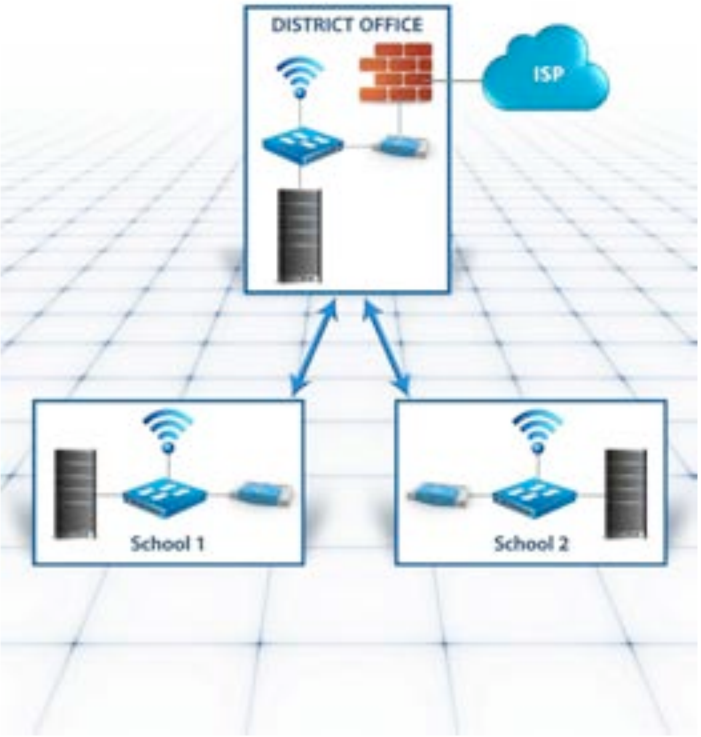
The expression "begin with the end in mind" is particularly true when designing networks. The classic "Requirements Definition" step in building any large project is critical. Requirements of the network can be thought of as being determined by the services that use the network, which are the applications that bring the information or service to the user – a video for a teacher to share with students, a phone call between colleagues, or an online assessment of progress are a few examples. There are many more applications and services, each with their own needs from the network. It is therefore necessary, as determined by the vision, mission and goals mentioned above, to develop a clear understanding and inventory of the applications and services and their precise requirements from a networking perspective. These requirements will, ultimately, be reduced to very technical elements, but, as was discussed in the section on *Data and Capacity*, the end result will be about various forms of data and how fast it must be delivered over the network. Additional requirements regarding a host of services such as resiliency of the network, securing the network and backing up the network's data add further requirements to inform the design.

Most schools have existing networks and, in large part, have been able to deliver varying degrees of service and many are on a path toward the transformative capabilities and teaching models described previously. Irrespective of where a school may be on their journey to transformation, they all should always compare their requirements to their existing conditions – using as much data as possible to describe the existing infrastructure and **producing a gap analysis detailing exactly what must be done in terms of enhancing the network in order to achieve their goals.**

Network topology

Key in supporting the mobile user is a solid infrastructure. Generally thought of as the *network core,* this includes the connections to the Internet and to schools within the school district. Many options are available to schools in designing networks, but the most prevalent are star, ring and hybrid (ring/star) options (see the following diagrams). While many factors, principally cost, affect the type of design chosen, **a guiding consideration should be the ability of the network to minimize outages in the event communications are lost to a given node**. This is particularly important in environments where the district centrally provides application and Internet services to all schools. School districts should review their exposure to such risk and develop strategies to maximize resiliency. Desirable options include *secondary data centers and redundant or backup paths to nodes*.

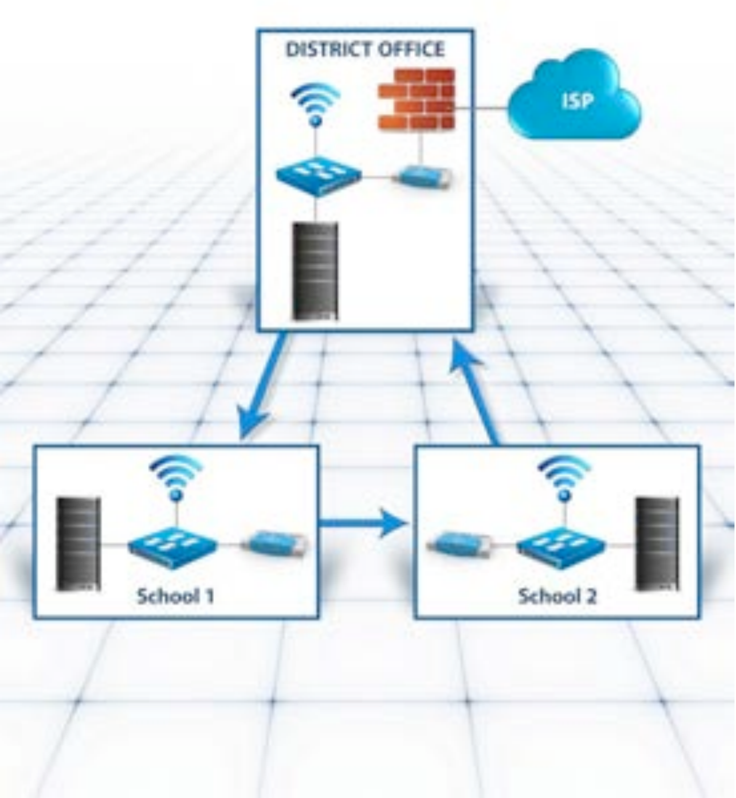
Star:



A star is a common design used by many schools today. This approach grew out of the “leased data circuit” approach to building networks. Historically, schools connected to the district data center using leased data circuits in a star (or “point-to-point”) topology. Over time, these may have migrated to dark fiber or leased-fiber media. Simple to operate, they are still in use by many schools.

Many options are available to schools in designing networks, but the most prevalent are star, ring and hybrid (ring/star) options.

Ring:



Correctly designed, rings provide a more resilient level of availability. Nodes on the ring stay in communication with each other even if a service interruption occurs along the ring. This "self-healing" property has associated costs but maximizes availability.

Hybrid:

To gain reliability and minimize costs — especially with schools in close proximity to each other — consider a hybrid model. Similar to star or node-off-a-ring, this method essentially delivers one big "pipe" to the hub school with somewhat smaller connections to "spoke" schools — and eliminates equipment duplication, creating substantial cost savings.

There is no single "correct way" to design a network. Some topologies better lend themselves to redundancy and robustness, but the method of

There is no single 'correct way' to design a network. Some topologies better lend themselves to redundancy and robustness, but the method of bringing a connection to a device can vary.

bringing a connection to a device can vary significantly from one location to another.

Many network transport infrastructures were implemented prior to new technology advances; therefore, many current designs only provide a single-service delivery location and single route from the campus to the service. Although secondary or redundant links are not E-Rate eligible, a multi-link or multi-site delivery model should be considered as schools plan for growth and capacity strategies. A multi-site delivery model can simultaneously support virtualization, disaster recovery and business continuity planning

Dynamics in the new networking environment

Design requirements for education networks have changed, as have the service delivery models, available services for information and communications technologies, access devices and access locations. In short, *everything* has changed during the past few years. Now is the optimal time to re-evaluate and re-build the network, if possible.

A few requirements to consider when re-designing the network:

- The Internet is mission-critical and will continue to grow in use
- 24/7, mobile, anytime computing is critical to the support of Personalized Learning Environments (PLEs)
- Private, hybrid and public clouds are education network requirements
- Internet services will grow substantially, meaning that associated school Internet infrastructure components must be sized adequately and scalable
- The WAN and Internet service design directly correlates to the viability of managed services as a valuable option for schools
- Wireless network design is about capacity *and* access
- Student computing, BYOD/T and mobile devices are untrusted and will likely be the primary devices accessing the network
- Consider point-to-multipoint network designs. These networks are eligible for E-Rate under certain circumstances.[9]
- Describe and define the current and future roles for mobile broadband (3G/4G) with respect to district network strategies. Wireless Internet (3G/4G) services are eligible for E-rate under certain circumstances.[10]
- Security models are changing
- Software-defined networking will impact school network designs and

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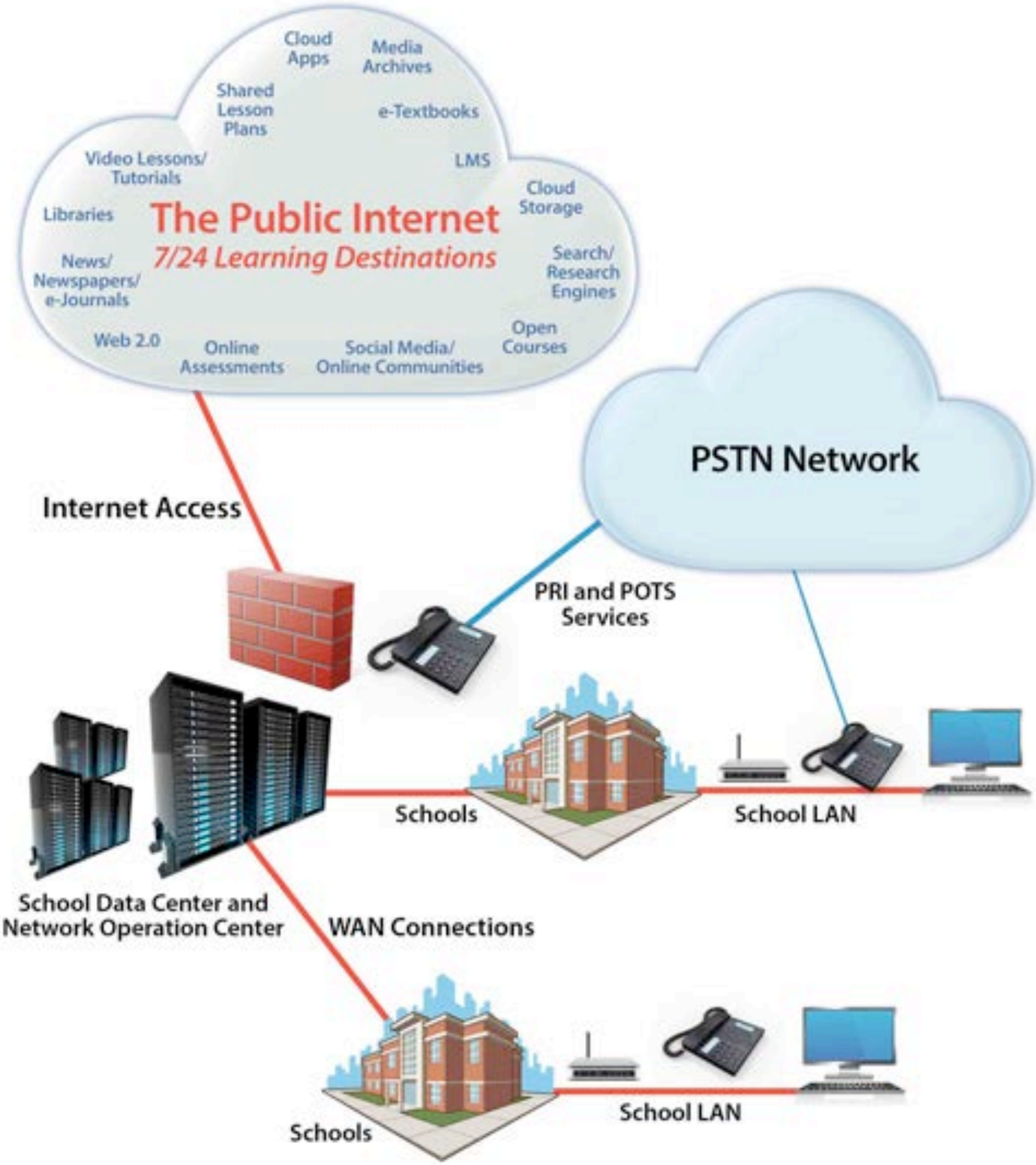
[9, 10] USAC Eligible Services List http://www.usac.org/sl/applicants/beforeyoubegin/eligible-services-list.aspx 2014

In a few short years, *everything* has changed. Now is the optimal time to re-evaluate and re-build the network, if possible.



A robust, full-service education network envisions many partners and methods of delivering service to schools and other locations.

- Virtualization is an important education network component.

A robust, full-service education network envisions many partners and methods of delivering service to schools and other locations (see diagram, p. 28).

Network addressing schemes and VLANs

Good planning is essential. Networks must accommodate for the likelihood that schools will have **many more devices**, and hence more addresses, requiring more connectivity than ever before. **Security, management and monitoring** must also be integrated into the design. Emerging best practices recommend that **the network to be as segmented as possible and that separate VLANs for students and staff** be established to properly secure the network — especially as the BYOD model increases in prevalence. The network diagram below represents a high-level design for an advanced school network.

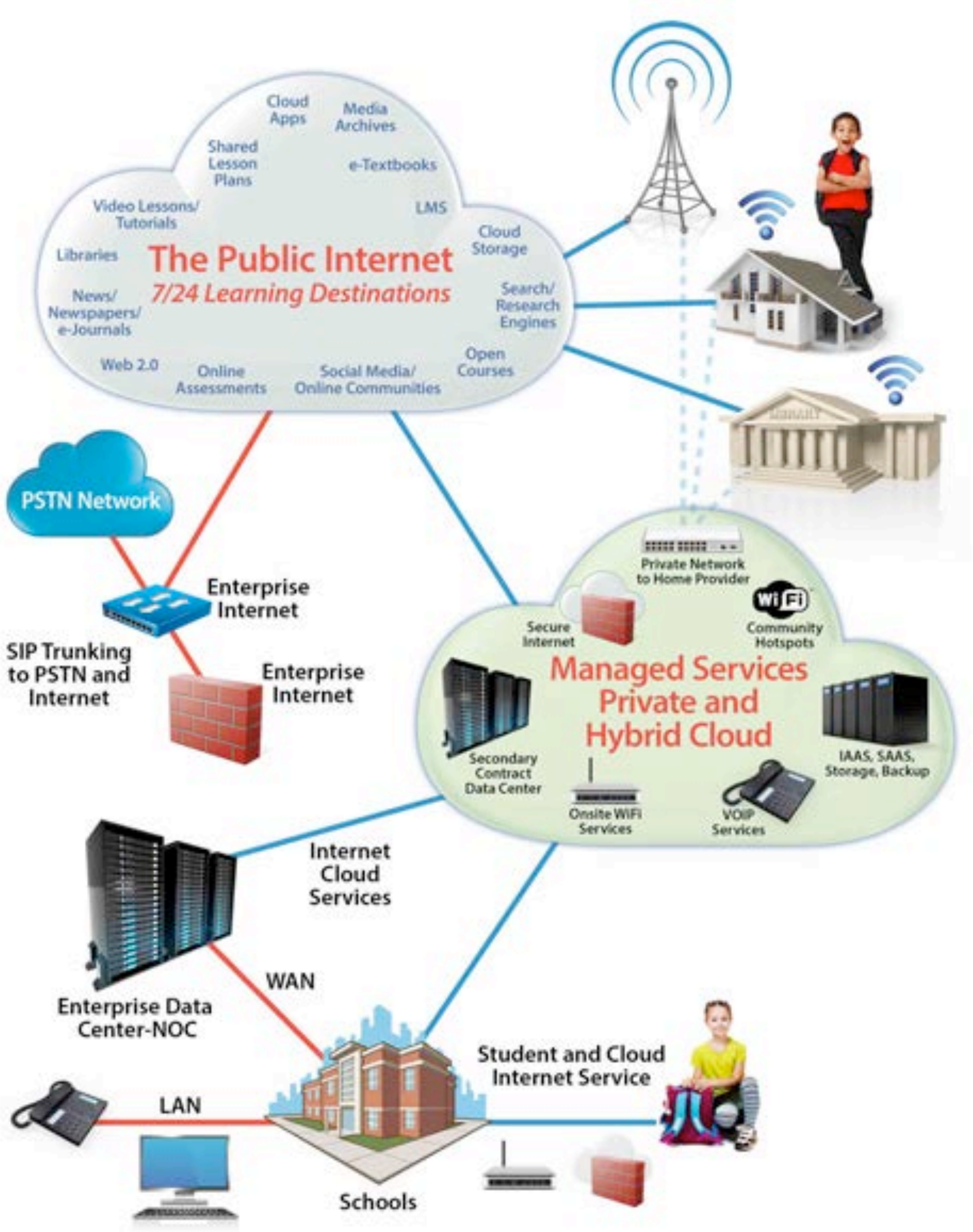
In addition to the use of VLAN technology, designers may also take advantage of "quality of service" (QoS) technology available in networking equipment to help their network effectively deliver critical user applications. In the context of network congestion, QoS is using a prioritization scheme to ensure (as best as possible) that critical services such as phone calls (VoIP) or content delivery to specific users or applications are not delayed. For example, video conference calls require higher allocations than audio calls, while audio calls require higher allocation than downloads such as web pages or documents for reading or editing.

Broadband access

Internet service is mission critical. The ConnectED announcement calling for E-Rate modernization to prioritize Internet service, and the FCC 2011 Transformation Order outlining overhaul of our telecommunications systems to prioritize Internet access, reflect the importance of Internet access in homes, schools and communities. CoSN's recent *E-Rate and Broadband Survey 2013* reveals that virtually all (99%) of schools surveyed stated they will need increased Internet bandwidth and connectivity in the next 36 months, with over 60% stating that they *do not* have sufficient capacity now or within 12 months. One way of looking at the important role of Internet access in school operations is to consider the Internet as we would any other utility — critical for daily operations and must be funded. For the Internet, this includes the need for all components necessary to deliver the service to students and staff.

As Internet design requirements have changed significantly, so should network design models. Capacity and mission-critical requirements alone can drive design change, however, as the Internet plays a lead role in disaster recovery/business continuity, in providing PLEs, in virtualization and in services and for communications and

Networks must accommodate for the likelihood that schools will have many more devices, and hence more addresses, requiring more connectivity than ever before.



Virtually all (99%) of schools surveyed stated they will need increased Internet bandwidth and connectivity in the next 36 months...

information dissemination — it becomes *the priority* capability.

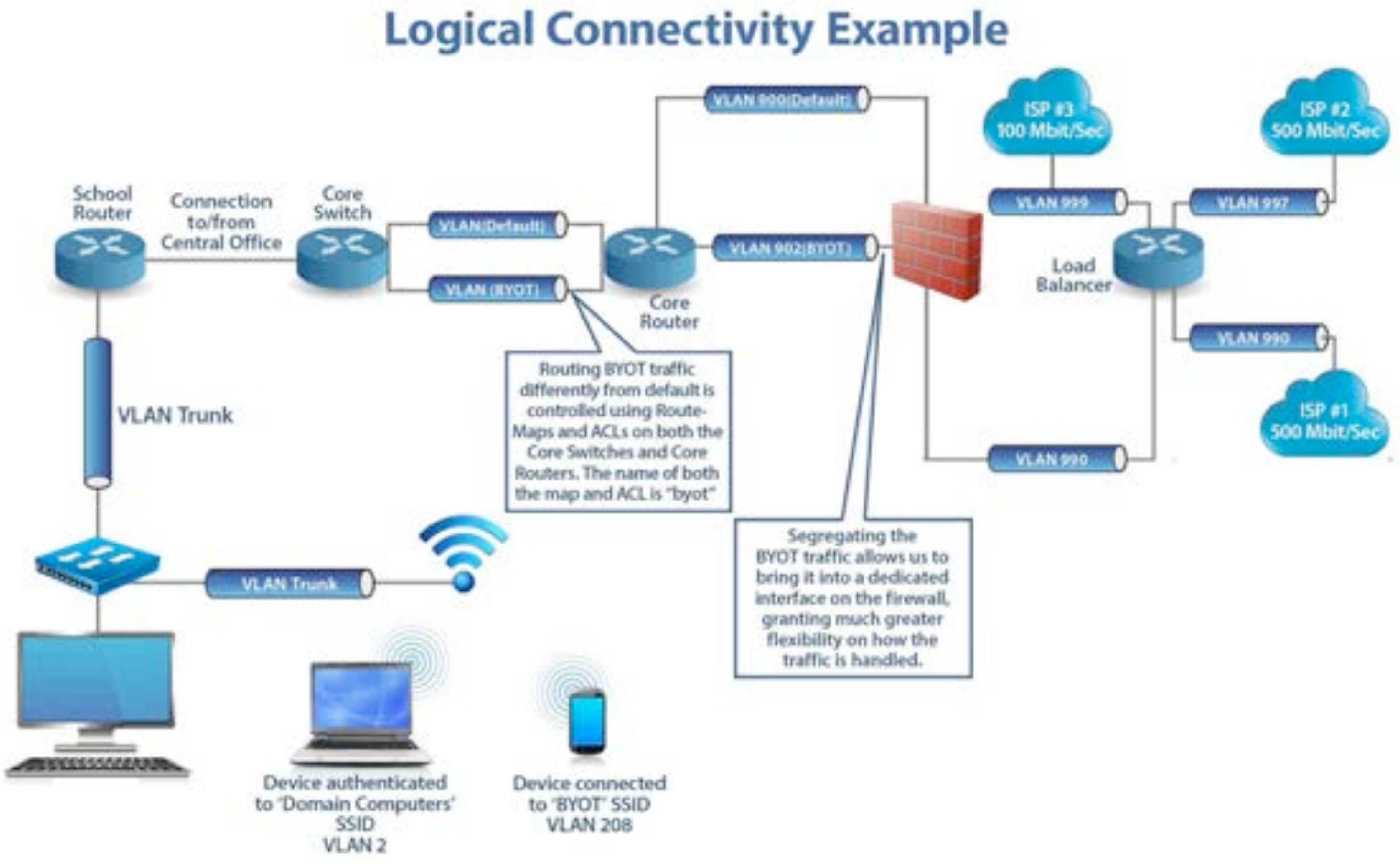
Listed below are design guidelines relating to Internet service:

1. Contract with multiple Internet Service Providers if needed for redundancy and sufficient capacity

- Having multiple ISPs increases capacity resilience, and service-provider flexibility
- Obtain an Autonomous System Number (ASN) https://www.arin.net/resources/request/asn.html

2. Design multiple delivery locations within the WAN for Internet Access

- Allows for better opportunities from alternative providers


Logical Connectivity Example

Routing BYOT traffic differently from default is controlled using Route-Maps and ACLs on both the Core Switches and Core Routers. The name of both the map and ACL is "byot"

Segregating the BYOT traffic allows us to bring it into a dedicated interface on the firewall, granting much greater flexibility on how the traffic is handled.

Device authenticated to 'Domain Computers' SSID VLAN 2

Device connected to 'BYOT' SSID VLAN 208

As Internet design requirements have changed significantly, so should network design models. ...The Internet becomes *the priority* capability.

- Increases resiliency
- Supports secondary network operations locations and secondary data center services.
- Build the WAN for multiple service delivery locations
- Consider point-to-multipoint transport services or modify and add from the existing WAN
- Multiple delivery locations can also double capacity without moving to a high-capacity, expensive service transport network

3. Consider a professional, carrier-neutral data center as the additional service delivery location.

- Carrier-neutral data centers provide opportunity for high-capacity, low-cost Internet
- Professional data centers support disaster recovery, business continuity, Infrastructure as a Service (IaaS), Internet and power
- The data center should have access to high-quality, high-capacity Internet providers to lower transport cost

4. Consider managed service options to scale Internet capability

- Managed Border Gateway Protocol (BGP) routing services, generally needed in a multi-provider environment, can be provided by an Internet Service Provider even if the school has two providers
- Managed firewall service for a student Internet service provides scalability and reduced capital cost
- A student firewall service may not require the same rule and management as the traditional enterprise firewall

5. Consider affiliation with regional or statewide networks associated with Internet2

- Internet2 permits commercial peering services, and routing pathways to such commercial entities as Microsoft, Apple, Google, etc., which are the sources of much cloud-based and software update traffic
- Regional and statewide networks may provide other cost-effective, enterprise services such as Intrusion Protection Services (IPS), Unified Threat Management (UTM), traffic/packet shaping, IPv6 routing, firewalls, etc
- Due to the end-to-end managed design of Internet2, regional and statewide networks provide different levels of service by employing Intranet routing strategies
- Consider these networks where available, for more information see the Internet2 K-20 Initiative: https://k20.internet2.edu/

When building next-generation Internet service or evaluating existing service for scalability, all components of the Internet service must be

All components of the Internet service must be assessed based on capacity, memory, bandwidth, and specifications.

assessed based on capacity, memory, bandwidth, and specifications.

1. Demarc or Border Gateway Protocol (BGP) router — BGP is the most popular exterior routing protocol as it allows for decentralized routing, which is beneficial in a multi-homed environment)

2. Firewalls

3. Wireless controllers

4. Content filters

5. Intrusion protection systems, stand-alone or part of Unified Threat Management (UTM)

6. Packet shapers, critical in traffic management in a constrained bandwidth environment

7. Core router

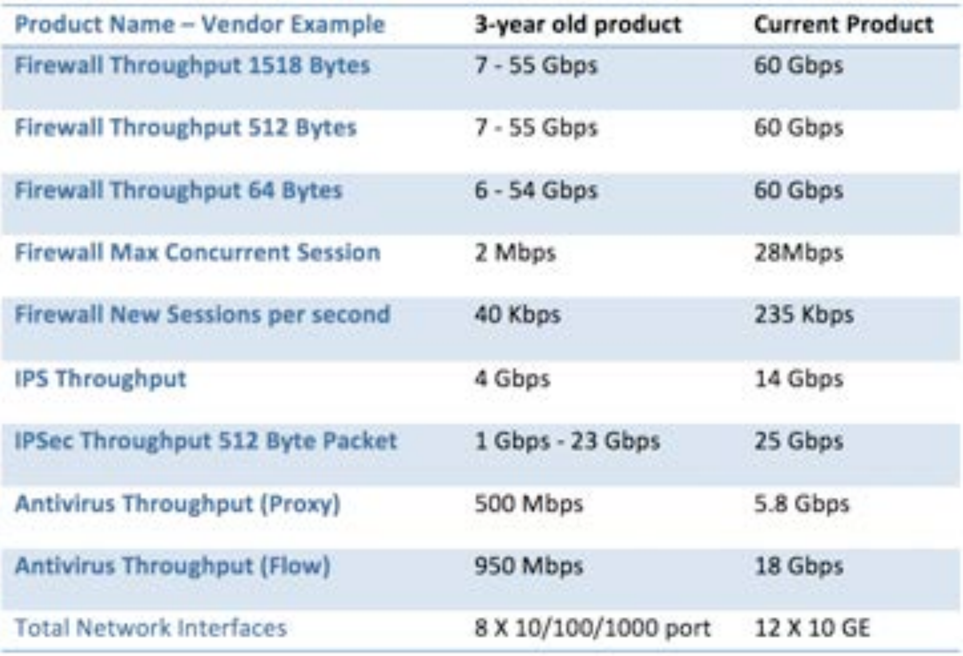
8. Layer 2 switches in DMZ, external or Internet segments on the Internet Service.

Internet infrastructure equipment manufacturers have answered the need for high-performance, high-capacity equipment such as next-generation firewalls and UTMs that can process Internet content with increased size and sessions per page and devices.

Following (see table) is an example of a manufacturer platform specification from three years ago versus current next-generation hardware and capability. Note that numbers represented might be theoretical maximums and could be significantly less as more features (filtering, antivirus, anti-spam, etc.) are enabled. As cost of these core devices is a non-trivial consideration, work closely with knowledgeable engineers to avert operation oversubscription from day one.

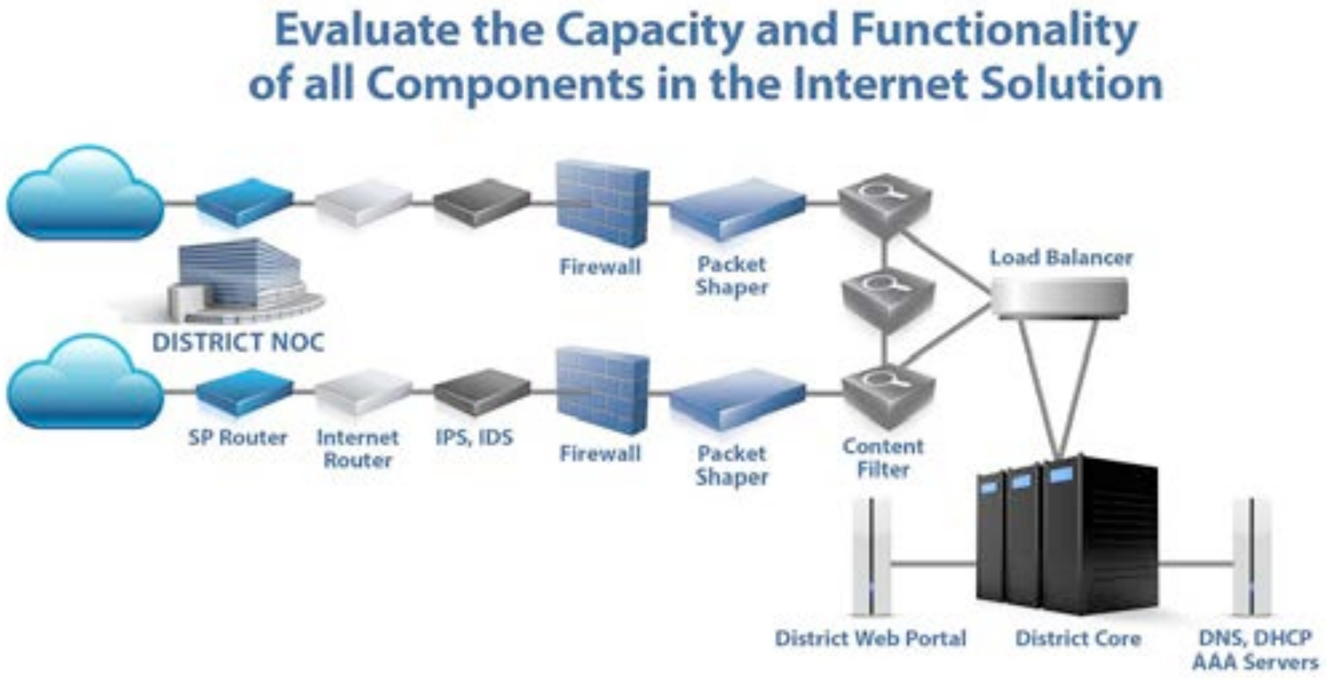
Mobile (3G/4G)

Securing affordable and sufficient broadband access for local-area connectivity via Wi-Fi is the primary



Product Name – Vendor Example	3-year old product	Current Product
Firewall Throughput 1518 Bytes	7 - 55 Gbps	60 Gbps
Firewall Throughput 512 Bytes	7 - 55 Gbps	60 Gbps
Firewall Throughput 64 Bytes	6 - 54 Gbps	60 Gbps
Firewall Max Concurrent Session	2 Mbps	28Mbps
Firewall New Sessions per second	40 Kbps	235 Kbps
IPS Throughput	4 Gbps	14 Gbps
IPSec Throughput 512 Byte Packet	1 Gbps - 23 Gbps	25 Gbps
Antivirus Throughput (Proxy)	500 Mbps	5.8 Gbps
Antivirus Throughput (Flow)	950 Mbps	18 Gbps
Total Network Interfaces	8 X 10/100/1000 port	12 X 10 GE

As cost of these core devices is a non-trivial consideration, work closely with knowledgeable engineers to avert operation oversubscription.



focus of building effective education networks on school grounds to support robust wired and wireless environments. However, ensuring continuous connectivity after the final bell rings should also be a significant concern of network planners and school administrators. Several studies and pilot programs have demonstrated that making course content available and providing a means of collaboration among students and with teachers on a continuous and convenient basis drives significant benefits for students and advances in learning effectiveness. The use of mobile (3G/4G) connectivity can play a significant role in ensuring such continuous access for 1-to-1 programs.

Anywhere, anytime connectivity provides students with the opportunity to insert their studies into real world settings, whenever the time or context is conducive to learning. Furthermore, for many students a mobile (3G/4G) connection will be their only means of connecting from home. Some districts share that as high as 70% of their students do not have broadband and Wi-Fi access at home in some regions, making many of the advantages of 1-to-1 programs and digital content inaccessible to this group as soon as they step off of school grounds. Additionally, regardless of whether the proportion of students without access to a Wi-Fi connection at home is 70% or 10%, network planners and school administrators must be diligent not to create a digital divide between students who

An infrastructure for learning is always on, available to students, educators, and administrators regardless of their location or the time of day.

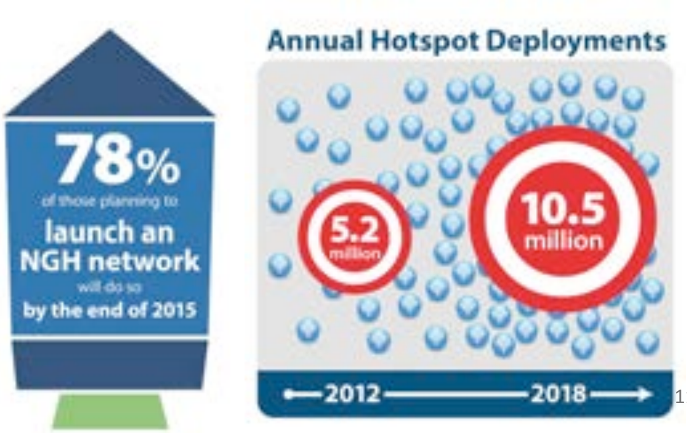
have access to learning content and opportunities while in the comfort of their own homes, and those who do not.

As schools work to ensure that all students are Internet-connected at home and in the community, it is recommended that network planners meet with mobile network operators or education-focused mobile service providers to better understand service options, coverage and costs. As previously described, mobile (3G/4G) networks will offer good coverage to the vast majority of homes and public places, and mobile service providers have been working to develop and bring to market solutions that address the needs for cost and security controls.

Community hotspots

Another strategy for supporting off-campus connectivity is the siting and deployment of community hotspots. Community hotspots were in fact listed as one of the services that will be considered in the modernization of E-Rate for 2014. These are an opportunity for public/private partnerships whereby school districts can extend high-capacity, highly available Internet access to student-frequented facilities or locations in the community. Such community hotspots can serve a useful function in supporting out of school connectivity in areas where large numbers of students may be congregating and attempting to connect simultaneously, or at times when large volumes of download or upload activity can be more efficiently and cost-effectively offloaded to an available Wi-Fi network.

Furthermore, technologies such as Hotspot 2.0 – also known as Next Generation Hotspots or (NGH) – will offer seamless interworking between 3G/4G and Wi-Fi networks. This capability is ideal for the student populations considered in these guidelines as it essentially takes the guesswork out of selecting which network a device should access at a given time and context. With Hotspot 2.0, the device is capable of identifying available Wi-Fi, 3G and 4G networks, understanding likely throughput speeds of each available network, then determining the best possible means of establishing a connection based upon security, performance, Quality of Service, network policies, and a host of other factors.



[11]

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[11] Global Trends in Public Wi-Fi — WBA Wi-Fi Industry Report, 2013

With respect to WAN/LAN, analyze needs and then purchase as much additional capacity as possible for use over the financial planning horizon.

As it becomes commercially available, Hotspot 2.0 or NGH will provide another valuable tool for schools to seeking to enable 24/7 learning for their students.

Backhaul or WAN/LAN considerations

Generally, schools have done a great job installing networks to provide a baseline for connectivity and applications. As discussed earlier, demand placed on those networks is increasing. CoSN's *E-Rate and Broadband Survey 2013* indicates that, while having more broadband is top priority for schools, this is quickly followed by a need for wireless and WAN/LAN capacity. Network routing and switching capacity must keep pace with the needs of the applications. Providers are responding, making 10 Gbps and 40 Gbps capability available. The guideline with respect to WAN/LAN is to analyze needs and then purchase as much additional capacity as possible for use over the financial planning horizon. Additionally, virtualization and technologies such as Software Defined Networking (SDN) offer the promise of better manageability and affordability. In planning for WAN/LAN implementations or upgrades, schools should consider:

1. Point-to-multipoint WANs for increased capacity and resiliency

2. Managed services

3. Long-term dark fiber infrastructure to support scalable transport.

A key, determining factor to consider is the density of clients expected on each access point.

In evaluating service options, schools should consider all of the costs associated with each option and any significant differences in performance capabilities.

The connection between wireless access hardware (access points, arrays, etc.) and their associated core **connection point should be at least 100 Mbps, with 1 Gbps (or higher) preferred.** A key determining factor to consider is the *density* of clients expected on each access point (hereafter referred to as 'AP'). The greater the number of expected clients, or density, the higher the bandwidth needed for the backhaul connections. Some APs also support use of redundant (for reliability) or bonded (for more bandwidth) connections, possibly requiring additional cabling runs if pre-existing infrastructure is inadequate.

Additionally, many APs require communication from a central management controller and while overhead should be minimal, if there is a marginal connection to begin with, operation of the network could suffer as a result. Bandwidth, even at 1 Gbps, is relatively affordable on most school networks so there is no reason to under-design this connection.

Another point of consideration with the backhaul or LAN component of the network is the fact that many APs (and other devices such as phones) now draw electrical power from network cabling, known as Power over Ethernet, PoE or PoE+. While negating the need for endpoint power, it may render older cabling unusable. In fact, **if pre-existing cabling is not at least Cat 5e, and preferably Cat 6, then the cost to replace or augment pre-existing cabling will need to be considered when designing your network**. Similarly, total power available to wiring closets needs to be evaluated since these devices (e.g., APS and phones) are being powered by switches which themselves are drawing more power.

SUSTAINED SURPRISE >> **Forsyth County Schools** in Georgia has a very large wireless infrastructure supporting more than 45,000 users. At any given time during the school day, nearly 20,000 unique devices associate with their wireless hardware. Nearly six years into supporting devices in this manner, they've found that even their most heavily-used arrays (wireless APs) only experience approximately 10-15 Mbps of sustained usage on their backhaul — even with upwards of 200 devices attached — many arrays experience significantly lower levels of sustained usage. Considering the high rate of technology buy-in — both from the district and the community at-large — they were surprised to discover such small sustained usage on backhaul links. Nevertheless, as an aggregate number for the district, it's not uncommon to see nearly 800 Mbps sustained usage directed to district Internet circuits. This is in addition to the 22,000 district-supplied computers that may be in use on the wired network. ■

Keep in mind that adding bandwidth is not a "fix-all." Simply providing more capacity in an environment might seem like a quick cure for your

Adding bandwidth is not a 'fix-all' ... it is important to diagnose and address the root cause of the issue.

network problems, but it is important to diagnose and address the root cause of the issue. **Many enterprise-level wireless solutions provide integrated reporting, which is invaluable in proactively minimizing problems.**

Some APs can also perform application/web filtering at the edge of the network so as to reduce network traffic on the backhaul and Internet links, a key ingredient when determining and designing backhaul bandwidth or speed.

Lastly, but very importantly, according to CoSN's E-Rate and Broadband Survey 2013, 26% of districts are using slower copper backbones and 2.3% are using wireless backbones in their school LAN**. In general, these need to be replaced with fiber connections to wiring closets.** There are cost tradeoffs between network electronics components and single-or multi-mode fiber so schools should work closely with their equipment provider

Staffing, training and leadership

Human capital and leadership must be included in network design and operation. Developing human leadership capacity for technology is critical in the design, planning and continued operation of superior networks for students and teachers. Working with technology leaders, CoSN offers a range of solid resources, most recently CoSN's Certified Educational Technology Leader (CETL) program, which is focused around a framework of essential skills and provides a comprehensive developmental and certification process for technology leaders. Find out more at: http://www.cosn.org/certification

Access Points and Wireless Connectivity

As the effectiveness afforded by mobility continues to be realized, design and implementation of wireless services (Wi-Fi and 3G/4G) become critical. Unlike the wired environment, in which capacity and reliability was relatively assured because of dedicated resources, wireless technology has a different set of deployment and use challenges centering on capacity, especially in scenarios in which there are many users of data-intensive applications. This and other challenges, such as walls and building materials, which limit reception, can be overcome with good analysis and design.

Beyond the physical signal and capacity considerations, wireless technology also compels the designer to include address planning, security, and identity management into the design — especially as privately owned devices are likely to be used.

Design questions

Contrary to popular belief, properly implementing a wireless network is neither quick nor easy. It is

Thoughtful analysis and design are critical; start with a plan and then go about determining how best to implement that plan.

entirely possible to buy a consumer-level product from the nearest electronics store, connect it to the network and begin offering a wireless connection for students, however, doing so would be courting failure. Thoughtful analysis and design are critical; start with a plan and then go about determining how best to implement that plan.

Some questions to inform design:

- **How much coverage and at what densities?**

Is the intent to provide coverage just to classrooms or to the entire campus? After deciding which areas to cover, a proper site survey is the next step. Once coverage areas are decided, a survey will show where APs need to be placed to provide adequate coverage for expected user densities. Special care should be given in determining AP placement. **Be sure to allow enough coverage overlap to compensate in the event of an AP outage.**

- **What types of devices will be allowed to connect?**

The broad array of end-user devices (notebooks, handhelds, tablets, game systems, e-readers, etc.) presents a challenge in designing and administering networks. While it might seem reasonable to assume that if the network can handle one type of device, it can handle them all, that is not necessarily the case. Some devices require certain conditions to be present on the network to function properly. **Strategies here include testing many of the common devices to ensure successful access and/or to limit devices to a specific type.** Not doing so sets up poor user experience and may impact the network.

SMART SUPPORT >> **A district decided** not to support 802.11b-only devices on the network. Even though 802.11g was backwards-compatible with 'b', any 'g' radio would have to slow down to 'b' speeds (impacting *all* connected devices) if a 'b' device associated. As 802.11b devices were on the wane when the district implemented its BYOT solution, it was assumed the impact would be minimal with, at worst, a few handheld gaming systems losing connectivity. Fast forward a few years to Christmas 2012: the latest Kindle Fire, which supported 802.11g, would not attach to the BYOT network. Working closely with the wireless vendor, it was discovered that the Kindle required 802.11b support, even though it wasn't going to use it. Since the network had 802.11b support disabled, the Kindle refused to connect. The vendor developed a quick patch to fool the Kindle into thinking the network supported 802.11b, even though it did not. A close relationship with one's wireless vendor and/or VAR can be a wise move. ■

- **Are you starting from scratch, or is there a pre-existing wireless network?**

Quite often, implementing a new wireless solution is much easier than integrating new hardware with a pre-existing setup. Nevertheless, should a partial solution already be in place, carefully

In planning a partial new implementation, select hardware that can scale to a larger installation.

consider how the two disparate solutions will interoperate. In planning a partial new implementation, **select hardware that can scale to a larger installation.**

▪ What construction materials are used in the buildings?

Though technology personnel might not have direct input into building materials, good relations with the school's' facilities department provides greater understanding of potential problem areas.

▪ Which district resources are available?

The answer can greatly impact the design, complexity, and cost of an installation and is further complicated by the ownership of the device – school or student. An appropriate guideline is **design to provide student access to services they would normally have in an in-school wired environment when using school-owned devices. With BYOD, provide similar but web-enabled services deliverable securely through mobile browsers**.

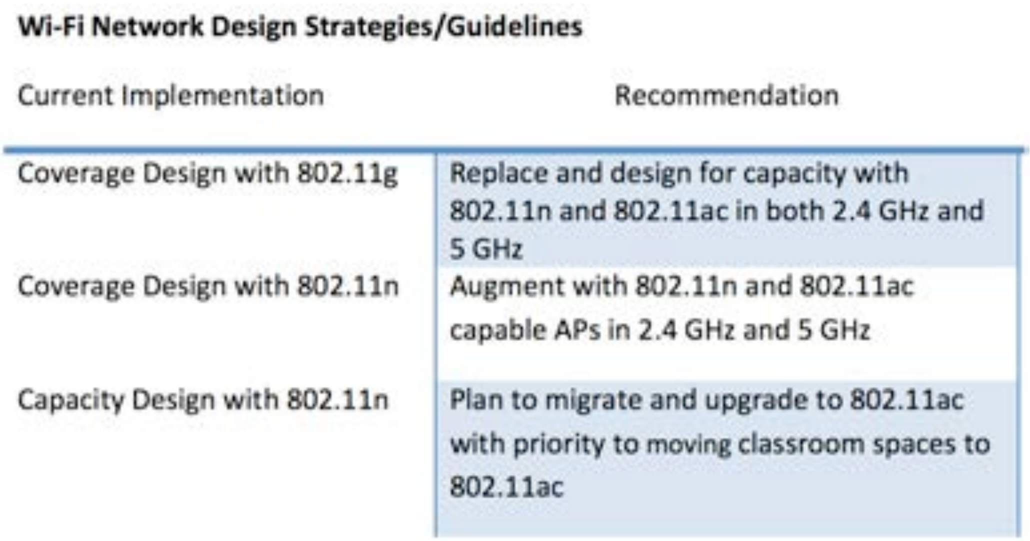
With limited internal resource access (printing, file shares, etc.), consider a mobile device management (MDM) solution. An MDM can help assure that clients meet a minimal security posture while authenticating access to desired internal resources. Using MDM to regulate is only one option; consider using a virtual desktop product to provide a secure environment in which users can safely interact with school resources. Of course, these options can add cost and complexity as well as some measure of resource overhead in the form of hardware, software, and personnel.

Another option: simply allow *only* Internet access by blocking all internal access, and direct all traffic out the Internet gateway. While this is the most secure option, it has the negative side effect of preventing access to potentially needed internal network files.

▪ How clean is the radio frequency (RF) spectrum?

A survey of the school by a qualified wireless professional will provide an assessment of how "clean" the RF spectrum is at any given site. Even if there is no pre-existing wireless network, the spectrum might not be as free from congestion as one might think. Besides ever-present background noise, if a school is in or near a neighborhood or urban area, impingement from outside wireless networks is almost assured. Since the 2.4 GHz and 5 GHz bands are unlicensed, meaning that no license is required to operate equipment in these bands provided maximum power levels aren't exceeded, there isn't much that can be done to mitigate interference from outside sources. Proper channel planning and layout is essential in providing the best possible connection in a challenging environment. **Over time, the growth of newer standards relying on the "cleaner" 5 GHz should help mitigate congestion issues evident in 2.4 GHz.**

Proper channel planning and layout is essential in providing the best possible connection in a challenging environment.



Wi-Fi Network Design Strategies/Guidelines

Current Implementation	Recommendation
Coverage Design with 802.11g	Replace and design for capacity with 802.11n and 802.11ac in both 2.4 GHz and 5 GHz
Coverage Design with 802.11n	Augment with 802.11n and 802.11ac capable APs in 2.4 GHz and 5 GHz
Capacity Design with 802.11n	Plan to migrate and upgrade to 802.11ac with priority to moving classroom spaces to 802.11ac

- **How will rogue APs be mitigated?**

No matter how secure the design, there will *always* be unauthorized, or rogue, networks with which to contend. A rogue AP can have a deleterious impact on a wireless network — as a source of interference, a path to avoid network filters, a security issue (in the case of an impersonated SSID) and in certain circumstances as an unprotected threat vector for malicious software or users to gain access to the internal network (in the event a user connects to the rogue with their wireless card while simultaneously connected to the internal, wired network). **A smart design includes features to "sequester" rogue traffic — both the rogue itself and any connected clients — effectively neutralizing the offender. While this won't clean the spectrum, it does "enforce" expected behavior by making rogues unusable.**

Addressing key challenges in Wi-Fi deployments

There is a finite amount of RF spectrum available, especially in the 2.4 GHz band (used by 802.11b/g/n) with only three non-overlapping channels (1, 6, 11) available for use. *Overlapping* is the term used to describe the "bleeding over" of a signal's primary frequency (or "center channel") into neighboring frequencies. Wi-Fi channels in the 2.4 GHz spectrum will overlap two channels on either side of the center channel (i.e., channel 6 will also impinge channels 4, 5, 7, and 8 — as those are the channels within the two-channel overlap on either side of the center channel). This is why, even though there are 11 channels in the 2.4 GHz spectrum in North America for wireless networking, only *three* channels - 1, 6, and 11 - don't overlap with each other and should be used to implement the most robust 2.4 GHz network.

For example, if there is already a wireless AP running on channel 6. This means that channels 4, 5, 6, 7, and 8 are being used (center channel 6, plus the two neighboring channels on either side of 6). If an additional AP is to be added and not interfere with the existing AP, channel 1 or channel 11 must

Though there are no rules mandating the use of only channels 1, 6, or 11 for networking in the 2.4 GHz spectrum, using anything else can *seriously affect* communications...

be selected. If the AP were to be configured to run on channel 2, it would impinge on channels 0*, 1, 2, 3, and 4 (*there's not really a 'channel 0'— it is just being used as a "placeholder"). Since channel 6 also impinges on channel 4, then center channels 2 and 6 are overlapping, which can create communication problems. Though there are no rules mandating the use of only channels 1, 6, or 11 for networking in the 2.4 GHz spectrum, using anything else can *seriously affect* communications and *negatively impact* a wireless engineering plan. It is also considered to be best practice to use channels 1, 6, and 11, as well as being a "good neighbor" when other entities might be within close proximity.

As a great majority of consumer hardware uses the 2.4 GHz bands, congestion rapidly degrades performance. Fortunately, there is another bit of unlicensed spectrum: the 5 GHz band with up to 23 non-overlapping channels available and used by 802.11a/n/ac. Though initially far less common in the consumer and business space, the widespread adoption of dual-band 802.11n (and the forthcoming 802.11ac standard) has made devices that support the 5 GHz spectrum somewhat more common. **Nevertheless, a great majority of devices will still prefer 2.4 GHz unless configured to prefer 5 GHz**. Not only can the 2.4 GHz spectrum be more crowded with clients, it's also congested by non-802.11 traffic from Bluetooth devices, gaming systems, personal hotspots, microwave ovens, and even improperly grounded electrical systems.

TRAFFIC TRENDS >> **Officials at Forsyth** County Schools, with nearly 20,000 concurrent wireless devices on their network, have noticed that, while the number of 5 GHz-capable devices has indeed increased on their network, it hasn't kept pace with the overall growth rate of wireless devices on the network. Obviously, even with dual-band 802.11n (and pre-802.11ac) devices, the great majority of devices are still operating in the 2.4 GHz spectrum. Though this should begin trending more in the direction of 5 GHz devices in the future, in the near-term, there will still be significant 2.4 GHz traffic. ■

Nevertheless, even 5 GHz has limitations since its higher frequency is more prone to signal loss (the 5 GHz signal is more readily absorbed — or 'attenuated' by obstructions between the AP and the device) and generally has a shorter range than 2.4 GHz devices at the same power output. **Careful planning is required when designing an infrastructure that will support both 2.4 GHz and 5 GHz spectrum.**

Design for the needed density (capacity)

Designing a network for a high-density user environment can present many initially non-apparent challenges. One of these is the people themselves. The human body, which is about 60% water, is a significant signal-absorption material. When performing a site survey and using predictive analysis, many underestimate the amount of signal

Construction materials, as well as furniture and fixture placement in a room, can significantly impact signal quality.

loss occasioned by simply by having large numbers of students in a classroom. This issue isn't often found in many corporate or office scenarios as it's not normal to have 30+ people regularly grouped together in a relatively small space. **This can be mitigated by having APs closer to the users, even investing in one AP per classroom.** A cautionary note: such density, especially in the 5 GHz bands will be effective but may negatively impact the RF spectrum in the 2.4 GHz bands. Thus, a thorough site survey is critical in designing a robust, and fault-tolerant wireless network. Some guidelines for existing wireless infrastructure are as follows:

Building materials and building architecture matter

Construction materials, as well as furniture and fixture placement in a room, can significantly impact signal quality. Though signal loss will even occur in empty space, signals passing through one or more walls, filing cabinets, interactive whiteboards or doors will encounter more loss. Additionally, mirrors in a dance studio, or more commonly, sound-absorbing materials in a music class require special attention. Users will also need to have realistic expectations in a wireless environment. Providing a Wi-Fi signal could be considered a "best effort" medium. All other things being equal, a *wired* connection will always be more reliable and faster as so many more variables can impact wireless service. Even the type of device can change the quality of service and user experience.

A device could be very close to an AP and still not receive a usable signal. Depending on the reflectivity of nearby surfaces, it's possible for a station to receive primary *and* reflected signals. If the signals are 180 degrees out-of-phase (meaning the crest of one signal matches exactly with the trough of another), it can effectively cancel itself out. Understanding RF environmental characteristics can go a long way in assisting with designing for optimum connectivity.

Address planning, design, and management

As previously mentioned, as device count increases, the number of public IP addresses — and their associated network address translation (NAT) and port address translation (PAT) that are available to the connection is of critical importance in a smart network. With the explosive growth of BYOT/BYOD hardware, it's not unusual for a user to carry multiple devices with them and even use those devices simultaneously. Further, each open application might open a corresponding 10-20 ports assigned for the duration of the session. If a user has four applications open, then each device might have 80 or so ports assigned. Carrying an average of two devices each, that's 160 ports assigned per student. In a 2,000-student scenario, that could translate to 320,000 ports allocated. Since each public IP address can only have approximately 59,000 assigned ports, that could mean six public IP addresses would be needed to support that number of users in that scenario. That might seem like an extreme

With the explosive growth of BYOT/BYOD hardware, it's not unusual for a user to carry multiple devices with them and even use those devices simultaneously.

scenario, but there have been instances of exhausted address tables resulting in sporadic Internet access, even with plenty of bandwidth available.

The Certified Wireless Network Professional Association offers certification programs and training guides to help leaders and engineers in designing and deploying wireless networks. Its "Certified Wireless Network Administrator Guide" http://www.cwnp.com/certifications/cwna is an excellent tool, both in studying for an industry certification *and* as a reference guide for effective implementation and management of wireless networking.

Responsibilities of student data security

State and federal guidelines and laws such as the Family Educational Rights and Privacy Act of 1974 (FERPA), the Children's Internet Protection Act (CIPA) and the Children's Online Privacy Protection Act of 1998 (COPPA) address student data security requirements and concerns. Additionally, the Protection of Pupil Rights Amendment (PPRA) protects rights of students and parents regarding surveys, analysis or evaluations conducted by the US Department of Education.

Familiarity with those requirements is critical in network design. Data security should be a high-level consideration and should not be minimized due to cost concerns. With the Berkman Center for Internet Law, CoSN is building a Toolkit on Privacy, which will include a summary of FERPA. Additional resources can be found in the Harvard Law School publication *Privacy and Children's Data: An Overview of the Children's Online Privacy Act and the Family Educational Rights and Privacy Act.* http://cyber.law.harvard.edu/publications/2013/privacy_and_childrens_data

NOTEBOOK NOTES >> **In 2008, Forsyth** County (GA) initially rolled out coverage to support notebook computers — which generally have a robust antenna design and can be usable even in a relatively weak Wi-Fi environment. With the proliferation of handheld/tablet devices, it became apparent that their antenna design was significantly *less* capable than what was found in notebooks. In a large number of areas notebooks functioned just fine — but tablet devices did not. It was determined that the minimum usable signal for handhelds/tablets was -65 dBm RSSI, whereas 72 dBm RSSI is adequate for laptops (the farther the number from '0', the weaker the signal). RSSI (received signal strength indicator) is a measurement of power present in a received radio signal. The stronger the received radio signal, the faster communication can occur between client and AP. ■

Encryption and security considerations

When deploying wireless networks, encryption *must* be a part of the design discussion. Though there are several encryption methodologies from which to choose, WEP is easily compromised and should never be considered. **If encryption is chosen, use**

WPA2 to secure wireless connections. WPA2 can be combined with other options, such as certificate-based authentication or RADIUS, to further tighten security.

More sophisticated designs and implementations can also intelligently assign devices to particular networks/VLANs depending on criteria such as user credentials, the existence of particular management software, and other conditions. This provides an extra layer of protection to traffic and/or internal resources, though it does add to cost and complexity. One approach is a WPA2-protected SSID, with the key distributed via Active Directory group policies, coupled with certificate-based RADIUS authentication (certificate pushed to clients via group policies) for district-supplied devices. These devices would have full access to internal resources limited only by group membership of the authenticated user.

Security is a vital consideration. Whether protecting a building, an automobile or a network, proper security provides for intact and continued operations. Users expect their data is as secure as can be reasonably assured while using a school's network. CTOs and system administrators must ensure that district resources are accessed only by those with appropriate authority. Laws and guidelines compel a district to apply certain controls to protect employee and student information. For the core of the network, threat mitigation technologies such as intrusion prevention and intrusion detection services (IPS/IDS), anti-virus and anti-malware services are essential to a safe and secure operation of the network. These considerations, individually and in concert, inform and specify network security design.

Best practices would suggest having a network (VLAN) dedicated solely for BYOD/T hardware even if the desire is to give those devices access to the same resources as if they were using school-supplied devices. Segregating the networks allows for more granular control of the traffic on a less trusted, or untrusted network through firewall policies, access control lists, and other means of the traffic on this untrusted (or *less* trusted) network, should the need arise.

Combining such network segregation with a tool such as MDM can further ensure secure data, as only properly authenticated devices will be allowed on the network.

Additional protection from undesired "snooping" would include use of a wireless product providing some level of sequestered network connection: *the client can access all allowed network resources, but clients are precluded from accessing each other.* This helps dissuade some of the more curious users from "exploring" the network beyond what's intended by the school or district. However, this may prevent some legitimate, in-building, point-to-point services (such as a networked voting device) from operating

Smart network design and development must include methods of granting users appropriate and secure network access.

if they use the school’s wireless infrastructure as a transport method.

Identity and Access Management (IAM)

Smart network design and development must include methods of granting users appropriate and secure network access. With today’s complex fabric of multiple systems, user management, including provisioning, de-provisioning and granting specific authorizations, is both essential and increasingly resource intensive. Effective IAM design and operation strategies are just as important, in many respects, as the design of hardware and software customarily considered part of the network. Although there is no single best way to design a school’s IAM method, resources exist to assist the designer and CTO in formulating a smart approach. CoSN is a contributing member of the National K-12 Federated Identity and Access Management Task Force (see https://spaces.internet2.edu/display/K12FedIAMTF/Home) — and has developed the document, *Single Sign-On, Multiple Benefits: A Primer on K-12 Federated Identity Management and Access Management*. http://www.cosn.org/FederatedIdentity

Connecting Devices to the Network

What’s the point in having a network if not to allow devices to connect? The question, then, is how best to accomplish this while ensuring both infrastructure and device security.

Authentication of devices and users

How are you planning to authenticate devices to your network? Are you simply going to allow *any* device to connect without regard to user or device identification? That may provide support to the largest number of devices, but can mean that CTOs and network administrators have no specific and identifiable knowledge about users and devices on their network. **An effective design approach is to authenticate via web page redirection where, when the mobile browser is launched, a user is required to pass credentials for authentication.** Integrated into the schools directory services or security systems, this can help ensure all users, before Internet use, agree to a ‘Terms of Service’ (which can neutralize the *‘I didn’t know I wasn’t supposed to do that!’* argument). This redirection may have small limitations such as not supporting all user-supplied devices, or precluding guests from using the network unless provisions are made, but professional, responsible network management and security always trumps such outcomes.

How much time, effort and manpower are you willing to dedicate to student-supplied devices?

If an authentication method is chosen, can users opt-out? If so, will they be afforded *any* sort of access? While there is no single 100% correct solution, careful planning and consideration should make it possible to find something that works for your school district.

Management of devices

With a secure wireless network now available to students, how can one smoothly manage a hardware influx? While there is no one-size-fits-all solution, smart designs include deploying some management tools.

- *Bandwidth management* - Is there a particular application or site consuming an inordinate amount of bandwidth? Block it with common filtering tools, but some legitimate education-related content may become inaccessible. **A better solution would be to limit the amount of traffic that can flow to and from the bandwidth hog and establish priority for critical traffic such as email, and online testing.** Newer-generation filters and firewalls easily do this, often providing significant bandwidth savings.

- *Mobile device management (MDM)* - Part of an overall strategy to manage all network devices, MDM solutions are very useful, giving districts granular control over a user's device, from granting access to the district's network to location tracking and camera access. They can also assist in software installations including license management and security.

- *Technical support of personally-owned devices* - How much time, effort and manpower are you willing to dedicate to student-supplied devices? Does your district have the capability, or desire, to provide support for hundreds if not thousands of disparate device types? Are you ready to be responsible for any user-supplied hardware problems if, for example, they are in any way related to district staff performed work? Given costs implicit in a high-support model for user-owned devices, a thoughtful approach may be to leave support for any BYOT/ BYOD hardware to the end user.

Web and content access management

Responsible and appropriate content management is another important consideration in network design and is a constant challenge for network managers. Compliance strategies exist both for student protection and legal necessity. **In wireless settings in which BYOD is encouraged, it is important that the school continue to ensure personally-owned devices using school-provided Internet service only be allowed to access content deemed appropriate by the school.** This may require additional technology or orchestration of other directory and filtering strategies, but it is wise to prevent students from accessing inappropriate content in all settings, not just while on the district's network.

Mobile device availability and adoption continues to rise in the workplace, consumer space and increasingly in education.

Connecting from Outside of School

Support for anytime, anywhere learning

Mobile device availability and adoption continues to rise in the workplace, consumer space and increasingly in education. Mobile devices incorporating wide-area or cellular connectivity are turning into multi-purpose, highly capable portable computers enabling greater interaction with increasingly immersive and always-available learning experiences. When effectively and securely supported, they have the potential to deliver highly-customized and genuinely transformative learning experiences both inside and outside the classroom.

Various pilot projects have demonstrated that supporting the ability of students to access learning content, interact with teachers, mentors and peers anytime, anywhere has a beneficial and transformative impact on learning effectiveness. Forecasts for substantial use of blended learning (50% of courses by 2019) further confirm the mainstreaming of this new model into K-12.

These pilots and a growing number of other experiences demonstrate that students and teachers benefit from gaining access to learning curricula and other resources that will reside on school networks on a 24/7 basis, in or out of the classroom. **There are a variety of possible approaches to achieve this result, from matching Wi-Fi devices to portable 4G hotspots, issuing mobile devices with built-in mobile broadband connectivity, or BYOD which effectively allows parents and students to select their preferred device, and managing connectivity requirements directly.**

MEANINGFUL K-NECTIONS >> A pilot program initiated in the interest of exploring whether providing students with 24/7 connectivity (via smartphones) could play a role in enhancing student engagement and learning, Project K-Nect addressed the need to improve math skills among at-risk students in North Carolina who scored poorly in math and did not have home Internet access. Algebra I digital content aligned with current lesson plans was created and students were encouraged to learn from each other in and out of the classroom. Students did so by using social networking applications on the smartphone, as well as other Internet resources such as www.algebra.com. Students at one of the participating classes increased their proficiency rates by 30 percent on the end-of-course exam when compared to classes not in Project K-Nect but taught by the same teacher. The complete case study available at http://www.qualcomm.com/media/documents/wireless-reach-case-study-united-states-project-knect-english ■

Support for 24/7 accessible learning programs considers equitable access to learning content and opportunities for all students, regardless of the availability of connectivity at home. Some school districts may have a significant proportion of their

Well-defined access policies that consider multiple device types, operating systems and use cases are critical to a successful mobile device strategy.

students lose access to Internet connectivity as soon as they step off the school grounds. In these cases, the use of mobile broadband (3G/4G) technology, such as the Kajeet SmartSpot discussed in the sidebar from Detroit Public Schools, or mobile broadband (3G/4G) capable devices is often the most effective means of ensuring that district IT policies are not exacerbating a digital divide.

While the cost of mobile broadband service is a valid concern, steps can be taken to limit abuse and control expenditures. Further, many mobile network operators are exploring education-specific plans tailored to student, parent and school administrator needs. Some schools and districts are partnering with wireless vendors to provide a mobile broadband solution, complete with CIPA-compliant filters.

In response to mobile device proliferation among consumers, including both parents and their school-aged children, school IT managers are designing networks to accommodate mobile device access from district- and personally-owned devices as the norm, rather than the exception. **Network administrators will need to carefully balance teacher and student preferences with network security and student safety concerns in implementing effective mobile device policies.** Mobile devices present additional challenges of accessing network resources not only from within a school campus, but also from beyond the relative safety of on-campus firewalls. Ideally, IT administrators should be able to manage mobile devices in the same manner, using the same policies regardless of the location or network access method being used by a specific device at any given time.

Mobile device and access management

Thorough and thoughtful network planning is critical to efficiently supporting mobile devices and protecting against their unique risks. Inconsistent management tools and policies across the Wireless-LAN and mobile broadband — which often result from addressing mobile and personally-owned devices as an afterthought — will substantially increase complexity for network managers and drive up IT costs.

Well-defined access policies that consider multiple device types, operating systems and use cases are critical to a successful mobile device strategy. The vendor community offers a number of helpful management solutions and should provide support for the following needs and guidelines:

- **Ensuring devices accessing the network aren't inappropriately modified ("jail-broken" or "rooted") and are free of malware, software that can negatively affect school network performance**
- **Ensuring that connectivity is provided only to positively identified and authorized users on devices meeting district or school requirements**

Recent research into consumer habits indicates that a majority of users look at their mobile phones at least 150 times per day.

- **Maintaining visibility into all users, devices, and applications running on the network**
- **Ensuring the transfer of content access policies from in-school settings to external wireless settings both Wi-Fi and mobile broadband**
- **Enforcing device-level security measures such as remote wipe, enabling management of lost, stolen or otherwise non-compliant devices at any time.**

Understanding Device Capabilities

Mobile and portable computing devices are increasingly at the center of many aspects of our lives. In 2012, total global mobile (3G/4G) connections reached 6.6 billion devices, owned by approximately 3.2 billion individuals amid a total global population of just over 7 billion. Recent research into consumer habits indicates that a majority of users look at their mobile phones at least 150 times per day. Furthermore, in a *TIME* magazine mobility poll[12] 84% of respondents said they couldn't go a *single day* without their mobile phones, and 66% of users *sleep* with their primary mobile phone right next to their beds.

With moves by wireless operators and device manufacturers to make smartphones and their associated data plans more flexible and affordable,

OFF-CAMPUS BROADBAND EQUITY

>> Detroit Public Schools (MI) uses a combination of private and public funding to provide low-income families with laptops and education broadband access off-campus. Detroit's CIO and Chief Strategic Officer, Diane Jones, recently spoke about their program on Education Talk Radio. Detroit provided students with CIPA-compliant broadband via the Kajeet SmartSpot™, a portable Wi-Fi hotspot using 4G LTE technology and district policy management. Students who now have Internet access at home, feel they are equal to their classmates in technology. **>> Two studies by** Project Tomorrow examined tablet use by fifth-grade students in Chicago Public Schools (IL) and eighth-grade students in Fairfax County Public Schools (VA). The studies contrasted technology attitudes and use in more affluent, connected communities with chronically challenged low-income families for whom the tablet was both their first computing device and their first internet connection in the home. A web panel with both districts discussed the findings in December. The tablets use mobile broadband to provide anytime, anywhere access managed by the respective schools' policies. Under a separate program dubbed Access4All, Fairfax is also providing laptops and Kajeet SmartSpots for student checkout. **>> With off-campus access** now shown to be affordable via managed restriction of bandwidth intensive non-academic use (primarily consumer streaming media), more districts across the country are pursuing similar programs including Forsyth (GA), Green Bay (WI), Tucson (AZ) and Ector (TX). Recognizing the persistent digital divide, some community projects, such as Project L.I.F.T. in Charlotte (NC), are also working with their schools to provide access. Whether 1-to-1 or BYOT, the digital revolution is inherently reliant on student connectivity, both on and *off* campus. ■

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[12] "10 Ways Mobile Technology is Changing Our World," Time 27 Aug. 2012. Print.

We can start with the assumption that smartphones and tablets will be increasingly powerful and present among student populations in the near term.

smartphone adoption is forecast to continue on its current strong-growth trajectory. In 2012 alone, 1 million new smartphone users were added every day, many aged 24 and under. Tablet computers are similarly upwardly trending with most forecasts projecting 25%-30% annual growth, compared to laptop and mobile PCs with an expected growth rate of only 2% per year. [13] Further, total tablet sales surpassed that of laptops during 2013.[14]

A key take-away from such statistics is that smartphones and tablet computers will be highly familiar and heavily used devices for the majority of students. Students are bringing these devices into the classroom and attempting to access whatever networks are visible to them. Keep in mind that these are, in effect, highly capable portable computers. The processing power of today's leading smartphones already equals that of most PCs sold in 2009, and easily surpasses the computing power of the entire Apollo 11 project when it successfully landed a man on the moon.

As device capabilities and connectivity options increase, and costs decline, it becomes relatively straightforward for students to access a growing abundance of rich digital content and online resources. In such an environment, robust and reliable education networks become a critical enabling infrastructure element for teaching and learning effectiveness. **Furthermore, network designers and planners need to operate under the assumption that both the total population of devices and the volume of data traffic driven by those devices will increase dramatically over the next several years.**

So what can we do with this information? We can start with the assumption that smartphones and tablets will be increasingly powerful and present among student populations in the near term. When incorporating either district-procured or student-owned devices into the learning curriculum, it is important to thoroughly evaluate and understand the use cases and required device capabilities of teachers and students. Additionally, recognize that device interaction models, feature usage and requirements may vary significantly from one classroom to the next.

While the current minimum device requirements and recommendations of the online assessment standards organizations, the Partnership for Assessment of Readiness for College and Careers (PARCC) and the Smarter Balanced Assessment Consortium (SBAC) serve as a useful reference point for making device decisions, these should be considered a starting point, not an endpoint. The minimum and recommended system specifications published by PARCC and SBAC can be found on their respective web sites http://www.parcconline.org/ and http://www.smarterbalanced.org/ or at the State Educational Technology Directors Association http://SETDA.org.

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[13] Gartner, Inc. and International Data Corporation (IDC), September 2013

[14] Gartner, Inc. and Strategy Analytics, June 2013; IDC, May 2013

It is imperative that educators and IT decision-makers recognize and address the importance of 24/7 connectivity for mobile learning devices after the school day ends.

Transforming learning through 24/7 access

While the quality and reliability of network access in school is essential and well understood, enabling the same level of access and student learning experiences from outside of school is becoming equally critical. Students who are continuously connected are able to extend their learning time using the same tools, resources and approaches that have been introduced in the classroom. They can conveniently contact and collaborate with peers and teachers, access online resources, and use built-in device features to produce highly engaging multi-media deliverables. It is imperative that educators and IT decision-makers recognize and address the importance of 24/7 connectivity for mobile and portable learning devices after the school day ends. Options might include raising awareness of fixed broadband and mobile broadband (3G/4G) vendors that support key education requirements, and helping to identify and inventory approved connectivity options from public institutions such as libraries and community centers. A challenge that IT leaders must also address when supporting out of school connectivity is that student data protection measures and online access controls need to remain as enforceable as they are when a device is connecting from the classroom. As outlined previously, there are multiple device management solutions offered by the vendor community to help accomplish this objective, with more solutions that address education-specific use cases becoming available.

LEARNING POWERED BY TECHNOLOGY

>> **An infrastructure for** learning is always on, available to students, educators, and administrators regardless of their location or the time of day. It supports not just access to information, but access to people and participation in online learning communities. It offers a platform on which developers can build and tailor applications. An infrastructure for learning unleashes new ways of capturing and sharing knowledge based on multimedia that integrate text, still and moving images, audio, and applications that run on a variety of devices. It enables seamless integration of in- and out-of-school learning. It frees learning from a rigid information transfer model (from book or educator to students) and enables a much more motivating intertwinement of learning about, learning to do, and learning to be. ■

—U.S. Department of Education, Office of Educational Technology, *Transforming American Education: Learning Powered by Technology*, Washington, DC, 2010.

Cost concerns have motivated many districts to specify or favor Wi-Fi only devices, however the inability to ensure consistent network access beyond school grounds has proven challenging in some recent large-scale deployments of Wi-Fi only tablets. Given that experience, the usefulness of mobile (3G/4G) or wide-area wireless connectivity should also be carefully considered. Several districts, for example, are purchasing mobile internet hotspots for students without home connections as an interim step. As mobile devices

We believe that the majority of U.S. schools and school districts are at a critical juncture in their technology planning and investment life cycles.

become more affordable and mobile network operators offer increasingly flexible connectivity plans, the barriers that have prevented adoption of dual Wi-Fi and 3G/4G devices in the past are beginning to fall.

Additionally, as more parents, teachers, administrators and students experience the advantages of always-on connectivity from personally-owned mobile devices, demand for anytime, anywhere access is expected to increase. Flipped learning models and other digital learning approaches that rely upon 1-to-1 computing will also drive the need for more connectivity options. Finally, digital equity concerns, which include universal access to connectivity, and the necessity of ensuring that all students are able to access content from home have helped demonstrate the effectiveness of mobile (3G/4G) connected devices to complement wired broadband plus Wi-Fi.

Following are some useful questions to ask when making recommendations on specifications for either district-procured devices or to students and parents seeking guidance on 'school-ready' devices.

1. Is the school and district committed to learning powered by technology in the school site and after formal school hours?

2. How many teachers have incorporated or plan to incorporate flipped learning techniques into their curricula?

3. Do teachers and students intend to use mobile devices outside of the classroom, in outdoor or field trip settings?

4. What proportion of students currently has access to Wi-Fi at home?

5. How can the school and community help ensure all students have equitable access to learning opportunities?

6. Will the recommended devices enable continuous access to learning resources and frequent opportunities for student-teacher and student-student interaction?

Conclusion: Looking Ahead

Adoption of 1-to-1 computing is becoming increasingly prevalent within K-12 classrooms, driven in large part by the proven success of flipped and hybrid learning models, the growing availability of digital content and interactive textbooks, as well as the movement to online assessments as a result of Common Core standards. In this environment, Education Networks have become in some ways the most critical infrastructure component of school operations and a primary determinant of the methods, content and teaching strategies that teachers will be able to use effectively in the classroom.

We believe that the majority of U.S. schools and school districts are at a critical juncture in their technology planning and investment life cycles. Education leaders and IT decision makers can easily be overwhelmed by the acceleration of change observed in classroom instructional techniques, the often widespread proliferation of consumer devices on their campuses, and the promise of transformative teaching and learning effectiveness offered by making mobile computing technologies an integral part of instructional models. Student engagement and academic achievement does have the potential to be transformed by 24/7 access to quality digital content, as well as highly interactive, personalized and collaborative learning models. However, robust, reliable and highly available Education Networks are a necessary precondition of realizing this potential. **Furthermore, network designers must consider not only meeting the bandwidth demands that are apparent today, but must also think about establishing the foundations for future learning innovations.** Additional challenges that need to be addressed by well-planned Education Networks include ensuring equitable and efficient access to learning content and opportunities both inside and outside of the classroom, regardless of a student's home address or economic status. The SEND Guidelines for School System Chief Technology Officers lists the following core recommendations.

Core Recommendations:

☑ **Recognize that education networks have become one of the most critical infrastructure components of any school's operations**

☑ Recognize that 1-to-1, or many-to-1 technology programs are quickly becoming mainstream, and plan for bandwidth capacity accordingly

☑ **Start every Education Network planning and upgrade process by closely consulting with teachers and administrators regarding intended uses of technologies in the classroom and ensure that network hardware and services are capable of supporting peak loads**

☑ Plan for substantial training and support of teachers and staff as part of any technology rollout

☑ **Understand that accessing content and resources while outside of the classroom – from home, class field trips, and in the community – is as critical to effective learning as in-class connectivity**

☑ Ensure that rigorous security measures, regardless of the type of connection, are built into your network design – this is both for the purposes of preventing unauthorized access to network content and resources, as well as complying with federal and state student protection laws

☑ **Make design choices that lay a foundation for the future, both in terms of scalability and the ease with which new device capabilities and technologies can be supported.**

References and Resources

"E-Rate and Broadband Survey 2013." CoSN (Consortium for School Networking), October, 2013. http://www.cosn.org/e-rate-broadband-survey

"The Broadband Imperative: Recommendations to Address K-12 Education Infrastructure Needs." State Educational Technology Directors Association, May, 2012. http://www.setda.org/web/guest/broadbandimperative

"Privacy and Children's Data: An Overview of the Children's Online Privacy Act and the Family Educational Rights and Privacy Act." Berkman Center for Internet & Society at Harvard University, November, 2013. http://cyber.law.harvard.edu/publications/2013/privacy_and_childrens_data

"Kajeet and Project Tomorrow Announce Results from Landmark 1-to-1 Mobile Learning Study", Kajeet, Inc., November, 2013. http://www.kajeet.com/4u/education/aboutUs/news/press/Results-from-Landmark-1-to-1-Mobile-Learning-Study.html

"Assessment Capacity Planning Tool." Partnership for Assessment of Readiness for College and Careers, March, 2013. http://www.parcconline.org/sites/parcc/files/PARCCCapacityPlanningTool_3-5-13_Printablev1.0.pdf

"Certified Wireless Network Administrator Official Study Guide." Certified Wireless Network Professional, May, 2012. http://www.cwnp.com/certifications/cwna

Smarter Balanced Technology Strategy Framework and System Requirements Specification –Feb 6, 2013 Update) http://www.smarterbalanced.org

National K-12 Federated Identity and Access Management Task Force. https://spaces.internet2.edu/display/K12FedIAMTF/Home

http://www.cosn.org/FederatedIdentity

"Leadership for Mobile Learning". CoSN. http://www.cosn.org/mobilelead

Accessing content and resources while outside the classroom ... is as critical to effective learning as in-class connectivity.

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☑ SEND Checklist:

page 1 of 5

USE: For CIOs, CTOs, superintendents and other school technology leaders in designing smart education networks in your community	Describe current state	Describe desired state/ goal	Describe action steps/ resources needed and person/position responsible
☐ **ALIGNMENT & INTEGRATION** with district vision, mission & goals			
☐ Ensure that all stakeholders have participated in developing a clear vision of digital transformation with goals & have recognized the impact upon & importance of the network in supporting the vision & mission. **p. 8**	▪ ▪ ▪ ▪	▪ ▪ ▪ ▪	▪ ▪ ▪ ▪
☐ Provide clarity in the district action plans to build networks that allow for a robust integration of the power of technology not only into the curriculum, teaching & learning practices, but also into professional development & in the administrative practices & systems that serve the staff and the public. **p. 8**	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪
☐ **DEFINING PERFORMANCE** requirements			
☐ Network design should be determined by requirements stemming from the vision, mission & goals. The key users of the system - the teaching and learning function & the district operations function - generally determine these requirements. **p. 25**	▪ ▪ ▪ ▪	▪ ▪ ▪ ▪	▪ ▪ ▪ ▪
☐ **GAP AND DATA** analysis			
☐ Conduct a gap analysis to determine & inform the functional & technical enhancements necessary for the network. **p. 26**	▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪
☐ Collect & examine data such as inventory & its age, elaborated network traffic analysis at multiple points in the network & time of day & year, help desk records, etc. If the district does not have network data or the capacity to collect it, consider contracting to gather these data over an extended period. **p. 26**	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪

☑ SEND Checklist *for school technology leaders*

	Describe current state	Describe desired state/ goal	Describe action steps/ resources needed and person/position responsible
☐ **DESIGN** for success			
☐ WAN/LAN topology or services are resilient. Consider private fiber-based networks or scalable services from providers. Establish risk tolerance & performance metrics. p. 26	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
☐ The network core should be scalable & of sufficient capacity for the planning period. All components in the network core must be correctly sized to accommodate the services needed & traffic anticipated. Consider designs such that components within the core able to be upgraded as needed. p. 36	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■
☐ The network "edge" (schools and classrooms) should have fiber connections to & between wiring closets with Category 5e (legacy connections) or Category 6 cabling for new wired connections (computers, access points, etc.). New wireless technology may require two Ethernet Category 6 cables in order to maximize performance. p. 37	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■
☐ For wireless applications, ensure that sufficient power through Power over Ethernet (PoE), PoE+, or vendor-specific power technology is available. p. 37	■ ■ ■	■ ■ ■	■ ■ ■
☐ Wireless effectiveness is determined by coverage & capacity. A wireless survey is essential for all spaces in which mobile access is planned. Consider 802.11n & 802.11ac as the best in-school technology & mobile broadband (3G/4G/LTE) for access when away from school. pp. 34, 42, 49	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■
☐ Understand the barriers caused by certain construction materials. In new construction, consult with the engineers to mitigate impairments for certain wavelengths. p. 45	■ ■ ■	■ ■ ■	■ ■ ■

☑ SEND Checklist *for school technology leaders* *page 3 of 5*

	Describe current state	Describe desired state/ goal	Describe action steps/ resources needed and person/position responsible
☐ **ADEQUATE & ROBUST INTERNET** is essential			
☐ Internet capacity should be significant and may be obtained from multiple providers if necessary. State and regional networks, possibly with Internet 2 connections, are options if available in the community. Consider multiple carriers or other strategies for redundancy. p. 30	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
☐ Internet service, & related or supportive technologies, must now be viewed as any other important utility used by the school by providing an adequate line item budget to match the needed capacity. p. 30	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
☐ **MANAGING & OPERATING** the network			
☐ Consider separate VLANS for students & ensure sufficient address space since multiple devices per person are increasingly common & software applications are requiring more addresses & ports. Review segmentation of employee network & student networks with VLAN strategies to increase security of essential district data, systems & confidentiality requirements. p. 35	■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■
☐ Design for and implement end-to-end Quality of Service (QoS) to support latency-sensitive applications. p. 30	■ ■ ■	■ ■ ■	■ ■ ■
☐ Monitor the performance of the network at all critical points & intervene as necessary. p. 30	■ ■	■ ■	■ ■
☐ Automate the management of mobile devices using MDM technologies. pp. 40, 47	■ ■	■ ■	■ ■
☐ Implement an Identity and Access Management (IAM) system to help secure the network & minimize operating expenses. p. 46	■ ■ ■	■ ■ ■	■ ■ ■

Smart Education Networks by Design a CoSN leadership initiative

CoSN LEADING EDUCATION INNOVATION

☑ SEND Checklist *for school technology leaders*

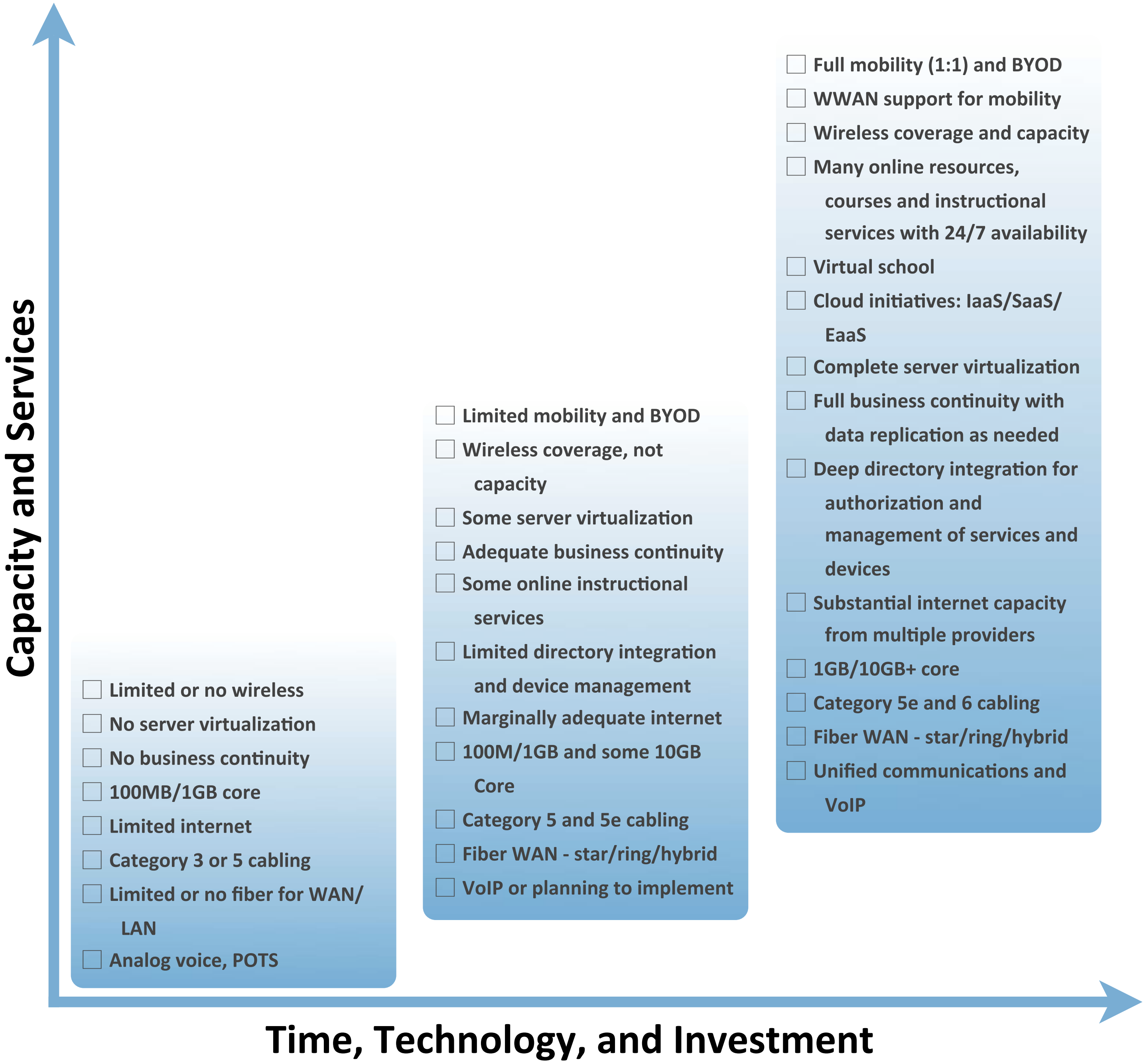
	Describe current state	Describe desired state/ goal	Describe action steps/ resources needed and person/position responsible
☐ **PROTECTING** privacy & data			
☐ Use technology where appropriate to ensure that district is complying with the law e.g., CIPA, COPPA, FERPA, HIPPA, PPRA, etc. & that data, either possessed by the district or, increasingly, by partners, are secure. **p. 44**	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪
☐ Implement rigorous wireless security measures such as WPA2, RADIUS, etc. as mobility & BYOD become prevalent. **p. 45**	▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪
☐ Implement Intrusion Prevention/Detection technologies to minimize threats as the use of Internet-based resources increases. **p. 45**	▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪
☐ **TEACHER** training & technical support			
☐ Even with the implementation of smart network designs, the district commitment to fund training and ongoing support is critical. Teachers are the primary providers of digital transformation and they must be trained and adequately supported. Similarly, technical support staff must also receive training. **pp. 14, 46**	▪ ▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪ ▪
☐ **BUDGET** & investment			
☐ Supporting the vision, mission & goals of digital transformation & the smart networks necessary to enable & sustain the transformation requires sufficient budget funds, a continuing investment in success. **p. 8**	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪	▪ ▪ ▪ ▪ ▪

Smart Education Networks by Design a CoSN leadership initiative

CoSN LEADING EDUCATION INNOVATION

Progression of K-12 Networks

Checklist activity: **Where are you (the district) on this progression?**



Capacity and Services

- ☐ Limited or no wireless
- ☐ No server virtualization
- ☐ No business continuity
- ☐ 100MB/1GB core
- ☐ Limited internet
- ☐ Category 3 or 5 cabling
- ☐ Limited or no fiber for WAN/LAN
- ☐ Analog voice, POTS

- ☐ Limited mobility and BYOD
- ☐ Wireless coverage, not capacity
- ☐ Some server virtualization
- ☐ Adequate business continuity
- ☐ Some online instructional services
- ☐ Limited directory integration and device management
- ☐ Marginally adequate internet
- ☐ 100M/1GB and some 10GB Core
- ☐ Category 5 and 5e cabling
- ☐ Fiber WAN - star/ring/hybrid
- ☐ VoIP or planning to implement

- ☐ Full mobility (1:1) and BYOD
- ☐ WWAN support for mobility
- ☐ Wireless coverage and capacity
- ☐ Many online resources, courses and instructional services with 24/7 availability
- ☐ Virtual school
- ☐ Cloud initiatives: IaaS/SaaS/EaaS
- ☐ Complete server virtualization
- ☐ Full business continuity with data replication as needed
- ☐ Deep directory integration for authorization and management of services and devices
- ☐ Substantial internet capacity from multiple providers
- ☐ 1GB/10GB+ core
- ☐ Category 5e and 6 cabling
- ☐ Fiber WAN - star/ring/hybrid
- ☐ Unified communications and VoIP

Time, Technology, and Investment

CoSN
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