The Next Gen Classroom:
Spectrum Policies for the 21st Century School

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reluminati

November 2014

Contents

Abstract

Drawing on interviews with experts and an examination of available data on demand for broadband in K-12 schools, this paper makes three central findings:

- First, trends in Internet access suggest that connectivity to K-12 schools will reach gigabit speeds in this decade.
- Second, K-12 schools are adopting policies and educational technologies that trend toward high-bandwidth consumption in the classroom.
- Third, ubiquitous, high-speed Wi-Fi in the classroom depends – to a greater and greater extent – on access to sufficient unlicensed spectrum.

The paper concludes with a series of policy recommendations. In particular, it encourages leaders in K-12 education to work with policymakers and examine opportunities to expand access to unlicensed spectrum to support improved connectivity in schools.

I. Introduction

> "In a country where we expect free Wi-Fi with our coffee, we should definitely demand it in our schools."
>
> – President Barack Obama, February 4, 2014

Ubiquitous connectivity is coming to K-12 schools. In a decade or less, the wired computer lab will seem as antiquated as a chalkboard or, for that matter, a hard-cover textbook. Most students and teachers will connect to their school's network with more than one device. Indeed, within a decade, the wireless local area network (WLAN) will be firmly established as the central nervous system for most K-12 schools. Cisco Systems predicts that 64% of U.S. Internet traffic will travel over a Wi-Fi network by 2018,[1] and the nomadic nature of the K-12 school environment suggests that the percentage of K-12 Internet traffic that travels over Wi-Fi networks may well exceed this projection.

Today, in schools that have access to what President Obama describes as "next-generation broadband," wireless networks are already connecting students and teachers to compelling educational content. In the foreseeable future, wireless networks will connect devices to provide enhanced school safety; will provide parents, teachers, and administrators with real-time attendance information; and will enable interactive HD-quality tele-learning. Given the many and multifaceted mission-critical roles the wireless network will play in the school of the future, students, teachers, and administrators will count on these networks to provide seamless and reliable connectivity. Less than optimal performance of a school's network will be felt throughout the school, but particularly in the classroom as students' work and teachers' lesson plans could be disrupted.

The Obama Administration estimates that only 30% of students currently attend schools with internal connections necessary to support high-speed Internet in the classroom.[2] Ensuring that K-12 schools have the resources necessary to provide students with Wi-Fi access to next-generation broadband is a priority of the Administration. This paper seeks to spark a policy discussion about the adequacy of available unlicensed radio frequency spectrum necessary to facilitate K-12 access to ubiquitous, high-speed wireless broadband.

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1 Cisco Systems, *VNI Forecast Highlights, 2013 – 2018*, *United States – Network Connections*, http://www.cisco.com/web/solutions/sp/vni/vni_forecast_highlights/index.html (last visited Oct. 7, 2014) (filter by country to obtain information for the United States and select Network Connections/Fixed-Wi-Fi).

2 Remarks by the President on ConnectED, Buck Lodge Middle School, Adelphi, Maryland (Feb. 4, 2014), *available at* http://www.whitehouse.gov/the-press-office/2014/02/04/remarks-president-connected.

Drawing on available data and interviews with experts, this paper argues that educators should work together with policymakers to advance spectrum policies that facilitate and support K-12 classroom connectivity. Indeed, available data illustrate that access to adequate unlicensed spectrum will be an increasingly critical input into the connected classroom of the future.

Beyond this paper's specific analytical focus, our schools need access to adequate spectrum in high, medium, and low frequency bands for connectivity to flourish. Today, schools depend heavily on the 2.4 GHz frequency band for Wi-Fi, but lower frequencies of unlicensed spectrum, including the 600 MHz band that is the subject of the Federal Communications Commission's (FCC) incentive auction proceeding, would cover greater distances and help extend the reach of broadband in schools. Furthermore, educators' access to the next generation of Wi-Fi speeds, as discussed in this paper, will depend on adequate spectrum resources in the 5 GHz frequency bands. Each of these bands solves a different connectivity challenge, and, when taken together, they create a powerful set of tools for connecting students, educators, and administrators to the Internet.

Because spectrum policy changes can take many years to enact, it is critical that education leaders initiate efforts to secure more unlicensed spectrum at a number of frequencies in order to support connectivity in K-12 schools.

This examination of Wi-Fi in K-12 classrooms and the importance of spectrum policy has three sections. The first section examines current and future levels of connectivity provided by external networks that connect K-12 school buildings to the Internet. The performance and capacity of a school's wireless network is supported by (or limited by) available backhaul capacity provided by these external networks. The paper's second section examines current and future levels of wireless connectivity in K-12 schools. This assessment includes consideration of both the availability of Wi-Fi (which in many cases can be a function of funding availability) and the demand for wireless connectivity. Wireless connectivity in K-12 schools is, ultimately, a function of both supply and demand. The final section considers the policy implications of these assessments. The paper concludes with recommendations and a call for educators to engage policymakers about the need for adequate unlicensed spectrum.

II. Next-Generation Broadband Access in K-12 Schools

With the launch of the ConnectED initiative in 2013, President Obama established a national goal that 99% of students should have access to next-generation broadband by 2017.[3] While "next-generation broadband" is not directly defined, it is clear that the Administration believes that network connectivity in K-12 schools must be seen in a new light. Indeed, ConnectED-established targets for K-12 broadband capacity, the private sector's commitments of software and devices, and the reforms to the E-rate program suggest the following about the Obama Administration's vision of next-generation broadband:

Next-generation broadband networks:

1. Scale to gigabit Internet and intranet speeds,

2. Accommodate connected devices and interactive and collaborative educational applications, and

3. Support high-speed wireless connectivity.

This paper considers the momentum surrounding each of these elements, as well as the implications of each for the connectivity requirements of the K-12 classroom of the future. The need for adequate unlicensed spectrum to support connectivity in K-12 schools becomes particularly acute when connectivity in K-12 schools approaches gigabit-per-second network speeds. An appropriate starting point for this examination of gigabit Wi-Fi is an assessment of the external networks that – now and in the future – connect K-12 schools to the Internet.

A. Gigabit Broadband Capacity in K-12 Schools

In recent years, 10,000 K-12 schools have been upgraded to high-speed infrastructure through the U.S. Department of Commerce, National Telecommunications and Information Administration's (NTIA) Broadband Technology Opportunities program.[4] Moreover, E-rate submission data suggest that K-12 demand for high-speed broadband is growing rapidly. According to Funds for Learning, an E-rate Consulting firm, 26.9% of K-12 E-rate applicants in 2014 requested support for capacity of 200 megabits per second (Mbps) or

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[3] White House, ConnectEd Initiative, http://www.whitehouse.gov/issues/education/k-12/connected (last visited Oct. 8, 2014).

[4] *See* NTIA, BROADBANDUSA CONNECTING AMERICA'S COMMUNITIES, *Digital Learning Program Prepares Students for School, Careers and Life in the 21st Century* (Feb. 5, 2014), *available at* http://www2.ntia.doc.gov/node/870.

greater.[5] As recently as 2010, the number of applicants requesting support for this level of broadband capacity was too small to measure. The FCC's national broadband map, which tracks U.S. schools' access to high-speed infrastructure, provides additional data. According to the National Broadband Map, K-12 districts throughout the country report that they have more than 50% of their schools connected to next-generation broadband infrastructure.[6]

Recommendations about K-12 broadband capacity issued by educators suggest that the trend toward gigabit capacity will continue between 2014 and the end of the decade. "The Broadband Imperative: Recommendations to Address K-12 Education Infrastructure Needs,"[7] issued by the State Educational Technology Directors Association (SETDA), establishes per student/staff broadband capacity targets for school years starting in 2014 and 2017. As illustrated below, the SETDA recommendations, which helped inform the target levels of Internet access called for by the Obama Administration's ConnectED initiative, establish a minimum recommended network throughput for K-12 schools of 100 Mbps in 2014. The SETDA report calls on schools to plan for a 10-fold increase in K-12 broadband between 2014 and 2018, with the target for minimum speed for a K-12 school with 1,000 students/staff reaching 1 gigabit per second (Gbps) by 2018.

Broadband Access for Teaching, Learning, and School Operations	2014-15 School Year Target	2017-18 School Year Target
An external Internet connection to the Internet service provider (ISP)	At least 100 Mbps per 1,000 students/staff	At least 1 Gbps per 1,000 students/staff
Per Student Speed Capacity	100 Kbps/student	1 Mbps/student

According to interviews with experts, the state of Internet connectivity at K-12 schools ranges widely. Leading school districts use gigabit broadband access for teaching and learning, with schools such as McKinley Technology High School's

5 Remarks by John Harrington, CEO, Funds for Learning, SHLB SYMPOSIUM, Washington, D.C. (Oct. 2, 2014), *available at* www.shlb.org.

6 *See* Federal Communications Commission, FCC E-Rate Maps of Fiber Connectivity to Schools and Libraries (Nov. 6, 2014), *available at* http://www.fcc.gov/maps/E-rate-fiber-map.

7 C. Fox, J. Waters, G. Fletcher, and D. Levin, STATE EDUCATIONAL TECHNOLOGY DIRECTORS ASSOCIATION, *The Broadband Imperative: Recommendations to Address K-12 Education Infrastructure Needs* (2012), *available at* http://www.setda.org/wp-content/uploads/2013/09/The_Broadband_Imperative.pdf.

broadband usage surging above 500 Mbps.[8] In other school districts, however, connectivity limitations force schools to back-up their systems at night so that the key backups do not monopolize available broadband throughput. Survey data released by the Consortium for School Networking (CoSN) in October 2013 seem to confirm a varied picture of K-12 access to the Internet. According to data provided by 460 respondents from 44 states, 43% of school districts reported that none of their schools meet the SETDA recommended broadband goal.[9]

Spotlight on North Carolina: Broadband Requirements of K-12 Schools with Access to a Next-Generation Broadband Network

Data released by MCNC, a broadband service provider to 2,500 schools in North Carolina, provide a useful gauge of the Internet access capacity required by K-12 schools. MCNC's data indicate that, in 2013, MCNC provided Internet access capacity equal to 15 Gbps to K-12 schools.[10] Demand for broadband capacity by North Carolina's K-12 schools is growing at 100% to 150% per year.[11] Assuming this growth rate were to continue between 2014 and 2018 (the period covered by the SETDA targets), the average capacity available to K-12 schools in North Carolina would, indeed, meet or exceed the SETDA targets.

MCNC	2013 (Actual)	2018 (Projected)
Total Bandwidth Consumption: K-12	15 Gbps	1,000+ Gbps
Student Enrollment	1,474,434	1,526,767

The MCNC data are particularly useful for the purposes of this paper for two reasons: 1) the data reflect the requirements of K-12 schools with access to a scalable next-generation broadband network designed to meet the bandwidth requirements of North Carolina's schools, and 2) the statewide average

8 Remarks by Tegene Baharu, Deputy CTO, DC-Net, SHLB SYMPOSIUM, Washington, D.C. (Oct. 2, 2014), *available at* www.shlb.org.

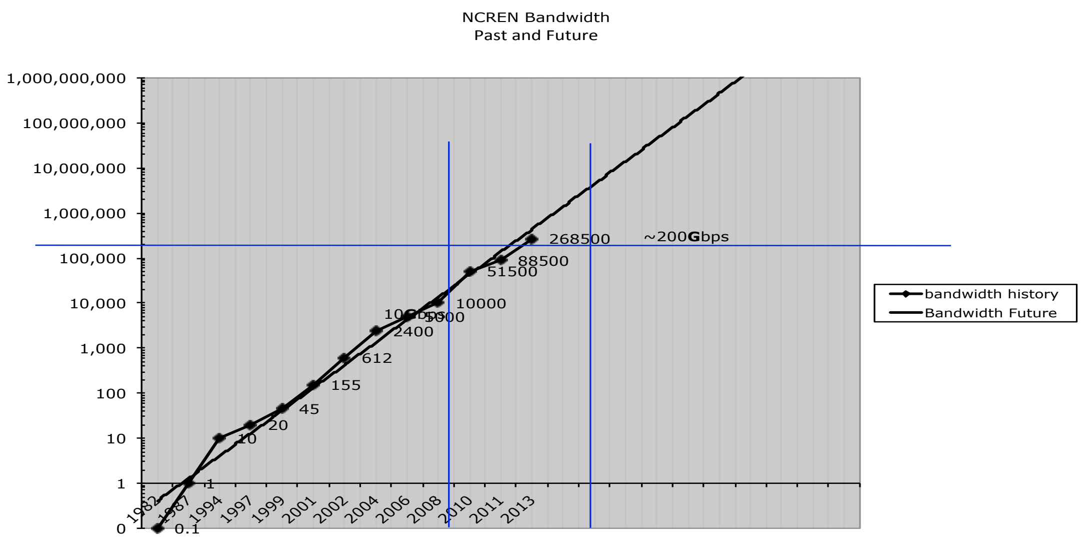
9 Reply Comments of the Consortium for School Networking at 1, WC Docket No. 13-184 (filed Nov. 6, 2013) ("CoSN Reply Comments").

10 Presentation by Phil Emer, Director of Policy and Planning, the William and Ida Friday Institute for Educational Innovation, North Carolina State University, *Theory of Large Numbers Reprisal, Rants and Raves: 1998-2013* (Nov. 15, 2013), *available at* https://www.mcnc.org/sites/default/files/MCNC-CommunityDay2013-Phil-Emer.pdf ("Presentation by Phil Emer").

11 *Id.*

established in North Carolina, given the size and geographic diversity of the state's K-12 school system, provides a benchmark through which to evaluate the reasonableness of national recommendations established by SETDA.

Experts interviewed for this paper provided forecasts that network capacity to accommodate K-12 demand for Internet access will grow at 25% to 50% per year for the foreseeable future. The experts did not rule out, however, more rapid growth if an unexpectedly large number of schools and school districts commits to fully connected classrooms. A chart of MCNC's broadband capacity over the past 30 years suggests a dramatic increase in capacity is certainly possible.



Source: Presentation by Phil Emer (citing Mark Johnson, MCNC)

As MCNC's Chief Technology Officer (CTO) noted during an interview for this paper, MCNC did not add capacity because it accurately forecasted the emerging popularity of bandwidth-thirsty applications. Instead, MCNC has added capacity consistently over 30 years because demand for bandwidth has grown just as consistently. Taking into consideration the historical growth of MCNC's network in North Carolina serves to help validate SETDA's forecasts as a reasonable baseline scenario.

The Projected Impact of ConnectED on K-12 Internet Access

Assuming ConnectED objectives are met and 99% of students have access to next-generation broadband by the 2017-2018 school year, then, using the data developed in this paper, the total K-12 network capacity demand would surpass 56 terabits per second (Tbps).

Year	Number of Students Note: Figure constitutes 99% of estimated total per the ConnectED objectives	Projected Total K-12 Internet Access Capacity Nationwide Per SETDA's Forecasts
2018	56.5 million	56.5 Tbps

These figures represent an extraordinary level of connectivity. If these figures are met, thousands of additional schools will have connections to the Internet at gigabit speeds. By way of comparison, the network backbone of Internet2, a broadband provider to universities and research organizations, currently has capacity totaling 8.8 Tbps.

Key Finding #1: Projections of total K-12 Internet access support a conclusion that K-12 schools across the United States will have access to gigabit broadband Internet speeds in this decade.

B. Connected Devices and Upgraded Local Networks in K-12 Schools

An increasing number of connected devices and connected classrooms will drive the anticipated growth in K-12 broadband demand. Whereas a school might have had Internet access sufficient to support a computer lab or a limited number of wireless mobile carts containing connected devices, the network environment of the school of the future has hundreds or thousands of additional connected devices and dozens of additional connected classrooms.

In 2008, the National Center for Education Statistics reported to the FCC that the average ratio of students to a computer with Internet access in public schools is 3:1.[12] Changes in school policy favoring ubiquitous connectivity and the continuously decreasing cost of connected devices over the last 5 years suggest that this ratio will soon be reversed. In its "Blueprint for the Next-Generation Classroom," Aruba Networks, a leading technology vendor to K-12 schools,

[12] L. Gray, N. Thomas, and L. Lewis, U.S. Department of Education, National Center for Education Statistics, *Educational Technology in U.S. Public Schools: Fall 2008* at 2 (2010), *available at* http://nces.ed.gov/pubs2010/2010034.pdf.

recommends that K-12 schools plan to support 100 devices for a classroom of 30 students.[13]

Industry reports illustrate that millions of additional devices are connecting to K-12 school networks each year. According to International Data Corporation, shipments of tablets to K-12 schools reached 3.5 million in 2013. The research firm Gartner estimates that the 79% year-over-year growth in Chromebook sales in 2013 was largely driven by the U.S. education sector,[14] and Apple Chief Executive Officer (CEO) Tim Cook has observed that the K-12 sector is a major contributor to overall tablet sales.[15]

In addition, many K-12 school administrators have begun to implement policies that are reversing this historical ratio of people to computing devices. Two key policies include:

One device per student initiatives (often termed "1:1") aim to provide each student with at least one computing device (e.g., notebook, tablet, smartphone) and are on the rise in K-12 schools. Examples of a few large school systems illustrate what seems likely to become a more pervasive trend in the future. The State of Louisiana reported that its school districts distributed more than 68,000 devices to students during the first half of 2013.[16] In 2014, Baltimore City Public Schools began a 5-year program to provide devices to all 113,000 of its students.[17]

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13 Aruba Networks, *Blueprint for the Next-Generation Classroom* at 1 (2014), *available at* http://www.arubanetworks.com/pdf/EO_BlueprintNextGenClassroom.pdf.

14 Gartner, Press Release, *Gartner Says Chromebook Sales Will Reach 5.2 Million Units in 2014* (Aug. 11, 2014), *available at* http://www.gartner.com/newsroom/id/2819917.

15 *See, e.g.*, Sean Cavanagh, *Apple Touts Strong iPad Sales in Global School Market* (July 24, 2014), *available at* http://blogs.edweek.org/edweek/marketplacek12/2014/07/apple_boasts_of_surge_in_worldwide_sales_of_ipads_for_education.html.

16 *See* Louisiana Department of Education, *Louisiana Believes: Louisiana's Technology Footprint*, LOUISIANA MAKING PROGRESS, Vol. 2 (Jan. 2013), www.louisianabelieves.com/data/files/footprint/statewide_footprint.pdf.

17 Liz Bowie, *Baltimore County Schools Begin Technology Initiative*, THE BALTIMORE SUN (Feb. 28, 2014), *available at* http://www.baltimoresun.com/news/maryland/education/blog/bs-md-co-technology-initiative-20140208,0,1034541,full.story.

Spotlight: Davis School District, Farmington, Utah

Davis School District started its migration to a 1:1 policy with initial pilot programs in 2012, and continued expansion in 2013 and 2014. The growth in client devices connected to the network and the utilization of the network have increased significantly in the schools where a 1:1 initiative has been implemented. In 2013, as many as 6,900 devices connected to the network at any one time. In the first half of 2014, that number nearly tripled to more than 18,000 devices. By 2015, it is expected that up to 30,000 devices will connect to the network at once. Similarly, in 2013, utilization of the network (measured in the bytes that traveled across the network) had more than doubled compared to the network utilization before the 1:1 policy was established. Data from the first half of 2014 reflect that increased network utilization continues. For example, at Endeavor Elementary School and Central Davis Junior High School, network utilization levels are on pace to grow by approximately 50% over 2013 levels.

Davis School District also provides a notable example of the connectivity that leading schools districts are deploying in order to prepare for the future connectivity needs of their educators and students. In order to support the 1:1 initiative, the district's migration to Voice-over-IP (VoIP) handsets and centralized administrative servers, Davis has deployed two 1 Gbps circuits to each of the district's K-12 schools. In 2015, Davis will complete a network upgrade that provides the district with a 10 Gbps connection to the Internet. By way of comparison, 12 years ago, Davis School District's connectivity amounted to six T-1 lines.

<u>Bring Your Own Device</u> (BYOD) policies are also becoming more common in K-12 schools. Respondents to a 2013 survey indicate that 44% of K-12 schools in the United States and United Kingdom have implemented some version of this policy.[18]

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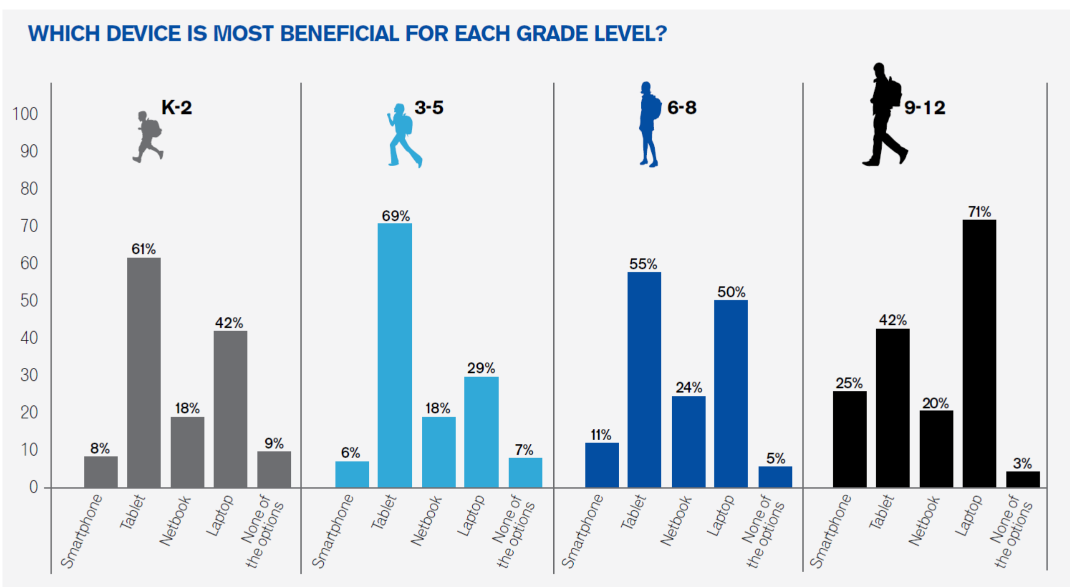
[18] Joshua Bolkan, *Report: 85 Percent of Educational Institutions Allow BYOD, Yet Security Lags Behind*, CAMPUS TECHNOLOGY (May 21, 2013), http://campustechnology.com/Articles/2013/05/21/Report-85-Percent-of-Educational-Institutions-Allow-BYOD-Yet-Security-Lags-Behind.aspx (last visited Oct. 7, 2014).

Spotlight: Shelby County Schools, Columbiana, Alabama

In 2011, Shelby County Schools included questions about a potential BYOD initiative in an annual survey to students and parents. Seventy-five percent of high school and 70% of middle school respondents indicated that bringing their own devices to school would help them learn more effectively. Sixty-seven percent of parent respondents indicated that they would purchase a device for their student(s) if they were allowed to bring the device to school.

Currently, 25 schools have established BYOD programs, and in those schools, 40% of students now bring their devices to school daily for use in class. For Shelby County Schools, the BYOD programs are a critical element of the district's "Iam21" effort to support the development of 21st century skills in their students. According to Shelby County's IT leadership, BYOD enables the classroom environment to become more like the world that students will encounter after they leave high school.

The BYOD initiatives illustrate the opportunity to use wireless networks in K-12 schools to transform a student's smartphone or tablet into a valuable educational tool. Indeed, devices are increasingly viewed as a critical tool – not just for computer class – for all classes. A 2013 Center for Digital Education (CDE) survey revealed that educators deemed different types of mobile computing devices as most appropriate for learning per age group.



Source: Center for Digital Education Survey, 2013

A school environment that provides only a limited number of connected classrooms no longer meets the requirements of students and teachers. Experts interviewed for this paper indicated that among government leaders, school administrators, teachers, parents, and even CEOs of leading technology companies,[19] there exists a shared commitment to ensure that classrooms have the connectivity required to incorporate the development of 21st century skills and up-to-date approaches to learning.

Spotlight: Glenbrook High School District 225, Glenview and Northbrook, Illinois

In 2007-2008, Glenbrook replaced teachers' desktop computers with mobile or nomadic devices. To allow teachers to use the devices everywhere and to support a number of mobile carts containing connected devices for students to use in the classroom, Glenbrook initially installed 180 wireless access points. The decision to adopt a 1:1 policy for all 5,000 students required a redesign of the Wi-Fi networks. Glenbrook's wireless network now has approximately 500 wireless access points supporting an average of 8,000 wireless devices. Glenbrook provides connectivity to students and staff via two 10 Gbps connections to their network backbone. According to Marcus Thimm, CTO of Glenbrook School District, "Wi-Fi is undoubtedly the future of networking in all schools."

C. Sources of New Funding Drive Wi-Fi Infrastructure Upgrades

A critical factor driving the specific nature and speed of Internet infrastructure deployments in K-12 schools is new funding opportunities. In July 2014, the FCC voted to reform the federal E-rate program and provide an additional $1 billion in 2015 and 2016 in order to advance deployment of Wi-Fi networks. The goal is to ensure that an estimated 20 million additional students have Wi-Fi in their classrooms, half of those by 2015.

State and local efforts to fund connectivity in more K-12 classrooms are also increasing as school districts prepare to adopt the Common Core State Standards. Forty-five states and the District of Columbia have adopted Common Core, and to satisfy the digital curriculum standards and testing requirements of Common Core, schools are expanding the footprints of their wireless networks.

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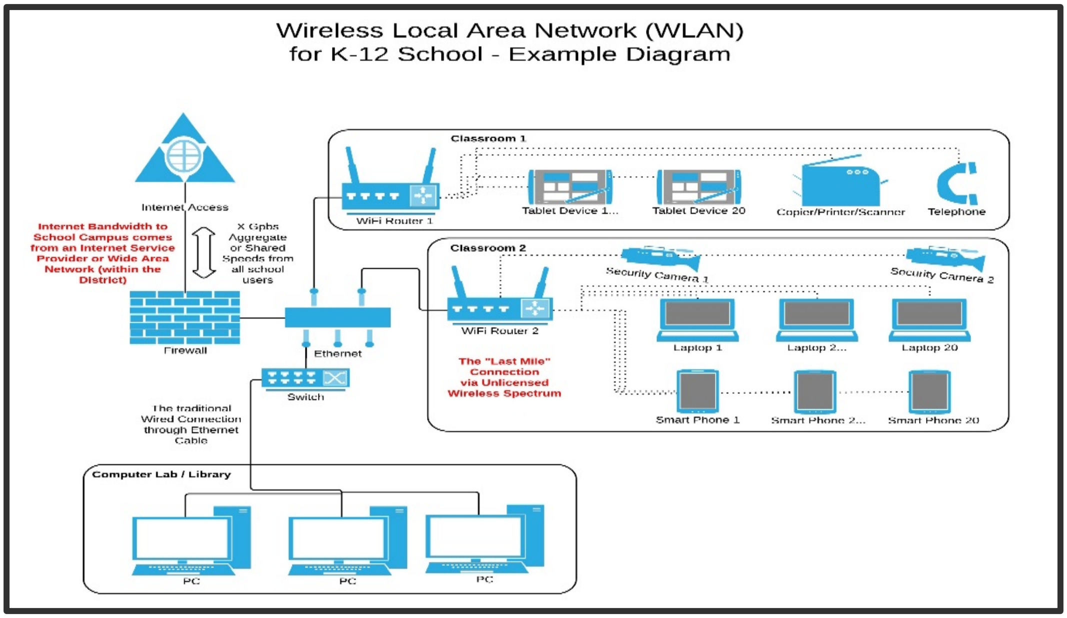
19 Letter from coalition of CEOs to Commissioners of the Federal Communications Commission (July 7, 2014), *available at* http://apps.fcc.gov/ecfs/document/view?id=7521371272 (noting the importance of E-rate modernization "in order to connect 99% of students to high speed broadband and ubiquitous Wi-Fi").

<u>Key Finding #2</u>: K-12 schools are adopting policies and educational technologies that trend toward high-bandwidth consumption in the classroom.

III. Spectrum Availability as a Driver of Connectivity in K-12 Schools

The forces driving increased broadband consumption in K-12 schools illustrate the centrality of wireless networks. In the foreseeable future, all students and staff will rely on wireless connectivity in all classrooms throughout the day. In the K-12 school of the future, the wireless connections between a school's network and the hundreds or thousands of connecting client devices is the critical "last mile" (though it might be more aptly described as the "last 30 feet" in most cases) connection between the end users and the network designed to serve them.

The network diagram below identifies some of the most common elements of a K-12 school's network. Illustrated in the diagram are three resources *shared* by all users of the network. The first shared resource is the Internet access capacity coming into the school, represented by a triangle in the diagram. All devices requiring access to the Internet share the available throughput to/from the Internet. The second shared resource in a K-12 network environment is the connection between classrooms, offices, etc. and a school's or school district's network. Represented in the diagram with a rectangle labeled "Ethernet," this WAN (wide area network) or LAN (local area network) provides networked connectivity between all devices on the network. This network is the avenue through which a connected device can access the Internet, but it also provides an avenue to resources cached locally on the network server. The third shared resource illustrated in the diagram below is represented by two icons labeled Wi-Fi Router 1 and 2. For devices connecting a school's network wirelessly, wireless routers (also known as wireless Access Points or "APs") provide the gateway to the network.



Source: Reluminati, LLC

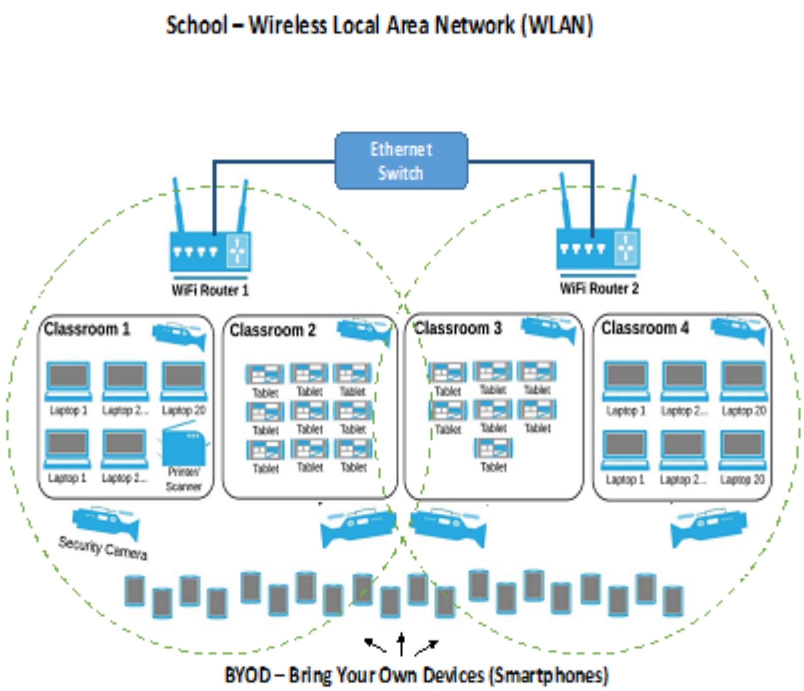
Because these network resources are shared, a network's performance can degrade if the demands on any/all of these resources surpass available capacity. A network's peak utilization – the time(s) when the total throughput requirements of all the devices simultaneously connected is the greatest – helps inform the manner in which K-12 schools deploy their networks and/or establish policies to govern network utilization.

K-12 schools experiencing an increase in users (such as in Glenview and Northbrook, Illinois) have accommodated increasing numbers of connected devices by adding wireless routers and enhancing their LANs/WANs and access to the Internet. K-12 schools can expand a shared resource (e.g., provide more throughput) or limit the number of users who use a particular resource (e.g., serve a conference room with two wireless routers instead of one). In this vein, K-12 schools pursue the same approaches to optimizing network performance as do other organizations with wireless networks experiencing rapid increases in demand, including airports, conference centers, and hotels.

According to Steve Hratko of Ruckus Wireless, a leading wireless networking company, there are limits to the efforts that network operators can make to optimize wireless networks. In certain environments, because of the cost and/or complexity of deploying networks able to accommodate the device density and bandwidth demands during times of peak utilization, it is not possible to optimize wireless network performance in order to meet demand. In such environments, network delays, lost packets, buffering, and other symptoms of network degradation can occur. Because limited spectrum availability can contribute to degraded Wi-Fi network performance in these circumstances, Ruckus Wireless and other members of the WifiForward Coalition describe these environments as suffering from "spectrum crunch."

This section examines the need for more unlicensed spectrum at a variety of frequencies to avoid a spectrum crunch in K12 schools. Central to this examination is recognition that there is a *fourth* shared resource present in the K-12 network environment: namely, the radio frequency spectrum over which Wi-Fi devices connect with wireless networks.

Wireless Connectivity in K-12 Classrooms



Source: Reluminati, LLC

A. K-12 Migration to Gigabit Wi-Fi and New Opportunities Enabled by Additional Unlicensed Bands

A variety of technological developments have the potential to meet growing K-12 demand while also providing opportunities for innovation in the connected K-12 space. In 2013, the IEEE Standards Association released a new standard for Wi-Fi technology – 802.11ac. Described as permitting gigabit speeds, the standard uses improved technology and wider radio frequency channels to deliver greater throughput. While a number of variables affect actual throughput, technical reviews indicate that wireless routers that meet the 802.11ac standard can deliver throughput of 400 Mbps to 600 Mbps using an 80 MHz channel. By bonding two 80 MHz channels into a 160 MHz channel, 802.11ac can deliver gigabit speeds. Throughput of routers using the "AC" standard is at least twice that of routers using the 802.11n standard, previously the Wi-Fi standard providing greatest throughput.

The release of 802.11ac comes at an opportune time for K-12 schools. Recent reforms to the E-rate program will provide an estimated $5 billion for Wi-Fi funding over the next 5 years. According to the FCC, the additional funding targeted to Wi-Fi is sufficient to expand Wi-Fi in all K-12 schools and will support Wi-Fi for an additional 10 million students in 2015 alone.[20]

According to projections from industry experts, the majority of K-12 schools will deploy wireless networks using 802.11ac technology. In an interview with Martin Costa, CEO of InLine, a broadband service provider in Birmingham, Alabama, Costa reported that InLine's customers are opting for wireless routers using the AC standard because they are competitively priced and offer greater capacity. Aruba Networks projects that, even though 802.11ac routers are only recently hitting the market, 1 in 5 schools will implement wireless networks using the 802.11ac standard in 2014 alone.[21]

In addition to 802.11ac – which is designed for use in the 5 GHz band – a number of other new technologies designed for use in other existing and future unlicensed spectrum bands could help meet growing K-12 demand and inspire new learning innovations. For example, IEEE standard 802.11af is designed for use in television band spectrum. This standard gives Wi-Fi a much broader reach due to the favorable propagation characteristics of the 600 MHz bands. Using 600 MHz Wi-Fi, schools could extend their reach outside a single classroom and make broadband wireless Internet available to students throughout a school, over an entire campus, or even elsewhere in the community from a transmitter in the school. Using 802.11af access points also has the potential to decrease the costs of providing wireless Internet across large school campuses because schools would require fewer access points to reach the same number of classrooms.

The 3.5 GHz band could also provide interesting new opportunities for bringing wireless connectivity to schools. The FCC is considering whether to adopt an innovative new method for sharing spectrum that would allow government

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[20] Federal Communications Commission, Press Release, *FCC Modernizes E-Rate Program to Expand Robust Wi-Fi Networks in the Nation's Schools and Libraries* (July 11, 2014), *available at* http://www.fcc.gov/document/fcc-modernizes-E-rate-expand-robust-wi-fi-schools-libraries.

[21] Lisa Phifer, *802.11ac Wi-Fi Part 3: Adoption*, INFORMATIONWEEK: NETWORK COMPUTING (Feb. 3, 2014), *available at* http://www.networkcomputing.com/wireless-infrastructure/80211ac-wi-fi-part-3-adoption/d/d-id/1234655?.

users like radar to share with priority access users and unlicensed users. If this proposal is adopted, schools could supplement their existing Wi-Fi networks with 3.5 GHz band spectrum, which could help them ease congestion on existing bands and create new opportunities for network design that minimizes RF interference.

B. The Need for Additional Spectrum to Support K-12 Demand

To ensure that K-12 school's wireless networks are able to perform optimally at gigabit speeds, however, additional spectrum must be made available. There are two primary reasons that existing spectrum may not be adequate for future connectivity needs of the K-12 classroom.

Limited Number of Non-Overlapping Channels

A basic rule of network planning is that you need a variety of non-overlapping channels to maximize throughput and minimize interference. The fewer non-overlapping channels you have available, the more devices transmit on a single channel, decreasing throughput. Moreover, the fewer non-overlapping channels available, the greater the risk that Wi-Fi access points on the same network might interfere with one another. Additional and different spectrum resources can help to minimize these problems.

In the 5 GHz band, the wider channels utilized by the 802.11ac wireless routers result in far fewer non-overlapping gigabit Wi-Fi channels than were previously available for Wi-Fi network operators, but will increase throughput dramatically. Whereas previously a network operator could deploy new routers and set them to 1 of 20 or more non-overlapping channels in order to avoid interference with existing routers, available spectrum can only support a very limited number of non-overlapping gigabit Wi-Fi channels. Current unlicensed spectrum designations in the 5 GHz band – which 802.11ac is designed for – provide for six 80 MHz channels, which can be bonded to provide two contiguous or various non-contiguous 160 MHz channels. However, many of the existing bands have stringent technical rules that make them difficult for Wi-Fi to use, and impossible for Wi-Fi to use to achieve ubiquitous (i.e., outdoor) coverage. As discussed in further detail below, there is currently only one, non-contiguous 160 MHz channel suitable for ubiquitous Wi-Fi coverage.

Additionally, while Wi-Fi network operators currently rely primarily on a few channels in the 2.4 GHz and 5 GHz bands, adding additional non-overlapping channels in other spectrum frequencies can help build better Wi-Fi networks. Adding new unlicensed spectrum in different frequency ranges – the 600 MHz band and 3.5 GHz band, for instance – gives network operators more channel options, increasing flexibility and minimizing problems with network congestion and interference.

A consequence of a limited number of Wi-Fi channels is illustrated by a K-12 use case. For a K-12 school with a network of 802.11ac wireless routers serving every two classrooms, upwards of 60 students/teachers require Internet access. A hypothetical peak load on the network is a time when 60 users all require Internet access to support an interactive distance learning application. Based on the minimum bandwidth requirements of popular interactive applications, two classrooms of students might require 240 Mbps throughput.

Bandwidth Requirements for Popular Educational Applications	
Activity	**Bandwidth Requirements (per student)**
Basic Video Conferencing	1 Mbps
Interactive Online Learning Games	1 Mbps
HD Conferencing & Tele-learning	4 Mbps
HD Video & Online Learning Games	4 Mbps

While a wireless router using 802.11ac technology is likely able to deliver the required throughput, network administrators interviewed for this paper raised concerns. According to one administrator with a significant BYOD initiative in his school system, wireless routers serve network management and administration functions and handle video surveillance and building management functions, in addition to delivering the required Internet access. The wireless network must deliver adequate throughput to support these functions as well as the "spikey" bandwidth requirements of the teachers and students. As a general rule, he seeks to engineer his networks and set network-use policies that ensure that students and teachers access only 50% of available bandwidth, so that there is available throughput for the network's other functions. In the use case examined here, if a router's throughput to the two classrooms were 400 Mbps and policies limited classroom throughput to 50% of total capacity, the network would not most effectively support the needs of the teachers and students.

The Lack of a Contiguous 160 MHz Channel

Considering that the 5 GHz band does not currently offer gigabit Wi-Fi to network operators, a contiguous 160 MHz channel under favorable technical rules is an additional concern. Recent action by the FCC has raised the maximum transmit power and removed the indoor use restriction on the U-NII-1 band. This action creates one non-contiguous 160 MHz 802.11ac channel with favorable technical rules using spectrum at U-NII-1 and spectrum at U-NII-3. Because of the technical restrictions on the U-NII-2A band, a contiguous 160 MHz channel spanning U-NII-1 and U-NII-2A is not ideal. Current rules require operations in the whole channel to abide by the U-NII-2A restrictions.

FCC action to apply accommodative technical rules to U-NII-4 would permit the first useful contiguous 802.11ac channel (spanning U-NII-3 and U-NII-4).

According to experts in Wi-Fi deployment, a contiguous 160 MHz channel will yield a better end-user experience in environments such as K-12 schools, where high throughput is required. The reason for this relates to the fact that Wi-Fi deployments in K-12 schools require multiple wireless access points in order to create a contiguous network of coverage with adequate capacity. In the absence of a contiguous channel, and in order to mitigate the consequences of congestion, K-12 schools would be forced to incur unnecessary additional cost or suffer network inefficiency. Additional cost would derive from the need to substantially increase the number and density of Wi-Fi access points. Constructing additional Wi-Fi access points is an expensive proposition, as Wi-Fi network operators must deliver a power supply and extend backhaul to each additional access point. A contiguous 160 MHz channel with favorable technical rules will provide gigabit Wi-Fi operators more flexibility to engineer their networks in a manner consistent with current practice.

Key Finding #3: Ubiquitous, high-speed Wi-Fi in the classroom increasingly will depend on access to sufficient unlicensed spectrum. In particular, the limited number of Wi-Fi channels and the lack of a contiguous 160 MHz "gigabit" Wi-Fi channel could contribute to degraded wireless network performance in the K-12 school environment.

IV. Recommendations

The findings summarized in this report support a conclusion that the Obama Administration's ConnectED initiative should be expanded to include consideration of its spectrum policies. Because unlicensed spectrum constitutes the "last mile" of a K-12 school's broadband network, educators should seek to work with policymakers at the NTIA and FCC to ensure that spectrum policies support the Administration's efforts to advance Wi-Fi connectivity required by K-12 schools.

In particular, educators should raise the following points with policymakers:

K-12 schools will benefit from policies that build robust wireless connectivity through adequate access to unlicensed spectrum in high, medium, and low frequency bands including:

Policies that permit gigabit Wi-Fi services to access additional unlicensed frequencies in the 5 GHz band, especially spectrum at U-NII-2B and U-NII-4. Access to additional 5 GHz spectrum will provide additional 80 MHz building blocks and additional 160 MHz channels to support gigabit Wi-Fi. If unlicensed access were permitted in all of the 75 MHz of U-NII-4, this would support a 160 MHz contiguous channel spanning U-NII-3 and U-III-4, and also a new 80 MHz channel, also spanning U-NII-3 and U-NII-4.

FCC action in the pending incentive auction proceeding that provides enough spectrum in the 600 MHz frequency bands to support investment and innovation in TV White Spaces. Signals in these lower frequencies propagate very well – meaning they can penetrate walls, roofs, and other obstacles, and can reach long distances. These bands could become part of robust wireless networks to amplify schools' bandwidth and serve local communities that are underserved and unserved by other broadband options.

Reasonable rules for spectrum sharing in the 3.5 GHz frequency band that would incentivize new broadband deployment, lower entry barriers for a diverse range of users, and promote innovative uses in a band currently underutilized. The FCC has asked how it can turn the 3.5 GHz frequency band into a fully utilized "innovation band" that is available to consumers and companies, and is considering a three-tier access plan. Schools are well positioned – if the rules are structured well – to be second-tier licensees and/or third-tier users of this band.

Wi-Fi usage on a K-12 campus and the prospect of a K-12 school providing Wi-Fi connectivity to students who live near a K-12 campus will benefit from additional bands of spectrum designated for unlicensed uses.

Feedback from K-12 broadband providers, including from the CEO of Merit Network, indicates that as much as 60% of the broadband traffic attributable to a school's 1:1 initiative will occur as a result of students and teachers connecting to the K-12 servers from home. This input suggests that the millions of students and teachers who will increasingly rely on Wi-Fi connectivity in the classroom will also connect to K-12 networks from home. For these types of ubiquitous, indoor/outdoor WANs, there currently are no contiguous 160 MHz channels available, and only two 80 MHz channels. Access to U-NII-4 spectrum is particularly important for outdoor networks, as it would provide a third 80 MHz channel and the first 160 MHz contiguous channel governed by favorable technical rules. The FCC should designate additional 5 GHz spectrum for unlicensed use, while NTIA should recognize the importance of the 5 GHz band for education, digital inclusion efforts, and U.S. broadband policy writ large.

V. About the Author

Bill Maguire is a Partner in Reluminati, LLC, where he heads the consulting firm's public-private partnership practice. Formerly, Bill served as Chief of Staff for the Broadband Technology Opportunities Program (BTOP) at the National Telecommunications and Information Administration (NTIA). Through the $4.7 billion BTOP program, NTIA supported the deployment of 100,000 new and upgraded fiber network miles connecting 20,000 anchor institutions, including more than 10,000 K-12 schools.

This study was commissioned by the WifiForward Coalition. The author would like to thank Rob Alderfer, Martin Costa, Essam El- Beik, Don Freeman, Barry Graves, Steve Hratko, Mark Johnson, Adam Martin, Brian Metzger, Tom Miller, Bill Mott, Dennis Sampson, Khushuru Tata, Marcus Thimm, and Don Welch, as well as Paul Margie and Danielle Pineres, for their input, comments, and suggestions. Bill Maguire is solely responsible for the views and content of the study.