White Paper

Intel Information Technology

Computer Manufacturing

Mobility Platforms and Solutions

Wireless Technologies and e-Learning: Bridging the Digital Divide

To narrow the digital divide in education, Intel® Innovation Centre is developing an array of information and communications technology (ICT) strategies and implementing e-Learning and wireless technologies. By taking advantage of developments in wireless standards and technologies—particularly in the areas of Wi-Fi*, Worldwide Interoperability for Microwave Access (WiMAX), and mobile computing—ICTs offer opportunities to reach new audiences and extend the benefits of digital technology and e-Learning to previously unreachable populations.

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IT@Intel

Executive Summary

To reach new audiences and extend the benefits of digital technology to previously unreachable populations, Intel® Innovation Centre is developing an array of information and communications technology (ICT) strategies as well as e-Learning programs using wireless technologies.

New ICT and e-Learning strategies and advances in wireless standards and technologies—particularly in the areas of Wi-Fi*, WiMAX, and mobile computing—can help bridge the digital divide in education.

ICT and e-Learning platforms provide alternative channels for improving the quality of education and extending its reach to broader audiences. A significant challenge in realizing the full promise of ICT worldwide has been lack of access, particularly in developing countries and in rural communities. Deploying traditional wired infrastructures in remote, sparsely populated areas has been commercially unfeasible and has created a huge financial barrier to getting these communities connected to the Internet.

This limitation has created a "digital divide"—a gap between those able to benefit from digital technology and those who cannot. Although socio-economic factors are the primary cause of the digital divide, additional factors include differing levels of literacy and technical skills, social and legal constraints, as well as access to relevant, high-quality content.

New ICT and e-Learning strategies and advances in wireless standards and technologies—particularly in the areas of Wi-Fi*, Worldwide Interoperability for Microwave Access (WiMAX), and mobile computing—can help bridge the digital divide in education. Using open broadband wireless standards and implementing mobile computing architectures, we can:

- Overcome the challenges of terrain, infrastructure, and finance to increase access
- Deploy broadband quickly and cost-effectively to areas currently not served
- Extend the benefits of digital education to previously unreachable populations

In sharing case studies of our experiences expanding innovative uses of ICT, Intel Innovation Centre can help educate the global community.

Contents

Background: The Digital Divide

Information and communications technology (ICT) and e-Learning platforms extend the reach of education to broader audiences and provide ways to enhance traditional education, generating significant social and economic benefits to populations who have access to them.

More than one billion people can connect to the Internet and take advantage of its broad array of information-rich experiences. The remaining 5.5 billion people, however, do not have access to computers or the Internet.[1,2]

[1] "Global Challenges Facing Humanity." The Millennium Project: Global Futures Studies & Research. American Council for the United Nations University (AC/UNU). 2006. www.acunu.org/millennium/Global_Challenges/chall-06.html

[2] "World Internet Usage Statistics—News and Population Stats." Miniwatts Marketing Group. 2001-2006. www.internetworldstats.com/stats.htm

This "digital divide"—the gap between those who benefit from ICT and those who cannot—has been attributed most commonly to socio-economic factors, affecting developing countries disproportionately. Africa, for example, accounts for about 14 percent of the world's population, but only 3.6 percent of its population can connect to the Internet. In contrast, North America makes up about 5 percent of the world's population and 69 percent of its population has access to the Internet.[3]

Financial factors contribute significantly to the ICT deficit for lower socio-economic groups within our communities and in less economically developed countries. Deploying traditional wired infrastructures in remote, sparsely populated areas has been commercially unfeasible and has created a huge financial barrier to getting these communities connected to the Internet.

A community's inability to use ICT effectively also contributes to the digital divide. Causes for this "ability gap" include differing levels of literacy and technical skills, as well as the gap between those groups that have access to relevant, high-quality digital content and those that do not.

Location, age, culture, and background significantly influence the likelihood that users will embrace ICT and e-Learning. For example, usage models that assume learners own their own PCs, personal digital assistants (PDAs), or other mobile devices and require European-style multimedia content may not be suited for rural learners in developing countries who share ICT equipment and do not identify with the content design. Even sophisticated users, especially students, experience the effects of the digital divide when schools and other educational institutions do not advance quickly enough to provide relevant content. Thus, bridging the digital divide in education requires addressing access issues as well as ensuring that new users can fully benefit with appropriately designed e-Learning.

Benefits of Information Communications Technology

Expanding the reach of ICT and building more effective e-Learning platforms offer social, governmental, and business advantages, including:

- Expanded access to educational resources for a significantly larger user base
- Increased availability of information for all users
- Improved lifestyle for citizens regardless of socio-economic status
- Unprecedented opportunities to exercise entrepreneurial skills regardless of user background

Citizens benefit from better education and information, thus increasing their opportunities for social and economic mobility and enabling greater participation in their communities. Businesses benefit from larger, more educated and qualified labor pools, the chance to increase productivity through infrastructure creation and access to new and improved services, and expanded channels for selling their own products and services. Affordable broadband services attract new investment, creating jobs and increasing a country's gross domestic product (GDP).[4]

Technology Challenges

Cost and the practical limitations of current infrastructures have prevented DSL and cable technologies from reaching many potential broadband users. Generally, DSL only extends about five kilometers from the central office switch and many existing cable networks do not provide a return channel. Converting these networks to support high-speed broadband or deploying wired infrastructure to new areas with low subscriber density is generally commercially unfeasible and requires years of disruptive installation. All of these factors more acutely affect developing countries where infrastructures aren't as advanced or don't exist.

[3] ibid.

[4] "TRAI Releases Recommendations on Broadband India: An Integrated Policy for Accelerating Growth of Internet and Broadband Penetration." Telecom Regulatory Authority of India. April 29, 2004. www.trai.gov.in/trai/upload/PressReleases/177/Press%20Release%202004-04-29%20FINAL.pdf

Closing the Gap

Narrowing the digital divide in education can begin with expanding access to ICT using new wireless technologies. However, realizing the full promise of e-Learning also requires understanding our audiences and building tools that meet their needs.

Our research at Intel suggests we have reached a turning point in our ability to effectively address the digital divide, due to a variety of factors:

- Computing costs are steadily decreasing and capacity is increasing in a variety of devices at prices many users can afford.
- New wireless protocols are overcoming the technical and financial challenges of expanding access to rural communities and developing countries.
- The convergence of computing and communications creates the opportunity to build more relevant e-Learning content, facilitating education to a broader student audience.

We believe the time is right to focus more explicit and coordinated attention on the issue of Internet access and the attendant educational opportunities.

Advances in wireless standards and technologies—particularly in the areas of Wi-Fi, WiMAX, and mobile computing—allow us to reach new audiences in remote locations. Using these open broadband wireless standards and implementing mobile computing architectures, we can:

- Overcome the challenges of terrain, infrastructure, and finance to increase access.
- Deploy broadband quickly and cost-effectively to areas currently not served.
- Extend the benefits of digital education to previously unreachable populations.

Gartner predicts the installation of more than 167,000 public wireless LAN (WLAN) hotspots around the globe and over 75 million wireless users worldwide by 2008. WLANs give users high-speed wireless access and give service providers opportunities to stimulate growth in the wireless data market.

While these technologies expand Internet and ICT access to new audiences, closing the digital divide also requires building content that addresses various levels of ability and sophistication and the cultural differences of these new users.

Intel Innovation Centre's involvement in developing ICT strategies and implementing e-Learning and wireless technologies demonstrate ways to narrow the digital divide in education: both by increasing access to ICT and by learning more about our users so we can develop more appropriate e-Learning tools. By sharing our experiences and expanding key uses of ICT in education to other groups within our own society and in the developing world, we can realize the benefits of a more educated, informed, and satisfied populace.

Candidate Wireless Technologies

Figure 1, on the next page, shows the main network types and the prevalent technologies associated with each, mapped against usage models and access modes. Table 1 describes wireless technologies and standards and the associated benefits.

Proposed Solution

Using Wi-Fi and WiMAX open broadband wireless standards and implementing mobile computing, governments and partners can quickly and cost-effectively deploy broadband to areas not currently served, with little or no disruption to existing infrastructures.

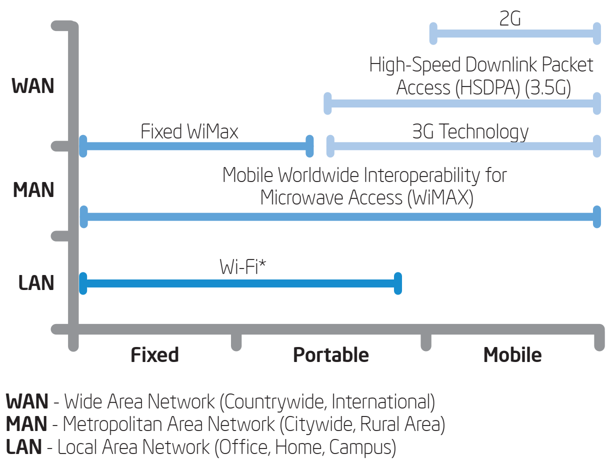

Figure 1. Wireless technologies: network type, range, and throughput.

Standards-compliant WLANs and proprietary Wi-Fi mesh infrastructures are being installed rapidly and widely throughout the world. Standards-compliant WiMAX products can provide non-line-of-sight (NLoS) backhaul solutions for these local networks and WiMAX subscriber stations can currently provide Internet access to customers such as schools and other educational institutions and campuses.

In 2007, next-generation Wi-Fi and WiMAX enabled clients will directly access legacy proprietary Wi-Fi mesh networks, newly deployed standards-compliant Wi-Fi mesh networks, and WiMAX networks.

By capitalizing on these emerging technologies and standards and promoting and supporting their implementation, we can lay a solid foundation for expanding ICT services.

Table 1. Wireless technologies

Standard	Usage	Characteristics	
Third Generation Wireless Format (3G)	WANs, national and international deployments	▪ Designed primarily for voice communications ▪ Suitable for e-mail and basic data connectivity	▪ Equipment is readily available ▪ Supports full mobility ▪ Spectrum is established
High-Speed Downlink Packet Access (HSDPA) (3.5G)	WANs, national and international deployments	▪ Has lower throughput than WiMAX, but greater mobility (for example, the initial download speeds in the United Kingdom are about 1.8 Mbps and rising to 3.6 Mbps in 2007) ▪ Uses existing 3G spectrum	▪ HSDPA-enabled devices are currently coming to market beginning with laptop data cards; the cellular industry soon will announce full user device integration ▪ Combines existing 3G mobility with higher data capacity for downlink
Wi-Fi*	LANs, indoor and privately owned outdoor deployments in localized areas such as offices, hotspots, campuses, and homes	▪ Standards are mature ▪ Uses unlicensed frequencies ▪ Equipment is readily available ▪ Primarily designed for indoor implementations	▪ Has a theoretical maximum throughput of 54 megabits per second (Mbps) and a range up to 100 meters ▪ Spectrum allocation is not an issue
Worldwide Interoperability for Microwave Access (WiMAX)	Metropolitan area networks (MANs), citywide deployments, and rural deployments across large geographic areas	▪ Standards have been ratified and are maturing ▪ Uses unlicensed and licensed frequencies ▪ Equipment is currently available for the fixed standard and is being tested for the mobile standard ▪ The mobile standard will deliver full mobility	▪ Designed for longer range outdoor deployments, with a range of two to six kilometers for urban deployments and a significantly longer range for rural deployments ▪ Has a theoretical maximum throughput of 75 Mbps
Wireless Mesh Network Solutions	LANs, indoor and privately owned outdoor deployments in localized areas such as offices, hotspots, campuses, and homes, MANs, and citywide deployments	▪ Infrastructure mesh networks combine the characteristics of cellular networks with Wi-Fi technology ▪ Dense mesh architecture is capable of cost-effectively and securely delivering broadband data to standard Wi-Fi clients over entire metropolitan areas	▪ A standard does not currently exist for wireless mesh networks, although work is currently underway to incorporate a specification under the 802.11 set of standards ▪ The majority of wireless LAN equipment vendors offer proprietary mesh implementations
Mobile Computing Architectures and the Occasionally Connected Computing (OCC) Model	Reduce network dependency by making data and applications available offline and synchronizing data on reconnection	▪ Online/offline functionality allows users to work anywhere, any time, without disruption, even when network connections are interrupted ▪ Intelligent roaming capabilities let users move from hotspot to hotspot; users won't waste time reconnecting or lose critical data because of dropped connections	▪ Various computing devices—for example, laptops, desktops, handhelds, or servers—can access data and applications ▪ Tuning applications conserve power and maximize performance, extending battery life and delivering fast application execution

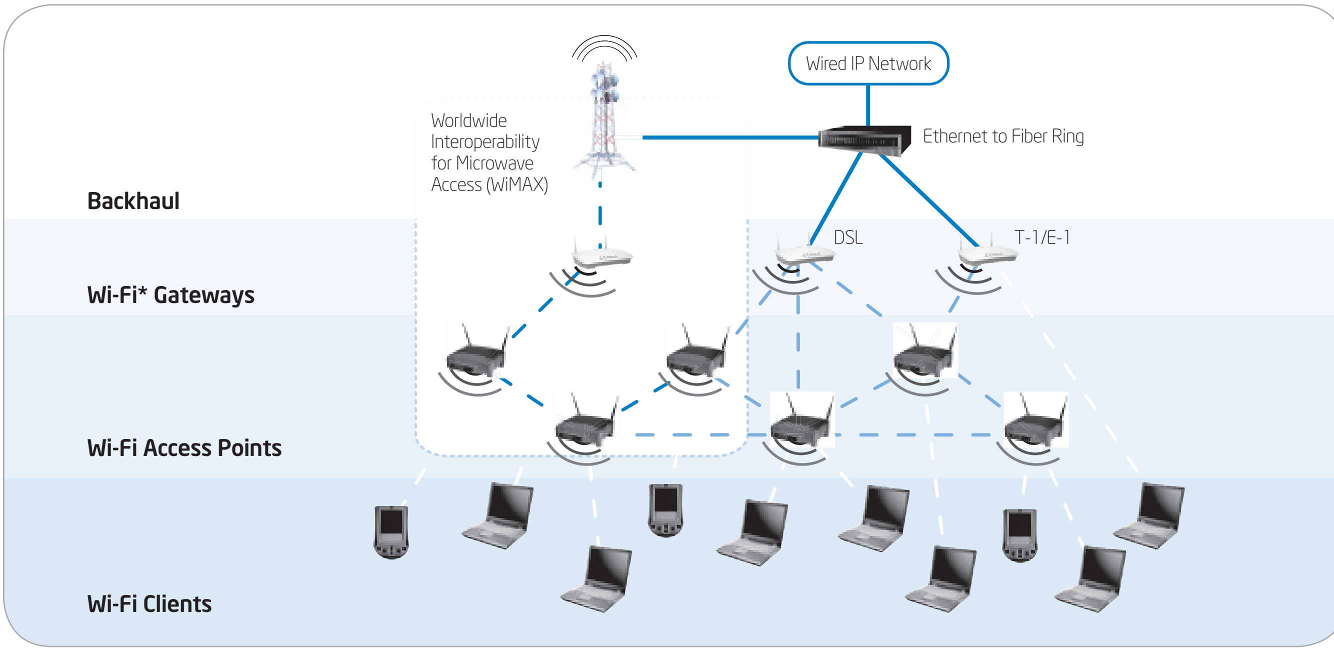

Figure 2. WiMAX and Wi-Fi integration.

Case Studies: e-Learning Innovations at Intel

Intel Innovation Centre's involvement in developing ICT strategies and implementing wireless technologies in several e-Learning projects provide some examples of how wireless technologies can help close the digital divide.

These case studies involved:

- Developing and presenting a wireless strategy for a Digital Community initiative in India
- Supplying architecture and technical expertise for the SchoolSat initiative in Ireland, demonstrating the delivery of education-focused Internet services to schools via satellite technologies
- Designing and delivering the skoool™ Learning Technology platform, a service that delivers e-Learning to students anytime, anywhere, in low or high bandwidth environments

Evaluations and key findings from case studies can inform future designs and implementations.

Case Study 1: Digital Community Initiative in the Developing World

Intel Innovation Centre presented a compelling case for implementing a Digital Community initiative in the state of Karnataka, India, which addresses facilitating education to students and adult learners, many of whom live in remote areas. The initiative proposes a comprehensive program that is cohesive, standards-based, scalable, and future-proof, with formal, ongoing education as a key objective. It addresses economic vitality, citizen satisfaction, and bridging the digital divide. The proposed strategy includes four phases, as shown in Figure 3 on the next page. Table 2 outlines the key recommendations for the project.

In response to our presentation, the chief minister of Karnataka released an expression of interest, which will lead to a request for proposals for implementing the Digital Community strategy in Bangalore (or Bengalūru), Karnataka's principal city.

Case Study 2: Satellite Link for SchoolSat in Ireland

SchoolSat, an initiative funded by the European Space Agency, focuses on improving access to the Internet and delivering education-focused Internet services with an innovative two-way "Internet via satellite" network to remote Irish schools (see Figure 4). ATiT Ireland managed the project, with Intel Innovation Centre and others providing the architecture and technical expertise.

The project provided small satellite dishes to nine post-primary schools in areas poorly served by broadband. The local authority had had difficulty facilitating Internet access requirements for the schools in this region and decided that a satellite service could play an important role in meeting these needs.

ATiT Ireland implemented the satellite infrastructure and set up a multicasting service that pushed selected educational content from a number of leading sources, including Intel Innovation Centre's skoool Learning Technology platform on a weekly basis. Caching the content on a server at each school provided local access for students and teachers, which enabled a rich media learning experience. For interactive tasks, such as filling out questionnaires and online research, users could access the Internet through the satellite link.

Using satellite technology for this type of service offers several advantages:

- Gives schools fast access to the Internet
- Can be installed in any school regardless of location
- Can be installed quickly—on average equipment setup at each school took half a day
- Provides a secure, managed network for schools
- Gives stakeholders a system capable of pushing specific web-based content and digital resources to all schools instantly
- Can be integrated with other compatible services where such services exist

Table 3 summarizes the key findings from evaluations of the program at participating schools.

Plans are currently underway for implementing multicast broadband over WiMAX technology as the next phase to this project. In support of this effort, Intel Innovation Centre has completed a comprehensive research study on the technical and commercial feasibility of multicasting over WiMAX.

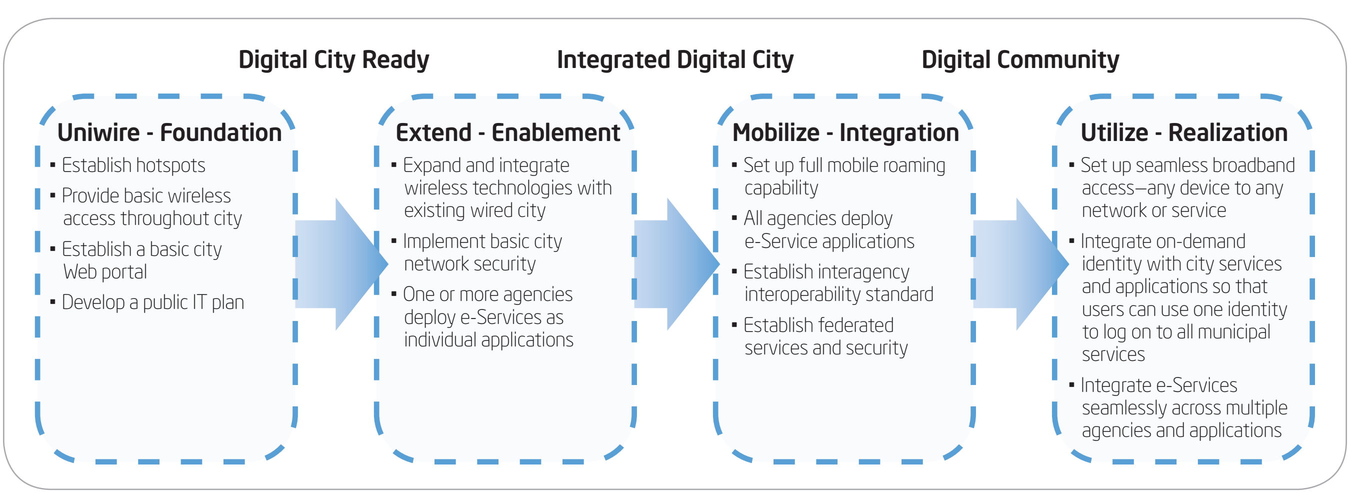

Figure 3. Digital community continuum: WiMAX and Wi-Fi* integration.

Table 2. Key recommendations for implementation of a digital community in Bangalore, India

1. Short-list Potential Principal Partner(s)	Using pre-defined criteria, short-list a number of potential principal partners for investment on the project.
2. Invite Expressions of Interest (EoIs)	Initiate a commercial framework for the project by inviting EoIs from those short-listed parties interested in becoming principal partners.
3. Issue Requests for Proposals (RFPs)	Issue detailed RFPs to prospective principal partners, as determined through the evaluation of EoIs.
4. Select Principal Partner(s)	Formulate technical and commercial bidding processes and, using this process—which may include a pre-bid conference—select one or more principal partner(s) for delivery and post-delivery services and maintenance of the project.
5. Deliver Business Case	Form a dedicated team of skilled people from local government, principal partners, and external parties, where necessary, to deliver a compelling business case and business plan for the proposed project.
6. Deliver Technology Evaluation, Infrastructure, and Applications Architecture	Form a dedicated team of skilled people, again from local government, principal partners, and external parties, where necessary, to deliver a detailed technology evaluation and define the infrastructure and applications that would quickly draw a critical mass of users (and thus revenue) to the project.
7. Deliver Commercial Framework	Deliver a strong investor-ready commercial framework and plan for the development of Wi-Fi* enabled mobile software applications; work with a principal partner to establish the infrastructure.
8. Deliver Wireless Bangalore	Deploy Wireless Bangalore, employing a phased approach to prove the concept, positively influence further investment, and generate early revenue streams that can finance subsequent phases; integrate the project with the citizens and businesses of Bangalore as it is being implemented.
9. Sustain and Enhance Wireless Bangalore	Local government and partners should continue to maintain the infrastructure and enhance existing applications and services while adding new services, as deemed appropriate by usage metrics and patterns.

Table 3. SchoolSat key findings

Key Learnings	▪ All schools reported making valid educational uses of the Internet. ▪ In some cases, the Internet provided the basis for teaching a particular subject. ▪ Teachers perceived significant learning benefits, including increased student motivation. ▪ In project work, teachers reported that students took more responsibility for their own learning. ▪ Teachers using online tests reported that they particularly engaged weaker students who were anxious to retake the tests and increase their scores.
Key Barriers	▪ Some teachers were unsure of how to use the technology, especially in a classroom setting. ▪ Students and teachers had difficulty in getting access to the computer room. ▪ Some teachers and parents worried about the relevancy of working online in preparing students for examinations.
Technology	▪ The satellite link provides 56 kilobit per second performance for the initial request through the phone line and high-speed access for subsequent requests after the satellite link is established. ▪ With an average half-day equipment installation, set up is fast.

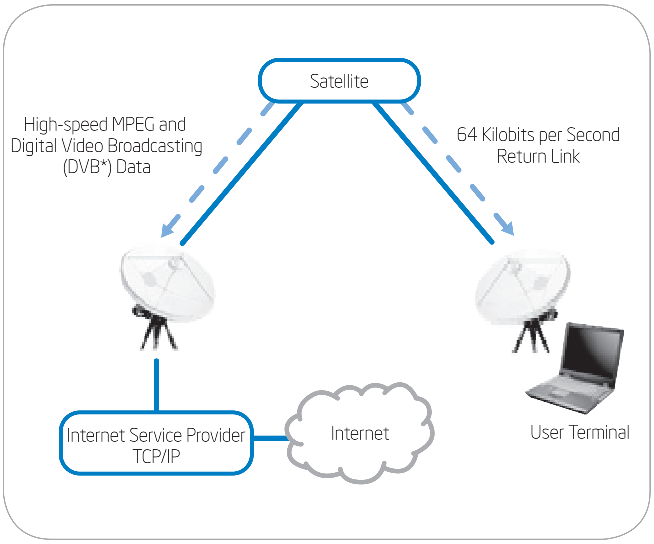

Figure 4. SchoolSat technology overview.

Case Study 3: skoool™ Learning Technology

Intel Innovation Centre's skoool Learning Technology delivers leading-edge e-Learning to students anytime anywhere in low or high bandwidth environments. Currently, it is available in schools in the United Kingdom, Ireland, Sweden, Turkey, and Thailand. Saudi Arabia, South Africa, and Spain are all due to launch late 2006 or early 2007. Plans are also underway to offer tailored versions to developing countries in West Africa.

The skoool Learning Technology platform features:

- A state of the art database-driven site running on high-end Intel® architecture-based servers
- The Intel® Electronic Content Distribution System (eCDS) peer-to-peer product for delivering high-quality media content
- An efficient and flexible content management system and information architecture
- Tools for supporting customers, registering users, and setting up virtual communities
- Dynamic and flexible usage reporting
- A well-defined brand that parents, teachers, and students recognize and trust

In addition to the PC-based online and downloadable services available on this educational portal, the Intel Innovation Centre has developed similar services and learning materials designed for PDAs, mobile phones, and smartphones. These services include

Table4. skoool™ Technology key findings for the United Kingdom (UK)

Key Learnings	▪ Educational experts reviewing the smartphone learning objects (LOs) during our proof of concept agreed that these objects could be useful in the educational process. ▪ Short Message Service (SMS) campaigns—for example, study tips and competitions—have proven successful with users. ▪ Of all the SMS campaigns organized for participating users over the course of the school year, exam tips have been the most popular. ▪ Some findings suggest that SMS and phone delivery initiatives appeal to students who may be considered borderline performers.
Key Barriers	▪ Not enough students own sophisticated handsets. ▪ Smartphone pricing and design has been focused largely on the business community, rather than students.
skoool Technology UK Statistics (2005)	▪ 67 percent of Key Stage 3[Δ] students reported using the SMS service. ▪ 38 percent of Key Stage 4[Δ] students reporting using the SMS service. ▪ 15 percent of Key Stage 4 students reported using skoool technology content on PDAs.

[Δ] Key Stages 3 and 4 define curriculum in the UK for students aged 11-14 and 14-16, respectively.

smartphone learning objects (LOs) and short message service (SMS) campaigns, such as study tips and competitions. We have tested these services in a proof of concept study and implemented them in a limited capacity. They are ready to be deployed more fully when a critical mass of users have appropriate devices. Table 4 summarizes the key findings from evaluations of these services from educators and students in the United Kingdom.

Conclusion

People at all socio-economic levels benefit enormously from the innovative creations of the ICT industry. Expanding these benefits to previously underserved populations generates improvements in education and income, and begins to close the digital divide.

Proliferation of e-Learning tools, such as skoool Learning Technology, depends upon a solid infrastructure. In many cases—especially in developing countries—a wireless approach offers numerous advantages, including:

- Low cost for setup and maintenance (as compared to wired technologies)
- Short, non-disruptive installation period
- Technology well-suited to physical and environmental challenges
- Standardized network equipment with a strong product roadmap

Intel Innovation Centre has a unique opportunity to develop both content for e-Learning and infrastructure in wireless technologies.

Going forward, we will continue to work on existing projects and initiate new projects with a specific emphasis on Wi-Fi, WiMAX, and mobile computing architectures. We will continue to expand the skoool technology to other geographies worldwide, including developing countries in Africa, tailoring the implementation to meet regional requirements. We will continue to share our experiences and key findings to inform and promote the future of e-Learning and other technologies and strategies that will help us narrow the digital divide.

Authors

Gerard Smyth is a senior technologist with Intel® Innovation Centre, Intel Ireland.

Acronyms

EoI	expression of interest
ICT	information and communications technology
IEEE	Institute of Electrical and Electronics Engineers
3G	third-generation wireless format
3.5G	The next evolution of 3G towards 4G, often associated with HSDPA
HSDPA	High-Speed Downlink Packet Access
MAN	metropolitan area network
NLoS	non-line-of-sight
PDA	personal digital assistant
RFP	request for proposal
UWCC	Universal Wireless Communication Consortium
Wi-Fi*	wireless fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	wireless LAN

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