

The One Laptop Per Child (OLPC) Project

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Abstract

It is of value to decision makers in developing nations involved in the area of ICT for Development as well as ICT for Education to understand the implications and benefits of new technologies. The One Laptop Per Child (OLPC) device (XO) is one such new technology that has received significant media attention in the past year. As such, this paper seeks to provide a detailed understanding of the OLPC project and to highlight, explain and contrast key technical aspects and capabilities of the OLPC and similar devices from the perspective of education in developing countries.

Keywords

OLPC, ICT4D

1 Introduction

The organization producing the OLPC device (XO) is a non-profit US based corporation called OLPC. The OLPC device is currently called the XO. In the past, it had labels such as the MIT \$100 laptop and 2B1 which may be more familiar due to past media attention around those labels. The OLPC organisation was founded by Nicholas Negroponte of the MIT Media Lab. The OLPC organisation also has several other MIT Media Lab faculty on its organisation list including Walter Bender, Mary Lou Jepsen, Barry Vercoe and Robert Fadel. OLPC is based in Boston, MA, USA but has employees and contractors as well as volunteers around the world that are helping to build the device.

The XO itself is best described as a laptop-like device. Illustration 1 is a picture of the current beta test version of the XO. It is targeted at education for children in a rural environment. The OLPC website at <http://laptop.org> states this very clearly.

“OLPC is a potent learning tool created expressly for the world's poorest children living in its most remote environments... The result is a unique harmony of form and function; a flexible, ultra low-

cost, power-efficient, responsive, and durable machine with which nations of the emerging world can leapfrog decades of development—immediately transforming the content and quality of their children's learning.”



Illustration 1: : OLPC B-Test1 Unit

This statement regarding the use of the XO to address educational needs of poor children in rural areas has seen some debate and controversy in the media ever since the OLPC was announced. It is however beyond the scope of this paper to address many of those issues. Instead, this paper is intended to help decision makers understand and gain the ability to leverage the technical aspects of the technology used in the OLPC XO and similar devices.

OLPC has stated that it receives sponsorship from the companies profiled as follows. AMD, which is the well known US processor company and the manufacturer of the Geode GX2 CPU utilized in the XO. Brightstar, which is a US based logistics and supply chain management organisation known for distribution of cellular and mobile phone related products. eBay, which is a US based internet company best known for its online auction and shopping website., Google, which is a US based internet services company. Marvell, which is a US based semiconductor company and manufacturer of the camera and wireless chips utilised in the XO,

News Corp, which is a US based company known as the world's largest media conglomerate. Nortel, which is a Canada based company best known for its telecommunications devices and services. Quanta Computers, which is a Taiwan based electronics manufacturer known as the world's largest OEM for notebook computers. Redhat, which is a US based software services company. SES Astra, a Luxembourg based company known as the operator of the Astra geostationary satellites and others.

The OLPC organisation has stated that it will only sell XO laptops to governments. This is a key point to note for decision makers. OLPC has also stated that the governments will be required to donate the XO laptops to children. At the time of writing, Libya, Brazil and Nigeria were stated as initial launch countries for the XO.

2 OLPC Hardware Capabilities

A good understanding of a device's hardware architecture is essential for decision makers. This is more true for the XO than for typical devices. This is because the software on the XO is completely free and open source. It is important to distinguish that while the software is free and open source, the hardware design is proprietary. The utilisation of free and open source software on the XO means that a participating entity could in theory replace any or all software or applications on the laptop. OLPC has stated that they wish to encourage end user tinkering. As such, this software architecture gives a significant amount of freedom to participating entities. Any entity with the necessary technical know-how could easily modify any functionality on the system ranging from as low level as the Linux kernel right up to modifying user interfaces, replacing or adding images, content and other functionality. For example, a particular school in a rural area could possibly add an application that provided maps of the local region and allowed student participation in helping to document the varieties of local flora and fauna using the built-in camera. The only factor restricting these applications is the hardware capability of the device. Hence, the importance of understanding those capabilities.

2.1 OLPC Hardware System Architecture

Table 1 provides an overview of the hardware capabilities of the XO. Each feature is explained in detail in the following subsections.

Feature	Details
CPU	AMD Geode GX2 366MHz 2 Watts typical
RAM	128MB DDR SDRAM
Storage	512 MB NAND Flash
USB	3 x USB 2.0 (Hi-speed)
Misc	SD Card Slot
Wireless	802.11b/g + 802.11s mesh Off Host Mesh
Audio	Stereo on-board speakers On-board microphone Jacks for external speaker and microphone
Display	7.5" TFT LCD display Dual mode Reflective : 1200x900 Transmissive: 640x480 200 DPI
Input	Sealed membrane keyboard Dual-mode touchpad
Camera	VGA CMOS Camera
Battery	NiMH 2 hour battery Human powered charger Wide-range DC input power
Chassis	Thick plastic Dirt/Moisture resistant Pivot hinge (Tablet mode) Movable antennas

Table 1: Hardware Specification

2.1.1 Display

There are several innovative aspects of the OLPC. But it is the display that is the most unique. It is even possible that aspects of this display technology designed for the OLPC will make their way into commodity displays for all sorts of devices.

The display used in the OLPC is TFT LCD. TFT LCD is the same type of display you find in most laptops. However, most laptops use a CCFL backlight. CCFL stands for cold cathode fluorescent lamp. It consumes a significant portion of the power used in a laptop. The light from such a backlight is what passes through polarisers, the LCD pixel and finally the colour filter before it reaches the user's eye. The OLPC display is innovative in that it discards two aspects of that design. It discards the backlight in favour of very low power LEDs that are more efficient and

last longer. It discards the colour filter in favour of a very unique plastic diffraction grating that generates the primary colours in the display. Discarding the filters implies that more light can get to the user's eye thereby reducing the amount of light needed from the backlighting system. Thus, saving both power and costs.

The technology behind the diffraction grating and the colour generation has not yet been detailed publicly. But the device itself has been manufactured and made available to many people. This demonstrates direct proof that the technology behind the display does work. The OLPC team has stated that the cost of such displays is approximately USD\$35 in contrast to the USD\$100 or more associated with equivalent sized and equivalently bright displays. The display also has a grayscale reflective mode where no backlighting is used, thereby enabling it to serve much like the LCD in a calculator and to be utilised in full daylight conditions. This enables the XO to also serve as an E-book. The E-book resolution is 1200x900 and is sufficient to display detailed diagrams as would be commonly found in textbooks. The transmissive colour mode has a resolution of 640x480 and is sufficient to deliver VCD quality images and video content.

2.1.2 CPU, RAM and Storage

The Geode GX2 is an embedded x86 CPU running at 366MHz and consuming about 2W in normal usage modes. This CPU has low power consumption and many integrated features that serve to reduce the cost of systems built using it. The performance of this cpu varies significantly based on the workload. It would be fair to say that it is quite capable of running a fully functional web browser, playing back VCD quality video, providing office productivity tools. The 128MB of DDR SDRAM memory is also sufficient to accommodate all the afore mentioned functions.

The use of solid state storage via NAND flash in the XO serves many purposes. NAND flash is far more resistant to the wider range of temperatures, humidity, heat and rougher usage models than the hard drives more typically found in laptops. It also consumes far less power. The 512MB used in XO is adequate to accommodate a large amount of system software as well as providing sufficient storage for most types of user generated content.

2.1.3 SD Slot and USB slot

The SD slot and USB slots provided on the XO enable full expansion of storage on the XO. This could serve as a very viable way of delivering a significant amount of educational material with very low costs. Currently, a 1 Gigabyte SD card costs approximately USD\$25 and can hold over 120 minutes of high quality video lectures or educational documentaries. Or over 40 hours of audio lectures. Or over 200 E-books. Ministries of education in developing countries could pool efforts to develop low cost digital educational content in fully localized form to deliver via SD cards or USB storage devices. The small size coupled with high reliability of these solid state storage devices means that they can be more easily transported and delivered to rural areas.

2.1.4 Wireless

The Marvell wireless chip used in the XO is fairly typical in the sense that it supports the 802.11b/g wireless networks and hotspots that are increasingly available throughout developing countries. A distinguishing factor of this chip is that it can function independent of the main CPU on the XO. This means that a mesh network can be sustained even if many of the participating XO units are not being used or turned partially off. The benefit of a mesh network is that it requires no infrastructure and that each additional member of such a network would improve the quality of the network. One possible usage scenario could be as follows. A village where the school has one XO that is connected to the Internet through a USB modem. Other XO units in the homes surrounding or nearby the school would be able to utilise the mesh network formed by all the units together with the school's XO in order to gain internet access for all units rather than just the school's XO.

The distances associated with mesh networks can be quite large. While two individual units must be within a few hundred metres of each other for typical 802.11 radio connectivity to work, a mesh network made up of say 100 units could span a few square kilometres thereby providing free communication within a rural locality. This is true even if there is no internet access method, since the XO units are able to communicate with each other over the mesh. This can serve many

purposes and also help to leverage educational services that are delivered via networks.

2.1.5 CMOS Camera Sensor

The VGA quality CMOS camera can be used for many things. It can be used for video conferencing. That in itself can serve a myriad of educational goals. The lack of teachers in particular rural areas could be mitigated by allowing teachers from cities to connect to XO enabled students or schools via the network in rural areas. The quality and health of schools and infrastructure could also be conveniently monitored by central ministries since they would be able to inspect the site remotely as well as remotely evaluate teachers and students.

2.1.6 Audio and Analog Input

The XO has a fairly standard stereo audio subsystem. A differentiating feature is the ability to use the audio input (microphone input) as an analog input. This can serve to capture data from any analog sensor. For example, it could be used in a physics demonstration to directly illustrate the photoelectric effect. Other possible applications include monitoring environmental data, custom built input systems such as musical wands, and oscilloscope type usage.

2.1.7 E-Book mode



Illustration 2: E-Book Mode for XO B-Test 1

As shown in Illustration 2, the XO display is mounted on a hinge thereby enabling the unit to be swiveled into a tablet or E-Book mode. The keyboard is therefore moved underneath the screen. However, two input methods remain

accessible. These are a 5-way cursor pad and a 4-way gameboy style button set. These can be used to page through E-Books as well as scrolling and other tablet like functionality. It is important to point out that the OLPC display is not overlaid with a touchscreen.

2.1.8 Keyboard and Touchpad

The keyboard for the XO uses a rubber based membrane rather than the typical ABS plastic based keyboards. This makes it cheaper and also easier to localize as silkscreening different characters would be a single step process.

The touchpad uses two modes. It has a capacitive section where the user can draw on it using either a stylus or a finger tip. It also has a resistive section intended for stylus only input. This may make it possible to enable additional input methods for cursive or ideogram based writing systems.

2.1.9 Battery and Power Generation

The battery used on the XO is based on rechargeable NiMH instead of Li ion technology. It is estimated to provide several hours of use on a full charge with existing power consumption levels. This should improve further as the XO software support for power management is added and customised.

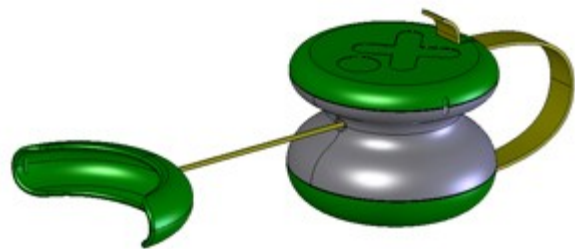


Illustration 3: XO pull powered generator from Potenco

The XO accepts a wide range of input voltages in order to charge the battery. The stated range is 10 Volts through 25 Volts. This should make it possible to charge it through external mechanisms such as photovoltaic solar panels, bicycle generators, car batteries. OLPC has mentioned a custom designed pull powered generator. This is pictured in Illustration 3. Details of the generator are not yet publicly available.

3 OLPC System Software Architecture

The OLPC is based on free and open source software. Each category of system software is explained as follows.

3.1 Core Operating System

The OLPC currently uses the fully free GPL licensed BIOS software called LinuxBIOS. LinuxBIOS is quite different from typical commodity BIOS' in that it allows the developer to minimize boot time and to discard much of the legacy issues associated with x86 based devices. LinuxBIOS is accompanied by OpenFirmware which is also open source and is used to load the Linux kernel from either the onboard solid state storage, USB or SD connected device or to boot over the network. The USB mechanism is advantageous to organisations that wish to change or modify the software on the unit. This is because, if a software replacement failed or caused the unit to be non-functional, the USB update mechanism could be used to reflash the firmware.

The Linux kernel, GNU libraries, Xorg server and other free and open source system tools and libraries are utilised as the core of the operating system for the XO. This is in contrast with solutions that would use a proprietary operating system. This is an important and valuable fact for developing countries. The complete, permanent and unambiguous freedom from licensing costs for the operating system helps minimise the cost of the unit. Just as valuable is the complete access to the source code and the ability to modify and replace whole or partial sections of it. For example, if due to an unforeseen event, the OLPC organisation was shutdown, a customer country would still be able to use its own resources to continue to support and maintain the software without needing permissions or licenses from any organisation.

3.2 Applications and User Software

The XO uses the following major applications.

3.2.1 Web Browser

The browser is called xulrunner which is a customized browser that shares the same core code as the better known Firefox browser. It is designed to be very efficient and better at conserving memory resources when compared with more

typical browsers. It is a fully functional browser and meets all the expectations of a typical desktop browser. It will function with JavaScript based sites and modern AJAX based applications such as Google Mail and Google Maps. However, it does not currently support Java or Macromedia Flash. There is nothing preventing the addition of Java support and it may be a likely future addition. Macromedia Flash (needed for websites like Youtube and Google Video) on the other hand is a proprietary application rather than one for which source code is available and as such does not fit the model of encouraging user tinkering.

3.2.2 Word Processor

The word processor is a customized version of AbiWord. This is a reasonably popular FOSS word processor. There is nothing that would prevent addition of other Office productivity suites like OpenOffice.

3.2.3 Music and Multimedia

Several powerful multimedia applications are currently included on the XO. These are targeted at children but are very powerful in their capabilities. Among these are csound, TamTam, eToys (Squeak). Several other applications such as mplayer and Helix are also known to work on the XO.

4 Challenges

The OLPC XO is currently in beta testing. It is likely to enter into initial deployment in late 2007. From a technical perspective, the software and hardware appear to be of good beta quality and within 4-6 months of production quality. As a result, the remaining challenges will probably be associated with achieving the minimum order quantities needed to achieve the USD\$100 - \$150 pricing target. It is estimated that at least 5 million units need to be ordered before that target can be achieved.

5 Similar Devices

The OLPC XO is not alone in attempting to address this market for a low cost educational device for developing countries. There are several competing and complementary efforts from around the world. The fact that all these products are entering the market indicates that consumer

electronics manufacturers clearly see that there is a profitable market in addressing the needs of developing countries. The following is the list of those devices.

5.1 Intel Classmate PC

This a product that is very similar in functionality and description to the XO. It uses a Intel Celeron M processor, has a 7 inch 800 x 480 LCD, 256MB of DDR2 RAM, 1GB NAND flash, and uses Embedded XP from Microsoft. The pricing is estimated to be around USD\$400.

5.2 EncoreTech Mobilis Wireless

The EncoreTech Mobilis Wireless is a webpad like device using a 400MHz Xscale PXA-255 CPU with a 7" TFT. It uses an embedded Linux based operating system. It is priced at USD\$250.

5.3 Novatium NetPC

The NetPC series devices from Novatium is a different take on solving the problem. The NetPC is a very lightweight embedded Linux based client that serves a thinclient. Rather than use a traditional processor, it uses a very low cost mobile processor similar to the ones used in cellphones. It is connected through an ethernet network to a Linux terminal server. It then delivers typical functionality like multimedia applications, office tools, web browser and others from the server. It is priced at under USD\$100.

5.4 Yellow Sheep River Municator

This product uses a 600MHz [Godson-II](#) MIPS64-like CPU, 512MB DDR PC2700 SODIMM, flash based, Marvel MV64420 NB and an ATI Radeon 7000M with both VGA and svideo out, 10/100 ethernet and optional USB wifi and USB HDD. It is also based on an embedded Linux operating system. The price is around USD\$200.

5.5 VIA PC-1 Series

VIA is a major consumer electronics manufacturer. The VIA PC-1 series is a set of products targeted at rural and computing for developing countries. The PC2500 and PC1500 products can be considered to be desktop computers but customized for developing country type

environments. The pricing starts at around USD\$200.

6 Conclusion

The OLPC project is a unique effort. It is a combination of commodity hardware, custom design, high volume production and free and open source software in order to deliver a low cost device that provides a great deal of potential. The pricing of the OLPC at USD\$100 - \$150 sets a challenge for commercial corporations to generate similar cost/capability tradeoffs in order to address untapped opportunities in these neglected market segments. That is certainly a good thing for developing nations in the long term.

Ultimately, the success or failure of the OLPC project is not important. What is important is that decision makers find the optimal combination of methods to deliver educational services at the lowest cost to the maximum number of people. The issues facing developing nations are very wide in variation. A device like the OLPC alone cannot address all problems. It can only be a combination of having one lunch per child, one teacher per classroom, one school per village and many other things that will serve to deliver the rich human potential that exists in developing nations.

7 Acknowledgements

Illustrations 1, 2, 3 and 4 are Copyright © OLPC and used with permission under the CreativeCommons 2.5 Attribution license. The author thanks the OLPC organisation for providing a beta test unit for development and testing.

References

- [1] OLPC. 2006. <http://laptop.org>

Author Profile

Jaya Kumar is an embedded systems architect with a strong interest in using technology to address issues in developing countries. He is a contributor to several FOSS projects including the Linux kernel and the Xorg server. He is the author of the audio driver used on the OLPC XO.