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intermedia

September 2011 Volume 39 Issue 4

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The Green Cloud: a broadband springboard?

Appropriate hosting infrastructure improves broadband economics

Most developing countries face financial, geographical, infrastructural, and power constraints that have largely prohibited development of reliable communications networks, data centres, and local ICT-related activity - all of which could be contributing to socio-economic growth and development. This situation is particularly unfortunate since emerging economies stand to gain a great deal from the benefits associated with telecommunications and related ICT advances that make distance obsolete. Yet ICT-related development cannot move forward unless the energy to power the technology is sufficient, affordable, and reliable.

Regrettably, in many developing regions, diesel generators are widely used for power in the absence of a stable electrical power grid. Yet this expensive, stop-gap measure hampers economic growth, keeps developing economies dependent on volatile world oil prices, and increases pollution. A great irony contributing to this inauspicious situation is that a sizeable number of states in the developing world have tremendous amounts of wind and/or solar energy that could be harnessed and used in place of imported fossil fuels. This paper posits that when ultra-efficient technologies are employed and existing technological breakthroughs are combined, power demands can be decreased significantly, so that renewable energy can be affordably scaled to provide sufficient power to meet ICT-related energy demands.

Does public policy promote?

Public policy measures are important in promoting renewable energies. Germany serves as an excellent example, as the country has become the world leader in solar power, with half the world's installations within its borders, thanks to policies including aggressive renewable energy subsidies and large sums of money devoted to research.[1] Even so, developing countries may not find Germany's example easy to follow, given constrained governmental resources and limited institutional capabilities. Still, there are policies that can be put into place that can promote the use of renewable energy. Public-private partnerships can serve as an important way forward. This paper addresses the call for this form of cooperation to address energy poverty, particularly in the developing world.[2]

As a first step, governments must take a longer-term view on how to address their energy situation, and commit to a plan of action that includes the entire energy-related picture, from generation, to distribution, to end use.[3] This will include consideration of financing, institutional capacity building, improving access to technologies, and enabling policies through various legislative measures: "The important aspects of policy and regulatory reform include the establishment of a robust institutional and legal climate, an efficient financial system, as well as stability of environmental regulation."[4]

Thus, large-scale public and private (or partnered) investments are one way forward. Yet, given the level of commitment and the long-term nature of reforms required that are associated with improvements in institution-building and overall economic and governmental openness and functionality, we wish to explore smaller and shorter-term policy actions that can be taken. Such actions may be viewed as proof-of-concept, "quick-win" projects that can help make the case for longer-term and wider-ranging reforms and development-related

1 M. Landler. 2008, May 16. Germany Debates Subsidies for Solar Energy. New York Times. Available at http://www.nytimes.com/2008/05/16/business/worldbusiness/16solar.html?ex=1368849600&en=0892c2ad599a2aaf&ei=5124&partner=permalink&exprod=permalink
2 E. Oldfield. 2011. Addressing Energy Poverty Through Smarter Technology. Bulletin of Science, Technology & Society, 31(2) 113-122.

3 Ibid. p. 116.
4 While energy poverty affects citizens worldwide, issues hobble investments. (2010, September 13). World Energy Congress, Montreal 2010, Special Information Feature. The Globe and Mail. Available at http://membernet.capp.ca/raw.asp?x=1&e=PDF&dt=NTV&dn=177441

actions. One such project, detailed in this paper, rather ironically springs from a governmental decision to take a hands-off approach to dealing with energy issues - illustrating that even under less-than-ideal circumstances, ways forward can be forged. Even so, incentives matter a great deal, and so merely allowing the market mechanism to function will not always lead to ideal outcomes. This paper therefore takes an example of where the leveraging of ultra-efficient technologies can be employed, along with a re-setting of the bigger-is-better mindset to a small-is-beautiful one, so that data centres can be powered entirely with renewable (in this case solar) power. Subsequently, this case can illustrate how similar use of efficient technology and rethinking can be combined and similar renewable energy solutions can be applied on a much wider scale.

Why locate data centres in the developing world?

Moving processing and data closer to the end user in the developing nations serves three key functions:

- It keeps needed jobs and systems ICT workers in-region, preventing brain-drain;
- It sidesteps telecommunication bandwidth costs and network latency issues in and out of the region and,
- It assures quality of service: in-region computing can remove major points of network failure and potential bandwidth bottlenecks.

A number of papers have been written on how Cloud Computing will help the developing world by lowering ICT costs[5], yet this is a flawed theory, because the cloud computing data centres, where the data is stored, remain in the developed countries. To rely solely upon the cloud computing model misses the importance that having an ICT-related sector in the economy has for developing countries. The ICT-related service industries generate both direct and indirect economic growth and employment opportunities to local economies.

Data centres are at the heart of these services. To grow and keep local expertise in ICT-enabled services, including in systems and development, the processing and storage of these types of services need to remain local. At present, even if high bandwidth is brought to these nations, their data is still housed long distances away. If developing countries had data centres locally, they would benefit from ICT (and complementary) sectors in their economy, the security of having their data close-by, and could serve as local technology hubs within their region.

The question is how to exploit the bandwidth that a growing number of emerging economies are experiencing, thanks to the growth of numerous undersea cables initiatives, as well as to the manifold wireless and wi-fi initiatives around the globe, in order to grow the local ICT sectors in developing nations. We propose the adoption of ultra energy efficient technology approaches to building small, local data centres: the Green Data Centre in a Rack.

Designing ultra energy efficient data centres for developing regions requires a specialized vertically integrated effort focused on key energy-efficient technologies in computing (cloud computing), electronics (energy efficient CPUs and systems), and building systems (spot rack cooling, higher ambient temperatures, and natural convection cooling). Collectively, the technologies mentioned above address significant near-term and long-term energy challenges and environmental issues.

This article will focus on how these new energy efficient technologies for processing, storage, and software, that together make using renewable energy both feasible and affordable for small, localized data centres, can benefit emerging economies. There are numerous policy applications for the Green Data Centre in a Rack, as they can be built in critical locations close to end users, in a way that balances the desires of local commercial, educational, and governmental operations. In order to illustrate the relative simplicity and widespread possibilities of creating and deploying a solar-powered Data Centre in a rack, we present the following case study based in Senegal.

Case study: Senegal

Senegal faces a particularly constrained energy situation at present: rolling daily blackouts are the norm and economic growth is being severely limited as a result. The national energy issues are being addressed at the highest levels of government; however the approach is not necessarily to provide additional energy to the country.
One recent change has been that government institutions, such as universities, now will be responsible for paying their own energy bills. Hence, the University of Dakar (UCAD) is looking to reduce its energy consumption.

5 See, e.g. S. Malik & V. Sinha. 2010. Cloud Computing—A Hope for the Rural India. International Journal of Computer Applications, 1(20), 10-13. K. Juster. 2009. Using Cloud Computing to Close the Development Gap. Foreign Service Journal, p. 47, September.

Since UCAD's data centre power consumption had been de-coupled from the responsibility for running the data centre, the levels of energy consumption previously had not been of major concern, nor were they measured, and little was done to make improvements with regard to energy usage.

Now, under the new directive of being responsible for energy consumption, the university data centre's energy usage is of paramount concern. By approaching the challenge in a creative way, UCAD stands to leverage this situation as an opportunity to be a showcase for West African universities, and beyond, in utilizing Green ICT and pioneering advanced techniques for energy savings.

The UCAD Data Centre

The data centre facility at UCAD provides campus-wide computing services. It is a student-managed, facility supervised environment providing network connectivity via a high-capacity Ethernet campus-wide backbone. Data centre space occupies approximately half of the building's first floor area. It is estimated that the data centre occupies approximately 60 square meters. The remainder of the first floor is one large open space used by student programmers. Academic and student offices occupy the second storey. The data centre's IT and environmental systems operate year-round, 24 hours a day.

The current data centre for the university is made up of three rooms, with various racks of equipment in each, most installed in 2005. Each room is cooled with a mix of single zone air conditioning units. Several units failed in 2010 and were replaced with 3950-watt units.

In March 2011, a high-level site survey of the current data centre environment was carried out. This environment is made up of servers, Ethernet switches, and data storage servers from the 2005 timeframe and it was noted that the servers are using about 500 watts each; approximate estimates were made for the remaining equipment.

The current "high level" inventories of major data centre IT & cooling equipment are shown in Table 1.

The servers and air conditioning units by percentage use the bulk of the electric power.

Table 1

ROOM	#	EQUIPMENT	ENERGY USAGE (W)	TOTAL
1	14	Server	500	35,000
1	2	Ethernet Switch	350	700
1	2	Single Zone AC	3950	7,900
2	10	Server	500	5,000
2	1	Ethernet Switch	350	350
3	10	Server	500	5,000
3	2	Ethernet Switch	350	700
3	2	Single Zone AC	3950	7,900
All	5	Lighting	120	600
Total				**63,150 Watts**
Total per Rack				**15.7 kW**

Green Data Centre Approach

Ultra energy-efficient computing and networking cannot be achieved without integration between computer science, electrical engineering, mechanical engineering, and environmental science. Designing data centres for high performance and extreme low energy usage requires a vertically and horizontally integrated effort to drive key energy-efficient technologies in computing (cloud computing), electronics (low power CPUs and systems), and building systems (spot rack cooling, higher ambient temperatures, and natural convention cooling). Collectively, these existing and cutting edge technologies address very significant near-term and long-term energy and computing challenges and environmental issues.

The approach we proposed for UCAD is a "Green Data Centre in a Rack," which incorporates cloud computing using low power CPUs, servers, renewable energy, and most importantly, keeping all of this close to the end user. By contrast to the Western model, the Green Cloud Computing approach uses a specialized, environmentally closed 42 unit- high rack specifically designed for use with low energy usage equipment. With little heat waste, this solution does not require all the special air conditioning of the modern data centres: these racks have their own air climate control units. By employing cloud computing in these data centre racks, we can maximize the server utilization, which then facilitates a smaller number of active servers and energy usage to meet the constraints of the local circumstances.

Cloud computing saves energy by employing:

- Workload diversification: Because many different sorts of users will be availing themselves of diverse cloud resources – different applications, different feature set preferences and different usage volumes – this will improve hardware utilization and therefore make better use of power that is being used anyway to keep a server up and running.
- Power-management flexibility: It is easier to manage virtual servers than physical servers from a power perspective. If hardware fails, the load can automatically be deployed elsewhere. Likewise, in theory, all virtual loads could be moved to certain servers when loads are light and power-down or idle those that are not being used.

Low power CPUs have recently come to market thanks to a design for developing regions, the OLPC XO laptop. The OPLC project was based on development of a laptop using a low power CPU and low cost components to meet the price point and educational needs of the developing world. From this project, a whole netbook market was born and with it, the development of low power CPUs such as the Intel Atom, AMD Nano, and ARM based processors.

These processors use 5% of the energy of a normal server CPU while still delivering 60% of the performance. The other advantage these processors offer is that they have been designed to run at higher ambient temperatures, so normal "meat locker" style air conditioning for data centres is not required when these processors are used in servers. Today's low power CPUs offer compute abilities that greatly exceed servers of even five years ago. The trend today for data centres is no longer for more and more compute power, but rather for a balance between power and energy efficiency. For developing world markets, the trend toward energy efficiency is more important than any other single factor.

But will these low power CPU's really do the job for UCAD? Microsoft Research has an organizational division called Cloud Computing Futures (CCF), which is focused on reducing the operational costs of data centres and increasing their adaptability and resilience to failure. Their first project was to find a way to lower hardware costs, power consumption, and the environmental impact of data centres using cloud computing, i.e. Low-Power Processors in the Data Centres. Their experimental prototype was used to study the use of these low-power processors in the data centre. They found: "These processors offer substantial fractions (33% to 50%) of the performance of the high-performance processors used in Microsoft data centres but consume a disproportionally smaller amount of power (5% to 10%)."[6]

Comparable studies have been performed, obtaining similar results, at Carnegie Mellon University's "FAWN: A Fast Array of Wimpy Nodes,"[7] the Greenscale Centre for Energy-Efficient Computing at the University of California at Santa Barbara[8], and at the ARM Corporation.

Focusing on building a Green Cloud Computing centre—a "Data Centre in a Rack" approach—can be the starting point. There has been much written on modular container data centres and pod approaches. This rack approach can also be viewed as a pod approach in that it is a self-contained system that can be added to in a modular fashion.

Each "rack" contains the ability to perform complete data centre functions. It can provide content management, web services, email, calendaring, and other university software applications that are cloud enabled, all running in a private cloud computing scheme. Using cloud computing, this rack approach can replace 4 or 5 racks of servers and storage that follow the traditional silo application approach. Recent implementation of cloud computing/virtualization at a Canadian non-profit, Earth Rangers, demonstrated their ability to replace

6 Microsoft Research, Low-Power Processors in the Data Center, DemoFest 2009, http://research.microsoft.com/en-us/events/techfest2009/demos.aspx
7 D. Andersen, J. Franklin, M. Kaminsky, A. Phanishayee, L. Tan, V. Vasudevan, "FAWN: A Fast Array of Wimpy Nodes", Carnegie Mellon University & Intel Labs, Oct 2009
8 Greenscale Center for Energy Efficient Computing, The Institute for Energy Efficiency, UC Santa Barbara, http://iee.ucsb.edu/greenscale

Table 2

WATTS	SWITCHGEAR	UPS	PDU	IT GEAR	ZONE AC	TOTAL
Green Cloud Rack	**0.05**	**0.08**	**0.05**	**0.6**	**0.2**	**0.98KW**
Current Data Centre Racks	**0.1**	**0.5**	**0.9**	**9.8**	**4.5**	**15.7KW**

4 racks of servers with ½ rack of servers and ½ rack of storage for their entire IT operation.[9]

Solar PV Array

This "rack" design can be powered using renewable energy, integrating the solar charge controller and batteries into the rack. As an example, 20KW of solar PV can provide the primary energy source and the electric grid and/or diesel generator as the emergency back up. The peak daily energy for the rack approach is estimated at 23KW, but the average normal daily usage is estimated at 6.8KW, as nighttime usage drops dramatically. By adding an energy aware cloud computing scheme, the power can be managed to allow a 20KW solar PV array to completely power "two full racks", 24 hours a day, 7 days a week.

20 Kilowatts of Solar PV amounts to about 110 185w 24v solar PV panels. For a typical roof mounted installation, about 1,240 square feet or 115 square meters would be required for these 110 solar panels.

How does the energy needed for the Green Cloud Computing data centre rack approach compare to a normal data centre? We can estimate the reductions of each in three main areas: Power equipment, IT equipment, and cooling. The results, as shown in Table 2, are that the Green Cloud Computing data centre in a rack requires 94% less energy, which makes using renewable energy both feasible and affordable.

In conclusion, approaching the rack as a small data centre, we can integrate computer science, electrical engineering, mechanical engineering, and environmental science into a self-contained rack environment. Using low power, but not low performance, as our guide, we can also design this system using 90% less energy. By doing so, we address a key issue facing not just UCAD but the majority of the developing world: energy sustainability – the use of renewable energy. Cloud computing becomes the enabler in this rack to provide elastic computing over low power CPU servers, energy interface control, and integrated system management over the applications.

This paper has put forth the argument that existing technological breakthroughs regarding energy efficiencies can be harnessed, combined, and leveraged in order to make powering them with renewable energies not only feasible, but attractive. In order for this scenario to become a reality, the bigger-is-better mindset must be reconsidered, and realigned to mirror the realities of constrained circumstances in emerging markets.

Public policy decisions will play a significant role in this process. Significant and long-term commitment on the part of governments, to a plan of action that promotes renewable energy and comprises the entire value chain of the energy industry, from generation, to distribution, to end use, is required, as is a simultaneous commitment to transparency of government and of the business- and energy-related sectors.

We have presented a case-study from Senegal that could be considered a small-scale showcase that may be viewed as a proof-of-concept, or "quick-win" project to can help make the case for longer-term and wider-ranging reforms and development-related actions. We believe that examples such as this can pave the way for a rethinking of how to harness ultra energy efficient technologies to be powered with renewable energy, and will lead to the necessary larger, public-private partnered projects needed to scale such renewable energy initiatives across the developing world.

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9 Earth Rangers, http://www.earthrangers.org/earth-rangers-centre-for-green-technology/, Dec 2008

the networked world, and has been highlighted by many technologists and policy makers. The introduction of spime, objects that will also need to individually self-identify in diverse environments, will only exacerbate the situation.

Equally, although efficiency and accuracy are valid overall goals, particularly in the current economic climate, one must take care not to reduce citizens to mere numeric identifiers in the pursuit of this goal – and certainly not to the point that the identifier begins to take precedence over the identity itself. As each individual will associate with an infinite number of things and environments, the stories told by these spimes and the interpretation of them by societal constructs will have a great impact on the identity and reputation of that individual. In this context, it will be important to ensure that an Internet of Things remains primarily an Internet of people, rather than an Internet that exists merely for the things it networks.

It may be argued that we are relinquishing more and more of our decision-making process to networks and software: for instance, many drivers now obey their GPS blindly without questioning it, even when simple observation would have been more prudent. One wonders to what extent the norm is "mind over net", rather than "net over mind". We have already begun relying unduly on purely external information. The problem is that there is no end to the sheer quantity of information and data in existence and it is multiplying at an exponential rate. But the more information we download, the more cluttered our hard disks - and brains - become. Paraphrasing the words of James Gleick, when information infiltrates us, do we cease to be its master? (*The Information Palace*, New York Review of Books, 8 December 2010).

Finally, and perhaps most importantly, we will have to strive to find a balance between the individual and the collective - to find space and time away from the net and from the networked objects all around us – in order to ensure that our capacity for independent thinking and decision-making, upon which all social progress rests, is maintained in an open and diverse society.

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The Revenue Model

The cost of implementing the infrastructure, and reimbursement of tele-health services remain two major obstacles both in the US and in Europe. Although many studies show the potential cost savings of tele-health and remote monitoring, most of these studies involve small sample sizes with diverse types of tele-homecare intervention for few select chronic illnesses. Nevertheless, few studies examine the potential economic return to employers, such as increased productivity. There are no current comprehensive studies of the economic benefits of tele-health to society in general and specifically, the extent to which tele-health can reduce the total health care bill as recent reports suggest.[15]

With regards to developing countries, however, the literature on the cost of ICTs in health is largely limited to OECD countries, with a focus on the role of ICTs in improving health sector efficiency, deriving value from tele-health systems, and assessment of the economic impact of tele-health investments. mHealth is not the explicit research focus.[5] Overall, the cost of tele-health is not yet well established. The greatest costs expected to be incurred are training and human resource implementation costs, since hardware such as mobile phone devices are not expensive, and mobile networks are already established. There are expected cost savings based on several pilot tests.

Conclusions

Our discussion above shows that there is a large and growing consumer interest in tele-health and mHealth which provides a solution to growing health costs for many people. However, besides the presence of technology issues, such as security, the non-technological challenges are particularly salient. These include regulatory, organizational and revenue-based issues. In summary some key requirements in both developed and developing countries need to be met to accelerate adoption:

- » mHealth devices and applications must be able to accommodate patients' differing physical capabilities
- » Open, non-proprietary, platforms provide potential for greater innovation from end-users, though regulation is still important. Non proprietary or open systems would help ensure rapid innovation of new services. These platforms must provide for ubiquitous access
- » Interoperability of access devices is crucial for rapid adoption and to ensure medical applications will not fail on different devices
- » The technical complexity in the delivery of e-health services requires the active participation of network service providers. In the US market, network service providers are now just beginning to explore eHealth. Network service providers also offer the advantage of being able to set and/or establish standards and protocols
- » Effective delivery of tele-health applications requires pooling of resources across different stakeholders in the eco-system. Coordination of effort across the different partners will be crucial for success. Because total benefits accrue to all stake-holders in society, "subsidized pricing" by corporations, government and other private stakeholders are both appropriate and necessary for ubiquitous adoption.

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