Tucker, W. D., & Westerveld, R. (2015). ICT4D and Local Access. In R. Mansell & H. A. Peng (Eds.), The International Encyclopedia of Digital Communication and Society (1st Edition, pp. 365-368). John Wiley & Sons.

ICT4D and Local Access

WILLIAM D. TUCKER
University of the Western Cape, South Africa

RUDI WESTERVELD
Delft University of Technology, The Netherlands

Local access in the context of regions in the global South continues to undergo transformation due to the growing ubiquity of mobile connectivity and the recent appearance of what have been termed "inverse" telecommunication infrastructures, that is, bottom-up, self-organized, user-driven, and decentralized networks (Egyedi, Vrancken, & Ubacht, 2007). The "last mile" traditionally is defined in countries and regions in the global North in a telecommunications context as the physical connection between a subscriber and the nearest telephone exchange.

This connectivity is most often wired - for example, copper, coaxial (cable), fiber, or power line - and also increasingly wireless, using mobile cellular networks referred to variously as 2G (second-generation mobile network mostly based on GSM, Global System ofMobile Communications, one of several mobile cellular network standards); GPRS (General Packet Radio Service data network standard in GSM); UMTS (Universal Mobile Telecommunications System, advanced mobile cellular network standard, also called 3G or third-generation mobile network, mostly based on UMTS); HSDPA (High Speed Downlink Package Access, subsystem of High-Speed Packet Access (HSPA) standards in UMTS); and 4G (fourth-generation mobile network mostly based on LTE, or Long Term Evolution, a standard for wireless communication of high-speed data for mobile phones and data terminals).

Last mile connectivity can also come through fixed wireless networks like wi-fi (Wireless Fidelity, wireless local area network (WLAN)- based IEEE 802.11 standard), WiMAX (Worldwide Interoperability for Microwave Access, a wireless communications standard designed to provide high-speed data access for fixed stations), and satellite. Regardless of the technology, the idea is that the last mile is the last bit of connectivity between a service provider and an end user (subscriber), and is meant figuratively, not literally, as a single mile. Telecommunications connectivity increasingly supports both voice and internet data, and this entry addresses both interchangeably. In the development literature, the term "last mile" is sometimes reversed to become the "first mile," reflecting the importance of the end user (Talyarkhan, Grimshaw, & Lowe, 2005).

The last mile problem is not limited to telecommunications. Similar challenges in achieving access apply to water supply, health, electricity, transport, and almost any form of services and goods distribution. For an operator, the challenge is to design a distribution network where the part of the network that is shared among many users is as large as possible. In that way the costs can be distributed over many users. The part of the network that is dedicated to each user is relatively expensive. The network designer tends to plan the access points of the shared network as close as possible to a cluster of users, so that the "last mile" line is shortest. This entry discusses the last mile for telecommunications, and the definition provided above holds for many regions in the global South, although the character and nature of the last mile often differs because of several factors.

First, the most obvious difference is economic. For example, in parts of rural South Africa such as Nyandeni municipality, a US$115/month household income with roughly five people per household (see www.statssa.gov.za) yields only $23/month per person. A low-end mobile phone like a Nokia 111 might cost US$30 (see any South African mobile operator's webpage, e.g., MTN), and is relatively expensive for such end users. Add monthly consumption of telecommunications, which can include heavily marked-up airtime and the need to pay to charge a phone's battery (Rey-Moreno et al., 2013), and this means that while many in regions in the global South have connectivity, there is limited use of it due to the high cost of using it.

Second, in many of these regions, grid electricity does not exist. Charging mobile phones is an obstacle, and even cheap and renewable sources of energy such as solar and wind are not very common because they are expensive. Such alternative power sources are also susceptible to theft just as wired lines are. Thus, copper, fiber, and cable connectivity is relatively difficult to provide and maintain in many of these regions. Once heralded as the "next big thing" in last mile connectivity, Broadband over Power Line (BPL), which uses standard mains electricity lines to carry network data in addition to electricity, is also rare because of the lack of grid electricity.

In the telecommunications sector, the last mile is also known as the local loop and, in the case of wireless, as WLL (Wireless Local Loop, which uses various wireless transmission techniques to access a wider telecommunications network). WLL is gaining ground in many regions in the global South as wireless broadband systems continue to evolve. When comparing wired with wireless technology, the latter benefits from greater flexibility and lower expansion costs. For example, upgrading a wireless service offers the convenience of changing equipment only at the customer and/or provider premises without having to change a wired last mile connection itself. In the case of wired connections the old lines have to be dug up to put in new ones.

An example is WiMAX, which was intended to provide municipal broadband connectivity from distribution towers to fixed mobile access points in subscribers' homes. The WiMAX unit in the house does not move, although it provides wireless local access to the service provider network. An upgrade to the WiMAX service entails equipment changes at subscribers' homes and/or at the provider's distribution tower, but nothing more.

A similar example is the mobile space: a mobile data USB or Universal Serial Bus, which is a ubiquitous worldwide standard for wires, connectors, and means of transmitting data. A USB "stick" plugged into a USB connector with a mobile SIM card gives access to a mobile data network and can also be plugged into a wi-fi router. A SIM or Subscriber Identity Module is a small integrated circuit on a rectangular piece of cardboard and is associated with a unique phone number on a GSM network. Devices near a router can have easy wi-fi access to the internet via the mobile data connection. A speed upgrade is as easy as changing to a newer USB stick that supports a faster mobile data connection. In addition, many mobile data routers are intended to be mobile with built-in long-life rechargeable batteries. While common in wealthy countries in the global North, neither of these are typically available in most regions in the global South, especially rural ones, despite the fact that they are very easy to upgrade. Wi-fi typically reaches up to 100 m and WiMAX up to 40 km.

There are three main reasons that wired local loop technology has yet to be rolled out in most regions of the global South. First, they are vulnerable to theft. Second, they easily break under extreme weather conditions. Third, they are expensive to deploy and maintain. For similar reasons, wireless satellite VSAT (Very Small Aperture Terminal - a two-way satellite ground station) systems are quite rare.

For these reasons, wireless local loop access, mostly in the form of mobile GPRS and HSDPA, has emerged as the reigning last mile technology in many low- and middle-income regions. These are the mobile data protocols that most mobile phones worldwide use to access the internet and which allow the distance from handset to a distribution tower to be several kilometers.

With the rapid growth of mobile phone use, discussions about the mobile last mile dominate discussion in many regions of the global South where - as, for example, in sub-Saharan Africa - internet access is expected to be delivered via mobile because it is estimated by the United Nations that fixed-line usage is only around 1%. Nevertheless, mobile and internet penetration rates are the lowest globally. The digital divide persists with the inequalities in the spread of digital technologies between and within countries and for reasons associated with gender and local power hierarchies (Norris, 2001).
Mobile bandwidth is much slower in these regions than in wealthier regions: for example, from 0.1 to maximum 2 Mbps versus 10 to 50 Mbps (Broadband Commission, 2013). When people can afford mobile internet subscriptions and the costs of data communications in regions such as sub-Saharan Africa, they can expect to be "surfing the net" at maximum 2 Mbps, a fraction of the typical speed of an

average broadband subscription in the global North. Remote regions on the African continent are underserved (Singh, 2009) and mobile network coverage in rural areas tends to be restricted to high traffic density links (Jotischky, 2010).

Thus far, this entry has described the last mile mainly from the perspective of the service provider. From the end user's perspective, the last mile is the "first mile." There are various ways to provide the first mile, sometimes referred to as inverse architecture since they often emerge from the ground up. One such infrastructure is based on the idea that full-time network access is not always needed. These may be called Delay Tolerant Networks (DTNs - that are able to overcome temporary or even prolonged drops in mostly wireless network coverage), such as DakNet (Pentland, Fletcher, & Hasson, 2004), where a so-called data mule (a transportable computer with wireless access through wi-fi) connects remote subscribers to the internet on a periodic basis when it passes in close proximity. Examples include placing the data mule on a motorcycle or a bus whereby when it comes into close proximity to a subscriber's computer it initiates an exchange of information while it is in range. The data mule later enables an external information exchange with the internet at a "home" base. A contemporary example of a data mule or DTN is D'Souza's wi-fi Dropbox device, called NomadEDU, which takes advantage of the fact that Dropbox files can be read and modified offline and synchronized later when connectivity is available. Both DakNet and NomadEDU have been deployed in regions in the global South.

An inverse infrastructure may take the form of a community provided network. Examples are Village Telco and OpenBTS, which is a base transceiver station controlled by open software and can be accessed by GSM telephones. A Village Telco is a local telecommunications company offering interconnected wireless-enabled nodes (wi-fi) - or so-called "mesh potatoes" - at each user's premise (see http://villagetelco.org). The "potatoes" establish an ad hoc (mesh) network among themselves, which means nodes talk to other nodes around them automatically and can relay information anywhere in the network as it grows. Each mesh potato supports voice and data communications and has a plug for a standard telephone handset.

A Village Telco business model might permit free local calls and charges collected by a community trust, for example, and enable connectivity with an external wired or wireless network like a mobile cellular network (Rey-Moreno et al., 2013), but the use of these networks is often affected by local power structures. Numerous examples of Village Telcos exist, for example, in South Africa, Nigeria, Columbia, Puerto Rico, and East Timor (see http://villagetel co.org/deployments) although none rival traditional telecommunication operator owned networks in terms of numbers of users or scalability.

A similar approach to the "build your own" network is the OpenBTS, which is essentially a "do it yourself" mobile network based on GSM. Like the mesh potato, but with GSM instead of wi-fi, OpenBTS is an open source system providing "free" mobile telephony to a local network, with the potential to connect via a gateway to other networks to support voice and internet access (Heimerl & Brewer, 2010).

In inverse infrastructure network architectures, the last mile is built and controlled by subscribers, or by a commercial or social entrepreneur on behalf of end users, in contrast to the way networks are provided by centralized telecommunication operators. All forms of inverse infrastructure are constrained by the availability of the radio frequency spectrum and licensing conditions. In the case of a Village Telco, spectrum use is unlicensed although it may be subject to regulation depending on the strength of the power source used to support the network. In the case of OpenBTS networks, the use of the spectrum is regulated by national telecommunications regulations and licenses for use of the spectrum can be very costly.

Another promising alternative to wireless last mile solutions, whether traditionally "top down" or provided by a telecommunications or mobile operator centralized, or an inverse infrastructure, is called TV white space. These UHF spaces - or Ultra High and Very High Frequency bands - are used for television and FM radio and have been used to prevent "bleed" or interference between over-the-air television channels. These spaces may be appropriated to support proximity based communication, for example, localized mesh networks as in a Village Telco, in low-income countries. These frequency bands enable signals to penetrate buildings and foliage much better than wi-fi and so far these bands are not regulated, thereby circumventing some spectrum licensing issues and costs. However, licensing and technical challenges do remain to be solved and these spaces are unlikely to provide a solution to last mile challenges in the near term (see http://www.shuttleworthfoundation.org/category/tv-white-spaces/).

SEE ALSO: Digital Divide(s); Geographical Information Systems in the Global South; ICT4D; ICT4D and e-Business; ICT4D and Mobile Communication; ICT4D, Monitoring and Evaluation of; ICT4D and Participatory Design; ICT4D and Sustainability; ICT, the Environment, and Climate Change; ICT and Gender; Mobile Money; Online Labor and Business Outsourcing; Open Content

References

Broadband Commission (2013). *The state of broadband2013: Universalizing broadband*. ITU &UNESCO.

D'Souza, N. (2012). *Reaching the last mile: Neil D'Souza on 21st century learning in the developing world*. Retrieved from http://www.technapex.com/ tag/nomadedu/

Egyedi, T. M., Vrancken, J. L. M., & Ubacht, J. (2007). *Inverse infrastructures: Coordination in self- organizing systems.*

In P. Feng, D. Meeking, & R. Hawkins (Eds.), Proceedings of the 5th international conference on standardization and innovation in information technology (pp. 23-36). University of Calgary, Canada.

Heimerl, K., & Brewer, E. (2010). *The village base station*. In Proceedings of the 4th ACM workshop on networked systems for developing regions, Article 14.

Jotischky, N. (2010). Rural connectivity in Africa: Providing ICT access to rural areas. *Informa Telecoms & Media,* November.

Norris, P. (2001). Digital divide: Civic engagement, information poverty, and the internet worldwide. Cambridge, MA: Harvard University Press.

Pentland, A., Fletcher, R., & Hasson, A. A. (2004). DakNet: Rethinking connectivity in developing nations. *IEEE Computer,* 37(1), 78-83.

Rey-Moreno, C., Tucker, W. D., Bidwell, N. J., Roro, Z., Siya, M. J., & Simo-Reigadas, J. (2013). *Experiences, challenges and lessons from rolling out a rural WiFi mesh network*. In 3rd annual symposium on computing for development. Article 11.

Singh, R. (2009). *Mobile phones for development and profit: A win-win scenario*. Overseas Development Institute: Opinion, April.

Talyarkhan, S., Grimshaw, D. J., and Lowe, L. (2005). Connecting the first mile:Investigating best practice for ICTs and information sharing for development. Rugby, UK: Practical Action.

William Tucker is an Associate Professor of Computer Science at the University of the Western Cape in South Africa. His work includes last mile access for a remote rural community with mesh networks and first mile access with mobile phones for a deaf community in Cape Town.

Rudi Westerveld is a retired member of the Faculty of Technology, Policy, and Management at Delft University of Technology in the Netherlands. He has extensive experience in Africa from early television to 3G networks and inverse infrastructure.