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TECHNOLOGY INNOVATIONS TO ADDRESS GLOBAL CHALLENGES

The Second Wave of Wireless Communications: A Game Changer for Global Development?

The world is about to experience the emergence of a second wave of wireless technology. It will be a "disruptive technology" globally and could contribute to accelerating the socioeconomic development trajectories of the world's poorest countries, according to a presentation made by Jeffrey Reed of Virginia Tech and James Neel of Cognitive Radio Technologies during a workshop entitled "The Second Wave of Wireless Communication – A New Wave of Disruptive Technology."

In the twenty years since cellular technology was introduced to the world, this first wave of wireless communications has proven to be a disruptive technology affecting nearly all aspects of life by providing users the ability to place a voice call at low cost to almost anyone from almost anywhere. Now, global society will again experience new technology with such a potential game-changing impact with the second wave of wireless communications, one that is driven by data transferred between people and machines and from machine to machine. Harnessing second wave technologies could be a critical "enabler" in efforts to address global challenges such as resource scarcity, energy security, global health, food and water shortages, and overall sustainable development.

While there are substantial short, medium, and long term benefits to the application of these new technologies, there are also significant new security risks these new technologies pose to society. Additionally, many regulatory, legal, and cultural hurdles must be addressed in order for these new technologies to be widely deployed.

Technology Innovations and Global Challenges

The Second Wave of Wireless Communications presentation was held at the Atlantic Council on October 29, 2010, and is part of a workshop series in the Atlantic Council/National Intelligence Council (NIC) joint project, "Technology Innovations to Address Emerging Global Challenges." This joint project explores potential technological solutions to global challenges identified in the NIC report *Global Trends 2025: A Transformed World* and other long-term trends assessments that pose grave challenges to the future prosperity and security of the United States and the global community. This unique project convenes four communities whose synergism we believe will enhance prospects for identifying and effectively promoting technology innovations to address global challenges:

- Global trends experts who identify the drivers of long-term social, political, and economic change; the challenges and opportunities these trends pose to the international community; and the potential long-term impact of new technologies.
- Scientists, technologists and engineers who can help identify existing and potential technologies that could be promoted to address long-term challenges as well as identify technology developments likely to occur that will shape the global environment.
- Policymakers and advisers who foresee requirements for technological solutions and identify policies to foster technology innovation and implementation.
- Venture Capitalists and business leaders who can identify sources of capital for developing and disseminating technological solutions as well as advise the government on policies to promote private sector involvement in solving global problems.

The First Wave Has Played Out

The first wave of wireless technology – the expansion of information ubiquity – irrevocably altered the conduct of global communications and commerce. Digital information is found everywhere and is displacing traditional content delivery; video delivery over the Internet, including Netflix and YouTube, is currently the largest and fastest growing use of wire-line transmission bandwidth and could become the largest use of wireless as well. As mobile data traffic rapidly increases, wireless service providers are seeking access to a broader radio transmission spectrum to carry that additional traffic. The needed spectrum currently exists, but due to current government-regulated allocations, this spectrum is now off limits to wireless providers, especially in the United States and other developed countries.

New cellular hardware such as "femtocells" offer the opportunity to expand available bandwidth by more efficiently utilizing the existing limited spectrum. These are low-cost base stations which extend wireless coverage indoors in urban areas and provide inexpensive broadband wireless access in remote rural areas. In the medium-to-long term, femtocells will improve access to broadband wireless data transmission bringing the internet, telemedicine, economic information and communication, and educational opportunities to poor rural villages in developing countries that now have little or no connectivity even for conventional wireless services. Reed proposes a proof-of-concept pilot project in Mali that provides a business model for potentially linking such areas at low cost to the rest of the country and the world [See Box, "Proposed Pilot Project for Mali"]. The technology would enable commercial mobile communications providers to make a profit providing services to remote villages.

Ringing in the New Wave

Second wave wireless technologies will utilize enhanced sensory data collection and analysis devices and advances in artificial intelligence which are poised to reshape the ways humans perceive and interact with each other and the world around them. Increased sensory perception and analysis via the introduction of intelligence and sensors in wireless devices will create "agents" capable of recognizing context, sensing, and adjusting to changes in their environment; exhibiting awareness through signals and channels; presenting information from an array of data; and providing users with expanded and augmented means for responding to various situations.

Primary Examples of Second Wave Technologies

Cognitive radios - Software radios that incorporate intelligence characteristics by having a degree of autonomous behavior. Some autonomous behaviors of which cognitive radios will be capable include control of the radio itself and its use of the wireless transmission spectrum through links and networks; sensory perception and awareness of surrounding environs; and increased capabilities for negotiating waveforms with other radios (i.e. the ability to increase or decrease spectrum usage as necessary to thus expand available spectrum in real time). For example, during natural or human-caused disaster, calls may be blocked by too much traffic on the network, however in the future that cell phone might be able to use television spectrum to maintain connectivity.

Intelligent gateways - Networks designed to connect previously incompatible systems, decrease wireless dead zones, and improve the quality and quantity of network connectivity. For example, one's car may contact the car dealership from time to time and report its condition, or the dealership may contact the car to provide new software updates.

Self-organizing base stations - These autonomously network together and collaborate with each other to maintain wireless spectrum access, effectively reducing costs and the need for technology specialists to initiate and maintain networks. This capability would be especially important for poor, rural areas where broadband wireless could be set up without the need for highly-trained technicians.

Dynamic Spectrum Access (DSA) - DSA allocates underutilized spectrum without interference to applications or devices based on location and preconfigured rules for network operation. For instance, new WiFi devices will eventually operate in unoccupied televisions bands alleviating the congestion experienced by these devices in the current unlicensed bands.

This second wave will be the first of its kind to make use of previously untapped bands of the wireless transmission spectrum. The most potentially lucrative bandwidth presently underutilized is television white space (TVWS) – radio bands or channels which for multiple reasons go unused. Prior to the transition to digital television, many of these unused channels were left fallow on purpose in order to reduce the possibility of television broadcast transmissions interfering with one another. Digitization of television means the number of channels used to broadcast television signals is significantly compressed because digital transmissions can be made on adjacent channels and thus do not require the allocation of TVWS in order to reduce transmission disruption. This means that large areas of UHF and VHF television broadcast frequencies, especially between the 50-700 MHz frequencies, that now go unused could be available for other purposes including broadband wireless communication. UHF white space exists mainly in the United States, but VHF frequencies exist ubiquitously in developed and developing countries.

Thus, TVWS now offers a new, low-cost realm of the radio spectrum for data transmission because new technology allows the coexistence of data transmission and TV signals within the TV spectrum. WiFi and 3G technologies are predominant in urban areas, but are not effectively deployed in less urbanized areas because the current cost is high to cover large areas and the potential market is small. TVWS, however, is increasingly available the further one travels outside urbanized areas, and at these frequencies signals propagate further. This makes TVWS a far more cost-effective broadcast spectrum for rural and underdeveloped areas than WiFi and 3G, as it provides huge opportunities for cheaply extending the range of wireless transmission "over the horizon" without expensive cell tower and transmission infrastructure.

Real World Applications

The second wave of wireless technology will provide a bevy of new applications for business and international development.

New Business Opportunities

Intelligent wireless technologies have the potential to open up new markets in developing countries and create new revenue streams that were previously unattainable because of infrastructure, bandwidth, cost, and other constraints. A number of developed countries, including the United States, Canada, Great Britain, and Japan, as well as the EU, have already begun government- and private sector-supported initiatives to increase the utilization of TVWS by second wave technologies. If pioneering companies adopting and adapting to the second wave of wireless effectively adjust their business models, the new wave could make expansion of broadband and wireless technologies into developing nations far more economically efficient and profitable. China, Japan, Indonesia, South Korea, Singapore, Canada, the United Kingdom, and the European Union, for example, have begun their own initiatives to adopt technologies that expand the use of TVWS and other underutilized frequencies.

Increasing the sensory capabilities and introducing intelligence into wireless devices also reduces the cost of training workers and citizens for new skills. With these new devices people are able to diagnose and respond to challenges at home and in the workplace more quickly and with less user-specific skills requirements. This improves worker productivity through the reduction in training and educational costs for businesses and reduces the costs citizens with access to these technologies previously needed to pay when purchasing high-skilled labor services. Enhanced reality or augmented reality with wireless terminals can provide poorly educated workers with visual instructions for dealing with complex systems.

International Development

The advantages of deploying second wave wireless technologies in the developing world go well beyond the expansion of data transmission and the creation of new markets for wireless service providers to exploit. There are several broader implications for socioeconomic development.

Next generation wireless tools will introduce new capabilities to the developing world as these technologies begin to emerge in developed countries. The second wave engenders a reduced need for developing nations to invest in and build expansive, costly communications infrastructure. Developing nations have already leapfrogged over wired communications systems deployed by developed nations by moving directly to cellular communications systems and now could proceed relatively quickly to using second wave devices at significantly lower cost, including deployment to areas not yet touched by first wave cellular communications.

The use of TVWS, femtocells, and other second wave-enabling technologies reduces the urban-rural split that characterized first wave technologies, especially in developing countries. These technologies offer the same increase in digital communications capabilities to remote, unwired places as they offer to densely populated, developed areas. Even rural areas of the U.S. will benefit from this technology.

As second wave technologies become ubiquitous, the hardware and deployment costs to rural areas will be dramatically reduced. These new technologies will also reduce the need for high-wage, skilled technicians to install broadband wireless systems in remote areas. This will make second wave wireless more affordable for developing countries than previous generations of digital communications systems. Thus, the second wave of wireless will enable Third World countries to develop second wave digital communications infrastructures far more quickly and at low cost. In short, the new generation of wireless technologies will continue the work begun by the creation of the internet to expand information collection, analysis, and dissemination on an unprecedented, global scale as an enabler of accelerated economic development.

Collection of new and previously under-analyzed data will become possible. The introduction of new sensory technologies and intelligence in wireless technologies, coupled with the potential exponential expansion of data collection and transmission, will make possible provision of currently uncollected and/or under-analyzed data about the environmental conditions of all regions of the world to the general public as well as to scientists, governments, and businesses. This phenomenon could have vast implications for the monitoring of changing environmental and human living conditions, the mitigation of climate change, the containment of the spread of disease, the improvement of health monitoring and care, the management and protection of scarce resources and endangered species, and overall national security. The benefits of this change will be especially significant in less developed nations that currently lack the communications infrastructure necessary to collect and analyze environmental, health, and demographic information in more conventional ways.

Intelligent wireless devices can be particularly useful to provide timely responses to natural and humanitarian disasters. By improving data collection and analysis as well as communications in disaster- and extreme-weather prone regions, these new technologies can improve the coordination and effectiveness of disaster relief. They also may empower non-state actors to respond to situations more quickly and effectively than less capable (or sometimes perhaps less willing) governments and militaries. This could be particularly important as the frequency and severity of acute climatic events increases with climate change.

As these second wave technologies become ubiquitous, they could contribute to increasing the environmental and energy sustainability of development. Cognitive radio technologies will be critical in the creation and deployment of smart grid energy infrastructures, for example. Smart grids will require significant spectrum usage with reduced transmission interference made possible by second wave wireless technologies like femtocells and the increased usage of TVWS. Intelligent wireless technologies will improve the efficient use of scarce and costly energy and other natural resources. This can be done, for example, in the building and maintenance of infrastructure through careful monitoring and automated, autonomous adjustment to changing environmental conditions. Wireless technologies that control heating and air conditioning at homes are already being used to reduce the need to build additional power plant to cover peaks in power demand. Expectations are that smaller devices and more granular control over building environments will lead to further power savings.

In the long term, broad-based deployment of second wave wireless technologies implies more effective monitoring of governmental performance by government and non-government actors. Through the increased ability to collect and analyze information, governments can potentially reduce incidences of corruption and criminal activity, increase access to government in previously ungoverned, semi-lawless regions, and increase overall good governance through greater transparency and citizen feedback. The increased freedom of information provided by these new wireless technologies may facilitate the spread of civil liberties, access to justice, freedom of speech, and perhaps, ultimately, democracy. These new communication systems will also need power and, in developing countries, this may mean dirty diesel power. Power for information technologies is already a major reason for pollution and the wider adoption of these technologies may also put pressure on the environment.

On the Other Hand...

Technologies are tools and fundamentally neutral in nature. Their use for good or ill is determined by their end user. Second wave wireless technologies can be used to improve healthcare, climate change mitigation, sustainable development, and good governance. On the other hand, they can also be used directly for purposes such as terrorism and cyber crime, as well as increasing the vulnerability to, and consequences of, malicious hacking.

First wave technologies, especially when used beyond voice communications for financial transactions and commerce, remain surprisingly vulnerable to hacking. As societies increasingly rely on the second wave of wireless technology for the provision of public goods and services such as healthcare and education, and for commerce, the potential for malign use of these new technologies will increase correspondingly as will the need for improved hardware and software security. At present security services for first wave technologies are far behind the curve of technological development, especially compared with personal computers. There likely will be a significant lag between the deployment of second wave technologies and advances in device and software security.

Harnessing New Technology to Address Global Challenges

Second wave wireless communications is destined to become a ubiquitous and disruptive technology in both the developed and developing worlds. The second wave also offers a potential leapfrog in technology deployment to enable accelerated economic development in developing countries, especially their poorer, rural regions. This report has sought to highlight both aspects of this new technology – the trend in its development and the potential for its application to change the trajectory of worrisome global challenges if it is adequately promoted.

No doubt the imperatives of economic competition will spur development and deployment of second wave technologies in developed countries and in the more prosperous cities of the developing world. New government regulations such as freeing up TVWS spectrum for wireless communications will help this process move forward faster. But rapidly bringing second wave wireless to poor, rural areas of developing countries – and even in areas of the "developed" world – will likely need a more concerted effort by the "four communities" to identify government policies and sources of capital to make this possible.

These four communities represent the human aspects of technology innovation's supply chain. This Atlantic Council/NIC project on "technology innovations to address emerging global challenges" brings together the four groups – groups that rarely meet – to explore the possibilities of a new technology, in this case, second wave wireless technology. The project proposed by Professor Reed offers a low-cost opportunity for "proof of concept," including the business model for profitable provision of wireless to remote communities. Such a pilot project needs support from foundations, international development institutions like the World Bank, the U.S. government, or private business. More broadly, the workshop exposed trendologists, policymakers and venture capitalists to the promise of a new, disruptive technology and the role that they can play in fostering its development and deployment to address "emerging challenges." The Tech Innovations project will explore other potentially "game-changing" technologies in future workshops.

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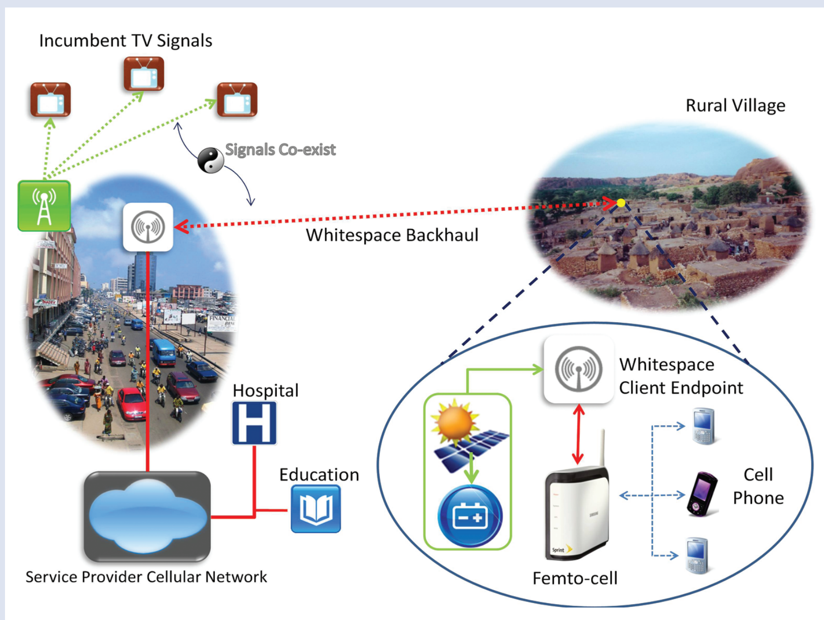
Proposed Pilot Project for Mali

Low-Cost Environmentally Friendly Telecommunications: Summary of A New Business Plan for Service Providers in Developing Countries

By Jeffrey Reed

Developing nations and remote communities often lack basic communications services, creating a social inequality impossible to bridge without targeted technology development. Installing fixed wire-line infrastructure is infeasible given the high cost per mile. Similarly, wireless deployments face hurdles due to lack of existing backhaul infrastructure, energy costs of base stations, and requirements for skilled network engineers to manage network initialization and operations. Large geographic area, lower population density, and economically depressed customer bases, in relation to deployment and operation costs, impedes establishment of basic communication services, creating a perpetual cycle of underdevelopment. We propose a pilot project to demonstrate that second wave wireless broadband communications potentially offers cost-effective solutions for critical social issues such as access to healthcare and economic development including telemedicine, remote education, and micro-finance, all of which hinge upon communications infrastructure. Mali, for example, has remote field clinics that remain understaffed due to lack of basic and broadband communications. (The "Low-Cost Environmentally Friendly Telecommunications" pilot project proposal for Mali is available from Jeff Reed at **reedjh@vt.edu**.)

Traditional cellular networks entail high overhead costs and a large customer base to enable service providers to earn a sufficient return on investment (ROI). Additional costs within the traditional framework arise in the form of technical personnel who are necessary to manage the network and spectrum. Service providers currently do not have the incentive to provide the architecture for wireless telecommunications to remote communities, especially in developing nations that are often impoverished and geographically dispersed. The social value of providing such communication infrastructure is evident for telemedicine, education, and economic development. The problem is enabling service providers to profitably invest in a communications network that would establish a sustainable second, as well as first, wave of wireless communications for developing countries and communities.



The Low-Cost Environmentally Friendly Telecommunications (LEFT) architecture is specifically designed to achieve this goal. This framework consists of three new technologies: the femtocell, whitespace communications, and renewable energy sources such as solar. To connect to a service provider network, base stations like femtocells require a "backhaul" link. Femtocells in buildings and homes can use a wired backhaul link (e.g. DSL link and cable modems) to make this connection. This wired backhaul can be replaced with "whitespace" backhaul, which accesses additional unlicensed broadband spectrum. Two whitespace devices (WSDs) are used to access this. One is deployed in a densely-populated location that connects to a service provider network; the other is integrated with femtocells in remote communities. WSDs thus can provide the whitespace backhaul femtocells require for end users in rural areas to connect to service provider networks. Femtocells and WSDs are solar- and battery-powered, substantially reducing their long-term costs and lowering their carbon footprints. Through this framework, end users in impoverished, rural communities can now have access to cellular networks, providing broadband communications to support access to critical services such as health care, microfinance, education, government, and national and international markets.

LEFT appeals to service providers for a number of reasons. First, the main components – femtocells and WSDs – will experience huge price drops with economies of scale. Estimates show both will grow in user base over the next ten years. Femtocells are predicted to reach 120 million customers by 2012. As a result, a femtocell's cost will drop from $200 to $100, and possibly down to $20 within the next decade. Similarly, though first generation WSDs currently cost around $30,000, WSDs will realize economies of scale through market penetration, which should drop second generation device costs to $150 in ten years.

Femtocells and WSDs are also more attractive investments due to low operating costs and energy savings from use solar and battery power. Currently, the estimated cost of solar panels is $3/Watt. This value continues to decrease as governments and businesses globally further emphasize alternative energy sources' cost-effectiveness. Battery technology innovations also ensure that battery performance and cost will become increasingly efficient. Nearly 80 percent of service providers' carbon footprints originate from power required for traditional base station operations. By using femtocells as base stations, service providers minimize this aspect of their carbon footprint.

While traditional communication networks require high-skilled technical management and support personnel, femtocells and WSDs are self-regulating and self-integrating. This substantially reduces the amount of extra spectrum management and network support – a cost for service providers tack onto end users' bills. The whitespace backhaul this architecture uses is spectrum-efficient and self-managing, further lowering the cost of investment of the LEFT infrastructure.

It is possible to calculate an estimate for the total cost of this design. At present, a single femtocell can service up to 32 users at once, and that number will only increase over time. Several femtocells can operate off one WSD link. This pilot project assumes two femtocells share one WSD link. In addition to femtocell installation costs, estimates include the WSD for the client (in a remote location only; not a primary device in a major city), solar power costs, and the price of a battery.

Cost Estimates for Mali Pilot Project

Item	2010	2013	2020	Notes
Two Femtocells	$ 500	$ 200	$ 80	*Estimate based on economies of scale. NO reference available.
White Space Device-Client (only)	$ 30,000	$ 5,000	$ 150	*Estimate based on economies of scale. NO reference available.
Battery (12 V Sealed Gel Cel)	$ 139	$ 139	$ 139	*Kept Gel cel costs same. Given R&D in electric vehicles and lithium ion batteries could be much smaller in 2020.
BP SX320J 20W Solar Panel	$ 180	$ 140	$ 80	*8% decrease/year.
Morningstar 6am Charge Controller	$ 40	$ 40	$ 40	*Cost remains same, but may decease over longer periods of time.
Samlex 150W 12V Pure Sine Wave Inverter	$ 109	$ 109	$ 109	*Kept the same, should go down over time.
Total	**$ 30,968**	**$ 5,628**	**$ 598**	

By 2020, the cost of this technology infrastructure will have dropped to approximately $598 from over $30,000 today to provide services to up to 32 users. If the potential revenue per consumer in a developing nation is estimated at $5 per month per customer, then the return on investment in 2020 for an installation of this design would take less than 4 months.

LEFT allows service providers to enter untapped markets in poor, rural communities by combining low-cost, environmentally-friendly, self-regulating technological equipment to offer residents access to high-speed wireless communications networks. These cellular networks provide the infrastructure necessary to develop health care, education, and microfinance systems. The social good LEFT offers developing nations, combined with its low costs and rapid, high returns to investments, should make LEFT even more attractive for service providers and become a significant "enabling" technology for overall economic development and poverty reduction.

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