MOBILE COMPUTING AND GLOBAL PROBLEM SOLVING

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Mobile computers—including smartphones, GPS wrist-watches and tablets—are not only transforming the nature of computing, they are revolutionizing the way we work, learn, create and collaborate to solve problems. With mobile devices spreading faster than any other consumer technology in history, they have become one of the most important tools in the toolkit for global problem solvers—from new opportunities to deliver to vital services to disenfranchised communities to the ability to engage people and organizations that were previously excluded from global decision-making, thereby allowing global solution networks (GSNs) to operate with greater legitimacy.

Case studies demonstrate how mobile computing technologies are already changing the way the world responds to global problems and how leading networks are harnessing these tools to improve outcomes.

GLOBAL SOLUTION NETWORKS

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> *"Mobile computers—including smartphones, GPS wristwatches and tablets—are quickly replacing desktop computing and spreading faster than any other consumer technology in history."*

Welcome to the Mobile Future

In parallel with the rise of the social Web, advances in mobile technology are fundamentally transforming computing as we know it. In fact, mobile computers—including smartphones, GPS wristwatches and tablets—are quickly replacing desktop computing and spreading faster than any other consumer technology in history. Smartphones already outsell PCs, while touchscreens outnumber keyboards. In emerging economies, mobile Internet traffic now exceeds desktop traffic, indeed India has earned the status of being home to the second largest mobile phone user base in the world. Meanwhile, enormous increases in wireless data bandwidth have made a wide range of mobile endpoints for applications possible, and this will continue.

According to the International Telecommunications Union (ITU), the number of mobile subscriptions reached 6.8 billion in May 2013, a global penetration rate of 96%.[1] By 2016, there will be over 10 billion mobile devices, which means more connected devices than humans. While mobile devices are not evenly distributed, some 80–90% of the populations of Brazil, India, China, and South Africa currently own one; and thanks to growing availability of telecottages in rural Africa, 97% of Tanzanians report that they can rent access to a mobile phone when they need to.[2] Comparatively speaking, smartphones are still in the early stages of deployment. But with 1.5 billion smartphone users worldwide already, a 30% annual growth rate, and considerable improvement in affordability on the way, it won't be long before all mobile handsets are smartphones to some degree.[3]

Mobile computing represents more than a simple shift in access devices from PCs to handsets and tablets. Mobility changes our patterns of connectivity, keeping us permanently connected to people, processes and places. It transforms the way we interact with information, with location-based services and augmented reality providing richer interfaces between the physical and digital worlds. And it vastly increases the capabilities at our fingertips, allowing users to do anything a desktop computer can do and much more. Indeed, with leading providers like Apple and Google offering close to a million third party apps, the possibilities to extend a typical smartphone's range of functions are practically infinite.

As this report indicates, there are new waves of mobile innovation on the horizon. Improved battery life, faster processors, lighter-weight materials and higher bandwidth networks are all on the way. But so too are increasingly power-efficient and flexible displays that will soon reach "retina resolution." Not only will new displays dramatically boost the clarity of text and images, their capacity to be flexible and even foldable will increase versatility, making it possible to embed displays in clothing and countless other surfaces. Smart devices will also incorporate myriad new mobile sensors—biometric sensors, pressure sensors, pollution sensors and much more. The development of infrared keyboards, gesture and retina tracking, enhanced artificial intelligence, and new context-aware user interfaces will generate unimaginable new applications and form factors.

As the technology evolves, so too will the way we use and interact with mobile devices. Today, a typical smartphone user reaches out to their phone 150 times a day.[4] As wearable devices proliferate, many of these 150 interactions could be hands-free. The amount of fitness data shared from mobile and wearable devices is already doubling each month. Most of this data streams to the Web automatically, withoutany intervention from the user. Indeed, after photos and videos, the next big wave of content uploaded from mobile devices will be personal data. Not only fitness data, but location data, user reviews, and check-ins fuelled by the rise of wearable and drivable mobile devices such as Nike Fuel, Google Glass or Waze-enabled cars.

For GSNs, mobile computing will enrich the toolkit for problem solving in manifold ways. The growing ubiquity and versatility of mobile devices not only makes it possible to reach remote communities with vital services, it fosters an opportunity for governments to partner with GSNs to reinvent the entire modus operandi for how public services are designed and delivered. As this report shows, domains ranging from financial services to health care are rife with new innovations. And in many cases, GSNs are helping developing countries leapfrog their more affluent neighbors. At the same time, emerging mobile sensor networks are unleashing distributed models of environmental monitoring and urban sensing that empower mobile-equipped citizens and GSNs to play a more active role in regulation. And finally, at the very frontier of mobile technology, we are seeing how a combination of new mobile interfaces, geospatial data and augmented reality applications can enable powerful forms of communication and social engagement.

Opportunities for Mobile Innovation: Enriching the Toolkit for Problem Solving

In the domain of global problem solving, mobile technology is critical for several reasons. One of the most important is the speed at which the mobile revolution is breaking down barriers to access, making the online population much more representative of the global population as a whole. A decade ago, policymakers were forecasting that it would be 2050 before a majority of the world got connected to the Web. But with 40% of the global population online already, and adoption of mobile broadband Internet services doubling annually in Africa, global Internet usage will easily surpass 50% by 2020, thirty years earlier than predicted.5

Mobile connectivity means billions of individuals can now participate in new patterns of global economic production and collaboration. In fact, the diversity of new start-ups exploiting the combination of mobile technology and entrepreneurial energy is truly inspiring. Jana, a global market research and rewards company, connects global brands with 3.5 billion people in emerging markets by giving free mobile airtime to consumers who take market research surveys and try out products. With services like

> *"The economic potential unleashed by ubiquitous mobile connectivity will reshape the world we live in, creating unforeseen opportunities for growth, innovation and job creation."*

CloudFactory, a business automation start-up in Nepal, companies can now crowdsource basic text, image and audio-based tasks to thousands of mobile phone users, most of them in developing countries. The company's founder and CEO, Mark Sears, is aiming to connect one million people to digital networks in the next five years, with other entrepreneurs in emerging nations quickly following on his heels. In fact, the African Digital Jobs Initiative, supported by the Rockefeller Foundation, already leverages mobile technology to provide digital jobs that pay a living wage to one million African youths in six countries. As proof of the viability of the concept, a Rockefeller Foundation survey of three freelance micro-work platforms—ODesk, ELance and Mobile Works—found that there were already over 10,000 Nigerian workers accessing regular digital work through these platforms.6 Meanwhile a growing cohort of talented mobile application developers is emerging across Sub-Saharan Africa. The talent pool is sufficiently rich that talent-hungry companies like Google are now working with thousands of Android developers in countries such as Nigeria, Kenyan, Tanzania, Senegal, Ghana and Cameroon.

The economic potential unleashed by ubiquitous mobile connectivity will reshape the world we live in, creating unforeseen opportunities for growth, innovation and job creation in places that many feared would be by-passed by the digital revolution. Yet, the possibilities for mobile innovation and opportunity creation do not end there. Indeed, the potential applications of mobile computing for global problem solving are nearly as large and heterogeneous as Apple's app store. Where there is a need that needs fulfilling—or a problem that needs solving—there is probably a role for mobile devices to connect and coordinate individuals, provide more convenient access to information or services, or empower activism and dialogue. For the sake of illustration, the report highlights four emerging opportunity spaces: mobile service delivery, mobile health, mobile sensing and mobile browsing, which includes the use of mobile phones to enable powerful new interfaces with the physical world around us. The discussion begins with a look at how operational and delivery networks are deploying mobile technology to reinvent service provision in low-income countries.

Mobile Service Delivery: Improving Access to Public Services

It's morning time in Kinshasa and Miriam enters a code on her mobile phone as she walks out the door, displaying a traffic report she will use to decide which route will get her to the office faster. The report, compiled from government data, doesn't tell her about the police spot check she encounters minutes later. But the delay is brief. The officer who checks Miriam's license scans the two dimensional barcode on the back of her card into a mobile device, which quickly tells him she has no outstanding traffic tickets.

There is a nasty pothole around the corner from her office, so as soon as she parks her car, Miriam sends a quick text message to the city roads

department's complaints hotline. Her phone buzzes a few minutes later with a reply telling her the pothole complaint has been added to a queue of issues for the city's road crews to address. Miriam texts another number and enters her license plate number to pay for parking. When she leaves she will send another text to check out of the lot, and she will pay for the exact length of time the car was parked. By photographing her license plate with a cameraphone (optical character recognition identifies the plate number), a parking enforcement officer can check whether she has paid.

Mobile phones now provide access to a breadth of services such as mobile banking for developing countries.[7]

A few blocks away, Sam is tending his stall at a public market. Sam too has been using his mobile phone this morning. Before leaving his farm outside the city this morning, he checked the daily agricultural price report the government sends to small farmers via short message service (SMS), to see what his crops were worth. Now another message reminds him that it is time to renew the permit for his market stall. Sam does so using his mobile phone.

The account above may be fictional, but the possibilities for improving access to essential services are very real. Mobile technology has led to an explosion of new applications aimed at solving or ameliorating problems faced by the world's poor. In fact, mobile technology is not only improving public services in cash-strapped nations at a rapid pace, it's arguably allowing emerging nations

to develop completely new service delivery paradigms that leapfrog those offered by their supposedly more advanced counterparts in affluent nations.

Mobile banking is one of the most compelling examples of leapfrogging, where a lack of robust financial infrastructure in developing countries has led to some remarkable financial ingenuity. In Kenya, for example, M-Pesa became the first mobile money transfer service, making it easy for anyone with a cell phone to send and receive cash. Run by Safaricom, a Kenyan mobile-phone operator, the service is overwhelmingly popular, with 15 million subscribers (from an adult population of 43 million) who use it for everything from paying electricity bills to school fees.[8] Thanks to a simple text-based menu, M-Pesa is accessible on even the most basic mobile phone.

In 2013, Safaricom rolled out a complementary savings and loan service called M-Shwari. The service, which can be set up instantly and accessed on any device, promises to extend financial services to a large population of Kenyans that was previously excluded. Bob Collymore, Safaricom's chief executive, believes that Kenya's unbanked sector could have savings of $3.4 billion, much of it stuffed in jars or mattresses, earning nothing and vulnerable to thieves. M-Shwari acquired 2.3 million customers in its first four months, one-third of whom have applied for small business loans, averaging around $12.[9]

Kenya's success with M-Pesa has inspired other innovators and mobile banking service offerings have since exploded in countries that have disjointed, untrustworthy or nonexistent financial systems. The benefits of mobile banking, however, go well beyond increased access to credit and financial services. Maura O'Neill, Chief Information Officer and Senior Counselor at USAID, calls mobile banking and digital cash "a game-changer in development" and recently set up a mobile solution group to pursue opportunities for innovation. "We discovered that there were two billion people in the world that had mobile phones but didn't have bank accounts," says O'Neill. "If we could turn every mobile phone into a digital wallet, three amazing things could happen: there would be less corruption, reduced administrative costs in government services and aid, and a more robust entrepreneurial network."[10]

Mobile innovation in service provision is not limited to financial services either. The Kenya Agricultural Commodities Exchange (KACE), for example, recently began providing agricultural pricing to smallholder farmers via SMS. Many small-scale farmers in Kenya, and indeed most African countries, lack access timely information on market prices for their crops, which creates a situation where middlemen can easily exploit them. The KACE service has reportedly improved the bargaining power of smallholder farmers dramatically, increasing their earning by as much as two to three times in some cases.[11]

With thoughtful design practices, users needn't have access to advanced smart phones to access better services than what might otherwise be available in their community. A program called Lifelines India, for example, allows farmers to call a number on either a landline or a mobile phone

"The growing ubiquity and versatility of mobile devices fosters an opportunity for global solution networks to reinvent the entire modus operandi for how public services are designed and delivered."

(four fifths of India's phones are mobile) to ask questions about agricultural market prices and procedures, banking, government funding plans and other topics. For example, a farmer could post a query on a pest-management solution to save his dying crop in the field. Such questions are then recorded and answered by a team of workers who can search databases of existing answers or refer questions to subject matter experts. Today, Lifelines India reaches over 150,000 farmers in 1,000 villages and answers about 350 questions a day.[12]

Operating since October 2006, Lifelines India was developed through a partnership between British Telecom, Cisco and OneWorld, an operational and delivery network that works to harness the democratic potential of information technologies to promote human rights awareness and sustainable development across the globe. In 2008, OneWorld's service was expanded to provide pedagogic support to schoolteachers in rural India. As of July 2013, some 500,000 schoolteachers in 100,000 schools across the country are using the service to query a wide range of topics, from subject lessons and teaching-learning methods, to classroom management and child psychology, to general knowledge and current affairs.[13] OneWorld sees the grassroots knowledge services as a means to increase educational and livelihood opportunities for rural communities through access to decisive information. It's also an outstanding example of a sustainable delivery model in which a growing contextual knowledge base is developed as information exchange takes place through the service.

While Lifelines India demonstrates the power of grassroots knowledge exchange, mobile technology has also proven useful for pushing time-sensitive information out to people who need it in an emergency. In countries such as Malaysia and Indonesia, electronic sensors are placed in flood-prone areas. When they detect high water levels, they signal an operations center that in turn uses SMS to send warnings to the mobile phones of citizens in the danger zone.[14] SMS notifications are also part of a new global tsunami warning system set up by the United Nations in the aftermath of the Indian Ocean Tsunami that claimed the lives of over 200,000 people.[15]

In the short-term, mobile innovations can make a wide variety of services available across vast distances, reducing the need for physical service centers and improving the productivity of people and government. For many, the opportunity to pay electricity bills from home is a welcome improvement over carrying cash to a distant office and having to wait in a long queue. Mobile services not only offer cheaper, faster, and more reliable access to services, they offer citizens access to functions of government that would have been unaffordable and inaccessible in the absence of a mobile delivery platform.

In the long run, however, mobile government offers much more than just a new channel for service delivery. It could literally transform how government relates to citizens, businesses and its own employees. In other words, developing countries could seize the opportunity to develop truly networked models of government that cut across traditional departmental silos. In the

process they could invite citizens, non-profits and private enterprises to play a more active role in value creation through multi-stakeholder networks.

Safaricom did not wait for a government mandate to roll out the M-Pesa service. It saw a financial need that it could fulfill and seized the opportunity to innovate. Similarly, OneWorld worked with BT and Cisco to improve livelihoods in rural India by providing farmers and educators with essential, demand-based information, guidance and advice through mobile devices. Indeed, M-Pesa, Lifelines India and other examples suggest that it would be a significant mistake to simply replicate existing government structures on mobile devices. Instead of creating new departments and new layers of management, governments should be using mobile computing as a platform for opening up public services and processes to broader input and collaboration.

Mobile Health: Providing Affordable, Accessible Care Around the Globe

Around the world, healthcare systems are under severe stress, both in developed and developing countries. In developed countries the cost of delivering healthcare is a major concern. Growth in spending on healthcare now outstrips GDP growth in many markets and the cost burden will be unsustainable if unchecked. In 1960 the United States, for example, spent only 5.2 percent of GDP on health care. By 2009 that number had risen to 17.3 percent, which means America now spends more on health care than it does on food.[16] The underlying causes are complex and include factors ranging from the expansion of medical services thanks to new technologies and research to demographic and lifestyle factors such as aging populations and poor diets.

In developing countries, the health-related challenges are greater while access to high quality healthcare services is severely limited. Lack of access to medication and essential health services leads to high rates of infant mortality and higher mortality from treatable diseases such as HIV/AIDS and malaria. At the same time, developing countries must cope with health impacts related to environmental factors that contribute to disproportionately higher rates of death, disease and disability. These factors include poor water quality, limited water availability, and poor sanitation; vector-borne diseases; poor ambient and indoor air quality; environmental exposure to toxic substances; and global environmental changes that contribute to desertification, rising sea-levels, extreme weather events and a loss of biodiversity.[17]

While no panacea, innovative mobile health strategies and solutions provide an opportunity to rethink and reshape many aspects of health care delivery in developed and developing countries alike. For example, SMS alerts can remind patients to take their prescription drugs at the appropriate time. Frontline health workers with mobile devices can offer remote diagnosis

"Mobile health interventions could save some of the three million lives lost each year across Africa to HIV/AIDS, tuberculosis and malaria."

and even treatment for patients who do not have easy access to a physician. Wireless health monitoring devices can track patients' conditions remotely and relay information back to central databases that are monitored by clinicians, thereby improving treatment compliance, reducing the need for costly hospital visits (except in emergency situations) and improving quality of life for patients with chronic conditions.

McKinsey estimates that remote monitoring schemes alone could reduce the growing cost burden of chronic diseases (approximately two-thirds of total healthcare expenditure) by up to $200 billion in Organization for Economic Cooperation and Development (OECD) and BRIC (Brazil, Russia, India, and China) countries.[18] MedicallHome, a tele-health service provider in Mexico with more than one million subscribers, has found, for example, that a full 62 percent of the patient calls are resolved directly over the phone, with the balance referred to a network of physicians and clinics for diagnosis and treatment.[19] These asset-light models exploit existing telecommunication infrastructures, while reducing in-person visits to physicians and clinics, and the associated costs.

For countries that lack comprehensive health care infrastructure, mobile innovations like these could partially alleviate the need for health authorities to build costly bricks and mortar infrastructure. At the same time, they vastly enhance the quality of services available to populations that were previously hard to reach. Frontline health workers equipped with mobile health applications, for example, have been successful in dramatically speeding up the process of diagnosis, treatment and referral for patients located in rural areas of the developing world.[20] These interventions have proven particularly effective in improving health outcomes in antenatal services and the prevention of mother-to-child transmission of HIV. Delivering mobile-assisted awareness programs to pregnant mothers and traditional birth attendants, for example, has been found to reduce prenatal and maternal mortality by up to 30 per cent.[21] In fact, recent studies suggest that mHealth initiatives in Africa could save millions of lives annually. A recent report by PricewaterhouseCoopers India concluded that mobile phone interventions to ensure patients comply with treatment, to check availability of medical stock and to assure that healthcare workers stick to treatment guidelines could save some of the three million lives lost each year across Africa to HIV/AIDS, tuberculosis and malaria.[22]

Another particularly successful example is Magpi, a mobile phone-based data collection system that health workers across Africa are using to collect and monitor information regarding clinic supervision, vaccination coverage, medicinal supplies, disease outbreaks and other important public health issues. In 2008, Kenyan health workers used Magpi to track an emergency polio vaccination campaign and managed to stop a potential epidemic in its tracks. In 2010, the application had a successful trial for feasibility and scalability in a pilot in Malawi that monitored the availability of malaria medicines via mobile phones. As of June 2013, Magpi had 20,000 users in more than 170 countries including the US, Kenya, Guatemala, the UK, Tanzania, India, Pakistan, Mali, the Philippines, Zambia, Malawi, Nigeria, Peru, Brazil, Indonesia, and Liberia, making it the most widely-used mHealth

software in the world.[23] What's more, the application is programmed and supported by DataDyne in Kenya and is funded entirely by its paying users, making it a model for sustainability in a world where many tech projects die when the initial seed funding dries up.

Mobile phone being used in the delivery of health services.[24]

The ability of mobile health delivery initiatives to improve outcomes and save lives is widely attributed to two related characteristics. First, they take advantage of the advanced communication and processing technology already available to a large part of the world's population. In doing so, they offer better services to a larger number of patients, thus reducing inequalities in the service levels available to remote populations. But there are other important advantages too. Digitized services can be standardized and, to some degree, automated (e.g., diagnostic algorithms used in telemedicine centers), which cuts down on the need to use highly trained health professionals to field routine patient enquiries. Digitized services can be centralized such that one call center can offer services to an entire population, which leads to considerable delivery efficiencies. Digitized health services also allow several parties to collaborate and provide integrated care by sharing patient data among all parties involved in treating the patient. The same data can later be mined for new medical insights and become part of the knowledge base for science, health and medicine.

While the mobile health opportunity is very large, the efforts required to realize the benefits will be equally significant. To function effectively, the

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mobile health ecosystem must facilitate collaborations between all players, from device manufacturers, mobile network operators and application developers to healthcare providers, insurers/payors and regulators. Fortunately, operational and delivery networks like the mHealth Alliance have begun to recognize and respond to the need for multi-stakeholder collaboration and are currently investing heavily in building the infrastructure, skills and awareness required to enable low-income countries to take advantage of the power of mobile health innovations. Hosted by the United Nations Foundation—and funded by the Rockefeller Foundation, Vodafone Foundation, HP, the GSM Association, and Norad—the mHealth Alliance's activities focus on strategic priorities that address the gaps in the mHealth ecosystem. Patricia Mechael, executive director of the mHealth Alliance, says the alliance's priorities range from increasing interoperability among mHealth players to developing sustainable sources of financing for mHealth initiatives to building capacity by equipping field health workers with mHealth skills and applications.[25] As the world grapples with major health-related challenges on all fronts, many similar multi-stakeholder collaborations will be needed.

Mobile Sensing: Harnessing the Real-Time Data Revolution

On January 8th 2007, a strong, gas-like odor permeated parts of New York City and nearby areas of New Jersey, forcing several schools and companies to evacuate and interrupting traffic along some subway and train lines.[26] Emergency crews were unable to pinpoint any gas leaks or other causes, despite sending out a fleet of fire trucks and a hazardous materials crew. After searching 140 industrial facilities Mayor Bloomberg declared that they had given up hope of finding the source of the mysterious odor. While there were no reported casualties, the uncertainty caused anxiety and fear in a city where pungent odors can raise vague worries about a potential terrorist attack.

Fast-forward into the near future, however, and the series of events that bewildered local officials might have unfolded quite differently. The odor leaves traces of nitrogen dioxide that, in this alternate reality, are automatically detected by tiny wireless air quality sensors embedded in the mobile phones of millions of New Yorkers. A simple mashup of the data overlaid on a Google map identifies the culprit—a dangerous incinerator that is not supposed to be in use. City officials shutdown the plant immediately and issue a text alert to calm nervous residents who fear that some form of chemical attack had been unleashed.

This account may be fictional, but it is not far-fetched according to Eric Paulos, a computer scientist and director of the Living Environments Lab at the University of California, Berkeley. Indeed, with a few simple modifications, Paulos can already transform an ordinary mobile device into a powerful personal measurement instrument capable of sensing our natural environment and empowering collective action through everyday

grassroots citizen action.[27] Outfitting your average phone with a few simple sensors and some software, says Paulos, will allow users to get answers to a wide range of questions that would otherwise elude the average citizen, questions such as: how healthy is the air I'm breathing? Were pesticides used on these fruits? Are my children's toys free of lead and other toxins? Or, is my new indoor carpeting emitting volatile organic compounds (VOCs)? Answers to questions like these could be invaluable for a wide range of stakeholders that are working to address global problems.

Thankfully, the day when most mobile computing devices come preloaded with such diverse sensing capabilities is not that far away. Smartphones already pack a lot of processing power and that power is increasing over time. The network capacity required to carry the data streaming from a plethora of connected sensors is also growing rapidly. Meanwhile companies like Nokia are betting that embedded sensing capabilities could unleash a wide range of new consumer applications. The handset maker has already prototyped an "eco sensor" phone with novel sensing technologies for atmospheric gas levels including carbon monoxide, particulate matter and ground-level ozone detectors, ultraviolet radiation, and noise pollution, among other things.[28]

As a first step towards demonstrating the practical potential of urban sensing, Paulos and his team equipped street sweepers in San Francisco with sensors to measure pollution levels as they navigate around the city. The sensors convey data back to a central database that researchers use to create a real-time map of the city's environmental landscape. Once sensors become ubiquitous, the plan is to collect air quality data directly from consenting smartphone users. Interested citizens can already use a text-messaging service to receive daily air quality data for their zip code, but the team is in the process of launching a more full-featured website that will provide access to live and historical data, as well as online community features that allow citizens to discuss neighborhood issues and formulate strategies for addressing them.[29]

Similar urban sensing projects are popping up around the globe. Researchers at MIT's Senseable City Laboratory have outfitted bicycles in Denmark with portable monitors for multiple air pollutants, noise, temperature/humidity and GPS, giving users the ability to access data on the web and share data with friends or in public forums.[30] In Singapore, data gleaned from mobile phones and other sources provide a real-time picture of the flow of inhabitants across the city throughout the day, enabling planners to assess whether services such as public transportation routes are optimally distributed.[31] In a recent development, the city has taken to issuing hyper-local weather forecasts 10 minutes in advance, which taxi companies use to direct the city's many taxi drivers to the areas of the city where it is raining.

Bicycle in Copenhagen with intelligent wheel to monitor and track cycling data.[32]

Meanwhile in Manila, ordinary mobile-phone-toting citizens have joined forces with environmental groups in their fight against urban air pollution. While not quite as cutting-edge as their counterparts in Singapore and San Francisco, individuals using cell phones and mobile text messaging can report vehicles they see emitting excessive clouds of pollution to a central database called Smokebelchers Watchdog. Amelia Judones, a college student, is among the volunteers. "I do it in the car, on my way to class," she says. "It costs me nothing, and I feel I can contribute something to the fight against pollution."[33]

Most complaints are against trucking and commercial vehicle companies. At the end of each week, the environmental group leading the effort compiles a list of vehicles with five or more complaints against them and sends it to the Land Transportation Office (LTO)—the arm of the Department of Transportation and Communications that issues licenses to such companies. The LTO then summons offending vehicle owners to their offices for an exhaust test. In the first two weeks of the campaign, 123 vehicle owners were called in. "The volume was so great that we now receive the complaints not weekly, but every day," says Roberto Lastimoso, chief assistant secretary of the LTO.[34]

As the underlying technology develops further, a great deal of mobile sensing could be automated and become practically invisible to the average mobile phone user. But for watchdog networks or policy networks, the resulting data is potentially priceless, particularly where inadequate resources and

technological constraints limit the effectiveness of traditional pollution-monitoring paradigms.

Consider, for example, the fact that the US-based EPA recently concluded that its nitrogen dioxide air quality standards and monitoring technologies are woefully short of the standards required to adequately protect public health in light of new evidence of the health effects associated with short-term, near-roadway exposures.[35] Unfortunately, the paucity of near-roadway pollution monitoring sites in the US makes it nearly impossible to accurately assess the risks to specific populations or warn the public of the potential health hazards associated with their level of exposure. The EPA has proposed to establish a new near-roadway network with stationary pollution monitors

Concerned citizens protesting the harmful effects of pollutants in the environment.[37]

to better evaluate this key microenvironment.[36] But Jon Levy, a professor of environmental health at the Boston University School of Public Health, doubts whether this expanded network will be adequate to do the job.

The proposed network would consist of at least one monitoring site near a major road per urban area with 500,000 people or more and a second site for urban areas with 2.5 million people or more, with a resulting network of 126 near-roadway sites across the US. However, according to Levy, it is difficult to consider a single site within a large urban area reasonably represents all circumstances of near-roadway nitrogen dioxide exposure across the city, given that nitrogen dioxide concentrations are typically elevated within 200–500 meters of the roadway[38]. Moreover, Levy notes that

Stationary pollution monitoring site collecting car emission data.[39]

the proposed monitoring network appears unlikely to be implemented in full because of a lack of state andfederal resources. He predicts that perhaps half as many sites will come to fruition.

The tensions between temporal/spatial density of measurements and cost/resource constraints facing regulators are not limited to nitrogen dioxide. Levy estimates that they are generalizable across a wide range of other pollutants that are inadequately measured to provide accurate estimates of the associated health risks. Levy is one of many public and environmental health experts encouraging the EPA and similar agencies to investigate novel strategies and data streams that could characterize air quality at higher resolution, with greater frequency and greater precision.

An interesting parallel exists in the realm of traffic flow characterization. For years, traffic counts and estimates of vehicle speeds were available on a limited number of roadways, where local planning agencies could physically place traffic counters (often pneumatic tubes laid across roadways or, for smaller roads, staff with clickers literally counting the traffic). This provided robust characterization for a small number of roads over a small number of days, with models used to estimate annual counts and traffic volumes on unsampled roads, but missed some of the important granularity and localized hot spots that can exist.

Today, traffic volume and congestion are readily characterized in real time on many roadways across the planet using cell phone signals and other data resources that are rapidly integrated, processed and communicated back to the public. This density of information could never be collected by state or federal agencies, or by individual private companies. The data is only available

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because of the information gleaned from millions of individual drivers and their cell phones. Physical traffic counters still have utility for certain applications, but the distributed data collection with rapid synthesis provided by mobile phones creates a novel information stream for communication, analysis, and planning for policymakers, drivers and data innovators alike.

If mobile sensing offers significant advantages to urban planners and environment regulators in the world's most prosperous country, it is reasonable to assume that the potential is far greater for emerging nations and GSNs where the resources to conduct widespread environmental monitoring are even more limited. "In the developing world, there isn't a functioning census, you don't know where traffic is, you don't always have the data-gathering infrastructure of government," says Alex Pentland, director of the Human Dynamics Lab at MIT, who has long been interested in insights from data created by mobile phone use. "But all of a sudden, the one thing you do have—cell phones everywhere, especially in the past few years—can give you the equivalent of all that infrastructure already built in the developed world."[40]

Imagine a GSN organized around air pollution and environmental justice, for example. It might never be able to afford the air quality monitoring infrastructure of the EPA, but it could quite easily crowdsource air quality readings from mobile users around the globe with a modest investment in software development and Web hosting. Data overlaid on a Google map would quickly reveal potential correlations between high concentrations of air pollutants and high concentrations of poverty or high concentrations of disease. Community groups could name and shame local offenders and organize for political change. Armed with real data they could press regulators to proceed with enforcement actions and encourage urban planners to rethink zoning laws that locate polluting facilities in close proximity to poor neighborhoods.

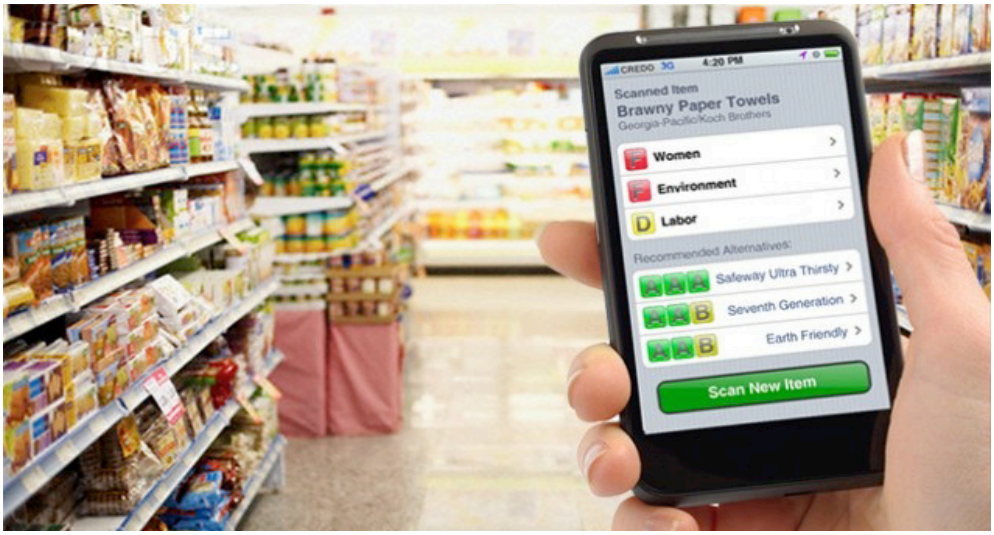
The technology to support mobile sensing applications is maturing quickly. Early examples can be observed and analyzed in Manila, San Francisco and Singapore. All that is needed now is the imagination, organization and dedication of GSNs to make it happen on a mass scale.

Mobile Browsing: Unleashing New Interfaces with the Physical World

A cell phone that alerts you when you come into close proximity to an urban environment with high-levels of dangerous toxins or carcinogens is potentially life-saving invention for billions of urban dwellers. Now imagine that the same phone's 3D display allows an emergency responder to quickly pinpoint the location of likely survivors by pulling up holographic blueprints for a building that collapsed in the wake of an earthquake. Or imagine

an interactive health kiosk with interfaces that citizens can activate and navigate simply by pointing their finger or focusing their mind.[41] As mobile computing technologies continue to develop, exciting new capabilities and interfaces are being unleashed that could have significant implications for the public good. In fact, the combination of powerful mobile devices, machine vision, geospatial data and new display technologies are already merging our experience of physical and digital spaces and forever changing the way humans interact with information.

One limitation of the Web today is that information in a browser, including a mobile browser, is flat and at best a poor proxy for what we experience in the real world. Most users can't search the physical world from their portable digital device. To make do, users conduct computerized searches in advance, and then go into the physical world with the information. These constraints limit the ability of global change makers to provide context-relevant information to citizens in the real world, in real time. Fortunately, many of those limitations are about to change.



Socially conscious consumer using Buycott App to evaluate potential purchase.[44]

As location-based services, augmented reality and holographic technologies mature, the question is not if the next-generation Internet will somehow embrace powerful new spatial capabilities, but when and how. Enhanced virtual reality applications already make use of spatial characteristics and 3D representations are being deployed in medicine, aerospace, and in manufacturing. Smarter handhelds, with bigger displays will increase the fidelity of our interactions and foster a "digitally-enhanced" experience of real life not unlike that portrayed in sci-fi films.

One of the most significant opportunities lies in the ability to create greater congruency between the world of digital information and real-life people and places. For example, mobile devices can act as a proxy for a person's identity (much like cards do today); objects and places can be tagged and linked directly to the data associated with them (phones will "recognize" faces, objects, and places), and rules can be applied to the transactions they are associated with. When you want to know whether you can park somewhere, that information will be available right at the parking spot. If you wish to apply for social security, you won't need to fill out a form since the relevant information will already exist on your mobile's smartcard. If a city planner shows up at a construction site they automatically see checklists of permits and approvals for any work they can see is underway. When a business sells an item, the sales tax could be reported (or even collected) as each and every sale is made. This convergence between physical and digital worlds will transform many aspects of service delivery—not only dramatically improving existing services, but opening up exciting new possibilities as well.

The convergence of bits and atoms and the rise of contextually relevant data will also create new opportunities for social activism. Doug McMellan, head of business development for Nokia, says "The connection of me, my location and my phone is generating a new social dynamic,"[42] creating new opportunities for precisely targeted interventions that use this information to enable powerful forms of communication and social engagement. Today, a health conscious shopper can scan a barcode on a food package to retrieve additional details about the product's composition, down to the farm it originated from. Meanwhile the socially-conscious shopper a few isles down can use Buycott to swipe a tag on a new sweater to assess whether the product is "sweatshop" free. The same app spits out a full list of companies and products to avoid based on the profile of the causes the shopper supports.[43]

Buycott is possible using today's technology, but more advanced augmented reality capabilities will bring more powerful applications to the average user in the near future. For instance, a refugee who has just been settled in a new city could be equipped with an AR app that helps them navigate through unfamiliar streets, identify buildings and locate helpful services and facilities nearby. Or a farmer trying to fix his farm tractor could point his phone at the engine and download a virtual overlay that labels the engine parts and provides helpful maintenance tips and diagnostics. No one can predict exactly where all this will end up, but one thing is certain: the mobile future will continue to get more and more interesting.

Implications for Network Leaders

The widespread and growing penetration of mobile devices around the globe makes them arguably the most important of all technologies in the toolkit of global problem solvers and the communities they serve. Mobile technology

offers much more than just a new channel for delivering existing information and services; it provides an opportunity to invent entirely new services and to totally transform how GSNs operate and engage with citizens. What follows are some key lessons and guidelines for global problem solvers with regard to the future of mobile computing, its core applications for global problem solving, and the strategies and tactics that GSNs should deploy to foster mobile innovation.

Mobile Innovation will Continue to Drive New Advances and Capabilities

Mobile technology is still advancing at a rapid pace. Much has changed in the mobile technology landscape in just the last few years. New sensors (eg., motion, accelerometers), onboard storage, sharper displays, improved battery life and camera resolution, smart machine vision, and location-sensing capabilities have all vastly enhanced the range of capabilities for mobile devices. And yet there is more mobile innovation to come—innovations that problem solvers ought to anticipate and harness as they build their strategies for deploying mobile technology. While many of the capabilities of mobile phones will continue to improve at the rate of Moore's law or better, some of the most exciting frontiers include flexible OLED screens, advanced data-driven applications and wearable computers like Google glass. Scheduled for release in 2014, Google Glass is essentially a camera, display, touchpad, battery and microphone built into spectacle frames so that you can perch a display in your field of vision, video, take pictures, search and translate on the go. In fact, any function that requires you to look at a screen could be put in front of your eyes courtesy of a small "prism screen" that displays information without obstructing your vision.

Eventually, our mobile devices will disappear and at some point they may be printed right onto our bodies. Indeed, the ultimate future of mobile computing is that our "devices" will be come less and less necessary as computers get embedded in everything and our interfaces with information get smarter, more powerful and more ubiquitous. As Ibrahim Kushchu, director, Mobile Government Consortium International, puts it, "In the future, the computers will disappear.... There will be small devices, intelligent and voice-enabled. They will be on our clothing. They will be all around."[45] Perhaps the inevitable expression of this trend is the dattoo: a customized electronic processing device that you can print onto your own skin. So-called organic computing "devices" could include printable input/output tools such as a camera, microphone, or laser-loudspeaker—all of which would be powered by energy from the human body. Researchers working on the technology note that the dattoos needn't be permanent. At the end of the day, users could simply wash the dattoos off, beginning anew the following day.

Mobile Applications for Global Problem Solving are Diverse and Growing

Mobile technology gets critical services into hard to reach communities. Of course, for users in many low and middle-income countries, future innovations like dattoos are a distant concern. Even simple mobile technology can dramatically improve the services on offer. The fact that mobile phone networks often surpass other infrastructure such as paved roads and electricity means the operational and delivery networks can reach rural and fragmented communities with services and facilities that they could not easily serve otherwise. The benefits are such that last year the Indian government finalized a $1.2 billion plan to distribute free mobile devices to every family living below the poverty line, along with 200 minutes of free talk time.[46] As this report argues, health care is a leading opportunity space where mobile applications for public health surveillance, education, diagnosis and remote monitoring can dramatically improve access to health services and save or improve the lives of millions.

Mobile services provide emerging nations with an exciting opportunity to leapfrog the status-quo. In fact, the opportunity to leapfrog exists in any nation where wireless Internet penetration exceeds wired, which accounts for a majority of emerging nations. In every case, mobile presents governments and GSNs with the chance to rethink processes that were often designed with the limits of paper-handling in mind. Mobile data access can help shed paperwork and permit reinvention of services ranging from security and inspection to licensing and identity management to disaster relief to health and support services. Imagine the ability to browse government services and information organized based on the relevance to your physical location,or the opportunity to replace reams of paper documents with searchable mobile records or 2-D barcoded hyperlinks, using computer image analysis of neighborhoods for bylaw inspection and enforcement, or perhaps even bringing forensic and diagnostic tools out of the lab and into the field.[47] Mobile services put all these possibilities and more within reach.

Mobile computing and connectivity makes information distribution much more efficient. People don't simply need information—they need it at the appropriate time and place. Traditionally, it has been housed away from the objects and people it's often about. To install a solar-powered water pump, most people have to pick up and read an instruction manual. When one sees a "For Sale" sign in front of a house, he or she must log onto the local multiple listing service to look up a price and description. When one needs to renew a vendors' permit, one has to allocate hours to physically navigate through forms, queues and signatures. Mobile connectivity, coupled with the application programming interfaces (APIs) and Web services that allow information to flow more freely, are key to making information more readily available, useful and even customizable for end users.[48] Location-based services and augmented reality will allow associations to be created between real-world places/people/objects and useful digital information, such as event histories, reputations, instructions, ownership data, structural details, and even interfaces and controls. A virtual "right click" on a real-

world emergency clinic could advise on the estimated waiting time for service and, if necessary, recommend a nearby alternative. Pulling up virtual records from the local land records department could help neighboring farmers determine property boundaries and avoid disputes. Unfortunately, public good applications of these technologies are currently primitive and more investment will be required to realize the potential.

Mobile sensing offers GSNs and developing countries an opportunity to amplify their monitoring and enforcement capabilities. After all, governments acting alone can't always anticipate how society's needs may change or all of the creative ways in which regulatory objectives could be achieved in the future. Nor can governments in either developed or developing countries necessarily afford the build-out of elaborate infrastructures for monitoring or supply an ever-growing field force of inspectors and investigators with the capacity to stay current with the latest technical, scientific and industry trends. Mobile sensing and participatory monitoring cannot address all areas of regulation, but in domains such as air pollution or traffic congestion there is an opportunity to piggyback on the sensing capabilities built into the mobile phones of billions of people. This suggests that GSNs could play a substantial role in governance by augmenting the regulatory functions of municipalities, regions and nation-states. By the same token, regulatory agencies that open up and collaborate with GSNs can stay more attuned to emerging issues and social expectations and leverage the complementary resources and capabilities needed to address them.

Mobile Innovations for Good will Spring from Multi-Stakeholder Collaborations

Create platforms for mobile innovation and networks for multi-stakeholder collaboration. To harness the power of people who organize themselves, you first need to build a platform or a context where potential collaborators can self-organize and contribute to solutions. If you are building a new mobile health information service, for example, don't simply load it up with static content. Instead, create the framework and tools for health care practitioners and even patients to create their own content and build communities. Such strategies can unleash the creative power of a larger, more diverse and ultimately more capable network of contributors than you could ever find in a single organization. But recognize that simply creating the platform for innovation may not be enough. Many collaborative communities never get off the ground without a core group of leaders that establish the vision and community values, help manage group interactions, champion the cause and attract more people to the ecosystem. This small group of key participants does a disproportionate amount of the work, often providing the social capital and technical infrastructure that other participants build on. All successful open source communities, for example, deploy structured and hierarchically directed processes for managing the tedious work of joining together all of the fragmented pieces and contributions. It allows these communities to harness an incredibly diverse talent pool while still achieving

the tight integration required for something as sophisticated as an operating system. A similar nucleus of committed individuals will be found behind any successful example of mobile innovation. If we want to tap into the power of collaboration we need to strengthen this vanguard.

Offer new incentives to build public good applications for mobile platforms. In particular, application development contests offer a means to incentivize and surface new mobile innovations. When the United States Agency for International Development (USAID) was looking for new ways to use mobile phones to address development challenges in poor countries, for example, it partnered with NetSquared to launch a Development 2.0 Challenge and put up $20,000 in prize money.[49] The winners, announced at the start of 2009, highlight the breadth and abundance of capability available in the civic sector. First prize went to a Child Malnutrition Surveillance and Famine Response system designed by a team of six students at Columbia University. The mobile application transmits nutritional data from growth monitoring clinics in developing countries to government and UNICEF databases, while providing instant feedback to mothers on the changing status of their child's growth and nutritional needs. Second and third place prizes were no less transformative. The runner-up was a health diagnostics application that connects health care workers in under-served regions to medical specialists and collects real-time data for interventions in areas such as maternal mortality, cancer or AIDS. Third place went to Ushahidi, the crisis reporting application.

Partner with leading innovators to foster public good applications of mobile technologies. In addition to contests, one of the best ways for GSNs to take advantage of the mobile technologies and capabilities described in this report is to partner directly with the companies and university research labs at the cutting edge. Universities such as MIT are well known for their numerous research labs chock full of eager grad students that are pioneering public good applications using advanced technologies. Most students would like nothing better than the opportunity to get involved in real fieldwork. Technology companies like Google, Facebook, HP, Intel and Cisco have demonstrated similar enthusiasm for getting engaged in global problem solving initiatives that showcase the social and environmental promise of their latest wares. In fact, projects such as Lifelines India, M-Pesa and the Mobile Health Alliance would not be possible without the support and involvement of leading technology players. However, business leaders that get engaged in GSNs will need to recognize that acute corporate self-interests and rivalries will need to take a back seat to the common good. Their task will be to promote the notion that by working together as industries, and by enrolling the support of civil society and government, they can extend and enhance the benefits of mobile technology for society.

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Global Solution Networks is a landmark study of the potential of global web-based and mobile networks for cooperation, problem solving and governance. This project is a deliverable of the research program, offered through the Martin Prosperity Institute at the Rotman School of Management, University of Toronto.

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