Institute for Security
And Resilience Studies
University College London

UCL

Exploring Data Generated by Pocket Devices

July 2013

Author
Vinay Gupta

The Institute for Security & Resilience Studies (ISRS) at University College London (UCL) provides a hub for scholars and practitioners to address the challenges of resilience and security in the 21st Century. We bring together the public, private and third sectors to seek out ways to catalyse innovation - so that we can all better cope with, and flourish in, increasingly uncertain times.

The contents and opinions expressed in this paper are entirely and solely those of the authors do not necessarily reflect the views or policy of HM Government or of University College London.

This paper was first published in July 2013.

Published by

Institute for Security and Resilience Studies
Gower Street
London
WC1E 6BT

+44 (0) 20 3108 5074

isrs@ucl.ac.uk

www.ucl.ac.uk/isrs

Institute for Security and Resilience Studies Limited is registered as a company in England and Wales. Registered office: 1 Beauchamp Court, Victors Way, Barnet, Herts, EN5 5TZ. Registered number: 06842634. VAT registration number: 103324470.

Table of Contents

The Brief

1. By 2020, very nearly every adult will have a cell phone, and a substantial majority will be smartphones. At the same time, advances in sensor technology make devices smaller, cheaper and more durable than ever before. In the US, there have been persistent suggestions of adding crude radiation sensors to cell phones to create a distributed sensor grid for radiological attacks, and security uses are only limited to available sensor technologies. A variety of medical devices (blood pressure, pulse rate, oxygenation) are becoming integrated into cell phones via small external devices aimed at athletes, and direct monitoring of other medical functions is (again) being developed at an ever-accelerating rate. Passive monitoring of cell phones is also extremely useful: traffic jams can be detected in real time, and the potential exists to monitor public panic events, civil unrest and similar disturbances in the normal flow of crowd behaviour. In some scenarios, life saving information could be transmitted directly to cell phones in an area depending on the threat at hand: a few minutes warning of an impending tornado, or spinal injury management advice beamed to everybody close to a car accident.

2. The two-way flow of data and advice presents a variety of huge technical problems: Consider creating suitable sensors and integrating these sensors into smartphones, as well as building business models for each kind of sensor's deployment, working with smartphone manufacturers and operating system vendors to make the sensors visible to application designers, and getting software written for ordinary users to take advantage of these new capabilities. Actually getting a common platform and standard for advanced sensors on consumer mobile devices could have widespread implications in fields as diverse as medicine and robotics. It's a unique systems integration problem even at the level of individual phones. When we then generalise to billions of phones, with a mixture of constant and intermittent data feeds, a variety of sensors available, and multiple hardware and software platforms, we see the scope of this problem and the potential for massive delays in deploying these new capabilities based on inadequate modelling and poorly managed standards processes. What are the fast tracks through this terrain to roll out both useful services now, but also to lay a strong foundation for the future of massively parallel sensor grids which can plug into smart cities, resilience, environmental monitoring, risk management and security roles? What are the correct primary metaphors to get diverse interests working together towards shared goals in this landscape? How do we facilitate the large scale cooperation necessary to achieve this? There are examples in previous times of correct standardization unlocking huge reservoirs of values (the PC itself, for example.) Can we replicate this success around sensor networks?

Value and Networks

What Happens When Things Change?

3. Thinking about the adoption of new technology in the early 21st century is easier if you have a theory of change. For our purposes in this paper, we are going to consider the *politics of efficiency* as a compass for looking at the changes wrought, and the positions taken, in an age of cheap information.

4. Consider a simple, abstract model of an ancient marketplace – a literal agora, a big square where people buy and sell. In this abstract marketplace are customers, vendors, guards, tax collectors, thrives and the like as one would expect.

5. Now let's imagine our mythic marketplace grows in size by ten times over a period of years. What are some changes that come with the new scale?
    a. Economies of scale may allow vendors to produce goods more cheaply;
    b. Vendors and customers may both feel even more reason to come to the marketplace, each drawn to the venue by the greatly increased number of potential trading partners;
    c. More specialised vendors may arise as customers with specific tastes now exist in sufficient quantity to allow them to turn a profit; and
    d. Various fundamental costs of running the market (price of guard labour, particularly) may increase less rapidly than the taxes raised from the market, making it more profitable for those raising taxes.
6. As the market grows larger, and in certain respects more efficient, the shifting ratios of costs and benefits may create a series of tipping points or phase changes in the market: monopolies may arise or be destroyed, or new classes of trade become possible because of concentrated demand, or sufficient taxes may be raised to pay for new infrastructure for trade like roads or canals. There may be competition between different classes of actors to grab the lion's share of increases in fundamental efficiency too.
7. If we take the simple example of an economy of scale, where producing ten times as much of something halves the price of production, consider the following simple outcomes:
    a. retail price drops keeping pace with production cost: customers get the benefits of the economies of scale;
    b. retail price is maintained at the previous level, leaving vendors with much wider profit margins which they keep, benefiting from the economies of scale;
    c. retail price is maintained at the previous level, but heavy new taxes are levied against vendors, giving the tax collectors the benefits of the economies of scale.
8. Of course, in the real world, changes of this kind are rarely simple, and far more complex negotiations and transformations occur to capture the creation of new value as efficiencies increase in some given area.

    In this paper, we will suggest it is the *conflict over the wealth created by increases in fundamental efficiency* that is at the heart of the struggle to deploy "smart" technologies in nearly every area of ordinary life.
9. Instead of an economy of scale (although those exist too) we have an economy produced by ever-cheaper information and better-quality automated decision-making. One might even refer to these as the *economies of omniscience*. The conflict between various parties to capture this value creates a set of political conflicts which are at the heart of the problems deploying technologies like Smart Meters, never mind the whole scale reengineering of the urban network.
10. **It is important to consider the whole smart cities / urban devices area as a series of efficiencies added to existing markets just as much as a new set of markets being created.** Resistance to change is usually rooted in a preference for an existing status quo, or a hidden cost to adopting the new methods that has not been taken into consideration.

Dotcoms – A little goes a long way

11. The classical dotcom business models included many simple reimplementations of existing business models. Most typically catalogue sales became e-commerce sites. Disintermediation of businesses that were not sufficiently agile killed market sectors like travel agents. The result was a general leap in efficiency, resulting in improved competitiveness, lower prices, and a general jump in customer satisfaction.

12. Then the second-order effects started to kick in. Amazon, having taken a sufficiently large sector of the mail order market, started to have new kinds of market power. It could track trends across extremely large numbers of people, and use this information to optimise what additional materials it attempted to upsell people or recommend when they were shopping. It could also target advertising more accurately using its models of people's behaviour. All of this value was captured within Amazon because they were conducting the statistical analysis on data they had gathered - a market efficiency which only one of the players could capture. It is notable that the dotcoms are generally not paying regional sales tax either, at least in America.

13. The current "new new thing" in dotcoms is "social." Google, LinkedIn, Facebook, Twitter and many others all maintain a "social graph" about their users: a semantic map of who you know and who you talk to. Some of these networks (Twitter) are sparse - they just map whose tweets you want to read and who you talk to. Others (LinkedIn, particularly) are rich, they ask you to identify how you know people - employees, employers, co-workers, contractors and so on. At this point, none of the major online retailers (or even music services like iTunes or Spotify) have managed to successfully integrate social features. There have been several attempts, including Apple's failed social network built into iTunes, but for whatever reason, the spark has not jumped yet. The social network we talk with - often including product recommendations - has still not become integrated into the retail systems which recommend products to us. This is extremely odd, all things considered, given how we tend to form tastes depending on what our influences our friends expose us to, and what we are recommended.

14. A similar mysterious market gap is neighbourhood networks. Although some apartment buildings now have Facebook groups, the needs of people to coordinate with their neighbours are not integrated into any of the social services, or into internet retail (i.e. bulk purchase, delivery cost sharing, holding deliveries for neighbours etc. are all unexplored.) The uneven and unexpected nature of success or failure in the social graph is very important when considering the wealth created by sensor networks.

The wealth of (sensor) networks

15. We now have an analytical framework from which we can examine wealth creation by the extension of sensor networks, largely carried by building-integrated devices and phones, personal communications terminals and other "pocket devices." As with many other new technologies, they are entering an existing marketplace filled with structural conditions sometimes created over centuries (consider London's complex jurisdictions including the City of London.) It is the pervasive disturbance of existing conditions that creates both the resistance to change, but also the opportunities created by new technology. The critical challenge is figuring out how to divide the pie - and explain how the pie is being divided - to a population which is sceptical about technological change and the increasing shift of power toward vendors brought about by whole-systems integrations of the type managed by Amazon and Facebook. This is not simply limited to the financial rewards generated by these smart systems as they come into cities, but

also the shifts of risk, responsibility, differential empowerment of different demographics.

16. Below, in some short case studies, we will examine how dotcoms like Uber place pressure on taxis, and AirBnB puts pressure on hotels and contributes to changing San Francisco rental markets. Here is a common thread through both of these stories:

    a. A situation changes in a way which creates gains or efficiencies in an existing marketplace
    b. Different actors in the market place have strategic options to attempt to capture some of the value being generated by these shifts
    c. Parties losing power or control will resist the changes, unless the deal is sweetened in some way
    d. The goal of system integrators is to get the size of the pie to rapidly increase for all parties by deploying new technologies swiftly.

17. It is within this frame that we can actually ask some questions about the future of smart devices in a way which is politically and economically realistic, rather than being simple technological futurism. As the size of the pie is increased by these technologies, and as they change the shape and flavour of the pie, the political equilibria at the heart of our society, and particularly at the heart of our cities, change.

Lightweight case studies – AirBnB and Uber

AirBnB – a decentralised hotel?

To make room for employees, Brian Chesky gave up his bedroom and lived through the Airbnb service until the company moved into its first office space.
(Robin Wauters, TechCrunch.com, June 2010)

18. AirBnB is a successful company which operates a central reservations service for renting other people's guest bedrooms as a sort of decentralised hotel. I have used the service myself several times, including one very successful holiday around Spain during which I barely touched hotels. AirBnB has a current valuation around $10,000,000,000 and was listed as one of the new Billion Dollar Startups by the New York Times. (The New Start-Ups at Sun Valley, Evelyn Rusli, The New York Times. 8 July 2011).

19. Why does AirBnB work? There are four key technical considerations:

    1. AirBnB handles the money, taking payments and ensuring there are no billing problems.
    2. AirBnB provides insurance on the transactions, particularly valuable for homeowners.
    3. AirBnB provides a trust-and-accountability framework for substandard accommodations.
    4. AirBnB collects enough offers into one place to establish market prices for this new class of services.

20. There are also some minor transactional glitches which have recently been ironed out of the economy making AirBnB easier to use. Ubiquitous digital maps mean that finding one's way to a quiet residential neighbourhood is easy, even in a foreign country. This makes the transactional friction substantially less than it would have been if, say, AirBnB had started in the 1990s when digital walking and public transport maps were still poor or non-existent. The impact is that real estate markets are starting to shift, because renting a room out for a week or a month can bring in as much money as sharing the house with a roommate (Short-term rentals disrupting SF housing market, SFGate, Carolyn Said June 10, 2012). New York City considers AirBnB a substantial threat to the current order of business, and is making moves to hammer the service (AirBnB Vows to Fight NYC Ruling Against Room Sharing, WIRED, Marcus Wohlsen, 6 June 2013).

21. **AirBnB is perhaps best understood as a "smart city" version of the hotel.** A smooth, highly liquid, instantaneous feedback digital market for accommodations, running on remote computer clusters, smart phone applications, decentralised trust networks, reviews-and-reputation, with digital images piped over a network to let people understand exactly what particular experience they are buying without the brand-name of Hilton or Motel 6. You can get better information about where you will be staying for the evening from AirBnB than from the Radisson web site: you can see the room, often right down to the books on the bookshelf.

22. This is entirely typical of the way that digital networks intersect with the world, transforming the traditional structures and institutions.

Uber – a taxi in every driveway?

23. Uber takes the conventional taxi model - tightly regulated vehicle fleets with centralised dispatch - and breaks it open in much the same way as AirBnB. A wide variety of commercial vehicles (rental limos) and personal vehicles become available for hire, often (but not always) from commercial drivers who are waiting for other gigs. These one-ride microcontracts work almost exactly like taxicabs, but with a digital network (a smartphone app) doing the dispatch and the usual internet profile system providing the trust network. Needless to say, Uber has run into the same kind of regulatory opposition as AirBnB, with New York City leading the charge. A NYC taxi medallion (license) typically changes hands for around $100,000 so there's everything to play for.

24. Uber's current valuation is around $3,500,000,000. (Uber Looking To Raise An Uber Round Of Funding Led By TPG, At A $3.5B Valuation Ryan Lawler, TechCrunch, July 2013).

Digital capital and physical infrastructure

25. Uber and AirBnB have market capitalisations equal to many much older companies with vast physical assets. How is this possible?

26. The answer is that as digital networks interpenetrate existing markets - in this case, transportation and housing - the basis of value in these markets is transformed. Uber and AirBnB have huge market capitalisations because they are the mechanisms by which *vastly larger* pools of capital are managed. AirBnB has around 250,000 listings. (With Neighborhoods, Airbnb expands its horizons, CNN, Jessi Hempel, November 13, 2012).

27. How much value is that? 250,000 homes at an average value of $200,000 each would give a total value of $50 billion. Roughly 1/3 of each home is being let, giving about $16bn of rough capital value. AirBnB is being valued by investors at a very substantial fraction of the capital assets that it makes a market for. Uber does not disclose how many cars it has on the books, but at $20,000 per vehicle, the numbers add up almost as fast as housing (given that 100% of each car is in use at the time it is being accessed, rather than a fraction of a house).

28. (All of these estimates are very approximate, and cannot likely be made accurate without very extensive access to proprietary data).

29. Subtracting out unrealistic dotcom value still leaves several billion dollars of value being captured by the control structures which give access to - and make a market for - precise access to physical capital assets when required. **This is a pure information market which is extensively dependent on pocket devices for access to the physical needs and wants of ordinary people.**

30. The transformation of life brought about by pocket devices is most clearly felt in places where information changes the mechanisms by which people access the physical capital assets around them. Let us look at two more examples:

Barclays Cycle Hire aka Boris Bike

31. 8000 bikes at nearly 600 stations, with nearly 50000 rides being taken in a single day. Nearly half of the bicycle users are new users who would not otherwise cycle in London.

32. The critical pocket device aspect of this is that finding out where you can get a bike - how many are in any given location, for example - is only possible because of the digital network. Similarly, figuring out where there is an empty stand to check the bike in at your destination is also done using a digital device. The overall characteristics of the network - for example, picking up bikes in places where too many accumulate and trucking them to bikeless locations - are also managed by digital systems.

33. These bikes are not actually bikes any more, any more than an AirBnB house is still a conventional single family dwelling, or an Uber'ed limousine is just another hire car. The digital network which provides coordination functions is actually a fundamental domain-crossing infrastructure which carries the goods where they are useful, in a manner similar to conventional non-digital markets of the past.

34. The critical distinction is that market makers - Uber, AirBnB and the Boris Bike administrators - have a fundamental top-down understanding of the system at all times because the assets which are inside of the asset management network are completely legible and controllable through software and digital networks. The element of making the previously-invisible economic opportunities visible is key to understanding why these new networks are rapidly displacing more conventional market access systems, and moving the markets in new directions. Although superficially bicycle hire, car rental and rooming houses have always existed, enormous value is being liberated by the shifting landscape of digitisation. The top-down god's eye view of these kinds of markets has never existed before, and whole systems optimisations like trucking bikes to where they will be needed ahead of time would be much harder in a network of small, independent bike hire shops. The efficiency gains of these systems are substantial, and there is now a

head-on struggle for who will control this value: customers, vendors, taxmen, or these new digital market-makers, the brokers.

Automated Transport Networks

35. An Automated Transport Network (ATN) is a head-on collision between the Docklands Light Railway (DLR) (and any similar self-driving train system) and the Boris Bike. A simple ATN is in use at Heathrow Terminal 5, the "Heathrow Pod." In the system, small six-seater self-driving smart electric vehicles navigate special tracks. Self-driving is already reliable within safe limits in a tightly controlled environment, as we have seen with the driverless self-driving trains of the DLR. In an Automated Transit Network, passengers summon podcars by going to stations and indicating where they want to travel to, rather like calling an elevator. When a car is free, it picks up passengers, and takes them to their destination. These self-driving pod cars can pre-position themselves according to anticipated needs, a much more elegant solution than trucking Boris Bikes around London to meet demand. Larger podcar networks begin to take on the characteristics of packet switched networks like the internet, where cars are routed across a complex network by software which computes optimal routes, including awareness of all the other cars in the transit network. A large ATN is a little like a road network with self-driving cars, if the roads were free of all other vehicles and the system was globally controlled by a central intelligence that never makes mistakes. Indeed many ATN proposals suggest running many of the ATN tracks above existing roads and occasionally buildings.

36. ATNs have been discussed and implemented on a trial basis for almost 50 years. In Morganstown, West Virginia in the USA an ATN project started in 1970 and is still running today. However, as more sophisticated digital systems come into play, the barriers to these kinds of systems come down and down. An ATN system with tight controls can use the combined battery capacity of its entire fleet as a peak electrical grid load resource, for example. It can swarm cars to areas where a large mass of people will seek transport at an anticipated future time (the end of a concert, perhaps). It can route cars by the most efficient route *for the network* perhaps at the cost of suboptimal routing for the individual, and so on. More or less any given algorithmic optimisation or preference can be added to an ATN network, including premium access for a higher price, direct routing in which high priority traffic displaces other traffic to less direct routes, and choices about which events to pre-position the car fleet for. All of these decisions are possible in software, without having to modify the fundamental hardware of the network.

37. At this point, we cannot easily imagine what an ATN-like transformation might look like in terms of other physical assets. But imagine a "fully decentralised hotel" in which an AirBnB-like marketplace is paired with a comprehensive system of electronic locks. A guest rents a room and has a "key" transmitted to their personal electronics. This key then opens the door for as long as they have paid for the room. Sensor networks inside of the room monitor for abuse (i.e. fire) and take intelligent action to protect the room, much as ATN network cars which detect attempts to damage them could auto-drive to the nearest police station. The relationship between owners of assets, users of assets, and the customary markets is completely transformed: goods and services fluidly interpenetrate as higher-order synchronisation functions are managed by digital networks which ordinary people access through their "phones." Pocket computing terminals plug everybody using them into a nascent "Enterprise Resource Planning"

system which actually manages assets across a huge number of owners, peering both individual and company assets in a single accessible web.

Pocket devices *terminals to access networked property rights*

38. Once a pocket device like a cell phone is understood in its true context - as a node in a set of enterprise resource planning type systems which mesh together to give fluid access to resource on demand - it becomes much easier to reason about their utility when used as sensor nodes under non-normative conditions like natural disaster.

39. It is the embedding of **complex property rights in the electronic network** which the pocket device gives access to that is the key to understanding the future sensor-grid environment. The phone is the access terminal to the digital property rights network, including the markets, property rights registers, and logistical/technical data including transport availability, energy prices and so on. All of this information is built on the same social foundations of the pre-Medieval marketplace, scaled and expanded to a real-time data environment. The information about where the train is, when it arrives, and how likely it is to be on time is information about a networked property right - "can I exercise your option to ride the train at this time?"

40. The traditional marketplace conflicts between Customers, Vendors, Guards, Tax Collectors and Thieves still underlie the struggles in the integration of pocket devices into our lives and society. What starts with electronic photo albums to be shared with grandma escalates into a whole scale fluidisation of property rights at the heart of our societies - housing and transport today, perhaps intellectual property, seat reservations at restaurants, concert tickets - even food supply, water supply and electrical power supplies tomorrow. Although the pocket devices start as simple terminals, once the terminals are sufficiently widespread, the entire world starts to look like a trading floor.

What is, what you know worth?

41. **In this environment, ordinary people may now ask: "What is the data that I generate worth? What can I exchange it for in this global marketplace? Who can I trust to give me a fair price?"**

42. In the pre-medieval marketplace individuals had a little knowledge, and could use it for competitive advantage in their local marketplace. There was no possibility of aggregating the data about what was in the marketplace to increase efficiency.

43. In the networked property rights environment, extremely large analytics analysis can produce efficient decision-making on a scale never before imagined. A simple example of this is **targeted advertising** in which the data trail left by an individual's day-to-day activities is aggregated and correlated with the behaviour of a billion or more other individuals. The insight into an individual's behaviours and preferences from just their history is relatively small. But compared with a billion other individuals, spotting trends and correlations, and the increase in effective economic behaviour is large. How large? 96% of Google's revenue of $38,000,000,000 is generated from targeted advertising, with targeting guided by detailed profiles of user search history, browsing behaviour, contents of emails and so on (96 percent of Google's revenue is advertising, who buys it?, VentureBeat, Meghan Kelly, January 29, 2012).

44. It is all grist for the mill. But all of this value was generated from individual users simply living their lives. Google has managed to create $15 per year of value from every human being on the internet ($38bn of revenue, 2.5bn internet users). This is the value of correlated behavioural data. Profile data is valuable. Aggregated profile data is *incredibly* valuable.

Smart Cities: liquid networked property in the urban future

45. Smart Cities envisage applying this kind of monitoring and optimisation to cities: enterprise resource planning and logistics optimisation type approaches. If the data from people's netsurfing activity is worth an average of $15 per person to advertisers, what's the value embedded in pervasive life stream data to:
    1. Advertisers
    2. Brands (designing products, watching how people interact with products)
    3. Transport planners and providers
    4. Tax collectors
    5. Disaster managers
    6. Power companies
    7. Real estate companies
    8. Medical services providers
    9. Food and fuel logistics companies
46. It is very clear that pervasive awareness from pocket devices in smart cities is extremely valuable once systems start to optimise around human behaviour. Until very substantial datasets are available, estimating the actual value of the data is difficult - what can be correlated from these streams? What non-obvious optimisations and business models exist? If, for example, the housing market shifted by a few percentage points based on different real-estate provisioning patterns (already suggested to be a factor in some areas from AirBnB as we saw earlier) the total transfer of wealth involved is massive. "Smart Cities" (IBM) or "Sustainable Connected Cities" (Intel) envisage using huge data networks in concert with smart end-use devices (internet-connected refrigerators and air conditioners) to hugely reduce peak electricity loads in cities, trim transit times by optimising road traffic flows and transit interconnections and so on.

The future hardware environment

47. The extremely rapid technological acceleration we are currently experiencing is nowhere clearer than in pocket devices. The profusion of kindles, iPad Minis, new pocket gaming devices from brands like Nintendo, multi-core smartphones with more computer power than desktops had only a few years ago, Google Glass, bracelets which monitor heart rate and physical activity (streamed to the web through your cell phone) and so on amount to a Cambrian explosion in pocket gadgets to improve your experience of life. Although extrapolating consumer electronic trends is notoriously fraught (when, precisely, is "virtual reality" going to go mainstream?) the basic trends forwards in these devices are unmistakable: more processor power, more readable screens, better data connectivity at lower prices, with distinct signs of breakthroughs in form-factor to come. Devices are increasingly *expressions of underlying software*, as is particularly visible in

various health monitoring systems which interpret the output from a networked pedometer to rate your health and fitness.

48. Progress is dizzying.

49. However, these devices are mainly sensors. What progress is there in effectors? The primary visible push includes:
    a. Smart meters (allowing remote monitoring and control of electricity use)
    b. Self-driving cars (further out, but potentially more revolutionary)
    c. More flexible and widespread industrial robotics (from the mundane self-checkout through to automated production lines for iPhones)
    d. Quad-copters and other small flying devices (undergoing enormous increases in sophistication and availability, including discussions of parcel delivery by quad-copter as a service in major cities).

50. The pocket device revolution does not happen apart from progress in other areas: networked property rights intersect with advanced software for feed synthesis driving the inputs to self-provisioning transport systems. To focus on the device alone, rather than the systems it provides an interface to, misses the point: as Sun Microsystems used to say, "The Computer Is The Network." The pocket device's power comes from its network, not from the trivial sliver of computer power that resides on it, or a little bit of personal data. As we approach this convergence, ***every industry connected to the web of networked property rights is going to struggle for its share of the pie.***

51. How this convergence will affect ordinary people going about their day to day business is uncertain. Let's think about three scenarios:

Privatopia

52. In the Privatopia scenario, the data captured by pocket devices and ambient sensors (like house thermostats) is mainly controlled by agencies which operate in the public interest. A good candidate might be an equivalent of the Free Software Foundation or Linux. Although people think of Free Software / Open Source as a minority pursuit, Android phones are built on Linux (Android is Linux in Java, and regarded by Google as a version of Linux). Android is currently 50% of the smartphone market and accelerating rapidly, and although it is being spearheaded by Google, the codebase is substantially open to all. The possibility of an Android variant escaping from Google's hegemony and pooling data not in Google's servers but in an independent stack is entirely realistic, particularly given the doubts about Google's long-term intentions from the European Union. In this scenario, consumer activism produces a large scale data repository operated by a non-profit group which processes and sells the data on behalf of the collective of users, perhaps even with democratic governance of the organisation (vs. a public interest mandate and "if you don't like it, don't send us the data").

53. Smart cities etc. then only get access to the mass of consumer data if they meet the necessary privacy and service covenants imposed by this "digital consumers union."

54. Is it possible? I would estimate this to be of a similar level of complexity to the invention and propagation of the public library as an institution: it is a similar level of community self-organisation and coordination, with a broadly similar complexity and cost. Possible, of course, does not mean likely, but the future is full of surprises.

Googleworld

55. A substantially more likely pathway is that Google (or Apple, or some other company) winds up offering a single dominant technical standard for interactions between pocket device users and the wider world. Microsoft, in its day, had sufficient market share that systems had to be at least partially compatible with Microsoft standards to be remotely functional in a networked environment - and if you need partial compatibility simply to exist, why not go for the original-and-standard rather than using a compatible variant? In the current system, Google could become a hub-and-spoke vendor, where even non-Google systems use Google-operated APIs and translation software to talk to other systems. The Smart City winds up as a Google product on the cell phone which interfaces with an IBM/Intel/etc. implementation at the thermostats-and-batteries level. Technical hegemonies of this kind are typically not that stable - Microsoft was unassailable in the early 1990s and was blindsided by the internet badly enough to take nearly 20 years to find its feet again. Although it is not currently possible to see where the chink in such a hegemony might be, the constant onrush of new technologies will surely open the landscape in unexpected ways.

56. The counterpoint to this possibility is VISA, which has managed to surf wave after wave of change while retaining a very substantial hegemony. The VISA system has unusually flexible governance, acting as a representative organisation for card issuers: perhaps this continued ability to change the membership of the governance body explains their longevity? In any case, the prospect of Google or some other company becoming the definitive data-broker that realises the bulk of the value to be made from finding and exploiting correlations in the pocket devices / smart cities / big data ecosystem is very realistic, and perhaps not entirely reassuring.

Singaporous

57. What if the State steps in to realise the value in this "ecosystem of correlations" on behalf of everybody? Although typically the state has lagged far behind private enterprise in its use of technology, certain states and departments within the state have shown an almost disturbing faculty with technology. Perhaps the future technical ecosystem could be largely operated by the nation state, in much the same way the financial system once was, with government-run "cloud" infrastructure taking the same kind of role in society that government-operated railways and electrical grids once did. Although this seems improbable, given the market-led technological charge in America and the European Union, countries like Singapore and Estonia have shown that a more nimble state can use technology in unexpectedly effective ways. Could a government-run digital backbone support commerce, while maintaining and upholding the balance of interests between individuals and the companies that provide their services?

58. Although on first blush this seems impossible, the nation state has several very substantial levers to effect an expansion of its role into this territory. Anti-monopoly law, the ability to flexibly and selectively grant, withhold, and even invalidate patents, licensing and contracts at the municipal and national level and so on all form a suite of policy instruments which could channel development of a national solution to the economic opportunity presented by integrating diverse data sources into a coherent overview of what is happening in society. In this scenario, the full force of law might eventually be deployed to stabilise this equilibrium, in much the same way that "coin of the realm" secured the state's role in trade even in the time of the gold standard.

What's Next?

59. While prediction is difficult, especially of the future, it is possible to identify some key pressure points and opportunities in a few key sectors as areas for further investigation and study. For each area, there are two key questions: what is the critical value being created or enabled by the network, and who are the parties that will lay claim to most of that value.

Transportation

60. There are at least four or five on-going disruptions in transportation already:

    1. Death of the travel agent as democratised information about travel options is paired with search engines. This trend has probably run close to completion.
    2. Fluidisation of markets for vehicle rental, with or without drivers, including car sharing schemes, car rental search engines and so on.
    3. Bicycle schemes now operate in many major cities and with increasing familiarity may pave the path for sharing other forms of transport.
    4. ATNs look set to go through another round of deployment and development in the next few years, following on from their success in Heathrow.
    5. Transport route planners for metropolitan transport networks are now ubiquitous (Transport for London Route Planner) and urban transportation options are increasingly difficult to understand without using them.

61. Even with all this change, however, the bus is always late, the train always has either too many stops or too few, and prices are generally-speaking, far too high.

62. Is it possible to more accurately match transportation availability to demand? Do buses always have to run on the same routes to be effective, or is it possible to have some variations which are navigated using pocket devices? For example, after a major event like a football match or a concert, transportation networks are manually adjusted to manage the spike in demand: managers anticipate demand based on previous patterns. But for one-off events, could a small amount of reserve capacity be deployed on the basis of people in a large crowd sending out information about their future transport requirements? A system which say, instead of "hail me a cab" something like "in 20 minutes I'm going to want to go to Finsbury Park" coordinated with GPS, and – in the event of surge traffic, rather than polling for cabs, buses come. This is an example of "demand-side aggregation," a common model when dealing with energy grids, but not commonly applied to transport. But in such a model, although the possible efficiencies are clear (when not enough people want a bus late at night, fail over to taxis) what is not clear is how to resolve conflicts of interest between various transportation vendors in a common marketplace.

63. Another area where integration is possible but challenging is transit interchange. Many journeys are multimodal: train to tube to train to plane to taxi to hotel is a common enough pattern. At every stage different payment instruments are used: one cannot pay for a tube with an Oyster card as yet. Planning systems do not operate internationally: a user has to manually carry state across the airline travel site through to the train time table through to the tube planner to guess when they have to leave home to make their flight. And there is **certainly** no integrated payment gateway giving access to the entire

trip (what the customer actually wants to purchase) – every step is a different transaction.

64. It is unlikely that these issues will be resolved by a series of bilateral integrations. Rather, at some point, either a new payment standard or a new transport planning standard will result in a discontinuous evolution and the transportation network will be represented to users as a single useful interface, rather than as a series of cooperating-and-competing vendors without any over-all planning or responsibility for travel. An example of this in a common consumer version is Amazon. An enormous number of vendors, with multiple different logistical supply chains, are presented as a single store, with a single payments interface, dispute resolution system, review mechanism and so on. Although it seems like a stretch to imagine this for transport, it is clearly the way we would all like transport systems to work, and all that is standing between us and this condition is software, perhaps a small modification to payment systems, and cooperation between vendors who at-root have common interests. Every step towards this outcome will be seen as a step forwards, but who is positioned to take those steps, and to make them possible?

Logistics

65. Everything which is happening in transportation is also happening in logistics, although automation and integration are much further advanced in logistics than in people-moving. However, there are no shortage of horizons here either. For example, nearly every expedited delivery results in the use of air freight or expensive ground-based couriers to bring whatever component or device is required from a central depot. Huge energy is consumed, and there are often similar delays. Imagine a system where users could locate other people who had bought the device I was looking for in a hurry and ask whether I could buy-and-replace their unit. The archetypes of this situation are many: lost telephones, forgotten laptop chargers, a video projector that gets dropped on just the wrong day, car parts – or in a disaster, insulin, asthma inhalers, immunosuppressants. The world is a dilute solution of these objects, but because there is no way to search for them or to establish a transactional framework for retrieving them on demand, there are often expensive delays when problems arise. But in all probability, the credit card transaction records exist for most of the purchases of the objects in play. How could a privacy-and-market-making mechanism be created to replace expensive air freight with local sources, extras ordered and held in stock, or used equipment. This is a more subtle problem than eBay solves, because eBay requires an active act on behalf of the user to list items. Instead, envisage an automated logistics package which knows where things can be sourced from conventional suppliers and, in a pinch, can find you parts from a place down the road that just got a delivery, but would sell now for a premium.

66. No individual instance of such a system looks particularly significant. But a society which allows for such a search-and-use function (either for ownership or, even more powerfully, for rental) is an efficient society. The barriers between people and the things they need are largely informational, and reducing those barriers, for both purchase and sharing, is a huge gain. Negotiating the technical hurdles to this transformation is not easy, but navigating the social hurdles may be even harder. Perhaps there are narrow verticals in industry where companies in the same line of business could use each-other's supply chains as buffers, at a premium?

67. As information costs reduce and reduce, the balance of effort between physically moving objects half way across the world versus finding locally available resources changes. Right now this innovation is largely trapped inside of Amazon and Wal-Mart within their own logistical systems, but these systems only capture a fraction of the total need for dexterous logistics. What is the AirBnB or Uber of fast logistics? Only time will tell.

Energy

68. Concepts like smart grids and smart meters are pervasive in visions of the "next grid." Likewise concepts around decentralisation of energy resources so that, for example, air conditioning loads can be met directly by buildings with solar panels on the roof, taking advantage of the happy coincidence between maximum output from solar panels and maximum need for electricity for air conditioning.

69. Another common concept is "demand-side utilities" where (typically) smart thermostats in industrial refrigerators are asked to turn off for a while at moments of extreme peak load, freeing up much-needed grid resources for other users. Operators can over-cool their storage facility during times of low demand specially to free up capacity for these peak events. This is economic because peak load handling capacity is very expensive indeed compared to normal electricity provision.

70. However, this model is completely transformed in the environment being created by the intersection of ultra-cheap solar panels (expected to reach grid parity in the next few years) (Residential Solar Power Heads Toward Grid Parity, Peter Fairley, IEEE Spectrum, 28 Mar 2013). In many areas of the world it will never be economic to build an energy grid if solar energy continues to make progress. But solar is less than ideal for spike loads, leading to systems in which normal baseline loads are met by solar, but spikes are met first by shared batteries, and then by a failover to a diesel generator. The coordination challenge in providing good quality, reliable to energy to the many billions of people on this planet who lack access to a stable European/American style grid is substantial. But it is as much a challenge of business model and software design as physical hardware: the coordination and management of energy resources, simulations to ascertain optimal hardware configuration to meet demand, forecasting low energy availability periods and so on are all within the "pocket devices" paradigm. The smartphone becomes the interface to the power grid, the microgrid and the power market – local devices charge when power is cheap. This paradigm also covers water, waste disposal and many other infrastructure services in which spike demand is extremely expensive.

71. Although it is unlikely that our societies will radically adapt to demand-based pricing, current estimates forecast billions of people moving into the rapidly scaling and built-from-scratch cities by 2050. Around one billion people live in areas which are typically characterised as slums, but which could also seen as being informally urbanised. As the "feature phone" (typically manufactured by Nokia) is replaced with smartphones even at the base of the pyramid (a process picking up considerable speed already) new business models to solve the basic problems of human life may come out of the slums first. The combination of fluid communications, solar power and energy markets could provide near-grid services at a fraction of the cost with substantially better capital-handling characteristics (i.e. small purchases made frequently, rather than large up-front investments). Perhaps a laboratory or observatory looking for and fostering innovation in energy and other utility provision in the slums would be a useful source of much-needed innovation in our critical services.

Blue light services

72. Finally, let us consider the all-important blue light services. There are a wide range of useful services which our network infrastructure could do in an emergency. Consider four short scenarios:

    1. A car reports that it has crashed, using an on-board communications system. The speed of the crash suggests severe injuries, and the health monitoring bracelet worn by the driver (typically used to measure sports performance) indicates severe injuries. Cars nearby (and pedestrians) are automatically alerted by the 999 dispatcher evaluating the data from the car. The alert includes basic safety information, including instructions for not getting hit by passing cars when people stop to help, and instructions to not move anybody who's neck has been stressed unless their life is in immediate danger.

    2. A building reports that it is on fire. It provides fire fighters with a detailed map of the last known position of each inhabitant, and people are checked off a register as they are found at the assembly point, or rescued from the upper floors by fire fighters. Plans of the building are relayed to the firefighters as they are dispatched to the fire, with preliminary information from the building on where people were when the fire started. In areas where it is dangerous to send a fire fighter, small flying drones perform an inspection, remotely monitored by a remote facility.

    3. An older person has fallen. Neighbours are alerted by the 999 service and are issued a one-time electronic key code to open her front door. Once inside, they discover that she has stood up, dusted herself off, and is fine. Automated systems sometimes over-read. She and her neighbour have a cup of tea. The credit for going to check on the call is redeemable against swimming at the local pool, overdue library items, and similar local services provided by the council.

    4. There is an enormous flood. Tens of thousands of volunteer responders are going house-to-house to help people in vulnerable areas evacuate before their homes are inundated. Because of detailed measurements of rainfall and rain absorption, there is almost two days notice of what will flood (with >90% confidence) and families are helped by volunteers to get their valuables to upper floors, sealed in plastic, before the river bursts its banks. The combination of advanced notice and large scale volunteer efforts greatly reduces the cost – both human and financial – of managing the flooding produced by changing weather patterns. Similar programmes exist for managing a wide range of contingencies, up to and including pandemic flu. Organisations like the Scouts form the backbone of this civilian contingencies effort, and the combination of civic engagement and practical skills makes it a popular activity for teenagers and young adults in many areas.

73. In all of these scenarios the hard issues are not technological: they are about using technology to enable trust and cooperation in a catastrophe. The development of stories like these in the real world will be equal parts easy-to-use technology, and the careful creation and restoration of social fabric: helping people to help each-other as a way to extend our ability to respond to the difficulties we all face at times.

Conclusion

74. Progress towards a world dominated by concepts like the internet of things, smart city, always-on lifestyle and so on seems certain. In such an environment, the ability to understand what is happening in the world may exceed all previous levels, giving historically novel opportunities to coordinate action in ways which change fundamental underlying economic efficiency. The size of these shifts is enormous, so enormous that *globalisation* may, in the long run, be understood as simply the first phase of a much larger and more all-encompassing transformation. There is no telling where this ends, as every twenty years delivers a million more times computing power. There has never been a time like it.

75. The technology makes most imaginable things possible. Political and social factors constrain those possibilities down existing channels, as forces like regulation and capital allocation act on the raw stuff of technological potential.

76. Companies with the ability to deploy complex technological systems on behalf of government have a complex set of decisions to make about their positioning relative to the formation of a critical mass of correlated data which gives those with access to it decisive advantages in scheduling, demand forecasting, targeted advertising, medical care, logistics and almost any other area of business.

77. The fundamental tensions which have been with us since the discovery of the marketplace are with us to this very day. Positioning relative to this transformation requires a deep understanding of the political structure of these markets, simultaneous with an accurate understanding of the technological options which all sides have to bring to the table. The fundamental economic efficiency of our societies are in flux, so it is all to play for. In particular, the question about whether this kind of information synthesis function is a natural monopoly, and if so, questions about who will exercise and regulate that monopoly are key.

78. Governance structures and business models which are durable during times of exponential change in fundamental capabilities are unknown. Rapid technological change of the kind we are currently experiencing has some precedents, but very few structures from those periods of history were not hit *hard* by technological change. Identifying the worthwhile niches and business models - and, indeed, agendas for governance in such times - requires a constant, diligent questioning of previously-fundamental assumptions about the nature of the environment.

79. In a science fiction scenario, the human race might have a single big database into which the state of play in the material world was entered. Software would run against this database, and optimise our affairs. Money in the conventional capitalist economies is understood to work rather like this, with price signalling substituting for more sophisticated modes of communication (i.e. networking). What divides us from that state at this point in time is largely historical anomalies and politics: the technology is certainly there. How our history will intersect with unimagined possibilities for various kinds of global optimisation is currently unknown, but it is against this backdrop that the current round of confusion around copyright must be understood: an old order and a new order contest to provide goods and services to the people. The pocket devices and ambient sensor networks is another future battleground as the current equilibria of our societies are disturbed by now-constant change.

80. There is no easy way to pick winners in this environment. However, there are solid ways to pick losers: any actor that does not understand what is changing, and why, will rapidly be spaded under by coalitions of actors who understand the changes that are happening, and are aligned towards the future.

BIBLIOGRAPHY

The New Start-Ups at Sun Valley, Evelyn Rusli, The New York Times. 8 July 2011.

Short-term rentals disrupting SF housing market, SFGate, Carolyn Said June 10, 2012.

Airbnb Vows to Fight NYC Ruling Against Room Sharing, WIRED, Marcus Wohlsen, 6 June 2013.

Uber Looking To Raise An Uber Round Of Funding Led By TPG, At A $3.5B Valuation Ryan Lawler, TechCrunch, July 2013.

With Neighborhoods, Airbnb expands its horizons, CNN, Jessi Hempel, November 13, 2012.

96 percent of Google's revenue is advertising, who buys it?, VentureBeat, Meghan Kelly, January 29, 2012.

Residential Solar Power Heads Toward Grid Parity, Peter Fairley, IEEE Spectrum, 28 Mar 2013.

BIOGRAPHICAL NOTE

Vinay Gupta

Associate Fellow

A software engineer by trade, later becoming an expert in energy policy and disaster relief, Gupta focusses on making complex problems simple enough to solve with COTS systems and components. He is best known for the hexayurt shelter system (for refugees and natural disasters), Simple Critical Infrastructure Maps (in use at US DOD STAR-TIDES project), CheapID (a proposal for cryptographically secure private biometric ID cards) and his practical work on voluntary cooperation in organizational design. Current and former clients include Council of Europe, UK MOD, US DOD (OSD-NII).