Democracy and Security in the 21st Century: Perspectives on a Changing World

Edited by

Valentin Naumescu

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INFORMATION TECHNOLOGY: A FORCE SHAPING THE FUTURE

RAREŞ PATEANU

Abstract

To state that Information Technology (IT) has fundamentally altered just about every aspect of life as we know it, is to state the obvious. But the best is yet to come!

Many of the Information Technologies now in development will not only change more and more how we do things, but will likely have a lasting impact on how we interact, on human relationships, and on the very fabric of society. Things like piconets, real time analytics, and others will change the way humans interact with their environment and with each other, forever altering the future of our society.

This paper will examine some of the major ways in which IT will affect our future, not only from the point of view of changing our daily life, but more importantly, from the point of view of how it will change society as a whole.

Introduction

One of my favourite quotes is that "Predicting the future is like being in a dark room, looking for a black cat that may or may not even be there."[1] Why then, are we continuing to spend so much energy in doing precisely that? It is probably because a fundamental part of human psychology is to attempt to improve our odds when dealing with the unknown. In the area of science and technology, one might argue that such predictions should be easier to make. After all, science is dealing with facts and research, and perhaps extrapolating future developments from such a massive amount of current data should be easier. Yet the history of science is full of examples of predictions remembered for how wrong they were. Albert Einstein famously said:

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[1] Anonymous.

> "There is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will."[2]

The above quote is but one of many such predictions made by no lesser minds than Lord Kelvin, Sir Winston Churchill, Bill Gates, and many others, which have turned out to be so far off the mark as to making these predictions famous for the wrong reasons, in spite of the impeccable credentials of the predictor.

Therefore, this paper will stop short of actually predicting the future of technology, and will settle on the more modest goal to discuss seven IT developments that are very likely to have a substantial impact on society. The choice to focus on IT stems from the fact that over the years IT has evolved from being simply a field of technology, to becoming a universal enabler for many areas of science and technology. These days it is hard to imagine any new development from medicine to space exploration and everything in between that does not only rely heavily on IT, but has been indeed enabled by it. Simply put, IT often provides enormous leverage to other technologies.

The seven technologies discussed in this paper range from some that may already be present in our lives, but have only just begun to make their impact on society, to some that are so esoteric (and largely experimental) that even understanding what they are is a tall order, never mind the potential impact they might have in the future.

Either way, these technologies are characterized by a high degree of innovation and enormous transformative potential.

Innovation occurs at the conjunction of two very important forces. Firstly, a critical mass of knowledge has to accumulate for the quantum leap to be possible, since all innovation builds on successive accumulation of such knowledge, often in several fields. Secondly, a need (or perceived need) must exist to spur on the innovation process. In recent times, almost always a series of developments in IT was needed to allow innovation. For instance, many breakthrough medical imaging technologies that have moved forward medical science in leaps and bounds would not be possible without the advancements in digital images, their computerized processing and other related IT technologies such as mass storage, etc.

The level of innovation of the technologies selected for this paper puts them in a special category: disruptive technologies.

> "Disruptive technologies bring to market a very different value proposition than had been available previously. Generally, disruptive technologies

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[2] Interview, "*Atom Energy Hope is Spiked By Einstein / Efforts at Loosing Vast Force is Called Fruitless*" in Pittsburgh Post-Gazette, 29 December 1934.

> underperform established products in mainstream markets. But they have other features that a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, and frequently, more convenient to use."[3]

It seems perhaps counterintuitive that technology that underperforms established products can massively change afield of activity, but it is precisely because they assume a completely different value proposition (and a completely different way of using them) that such technologies completely change the playing field. Miniaturization is perhaps the simplest example of disruptive technology. By being so much smaller and emitting so much less heat, the transistor revolutionized electronics, in spite of being inferior to tubes in many specific metrics associated with performance of electronic components. Microchips in turn did the same to traditional transistors, and moved computing from the realm of the research lab and large corporations into every home.

As we look at the seven technologies selected for this paper, we will examine the various advances in other areas of technology that made the next step possible, the driving forces that made it necessary, and most importantly, the impact their disruptive nature might have on the world and society.

Grid Computing

During its less than 70 year-long history, computing power has grown in leaps and bounds. Empirical observation (often referred to as Moore's Law, although what Intel's co-founder Gordon E. Moore described in his famous 1965 paper[4] was actually referring simply to transistor density) asserts that computing power roughly doubles every 18 months. What exactly "computing power" is remains a complex question, but the general implication is that the ability to execute computations at a given cost doubles over 18 months.

This extraordinary growth has transformed computers from a science experiment into an indispensable and ubiquitous tool for every area of life, from science and technology to commerce and social interaction. In particular, it has allowed scientists to tackle problems with massive computational needs, such as genetics, image processing, space exploration etc. The need for such massive computational power has led to the creation of

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[3] Clayton M. Christensen, *The Innovator's Dilemma*, Boston: Harvard Business School Press, 1997, p. xv.

[4] Gordon E. Moore, "*Cramming More Components onto Integrated Circuits*" in Electronics, 19 April 1965, p. 114.

so called supercomputers, such as IBM's Deep Blue, famous for winning a chess match against world master Kasparov in 1997.

Such supercomputers are however very expensive, and therefore are rarely accessible for anything but the most advanced research facilities. On the other hand, many studies indicate that server utilization is on average around the 25% mark, due to many reasons such as the need for emergency capacity, cyclical down time, etc. Considering that some estimates indicate over 2 billion computers exist at this time in the world, the computing power available from these devices is staggering. Not surprisingly, the idea of harnessing this computing power is rather attractive.

Grid Computing is a form of distributed computing whereby a virtual supercomputer is "composed" of many networked computers acting together for a finite period of time to perform very large tasks. Highly specialized software is required to manage the interactions of such a large number of computers, the distribution of tasks, and the collection of results.

Needless to say, Grid Computing is not a universal answer for every large computational problem. Given how it works, it is most suitable for tasks that are relatively easy to decompose into a very large number of relatively small tasks. Developments in multi-threading technologies brought about in the last decade by the creation of multi core processors were in fact a key factor in the development of Grid Computing.

Another major factor is the dramatic increase in broadband communications technology, without which the vast communications needs of such a large network of computers would grind work to a halt very rapidly. Parts of the world with most advanced communication technologies currently have 30-50 Mbps internet (interesting to note that Romania is one of these countries), but at this time, the highest demonstrated speed has reached 40 Gbps[5]. For reference purposes, at this speed downloading a full length HD movie would take about 2 seconds.

Lastly, in order to avoid another possible source for bottlenecks, Grid Computing depends on the availability of very large data storage facilities that allow each computer on the grid to store the results of their computations. Such facilities are called SAN (Storage Array Networks) and are a common presence in data centers around the world. IBM is now selling a 120PB SAN (1 petabyte = 1024 terrabytes).

Grid Computing has been a reality for a while now. One of the best known examples is Einstein@Home[6]. It is hosted by the University of Wisconsin-Milwaukee and the Max Plank Institute for Gravitational Physics.

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5 http://www.engadget.com/2007/07/13/40gbps-internet-connection-installed-in-swedes-home.

6 http://einstein.phys.uwm.edu.

If it were a supercomputer, it would rank amongst the top 20 in the world. It consists of 135,000 host computers managed by a Grid Computing platform called BOINC. It has an average performance of 470 teraflops and a peak performance of just over 1 petaflop (or 10^{15} floating point operations per second). It is used to perform all-sky searches for previously unknown continuous gravitational-wave (CW) sources using data from the LIGO detector instruments.

The huge potential of this technology to change the future of society stems from the ability of combining the capacity of small individual computers for the purpose of resolving complex computational problems that might never be able to amass the huge funds a supercomputer requires, particularly when the problem itself might be transitory.

A perfect example of possible future use is contagious disease management. In a world so interconnected as ours, where the most remote parts of the planet are but a few hours away by plane, past events like the SARS crisis in 2002-03 have demonstrated how fast contagious diseases can spread. No medical system in the world has the resources to keep a supercomputer ready just in case an epidemic breaks out. However, when it does, understanding how and where the disease is spreading is critical for the defence strategies, and compiling that information is a massive computational task. With Grid Computing, health organizations would not need the power of a supercomputer. Instead they could have a much cheaper Grid Computing management facility, and simply appeal to the population to donate computer time by joining a temporary grid.

Disaster planning in general is very much a potential user of Grid Computing. Many recent examples show that in times of natural disasters, people have instinctively resorted to technology such as Facebook and Twitter to share information about events and people in the affected areas. Grid Computing deployed as a disaster management technology would allow enormous improvements in disaster response.

More generally, pretty much all types of complex modelling problems, from airspace traffic modelling to medical research can benefit significantly from Grid Computing in the future.

In summary, Grid Computing is in a sense a technological manifestation of a much larger social trend, namely bringing together a large community of shared interests to resolve a problem. In software development, we have the open source movement, news outlets frequently use contributions from the public - not hard to come by with every mobile phone having a camera these days -, and crowdsourcing is the hottest trend for financing small start-up companies. Just as it was hard to imagine 20 years ago that a community effort called Linux might one day rival the virtual monopoly Windows had in the operating systems space, it is hard to imagine now what Grid Computing might do for us in the future.

Wearable Computing

The drive to make computers smaller has probably started the same day the ENIAC was first turned on in early 1946. It weighed more than 27 tons, was roughly 8 by 3 by 100 feet (2.4 m × 0.9 m × 30 m), took up 1800 square feet (167 m2), and consumed 150 kW of power. The race to smaller, faster and cheaper was on.

Fast forward to 1973 when IBM Palo Alto Scientific Center developed a portable computer prototype called SCAMP (Special Computer APL Machine Portable), widely regarded as the first portable computer (although some refer to this class of computers as "luggable" since they resembled more a piece of luggage that a truly portable computer in the modern sense). It took another decade to get to the truly portable device we know as a laptop. The arrival of smart phones and tablets has taken the computer to the ultimate form of portability: pocketability.

However, no matter how small and light these devices have become, they retained a fundamental characteristic, namely the need to interact with them as a separate activity that requires us by and large to drop everything else we are doing.

Wearable Computing is a completely new computing paradigm that is characterized by continuous interaction with the computer concurrently with other activities, using specialized components for controlling the device, and having the computer attached to the person or their clothing as unobtrusively as possible.

To make Wearable Computing reality, many important technology advancements were necessary. First and foremost miniaturization has brought the size and weight of a computer to the point where having it permanently on your person is possible with reasonably little inconvenience.

Secondly, significant advances in power generation, storage and consumption were also critical. One front of this battle has been the continuous effort to increase power density in batteries, an effort driven by many other uses and industries. Another was the engineering of electronic components that consumes less and less electrical power for the same computational capability.

All these would however be useless without new and innovative ways of interacting with the computer. Technologies like voice recognition and generation, gesture recognition, accelerometers and gyroscopes of appropriately small sizes have all been essential to provide means of controlling the Wearable Computers without the benefit of the traditional keyboard and mouse.

Over time there have been many attempts (some more ridiculous than others) to create a computer we can wear. Arguably the first successful example (although not yet commercially available) is the Google Glass. As the name suggests, it takes the form factor of a pair of glasses, and it is equipped with an OMAP 4430 CPU running at 1 GHz using the Android 4 ICS operating system. It is equipped with a 5MP camera, a high resolution display equivalent to a 25” (or 63.5 cm) high definition display projecting directly on the retina, bone conduction transducer speakers, and WiFi plus Bluetooth connectivity.

The infographic in Fig. 3-1 below explains how Google Glass works:[7] Google has put together an interesting program called Glass Explorer, through which it has offered access to the new device to the authors of the top 2000 ideas on what to do with the device. When will the device (in whatever final form) become available is unknown at this time, but the sheer number of applicants to the program demonstrates that there is no shortage of ideas of how to use it when it does become available.

The power of wearable computers does not stem from what they can do. In fact, in the true spirit of disruptive technology, what they do is definitely limited compared to their more conventional counterparts. Their key advantage is their ability to execute tasks with minimal interference from other activities, using voice and movement controls, and superimposing the surrounding reality with electronically generated images. This capability will revolutionize many areas of human activity.

One of the more obvious fields to be radically changed is medicine. Imagine surgery where surgeons do not need to frequently raise their eyes from the operating theatre to look at charts, equipment readout, or monitors, because the relevant information can be brought in front of them literarily at the blink of an eye, superimposed over the real surgical theatre. Imagine nurses dispensing medicine while their wearable computer scans the barcode of the medication and the prescription chart to ensure correct medication at correct dosage. In 2000, the Institute of Medicine (IOM) published a report[8]stating that from 44,000 to 98,000 deaths occur yearly due to medical errors, making medical errors the eighth leading cause of death in the United States. The report identified medication errors as the most common type of

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[7] Infographic by Martin Missfeldt, Feb. 2013 at www.brille-kaufen.org.

[8] L.T. Kohn, J.M. Corrigan and M.S.Donaldson, “*To Err Is Human: Building a Safer Health System*” in Institute of Medicine, National Academies Press: Washington DC, 2000.

error in health care. Seven thousand (7,000) deaths annually were attributed to medication errors.

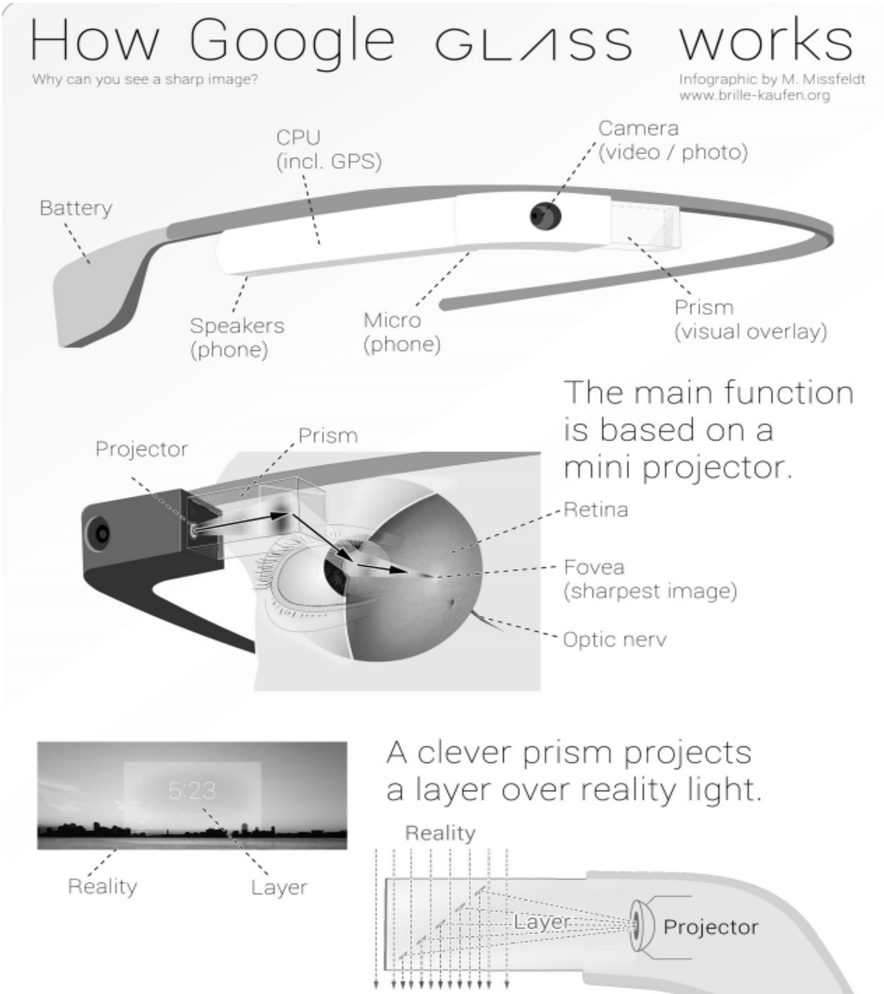

Fig. 3-1

The characteristics of wearable computers make them exceptionally good candidates for prosthetics, particularly in light of the advancements of controlling technology. It is possible to imagine image output from a wearable computer bypassing the eye and connecting directly to the optic nerve, providing vision for people with certain kind of damages to their eyes. Interaction between wearable computers and prosthetics could bring a new degree of freedom and capability to people affected by crippling diseases.

In other fields, so called e-textiles (wearable computers weaved into cloth) could improve protective clothing in dangerous professions, measuring and monitoring the environment for toxic substances and alerting the wearer when levels are dangerous. To date, social interactions and entertainment have been perhaps the most common uses of wearable computers, raising with them an entire new wave of issues related to privacy and security.

Real-time Analytics

Data analytics is a field as old as data itself. After all, what is the point of collecting the data if we do not interpret it and derive meaning from it. In fact data collection for the US Census Bureau was the impetus behind Herman Hollerith's invention of punched cards and the Electrical Tabulating Machine leading to the establishment of his Tabulating Machine Company later to become IBM.

The relationship between data and computing has become a giant upward spiral. As more data is available and it needs analyzing, bigger and more powerful computers are created. They, in turn, produce ever more data, that needs analyzing, and so the spiral goes on and on.

In many cases though, the timeliness of analysis is of the essence. If you are analyzing the trajectory of a space ship in order to provide input to a course correction, you have only so much time to do the analysis before the outcome is useless because the space ship flying at very high speeds has significantly changed position.

Real-time analytics aims to analyze data as it becomes available, and make the results of the analysis available quasi instantaneously. The analysis consists of attempting to find patterns that can be meaningful for solving a business problem, or assisting in some activity. Data from a variety of sources is continuously harvested and the results of the analysis are provided (and updated) as new data items come in, usually in the form of sophisticated dashboards. Think the control cockpit of a modern aircraft, and you get the idea. Flying a modern jetliner is a complex process, that relies on thousands of data points like attitude, altitude, speed, temperature, heading, and many others, all of which change very rapidly, yet need to be analyzed, correlated and displayed to the pilots extremely fast.

Traditionally computer engineering has to eternally assess the correct trade-off between quantity and quality, but in the case of Real-time Analytics, computers have to deal with both at the same time. Some of the critical IT developments that made Real-time Analytics possible have to do with maximizing the speed of running the analytical algorithms, a problem that has been approached from two sides.

First, analytical research has produced significant advances in the efficiency of algorithms, but on the other hand, new IT technologies allow for ever faster data processing. PIM (or Processing In Memory) is a new technology that combines the CPU and the memory on a single chip, allowing for much faster data transfers. Putting more and more CPUs (or cores) on a single chip is another trend that has started at least a decade ago (even smart phones at the high end of the specifications spectrum sport quad processor cores these days), but in the supercomputer arena the number of cores is approaching the 10,000 count. Distributing work across such a large number of processors is commonly referred to as MPP (or Massive Parallel Programming). This approach is particularly well suited to Real-time Analytics, because of the granular nature of data analytics (running the same algorithms on very large numbers of datasets). Last but not least, significant advances have been made in memory technology (and price) allowing high end servers today to support as much as 512 GB of memory. To get a sense of the magnitude of change in this area, note that at this time, 64GB DDR2 SDRAM memory can be purchased retail for about $2,000 US. Thirty years ago IBM was selling 64KB of memory for $275. In those terms, 64GB of memory would cost about $36,000,000 US, and if we account for inflation, in today's money that would amount to about $64,000,000 US.

With so much relatively low cost memory, entire databases (or significant portions thereof) can now be loaded in memory, increasing processing speed by orders of magnitude. This new database technology is referred to as IMDB (or In Memory Data Base).

Real-time Analytics is also one of technologies already present in today's business environment. Perhaps the best known example is in the area of financial trading systems. On the trading floors of major financial institutions, considerable trading activity is now automated, and a race is on for high speed trading, where the fastest market entrant has the price advantage. Obviously this kind of trading has to be automated, and is driven by very sophisticated (and proprietary) rules engines that decide what and when to trade. Of course, these decisions have to be based on the most up to date market data.

As with other technologies, using Real-time Analytics for high speed electronic trading is not without risk. On the late afternoon of April 23rd 2013, the Dow Jones Industrial Index fell about 1% in the space of two minutes. The reason? The Syrian Electronic Army (a collection of pro-government Syrian hackers widely believed to be associated with Syria's

President Bashar Al-Assad) hacked the Twitter account of the Associated Press, and falsely reported an attack on the White House, and the wounding of President Barack Obama. Real-time Analytics engines discovered and interpreted this information, and correctly assumed that markets will fall, and initiated substantial sale trades, which did in fact bring the Dow Jones Industrial Index down by 1%. The markets recovered quickly, and 1% might not be considered that huge a drop, but if you consider that 1% of the market measured by the Dow Jones Industrial Index amounts to about $136 billion US, and if you were on the losing side of those trades, you could be excused for having second thoughts about high speed electronic trading.

What is interesting to note in this example, is the fact that social media was one of the sources of data monitored. A lot has been said and written about the ways social media has sped up the news cycle, social interactions, opinion currents, etc. Not surprisingly, many companies and businesses are increasingly interested in tapping into this massive reservoir of data. Many people have noticed that while a complaint against some practice or another of a business will likely go unanswered for weeks when complaining to traditional customer service, tweets or YouTube videos going viral generate an instantaneous reaction from the offending company.

Where in the past a company wanting to launch a new product would distribute samples to a select test group of people, and collect their reaction over many months of pilot programs, in the future one might simply publish the idea, and let the social media react. Possibilities go far beyond that though. By their network nature, social media has topologies, just as networks do, and not all "nodes" are created equal. More sophisticated Real-time Analytics might detect and separate the influencers in a social network from the followers, and treat their opinions in a differentiated way. Actions might than be customized to the opinion makers, hoping to shift their opinion to a positive one, which in turn would hopefully, change the view of the majority. That is a lot more efficient and effective than blanket reactions based on weighing equally all opinions.

The future will likely bring more and more sophisticated ways to analyze the events of our life, and will vastly increase the speed of our social and economic interactions. Is that a good thing? That is a topic for another article.

Ultra Low Power Computing

Power usage matters in many ways in the computer industry, beyond the obvious fact that all computing devices require some form of power. As electrical current passes through electronic circuitry, it releases heat. The more current is needed for operating the device, the "hotter it runs" as the saying goes in the industry. In fact this very simple effect of physics has been one of the breaking forces slowing down microchip miniaturization.

As we moved into the world of mobile computing and devices needed to be powered by batteries, a whole new series of engineering trade-offs were required to balance the capabilities of the devices against the battery size (and therefore the length of time we could stay mobile). Of course, the faster the processor, the brighter the screen, the bigger the wireless connectivity range, etc. the more power is needed, increasing the size of the battery (and hence the size of the device) or shortening the up time between charges. This issue can obviously be addressed from both sides: reduce power consumption per unit of work, and increase power density (i.e., increase battery capacity per unit of volume).

Not surprisingly, a lot of the research went into finding ways to do the same work with less power, and we have come far indeed. It is in fact very valid to paraphrase Moore's Law (the same we referred to earlier) in stating that the electrical efficiency of computers measured in the number of computations per KWh has also roughly doubled every 18 months for quite a while, as shown in the graph below (Fig. 3-2).[9] Unfortunately I was not able to find a source extending this graph beyond 2009, but a rather unscientific comparison of today's laptops with the ones from 5 year ago would suggest that the trend has been maintained.

There is no agreed definition as to what exactly can be called Ultra Low Power Computing, but generally ULPC devices use a fraction of the computing power required by traditional devices for the same task, and often use different and unconventional sources for their power.

Photovoltaic charging (commonly known as solar power, even though it is in fact any kind of light that can be used as a source of energy) is one of these new ways of powering devices. The value proposition of this energy source comes primarily from the wide availability of the power source (light) and the relative flexibility of the form factor of photovoltaic chargers. The downside is that energy density is not that great, so solar energy is used either in ULPC devices, or in conjunction with a battery for more traditional devices. As an example, an Italian company eRALOS3 has started production of a bendable flexible photovoltaic charger that can be easily incorporated into textile, clothes, backpacks, and other wearable accessories.

Kinetic charging, which basically converts physical movement into energy is another great choice for ULPC devices, again because of the relatively low amount of energy that can be generated by the natural

[9] http://www.technologyreview.com/news/427444/the-computing-trend-that-will-change-everything.

movement of an individual. It is commonly used in watches, but as more devices reduce their power consumption to the levels provided by this charging approach, it is very likely that more kinetic charging devices will be part of our future.

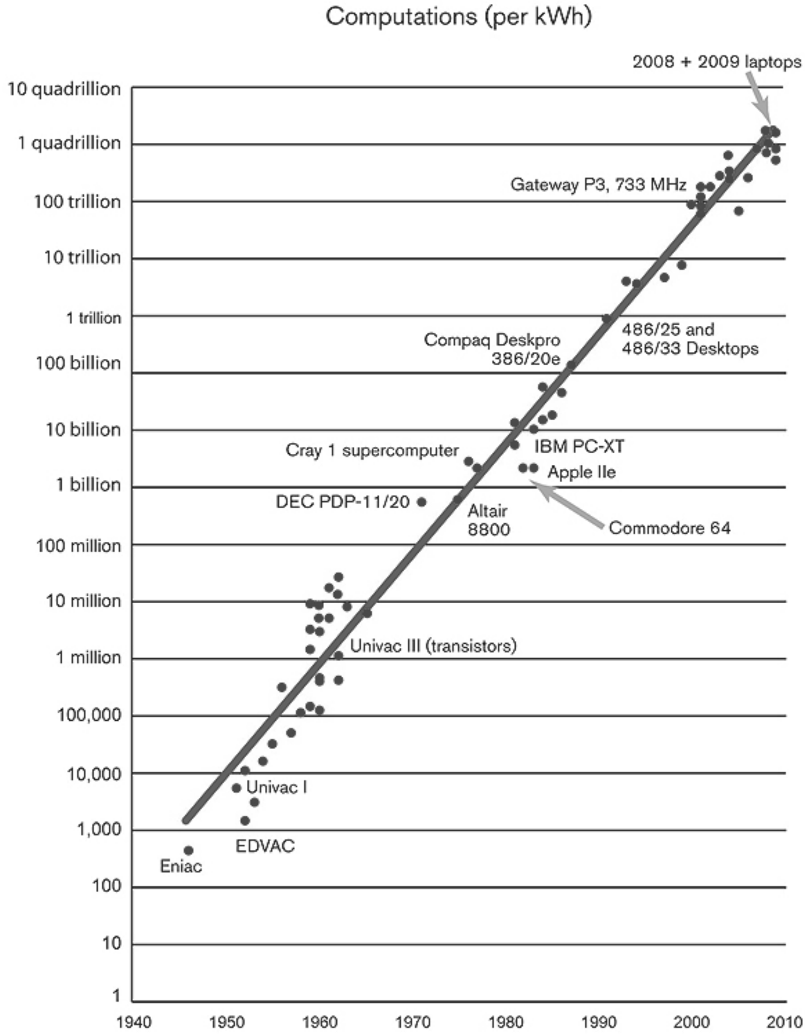

Fig. 3-2

Inductive charging on the other hand is not as much a new source of energy, as a new way to transmit the energy from source to consumer without the need for wiring. As a technology, it is not meant for ULPC devices. In fact, the city of Gumi in South Korea is experimenting with inductive charging for electrical buses. Charge plates embedded in the 15 mile route for about 15% of that length recharge buses on the go. Buses need much smaller batteries than otherwise needed, and use the OLEV (OnLine Electrical Vehicle) platform developed at the Korea Advanced Institute of Science and Technology.[10]The reason induction charging is relevant for ULPC is the ability to charge very rapidly from such sources, when very little power is required. Should a widely accepted standard be adopted in the future, and deployed in many areas of high volume transit (as an example) your ULPC devices could stayed charged for ever, just because you are taking public transit, or going by other places where inductive charging plates are present, and there wouldn't even be a need for you to stop there in order to take advantage of this source of power.

Going even further, small amounts of energy can even be harvested from radio waves, of which so many fill the ether, courtesy of mobile phones, wireless internet, and other forms of communication.

Last but not last, a myriad of new materials used for conductors and chargers have allowed continuous progress in the efficiency of generating and transmitting electrical energy.

The Massachusetts Institute of Technology's Technology Review noted:

> "To put the matter concretely, if a modern-day MacBook Air operated at the energy efficiency of computers from 1991, its fully charged battery would last all of 2.5 seconds. Similarly, the world's fastest supercomputer, Japan's 10.5-petaflop Fujitsu K, currently draws an impressive 12.7 megawatts. That is enough to power a middle-sized town. But in theory, a machine equaling the K's calculating prowess would, inside of two decades, consume only as much electricity as a toaster oven. Today's laptops, in turn, will be matched by devices drawing only infinitesimal power."[11]

The future applications for ULPC are as endless as the human imagination. Again medical devices stand to gain the most from this technology, because of the complication caused currently by the need to power implanted devices, such as pacemakers, etc. Experiments are already taking place with insulin pumps that release insulin as needed, allowing for a

[10] http://www.wired.com/autopia/2013/08/induction-charged-buses.

[11] http://www.technologyreview.com/news/427444/the-computing-trend-that-will-change-everything.

more precise and effective dosage and timing. They are now backpack sized devices, but miniaturization and ULPC technology might get us some day to a very non-intrusive version of such a device.

Another topic frequently discussed is M2M (Machine to Machine) communication, otherwise known as the “Internet of Things”. More about this in the next section of this paper, but yet again, ULPC is a major factor in making M2M reality. Small objects would not likely be in a position to connect with each other if significant power would be required. On the other hand, if connectivity power needs would not exceed the power that can be harvested from radio waves, just about any object in our household could connect to any other object. If food packaging would include this technology, you could have an instant inventory of what food you have in the house. Add the ability to communicate location information, and you will never lose your glasses or keys ever again!

If the trend discussed in the Technology Review quoted above were to materialize, imagine the possibilities for smart phones and tablets, which today have a considerable percentage of their volume taken up by their battery.

Piconets and M2M

To state that the Internet has fundamentally changed almost every area of human activity, is to state the obvious. We live in a permanently on, permanently connected world, and that has changed the social fabric of our civilization in ways that we may not have even figured out yet. From the compulsive need to check our smart phone even in the midst of a romantic dinner, to the boundaries between work and home blurred more and more by the intrusion of the work version of the same devices, social interactions will never be the same.

So, what is next in the world of connectivity? Very likely, objects will dispense with the need of a human intermediating, and will gain the ability to connect with each other on their own.

Piconets are general purpose, low-powered ad-hoc radio networks. Using ULPC (see previous section) and protocols that establish a network on-demand, but stay dormant when not needed, objects can simply connect with each other, and exchange minimal sets of information, such as identity, location, etc. Piconets are characterized by low range (typically a few meters) low power (they exchange very little information over these very short distances) and low rate of data exchange (again, speed is not of the essence, given the nature of the communication). Given the ad-hoc nature of establishing a communication link, they change frequency quite often, in order to avoid collision. Piconets generally have a master device, while the remaining devices are slave devices that can be activated by the master device.

The most critical contributing technology is ULPC (see relevant earlier section). It is simply not practical to equip a large variety of devices, with very different form factors, manufacturing technologies, and operating environments with power sources, so the ability to use one of the ULPC technologies discussed earlier is essential.

Miniaturization and other specialized technologies (such as printing circuits on just about any surface) were also precursors to piconets.

The most wide-spread example of piconets today is the RFID tagging (Radio Frequency Identification). RFID tags are common place on credit cards (and other payment devices such as tokens, chips, toll payment devices for automobiles, etc.). Another use for them is in implantable devices (mostly used to track animals). As an example, anyone wishing to bring a dog into the United Kingdom must have a chip the size of two grains of rice implanted by a veterinarian, and have the animal registered in the country of origin. The chip contains up to date information regarding vaccinations and health status, and it is read at customs on entry to the United Kingdom.

Speaking of travel, modern passports in Europe, USA, and Canada are also RFID equipped. The RFID chip is recognized by a master device (reader) and a piconet is established for the purpose of a quick exchange of information. Stores use such a reader to identify inventory that has not been paid. Merchandise has labels with RFID tags printed on them (now replacing bar codes). At the cash register, another master device changes the label printed on the merchandise to mark it as paid.

The expertise gained with RFID tags and the large volumes involved, have brought down the cost of piconet technology where it is possible to have communications capability attached to just about anything that can have a small label. Food labels could communicate with a tablet, and trigger the retrieval of recipes that can be cooked with the available foods (or with those foods available that a doctor has approved). Grocery lists could be generated, alerts could be created when food expires (or is about to), etc.

Sensors could interact with devices in the home to optimize the environment, from temperature and humidity to lighting and allergen management. A vast array of personalized services could be provided by establishing piconets between smart devices. Dating services could interconnect compatible people when in proximity to each other, items could be offered on sale to people who have indicated a specific interest, and so on.

Last but not least, by connecting a piconet to the internet, telecontrol of almost anything from almost anywhere becomes a possibility.

Quantum Computing

If so far we have discussed technologies that at least in some form are already present in our life, the last two are downright in the territory of science fiction (or almost).

From the 27 ton ENIAC to the current MacBook Air or smart phone, the process to make computers smaller has followed the same path:

1. Construct electronic circuitry using currently available components
2. Optimize use and size of the components as far as the physical characteristics of the current technology allows
3. Devise a new type of component that is smaller and faster and start the process again

This cycle has taken us so far from tubes, to transistors and to integrated circuits. Can this cycle continue, and if so, what are the components of the next turn of the cycle be made of?

One answer to that takes us to the world of quantum mechanics, the branch of physics that deals with physical phenomena at microscopic scale, typically at atomic or subatomic level. Yuri Manin[12]and Richard Feynman[13]introduced in the early 1980s the idea of Quantum Computing. The idea behind Quantum Computing is to make direct use of quantum mechanical phenomena to perform operations on data.

However, quantum computers are radically different from traditional ones:

1. Traditional computers use semiconductors to store bits of data; quantum computers use spinning particles called qubits for that purpose.
2. Traditional computers are deterministic (i.e., a bit takes up a value of 0 or 1, based on the two state nature of semiconductors; qubits can take up a value of 0, 1, or any quantum superposition of the two[14]

[12] Yuri Manin, "*Vychislimoe i nevychislimoe [Computable and Noncomputable]*" (in Russian) in Radio, 1980, pp. 13–15.

[13] Richard P. Feynman, "*Simulating physics with computers*" in International Journal of Theoretical Physics 21 (6) 1982, pp. 467–488.

[14] Quantum superposition is a fundamental principle of quantum mechanics that holds that a physical system—such as an electron—exists partly in all its particular theoretically possible states (or, configuration of its properties) simultaneously; but when measured or observed, it gives a result corresponding to only one of the possible configurations.

3. In traditional computers computations are irreversible while in quantum computers reversing the direction of spin would reverse the computation.
4. Traditional computers are linear, in the sense that computations are executed sequentially (notwithstanding the multiple core processors) while quantum computers are inherently parallel, since quantum particles move independently of each other.
5. Traditional computers use electrical current traversing logic gates to execute computations, while quantum computers use a variety of physics effects to control particle spin (Magnetic Resonance Imaging or MRI and Dynamic Nuclear Polarization or DNP are the most promising so far)

As a result, quantum computers are many orders of magnitude smaller and faster, and that is precisely why if realized on practical scale, quantum computers will radically alter everything about computer science. At this time, most of the quantum computing is still in the theoretical research phase, conducted under defense and intelligence research grants. The current focus of this research is on how to control nuclear spin.

Some of the more promising results are experimental devices, such as the ones below:

- IBM Almaden Research Center designed a 5 qubit QC using fluorine atoms controlled via radio frequency pulses[15]
- Waterloo Institute for Quantum Computing and the Massachusetts Institute of Technology devised methods for quantum control on a 12-qubit system[16] (quantum control becomes more complex as systems employ more qubits).
- Canadian startup company D-Wave demonstrated a 16-qubit quantum computer.[17] The computer solved a Sudoku puzzle.

The main value proposition of quantum computers is really the ability to solve problems that are simply beyond the capabilities of even the most powerful supercomputers today. One typical example is the problem of factorization of very large numbers, a fundamental issue in cryptography (hence the interest of intelligence agencies in knowing if and when this problem can be addressed by computers).

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[15] Colin R. Johnson, "*IBM quantum computer solves code cracking problem*" in EE Times, http://www.eetimes.com/document.asp?doc_id=1142044, 22 August 2000.

[16] No Author, "*12 Qubits Reached in Quantum Information Quest*" in Science Daily, http://www.sciencedaily.com/releases/2006/05/060508164700.htm, 8 May 2006.

[17] Geoff Brumfiel, "*Quantum Computing at 16 Qubits*" in Nature, http://www.nature.com/news/2007/070212/full/news070212-8.html, 15 February 2007.

A very natural fit for Quantum Computing is the analysis of complex quantum systems. This would allow us unprecedented understanding of interactions at atomic and molecular level, which in turn could lead to the design of new drugs, superconductors, and many other materials with unique properties.

More generally, the study of many natural phenomena is limited today by our computational capacity, because many natural phenomena are governed (or at least influenced) by a large number of parameters. When studying these phenomena today, computational limitations force researchers to limit the number of parameters they include in their study, bringing with it the risk of missing critical parameters, which in turn could limit or even invalidate the results of the research. Quantum computers on the other hand would allow massive parallel calculations, taking into account a much larger number of parameters.

Biologic Computing

Another path taken in the search for a different type of components for computers has turned to biology. A biologic computer uses systems of biologically derived molecules such as DNA or proteins to perform calculations. Using synthetic or natural molecules one can engineer a biologic computer, i.e. the chemical components necessary to serve as a biological system capable of performing computations, by engineering DNA nucleotide sequences to encode for the necessary protein components much like our DNA engineers an organism. Our brain (alas, not very well understood yet) is the ultimate biologic computer.

The key development that enabled the path to Biologic Computing is nanobiotechnology, defined as the design and engineering of proteins that can then be assembled into larger, functional structures.

As a domain of science, nanobiotechnology is not aimed at Biologic Computing as such, but at the synthesis of various biological materials for medical and other reasons. However, the knowledge we derived from these efforts has led to very incipient experimental ways to implement the key computational components in a biologic manner.

- Tom Knight from the Massachusetts Institute of Technology Artificial Intelligence Laboratory suggested that protein concentrations can be used as binary signals.[18]At or above a certain concentration of a particular biochemical product in a bio computer chemical pathway

[18] http://www.fastcompany.com/3000760/tom-knight-godfather-synthetic-biology-how-learn-something-new.

indicates a signal that is either a 1 or a 0, and a concentration below this level indicates the other remaining signal.

- A team of instructors and students at the Chinese University in Hong Kong have developed a method of storing information in bacteria DNA.[19]
- In March 2013, a team of bioengineers from Stanford University led by Drew Endy announced that they have created the biological equivalent of a transistor, which they dubbed a “transcriptor”.[20]

Together, the above three developments have demonstrated the ability of constructing all the major components of a computer (signal, storage and gates) using biological materials.

While indeed Biologic Computers would also be smaller and faster than the traditional ones, their enormous potential lies elsewhere. First, given their biologic nature, they have the capability to coexist well and interact with cellular level processes (think implanted biologic computers that modify biologic processes at the cellular level, opening up the potential of delivering the equivalent of immune system responses directly to the diseased cells). Secondly, once the sequence of creating a biologic computer has been encoded (similarly to the way DNA encodes the blueprints for developing organisms), these biologic computers could be reproduced extremely fast and cheap in very large numbers (because it ultimately is nothing but cellular reproduction).

As a result, we could:

- Execute cell level diagnostic (perhaps direct a cancerous cell to self destruct)
- Monitor effectiveness of drug therapy at the molecular level
- Repair tissue
- Transform passive medical implants into active / interactive ones
- … and many, many other developments unimaginable today.

Conclusions

In its less than 70 year-long history, computers and Information Technology have undoubtedly changed dramatically the world we live in, and with it just about every aspect of human interaction. More importantly, the rate of change is accelerating rapidly. To pick only a few examples:

- The cellular phone is only 40 years old

[19] http://digitaljournal.com/article/300831.
[20] http://news.sciencemag.org/biology/2013/03/computer-inside-cell.

- The WWW is only 20 years old
- YouTube is only 8 years old
- Twitter is only 7 years old

If someone went into a coma 40 years ago and would be revived today, he or she would be essentially unable to function in the usual sense of the word. No wonder we are all curious what the future will bring. This paper has attempted to provide a glimpse into what that future might look like. Only time will tell how accurate this glimpse might be.

Bibliography

Interview (1934), "Atom Energy Hope is Spiked By Einstein / Efforts at Loosing Vast Force is Called Fruitless" in Pittsburgh Post-Gazette, 29 December 1934

Christensen, Clayton M. (1997), The Innovator’s Dilemma, Boston: Harvard Business School Press

Moore, Gordon E. (1965), "Cramming More Components onto Integrated Circuits" in Electronics, 19 April 1965

Murph, Darren (2007), “40Gbps internet connection installed in Swede's home” [http://www.engadget.com/2007/07/13/40gbps-internet-connection-installed-in-swedes-home/], 27 August 2013

Website, “About Einstein@Home” [http://einstein.phys.uwm.edu/], 27 August 2013

Missfeldt, Martin (2013), “Infographic” [www.brille-kaufen.org], 28 August 2013

Kohn, L.T., Corrigan, J.M., Donaldson, M.S. (2000), “To Err Is Human: Building a Safer Health System” in Institute of Medicine, National Academies Press

Koomey, Jonathan (2012), “The Computing Trend that Will Change Everything” [http://www.technologyreview.com/news/427444/the-computing-trend-that-will-change-everything], 29 August 2013

Barry, Keith (2013), “In South Korea, Wireless Charging Powers Electric Buses” [http://www.wired.com/autopia/2013/08/induction-charged-buses/], 30 August 2013

Manin, Yuri (1980), “Vychislimoe i nevychislimoe [Computable and Noncomputable]” (in Russian) in Radio 1980, pp. 13–15.

Feynman, Richard P. (1982), "Simulating physics with computers" in International Journal of Theoretical Physics 21 (6) 1982, pp. 467–488

Johnson, Colin R. (2000), "IBM quantum computer solves code cracking problem" [http://www.eetimes.com/document.asp?doc_id=1142044] , 2 September 2013

No Author (2006),"12 Qubits Reached in Quantum Information Quest" [http://www.sciencedaily.com/releases/2006/05/060508164700.htm] , 2 September 2013

Brumfiel, Geoff (2007)"Quantum Computing at 16 Qubits" [http://www.nature.com/news/2007/070212/full/news070212-8.html] , 2 September 2013

Bluestein, Adam (2012), "Tom Knight, Godfather Of Synthetic Biology, On How To Learn Something New" [http://www.fastcompany.com/3000760/tom-knight-godfather-synthetic-biology-how-learn-something-new], 1 September 2013

Solar, Igor (2010), "Bacteria cells used as secure information storage device" [http://digitaljournal.com/article/300831], 1 September 2013

Service, Robert, F (2013) "A Computer Inside a Cell" [http://news.sciencemag.org/biology/2013/03/computer-inside-cell], 1 September 2013