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Paving the Path for the Future Technology Developments

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Technology Time Machine 2012 -Paving the Path for the Future Technology Developments

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Abstract—The IEEE Technology Time Machine (TTM) is a unique event for industry leaders, academics, and decision making government officials who direct R&D activities, plan research programs or manage portfolios of research activities. This report covers the main topics of the 2nd Symposium of future technologies. The Symposium brought together world renowned experts to discuss the evolutionary and revolutionary advances in technology landscapes as we look towards 2020 and beyond. TTM facilitated informal discussions among the participants and speakers thus providing an excellent opportunity for informal interaction between attendees, senior business leaders, world-renowned innovators, and the press.

The goal of the Symposium is to discover key critical innovations across technologies which will alter the research and application space of the future. Topics covered the future of Wireless Technology, Smart Grid, The Internet Of Things, Cloud Computing, Silicon, and non-Silicon technology, Biotechnology, and life Sciences. The following is a review of some of the areas covered at TTM 2012.

Networks Supporting Future Applications

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Throughout the evolution of mobile communication systems the main focus is increasing data rates within the access network. Indeed, data rate capabilities in the most emblematic cellular generations have increased one thousand fold, across the development of, 2G, 3G, and 4G systems. Short-range communication technologies have also undergone an impressive development, spread across a large number of technologies. Network operators face difficult times as the increases in data rate are difficult to monetize. Previously, as evidenced in the transition from 2G to 3G system, users are first drawn into and engaged by novel services, and not necessarily through the latest advances in the access technology. For example 3G offered higher data rates using WCDMA. However when compared to TDMA based 2G there were no substantial or new and attractive user services added. Currently services are developed and deployed through a mobile application interface, (apps) and or through an internet interface predominately through the use of cloud services. The attempts of network operators to enter the mobile application business have not been successful. One example is Vodafone 360, a former app store of the network provider. This leads to a possible risk wherein a given cellular network is to become a simple "dump pipes". –Translated this becomes nothing other than passing bits over the air, which is an unsustainable solution for network operators. The networks of the future have to adapt in order to remain viable players in this new mobile ecosystem.

A subset of key changes that will occur as we move into 2020 include: The support of an infinite set of devices, Low energy consumption on the network and device side, The ongoing and increased support of cloud services, and Very short response times within the mobile communication link. In addition architecture changes will occur to support novel topologies; for example a direct device to device communication infrastructure. While concurrent mobile communication sees the network side as the master of the communication, device to device communication will clearly break this paradigm. The introduction of sensors will self-perpetuate the device to device speed requirements. Factors that will influence the requirements are by low power consumption, and the need to quickly depower these devices once they have been interrogated. So, the higher a devices power consumption against its recharge or recycle time will drive the device speed, and the need to complete a transaction and have a device cycle from its on state (high power) to its off state (low power). When taken all together the total set of changes will lead towards improving the communication pipe intelligence, leading into a “smart pipe”.

In the following we will highlight the main network key changes case by case. Omnipresent communication networks are mainly serving mobile phones, which are represented by Nokia’s value proposition “connecting people”. In the future, in addition to person-to-person we will also have machine-to-machine (M2M) communication which will play a dominant role. One example of this is already taking place research, and also in test trials. The concept is “Intelligent Transportation”, and the enabler is an M2M integrated network. There are activities in the transportation space already rolling off the production line. Vehicles are being equipped with IP support to retrieve traffic information, access the web, and remember your favorite destinations and routes, and much more. The number of vehicles is marginal compared to mobile phones, but it shows a clear trend towards connected machines, and also that this market transcends a mobile device, in this case it is mobile transportation. Early in time we envision connected machines communicating over cloud services a la WAZE (social traffic guide), but in the future as a follow on step we predict vehicle to vehicle communications will be commonplace. This is one example where the quantity of sensors used in everyday life will exponentially rise, and become ubiquitous in our everyday lifestyles. The WWRF (Wireless World Research Forum) estimates that there will be on the order of a several trillion wireless communications nodes by 2017. This large set of devices will drive both Big Data and also the overhead network signaling requirements associated with handling all the requests. Standards will be needed to drive towards common solutions.

Supporting M2M communication adds the new network challenge; the support of short delays on the communication link (this is not just the wireless part). Currently network delays are optimized for web reading and an associated human user responsiveness, and are generally in the hundreds of milliseconds. This is an unacceptable delay in the M2M world, and also an unacceptable requirement when reduced to the on off state of the devices that are communicating in this M2M environment. M2M will drive optimization that is based on a machine response time which is far smaller than any human time constant. The challenge is then to reduce delay from hundreds of milliseconds by many orders of magnitude, and continually improve as the access network expands and improves itself.

We discuss three potential delay reduction solutions. First, a new over the air interface and advanced architecture will need to be developed. Improving the wireless link is a linear evolutionary step, while changing the architecture can be seen as quite disruptive and perhaps revolutionary. Since mobile phones are typically characterized as network slaves (with base stations as the master), wireless sensor nodes will be elevated as the domain master, while base stations will become the slave.

A second area that can be used to improve upon delay reduction is channel access. Channel access using current accepted schemes are too long given next generation machine communications. New solutions will be developed that allow devices to send or queue their information immediately and then enter back into their respective energy saving off state mode. The services should not be located deep in the backbone, but rather they should be located at the foreground within the access network.

The third area that will be leveraged to reduce delay is the set of cloud services deployed. Today we see cloud solutions as an essential part of our communication habits, for example Dropbox, Google calendar, Amazon cloud services, and many more. In order to reduce the delay to those services, both today and in the future, the physical cloud needs to be spread geographically. This requirement will continue in the future as geographically spread cloud services will become components of the access network. A near in vision is the concept of mobile clouds, where the cloud, or cloud subsystems are located in end user devices. Through this paradigm shift the cloud or what we define as the cloud becomes distributed, or geographically spread. As an example if one wishes to read a web based news article there is a high probability in the mobile cloud environment one would obtain cached data that is geographically close to your base station, or even better from the mobile device of person standing next to you. The access networks as currently known will undergo dramatic change in order to accommodate this paradigm shift. They will become self-aware, or "smart", and will be part of the overall component we label "smart living". Thus, as we align this new world order, the changes and capability of the mobile end user device, the technology under the cover, and the network itself must be accessible to the developers. When Apple first introduced the iPhone the only option to obtain 3rd party services on the platform were through the onboard web browser. As a reminder the first iPhones came with 2G technology not 3G. This changed through the introduction of apps and the app store. Developers were successful in creating new services for those platforms using a manufactures' APIs. First those applications were platform agnostic but as more and more onboard technology, (in this example sensors), were added such as GPS, accelerometer, compass, RFID; the end result is enriched applications. Later the applications were connected over the Internet making use of cloud services, which further pushed the proliferation of mobile apps. As seen by Vodafone 360, copying this approach and offering just the same apps on a different platform does not work.

Assuming mobile network operators wish to create the "smart pipe", they will need to offer developer's access to the network information through network oriented APIs. Currently developers are programming on the mobile side and the server or cloud side (sometimes this is even the same). Therefore a set of APIs retrieving knowledge about the network would be desirable and may be possible to implement in the short term. Being able to program for the network is not enough. The future lies in the combination of cloud services and mobile networks where the application might run in "my" network and not anymore in the end device. The future would be that the applications would be device agnostic and users only need a screen to obtain access.

All requirements of proposed solutions is that they are designed from the ground up to be green, and thus energy efficient. The need to be energy efficient is twofold. On the one hand the network operators have the requirement to reduce energy consumption. This is a cost on their side and also a burden on the grid infrastructure. On the end user side the mobile infrastructure; (phones and sensors); need to be operational as long as possible without the need for recharge. This is especially important for the sensors not having the luxury in many cases to simply plug in and recharge. Energy efficiency also incorporates energy harvesting through many different sources, but these sources are not pulling from the grid. In conclusion we have just entered the area of 5G, and described some of the requirements for 2020 and beyond.

Creation, Sharing and Consumption of Content in Mobile Devices

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Unprecedentedly, the ubiquitous accessibility of mobiles has removed many of the barriers that existed in high quality content creation. With skill, one can produce good audio and video on mobiles. This has led to fast, viral, sharing of content. The possibility for cheap creation affects the expected returns from information brokering in the future. The competition for attention becomes more relevant than the access to the information. At the same time new content types are emerging that shape the media experience of the future. Addressed below are ways to record and share future media content including the devices which may be used to consume it.

Introduction

What will the device landscape look like in 2020? Today, we are communication bandwidth limited. Teleconferencing systems have gained popularity in corporate settings and professional use, and there are strides to bring this into homes. In the future homes will have large screens that create an immersive vivid telepresence. We will have virtual see-through walls that can be used to connect families in real time. The feasible way to handle the one-to-one high definition content will use optical fiber connections for long distance and high bandwidth wireless inside homes [1].

Autonomous vehicles are in development and have started to gain approval for public roads [2]. This will create a mobile set up for on-the-go media consumption.

Inexpensive manufacturing of robotic machine vision has emerged, like the PrimeSense infrared emitter and camera combination. This technology base will enable a natural interaction between robots and humans so that robots maybe introduced to homes. Perhaps in future, a robot will play the violin at ones birthday party. Future music performances is then perhaps transformed from today’s recordings to live and in-person, albeit through our robotic orchestra.

In addition, a very specialized robot, the 3D-printer, will have an impact on production of goods. People will be able to create new items and devices in their own homes based on instructions from the internet. The home will regain its place in manufacturing which was lost during the start of the industrial revolution. A new type of media content will emerge - the control files for making physical things. This will create a new fresh angle on the internet of things.

New Content

Indeed, the type of the content we know today is changing. Cinemagraphs are redefining the line between a movie and a still picture. By capturing a panorama scene one can render the resulting stream so that the final view is decided through a natural viewer interaction [3].

3D imagery is looking for a breakthrough in the area of producing an immersive experience. It has become evident that future media content will have interactive elements - like 3D-audio that takes into account the listener's head movement, and images that refocus by gaze control.

Light field imaging [5] has roots down to Nobel physicist Gabriel Lippmann's work describing the use of a lens array to distinguish not only the spatial intensity of a focused image, but also the direction from where the light is coming into the photographic plate. In fact, this can be used so that the act of recording the content and viewing becomes separated. Hence, you do not have to decide the focus at the time of recording. Now, after 100 years this technology has become feasible in consumers products. One example are the Lytro cameras.

Intelligent Media

Complicated media, be it real time maps, control files for 3D-printers, or multi-view, game like video content changes the nature of data in the media. There will be a separation of media data and its rendering, which makes an image or audio file more like database put on display by queries from the user interface.

Traditionally the content and the rendering are equal: a picture on the wall is just a picture on the wall. Now, interactivity has brought a separation between these aspects. Intelligent mediators are embedded into the data stream. The stream will have aspects of an algorithmic database that is ready to provide an angle of view or composition implied by the user.

We may expect that the database will also have semantic qualities, that is, it will be able to analyze the meaning of the content using machine vision and object recognition. Actually, the data should be coded more and more so that it self comprehends, or it learns. As an example the image sensor that today measures the intensity of the image, but in the future also has code to perform face detection and inserts this information into a picture's metadata.

The cost of creating this information has significantly decreased, as mobile phones and web cameras have become capable of producing high quality content. Today one may claim the monetary value of data resides, not in the information itself, but in the attention received through the internet. In fact, the decay of attention is predictable: the span of collective attention half-life is 69 minutes [4]. At times the value is not the data itself, which is by the way free, but in the analysis machine on top of it that presents the data in an appropriate form.

Mobile Immersive Media

It is hard to realize interactivity in mass media, like a movie theater, but for individual, personal devices this can be achieved. A display that is small to carry, but large to look at is needed. There are multiple options for this, a foldable, a rollable device, a personal pico-projector, or a near-eye display that is carried like eyeglasses. These could be used for an interactive, maximally immersive experience. For example through the understanding of how a viewer's face moves in relation to the screen one can create immersive 3D like content on an ordinary 2D screen just by changing the content on the display accordingly [6].

Capturing immersive content may be accomplished by using depth sensing cameras that enable the formation of a real time 3D scenemodel. An example of this is Oliver Kreylos' work [7] that uses the Kinect sensor. It shows a future method to disseminate media teaching away from a traditional publication and moving to a Youtube video clip. Indeed, we expect strides in the compression and decompression of the content. For example, today we have tools to efficiently compress multi-view content [8]. In the future codecs will also be able to extract and code semantic information of the media. The semantic information may reveal who are in the video, and was it a sunny day. As near eye displays, foldable tablets, and pico projecters become of age, and technical problems are overcome, the personal mobile media center will offer an immersive all around dynamic viewing experience augmented spatial soundscape created with individualized head related transfer functions.

Augmented Senses

As our devices become more sophisticated they will also start to augment our senses. We can find a new realm of things at different scales. It is not only the high speed camera pictures of drops of water hitting a surface that can produce beautiful imaginary, but also one can magnify motions to show an elastic world that otherwise is not caught by our senses [9].

Conclusion

The social consequences of easy recording and sharing are just emerging now, the implications of easy recording in publishing, in media content control, and in preserving individual privacy will be significant. Some historical rights, like privacy of communication are in danger of eroding, for example, when employers require access to Facebook accounts. On the other hand, fast flow of information can enforce civil liberties and topple authoritarian governments. It will remain to be seen how free the internet will be in coming years.

We will see a rise of home grown high quality content, movies done by hobbyists [10], bloggers turned self-made journalists, and at the same time media spectacles requiring huge investments fighting for the available resources. What will remain of all this? Are the future generations able to break the blue-ray protection to follow our movies when all the devices to see them are gone? Will you be able to open the digital photographs a couple of generation backwards? Or will our content of the future be intelligent enough to be self-describing for the future machines trying to inspect it?

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Pathways to Servers of the Future

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Abstract

Computing server infrastructures are reflecting the backbone of modern information technology. The future architecture of servers is driven by three major factors. First, performance has to increase from a computational as well as from a data processing perspective. Second, energy consumption has to be substantially reduced. Energy efficiency is then a main driver for the third goal of reducing the total cost of ownership. In this extended abstract we will outline the challenges with respect to future server infrastructures as well as address some of the open problems with respect to energy efficiency.

Requirements of future server infrastructures

Modern IT environments have to cope with challenges coming from two different directions. On the one hand, an IT environment requires efficient communication paths comprising wired as well as wireless communication paths. In a world where more connected devices than people exist, wireless communication is central for a global IT infrastructure. On the other hand, servers increasingly provide services in the background following the “as-a-service” principle. Today’s compute infrastructures supply services on a platform, infrastructural, software, and data management level storing and processing in Tera- and even PetaByte-scale. For example, Google processes multiple Petabytes per day and 60 hours of video material is uploaded to Youtube every single minute.

Large scale data processing is becoming more and more the center for a huge variety of decision support systems ranging from supporting strategic decisions in product development and marketing to real-time decisions in the context of personalized online advertisement. The rise of data analytics in almost every domain changes the society: data is omnipresent and the outcome of sophisticated statistical algorithms has an impact on the economy as well as on our personal decision - be it implicitly or explicitly.

We therefore have to find an answer to the question on how to live with that development and how we are able to structure and implement these challenges from a social and from a technological perspective. From a computer science perspective, we clearly see a novel type of applications at the horizon - the merger of data crunching and number crunching applications and therefore associated techniques and methods: high-volume data will meet computational complexity; what-if scenarios will be evaluated on large empirically collected data sets to simulate the outcome of potential actions - ranging from personal buying decisions to political decisions.

Highly-adaptive energy-efficient Computing

To cope with these afore mentioned requirements, future server infrastructures have to significantly increase performance and--at the same time--substantially reduce energy consumption. A newly established Collaborative Research Center (CRC) at TU Dresden [1], funded by the German Research Foundation (Deutsche Forschungsgemeinschaft - DFG) is tackling some of the problems following a holistic approach of research in hardware and software.

The major obstacle in achieving energy-efficient computing infrastructures is the missing energy proportionality in computing systems: energy consumption is not proportional to the computing load, i.e. energy consumption is almost constant and--to a large extent--independent of the existing load situation. Based on this deficit, two major challenges can be identified to provide an infrastructure able to trade energy against utility (causing a system load):

- Hardware adaptability: How can we provide a flexible hardware platform without compromising performance?
- Software adaptability: How can we provide adaptability at the software level?

An overview of the holistic approach pursued within the CRC at TU Dresden is illustrated in Figure 1.

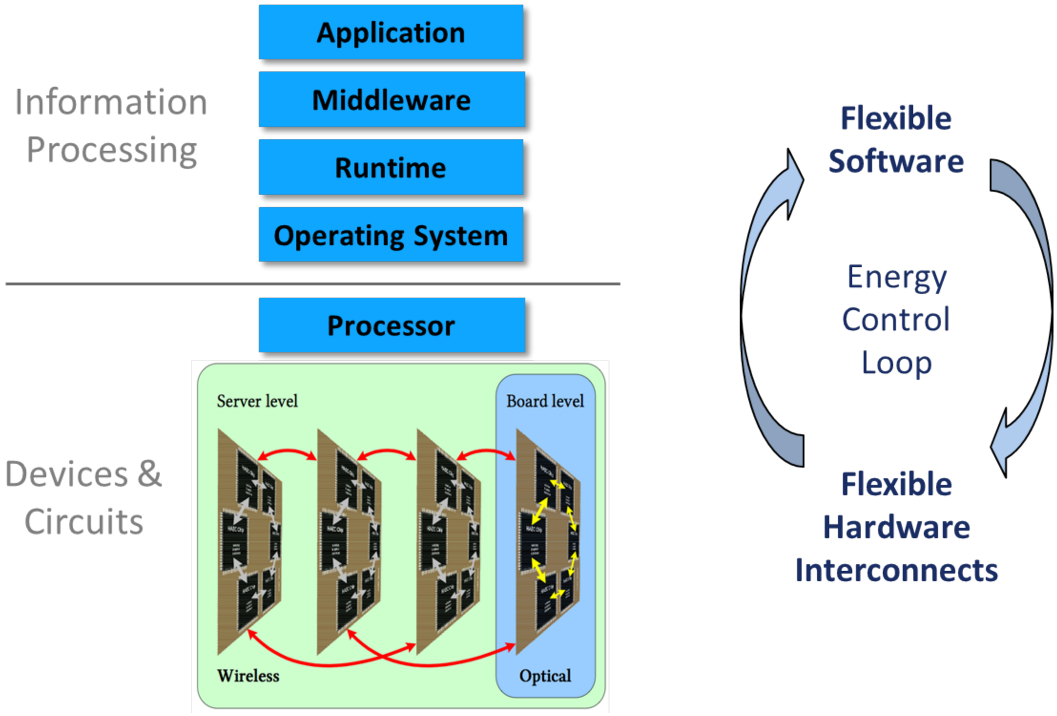

Figure 1: Highly Adaptive Energy-Efficient Computing}

Hardware Adaptability

Hardware adaptability is achieved following two different paths; energy-adaptive onboard links are developed using optical components with embedded polymer waveguides (e.g. 3D stacking of Si/III-V hybrids). Energy efficiency is achieved via adjustable link parameters (trading bandwidth versus power consumption) and low-loss coupling micro optic for passive alignment.

Backplane communication, i.e. communication between the different boards of a server infrastructure, is achieved via short distance radio interconnects. Individual server components comprise on-chip/on-package antenna arrays providing 100Gb/s within the 100-300GHz channel. Exploiting novel beam steering and interference minimization technology, a high degree of flexibility can be achieved reconfiguring the underlying hardware topology. Efficient and secure network coding techniques are developed for wireless and wired communication

Software Adaptability

Software adaptability has to be considered from two perspectives. On the one side, multiple variants of the same application logic has to be available and deployed dependent on the current context of the application and the system. On the other side, an efficient schedule has to be computed to map program tasks logically running in parallel to a set of computing units (cores, nodes, etc.) with shared and local memory.

The overall concept to achieve adaptability at the software side consists in providing an energy control loop including measurement of the current system context, an analysis phase, a short, mid, and long term verification and regulation phase, finally an infrastructure to deploy and schedule the most energy efficient configuration.

Use Case

To illustrate the mechanism trading energy for utility, we refer back to data analytics as the main driver in developing novel server architectures. For example, a large system is running some in-memory database services scanning their local base data leaving some of the computing units and interconnects under-utilized. Depending on the optimization goal (utility) of short individual response times or global system throughput, the runtime advisor may issue to exchange the memory scan by an index scan to access the individual data items. Additionally, database services or databases might be migrated to a single board in order to turn off boards and/or interconnects within the system (“scale-in strategy”). Alternatively, the runtime advisor might partition the database and increase parallelism (“scale-out strategy”) thus increasing performance (utility) at the cost of higher energy demand. Given the increase in hardware heterogeneity in combination with energy proportionality, we can expect further opportunities here to identify optimal configurations; those should be exploited via specialized database operators.

Summary

The merge of data-intensive and compute-intensive applications are demanding a server generation with a high degree of adaptability from a hardware as well as software perspective in order to reduce the overall energy demand. Hardware and software have to be co-designed and benefit from each other. Within a newly establish research cluster at TU Dresden, first steps are made into the direction of novel server architectures, providing optical onboard and wireless board-to-board communication in combination with runtime optimization to trade energy versus utility.

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Smart Power – An Energy System Transformation from Chip to Grid

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The smart use of power is not simply a matter of energy conservation. Rather, “smart” power is the efficient use of energy for applications at many different scales. In the past 30 years we’ve witnessed dramatic performance and energy efficiency improvements in automobiles, passenger aircraft, steel manufacturing, agriculture, computer systems and many other sectors. Computer systems have demonstrated perhaps the most impressive example of combined performance and energy efficiency improvement. The number of instructions per second per watt that a computer can execute has increased approximately 3 million percent since the late 1970s. To put this in context, if a modern laptop capable of meeting today’s functional demands were to operate at the energy efficiency of a computer from 1990, the laptop’s fully charged battery would last less than 3 seconds. Although this illustrates an impressive achievement in performance and efficiency, further advances will be required in many different areas. Consumers are becoming increasingly connected to electronic devices for all forms of business and personal activities and electrical grids are incorporating increasing amounts of distributed and intermittent sources of clean energy to meet rapidly growing demand in an environmentally sound manner. These trends are driven by both personal and societal interests and necessitate a smart energy system capable of handling a massive and integrated flow of information and electricity.

As evidenced by Moore’s Law, the performance of computing devices has grown tremendously in the past 3 decades, doubling approximately every 18 to 24 months thanks to an ever increasing number of transistors that can economically be incorporated into integrated circuits. Likewise, the efficiency of computing (computations per kilowatt-hour of electricity used) has doubled every 18 months and this trend, which is known as Koomey’s Law, started in the vacuum-tube era and continues today in the microprocessor era. Laptops, mobile phones, and other such devices are an integral part of our everyday lives thanks to the increase in energy efficiency that has accompanied substantial increases in computing power. The important ramification of this “smart” power evolution is that ever smaller and less power-intensive computing devices will continue to proliferate and pave the way for new mobile computing and communications applications that will enormously increase our ability to collect and use data in real time. This trend is already revolutionizing how we collect and analyze data and how we use data to make better decisions in all walks of life. The "Internet of Things" is quickly becoming a reality with more than 10 billion internet connected devices existing today and predictions for more than 50 billion connected devices by 2020. This level of connectivity has profound implications for how businesses, and society in general, will develop in the decades ahead. The smart power revolution enabled by parallel increases in computing performance and energy efficiency is driving our ability to control industrial processes with more precision, to assess and adjust our actions quickly and effectively, and to transform business practices.

Smart use of power at the microchip scale will continue for some time thanks in part to novel approaches to component scaling. However, evolution of chip-scale systems will also be driven by functional diversification related to non-digital information that compliments the continuation of Moore’s Law for digital content. More specifically, microchip technology will likely not follow only from Moore's Law and its resulting dimensional scaling, but also from the addition of new components, new layers and new functions inside the microchip itself. Examples are the introduction of passive radio frequency components, biosensors, and 3D integration. As stated in the International Technology Roadmap for Semiconductors, “whereas “More Moore” may be viewed as the brain of an intelligent compact system, “More-than-Moore” refers to the system’s capabilities to interact with the outside world.” This convergence of the analog and digital worlds is needed to support a smart power energy system transformation.

Deployment of advanced microchips and the devices in which they operate is fundamental to the grid-scale smart power energy system. Specifically the “smart” electricity grid is evolving as an energy and communication system that incorporates the internet and related communication technologies. The future smart grid will be an electrical system that is far more efficient and resilient than today’s grid and can prevent issues such as blackouts, accommodate intermittent, distributed power sources, and respond to consumer energy demand.

A smarter grid will incorporate advanced technological solutions for clean energy generation, transmission, distribution and end use. Power electronics, which process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited to the load, will play a key role in smart grid development. By 2030, the US Department of Energy expects that as much as 80% of all electric power will use power electronics somewhere between generation and consumption. Power electronics converters are essential components in clean energy generation technologies such as wind turbines and photovoltaic systems, where they convert variable voltage inputs into fixed voltage outputs for connection to the grid. AC power transmission will be greatly increased by power electronics via Flexible AC Transmission Systems (FACTS) that effectively deal with reactive power and have the potential increase electrical grid capacity by up to 30%. High Voltage DC (HVDC) will enable long distance power transmission capable of doubling the capacity of existing long haul lines.

“Wide bandgap” materials, such as silicon carbide (SiC), will increasingly replace silicon as the semiconductors of choice for power electronic applications. A material’s bandgap is the energy needed to excite electrons from the material's valence band into the conduction band. SiC electrons need approximately three times as much energy as silicon electrons to reach the conduction band and this is the property that lets SiC-based devices withstand far higher voltages and temperatures than their silicon counterparts. This will allow power semiconductors to eventually operate at power densities exceeding 250 kW/cm^3 and temperatures greater than 200 degrees Celsius, resulting in thin devices that are faster and have less resistance with less energy lost to heat during conduction of electricity. Solar and wind energy generation will benefit from inverters with significantly improved efficiency in converting electricity to a form that can be used on the power grid. The power grid itself will be transformed as the need for massive substation transformers is eliminated, thus saving considerable amounts of energy now wasted as electricity moves from power generation to final destination. It is easy to imagine the cost savings for utilities companies when they replace transformers weighing more than a ton with efficient solid-state transformers, each the size of a suitcase. As an indication of overall impact, Infineon has estimated that improvements in power electronics can eventually reduce electricity consumption by as much as 30 percent. Within the building and the industrial sectors, power electronics provide the opportunity for motor-driven appliances to become up to 40% more efficient, lighting up to 75% more efficient and computers up to 30% more efficient.

With regard to the built environment, approximately 40% of total energy consumption is consumed by buildings and so optimizing building energy systems through demand reduction measures is a key aspect of a smart power. Reductions will be achieved by building systems that integrate sensing, analysis and actuation capabilities for control of lighting, temperature and other such drivers of building energy performance. Sensors with microwatt energy demand that are capable of extracting energy from ambient light, motion, and/or heat and bring the possibility of indefinite operation with no external power source. This will enable data acquisition and analysis capabilities never before possible and greatly enhance our ability to optimize building energy performance.

A smarter grid will also bring consumers directly into the management of power demand. When consumers are aware of the actual price of electricity, which can change by large amounts during the day, they will often scale back their use during peak hours. In the future, homeowners will be able to program smart thermostats, appliances, and electric-vehicle chargers to adapt automatically to the changing price of electricity to effectively manage their electricity costs. In the near term, however, government subsidies are only just beginning to prompt utility companies to equip large numbers of homes with smart electrical meters that enable two-way wireless communication. Eventually however, utilities will move toward time of day pricing to modulate power consumption. This is an example of the type of business model transformation that smart power approaches are inducing.

Achieving the promises of smart power for the broader energy system will require advances in technology development and government policy support. Although consumer devices that incorporate smart power technologies may experience rapid uptake due to market forces alone, the same will likely not be true for all of the technologies required to achieve a smart energy system at grid scale. This is because at grid scale the costs of smart power technologies can be significant and the benefits not always directly observable. Therefore, supporting policies in the form of financial incentives or simply education and awareness will be needed. If we can achieve both market pull and government push for the broad spectrum of current and future smart power technologies, we will be able to achieve an energy system transformation, from chip to grid, that will bring considerable social, economic, and environmental benefits.

Firmware is dead - The Ephemeral Soul of All Things Computing

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Like energy and telecom capacities before, computing power has become a commodity that can be not only bought, but sold and traded. This has opened a way to a completely new world, where nearly everything can be virtual. This trend can be observed in the virtualization of computers, phones and cameras increasingly using software to perform tasks previously limited to the hardware domain, and will soon explode with the Internet of Things, all white label goods possessing communications and thus computing capability.

Combined with the commercialization of 3D printing, we will also see a countertrend - concretization of the virtual in as diverse domains as production of cars and buildings to the Smart Grid. In the virtualized world software and hardware, simulations, measurements and actuations converge. This is the Grand Unifying Theory of the Internet of Things In the telecom world, monitoring and management functions are being virtualized and eventually integrated with hardware elements. Focal operating centers are likely to become location independent and perhaps even crowd sourced. Network routing functions become dynamic and virtual, enabling more intelligent capacity handling. However, when the Internet of Things emerges, current telecom operators might be overwhelmed by industrial data and even replaced by more robust cyber-physical Service providers.

Another computing entity that is likely to be virtualized before 2020 is the current mobile interface. It would be invokable by any browser, residing in tablets, PCs, cars, public transport or even other physical phones. All essential features like address books, call history, recordings and applications - including voice - would be instantly available, just with scalable cloud computing power, vastly improving resource efficiency.

When 3D printing is commoditized enough, many existing hardware vendors become “recipeware” providers instead of suppliers of physical things. Recipes - combinations of printing instructions and associated operating software - continuously evolve within the vendor's cloud, operating partly there and partly downloaded to customer equipment when recipes are purchased or updated in the "app store". Add crowd participation, and this enables mass customization as opposed to rigorous standardization - customers can tailor their recipes in the cloud throughout the manufacturing process and after it.

This overarching concept of "virtualized everything" enables new applications and services, but ultimately leads to far better resource efficiency. With 3D printing and crowd sourced manufacturing, raw material recycling may be integrated into the processes - required physical objects are just grinded and re-printed for the next release of a thing.

What comes to security, cloud services will eventually become far more secure than isolated production networks of today. More advanced and evolving authentication and encryption methods are available and continuously monitored for intrusion attempts. Although an island network and physical hardware is often perceived as secure, this is often an illusion as it was recently demonstrated by skillfully engineered Stuxnet and Flame cyber-attacks.

Beyond CMOS Technology

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This Compilation is based on the TTM presentations by: Paul Farrar, Laurent Malier

Introduction:

Mobile devices will be a key instrument in modern society. Not only do we want to have access to information everywhere (Facebook, Twitter, Google+ etc.), we have learned to communicate in a mobile environment using ad-hoc infrastructure. Scenarios ranging from traditional traffic management and personal health management in the future may also be enabled by an ad hoc, but robust and reliable infrastructure. For example these and other applications may add layers such as real time advertisement, location specific micro marketing based on consumer activity, ad-hoc carpooling coupled with road conditions, and e-health connectivity through a trusted care network.

Nano Technology current and future role:

Technology will play a key role in this new paradigm and leverage all the technical “tricks” available. However technology alone does not drive a sustainable network access business model, but certainly is a necessary component; without technology advances the additional layers described above will not be introduced.

Some changes today that will be reflected in the design of new mobile device subsystems are contained within the underlying transistors that switch between the on and off states. It is actually this simple, and yet this complicated. As Paul Farrar stated in TTM 2012, the industry is searching for its next best switch. Best is in the eye of the user, but from a technology directive best implies improved speed, lower area, reduced power dissipation, all meeting industry lifetime expectations. Such a switch is in fact an industry game changer.

Diving a bit deeper this switch be it semiconductor or other material base has the following characteristic: There are at least three to four orders of magnitude decrease in power by placing a device, or switch in the off state, the more the better the device acts as a switch and the easier it is to design circuitry to take advantage of the switch.

Design tricks can certainly help improve this on off ratio. One of them segments design blocks not currently in use by controlling specialized power supply rail devices such as headers and footers to turn blocks on and off. One may further leverage this feature in the technology offerings that merge on chip digital Complementary Metal Oxide Semiconductors (CMOS) and Radio Frequency (RF-CMOS) , or the ability to provide wireless on and off chip communications. The new RF-CMOS technology will be a game changer in the ubiquitous sensors deployed as the Internet of Things (IOT) space develops. The design trick of depowering (in this example) the RF portion from the digital portion will enable longer battery life for these IOT sensors that communicate with most certainly the cloud. [1]. Thus the game changer is this scenario is a mobile ad-hoc trusted control of the IOT sensors RF communication.

The integration of "Hi-k" and "Low-k" dielectrics as well as "stressed-silicon" transistors will further assist in balancing power and performance requirement by providing designers options to tune the on and the off states, perhaps enabling dynamic real-time implementations . The dielectric constant "k", is a very important parameter that is leveraged for both increased speed and power efficient micro electronics. Through about the 90nm node, or through the scaling of nanotechnology to a 90nm minimum image the industry has been able to utilize silicon dioxide ($SiO2$) having a "k" of roughly 3-3.2 as its workhorse both under the gate in a transistor and in the insulation of the wiring of a chip. Silicon dioxide is a highly reliable material, and also integrates very well into the silicon lattice. However as we scale dimensionally smaller than 90nm researchers have found SiO2 to be too conductive as a thin layer, and also too capacitive to allow for high speed signal transport in and outside of a chip.

Figure 1 describes this problem by showing how off state and on state leakage are tending to merge over the generations of traditional CMOS gale length scaling. Figure 2 shows the improvement CMOS technology has made through the introduction of stressed silicon. This allows one to trade off performance and power. Figure 3 shows the leakage improvements made by the introduction of high-"k" dielectrics used under a CMOS transistors gate. Similarly, a low-"k" dielectric is desired in the many kilometers of wiring that sends signals into and out of a chip, for the main reason just introduced, ie reducing the wiring capacitance. This wiring is insulated by a dielectric. The lower the wiring dielectric constant, the faster a signal can propagate.

The actual controlling element of a transistor switch is its internal gate electrode. Scaling this electrode physically correlates to improved switching speeds, but this also implies scaling the power supply. CMOS devices over the last 30 or so years has scaled from roughly a 10um feature size to 90nm and below. The CMOS power supply has scaled from roughly 5V to between 0.8V-1.0V today. The gate oxide thickness has also scaled in proportion. Overall the electrostatic operation of the switched has improves and the on and off state of the intrinsic transistor has been preserved.

Unfortunately scaling to a thinner gate dielectric leads to undesirable current leakage through the gate as shown in figures 1 and 2. If left unchecked this ultimately increases power consumption and also degrades a transistors lifetime. Again electrostatically speaking we desire a dielectric with having a higher "k" as evidenced by the reduction in leakage of figure 2. This allows one to fabricate a physically thicker dielectric which reduces gate leakage, but electrostatically it behaves as a very thin dielectric and preserves the on and off state ratios.

The CMOS power supply is in need of innovation in order to scale. The transistor does reach a fundamental limit between the on and off state through the physics of a "built in voltage". [1,2].

Conclusion:

These are some of the areas that "beyond CMOS" addresses. The actual implementation, which includes the fabricators, the design subsystems, product yield and reliability are challenges for 2020 and beyond. What will the next switch actually be once all the tricks above have played out and the need arises for reduced size, lower power and improved performance? This does remain an open question, and perhaps the subject of IEEE's next TTM. Regardless of what we choose there is a large ecosystem today starting from the physical tooling suppliers to the design subsystems, the synthesis and layout and advanced packaging that is the backbone of the technology industry. Such an ecosystem has to be in place to support a future new switch.

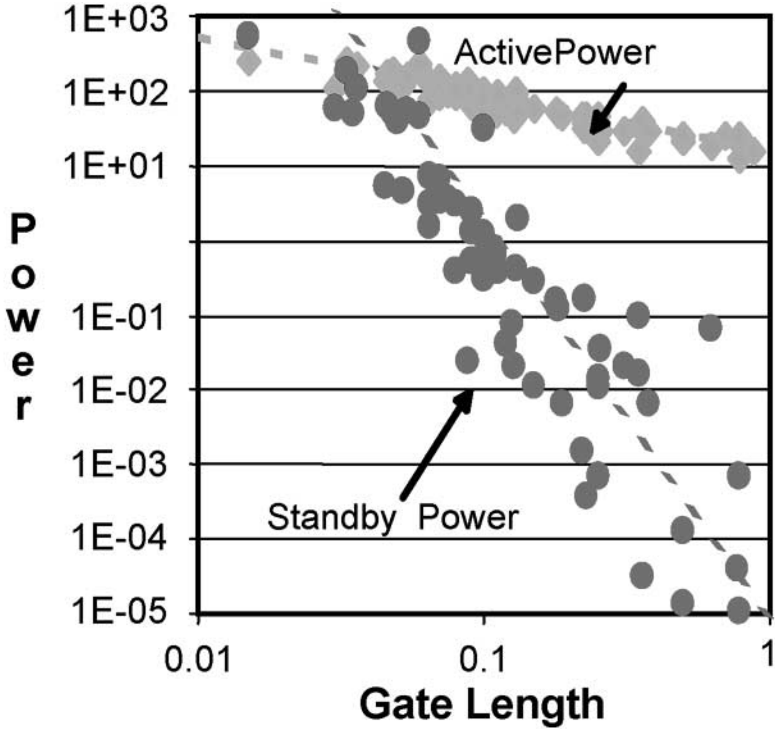

Figure 1:

Gate channel length over *V*DD scaling versus power in watts per square centimeter.. The prediction is at the 22-nm mode; the dc or standby power will be at the same level as active power. In terms of generational growth, active power and dc power are growing at ∼1.3× and ∼3×. Gate leakage power is growing at ∼4×. [1]

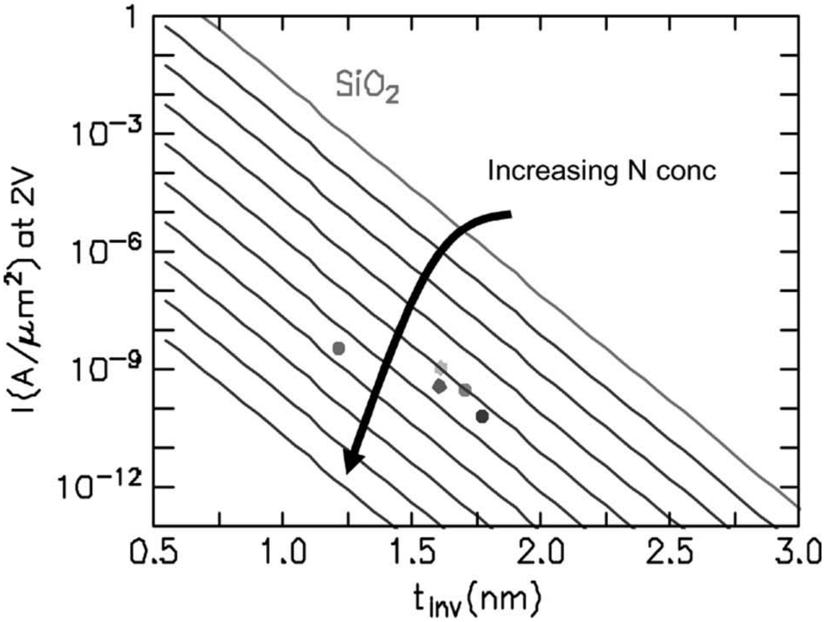

Figure 2:
Gate area leakage versus physical oxide thickness for various HiK dielectric systems, bounded by SiO2 and shown as a function of nitrogen concentration in the SiON layer of gate dielectric
Inversion layer t_{inv} is the thickness of a given stack in bounded by an SiO2 single dielectric.
thickness. [1]

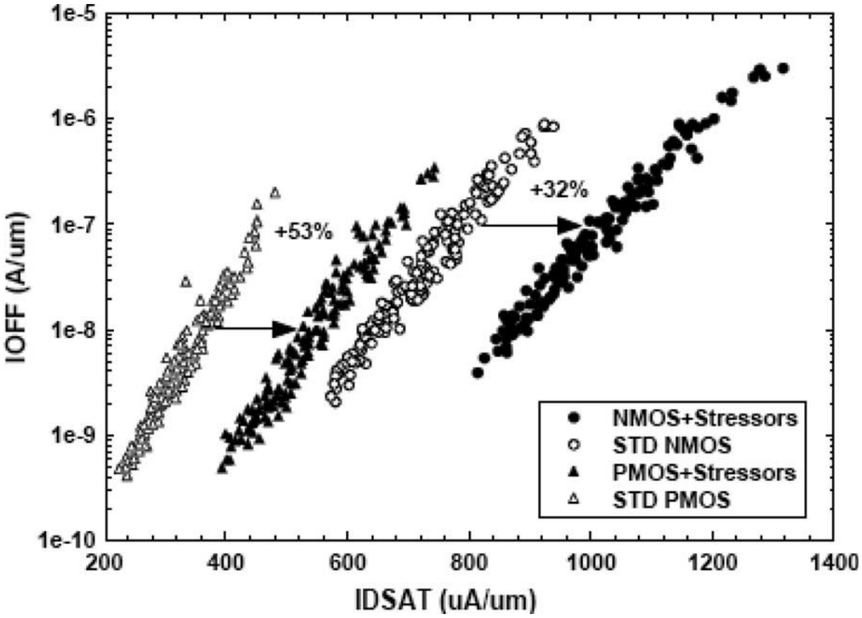

Figure 3:
Gain in *I*off versus *I*on of standard (STD) and stressed PFET and NFET transistors shown at constant width and varying channel lengths. Substantial current gains are universally observed for all stressed transistor variations as compared to the standard [1,3]

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Memristors: Past, Present, and Future

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A memristor is a 2-terminal electrical circuit element first postulated in 1971 [1] as the fourth basic circuit element, in addition to the three classic elements Resistor, Capacitor, and the Inductor [1,3]. Although a proof of principle was given with an electronic circuit via operational amplifiers, it was not until 2008 when a nano-scale TiO2 device was built at HP and published in the May 2008 issue of Nature [4] as well as a cover article in the December 2008 issue of the IEEE Spectrum.

The HP memristor is a nano-scale non-volatile memory device which has the potential to replace flash memories and DRAMs in the next few years. It has attracted unprecedented worldwide attention, with publications growing at an exponential rate, including two recent special issues on memristors published in the March 2011 issue of Applied Physics A and the June 2012 issue of the Proceedings of the IEEE, respectively.

It soon became apparent that many resistance switching memories published during the past two decades share the following common fingerprint of the memristor, as well as the generalized memristor device published in 1976 [5].

3 Experimental Tests for Memristors:

- The Lissajoux figure in the voltage-current plane is a pinched hysteresis loop when driven by any bipolar periodic voltage v(t), or current i(t), and under any initial conditions.
- The area of each lobe of the pinched hysteresis loop shrinks as the frequency of the forcing signal increases.
- As the frequency, Ω, tends to infinity, the pinched hysteresis loop degenerates to a straight line through the origin, whose slope depends on the amplitude and shape of the forcing signal.

It is important to emphasize that the pinched hysteresis loop is not a circuit model because both the shape and the area enclosed by the hysteresis lobes change with the input signal, and therefore cannot be used to predict the solution waveforms when the device is imbedded as a part of an electronic circuit. This is the reason why decades of research on resistance memories had failed to produce a practical nano-scale non-volatile resistance memory device. Only by recognizing that all resistance switching memories are in fact memristors - henceforth used as a moniker for memristive devices [5] - can engineers exploit memristor circuit theory to design and optimize industrial-scale resistance switching memories. In particular, the following resistance switching devices are memristors:

- RRAM: Resistance switching RAM
- ReRAM: Resistive RAM
- PCRAM: Phase-Change RAM
- MRAM: Magnetoresistive RAM
- MIM: Metal-Insulator-Metal memory cell

The uninitiated reader is referred to four recent tutorials [3,6,7,8] for an introduction to memristors. A simple yet accurate formal definition of a memristor is as follows:

> **A memristor is any 2-terminal device described by a state-dependent Ohm's Law.**

A less formal yet more practical definition is given by the following test:

> **Any 2-terminal resistance switching device which exhibits the phenomena listed in the 3 Experimental Tests is a memristor.**

It follows that whether a resistance switching memory device is a memristor or not shall henceforth be decided by conducting the above simple experimental tests. We end this paper with the following succinct abstraction of the above 3 memristor finger-prints:

> **If it's pinched it's a memristor.**

Acknowledgement

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Future of Media: A Two-Sided Market Perspective

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Technology convergence has enabled provisioning of media in various forms (newspapers, books, magazines and video) through a wide range of devices such as Smartphones, Tablets, and Laptops. There is also a paradigm shift in the delivery of media through a simple one-way broadcast network to two-way networks of networks. We observe the following trends in the future of media:

1. The digitization of the media and the creation of content enabled by peer-to-peer social networks (viz. Twitter and Facebook) have resulted in "democratization" of the media. The media content is more and more created by individuals and not by large media firms. The content is then transferred to others through the peer-to-peer or centralized network of networks, eliciting responses from the recipients thus adding to the richness of the content. This has broken the ownership patterns typically associated with the media firms. The delivery of content has also changed from one-way broadcasting (e.g. newspapers, Television) into a two-way interactive experience.

2. The media will be consumed more and more any-time, any-where (often while mobile) using devices such as Smartphones and Tablets. In countries such as India with more than 800 million mobile users about 40 percent are likely to use mobile as the first device to access Internet and digital content. Hence these devices are likely to be enriched by features such as 3D viewing, local information mapping, interactivity, and multi-touch to enhance the Quality of Experience, both for content generators and the readers.

3. The shelf space of the democratized content has reduced considerably (e.g. half-life of a tweet is just about 4 minutes) compared to almost half-a-day of a newspaper. This is the a driving need to create stickiness of digital news content.

4. The majority of users are local information seekers; hence the need to customize and provide locally relevant news [1].

5. Journals, magazines and books will be less and less owned. Predominant model for consumption will be subscription based and pay-per-use. Due to a decrease in upfront acquisition cost, digital media can potentially address a larger base of users compared to traditional media.

6. There are strong complementarities and network effects between the media content, smart devices, and network access service especially as more and more wireless broad band networks and smart devices are getting deployed worldwide. We view this phenomenon as a "Two Sided

Market" structure [2,3]. On one side of the market are media/ content providers and on the other side are consumers of the content. Platforms provide intermediation between the content and consumers. An example of the legacy platform is "newspaper" or "cable TV networks" owned by a firm that enables news from news agencies to reach the end consumers. However, in the current and future context, these platforms are "digital platforms" that connect digital media content generated by firms and individuals on one side with consumers on the other side. As we have seen, these platforms are often an oligopoly market. Structuring the pricing for the two sets of users on either side of the market is key to drive adoption and hence the associated cross-side network effects.

We observe the following trends in the future of such digital platforms:

- Platforms shall seamlessly connect the user generators and consumers of digital content (viz. enhanced versions of Twitter and Facebook).
- The platforms need to collate content from different sources in different languages, authenticate and localize them, and provide using an immersive personalized format.
- Digital platforms have the potential to bring in generators and users from all geographical regions and from all sections of the society, especially the next Billion Internet users from emerging countries such as India and the African continent, thus bridging the "digital divide".

We foresee the following challenges in the context of future media:

1. Who owns the Copyright of the content - Is it the platform or the generators? How does copyright enforcement works across geographies? What should be the length of the copyright agreement? Is it likely that we see "copy left" kind of arrangement as used in computer software applicable here as well?

2. What is the effect of content ownership in vertical markets where the firm owns content, platform/ devices and the subscriber base? Are principles similar to "Net Neutrality" as practiced in telecommunications applicable here?

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Global Healthcare Trends 2020 – the Pathway towards Distributed Health

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Global Demographics show alarming indicators that will affect the capability to provide healthcare within the next generation. OECD and UN data predicts a massive growth in the population over 65, and a parallel decline in the age group between 20 and 65. We observe rising chronic disease prevalence, and less available care capacity to deal with these as a result. This trend is universal, but happening in different rates and timelines across the globe. The current delivery model that has emerged in mature geographies will not be sustainable in this context, for at least three reasons: The reason usually mentioned first is economic - the cost of care is rising to levels that are arguably not sustainable. The US spent 17,5% of GDP on Healthcare in 2010, and growing. This pattern is seen across all mature economies. This rising cost of healthcare needs to be paid by the productive working population that drives the various economies, which leads to the second reason, which is less often mentioned: There will simply not be enough trained personnel to perform the care tasks in the current model. 2020 predictions are estimating a nurse shortfall of close to 1million in the US alone. Even if the cost can be paid, it is completely unclear where this workforce will be sourced from, how they will be trained, motivated and kept productive over a lifelong employment. The current model of nurse immigration that is seen in many countries is a local response, but globally unsustainable as demand will increase also in the emigrants home countries. Hence, the third reason that this model will not hold further is the strain that this care model puts on caregivers currently. Healthcare professionals, like nurses, and even more so, the informal care givers in close environment of a patient are suffering from collateral diseases, leading to widespread depression, burn out, and other socio-economically devastating epidemics.

From a control theory perspective, the feedback loops that are in place in the current system have led to an optimization towards an inefficient and ineffective system. The care model deployed today has been designed around a reactive “break-fix” concept of centralized care. Centers of excellence are in place to treat acute diseases and are becoming highly specialized in doing so. The technology analogy that can be used here is the one of the mainframe computer, or centralized telephony. This model has its roots in providing care for acute disease, and monetary incentives, as well as efficiency drivers, have led to growth in this model, which is highly geared towards a medical “repair” shop approach that works for acute disease. However, it can be predicted that it will not sustain for the growing needs of preventative and chronic care.

A paradigm that has the promise to break up this dilemma is “Distributed Healthcare”. By taking a patient centric view on personal care needs, and designing a care model around the needs, and the associated data flow that is derived from the medical decision-making following this care cycle, the current centralized model of “break-fix” care delivery can be complemented by a more effective, efficient, and patient friendly approach. This has promise to deliver on primary and secondary prevention. This innovation trajectory will be fueled by technology advancements, clinical evidence creation, and socioeconomic modeling. There are already initial examples of these approaches emerging on the markets, and the slow adoption of these models has given them bad press by technology-minded analysts. However, this is not unexpected. Analysis based on Rogers’s theory of innovation diffusion showed that healthcare innovation takes an average of 17 years from first proof in clinical practice to broad adoption.

From a technology perspective, the predictions on distributed Healthcare 2020 are relatively straightforward: Building on Information Technology, Mobile Wireless platforms and universal network coverage. The devices and solutions that will support the distributed care model will follow trends we have seen in mobile telephony, office automation, and video/data transmission. Systems currently used in a mainframe context needing expert users to interpret data will diverge into sub functions of information collection and data interpretation, allowing to unlock the current 1:1 caregiver/patient relationship in time and space. Data can be collected remotely, analyzed centrally, and interventions prescribed again in a distributed fashion. Initial remote patient care examples like Philips Motiva, Post Discharge Telemonitoring, and Standards Initiatives like Continua Health Alliance are indicators of this trend. These have the promise to provide affordable, accessible care to a rising global patient population in a sustainable way.

The Earth Seen from Space by Radar Remote Sensing: A Vision for 2025

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In a changing and dynamic world, high-resolution and timely geospatial information with global access and coverage becomes increasingly important. Constellations of radar satellites will play a major role in this task, since spaceborne radar is the only sensor that has all-weather, day-and-night, with high-resolution imaging capability. Examples of applications for such a constellation are environmental remote sensing, road traffic, hazard and disaster monitoring, geoscience and climate research, as well as reconnaissance and security related tasks. Long-term vision is a space based sensor web that provides a view of our planet similar to what we may see using Google Earth, but a significant enhancement is that along with high-resolution images we also can see relevant geospatial information that is being updated every few minutes.

A prominent example of the state-of-the-art is the German satellite mission TanDEM-X, the first radar interferometer in space that employs two satellites operating in a closely controlled formation flight. The primary objective of TanDEM-X is the generation of the Earth's topography with unprecedented accuracy as the basis for a wide range of commercial applications as well as for scientific research. It is expected that this data set will become a reference in geosciences and remote sensing applications [1], [2], [3].

TanDEM-X has an ambitious time schedule to reach the main mission goal. The operational bi-static data acquisition has started in December 2010. The next two years are dedicated to the global digital elevation model (DEM) acquisitions, followed by six months of additional acquisitions to cover difficult terrain with extreme topography. The distance between the satellites are optimized in each phase of the mission for DEM performance and varies between 150 and 500 meters. The global DEM data set will be available by mid 2014.

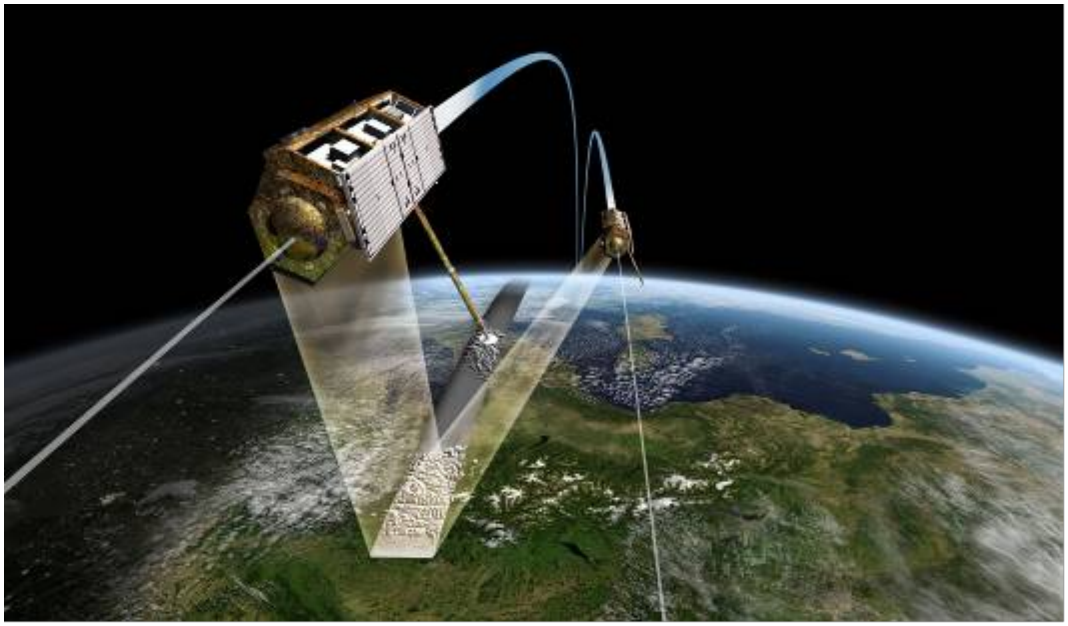

Figure 1 -TerraSAR-X and TanDEM-X flying in close formation. The distance between the satellites is optimized in each mission phase for optimum performance and varies between 150 and 500 meters.

The vision for spaceborne radar remote sensing looks exciting. Future SAR mission concepts with digital beamforming technology in combination with large reflector antennas are being developed which will outperform the imaging capacity of current SAR systems by two orders of magnitude. These highly innovative concepts will allow the global observation of dynamic processes on the Earth's surface with hitherto unknown quality and resolution. One example is the mission proposal Tandem-L which is distinguished by the high degree of innovation with respect to the methodology and technology. Examples are the polar metric SAR interferometry, multi-pass coherence tomography, the utilization of the latest digital beam forming techniques for increasing the swath width and imaging resolution, as well as the close formation flying of two cooperative radar satellites with variable adjustable spacing. The Tandem-L mission concept is based on the use of two radar satellites operating in L-band (23.6 cm wavelength). The utilization of the synthetic aperture radar technique (SAR) enables high resolution imaging of the Earth's surface independent of weather and time of day; it therefore offers the ideal basis for the continuous observation of dynamic processes on the Earth's surface. The goal of Tandem-L is to image the land mass interferometrically once a week and by this to provide urgently needed information for solving pressing scientific questions in the areas of the biosphere, geosphere, cryosphere, and hydrosphere [4], [6], [6].

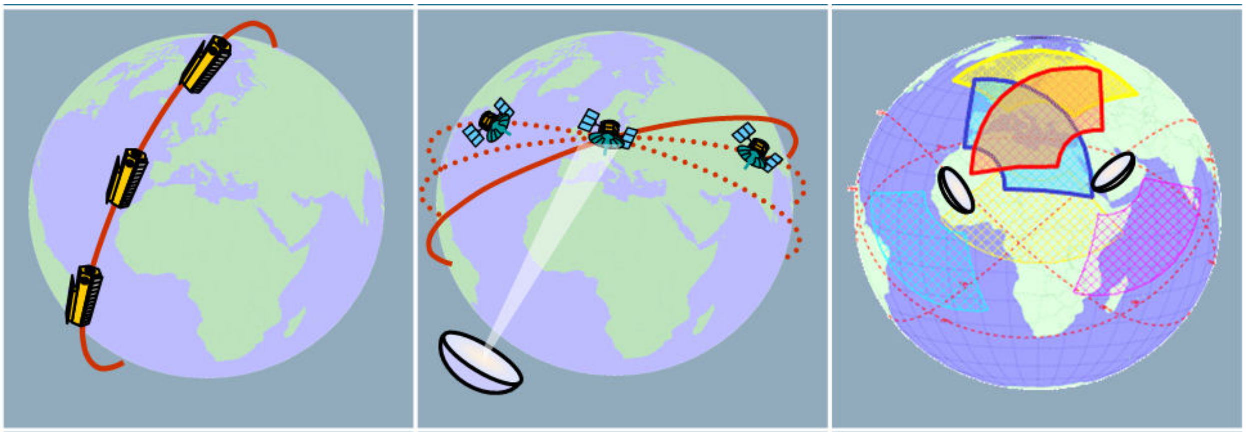

Figure 2: Concepts for a future constellation of radar satellites for quasi-continuous monitoring of the Earth. Left: Low Earth Orbit (LEO) satellites, middle: Geostationary Earth Orbit (GEO) transmitter with LEO receivers, right: Medium Earth Orbit (MEO) satellites.

New spaceborne radar technologies will also allow the implementation of a constellation of radar satellites for reliable and systematic monitoring of the Earth's surface (cf. Fig. 2). It will unlock the door to a future global remote sensing system for the continuous observation of dynamic processes over the Earth, as it currently exists for weather prediction, where a network of geostationary satellites is used.

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