Importance of Wi-Nano technology for Future Broad Band Communication Systems

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ABSTRACT

The devices in the future have to become more efficient, and easier to use. This paper reviews and examines the profound impact that nanotechnology would have on mobile devices in particular and future wireless devices in general. Devices of ultra-high- speed, long-range communication links, portable and power-efficient computing devices, high-density memory and logics and robust energy devices can be manufactured with the help of nanotechnology.

KEYWORDS: *ambient intelligence, ubiquitous sensing, Nanosensors, thermal management*

I. Introduction

One of the fundamental visions of the wireless industry is to have ambient intelligence i.e. computation and communication which are always available and are ready to serve the user in an intelligent way. This requires that the devices are mobile. The intelligence that is embedded in human environments – home, office, public places –in conjunction with mobile devices will create a new platform which will enable ubiquitous sensing, computing, and communication. This kind of ubiquitous ambient intelligence requires that the devices are autonomous and robust. They can be deployed easily, and they can survive without explicit management or care. As shown in Fig. 1, mobile devices will be the gateways to personally access ambient intelligence and desired information.

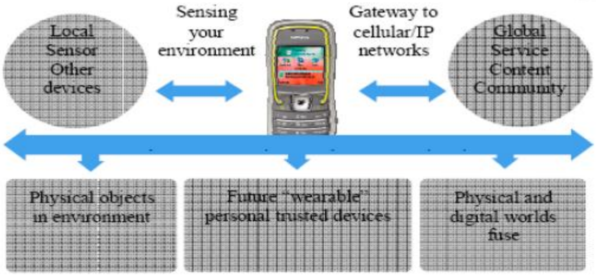

Figure 1: Mobile devices becomgateways to ambient intelligence and needed information

Mobility puts constraints on size and on the power consumption. In order to provide continuous and uninterrupted connectivity these ambient intelligent systems will require high data rates of the wireless links. Thermal management is a major challenge for these devices because increased data rates, intelligence, sensing and context awareness, require more memory and computation. Also, there are limitations on the size of the device. All these requirements combined lead to a situation which cannot be resolved with current technologies. As we see in the rest of this paper and in other literature, nanotechnology could provide solutions for sensing, actuation, radio, embedding intelligence into the environment, materials, mechanics, manufacturing, environmental issues power efficient computing, memory, energy sources and human–machine interaction,. Nanotechnology is a field of science and technology of controlling matter on a scale between 1-100 nanometers. It is a highly multidisciplinary field. Economic impact is foreseen to be comparable to information technology and telecom industries.

II. NANOSENSORS

One of the key requirements for embedding intelligent and autonomous devices into physical objects of the world requires that devices should adapt to their environment and become a part of the network of devices surrounding them. Such a system cannot be configured manually by using top down approach. Similar to biological systems which grow and adapt to the environment autonomously, nanotechnology can aid in the development of novel kind of intelligent devices where learning is one of the key characteristic properties of the system. To detect microscopic variations nano sensors act as chemical points that convey information about macroscopic world to the nano particles. To achieve insight into bio-chemical traces and processes nanosensors would assist users to examine the environment around them in completely new ways, like from analyzing air pollution. Nanotechnology would unleash novel potentials which might be as complex as helping us monitor evolving conditions in the quality of our surroundings, or as simple as knowing if the fruit we are about to enjoy should be washed before we eat it. Our capability to tune into our environment in these ways can help us make key decisions that steer our daily actions and ultimately can augment our health.

III. SOLUTIONS FOR RADIO

Range and interference avoidance, along with processing speed are the challenges posed by RF operation in the GHz frequency range. Since the radio frequency decides the basic clock speeds, the frequency at which certain physical and medium access control layer signal processing algorithms run per second is also determined by it. Here nanotechnology could be of great assistance. For example, recent advances in nanotechnology and scaling allow building of systems with a large number of nanoscale resonators, e.g., NEMS devices [1], which could be used for GHz signal processing applications. This type of a system can make spectral processing in RF domain feasible. This is of special importance for high data rate wireless communications systems. One particularly important application would be spectral sensing in mobile devices with flexible spectrum use and/or cognitive radio features. There wide radio spectrum bands need to be repeatedly scanned in real-time with low power consumption. In addition, a lot of processing speed and power is needed to analyze the data and run all the algorithms which enable intelligent use of spectrum and fast adaptation to dynamically changing radio environment. With current technologies only limited versions of fully cognitive applications could be realized, in particular when operation frequencies are in the GHz range. Another interesting application is wireless ad-hoc networks with large number of extremely low-cost, low-power elements. For example, all the required components of a wireless sensor node, i.e., a sensing unit, a processing unit, a transceiver unit, and a power unit have already been demonstrated with nanoelements, such as carbon nanotubes [2]. However, a lot of work remains to make these components suitable for nanosize wireless sensor nodes, and to integrate them together into a complete system. Once realized, this could enable a vast number of novel applications and possibilities of ultra-low power wireless sensor networks that have not been possible before. In addition to communication networks and environmental sensors, also applications to medicine and healthcare can be significant. Nanotechnology also offers new possibilities for antennas. Reducing the size of current antennas made from magnetic and conducting bulk material increases electromagnetic dissipation. The antenna geometry can be optimized using numerical simulations, but the radical enhancement of the performance could come from nanotechnology: by tailoring new materials, e.g., magnetic nanoparticles, we can hope to reduce the losses and tune the electrical permittivity and permeability to optimal values. Another intriguing possibility is metamaterials, which exhibit physical properties not appearing conventionally in nature [3]. Such materials/structures are attractive for near field imaging, filters and antennas

IV. MORE SPEED, LESS ENERGY

The constantly increasing wireless communication speeds require increasing amount of computation with limited power. It has become possible to follow the Moore's law and to provide electronics with all the time increasing performance with reduced price due to continuous innovation. Due to the limitations of the manufacturing technology the current approach of simply reducing the transistor size seems to come to an end by about 2015 [3]. By 2020, the traditional silicon CMOS is expected to reach a density of 1010 devices per cm2,switching speed of 12 THz, circuit speed of 61 GHz, and switching energy of 3x10-18J [3]. This should be considered a benchmark for new approaches based on nanotechnology. Such approaches include new materials which will lead to the development of transistors with improved properties (for example Intel's recent announcement on metal gate high-k transistors [4]), and to a combination of new type of nanoelements with traditional circuits [5]. Some circuitry can be replaced with application specific nanosystems, either digital or analogue, tailored to perform a specific signal processing task with vastly improved power efficiency and speed. At the nanoscale the operation of the devices is more stochastic in nature and quantum effects become the rule rather than the exception. It could easily be that the current standard computation methods and models will not be optimal with these new devices and technologies. As an example, parallel computing with neural networks could be optimal for processing and understanding information from sensors. Other ideas being studied currently are, e.g., spintronics [6] and cellular automata, realized with spin-based systems of nanosize magnetic particles [7].System design with these kinds of elements requires development of computing methods which are tolerant to failing components, and capable to take into account quantum-scale effects inherent in nanosystems.

V. More Memory

As of today, to store data, videos, music and pictures from a number of different applications mobile phones require a substantial amount of storage capacity. Considering, wider use of different tools which allow users to create their own content and the need for fast wireless links for loading of external content, we can easily expect that mobile phones will require up to 10 GB internal mass memory for short term and 50-100GB for mid and long terms. Memories for mobile devices should meet very tough requirements. Low power consumption is one such requirement. As we know battery energy is limited (typically 500-1500 mAh).Safety and reliability concerns have limited maximum heat dissipation (2-4 W). Low voltage is needed because of power limitations, battery voltage development, and system design. Currently the standard in the mobile industry is 1.8 V core and I/O and we expect a transition to 1.2 V within 3- 5 years. Thus in order to increase memory a range of new memory technologies have been explored namely ferro- electric RAM (FeRAM), magnetic RAM (MRAM),ferro- electric polymer FeRAM, phase change memory(PCM), resistive RAM (RRAM), probe storage, carbon nanotube memory (CNT), molecular memory, and many others. The concept for some of these technologies has been around for years, and even reached product phase like FeRAM, MRAM and PCM. A few are completely new. All the memory technologies mentioned have different levels of maturity. The status of some of them is shown in Figure 2.Taking into consideration the requirements for mass storage, the use in portable devices, the size limitations, and the status of the development of the technologies, the most promising choices are probe storage memories and PCM. However, a lot of research and development should be done before they will be able to compete with currently used Flash.

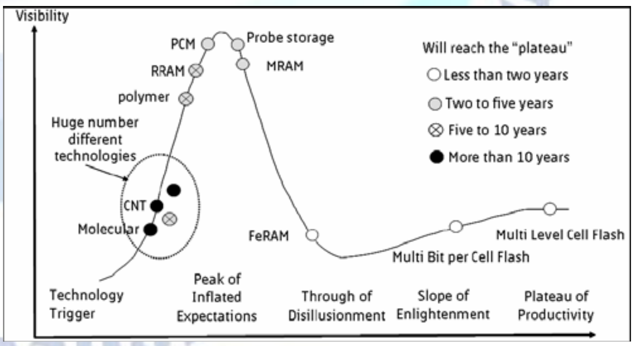

Figure 2: Status of emerging memory technologies

Recent Development is the emergence of TRRAM .TRRAM records data by altering the resistance of a metal oxide film known as Resistive Ram. RAM could make the future mobile devices high capacity storage and transparent devices thus giving the mobile devices a new perspective in data storage. Coupled with a high level of transparency, the new transparent chips are similar to CMOS chips, thus it can store non-volatile memory and it can be used in manufacturing various devices like cell phones. to bring a radical change in the devices the Korean Institute is working on combining flexible materials with the new TRRAM technology [8]. Since it is easy to fabricate TRRAM devices they may be commercially available in just 3-4 years. The manufacturing of electronics in new directions will be possible because of these new transparent devices. after its reliability is proven and once all the manufacturing issues are solved TRRAM could turn out to be one of alternative devices to current CMOS-based flash memory in the near future. Since transparent materials can be utilized as substrate and electrode hence there is a possibility that the new devices can be manufactured cheaply.

VI. Power and Thermal Management

The very large surface area of nanostructured materials would facilitate in the development of energy and power sources. This would be beneficial for different power harvesting devices, for the battery technologies and fuel cells; Nanotechnologies will thus pave the way for developing hybrid energy solutions. Nanotechnologies may thus create totally new kind of energy sources for autonomous systems and contribute to the deployment of distributed sensor networks and environmental intelligence. Miniaturization of future wireless devices and structures has lead to increasing power dissipation densities. This can cause excessive temperatures, if not taken properly into account. Thus, the significance of thermal management as one of the main enabling technologies has recently been emphasized. However, in small scale enough, certain effects can change the situation essentially compared to the conventional approach. For instance, phonon-boundary scattering increases, the thermal conductivity of material decreases continuously when we approach nanoscale dimensions .Additionally, analysis of the heat transfer gets more difficult when simple macro scale Fourier equation is no more valid. At dimensions comparable to phonon mean free path lengths (~300 nm for Si), much more complicated methods such as the Boltzmann transfer equation must be applied. Alternatively, the advance of nanotechnology may provide new die level cooling methods, such as greatly improved superlattice thermoelectric coolers. Transfer towards nano scale thus provides us both with new challenges as well as opportunities.

VII. Current Players

A. NOKIA

Nokia has some high hopes for what the company will be able to do in terms of the future of manufacturing handset design. Nokia aims to implement nanotechnology to create impressive mobile phones in future that can do everything\from tapping directly into your brain to capture your memories to serving as a second pair of eyes.

B. Datoos (DNA-based tattoos)

This is an idea that a company called Frog Design came up about what is going to happen to computer technology in the future. [8] The thought behind it is that humans wouldn't need to carry around a laptop or mobile phone anymore because they would be able to connect to the World Wide Web using their body alone. Human body would thus become a computer interface because recyclable materials would be implanted into humans. Humans could use their own body to place their calls and surf the web. It's not likely to happen quickly but news about the idea even point out that there was a time not all that long ago when the idea of mobile phones sounded as implausible to people as this idea does to us today

VIII. Economic Potential

According to the prediction of the U.S. National Science Foundation the global market for nanotechnologies will reach $1 trillion or more within 20 years. When nanotechnology will be in its mature form it is sure it will affect every industry, almost every area of society from communication to medicine, from agriculture to transportation and also in smarter living at home also. Owing to these implications nanotechnology is also called as general purpose technology. Nanotechnology is creating a likelihood of new materials and manufacturing, which in turn will strongly impact our economy and our environment. It is possible for manufacturers and researchers to fabricate materials molecule-by-molecule by using nanotechnology. Also by the new and improved businesses and industries using nanotechnology, the economy will grow at a faster rate and new jobs will be created.

IX. Future Impact on Industries

The research community is vigorously pursuing hundreds of applications in Nano materials and Nano electronics. Nanotechnology has an impact on all industries: ceramics, metals, polymers, and biomaterials. New materials are the basis of major technological researches. In the coming future nanotechnology will certainly have a colossal effect on the above mentioned industries. Future research could drastically alter our approaches to manufacturing, electronics, IT and communications technology. This new approach would make previous technology redundant and thus lead to the development of applications which have never been thought of. Taking into consideration the significance of research and development of nanotechnology, the Department of Science and Technology, Govt. of India, has been encouraging tremendous thrust on Nanomaterial. Realizing the potential of nanotechnology area of research the Indo-US joint forum on Science and Technology and Government of India's Nanomaterials Science and Technology Initiative (NSTI) have decided to have intense cooperation. [8] Thus powerful combination of materials science and nanotechnology will create entirely new processes and industries and put India among the world leaders thus leading to a nanotechnological revolution.

X. Challenges

The initial manufacturing cost could be very high because of the much research still that have to be done. Nanotechnology is an impending and fast growing field whose dynamics and prospects pose many great challenges not only to scientists and engineers but also to society at large. Although many optimistic scientific results have emerged from nanotechnology, the actual challenge for many nanotechnology topics is up-scaling from laboratory work to industrial scale manufacturing. Conversely, manufacturing and fabrication methods related to nanotechnology may be key enablers for future electronics manufacturing. The introduction of new materials and manufacturing solutions always has some dangers. Understanding and knowledge about the risks of nano scale particles and nanotechnologies have increased considerably during the last five years. The introduction of nanotechnologies requires committed research of biological risks of nanomaterials, strategies for risk management in research, production, and recycling, and dissemination of objective information with the public arena. Size of the particles is shown to be the major factor determining the rate of biological uptake of particles on the surface of the living cells.

XI. Conclusion

As opposed to focusing only on the potential hazards, we can also think about the use of nanotechnologies in a positive way. We can set the targets and objectives of the research so that they can help us to solve the environmental challenges that we will have to confront during the coming decades: we should develop new electronics materials that are easier to recycle and/or decomposable in biological processes, and optimize and minimize the energy consumption in the manufacturing of future materials and products. Let us set the targets right – focus in the right set of technologies and introduce nanotechnologies into the public arena in a responsible way. Nanotechnologies can be one key solution towards sustainable future.

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