Micro-Nano Scale Wireless Sensor Networks For Environmental Protection
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ABSTRACT
This paper provides an in-depth view on nano sensor technology. Wireless sensor networks have become very important in the field of protection and control of natural and man-made environment. Wireless sensor networks are one of the most rapidly evolving research and development fields for microelectronics. Their applications are countless, and the market potentials are huge. However, many technical hurdles have to be overcome to achieve a widespread diffusion of wireless sensor network technology. This paper summarizes the trends of wireless sensor network, significance of nanotechnology for future wireless devices. We outline the key prospects, research challenges and the common themes in the field.

I. INTRODUCTION

Keywords----- Nanotechnology, Wireless sensor networks, Significance of Nanotechnology, Prospects and Challenges

The emerging field of wireless sensor networks combines sensing, computation, and communication into a single tiny device. Through advanced mesh networking protocols, these devices form a sea of connectivity that extends the reach of cyber space out into the physical world. As water flows to fill every room of a submerged ship, the mesh networking connectivity will seek out and exploit any possible communication path by hopping data from node to node in search of its destination. The composition of hundreds of devices offers radical new technological possibilities[1]. The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves. Usage scenarios for these devices range from real-time tracking, to monitoring of environmental conditions, to ubiquitous computing environments, to monitoring of the health of structures or equipment. While often referred to as wireless sensor networks, they can also control actuators that extend control from cyberspace into the physical world. The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends. For example, a chemical plant could be easily monitored for leaks by hundreds of sensors that automatically form wireless interconnection network and immediately report the detection of any chemical leaks. Unlike traditional wired systems, deployment costs would be minimal. Instead of having to deploy thousands of feet of wire routed through protective conduit, installers simply have to place quarter-sized devices. The network could be incrementally extended by simply adding more devices, no rework or complex configuration. With the devices presented in this thesis, the system would be capable of monitoring for anomalies for several years on a single set of batteries.

II. WIRELESS SENSOR NETWORKS

A sensor network is defined as composition of low cost, low power multi functional sensor nodes which are highly distributed either inside or very close to the system[2]. The position of these tiny nodes need not be absolute, this not only gives the random placement but also means that protocols of sensor networks and its algorithms must possess self organising abilities in inaccessible areas. However nodes are constrained in energy supply and bandwidth, one of the most important constraints on sensor nodes are the low power consumption requirement. These constraints combined with a specific deployment, the concept of wireless sensor networks is based on a simple equation:

Sensing + CPU + Radio = Thousands of potential applications network. Hundreds of applications spring to mind. It seems like a straightforward combination of modern technology. A core challenge is to map the overall system requirements down to individual device capabilities, requirements and actions. To make the wireless sensor network vision a reality, architecture must be developed.
that synthesizes the envisioned applications out of the underlying hardware capabilities.

III. SIGNIFICANCE OF NANOTECHNOLOGY

Nanotechnology for Future Wireless Devices And Communications:

One of the central visions of the wireless industry aims at ambient intelligence: computation and communication always available and ready to serve the user in an intelligent way. This requires that the devices are mobile. Mobile devices together with the intelligence that will be embedded in human environments – home, office, public places – will create a new platform that enables ubiquitous sensing, computing, and communication[3]. It has been estimated that by 2015 the amount of data transferred via wireless connections will be greater than the data transferred via wireless connections in the US. The digital agenda for Europe has set a target of providing 30 Mbps access to all European citizens by 2020. This is a challenging target, since the radio frequency spectrum is a limited natural source, which needs to be shared by multiple different radio systems. Already, many of the frequency bands are becoming crowded, which hinders and slows down the data traffic. New spectrum sharing methods and protocols are being designed to alleviate the problem. To cope with the multitude of different operation frequencies mobile devices currently incorporate several different radio transceivers. A more flexible solution under development is to do the baseband and radio frequency processing with software and generic multiradio RF components. However, the electronics required for radio front ends is specific to the used frequency and cannot be tuned to all the required frequencies with current technologies. Now, more tunable radio front end components are required. Graphene nanoelectromechanical (NEMS) resonators have been proposed as tunable resonators. Graphene strip can withstand very high strains, which makes it possible to tune the operating frequency of the resonator over a wide bandwidth by straining it electrically[4].

Core requirements for this kind of ubiquitous ambient intelligence are that the devices are autonomous and robust. They can be deployed easily, and they survive without explicit management or care.

Mobility also implies limited size and restrictions on the power consumption. Seamless connectivity with other devices and fixed networks is a crucial enabler for ambient intelligence systems – this leads to requirements for increased data rates of the wireless links. Intelligence, sensing, context awareness, and increased data rates require more memory and computing power, which together with the size limitations leads to severe challenges in thermal management. All these requirements combined lead to a situation which cannot be resolved with current technologies.

Nanotechnology could provide solutions for sensing, actuation, radio, embedding intelligence into the environment, power efficient computing, memory, energy sources, human–machine interaction, materials, mechanics, manufacturing, and environmental issues. Nanotechnology is a field of science and technology of controlling matter on a scale between 1 -100 nanometres. It is a highly multidisciplinary field, bringing together many fields, including electrical and mechanical engineering, physics, chemistry, and biosciences. Nanotechnology will radically affect all these disciplines and their application areas. Economic impact is foreseen to be comparable to information technology and telecom industries.

More Speed, Less Energy:

Ever increasing wireless communication speeds require increasing amount of computation with limited power. Continued innovation has made it possible to follow the Moore’s law and to provide electronics with all the time increasing performance with reduced price. The current approach of simply reducing the transistor size seems to come to an end by about 2015 due to the limitations of the manufacturing technology. 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. This should be considered a benchmark for new approaches based on nanotechnology. Such approaches include new materials leading to transistors.

More possibilities with new materials:

Enhanced user experiences created via new and very useful device features and functions, good design and usability, and attractive personalized look and feel are
major drivers for the development of future communication devices. The wish to have high-performance devices with “all the features” in small, compact physical size and being easy to use and carry, sets high requirements for several technologies. Materials technology is in key role in the development of many areas such as device mechanics, core electronics, advanced user interfaces, displays, energy sources, and data storage.

Power and Thermal Management:

Nanotechnologies will contribute to the development energy and power sources mainly because of the very large surface area of nanostructure materials. This is beneficial for the battery technologies, fuel cells, and for different power harvesting devices. Nanotechnologies will also provide new ways to develop hybrid energy solutions. Nanotechnologies may 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 traditional approach.

Manufacturing and Environment:

Although many promising scientific results have emerged from nanotechnology, the real challenge for many nanotechnology topics is up-scaling from laboratory work to industrial scale manufacturing. On the other hand, novel manufacturing and fabrication methods related to nanotechnology may be key enablers for future electronics manufacturing. Printed electronics and related reel-to-reel manufacturing may be the first disruptive solutions that enable new kind of electronics industry: low cost, large area electronics that will open new applications in embedding electronics into human environments; we can imagine wall sized, interactive, touch sensitive panels, or new low cost useful computing and communication devices for developing countries. RFID technologies are clearly the first area where the manufacturing solutions based on bottom up self-assembling processes could simplify electronics manufacturing and lower the investments and assets needed for establishing manufacturing sites.

IV. MICRO-NANO SCALE WIRELESS SENSOR NETWORKS FOR ENVIRONMENTAL PROTECTION

Prospects and Challenges:

Wireless sensor networks have become very important in the field of protection and control of natural and man-made environment, providing vast arrays of real-time, remote interaction with the physical world. Smart, wirelessly networked sensors can collect and process a vast amount of data, from monitoring and control of air quality, traffic conditions, to weather conditions and tidal flows [5]. Drawn from industrial and commercial activities, the world’s human population concentrates on specific regions. Such a phenomenon is known as ‘urbanization’. Although the urbanization brings a higher economic development, the excessive population concentration will cause environmental damage and pollution like air pollution, noise pollution, water pollution, etc. Among various kinds of pollution, air pollution has a direct impact on our lives, because of the rapid emission of pollutants. Over the past decades, governments of many countries have imposed different regulations on air pollutants, so the severe damage brought to human health is reduced considerably. Although there may be no the immediate damage to human lives, air pollution still causes some chronic diseases. A sensor network monitors not only just a few isolated sensors, but also literally tens of thousands of intelligent sensor nodes providing local measurements as well as overall patterns of change. The promising technology of wireless sensor networks helps to run factories, optimize widely spread processes, monitor the weather, detect the spread of toxic gases in chemical industries and even provide precious extra time in advance of tornados and earthquakes. Widespread use of wireless sensor networks powered with the concept of distributed sensing and computing of indoor and outdoor environment promises to revolutionize the present state of environmental protection and control [7],[8]. Rather than transmitting large amounts of raw data, the sensor nodes can perform signal analysis, communicating only the modes of vibration or detected anomalies. Sensor nodes can monitor control networks to establish an activity when a sample is taken or even to determine when to sample. Because reducing the cost of obtaining and processing data reduces overall cost, increasing the timeliness of analysis can improve system performance [9].

Prospects of Ultra Wideband In Wireless Sensor Network:

A recent technology that is now being considered for deployment in WSN applications is Ultra Wideband (UWB) radio. UWB provides a power efficient solution with a location estimation accuracy of less than 1 m and as is commonly accurate up to 4 cm. UWB radio
communicates with baseband pulses of very short duration on the order of tenth of a nanosecond. According to the regulation of the Federal Commission of Communications (FCC), a signal is defined as a UWB signal if it has a K10 dB fractional bandwidth, FBW greater than, or equal to, 0.20 or it occupies at least 500 MHz. Since the allocated 7.5 GHz bandwidth (3.1–10.6 GHz) for UWB signals interferes with many narrow-band systems, FCC has also regulated the spectral shape and maximum power spectral density (K41.3 dBm/MHz) of the UWB radiation in order to limit the interference with other communication systems like UMTS or WLAN. For a bandwidth of 7.5 GHz and an average EIRP of K=2.5 dBm, there is a significant potential to provide coordinated multiple access for a large number of users[10]. According to Shannon’s capacity theorem, CZB log2 (1CSNR), for a desired SNR of 6 dB, the calculated channel capacity bound is approximately 17.5 GB/s. With a peak information rate of 250 Kb/s, 70,000 nodes could be accommodated, satisfying the requirement of a typical sensor network [10].

V. CONCLUSION

Micro-nano-scale wireless sensor networks have been reviewed and the prospects and corresponding challenges have been outlined. Possible usage of wireless sensor networks in environment protection and control has been indicated. If nanotechnology-based WSN is to be successful in environment applications it is inevitable that wireless communication of sensor data must be as good as that of a wired communication, maintain high data security.

REFERENCES
