SMART DUST: AN EMERGING TECHNOLOGY

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ABSTRACT

"Smart Dust" is an emerging technology made up from tiny, wireless sensors or "motes." Smart dust is a tiny dust size device with extra-ordinary capabilities. Smart dust consists of sensing, computing, wireless communication capabilities and autonomous power supply within volume of only few millimeters and that too at low cost. These devices are so small and light in weight that they can stay suspended in the environment just like an ordinary dust particle. These properties of smart dust will make it useful in examining real world phenomenon without disturbing the original process to an observable extends. Presently the obtainable size of Smart Dust is about 5mm cube, but we hope that it will finally be as small as a piece of dust. Each individual sensors of smart dust are often referred to as motes because of their small size. These devices are also called MEMS, which stands for micro electro-mechanical sensors. Eventually, these devices will be smart enough to talk with other sensors yet small enough to fit on the head of a pin. Each mote is a tiny computer with a power supply, one or more sensors, and a communication system

I INTRODUCTION

Smart dust was conceived in 1998 by Dr. Kris Pister of the UC Berkeley. He set out to assemble a device with sensors, communication device and small computer integrated into a small single package. The defence Advanced Research Project Agency (DARPA) funded the project, setting as a goal the illustration "that a complete sensor or communication system can be integrated into a small cubic millimetre package".

The current ultramodern technologies are concentrating on automation and miniaturization. The diminishing computing device size, increased connectivity and upgraded interaction with the physical world have characterized computing history. Recently, the popularity of small computing devices, such as hand held computers and cell phones; rapidly growing internet group and the diminishing size and cost of sensors and especially transistors have accelerated these strengths. The emergence of small computing elements, with irregular connectivity and increased interaction with the environment, provides enhanced opportunities to reshape interactions between people and computers and spur ubiquitous computing researches.

Smart dust is tiny electronic devices designed to capture huge amount of information about their surroundings while literally floating on air. Nowadays, sensors, computers and communicators are shrinking down to extremely small sizes. If all of these are packed into a single tiny device, it can open up new dimensions in the field of communications. The idea behind 'smart dust' is to pack sophisticated sensors, tiny computers and wireless communicators in to a cubic-millimetre mote to form the basis of integrated, massively distributed sensor networks. They will be light enough to remain suspended in atmosphere for hours. As the motes drift on wind, they can examine the environment for light, sound, temperature, chemical composition and a wide range of other information, and beam that data back to the base station, miles away.

II SMART DUST COMPONENTS

The goal of the project, a Smart Dust *mote* is illustrated in Fig. 1. Designers can use micro electromechanical systems to build up small sensors, optical communication components, and power supplies, whereas microelectronics provides increasing functionality in smaller areas, with lower energy consumption. The power system consists of a thick-film battery, a solar cell with a charge-integrating capacitor for intervals of darkness, or both. Depending on its objective, the design consists of various sensors, including light, temperature, vibration, magnetic field, acoustic, and wind shear, onto the mote. An integrated circuit provides sensor-signal processing, communication, control, data storage, and energy management. A photodiode allows optical data reception. Presently there are two transmission schemes: passive transmission using a corner-cube retro reflector, and active transmission using a laser diode and steerable mirrors.

The mote's minuscule size makes energy management a key component. The integrated circuit will have sensor signal conditioning circuits, a temperature sensor, and Analog to Digital converter, microprocessor, SRAM, communication circuits, and power control circuits. The IC, together with the sensors, will operate from a power source integrated with the platform.

The MEMS industry has large markets in automotive pressure sensors and accelerometers, medical sensors, and process control sensors. Recent advances in technology have set many of these sensor processes on exponentially decreasing size, power, and cost curves. In addition, variations of MEMS sensor technology are used to build micro motors.

III MAJOR CHALLENGE: LOW ENERGY COMPUTATION

A major challenge is to incorporate all these functions while maintaining very low power consumption thereby maximizing operating life given the limited volume available for energy storage. Besides advanced micro fabrication technology processes, using other techniques at every level achieves low-energy computation. First, because we use a high-performance process but operate at low speeds, we can drop the supply voltage to the minimum level at which the devices still function; theoretically this is 0.1 volt, 6 but for 0.5- to 0.2-micron processes it is more practically and realistically 0.2 to 0.3 volt. To minimize current leakage, due to which significant power consumption could be caused at the low clock rates and duty cycles that these low-energy architectures use, we can increase the channel-to-source junction's reverse bias, thus increasing the threshold voltage. Initially, adding two extra supply voltages in this package may seem onerous; however, if the mote looks for solar power, placing two small photodiodes on the integrated circuit provides the few atto-amps per device necessary to bias these junctions. The Smart Dust mote's tasks closely relate to the physical state, where the fastest sampling is 10 to 20 kHz for vibration and acoustic sensors so the amount of data is small enough that we can use low data transmission rates. Therefore we can use clock rates in the 1 to 180 kHz range for decreasing dynamic power consumption. Despite these clock rates are low, the circuits perform all their transitions during a small portion of the cycle; then they remain idle. Thus, powering down blocks for even a few clock cycle save energy.

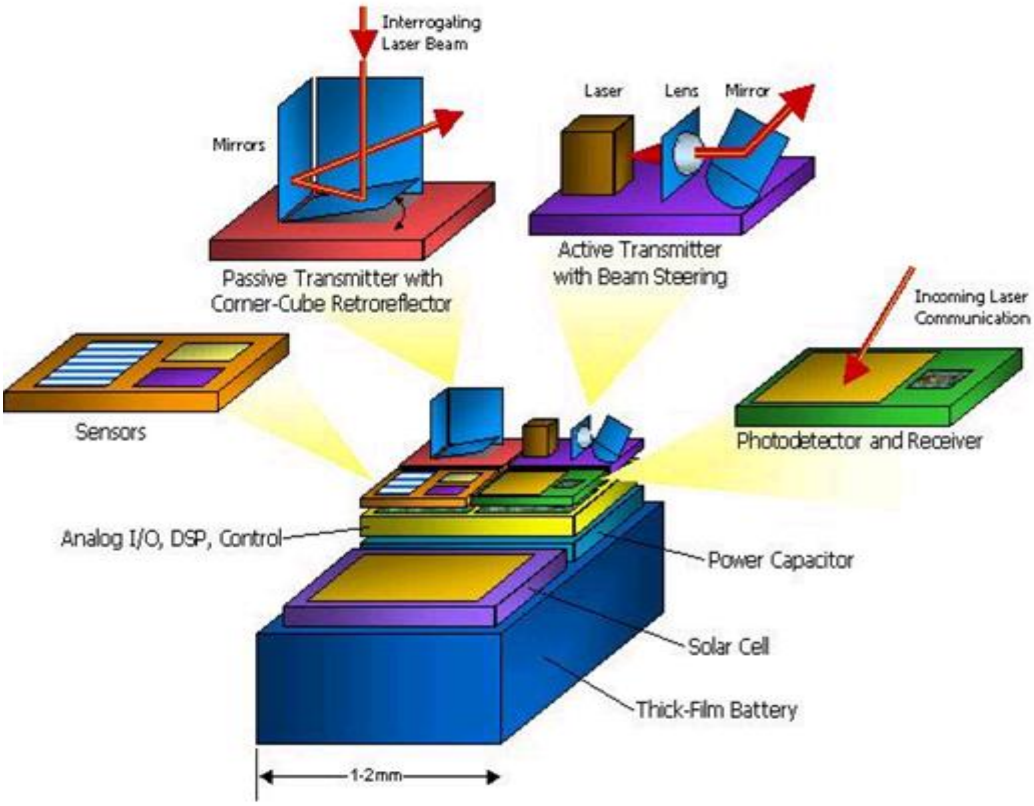

Figure 1. Smart Dust mote, containing micro-fabricated sensors, optical receivers, passive and active optical transmitters, signal-processing and control circuitry, and power sources.

IV COMMUNICATION MODES

There are several options for communicating to and from a cubic-millimeter computer. Radio frequency and optical communications each have their strengths and weaknesses.

4.1 RF Communication

Radio-frequency communication is well understood, but currently requires minimum power levels in the multiple milli watts range due to analog mixers, filters, and oscillators. It could be used to function as both uplink and downlink. Since RF transceiver typically consists of relatively complex circuitry, it is impossible to achieve the required low power operation using such an approach in a smart dust system.

4.2 Optical communication

Two approaches to optical communication are explored: Passive reflective systems and active steered laser systems. In a passive communication system, the dust mote does not require an onboard light source. Instead, a special configuration of mirrors can either reflect or not reflect light to a remote source.

4.2.1. Active-reflective systems

Active optical communication typically uses an active-steered onboard laser-diode based transmitter to send a collimated laser beam to a base station. Active optical communication is suitable for peer-to-peer communication when the application requires. Using MEMS technology, the components of the active communication network can be made to be small enough to fit into the smart dust motes.

One of the major disadvantages of the active transmitter is its relatively high power consumption. This leads to the use of active optical communication just for short duration burst mode communication.

4.2.2 Passive Optical Communication

One of the most major advantages in a passive optical communication system is that the dust mote does not need to have an onboard light source to transmit desired sensor information. The passive optical communication approach employs a micro-fabricated corner cube retro reflector (CCR). Passive optical transmission can be performed in the smart dust system since dust motes can modulate the optical signal without having to supply any optical power.

It has the disadvantage that communication between dust motes, so-called peer-to-peer communication, cannot be performed by passive optical communication.

V SMART DUST IN FUTURE

Smart dust vendors and researchers indicate that motes sold in future will be smaller and cheaper. They will have ability to steal energy to run smart dust devices longer. Even as the price of smart dust falls, revenues for the vendor of these devices are expected to increase. According to an estimate published in business week online, the worldwide market for wireless sensor networks was expected to grow from $347 million in 2004 to $7 billion by 2010.

"Smart dust will be one of the central industries of tomorrow," futurist Alvin Toffler told Investor's Business Daily.

"Today at a paper mill or a chemical plant or oil refinery, they have sensors everywhere, such as on the tubes to measure flow rates or pressure in the valves," Pister said. "All of that gets wired back to a central control computer."Smart dust is potentially revolutionary because the sensors are small enough to be put anywhere and work wirelessly, sharing data.

VI APPLICATIONS

6.1. Early applications

Smart dust was used to detect vehicles travelling through an isolated desert area in palm springs, California. The experiment was conducted with U.S. Marine Corps. It showed that how smart dust can be used by military and law enforcement personnel.

Smart dust was also used to detect presence of hydro carbon vapours from approx 65 mitres away. By doing this experiment the researchers predict that with appropriate chemical modification the smart dust sensors can also detect presence of bio-molecules, explosives, and chemical warfare agents such as sarin.

6.2 Business applications

Off the shelf mote systems can be configured with the sensors for numerous properties like temperature, humidity, barometric pressure, light intensity, acceleration, and magnetism. Some mote sensors can also determine their location using Global Positioning System.

6.3 Application in transport

For transport system it has many applications which are as follows:-

- Optical identification sensor
- Ice detector
- Laser scanner

Some other applications are as follows:-

- Biological sensors
- Building virtual keyboards
- Providing interfaces or the disabled
- Product quality monitoring
- Internal space craft monitoring.

VII CONCLUSION

Research in the wireless sensor network area is growing rapidly in both academia and industry. Most major universities and many companies now have sensor networking projects, and some are appearing on the market. Innovative research includes short-range micro power radio, energy scavenging from thermal gradient and vibrations, operating systems, networking and signal processing algorithms and applications. While the raw power of future computing environments will enable more massive and amazing software and hardware networks, a growing community will be pushing the limits on the lower end, building smaller hardware and writing terser code.

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