Smart Dust Technology

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Abstract: Advances in hardware technology have enabled very compact, autonomous and portable nodes each having one or more sensors, computation and communication capabilities with a power supply. The Smart Dust technology examines whether a tiny dust size device can exhibit such extraordinary capabilities within a confined volume of few millimeters at a very minimal cost. These devices have been proposed to be so minute and light in weight that can remain spatially suspended in environment like ordinary dust particles. It is the future of quantified world that can monitor any phenomenon without disrupting the primary functioning to a detectible extent. Smart Dust is made of "motes" which are tiny sensors that can perform a variety of functions. They are made of "micro-eletromechanical systems" known as MEMS.

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I. Introduction

'Smart Dust'-the sensor laden networked computer nodes just cubic millimeters in volume. The project envisages a complete sensor network including power supply, processor, and communication mechanisms in a single cubic millimeter. .Smart dust motes could run for years, given that a cubic millimeter battery can store 1J and could be backed up with a solar cell or vibrational energy source

A wireless sensor network (WSN) consists of spatially suspended sensors to monitor physical or environmental conditions such as sound, vibration, temperature, motion or pollutants and to cooperatively pass their data through the network to a central location. Military applications such as battlefield surveillance led to the development of WSN, leading it to be used today in many industrial and commercial applications. A WSN is fabricated of "nodes" which is connected to sensors. The smart dust (motes) propose to replace the nodes in a WSN. The motes function within the network and typically fulfill the applications of either data-logging, processing or transmitting sensor information from the environment. They gather scads of data, run computations and communicate that information. The transmission is carried out using MEMS. The MEMS consists of extensively tiny mechanical elements often integrated together with electronic integrity.

II. The MEMS Technology in Smart Dust

Designers use MEMS technology to construct small sensors, optical communication components and power supplies. These mechanical systems integrated on electronic circuitry are measured in micrometers and are made in a similar fashion as computer chips. It is not only the small structures that are advantageous but also that millions of system elements can be fabricated simultaneously. This renders systems to be both highly complex and extremely low-cost. The electronics in them are engineered using integrated circuit (IC) process sequences (e.g., CMOS, Bipolar processes), the micromechanical components are fabricated using compatible "micromachining". The deep perception of MEMS is as a new manufacturing technology, a way of making complex electromechanical systems using batch fabrication techniques similar to those used for integrated circuits, and fusing these electromechanical elements together with electronics. Unlike sensors and actuators that are the most costly and unreliable part of a sensor-actuator-electronics system, MEMS technology allows these complex electromechanical systems to be

manufactured using batch fabrication techniques, increasing the reliability of the sensors and actuators to equal that of integrated circuits. The performance of MEMS devices and systems is expected to be superior to macro scale components and systems, the price is expected to be much lower.

III. Characteristics &Fabrication of Smart Dust

i) Operation of the mote.

In general, the Smart Dust mote is used as a device to collect data and transmit the data to some control base. It is run by a microcontroller which not only determines the tasks performed by the mote but also monitors the power of all the components of the system so as to conserve energy. The microcontroller will then store the data into a memory and process it before sending them to the transmitter. The transmitter will then send out these data to the control base which might be receiving data from hundreds or thousands of motes before establishing them into a thorough report.

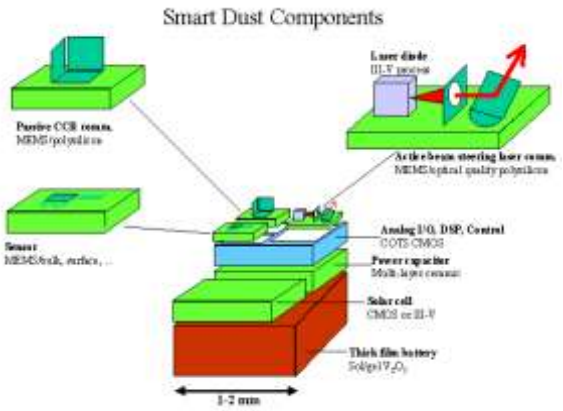

Fig.1 Components of Smart Dust

ii) Low Power Consumption

Before a new form of self-rechargeable power source is established, the energy from the conventional miniature batteries is limited, making the power consumption of the mote to be as minimum as possiblein order for the mote to last longer. Most of the time, the majority of the mote is powered off with only a clock and a few timers running. When a timer expires, it powers up a part of the mote to carry out a job, then powers off. Another way of minimizing power consumption is to employ a low supply voltage. In this way, the current involved will be generally lower compared to a system that uses a higher supply voltage. Leakage current can also be reduced by increasing the threshold voltage which is in turn achieved by increasing the channel to source junction's reverse bias. As the different units such as the sensors or the wireless transmitter might not need to operate all the time, more power is saved by powering down the individual blocks when they are idling.

iii) Wireless Communication

To realize this feature on the Smart Dust, a microcontroller will be required to perform the computation and programming of the mote operation. It is looked-for to remote control program certain functions of the smart dust by transmitting programming control signals to the motes which then receive and store these data in the program memory of the motes.Primarily, two technologies can be used for Communication between the motes and they are as follows:

I. Radio Frequency Transmission

II. Optical transmission technique

a) Passive Laser based Communication
b) Active Laser based Communication
c) Fiber Optic Communication

All of them have their relative advantages and disadvantages.

IV) Technology used

Assimilated into a single package are:-

1. MEMS sensors
2. MEMS beam steering mirror for active optical transmission
3. MEMS corner cube retroreflector for passive optical transmission
4. An optical receiver
5. Signal processing and control circuitry
6. A power source based on thick film batteries and solar cells

V) Overview of Architecture

The block diagram of the target Smart Dust prototype is shown in Fig. 2

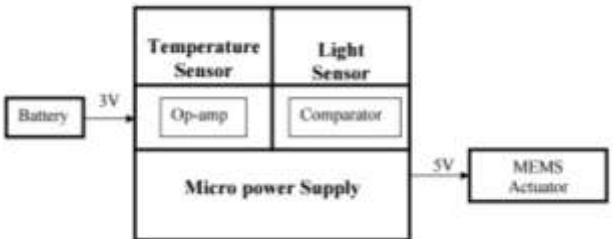

Fig.2 Block diagram of Smart Dust Prototype

A Smart Dust prototype is to be designed and fabricated such as to include a micro power supply, some sensors and a MEMS actuator. The battery will be the source of power for this prototype. The micro power supply takes in power from the battery, converts it to the respective voltages required before supplying the sensors or driving the MEMS actuator. In order to minimize the number of components, the on-chip operational amplifier and comparator designed for the micro power supply are also used as the main components in the Temperature Sensor and Light Sensor respectively. Although the wireless transmission unit is not included in this project, the micro power supply is designed to provide sufficient power for wireless transmission.

VI) Applications

It is very hard to detect the presence of the Smart Dust and it is even harder to get rid of them once implemented. Moreover it does not cost much so can be densely implemented. They remain suspended for hours in air and can also move in the direction of air currents. Potential commercial applications are varied, ranging from catching manufacturing defects by sensing out-of-range vibrations in industrial equipment to tracking patient movements in a hospital room. Some other varied applications are as follows:
1) Environmental protection (identification and monitoring of pollution).
2) Habitat monitoring (supervising the behavior of the animals in their natural habitat).
3) Civil and military application (monitoring activities in inaccessible areas, accompany soldiers and alert them to any poisons or dangerous biological agents in the air or battlefield).
4) Virtual keyboard: *A*dust mote can be glued on each of the fingernails.*A*ccelerometers will sense the orientation and motion of each of the fingertips. Combined with a MEMS augmented-reality heads-up display, your entire computer I/O would be invisible to the people around you.
5) Inventory Control Smart office spaces. *T*he Center for the Built Environment has fabulous plans for the office of the future in which environmental conditions are tailored to the desires of every individual.
6) Dust motes may be used in places where wired sensors are unusable or may lead to errors. E.g.:- Instrumentation of semiconductor processing chambers, wind tunnels, rotating machinery etc.
7) May be used in biological research e.g.:- to monitor movements and internal processes of insects.
8) Forest fire warning.
9) Enemy troop monitoring.
10) Defense-related sensor networks.
11) Inventory Control.

VII) Future of Smart Dust

The many prospective applications of the Smart Dust include weather or seismological monitoring on Mars, land or space communication networks, defense related sensor networks, smart environment conditioning in offices, chemical and biological sensors, and in sports such as sailing. But there are also barriers to overcome. The major challenges in further development of the Smart Dust lie as:
1. To feature all these tasks while continuing a low power consumption and minimization of the mote.
2. Augmenting operating life given the limited volume of energy storage
3. The functionality can be attained only if the total power consumption is regulated to microwatt levels.

Advancement in the Micro-electro-mechanical Systems (MEMS) technology will benefit to reduce the size of the sensors and actuators, and consequently minimizing the size of the mote. Studies are also made to fully assimilate the entire Smart Dust system only one single chip in order to overcome the size problem. On the other hand, the limit in size results in problematic power supply hindrance since the source of power has to be kept small. The finite amount of power in miniature batteries expediently in use now restricts the shelf life of the motes. However it is anticipated that such problems would be overcome when fuel cells that can absorb energy from their surroundings are developed.
Smart dust researchers say their theory of monitoring the world -- however it's realized -- will benefit people and the environment. Having more sensors improves the efficiency of a system.

VIII) Conclusion: The Smart Dust Revolution

In order to develop such a small intellectual mote, it was essential to revolutionize the procedures used in miniaturization, integration of the assorted components and efficient power management of the Smart Dust System. While researchers and commercial developers are agog over the potential applications for smart dust, they're also careful to point out the design and power issues that still need to be resolved. Due to the restricted size of the Smart Dust mote, efficiency and energy conservation has been important as batteries or large solar cells were inappropriate. Hence smart algorithms and a power operating system have been developed for the integrated microcontroller to run the operations of the sensors, actuators as well as the communication units efficiently. Presently, the Smart Dust concept and technology are used in dozens of educational and industrial research all over the world. Soon we will see Smart dust: mighty motes for medicine, manufacturing, military and more.

REFERENCES

[1] Yunbin Song: "Optical Communication Systems for Smart Dust"

[2] J. M. Kahn, R. H. Katz, K. S. J. Pister: Next Century Challenges:

a. Mobile Networking for "Smart Dust"

[3] http://www.coe.berkeley.edu/labnotes

[4] www.seminarsonly.com