**Smart Dust**

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**Abstract:** Smart dust is a hypothetical network of tiny wireless microelectromechanical systems ([MEMS](http://en.wikipedia.org/wiki/MEMS)) sensors, robots, or devices, installed with wireless communications, that can detect [light](http://en.wikipedia.org/wiki/Light) , temperature, or vibration.etc .These devices are intended to be the size of a grain of [sand](http://en.wikipedia.org/wiki/Sand), or even a [dust](http://en.wikipedia.org/wiki/Dust) particle. Hence the name smart dust. When clustered together, they would automatically create highly flexible, low-power networks with applications ranging from climate control systems to exploratory missions in Amazon jungle. Smart dust network can perform complex tasks. The smart dust concept was introduced by [Kristofer S. J. Pister](http://en.wikipedia.org/wiki/Kristofer_S._J._Pister).

**Key Words**: MEMS,Sensors,

**1.0 INTRODUCTION**

Imagine a small suburban neighbourhood or an apartment complex. The owner of this complex has to monitor the water and electric meter readings of each house. It is a tiring job for the owner to go to each house, check the water and electric meter readings and prepare their bills .But what if the owner sits in his own house and all the details i.e , electric and water meter readings of each house comes to the owner’s house whenever he desires. Meter readings can be hourly or daily as he desires. It may be impossible now, but may be possible soon with the help of “SMART DUST”.

There are thousands of different ways that smart dust might be used, and as people get familiar with the concept they come up with even more. It is a completely new paradigm for distributed sensing and it is opening up a fascinating new way to look at computers. If we survey the literature for different ways that people have thought of to use smart dust, we find a huge assortment of ideas. The future of smart dust lies on both optical communication and fiber-optic communication. Dust is usually a nuisance. But "smart dust" could revolutionize how we monitor and understand the world around us. If the smart dust networks successfully emerge, the line between reality and fiction would be blurred.

1. **BASIC IDEA**

Smart dust is a hypothetical network of tiny wireless microelectromechanical systems ([MEMS](http://en.wikipedia.org/wiki/MEMS)) sensors, robots, or devices, installed with wireless communications, that can detect [light](http://en.wikipedia.org/wiki/Light), temperature, vibration, stress, pressure etc. The smart dusts are also called “MOTES” and “WIRELESS SENSING NETWORKS”, as they are not connected by thick and heavy wires or cables. These devices or motes are intended to be size of a grain of sand or to be the size of a dust particle. Hence the name smart dust. Smart dust is derived from an earlier concept called “Smart Matter”.

The smart dust is the brain child of Kristofer S.J.Pister of University of California in 2001.When clustered together, they would automatically create highly flexible, low-power networks with applications ranging from climate control systems to entertainment devices that interact with appliances. These networks are tolerant to robot failures.

The smart dust concept creates a new way of thinking about computers, but the basic idea is pretty simple:

* The core of a smart dust is a small, low-cost, low-power computer.
* The computer monitors one or more sensors. It is easy to imagine all sorts of sensors, including sensors for temperature, light, sound, position, acceleration, vibration, stress, weight, pressure, humidity, etc. Not all smart dust applications require sensors, but sensing applications are very common.
* The computer connects to the outside world with a radio link. The most common radio links allow a smart dust to transmit at a distance of something like 10 to 200 feet (3 to 61 meters). Power consumption, size and cost are the barriers to longer distances. Since a fundamental concept with smart dusts is tiny size (and associated tiny cost), small and low-power radios are normal.
* Smart dusts can either run off of [batteries](http://www.howstuffworks.com/battery.htm), or they can tap into the [power grid](http://www.howstuffworks.com/power.htm) in certain applications. As smart dusts shrink in size and power consumption, it is possible to imagine [solar power](http://www.howstuffworks.com/solar-cell.htm) or even something exotic like vibration power to keep them running.

All of these parts are packaged together in the smallest container possible. In the future, people imagine shrinking smart dusts to fit into something just a few millimeters on a side. It is more common for smart dusts today, including batteries and antenna, to be the size of a stack of five or six quarters, or the size of a pack of cigarettes. The battery is usually the biggest part of the package right now. Current smart dusts, in bulk, might cost something on the order of $25, but prices are falling. It is hard to imagine something as small and innocuous as a smart dust sparking a revolution, but that's exactly what they have done.

## A TYPICAL SMART DUST

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MICA smart dust or a mote is a commercially available product that has been used widely by researchers and developers. It has all of the typical features of a smart dust and therefore can help we understand what this technology makes possible today. MICA smart dusts are available to the general public through a company called [Crossbow](http://www.howstuffworks.com/framed.htm?parent=motes.htm&url=http://www.xbow.com/Products/Wireless_Sensor_Networks.htm). These smart dusts come in two form factors:

* Rectangular, measuring 2.25 x 1.25 by 0.25 inches (5.7 x 3.18 x.64 centimeters), it is sized to fit on top of two AA batteries that provide it with power.
* Circular, measuring 1.0 by 0.25 inches (2.5 x .64 centimeters), it is sized to fit on top of a 3 volt button cell battery.

The main components of a smart dust are:

**3.1 Central Processing Unit (CPU)**

The MICA smart dust uses an Atmel ATmega 128L processor running at 4 megahertz. The 128L is an 8-bit [microcontroller](http://www.howstuffworks.com/microcontroller.htm) that has 128 kilobytes of onboard [flash memory](http://www.howstuffworks.com/flash-memory.htm) to store the smart dust's program. This CPU is about as powerful as the 8088 CPU found in the original IBM PC (circa 1982). The big difference is that the ATmega consumes only 8 milliamps when it is running, and only 15 microams in sleep mode.

**3.2 Memmory**

MICA smart dusts come with 512 kilobytes of flash memory to hold data. A flash cell is the basis for flash memory. A flash cell is based on a single transistor controlled by a trapped charge. The low power consumption of flash memory makes it suitable for this use.

**3.3 A/D Convertor**

There is a 10-bit A/D convertor(Analog to Digital Convertor) so that sensor data can be digitized.

**3.4 Sensor**

Separate sensors on a daughter card can connect to the smart dust. Sensors available include temperature, acceleration, light, sound and magnetic. Advanced sensors for things like [GPS](http://www.howstuffworks.com/gps.htm) signals are under development.

**3.5 Radio**

Another component of a MICA smart dust is the [radio](http://www.howstuffworks.com/radio.htm). It has a range of several hundred feet and can transmit approximately 40,000 bits per second. When it is off, the radio consumes less than one microamp. When receiving data, it consumes 10 milliamps. When transmitting, it consumes 25 milliamps. Conserving radio power is key to long battery life.

**3.6** **Battery**

The low power consumption allows a MICA smart dust to run for more than a year with two AA batteries. A typical AA battery can produce about 1,000 milliamp-hours. At 8 milliamps, the ATmega would operate for about 120 hours if it operated constantly. However, the programmer will typically write his/her code so that the CPU is asleep much of the time, allowing it to extend battery life considerably. For example, the smart dust might sleep for 10 seconds, wake up and check status for a few microseconds, and then go back to sleep.

**3.7 Antenna**

There is an antenna to send and receive signals

All of these hardware components together create a MICA smart dust. A programmer writes software to control the smart dust and make it perform a certain way. Software on MICA smart dusts is built on an [operating system](http://www.howstuffworks.com/operating-system.htm) called [TinyOS](http://www.howstuffworks.com/framed.htm?parent=motes.htm&url=http://today.cs.berkeley.edu/tos/). TinyOS is helpful because it deals with the radio and power management systems for you and makes it much easier to write software for the smart dust.

TinyOS is a [free](http://en.wikipedia.org/wiki/Free_software) and [open source](http://en.wikipedia.org/wiki/Open_source_software) component-based [operating system](http://en.wikipedia.org/wiki/Operating_system) and platform targeting [wireless sensor networks](http://en.wikipedia.org/wiki/Wireless_sensor_network) (WSNs). TinyOS is an embedded operating system written in the [nesC programming language](http://en.wikipedia.org/wiki/NesC) as a set of cooperating tasks and processes. It is intended to be incorporated into [smart dust](http://en.wikipedia.org/wiki/Smartdust). TinyOS applications are written in [nesC](http://en.wikipedia.org/wiki/NesC), a dialect of the [C programming language](http://en.wikipedia.org/wiki/C_%28programming_language%29) optimized for the memory limitations of sensor networks. Its supplemental tools come mainly in the form of [Java](http://en.wikipedia.org/wiki/Java_%28programming_language%29) and [shell script](http://en.wikipedia.org/wiki/Shell_script) front-ends.

## 4.0 HOW A SMART DUST WORKS

The Defense Advanced Research Projects Agency (DARPA) was among the original patrons of the smart dust idea. One of the initial smart dust ideas implemented for DARPA allows smart dusts to sense battlefield conditions. For example, imagine that a commander wants to be able to detect truck movement in a remote area. An airplane flies over the area and scatters thousands of smart dusts, each one equipped with a magnetometer, a vibration sensor and a [GPS receiver](http://www.howstuffworks.com/gps.htm). The battery-operated smart dusts are dropped at a density of one every 100 feet (30 meters) or so. Each smart dust wakes up, senses its position and then sends out a [radio signal](http://www.howstuffworks.com/radio.htm) to find its neighbors.

All of the smart dusts in the area create a giant, amorphous network that can collect data. Data funnels through the network and arrives at a collection node, which has a powerful radio able to transmit a signal many miles. When an enemy truck drives through the area, the smart dusts that detect it transmit their location and their sensor readings. Neighbouring smart dusts pick up the transmissions and forward them to their neighbors and so on, until the signals arrive at the collection node and are transmitted to the commander. The commander can now display the data on a screen and see, in real time, the path that the truck is following through the field of smart dusts. Then a remotely-piloted vehicle can fly over the truck, make sure it belongs to the enemy and drop a bomb to destroy it.

This might seem like an awful lot of trouble to go to, until you realize the system that these smart dusts replace. In the past, the tool a commander used to prevent truck or troop movement through a remote area has been [land mines](http://www.howstuffworks.com/landmine.htm). Soldiers would lace the area with thousands of anti-truck or [anti-personnel mines](http://www.howstuffworks.com/landmine2.htm). Anyone moving through the area -friend or foe -is blown up. Another problem, of course, is that long after the conflict is over the mines are still active and deadly -laying in wait to claim the limbs and even lives of any passerby. Since motes consume so little power, the batteries would last a year or two. Then, the motes would simply go silent presenting no physical threat to civilians nearby.

Imagine a suburban neighborhood or an apartment complex with smart dust that monitor the water and power meters. Since all of the meters embedded with smart dust having sensors in a typical neighborhood are within 100 feet (30 meters) of each other, the attached smart dust could form an ad hoc network amongst themselves. At one end of the neighborhood is a super-mote with a network connection or a cell-phone link. In this imagined neighborhood, someone doesn't have to drive a truck through the neighborhood each month to read the individual water or power meters, the smart dust pass the data along from one to another, and the super-smart dust transmits it. Measurement can occur hourly or daily if desired.

An ad-hoc (or "spontaneous") network is a [local area network](http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci212495,00.html) or other small network, especially one with [wireless](http://searchmobilecomputing.techtarget.com/sDefinition/0,,sid40_gci213380,00.html) or temporary plug-in connections, in which some of the network devices are part of the network only for the duration of a communications session. This concept of ad hoc networks formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another is extremely powerful.

**5.0 TYPICAL APPLICATIONS**

If we survey the literature for different ways that people have thought of to use smart dust, we find a huge assortment of ideas. Here's a collection of applications where smart dust can be used.

**5.1.In Bridges**

We can embed smart dust in [bridges](http://www.howstuffworks.com/bridge.htm) when we pour the concrete. The smart dust could have a sensor on it that can detect the salt concentration within the concrete. Then once a month we could drive a truck over the bridge that sends a powerful magnetic field into the bridge. The magnetic field would allow the smart dust, which are buried within the concrete of the bridge, to power on and transmit the salt concentration. Salt (perhaps from deicing or ocean spray) weakens concrete and corrodes the steel rebar that strengthens the concrete. Salt sensors would let bridge maintenance personnel gauge how much damage salt is doing. Other possible sensors embedded into the concrete of a bridge might detect vibration, stress, temperature swings, cracking, etc., all of which would help maintenance personnel spot problems long before they become critical.

**5. 2. In Machines**

We could connect sensors to a smart dust that can monitor the condition of machinery - temperature, number of revolutions, oil level, etc. and log it in the smart dust's memory. Then, when a truck drives by, the smart dust's could transmit all the logged data. This would allow detailed maintenance records to be kept on machinery (for example, in an oil field), without maintenance personnel having to go measure all of those parameters themselves.

**5.3 In Water Meters**

You could attach smart dust to the water meters or power meters in a neighborhood. The smart dust would log power and water consumption for a customer. When a truck drives by, the smart dust get a signal from the truck and they send their data. This would allow a person to read all the meters in a neighborhood very easily, simply by driving down the street.

**5.4. In Power Meters**

A building manager could attach smart dusts to every electrical wire throughout an office building. These smart dusts would have induction sensors to detect power consumption on that individual wire and let the building manager see power consumption down to the individual outlet. If power consumption in the building seems high, the building manager can track it to an individual tenant. Although this would be possible to do with wires, with smart dusts it would be far less expensive

**5.5. For Tracking Climate**

A farmer, vineyard owner, or ecologist could equip smart dusts with sensors that detect temperature, humidity, etc., making each smart dust a mini weather station. Scattered throughout a field, vineyard or forest, these smart dusts would allow the tracking of micro-climates.

**5.6. To Monitor Traffic**

Smart dusts placed every 100 feet on a highway and equipped with sensors to detect traffic flow could help police recognize where an accident has stopped traffic. Because no wires are needed, the cost of installation would be relatively low.

**5.7. For Biological Studies**

A biologist could equip an endangered animal with a collar containing a smart dust that senses position, temperature, etc. As the animal moves around, the smart dust collects and stores data from the sensors. In the animal's environment, the biologists could place zones or strips with data collection smart dusts. When the animal wanders into one of these zones, the smart dust in the collar would dump its data to the ad hoc network in the zone, which would then transmit it to the biologist.

**5.8. For Exploration Of Planets**

A recent survey about the application of smart dust says that smart dust can be used to explore planets .Tiny smart dusts that can be borne on the wind like dust particles could be carried in space probes to explore other planets. The devices would consist of a computer chip covered by a plastic sheath that can change shape when a voltage is applied, enabling it to be steered. Details were presented at the National Astronomy Meeting in Preston.

Smart dust could be packed into the nose cones of planetary probes and then released into the atmospheres of planets, where they would be carried on the wind. For a planet like Mars, smart dust particles would each have to be the size of a grain of sand. By applying a voltage to alter the shape of the polymer sheath surrounding the chip, dust particle could be steered towards a target, even in high winds. Wireless networking would allow these particles to form swarms. Dr Barker and his team in University of Glassgow has carried out mathematical simulations and have found that a swarm of 50 dust particles can organise themselves into a star formation, even in turbulent wind. The ability to fly in formation would allow the processing of data to be spread, or "distributed" between all the chips, and a collective signal to be beamed back to a "mothership".

**5.9. In Hospitals**

Another typical application scenario is scattering a hundred of these sensors around a building or around a hospital to monitor temperature or humidity, track patient movements, or inform of disasters, such as earthquakes.

**5.10. In Military**

In the military, they can perform as a remote sensor chip to track enemy movements, detect poisonous gas or radioactivity.

All of these ideas are good; some allow sensors to move into places where they have not been before (such as embedded in concrete) and others reduce the time needed to read sensors individually.

**6.0 POWER SUPPLY FOR SMART DUST**

New approaches for power supply are currently being tested for smart dust.

**6.1. ATP Molecules**

Scientists are currently carrying out experiments on solutions capable of supplying micro- and, in the future, nano-objects with energy that stems from living organisms, such as energy taken from spinach, sugar, slugs or flies. These new sources of energy use ATP molecules (Adenosine Tri Phosphate) which store phosphates of high energy in order to store energy just like in the muscles of living organisms.

**6.2.** [**Nuclear-Powered Micro Batteries**](http://en.wikipedia.org/wiki/Nuclear_micro-battery)

Other ways are also explored like [nuclear-powered microbatteries](http://en.wikipedia.org/wiki/Nuclear_micro-battery) for use in MEMS devices. Current research involves the incorporation of radioactive isotopes into such devices and production of electricity using thermoelectric phenomena.

**6.3. Solar Power**

As smart dusts shrink in size and power consumption, it is possible to imagine [solar power](http://www.howstuffworks.com/solar-cell.htm) or even something exotic like vibration power to keep them running. Solar panels having solar cells will convert the solar power into electrical power needed for running the mote.

One of the limiting factors in the development of smart dusts is the battery. Although a bigger battery would mean a longer life for the smart dust and farther transmission capabilities for its radio link, smaller smart dusts with smaller batteries are usually more versatile and flexible.

**7.0 CONCLUSION**

Dust is usually a nuisance. But "smart dust" could revolutionize how we monitor and understand the world around us. Smart dust is an ongoing research project whose main objective is to design a cubic micrometer-scale sensing nodes capable of bidirectional communication. The applications of miniature distributed sensor networks are numerous. Smart dust has four major components: power, computation, sensors, and communication. With these four components, a number of smart dust systems can be designed and modified depending on the applications.

Smart dust is a completely new paradigm for distributed sensing and it is opening up a fascinating new way to look at computers. If the smart dust networks successfully emerge, the line between reality and fiction would be blurred. Lets hope that the brainchild of Kristofer S .J. Pister i.e, “Smart Dust”, will make the entire world one huge ubiquitous and happy network.

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