Course5
Transformative intelligence

An Introduction to Smart Dust

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Introduction

In critical border areas, it becomes difficult for regular forces or even satellites to check for intruders, as the area that has to be monitored is quite large and complex. While the onus for border monitoring lies primarily with the border forces and the Army, a few companies are assisting them with technology.

These companies have been using the Smart Dust technology to produce motes for commercial and military use and in developing world-class remote premises surveillance technology. Military based solutions, built on Smart Dust technology, such as the **Smartdec wireless sensor network technology,** have been developed for autonomous monitoring systems, which relay information about human or vehicular intrusions back to the operator. Smartdec technology is being used at international borders, including NATO and EU, to help deal with criminal and terrorist threats. The wireless technology provides a highly portable surveillance solution with minimum configuration requirements and can operate up to 400 days without the need for battery charge.

While Smart Dust with computing abilities have been the subject of science fiction culture since 1960s, it is only now that these tiny machines, equipped with sensors, are becoming a reality. They are now being used to sense the environment while performing data processing and also communicate with each other to serve medical, industrial, and military purposes.

Jaanus Tamm
CEO, Defendec

"The Smart Dust technology has essentially limitless application potential. It enables transforming extremely large wireless sensor networks into smart systems which simplify our daily lives. This unique innovation helps to connect sensors or equipment with low energy consumption into a very large wireless network. It creates completely new opportunities for using wireless data communication sensors to monitor large areas and objects – for instance increasing city safety, road traffic surveillance, perimeter monitoring or controlling large areas and monitoring logistics."

History

Early 1990s
Initial concept of Smart Dust originated out of a military research project by US Defense Advanced Research Projects Agency (DARPA) and Research and Development Corporation (RAND)

1997
Group of young scientists from University of California, Berkeley presented research proposal on Smart Dust to DARPA which was finally approved for funding

2001
First prototype developed by Kristofer S.J. Pister, an electrical engineering and computer science professor at Berkeley

2002
Pister founded Dust Networks to bring the concept of Smart Dust to reality and also unveiled a 5 cubic-millimeter sensor that was the size of a grain of rice and was wireless and fully operational

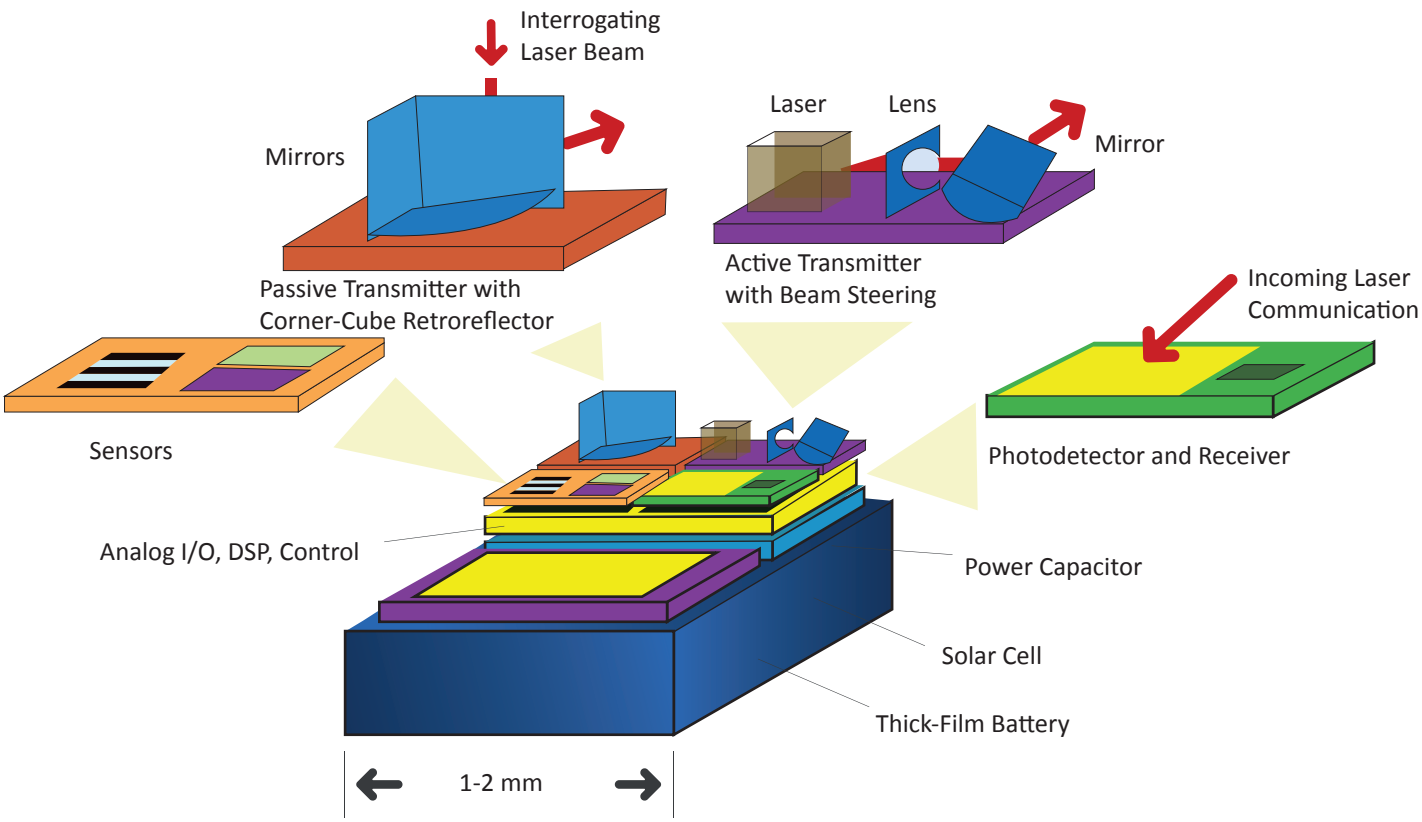
2006
Pister was awarded Alexander Schwarzkopf Prize, for developing and commercializing Smart Dust

2011
Linear Networks, an integrated circuits company, acquired Dust Networks to offer complete high performance wireless sensor networking solution

2017 and Beyond
Advancement in MEMS technology would reduce the size of sensors and actuators, thus minimizing the size of the mote.

Working of Smart Dust

Smart Dust is a system made of tiny, wireless sensors (also called motes) that can perform a variety of functions. The sensors have computational capability and can communicate with a base station or with other motes depending on the application. The transmission is carried out by microscopic devices known as micro electromechanical systems (MEMS).



History

Each Smart Dust device contains the following components:

- Sensors
- Active optical transmission using laser diode and beam-steering
- Passive optical transmission using corner cube retro-reflector
- Optical receiver using photodetector
- Analog I/O, signal processing (DSP or micro-controller) and control circuitry
- Power source based on thick film batteries and solar cells

The Smart Dust device is run by a microcontroller that helps in determining the tasks performed by the mote and also monitors the power of all the components of the system so as to conserve energy. There are different sensors to measure temperature, ambient light, vibration, acceleration, and air pressure. The microcontroller periodically gets a reading from the sensors and processes the data according to the sensor type, following which the results are stored in its memory. The optical receiver is occasionally turned on by the microcontroller to obtain information about any device willing to communicate with it. This communication includes new programs or messages from other motes. Based on the message received, the microcontroller uses the corner cube reflector or laser device to transmit sensor data or the message either to the base station or to another mote.

The issue faced in building smaller motes involves powering the device. Smaller batteries help in minimizing the size of the resulting mote but they have lesser energy and shorter life span compared to the larger batteries, thus requiring the motes to operate efficiently and conserve energy whenever possible. In order to conserve energy, the motes are enabled to 'sleep' most of the time, but 'wake up' regularly to take readings and communicate with other motes. This enables energy conservation during the sleep period.

Smart Dust Deployment

Bridges: The Smart Dust embedded in bridges helps in detecting the salt concentration within the concrete. It also helps to easily detect vibration, stress, temperature swings, and cracking, all of which would help bridge maintenance personnel spot problems long before they become critical.

Machinery Maintenance: Sensors are connected to the mote to monitor the condition of machinery such as temperature, oil level, and corrosion in aging pipes. The mote transmits all the logged data to the base station or to another mote when a truck passes by, thereby reducing the maintenance personnel's effort to measure all parameters.

Water Meters or Power Meters: The motes attached to the water meters or power meters log power and water consumption. The motes send their data when they receive a signal from the truck. This allows easy reading of the meters.

Health and Wellness Monitoring: With dust-sized, wireless sensors implanted in the body, internal nerves, muscles and organs can be monitored in real time. Neural dust monitors the brain from the inside. Electronic sensors, the size of dust particles, are sprinkled into the cortex, with each particle consisting of CMOS circuits and sensors that measure the electrical activity in neurons. The neural dust is interrogated by another component placed beneath the scale. This generates the ultrasound that powers the neural dust and reads its informational output. The data can be collected and stored outside the body for later analysis.

The University of California, Berkeley, team powered sensors with ultrasound pulses, which gave a real-time readout. The motes were built from biocompatible thin films, which would potentially last in the body without degradation for a decade or more. According to researchers, the motes could work equally well in the central nervous system and brain to control prosthetics and the goal of the neural dust project was to imagine the next generation of brain-machine interfaces and to make it a viable clinical technology.

Office Environment: Replacing wired routers with Smart Dust chip handles all hardware and software functions for distributed networks with lesser power. Equipping nodes with GPS receivers can also track visitors going to restricted locations. Attaching motes with induction sensors helps detect power consumption of electrical wires.

Agriculture: Motes embedded in each plant provide information regarding temperature, soil content, adequacy of water received, and whether the plant is diseased or not. Motes, when scattered through a field, allow tracking of micro-climates.

The motes of Crossbow can be used on the farm for irrigation management, frost detection and warning, pesticide application, harvest timing, bioremediation and containment, and water quality measurement and control.

Wildlife Habitats: Equipping endangered animals with a collar containing motes helps in tracking an animal's location and monitoring the microclimates in and around the nesting burrows. The motes collect data from the sensors as the animal moves around. When the animal wanders into one of the data collection mote zones, the mote dumps its data on to the ad hoc network, and transmits it to the biologist.

Roadways and Highways: Motes equipped with sensors are placed at every 100 feet along highways to detect traffic flow and help police recognize the spot where an accident has blocked traffic. As no wires are required, the cost of installation is relatively low.

Pei et al. has developed a Smart Dust wireless network to monitor pavement temperature and moisture presence to detect icy road conditions. An ice-detection algorithm was developed and embedded into the sensors to categorize pavement surface conditions as dry, wet, and frozen, based on sensor measurements.

Retail: Motes can be deployed to track inventory at any time in the logistics chain and monitor warehouse environments. It can also be used to track the location of customers in the store.

Environment Protection: Smart Dust helps in monitoring and protecting the environment. It monitors the state of forests and records and aggregates carbon dioxide emissions, which makes it a useful tool for scientists to combat degradation of the atmosphere.

Aircraft: Tiny sensors are embedded in paint to monitor aircraft stress during flights and the impact of crashes to help with traffic accident investigations.

Smart Dust Deployment

- The future of Smart Dust is being realized by a number of companies.
- CubeWorks aims to deliver true Smart Dust technology to open up the next generation of the computing paradigm, accelerating massive-scale realization of Internet of Things.
- Similarly, Hitachi has developed the world's smallest and thinnest RFID chip that may be utilized in a broad range of applications, such as Smart Dust, security, and logistics.

Challenges

Privacy: Smart Dust could become the tool of choice for corporate espionage. As Smart Dust becomes smaller and cheaper, privacy concerns are likely to increase.

Implementation Costs: Although Smart Dust is gaining popularity in many fields, all the elements needed to implement such a system may be expensive for a company.

Environmental Impact: There is an environmental impact if the Smart Dust that is sprinkled fails to function. Environmentally unfriendly components such as integrated circuits, batteries, and their impact, should be considered in order to prevent forest fires and other hazards.

Skin Infection: It is believed that Smart Dust is being distributed via chemtrails. This causes Morgellons disease, a condition where living fibrous organisms emerge from lesions in the patient's skin. Morgellons causes respiratory disease, chronic fatigue, joint pain, and immune disorders.

The Future of Smart Dust

Size

- Wireless devices would use radios instead of optical communication.
- Batteries with higher charge capacity would be used
- With these advancements, a complete wireless sensor node on a chip (the size of a grain of sand) with zero external components can be made.

Solar Sensors

- Solar power might be used instead of battery power.
- This would enable a sensor to power itself and send and receive information from a much smaller chip, thereby reducing the barriers related to powering of sensors.

Applications

Prospective applications include:

- Smart Dust injected into a person's brain for endoscopic medical imaging
- Invisible camera sensors on miniature drones or robots
- Weather or seismological monitoring on Mars and in sports such as sailing

Surveillance

With more affordable pricing and increased performance, this technology would be attractive to many different businesses. Governments, law enforcement agencies, insurance companies and others could sprinkle a few Smart Dust motes involuntarily on any person or vehicle for espionage reasons, and easily track their location, clock their rate of movement, and also record their conversations. When used surreptitiously, this technology poses serious privacy concerns.

Conclusion

Owing to the magnitude of improvement in size, power, and cost of wireless sensor networks, the applications of Smart Dust are expected to diversify and grow in the coming years. Smart Dust can be regarded as a potentially futuristic and important technology as it has the potential to be leveraged across various sectors and the possible applications hinge on detection, monitoring and tracking using chips.

The clientele of Course5 includes technology giants, chip makers, industry leaders and other research companies, who presumably would harness this technology for their business needs and would be interested in knowing use cases, market data and other aspects. The value proposition of Course5 would be to provide information, research data and market insights about this technology to their existing and newer clients, as we do with other technologies.

Though privacy is a concern, our whitepaper tries to point out that the benefits associated with this technology, if used correctly, can outweigh the risks posed.

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