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BRAINY MOTE- AN AREA EFFICIENT SMART SENSOR

Dumpala Rahul*, Rajeshwari Soma
*B.Tech ECE Department, CVR Collage of Engineering, INDIA
Assistant Professor,ECE Department, CVR Collage of Engineering, INDIA

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ABSTRACT
The new technology is the INTERNET OF THINGS, the general concept of the Internet of Things is that we can put a sensor on anything and have it send data back to a database through the Internet. In this way we can monitor everything, everywhere and build smarter systems that are more interactive than ever before. Now what if the sensors were in the air, everywhere? They could monitor everything temperature, humidity, chemical signatures, movement everything. The technology is called Brainy mote or Smart Dust. Smart dust is tiny electronic devices designed to capture mountains of information about their surroundings while literally floating on air like dust. Smart Dust is a self-contained network of tiny motes each having the capability of sensing and monitoring the environment conditions. Smart Dust is made of “motes” which are tiny sensors that can perform a variety of functions. They are made of “micro electro mechanical systems” known as MEMS.

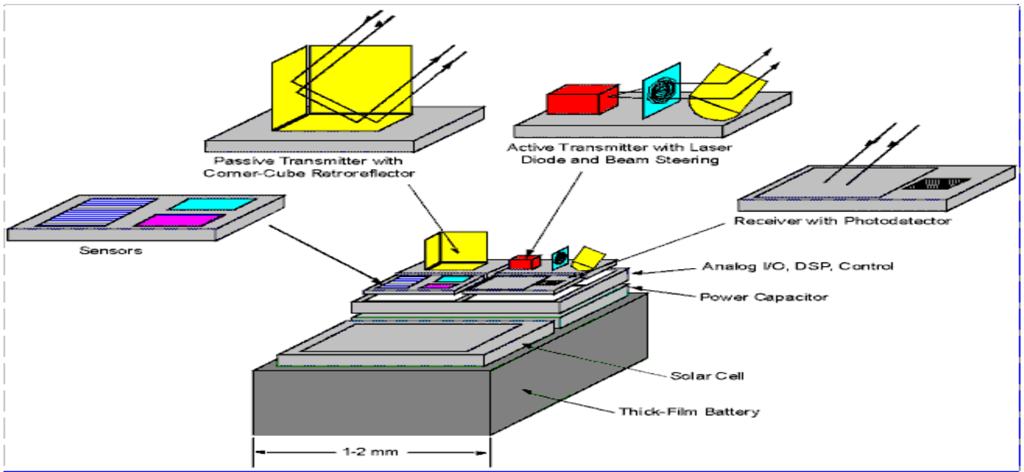
KEYWORDS: Sensors, MEMS, RF wireless communication, corner cube reflectors.

INTRODUCTION
The decreasing computing device size, increased connectivity and enhanced interaction with the physical world have characterized computing's history. Recently, the popularity of small computing devices, such as hand held computers and cell phones have increased significantly. Networks of wireless sensors have become quite interesting as a new environment in which to seek research challenges. Nowadays, sensors, computers and communicators are shrinking down to ridiculously small sizes. The new technology is the INTERNET OF THINGS, the general concept of the Internet of Things is that we can put a sensor on anything and have it send data back to a database through the Internet. In this way we can monitor everything, everywhere and build smarter systems that are more interactive than ever before. NOW what if the sensors were in the air, everywhere? They could monitor everything temperature, humidity, chemical signatures, movement everything. The technology is called Smart Dust. Smart dust is tiny electronic devices designed to capture mountains of information about their surroundings while literally floating on air like dust. If sensors, computation and communication technologies 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. Smart Dust as a concept originated out of a research project by the United States Defence Advanced Research Projects Agency (DARPA) and the Research and Development Corporation (RAND) in the early 1990s. We use the military anecdote above because it was these military research groups that first conceptualized Smart Dust but the practical application of the technology can be applied to almost any industry. Dust in the fields monitoring the crops. Dust in the factories monitoring the output of machines. Dust in your body monitoring your entire state of well-being. Dust in the forests tracking animal migration patterns, wind and humidity.

WHAT IS SMART DUST?
Smart dust is a self contained network of tiny motes each having the capability of sensing and monitoring the environmental conditions. Smart dust is made of “Motes” which are tiny sensors that can perform a variety of functions. They are made of “Micro Electro Mechanical Systems” known as MEMS.

Smart Dust concept has been credited to researchers at the University of California, Bekerley in 1997 by Prof. Kris Pister.They contain sensors which have the computational capability. They 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 system (MEMS)

SMART DUST TECHNOLOGY



Smart Dust is a Millimetre scale sensing and communication platforms. Each system will consist of one or more data receivers, and hundreds to thousands of sensor nodes. Each sensor node (dust mote) will consist of:
Power supply Solar cell array, thick film battery, or commercial hearing aid battery, individually or in combination.
Sensor(s) one or more MEMS sensors chosen from the set including at least: vibration, temperature, barometric pressure, sound, light, magnetic field.
Circuits' Analog interface to the sensor, analog to digital conversion, RAM and PROM, plus digital sequencing and control circuitry.
Communication Corner cube reflector (modulated retro reflector) and/or hybrid infrared laser diode for transmitting, photodiode for receiving.
These sensing elements will vary in size from 1 cubic millimetre for a mote with solar cells and thick film battery, down to 100 times thinner for a mote with just solar cell power, and up to as much as a sugar cube for units powered by commercially available batteries.
The smart dust mote run by a micro controller that can only determines the tasks performed by the mote, but controls power to the various components of the system to conserve energy. Periodically the microcontroller gets a reading from the sensors, which measure one of a number of physical or chemical stimuli such as temperature, ambient light, vibration, acceleration, or air pressure, process the data, and stores it in memory. It also occasionally turns on the optical receiver to see if anyone is trying to communicate with it. This communication may include new programs or messages from other motes. In response to a message or upon its own initiative the microcontrollers will use the corner cube retro reflector or laser to transmit sensor data or a message to a base station or another mote

COMMUNICATION TECHNOLOGIES

Smart dust full potential can only be obtained when the sensor nodes communicate with one another or with a central base station. Wireless communication facilities simultaneous data collection from thousands of sensors. There are several options for communicating to and from a mote.
Radio-frequency and optical communications are two options which have their own strengths and weaknesses.
RF itself has become synonymous with wireless and high-frequency signals, describing anything from AM radio between 535 kHz and 1605 kHz to computer local area networks (LANs) at 2.4 GHz. However, RF has traditionally defined frequencies from a few kHz to roughly 1 GHz
RF Communication usage leads to modulation, band pass filtering, demodulation circuitry, and additional circuitry, all of which needs to be considered, based on power consumption.

Moreover RF techniques cannot be used because of the following reasons

1. Large size of antenna.
2. RF communication can only be achieved by using time, frequency or code division.
3. TDMA, FDMA, and CDMA have their own complications.

There are several reasons for power advantages of optical links

1. Optical transceivers require only simple base band analog and digital circuitry.
2. No modulators, active band pass filters or demodulators are needed
3. The short wave length of visible or near infra-red light makes it possible for a millimetre scale device to emit a narrow beam.

As another consequence of this short wavelength, a Base Station Transceiver (BTS) equipped with a compact imaging receiver can decode the simultaneous transmissions from a large number of dust motes from different locations within the receivers' field of view, which is a form of space division multiplexing. Semiconductor lasers and diode receivers are intrinsically small, and the corresponding transmission and detection circuitry for on/off keyed optical communication is more amenable to low power operation than most radio schema.
There are two approaches to optical communications:

1. Passive Reflective Systems
2. Active Reflective Systems

PASSIVE REFLECTIVE SYSTEMS

The passive reflective communication is obtained by a special device called CCR (Corner Cube Retro Reflector) consists of three mutually orthogonal mirrors. Light enters the CCR, bounces off each of the three mirrors, and is reflected back parallel to the direction it entered. In the MEMS version, the device has one mirror mounted on a spring at an angle slightly askew from perpendicularity to the other mirrors. In this position, because the light entering the CCR does not return along the same entry path, little light returns to the source (a digital 0). Applying voltage between this mirror and an electrode beneath it causes the mirror to shift to a position perpendicular to other mirror, thus causing the light entering the CCR to return to its source (a digital 1). The CCR switch between these two states up to a thousand times per second, using less than a nanojoule per 0-1 transition.
A passive communication system suffers several limitations. Unable to communicate with each other, motes rely on a central station equipped with a light source to send and receive data from other motes, if a given mote does have a clear line of sight to the central station that mote will be isolated from the network. Also, because the CCR reflects only a small amount of light emitted from the base station this system range cannot easily extend beyond 1 kilometre. To circumvent these limitations, dust motes must be active and have their own on-board light source.

KEY POINTS

1. CCR-based passive optical links require an uninterrupted line-of-sight path.
2. CCR can transmit to the BTS only when the CCR body diagonal happens to point directly toward the BTS, within a few tens of degrees.
3. A passive transmitter can be made more Omni-directional by employing several CCRs oriented in different directions, at the expense of increased dust mote size.

ACTIVE-STEERED LASER SYSTEMS

It uses an on-board light source to send a tightly collimated light beam towards an intended receiver. Steered laser communication has the advantage of high power density. It uses burst mode communication, in which laser operates up to several tens of megabits per second for a few milliseconds, provides the most energy efficient way to schedule this network. The steered agile laser transmitter consists of a semiconductor diode laser coupled with a collimating lens and MEMS beam steering optics based on a 2 degree of freedom silicon micro mirror. This system integrates all optical components into an active 8mm3 volume.

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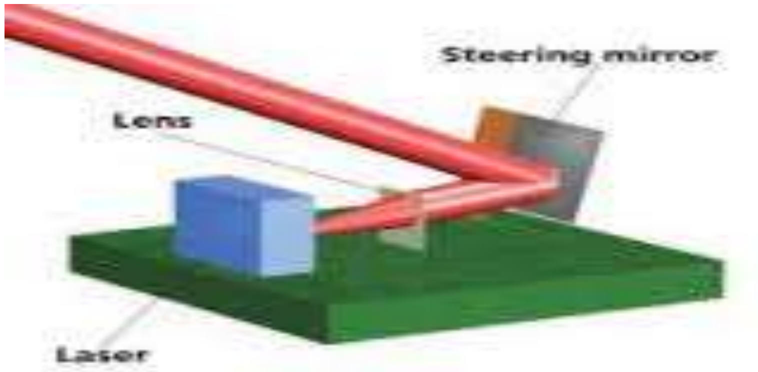
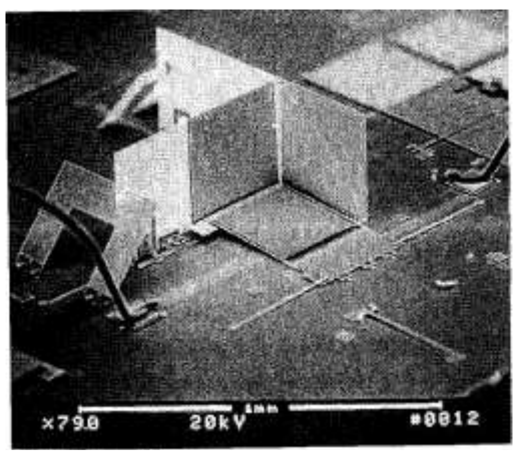


CORNER CUBE REFLECTOR

Corner cube reflectors work as transmitters by modulating reflected light. A laser beam entering a perfect 90 degree corner will bounce off of the three mirrors and return directly toward the source laser (although with some additional spread in the beam). If you are standing next to the laser, you will see a bright dot where the corner cube is sitting. If one side of the corner is moved out of alignment, even by less than a degree, the reflected light goes off in other directions. From the perspective of the observer near the laser, the spot goes out. This allows the corner cube to communicate digital information to the observer by the laser, merely by making very small motions of one side of the cube. The source of the optical power comes from the observer (interrogator).



With a photodiode on the dust mote, the laser interrogator can communicate *to* to the mote by modulating the laser intensity. In this way, the mote can remain passive unless it receives an appropriate coded signal. This means that an array of thousands or even millions of sensor nodes in a square kilometre area could be completely covert and undetectable. The CCR communication has inherently low probability of interception.
Corner cubes modulating at up to 10 kHz were demonstrated, and data transmission rates of up to one thousand bits per second (1 kbps). The corner cube driver circuitry currently uses an RS232 serial data transmission protocol.
The parallel transmission receiver consists of all off-the-shelf components: a small telescope (Edmund Scientific Celestron with a four inch aperture), CCD video camera, laptop PC, and video frame grabber. A 5 mW Radio Shack laser pointer is attached to the telescope to illuminate/interrogate the corner cubes. The images from successive frames of video are subtracted to remove background light, and whenever a corner cube in the field of view switches from on to off or off to on, this shows up as a bright spot in the image. Tracking the bright spots over time and converting the signal from serial/RS232 yields the data from each corner. Thousands of corners can transmit

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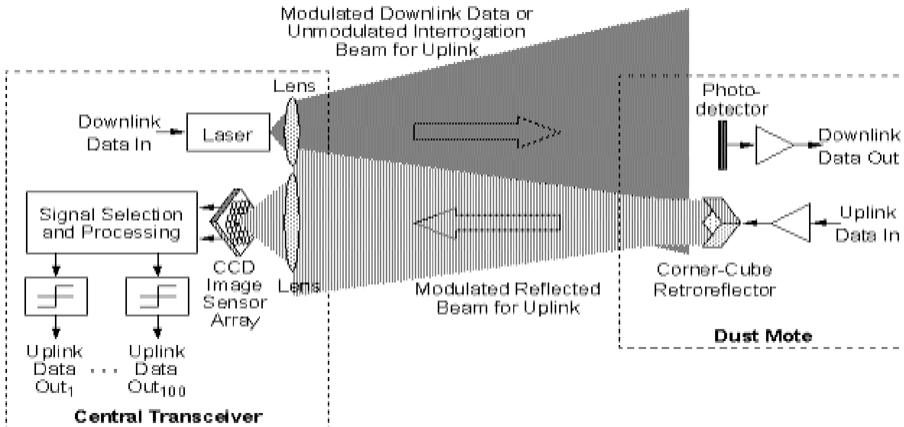
simultaneously because their signals are spatially separated in the image, so the signal will appear physically separated on the CCD camera and in the resulting frames.



The figure illustrates free space optical network utilizing the CCR based passive uplink. The BTS contains a laser whose beam illuminates an area containing dust motes.

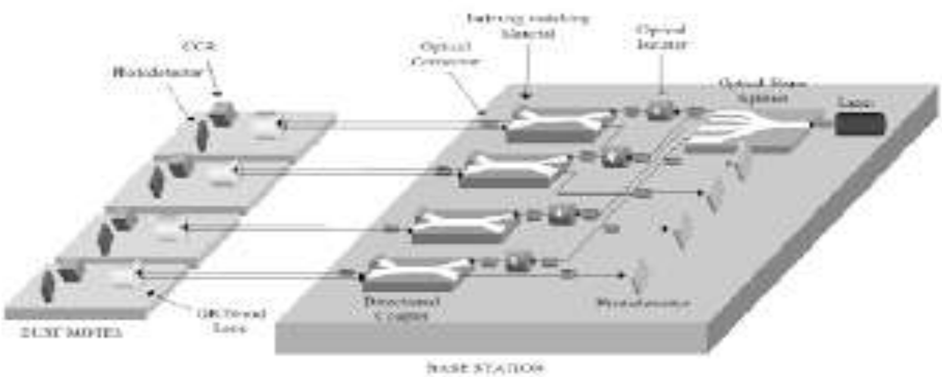
Downlink communication (BST to dust)- the base station points a modulated laser beam at a node. Dust uses a simple optical receiver to decode the incoming message.

Uplink communication (dust to BST)- the base station points an un-modulated laser beam at a node, which in turn modulates and reflects back the beam to the BST

FIBER OPTIC COMMUNICATION

Employs semiconductor laser, fiber cable and diode receiver to generate, transfer and detect the optical signal.

Similar to passive optical communication. Relatively small size of the optical transceiver is employed with low power operation. CCR employed on each Dust mote to modulate uplink data to base station.



ACTIVE OPTICAL TRANSMITTERS

When the application requires dust motes to use active optical transmitters, MEMS technology can be used to assemble a semiconductor laser, a collimating lens, and a beam steering micro mirror. Active transmitters make possible peer to peer communication between dust motes, provided there exists a line of path of sight between them. The dust motes can communicate over long distances at low data rates or higher bit rates over shorter distances.

DATA RECEIVERS

Many smart dust applications rely on direct optical communication from an entire field of dust motes to one or more base stations. These base stations must therefore be able to receive a volume of simultaneous optical transmissions.

Further, communication must be possible outdoors in bright sunlight which has an intensity of approximately 1 kilowatt per square metre, although the dust motes each transmit information with a few milliwatts of power. Using a narrow band optical filter to eliminate all sunlight except the portion near the light frequency used for communication can partially solve this second problem but, but the ambient optical power often remains much stronger than the received signal power.

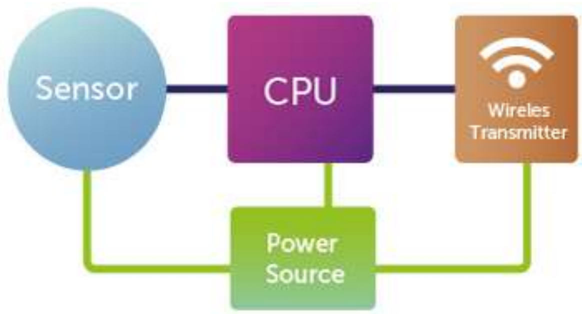
The data receiver will consist of a conventional optical system to collect the signals from hundreds or thousands of sensors simultaneously, a custom CMOS imaging chip to process the signals, and a display system to present the data. For data reception over longer distances receiver systems weighing 10kg will be able to read the sensor data at distances of up to several tens of kilometres, allowing reception from by unmanned aerial vehicles (UAVs).

The heart of the data collection system is the custom CMOS imaging chip. We have already demonstrated parallel data transmission using conventional CCD imaging chips, but these chips are limited to rates of a few thousand frames per second with reasonable resolution. Data transmission rates are limited to at most half the frame rate. With active pixel CMOS imaging, local processing of the image can be done at each pixel, or in pixel neighbourhoods, so that extremely high data rate signals from thousands of individual sensors can be collected by a single chip.

WORKING OF A BRAINY MOTES (SMART DUST)

Brainy Motes **(**Smart Dust) is a network of 'motes', identical or similar to tiny computers consisting of four miniaturized components:

1. Ambient Sensor
2. Wireless Transmitter
3. CPU
4. Power Source



The smart dust mote is run by a microcontroller that not only determines the task performed by the mote, but consists power to the various components of the system to conserve energy. Periodically the micro controller gets reading from one of the sensors, which measure one of a number of physical or chemical stimuli such as temperature, ambient light, vibration, acceleration, or air pressure, process the data, and store it in memory. It also turns on optical receiver to see if anyone is trying to communicate with it. This communication may include new programs or messages from other motes. In response to a message or upon its own initiative. The microcontroller will use the corner cube retro reflector or laser to transmit sensor data or a message to a base station or another mote. The primary constraints in the design of the motes is volume, which in turn puts a severe constraint on energy since we do not have much room for batteries or large solar cells. Thus, the motes must operate efficiently and conserve energy whenever possible. 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 the corresponding sensor, takes a sample, and converts it to a digital word. If the data is interesting, it may either be stored directly in the SRAM or the microcontroller is powered up to perform more complex operations with it. When this task is complete, everything is again powered down and the timer begins counting again.

TECHNOLOGY USED

Three technologies are used they are

1. Digital circuitry
2. MEMS Technology
3. RF-Wireless Communication

DIGITAL CIRCUITRY

Micro-electronic integrated circuits can be thought of as the "Brains" of a system. Because MEMS devices are manufactured using batch fabrication techniques similar to those used for integrated circuits, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost.

MEMS TECHNOLOGY

Micro Electro Mechanical System (MEMS) is the integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate.
While the electronics are fabricated using integrated circuits (IC) the micro mechanical components are fabricated using compatible "Micromachining" processes.

WIRELESS COMMUNICATION

A wireless communication system is required for sending and receiving data with data transfer rate of 1Kbps.
The devices for communication are subjected to size and power constraints. It must support bi-directional communication between a central transceiver and up to 1000 dust motes.

POWER SUPPLY

Solar cells deliver roughly 100 microwatts of power per square millimetre in full sunlight (i.e., with $1mW/mm^2$ incident optical power and 10% efficiency). Under laser illumination higher power output is possible. By placing cells in series or parallel the power can be delivered at any voltage desired, with corresponding reduction in current at higher voltage.

APPLICATIONS

Brainy motes have a wide range of applications which may completely transform the present sensing and sensor network technology. Brainy motes have applications in many fields

IT SECTOR

Brainy motes(smart dust) in IT Sector can be used as Accelerometers, MEMS microphones in portable devices, monitor speed and volume of traffic to avoid recurring traffic jams and also used in modern cars for a large number of purposes including airbag deployment in collisions.

DEFENSE APPLICATION

The motes used for defence purpose of consists of magnetometer, a vibration sensor and a GPS receiver. Motes can be spread on the battlefields by moving vehicles or soldiers with modified binoculars and also used to monitor critical parts of aircrafts and other war vehicles.

MEDICAL APPLICATION

Brainy motes can also be used in medicinal fields by proper designing of motes they can enter human bodies and check for physiological problems. Relay information about cancerous cells can be gathered easily. Doctors will be able to monitor health status accurately. Surgery will be more and more efficient and reliable as it will provide and extra arm for surgeons in their daily times.

ENVIRONMENTAL MONITORING

Motes can be used in environmental conservation, detect hazardous chemical and biological agents, monitoring nature of animals and measuring temperatures, humidity etc.

FOREST FIRE DETECTION

Motes self-organize into a network and the mote that detects a fire notifies central monitoring station and the mote location is the approximate location of the fire.

TRANSPORTATION MEANS

The Brainy Motes can be spread over the roads and any wear and tear on the roads can be easily detected and located. Firm can identify non-working street lights on the roads without a survey and repair can be organised in a more systematic manner.

ADVANTAGES

1. Small size
2. Better connectivity
3. Low cost

These are the major advantages of the Brainy Motes.

DISADVANTAGES

1. Privacy
2. Security of the information from the hackers

CONCLUSION

Many ongoing researchers on the Brainy Motes (Smart Dust) project are working on to make the size of the present latest generation mote as small as possible and to make it available at a low price. Soon we will see Brainy Motes being used in various applications of life leading the present world to a smarter world.

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