A Study on Smart Dust: An Extreme IoT

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Abstract

This paper deals with design and development of a smart dust. The technology consists of several nodes that form a network which communicates with the receiver or base station for information exchange. The device consists of sensors, actuators, transmitters and receivers. The nodes of smart dust are powered by solar energy. The challenging aspect of smart dust is the recovery of the failed nodes. The discorded ones adversely impact the environment.

Keywords: *Smart Dust, nodes, network, sensors, transmitters, receivers*

1.0 Introduction

Smart dust is the miniature IoTautonomous device consisting of sensors, actuators, power supply, transmitters and receivers [1]. It can be embedded anywhere because as it is miniaturized and free from human intervention. Smart dust is significantly gaining global market. It was originally designed for military applications to analyze the battlefield. Its other application areas are agriculture, medical diagnosis, environmental analysis and manufacturing. The nodes of smart dust network are spread across the area and the environment is sensed and transmitted to the receiver. Finding the appropriate protocols for mobile communication to the smart dust is challenging [1].

Smart dust introduction and their implementation. Operations of smart dust for communication. Optical transmission both actively and passively [2].An emerging ideology for replacing traditional solar cells with optical power for nano particles like smart dust. Makes use of photodiodes that will be implemented on the smart dust chip after testing the power requirement [3].

Smart dust market size and prominence of the smart dust market in next 8 years with the geographical analysis of smart dust implementation.

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Factors that are affecting the smart dust [4].Radio Frequency Identification technology for monitoring and communication, to understand the RFID and analyze the opportunities to implement a smart dust with RFID as an alternative to communication [5].

Approach for case study regarding Artificial Intelligence for smart dust using fuzzy logics, different algorithms for Self-organizing networks. Overview of power management policy [6].Brief overview about the problems in smart dust communication over networks like mixed packet problem and some approaches like plane partitioning for reducing the latency and increasing the throughput while node communication in smart dust [7].

Raise of a new perspective of nanometer sized smart dust like approach that focuses on monolithic structure and low power consuming IoT device. This acts according to the voltage variation [8].Authentication for smart dust for the purpose of security, Lightweight Authentication Protocol that helps the node’s authenticity. The smart dust network is enables with protocols to authenticate with its base station before data transfer [9].

2.0 Components and assembly of smart dust

The components include

- Corner cube retrospectrum for passive transmission
- Laser diode and beam steering for active transmission
- Photodetector receiver
- Solar cell
- Film battery

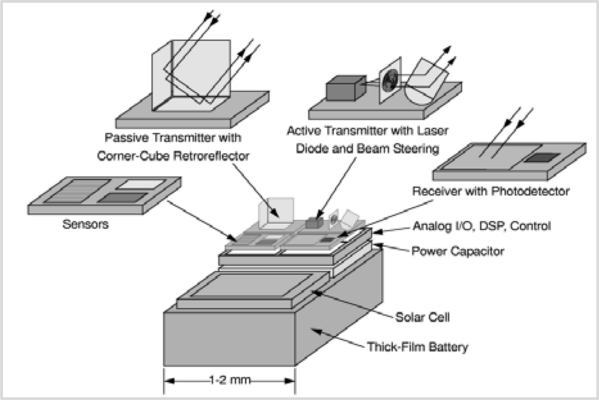

Fig. 1. Architecture of smart dust [1]

Each unit in network of smart dust is called mote or node [2]. Each node refers to the smart dust that will compose the architecture as shown in Fig. 1. Sensors will sense the data of the surrounding where it is put and then transmitted to the receiver. The transmission system in node is of two types active transmission with laser diode that transmits using beams and has voltage-based steering, second one is the transmission with corner cube retrospectrum that has three intersected reflectors for ranging the laser beams towards the receiver.

A solar cell[3] for autonomous power and a film battery sustaining power. It also consists of the receiver with photodetector since the communication is optical in most of the cases. Additionally, nodes consist of analog I/O and DSP controllerfor managing between analog and digital signals from sensors.

Alternatively, the communication can be taken place through radio frequency identification RFID [5]in case of less proximity. It is a wireless communication methodology that uses radio waves for transmission. Also has two kinds of RFID one is active with autonomous power another is passive that gets power from the transponder through antenna.Another alternative is GPS enabled smart dust that would work for tracking locations, in this way smart dust can be altered as per the change of requirement and demand.

3.0 Smart Dust with Artificial Intelligence

3.1 Self-OrganizingNetworks (SONs)

Self-organizing networks are a step towards automation of networks that are usually radio accessed network. The SONs can configure and manage automatically without the need of external management [6].

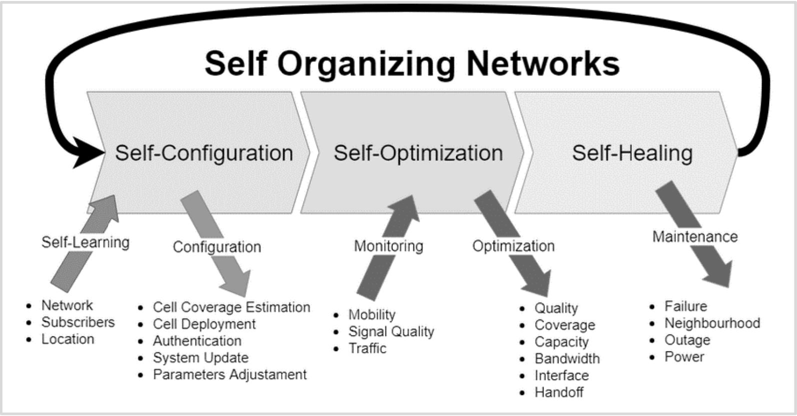

Fig. 2. Functions of Self Organizing Networks [6]

SONs have automated functions to handle the networks, some of them are:

Self-Configuration: The reorganization is done automatically also registration of new access points in case any new nodes are added to the network according to the requirement.

Self-Healing: In case of failure of base stations the nodes can heal themselves that helps in reducing the impacts on the efficiency of working.

Self-Optimization: Optimization for ensuring there is no traffic congestion or node collision, this optimization is also done automatically.

Basically, there are three types of self-organizing networks, Distributed SONs where each node communicated to other nodes of the network, in contrast centralized SONs through the central controller or any higher order nodes. Hybrid SONs are the combination of both distributed and centralized SONs

3.2 Finite State Machine (FSM) for smart dust

Finite State Machine is a model according to which a machine will have finite number of states. Here, a machine can be in one state at a time and the action of the machine is based on the state transition. A machine can be transitioned from on state to another to response to the input.

In case of smart dust each node can have finite number of states in order to manage the power, this can be done by introducing some of the states such as,[6]

- Sleep State
- Sense State
- Receive State
- Send State

Whenever the node is not actively sensing is will be in sleep state, so the power consumption is low at this state. Once the sensors are actively sensing the node transitions fromSleep to Sense State similarly the transition occurs from one state to another according the actions performed by the nodes.

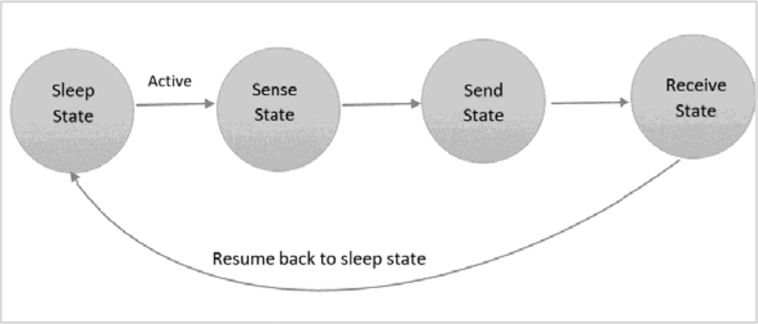

Fig. 3. States of FSM

3.3 Dynamic Plane Partition for Smart Dust

Communication over the network is using packets. It usually includes the control plane and data plane.

Control plane: Control plane basically defines the routes for the packet transfer from source to destination using aspects such as network topologies and routing tables.

Data plane: Data plane is responsible for actual packet transmission or packet forwarding over the route defined by the control plane.

In case of increase in number of packets or increase in node density may lead to problems such as network degradation and low throughput. By defining the different planes like control plane and data plane for the smart dust the throughput can be increased by increasing the processing speed using the dual plane development [7].

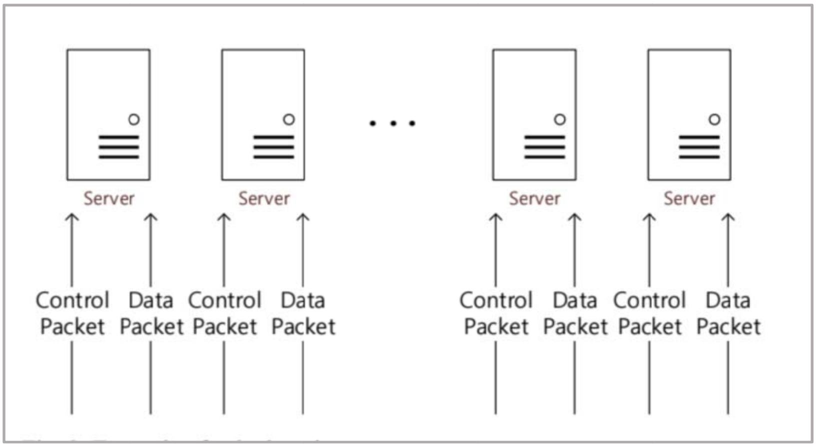

Fig. 4. Dual state environment sample [7]

Although the throughput is increased another concern is mixed packet problem when the proportion in signal packet and data packet is changing very frequently that again lead to degradation in throughput. Therefore, dynamic partitioning for dual plane can serve well in order to suffice this problem. Dynamic partitioning can be implemented by Artificial Neural Network (ANN). The control and data packets are accumulated and applied data augmentation for predicting the ratio of the planes incoming to the node and vice versa.

3.4 "Lablet" a microscale approach like Smart Dust

Lablet is formed with different components such as sensors, low power clock generator, finite state machine and actuators [8].

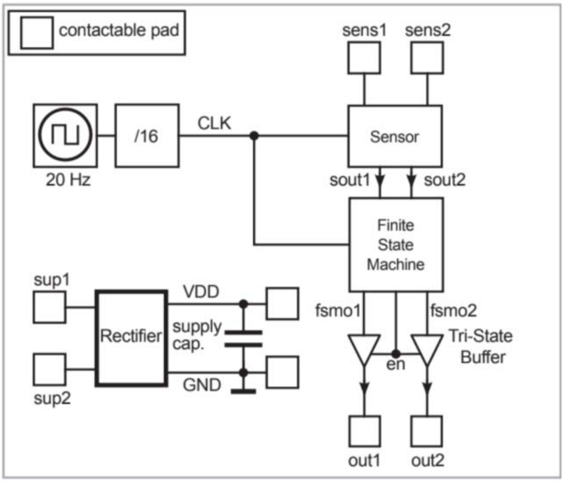

Fig. 5. Schematic diagram of lablet circuit

Smart dust volumes range in cubic millimetres. Whereas, the volume of lablet is reduced to nanometre scale by integrating the required components into a single structure. These operates at the voltage range of about 0.3v to 1.8v. The high-level functionality of lablet is to respond to the input potential changes through different voltage patterns.

3.5 Lightweight Authentication Protocol for Smart Dust

As smart dust is emerging the necessity for authentication is also increasing due to security concerns [9].All the other authentication methods need to store the keys in each node that is a challenge and a concern to size of smart dust too. Therefore, Lightweight Authentication Protocol (LAP) is introduced to the smart dust technology. In order to attain confidentiality, non-repudiation, integrity and such other security aspects in smart dust LAP is used. There are ways different ways to encrypt the data like hash function but they are comparatively complex, hence method like XOR manipulation is used for IoTs.

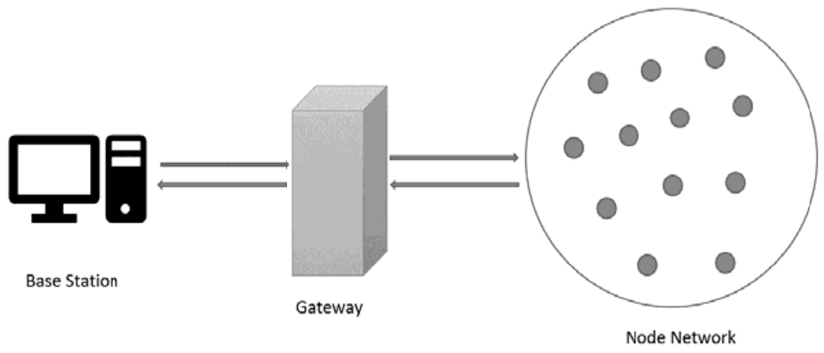

Fig. 6. Lightweight Authentication Protocol (LAP) basic setup

3.6 Smart Dust in Market

Table 1. List of some companies involved in smart dust related technologies

Competitors	**Beta Batt**	**Defendec**	**CubeWorks**
Description	They have developed and patented a three-dimensional energy conversion system. This system has been applied to Smart Dust.	Provides an efficient, autonomous, and self-healing wireless sensor network that consumes ultra-low battery energy for its operation.	Worlds smallest wirelesses sensor networks basically commercial of the shelf sensors.
Product name	DECTM Cell	Smartdec	Cubisens XT1, Cubisens TS110
Performance and life	Battery life 10 years with first installation.	Provides detection range of 35 m	can operate in sensing mode for up to 3 years
Limitation	Low power Power < 3 volts	Size goes up-to centimeter scale if increased in capability	Limited sensing ranges

3.7 Challenges

Sustainability, the challenge here is whether the smart dust is capable of remaining undamaged in the environmentif so, how long can it sustain.

Recovery and Disposal, Smart dust is not only beneficial but also can turn hazardous if it is left abandoned in the environment. The main challenge posed here is the recovery of smart dust and disposal or recycling. One of the ways is to track the smart dust network using the technologies such as GPS or RFID but the options is considered based on the proximity. This imposes the challenge of size. Practices of e waste management implementation like recycling or reusing of smart dust or its components are also one the ways to reduce the risks.

Environmental sustainability would be a risk if the motes are not disposed properly, hence disposal of smart dust is a major challenge to overcome either by increasing smart dust lifecycle or by reuse of recovered moted and such other aspects have to be handled.

Privacy, spread of smart dust has to be handled carefully to ensure that its legally used in approved areas only. That might cause a risk for both personal and compliant aspects.

Size and capability, as the requirements increase the capability should also increase. One factor to keep in consideration is the size. Although the capabilities increase the challenge here is to make it compact with increased capability in a very tiny size.

4.0 Conclusion

Smart dust can be both beneficial and hazardous at the same time but the effective utilization of this would harness the emergence of new opportunities to bring out the nano IoT into the various range of applications. Currently smart dust is working with optical passive and active transmission with the capability of autonomous power through solar cell also there are wide range of areas to explore in the same aspect in order to be more sustainable. Environmental sustainability is one of the concerns in smart dust about its disposal and recovery in case of failure. The future opportunities of smart dust are completely depending on the computational power it could bring in a very small size.

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