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A Hybrid Network Model for Increasing Bandwidth Using Nano Communication

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Abstract— Nanotechnology is the manipulation of matter on an atomic and molecular scale. We present the Nanopeers architecture paradigm, a peer-to-peer network of lightweight devices, lacking all or most of the capabilities of their computer-world counterparts. Hence, a P2P Worlds framework as a hybrid P2P architecture paradigm, consisting of cooperating layers of P2P networks, populated by computing entities with escalating capabilities has been proposed. In this paper, we review Nano networks from two aspects briefly: Nano networks with short range and long range communication. We proposed the P2P World framework based on the numerous real-world applications and reduction of complexity in Nano networks with open and well documented protocol specifications.

Index Terms— Nano networks, Nano communication, Nano network coding, Rate-delay tradeoff.

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1 Introduction

THE peer-to-peer (P2P) paradigm has emerged to be one of the hottest subjects of research and development of computer science during the last few years. The concepts in Nanotechnology were first pointed out by the 1965 noble laureate physicist Richard Feynman. He believed humans will be capable on downsizing systems dramatically in the future. At Nano-scale, a Nano-machine can be considered as the most basic functional unit. Nano machines are tiny components consisting of an arranged set of molecules, which are able to perform very simple tasks. Nanotechnology is composed of processing, separation, consolidation, and deformation of materials by one atom or molecule. “Nanotechnology provides the possibility of downsizing the machines in scale of 1 to 100 Nanometers. Each Nano-machine has been created from small components consisting of molecules that can do very simple computing functions. Relationships between Nano-machines could be defined of type voice, electromagnetic, chemical and molecular communications. In the molecular communication, molecule is introduced as a message between transmitter and receiver. Short-range Nano networks using molecular motors and calcium signaling work in the range of Nanometer to millimeter and long range Nano network using pheromones works in the range of millimeter to meter. We examine Smart Dust systems - an inherently pure P2P system - and present Nano Peer Networks: an approach to P2P networks comprised of micro-devices acting as lightweight peers in a P2P overlay, with restricted computing and energy capabilities. We try to identify the problems arising when applying computer-world techniques to this Nano-world, attempt to locate the cause of such discrepancies, and propose outlines of relevant solutions.

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2 Nano Networks

First Nano networks are based on many biological communication processes. However, the communication tasks occurring among these biological components are still not completely understood. The transmission and reception of information molecules is more related to the Nano-machines, more specifically with the molecular transceiver. There are many open questions regarding the transmission and reception such as (i) how to acquire new molecules and modify them to encode the information, (ii) how to manage the received molecules, and (iii) how to control the binding processes to release the information molecules to the medium. In models for flux and concentration detectors are presented. Such models demonstrate the dependence of the binding process on the medium conditions. This kind of models can help to understand the interaction between the receptors and the information signal, and to assess some transceivers features such as the molecule release rate or the sensitivity of the receptor. Nano networks and traditional networks can be compared shown in Table 1.

TABLE 1

Difference between Traditional Communication vs Nano Network Communication

Comparison Topic	Communication Network	
	Nano	Traditional
Communication Carrier	Molecules	Electromagnetic signals
Propagation Speed	Very Low	Speed of Light
Noise	Particles and molecules in the media	Annoying electromagnetic signals
Data Encryption	Process	Sound, image, text
Other features	Low energy consumption	High energy consumption

The propagation of the communication signals in Nano networks is totally different than in classical communication networks. Nano networks use molecules instead of electromagnetic or acoustic waves. The propagation of these molecules, which is subject to different medium parameters such as viscosity, temperature or pH, can be described using a particle diffusion model. Uncontrolled medium conditions such as rain, obstacles, wind or tide, can also affect the communication pathway. Prior to the development of communication mechanisms or protocols, it is important to develop, analyze and understand the channel model and the molecular signal propagation features. Brownian motion models were successfully used to describe the free movement of particles in fluids. Using similar models, the communication based on diffusion of pheromones in ant colonies has been described. These models can help to develop the channel and propagation models for Nano networks. Transmitter and receiver binding features can be added to these propagation models to assess the molecular channel capacity. Similar models, but including molecular propagation principles, can be used to explore more complex encoding techniques for molecular transmissions, such as AM and FM. If molecular motors are used as carriers, the propagation is restricted to the Nano network infrastructure and therefore the communication process can be considered to be more deterministic. The signal propagation speed using this physical channel as well as the reliability of the transmission using molecular rails still need to be measured.

3 Overview of Smart Dust

We shall now proceed with a quick architectural overview of Smart Dust systems. We'll also present two simple energy- and hops- efficient protocols for local detection and propagation of information in such systems, along with an analysis of their performance. The goal of this section is to act as a quick introduction to the concepts and limitations inherent in sensor networks for readers not familiar with such issues, and to give a first glimpse of the things we can expect when we dwell in the Nano-world of Smart Dust. Fig. 1 shows the architecture of Smart Dust. Smart Dust is comprised of a large amount of ultra-small sensors, called "grain" particles; homogeneous, fully autonomous devices as far as computing and communication issues are concerned characterized mainly by their available power supply (battery) and the energy consumption of computation and communication tasks. Each such particle features set of (light, pressure, humidity, etc.) sensors, two communication modes: a broadcast beacon mode (implemented using digital radio, for low energy short signals) and a directed to a point mode (implemented using a laser beam), and two modes of operation: awake (normal operation) and sleeping mode (all sensors and communication links are off). We'll assume particles have no storage capacity, although there exist variations with limited memory support. Unstructured peer-to-peer networks are flexible to churn while they usually achieve this goal by sacrifice the query competence and exactness. A variety of evidence indicates that the Gnutella network has a large and growing population of active users. To improve scalability, contemporary Gnutella clients accept two-tier overlay architecture. In this architecture a subset of peers called ultra-peers (or super-peers), form a top-level overlay while the majority of participating peers, called leaf peers. One or multiple ultra-peers. Ultra-peers communicate with one an-other using a superset of the original Gnutella protocol. When a leaf peer not find an available ultra-peer, it reconfigures itself as an ultra-peer after correcting that it has high bandwidth and can obtain incoming links.

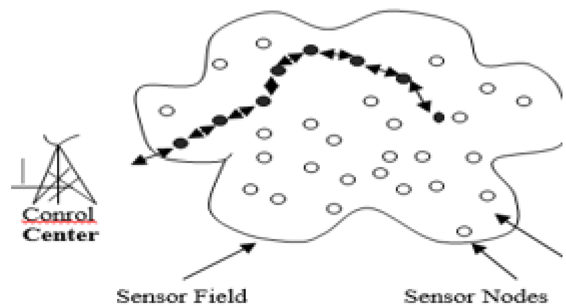

Fig. 1. Smart dust sensors communications tasks

4 Smart DUST: a P2P World

We'll now argue that Smart Dust particles act as lightweight peers in a P2P overlay of their own and discuss the applicability of PC-world techniques and protocols in this context. An SDC is, by definition, a pure P2P network; all "grain" particles are of the same stature, completely autonomous, and they all perform the same tasks (i.e. there is no specialized functionality at any particle). All communication is symmetric and the overall system operates in a completely self-organized, decentralized manner, since all operations are performed at every particle independently of the "wall" and the communication links are highly dynamic. The "wall" acts as an information sink, gathering observations from all particles. From a P2P point of view, we could model the "wall" as a crawler of the P2P overlay, visiting every and each node, or a set of super-peers, collecting all relevant information from the underlying Nano-P2P layer and manipulating it appropriately. This approach gives a new insight into Smart Dust systems and ubiquitous computing in general: we can simulate particles/entities with lightweight nodes in a P2P overlay, with arbitrarily restricted computing and power consumption capabilities. This, apart from providing us with a whole new test bench for protocols and techniques in the context of ubiquitous computing, allows us to reach a better understanding of novel P2P applications, utilizing lightweight and embedded devices.

5 Development of Nano-Machines

5.1 Short-range Nano Networks Using Molecular Motor

The first model of Nano networks have been inspired from designing of molecular communication and have been observed in the biological systems. Nano biological networks have been used within cells. Many of communication within cells are based on molecular motors.

5.2 Communication Process Using Molecular Motor

Molecular motors are used to carry vesicles containing information molecules that are transmitted from the transmitter to the receiver. To facilitate the reception, the transmitter uses protein tags that bind to specific receptors on receiver Nano-machines. Once the infrastructure is deployed between the transmitter and receiver Nano-machines, the process includes the following tasks.

5.3 Encoding

This task involves the generation of the information molecules. When an external stimulus is applied to transmitter Nano-machines, they generate these information molecules. The encoding process consists of selecting the right molecules that represent the information or the reaction to be invoked at the receiver. Thus, it is possible to control the reaction at the receiver by selecting the proper stimulus applied to the transmitter Nano-machine.

5.4 Transmission

This is a key task in this scenario and further research is needed to establish the process to attach the information packet to carrier molecules in an accurate way. The feasibility of this process is based on ligand-receptor binding process. A ligand molecule, usually a protein, can bind to another larger molecule referred as receptor according to the affinity between them. In chemical terms, affinity is defined as the trend of dissimilar elements to form chemical compounds based on their electronic properties.

5.5 Nano Network Components

The first models of Nano networks are based on those used in Information and Communication Technologies (ICT) for telecommunication networks. Nano networks components are functionally similar to those found in traditional networks. In Nano networks, we can identify five different components: the transmitter node, the receiver node, the messages, the carrier, and the medium. Each of these components affects the overall communication process, which includes the following:

(1) The transmitter encodes the message onto molecules.
(2) The transmitter inserts the message into the medium by releasing the molecules to the environment or attaching them to molecular carriers.
(3) The message propagates from transmitter to the receiver.
(4) The receiver detects the message.
(5) The receiver decodes the molecular message into useful information such as reaction, data storing, Actuation commands, etc.

6 P2P: A Hybrid Model

A better and more scalable solution to the problems that may arise in the SDC P2P world would be to have a Hybrid P2P system, consisting of heterogeneous particles, with escalating processing capabilities, network bandwidth, area of coverage, and power supply, allowing for multiple levels of peers. Fig.2 shows the architecture of Nano hybrid model. In this scenario, every set of homogeneous particles would form a separate Smart Dust Layer (or SDL). Particles would then contact the higher-order particle that is closer to them (discovered via the broadcast beacon mode). To go one step further, we can have particles use only the low-consumption digital radio transceiver to broadcast observations, under the virtual "umbrella" of one That is, SDLs consisting of particles with higher computing and power consumption capabilities than lower order SDLs. or more higher-order particles, much in the way overlapping GSM cells operate.

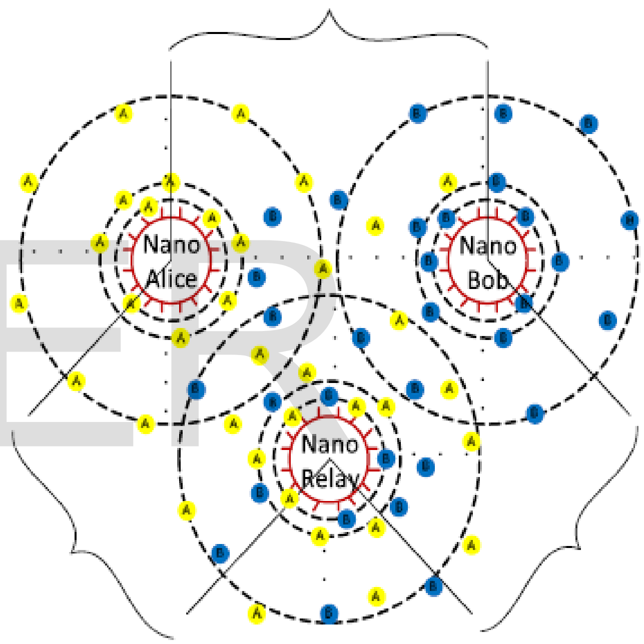

Fig. 2. Nano Network Coding Mechanism

7 Results and Working Communication

Using Hybrid Nano network model, the bandwidth of the network is increased. When we compared to existing P2P network model, this hybrid model increase the network bandwidth from 1 Gb/sec to 2 Gb/sec. Table 2 shows the comparison result of P2P communication network model with Nano network model communication.

TABLE 2

Comparison of P2P Communication vs Nano Network Communication

Size of File IN GB	Network Traffic Range in Percentage	Communicate via P2P in Min.	Communicate via Nano Network in Min.
5	20	5	2.5
8	20	8	4
10	20	10	5
12	15	12	5
15	15	15	6.5
20	15	20	9
23	10	22	9
26	10	25	10.5
30	10	29	12.5

8 Conclusion

The development of Nanotechnologies will continue and will have a great impact in almost every field. The use and control of these technologies will be a major advantage in economics, homeland security, sustainable growth and healthcare. We have presented Nano peer networks: a novel and highly interesting P2P application domain. We have argued for the similarities and differences between Nano world nodes and computer-world peers. We have included some relevant research results for the problem of routing at the Nano-level, which helps us better understand this largely unstudied P2P environment. We have analyzed the fundamentals of the intended functionality, looking at them from the point of view of P2P computing, and have proposed some initial (albeit naive) solutions to the problem of building a set of SDCs (or SDLs), following the paradigm of Hybrid P2P systems, and of locating higher-order SDC particles. Despite being a novel communication paradigm that requires an interdisciplinary approach, information and communication technologies (ICT) are called to be a key contributor for the evolution of the Nano networks. Network architectures, channel models, Nano-machines and transceivers architectures, medium access control and routing protocols are some of the contributions that are expected from the ICT field.

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