In Phase

IIT Guwahati-Cepstrum Magazine

March, 2009: Vol 4, Issue 1

A sneak peak into the future:

Cognitive Radio

Cover Article

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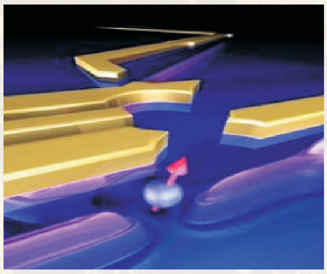

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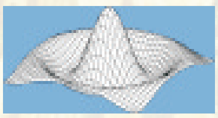

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From the editor...

At an undergraduate stage of one's career, we are all baffled by a significant question, "What should be my next career step: Job, MBA or MS/PhD"? In the latest issue of "In Phase" we present to you an interview with an Alumni of ECE department of IIT Guwahati pursuing Masters in a reputed US university. We hope that his experiences, views and advice would assist the readers of the magazine in making their significant career decisions.

In the cover article of this issue, we focus on an evolutionary technology, "Cognitive Radio. In an effort to make the budding researchers aware of this exciting avenue; the article outlines the fundamentals and gives the readers a sneak peek into the capabilities of the said technology.

In the "Next Trend" column we cover an exciting technology called as "Spintronics". This technology is the fundamental concept behind the Hard Disks and the present research in this field promises to change the way we design and think of electronic circuits.

In addition to the aforementioned advanced topics, we have also kept in mind the needs of the young minds. Tutorials on SPICE, Octave and an introductory article on TCP/IP have been included to cater the needs of sophomore students. Finally keeping with our tradition, we present to you the internship experience of our final year students and the popular cartoon column "Ecegiri".

This happens to be the last issue under the present editorial team. We hope that we have served the readers of "In Phase" well by keeping them updated with the latest in the field of Electronics and Communication. We thank you all for your support and co-operation and hope that you would continue to support us in future through your comments, views and constructive criticism.

Talla Vamsi
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Call for Articles

We are looking for technical as well as non technical and experience sharing articles from students, alumni, faculty members and industry professionals. Articles pertaining to completed/ongoing projects, views, discussions, topic introductions, applications and professional or educational experiences are most welcome. Articles must be 1500 - 3000 words in length and should be written keeping in mind the diverse range of targeted audience including people with little as well as extensive knowledge of electronics. Please email us at inphase@iitg.ernet.in for any clarifications or suggestions.

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Open Sources

Rahul Sangwan

All of us use Matlab in the lab. But has anyone ever given a thought to how much it costs? In the US, a single copy costs $1900. That's very, very expensive. I know some of you are thinking "Hehe, who needs a genuine copy?", but that kind of attitude only works here. When you go to a company and start working there, or start your own business you can't take that same attitude. You HAVE to use genuine softwares or you could be sued at any moment. So as you can see having a cheaper alternative to Matlab is very important. And so today it's not just open source fans who are using it, but also start-ups and established companies who don't need MATLAB's entire range.

Now you might be thinking that I don't want to learn a new software or that Octave can't possibly be as easy to use as Matlab. But the thing is that Octave is very similar to Matlab. When you start writing your code you create a ".m file", just as in Matlab. Hence you can transfer your code to a system that has Matlab and your code will run there also. And then Octave also defines variables with a matrix, just as in Matlab. And another very important similarity is that Octave functions have names similar to their Matlab counterparts. This is quite helpful since Octave does not have the great search and help capabilities as Matlab. But the solution is very simple, just search the online database of Matlab, find the required function, and then find the same function in Octave's help files.

One thing you will have to take care of is that

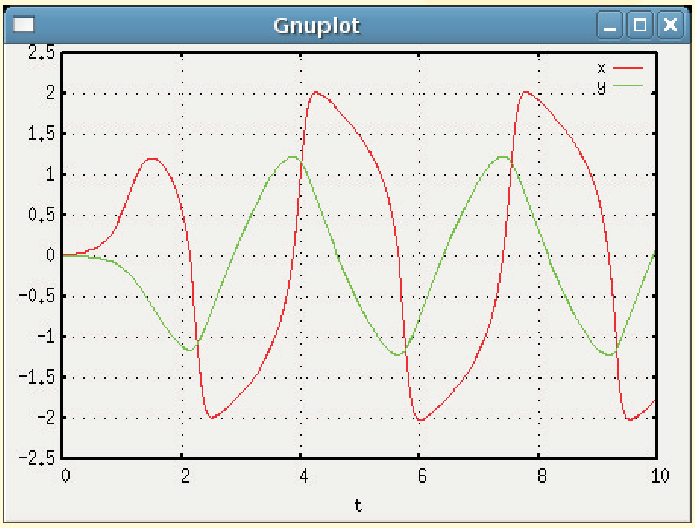
```
bash-3.1$ octave
GNU Octave, version 3.0.1
Copyright (C) 2008 John W. Eaton and others.
This is free software; see the source code for copying conditions.
There is ABSOLUTELY NO WARRANTY; not even for MERCHANTIBILITY or
FITNESS FOR A PARTICULAR PURPOSE.  For details, type `warranty'.

Octave was configured for "i486-slackware-linux-gnu".

Additional information about Octave is available at http://www.octave.org.

Please contribute if you find this software useful.
For more information, visit http://www.octave.org/help-wanted.html

Report bugs to <bug@octave.org> (but first, please read
http://www.octave.org/bugs.html to learn how to write a helpful report).

For information about changes from previous versions, type `news'.

hoctave:1> help for

*** for:

 -- Keyword: for I = RANGE
     Begin a for loop.
          for i = 1:10
            i
          endfor

     See also: do, while.


Additional help for built-in functions and operators is
available in the on-line version of the manual.  Use the command
`doc <topic>' to search the manual index.

Help and information about Octave is also available on the WWW
at http://www.octave.org and via the help@octave.org
mailing list.
octave:2>
```

Octave uses gnuplot for plotting. So you will also have to insure that gnuplot is installed and running on your system.

To download Octave go to "http://www.gnu.org/software/octave/download.html". Follow the instructions for installation. Once you have installed it just open a terminal and then type "octave". This will start the software. A prompt will appear of the form "octave:1> ". Here you can type any kind of operation which Matlab can handle. To see the help just type "help function name".

A very good place to begin is http://www.gnu.org/software/octave/doc/interpreter/index.html#Top. A comprehensive list of all the features of Octave and their usage are given here.

To create a script simply create a text file and then write your program. Remember that the extension of the file must be ".m". Also make sure to first go to the directory where you have created the file before entering Octave, otherwise the file will not be opened. To open a ".m" file just type the name of the file without the extension once you have entered Octave.



(Rahul Sangwan is final year student of ECE Department)

Alumni Talk

Akash Baid is a 2008 pass out from the department of Electronics and Communication at IIT Guwahati. Presently he is pursuing his Masters degree at the Department of Electrical and Computer Engineering at Rutgers, the state university of New Jersey, US. Notably, Akash was the founding chief editor of 'In Phase' and it is based on his visions that the current team is shaping 'In Phase'. We feel honored to cover him in the 'Alumni talk' section for this issue.

Q. Based on your experience, what is the basic difference between the education system in US and IIT Guwahati?

AB: We had all heard about it and for some who had gone out to do internships have seen it themselves – There is a huge difference in the education system in India and elsewhere. Saying that infrastructure in the US is better that India is an obvious understatement. I was amazed to see the entire setup in my university here which is ranked below 30 in the US! Imagine the top ones. Being a faculty here gives you a great chance to do actual research and pays good and no wonder there are professors here for whom you have to say 'Wow! He's actually smart'. It will require a great deal of analysis to describe why and how things are better but in short I feel the difference is that 'the system works' here and sadly it doesn't work that well even in IITs.

Q. What is your take on the worldwide recognition of IIT's and their conceived superiority? Do you feel this is justified? How did your IITian tag help you in the graduate admissions?

AB: Amongst those in the academic circles, there is no doubt that IITs are recognized as one of the best in the world. It helps you in getting admission, it helps in getting a financial aid and it also helps in getting the best projects here. Of course you have to perform after getting a relatively easy entry. The main factor here is the presence of IIT alumni – in the industry as well as the academics. I am sure IIT alumni work as faculty members in almost every top university in the US. My advisor here actually told me once – 'you know what, I boast to my colleagues back in Taiwan that an IITian is my teaching assistant! ' Only thing I am curious about is whether the IIT tag helps me get a job in these times here. I hope it does!

Q. Do you feel that the current IITG B.Tech curriculum is outdated and too rigid? Would you suggest something to rectify it?

AB: Too rigid – definitely yes but probably not that outdated. Believe it or not, some of things taught to us at the ECE dept. are covered at only the post-graduate level here in US and so all that really helps(even if you pretty much screwed up your grades like me back then!). I do hope however that we will see more options for courses in the dept and the term 'electives' will hopefully stop being a gross misnomer. There is, as we have felt for a long time, an immediate need to change the rigidity of the system – we don't need a factory production of engineers any more. Students should have the freedom to choose their courses, departments don't matter! Anyone who understands research would know that multi-disciplinary knowledge is the key to it. Being the 'best' in the country, there HAS to be more emphasis on being innovative, on not just rote learning, and to think broadly.

Q. How was your experience at IITG and how do you feel it is different from your current life in US?

AB: It's been too short a time to look back and say 'ah those days…' but I can't help saying it anyways! We all know that once you are done with your four years; there never will be a time quite like that! Life after Guwahati has been pretty good too so far, but with a stark difference in the lifestyle. I would rather not spoil the whole 'new experience' fun for you other than an advice to stay open to people from everywhere around the world. Wherever you go after graduation, two things are certain – you will never live with such a close group of friends again and two, you will never be so broke all the time again!!

Q. When did you realize that you wanted to pursue MS and why did you prefer it over a job?

AB: For me it was a tough decision, not as easy as most others who eventually came to the US. I guess I decided sometime in the 3rd year and amongst other reasons, I found out that I like projects and research and wouldn't even mind studying a few more courses if I have to do it for that. And up till now looks like a good choice. I think if you like technical stuff in general (and not the courses, which most people including me hate) you should consider doing a master's degree.

Q. *What are your career plans after completion of your master degree? Do you plan on returning back to India?*

AB: Plans after Master's are not too certain. The graduation date is yet too far. But I would like to have an experience of a R&D lab in the valley or a tech startup in my field of work. A PhD is also not out of the question yet. Eventually returning back to India is a certainty though.

Q. *We all know that the American Economy has been worst hit by the global economic slowdown. How has this affected your university (w.r.t. funded projects) and its current and prospective students, especially foreign?*

AB: There has been a widely varying degree of impact on universities. Most universities in the east coast, where the financial sector is dominant have been affected in terms of job prospects and project funding. While on the tech side in which we are more interested in, the impact is much less. In particular, Winlab at Rutgers where I am working in has fortunately not been affected that much. The sponsored projects have a long time-line and commitments and hopefully we can pass through this phase without much damage. Obviously it has had some impact on the issue of financial support for students but I expect the acceptance rate to go higher this year while getting an aid might become more difficult. On the whole, the impact is really specific to universities and even departments and labs.

Q. *In Phase is about to complete two successful years of publication. Our main aim has been to form a medium between the readers and the latest in the field of electronics, both in industrial and academic sphere. According to you how successful have we been and what are your suggestions to make it better?*

AB: It has been successful no doubt, and it gives no one more pleasure to see that than me! After this good start, the team should focus on not only a timely publication of issues but also look out constantly for ways to improve the content. If the content is good, readership and publicity will follow. Attention span is low and it is hard to make the content suitable and actually useful for people. On the whole the focus has to remain on electronics and communication /electrical/ computer engineering students but the scope of students might span the entire country.

Q. *Would you like to share a piece of advice with our readers about how they should plan their career moves.*

AB: If you are in a state where you can only wonder what you really want to do in life – consider yourself lucky if you ever get out of that state; most people don't even if they choose to do one thing or the other. The thing is, there is no way to know if you will like doing something unless you do it and then of course it's not too easy to change the course. Only advice that has helped me is to go with your feeling and be informed. And it is extremely important that you go out of your way to stay informed about things.

Q. *In terms of research, what according to you is the difference between IIT's and US universities? How can we narrow this gap?*

AB: Just one basic difference – finance. And it is hard to do anything about it in a short span of time. The kind of government, defense and industrial funding the US universities get is unimaginable in the Indian context and we can see of course that they simply can't afford it at the moment. If there is a consistently flow of funding, there's bound to be better people doing research in the IITs, better infrastructure and better results and thus better funding. How and where to break this cycle is a huge question. But somehow if someone manages to retain really good people in the IITs (which we see now in other IITs) then I have no doubt that the difference in terms of real research can get a whole lot better.

Q. *Your batch was 9th to graduate from IIT G. But unfortunately we still do not have a strong Alumni network. All other IIT's have a stupendous network of Alumni serving as a backbone. Where do you think we lack and how can we improve the Alumni network?*

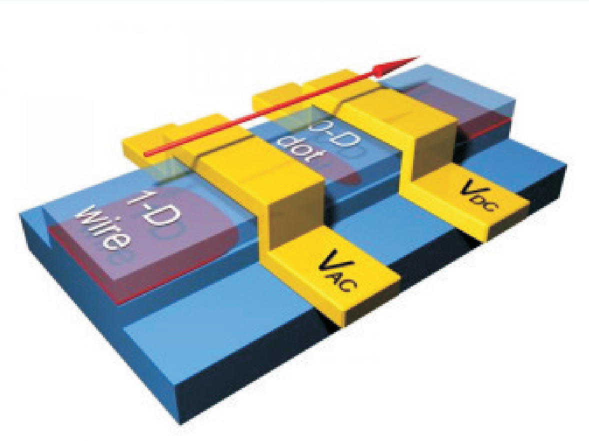
AB: I doubt if there is much we can do at the moment. People can't be millionaires or heads of multi-national organizations in 10 years. Other IITs have eminent alumnus working in virtually every one of the top 100 corporations of the world, and at good positions. It will take some time for us to go there. Till then we must focus on keeping contact with the alumni and of course creating even better batches of graduates who in turn can go far as an alumnus.

(Compiled by Final Year Students, Sourabh Sriom and Talla Vamsi)

Spintronics

Harpreet Singh

Electron, as we know, is the driving force on which our whole technology flourishes. Be it whatever gadget or equipment, the electron will have a role to play in it. That's what that makes electrons so indispensible. It wouldn't come as a shocker if someone were to say to you that electronic research amounts for more than half the total research conducted throughout the world. It is a brainchild of this research that we have with us a new face of technology called Spintronics. It is fast, reliable, less error prone and more robust. Let's take a peek into the amazing future of the gadgets that are so hard to live without.

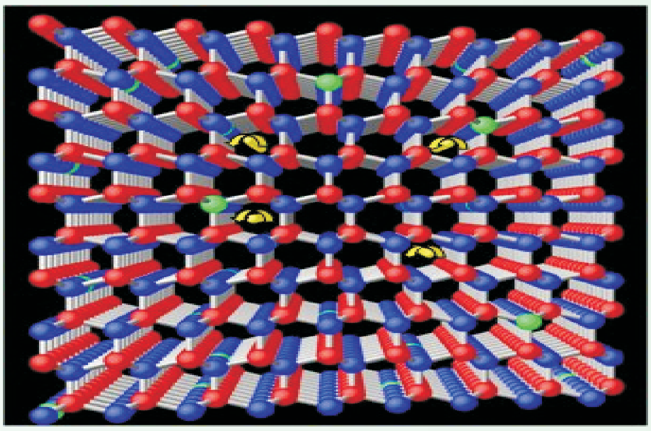


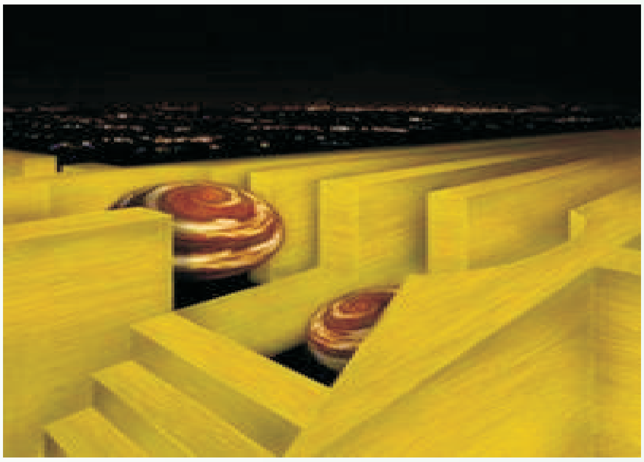
Spintronics, as the name suggests, deals with spin. But whose spin? It deals with electronic spin. Spintronics, or spin electronics, refers to the study of the role played by electron spin in solid state physics, and possible devices that mainly exploit spin properties instead of or in addition to charge degrees of freedom. In a more common language, it can be inferred that **spintronics**, also known as magneto electronics, is an emerging technology which exploits the intrinsic spin of electrons and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices.

It all started with Johnson and Silsbee in the year 1985, when while conducting experiments on spin-dependent electron transport phenomena in solid-state devices including the observation of spin-polarized electron injection from a ferromagnetic metal to a normal metal, the two observed that spin played a crucial part in the transport of information. If the spin could be exploited, amazing result could be achieved. Other notable contributors to this field include Albert Fert and Peter Grünberg who found a whiff of it while working on giant magneto resistance. The origins can be further traced back to ferromagnet/superconductor tunneling experiments pioneered by Meservey and Tedrow and initial experiments on magnetic tunnel junctions by Julliere in the 1970s. The use of semiconductors for spintronics can be traced back at least as far as the theoretical proposal of a spin field-effect-transistor by Datta and Das in 1990.

Spintronics makes use of the fact that electron have a distinct spin i.e. +1/2 or -1/2. They therefore constitute a two-state system with spin "up" and spin "down". The primary necessities to make a spintronic device are to have a system that can generate a current of spin polarized electrons comprising more of one spin species -- up or down -- than the other (called a spin injector), and a separate system that is sensitive to the spin polarization of the electrons (spin detector). In other words, we have a system that has electrons with up spin as well as down spin, however, the population of one of the types of the e^- is more than the other. On the other end of the system we have a sort of spin detector that is sensitive to the spin of the e^-. Electron spin during transport between injector and detector (especially in semiconductors) via spin precession can be manipulated using real external magnetic fields or effective fields caused by spin-orbit interaction. Thus this manipulation arms us with controlling the spin of the electron to our will.

The problem with the above mentioned technique is that it wouldn't work for non-





magnetic materials. Hence other methods are used to achieve results. Spin polarization in non-magnetic materials can be attained either through the Zeeman Effect in large magnetic fields and low temperatures, or by non-equilibrium methods. In the latter case, the non-equilibrium polarization will tend to decay over a timescale called the "spin lifetime". Spin lifetimes of conduction electrons in metals are relatively short but in semiconductors the lifetimes can be very long (probably lasting a few microseconds at low temperatures), especially when the electrons are isolated in local trapping potentials (for instance, at impurities, where lifetimes can be milliseconds).

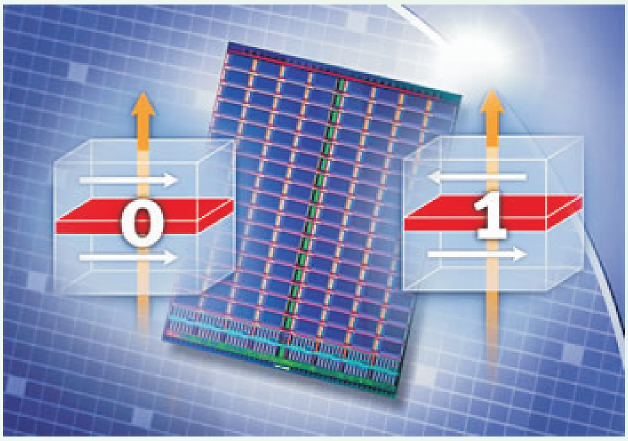
The spintronics field has numerous applications. To begin with, the storage density of hard drives is rapidly being increased along an exponential growth curve, courtesy spintronics, in part because the technique-enables devices like GMR (Giant Magneto Resistance) and TMR (Tunnel Magneto Resistance) sensors, in which it is used, to have an increase in the sensitivity of the read head which measures the magnetic state of small magnetic domains (bits) on the spinning platter. The doubling period for the areal density of information storage is twelve months, much shorter than Moore's Law, which observes that the number of transistors that can cheaply be incorporated in an integrated circuit doubles every two years.

MRAM, or Magnetic Random Access Memory, uses arrays of TMR or Spin torque transfer devices. MRAM is nonvolatile (unlike charge-based DRAM in today's computers) so information is stored even when power is turned off, potentially providing instant-on computing. Motorola has developed a 256 kb MRAM based on a single magnetic tunnel junction and a single transistor. This MRAM has a read/write cycle of under 50 nanoseconds. Another design in development, called Racetrac memory, encodes information in the direction of magnetization between domain walls of a ferromagnetic metal wire.

Advantages of semiconductor-based spintronics applications include potentially lower power use and a smaller footprint than electrical devices used for information processing. Also, applications such as semiconductor lasers using spin-polarized electrical injection have shown threshold current reduction and controllable circularly polarized coherent light output. Future applications may include a spin-based transistor having advantages over MOSFET devices such as steeper sub-threshold slope.

The other major application of spintronics is in Quantum Computing. A **quantum computer** is a device used for computation that makes direct use of quantum mechanical phenomena, such as superposition and entanglement, to perform operations on data. The basic principle behind quantum computation is that quantum properties can be used to represent data and perform operations on these data. In quantum computing, electronic spin represents a bit, called qubit, of information. The spin of the electron is exploited, instead of its charge and digitally used. If the electron is present on the surface, it is assigned "1" and if electron is not present, it is assigned "0".

Due to its higher retaining time period, data storage seems to be the major area of interest in spintronics. Spintronics can also be used in

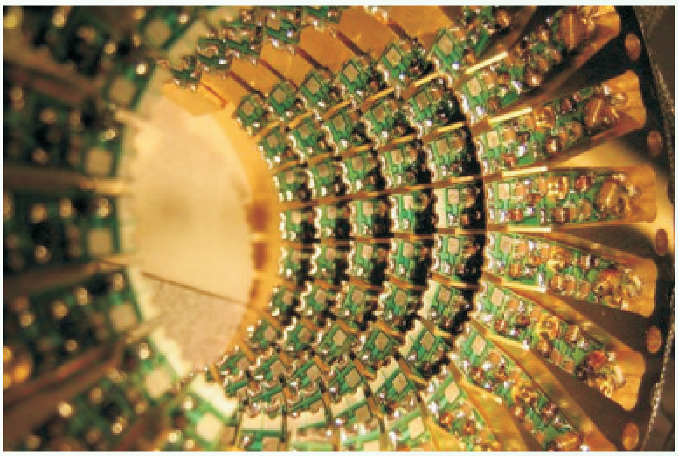


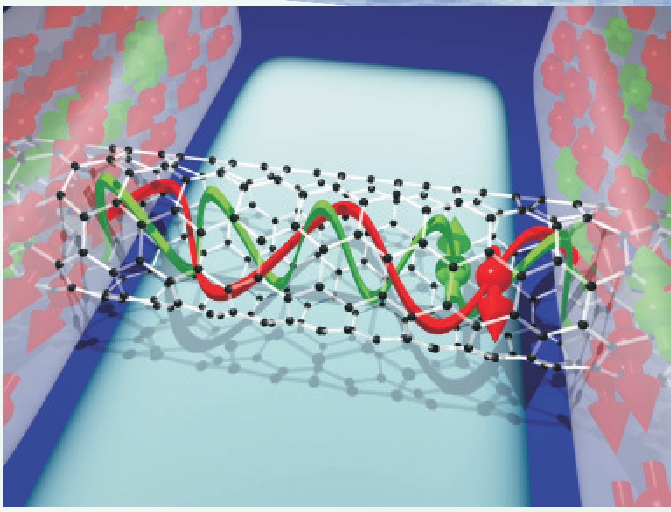
determining the magnitude of tunneling magneto resistance (TMR) in magnetic tunnel junctions (MTJ). Organic spintronics is also a field with upcoming promises. Research in the field of organic spintronics can lead to development in spintronics based organic memories, logic circuits, as well as improve efficiencies of organic light emitting diode (OLED)-based displays.

Silicon recently was found to prove as a haven for semiconductor spintronic researchers. The results mark another major steppingstone in the pioneering field of spintronics, which aims to use the intrinsic “spin” property of electrons versus solely their electrical charge for the cheaper, faster, lower-power processing and storage of data than present-day electronics can offer.

Spintronics, though seems to have endless uses, also has some shortcomings. The biggest one being that the efficiency can be improved only to a certain extent, not beyond a defined limit. Semiconductor spintronics is basically concentrated on problems like, coherent manipulation of electron spin at a given location, transporting spins between different locations within conventional semiconductor environment, all-electrical spin control via spin-orbit interactions, diluted magnetic semiconductors, and fixed or mobile spin qubits for quantum computing.

The key challenges of this field are the generation, manipulation and detection of spin in non-magnetic semiconductors. Various schemes have been proposed to tackle these challenges with different pros and cons. This can be taken of by studying the novel scheme of generation and control of spin current in semiconductors based on the discontinuity of





spin space in a spin heterostructure and the application of scheme in spintronic devices. Similar to the Josephson Effect, the equilibrium spin current is generated by the phase difference between the spin wave functions on the two sides of a junction. This problem is of important practical interest, because a spin current can be generated in a spin heterostructure without any external charge current and voltage and the approach has potential applications in low power spintronic devices.

In future, as we see, stress will be on achieving higher levels of efficiency and increasing the scope of spintronics. Currently, being in its infant stage, the technique is slated to become the next big thing. It is also supposed to replace electronics. Analyzing the pros and cons, this doesn't seem just a dream. Spintronics has helped create new levels of data storage and management. With a blend of spin and magnetic field, electrons, though being the tiniest indivisible part of the atom are set to shape the world that we live in. Big things do come in small packages.

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A sneak peak into the future: Cognitive Radio

Rohit Bahl

Traditional schemes of spectrum allocation for wireless applications have lead to under utilization of spectrum, which is a precious natural resource. Inefficient allocation and regulatory standards have lead to the common belief that there is a crisis of frequency spectrum which can be economically used. This misconception is further cemented by a look at the FCC frequency chart which shows multiple allocation over all frequency bands. On the other hand actual measurements reveal actual usage of only .5% in 3-4 Ghz bands which further declines to .3% in 4-5 Ghz bands (Figure 1) thus, although we have abundance of spectrum, the virtual shortage of spectrum is due to the regulatory climate.

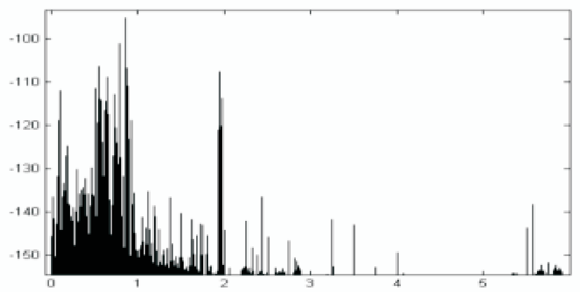


Fig 1: Spectrum Utilization Measurement

This strict distribution which has made spectrum scarce suggests the introduction of more flexible approach for spectrum access. Conventional wireless devices are tuned to operate within a fixed bandwidth to maximize their performances in that band. **Cognitive Radio** (refereed to CR henceforth) addresses this problem by dynamic allocation of spectrum to unlicensed secondary users (su) when the primary user (pu), who is the licensed user for that band, is not transmitting. Although there is no formal definition of the CR as of now, a useful definition summing up the characteristics of the CR is:

A Cognitive Radio is a adaptive multi-dimensionally aware autonomous system that learns from its experience to reason, plan and decide future action to meet consumer needs. A cognitive radio must be capable of : 1) sensing its environment 2) adapting its physical layer functionality 3) learning from its past experiences to deal with new situations in the future.

Clearly, such a revolutionary change in paradigm posses many challenges across all the ISO/OSI network layers as the CR must have: 1) a fully reconfigurable and generic hardware platform which is capable of receiving and transmitting signals which span in a wide range of frequencies and associated technologies 2) continuously sensing the spectrum to avoid interference between a su and a pu 3) sharing of control information about the spectrum within the CR network 4) efficient allocation of the unused spectrum so as to avoid interference between 2 su who compete for the same frequency band and 5) management of the unused spectrum bands for future allocation to su in case a pu starts to transmit in the bands being currently used by su. We will try to delve into these issues one by one.

Physical Layer

A generic architecture of a cognitive radio transceiver is shown in Fig. 2. The main components of a cognitive radio transceiver are the radio front-end and the baseband processing unit. The difference between conventional radios and CR is that each component can be reconfigured via a control bus to adapt to the time-varying RF environment. In the RF front-end, the received signal is amplified, mixed and A/D converted. In the baseband processing unit, the signal is modulated/ demodulated and encoded/ decoded. The baseband processing unit of a cognitive radio is essentially similar to existing transceivers. The challenging part of the CR is the RF front-end. It presents challenges unique to CR. The novel characteristic of cognitive radio transceiver is the wideband sensing capability of the RF front-end. This function is mainly related to RF hardware technologies such as wideband antenna, power amplifier, and adaptive filter. RF hardware for the cognitive radio should be capable of tuning to any part of a large range of frequency spectrum.

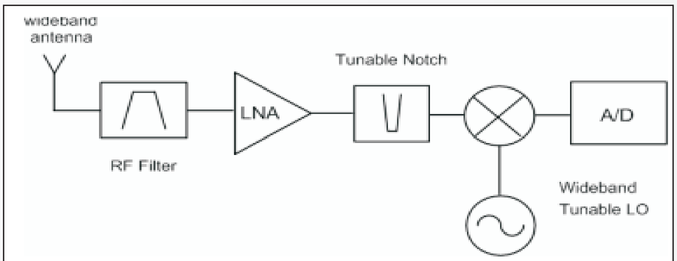


Fig 2: Wideband RF/analog front-end architecture for cognitive radio

The components of a cognitive radio RF front-end are as follows:

RF filter: The RF filter selects the desired band by band pass filtering the received RF signal.

Low noise amplifier (LNA): The LNA amplifies the desired signal while simultaneously minimizing noise component.

Mixer: In the mixer, the received signal is mixed with locally generated RF frequency and converted to the baseband or the intermediate frequency (IF).

Voltage-controlled oscillator (VCO): The VCO generates a signal at a specific frequency for a given voltage to mix with the incoming signal. This procedure converts the incoming signal to baseband or an intermediate frequency.

Phase locked loop (PLL): The PLL ensures that a signal is locked on a specific frequency and can also be used to generate precise frequencies with fine resolution.

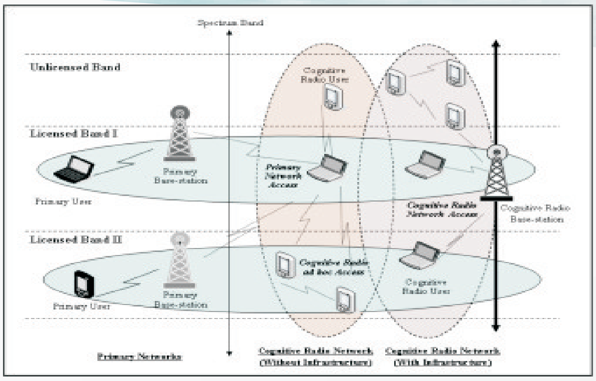
Channel selection filter: The channel selection filter is used to select the desired channel and to reject the adjacent channels.

Automatic gain control (AGC): The AGC maintains the gain or output power level of an amplifier constant over a wide range of input signal levels.

In this architecture, a wideband signal is received through the RF front-end, sampled by the high speed analog-to-digital (A/D) converter, and measurements are performed for the detection of the licensed user signal. However, there exist some limitations on developing the cognitive radio front-end. The wideband RF antenna receives signals from various transmitters operating at different power levels, bandwidths, and locations. As a result, the RF front-end should have the capability to detect a weak signal in a large dynamic range. However, this capability requires a multi-GHz speed A/D converter with high resolution, which is not be infeasible. The requirement of a multi-GHz speed A/D converter necessitates the dynamic range of the signal to be reduced before A/D conversion. This reduction can be achieved by filtering strong signals. Since strong signals can be located anywhere in the wide spectrum range, tunable notch filters are required for the reduction .Another approach is to use multiple antennas such that signal filtering is performed in the spatial domain rather than in the frequency domain. Multiple antennas can receive signals selectively using beam-forming techniques.

Spectrum Sharing

In CR networks, the other important challenge in open spectrum usage is **Spectrum Sharing**. Spectrum sharing can be regarded to be similar to generic medium access control (MAC) problems in existing systems. However, substantially different challenges exist for spectrum sharing in CR networks. The



coexistence with licensed users and the wide range of available spectrum are two of the main reasons for these unique challenges. The existing solutions for spectrum sharing in CR networks can be mainly classified in three aspects: i.e., according to their architecture assumption, spectrum allocation behavior and spectrum access technique. The first classification for spectrum sharing techniques in CR networks is based on the architecture:

Centralized spectrum sharing: In these solutions, a centralized entity controls the spectrum allocation and access procedures. With aid to these procedures, generally, distributed sensing procedure is proposed such that each entity in the CR network forward their measurements about the spectrum allocation to the central entity and this entity constructs a spectrum allocation map.

Distributed spectrum sharing: Distributed solutions are mainly proposed for cases where the construction of an infrastructure is not preferable. Accordingly, each node is responsible for the spectrum allocation and access is based on local policies.

The second classification for spectrum sharing techniques in CR networks is based on the access behavior. More specifically, the spectrum access can be cooperative or non-cooperative:

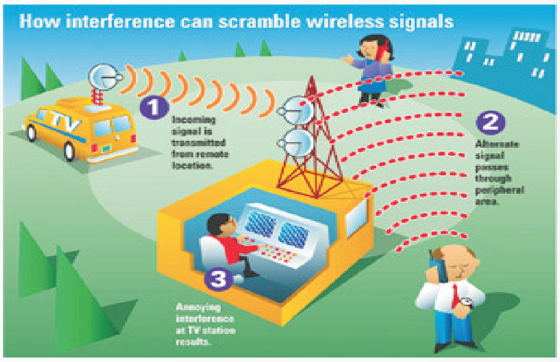
Cooperative spectrum sharing: Cooperative (or collaborative) solutions consider the effect of the nodes communication on other nodes. In other words, the interference measurements of each node are shared among other nodes. Furthermore, the spectrum allocation algorithms also consider this information.

Non-cooperative spectrum sharing: Contrary to the cooperative solutions, non-cooperative solutions consider only the node at hand. These solutions are also referred to as selfish. Non-cooperative solutions result in reduced spectrum utilization.

The third classification for spectrum sharing in CR networks is based on the access technology:

Overlay spectrum sharing: Overlay spectrum sharing refers to the spectrum access technique used. A node accesses the network using a portion of the spectrum that has not been used by licensed users. As a result, interference to the primary system is minimized.

Underlay spectrum sharing: Underlay spectrum sharing exploits the spread spectrum techniques developed for cellular networks. Once a spectrum allocation map has been acquired, a CR node begins transmission such that its transmit power at a certain portion of the spectrum is regarded as noise by the licensed users. This technique requires sophisticated spread spectrum techniques and can utilize increased bandwidth compared to overlay techniques.



Spectrum Sensing

Spectrum sensing is at the core of the CR concept and plays an instrumental role in the performance of a CR network. A CR opportunistically access the spectrum when the licensed user is not transmitting in that band. Therefore the objective of spectrum sensing is two-fold: 1) detection of spectrum holes which can be used by the CR 2) identifying primary user in the frequency band in which the CR is currently transmitting. By scanning the entire frequency band the CR can identify the bands which are vacant and hence can be used by a it. Now, as the pu is the licensed user, it does not need any kind of authorization and hence it may start transmitting any time irrespective of whether the su is using the band or not. It may so happen that a su transmitting in that band may then interfere with the pu, which then will degrade the QoS for the pu .Hence its the responsibility of the su to vacant the channel as soon as the pu starts transmitting. To maintain the QoS, the su must sense the channel after every ?t s , where ?t is the max time till which pu can stand interference. The goal of spectrum sensing is then to decide between the following two hypotheses:

$$x(t) = (n(t), H_o$$
$$h \times s(t) + n(t), H_1$$

where x(t) is the received signal, s(t)is primary user's signal, n(t) is the additive white Gaussian noise (AWGN), h is the gain of the channel, Ho denotes the absence of the pu and H1 denotes the presence of the pu. The key challenges then in spectrum sensing are detecting of primary user in low SNR environments and fading environments where it is hard to distinguish a low SNR primary signal from noise.

Cooperative Spectrum Sensing

Use of diversity in wireless systems for increasing the agility for the wireless system is a well studied topic. Effects such as Multipath, Shadowing and Fading are common in wireless systems and one way to counter them is by employing multiple antennas i.e. exploiting spatial diversity. In a CR network also, a particular node at any give time may experience the above mentioned path losses. Therefore at any give instant of time a particular node can be in a deep fade condition thereby reducing the power received at the node and hence reducing the probability of detection. Such conditions may therefore cause an increase in the interference caused to the pu, which is undesirable. To counter the effects of fading spatial diversity of various CR nodes is exploited. CR nodes are organized as clusters which cooperate among each other to increase the probability of detection, Pd. Rather than transmitting all the decision statistics, the CR nodes only transfer their final one bit decision about the presence or absence of the pu thereby reducing the overhead associated with cooperation. After receiving one bit decisions from all the nodes in a cluster the base station employees a fusion rule for deciding the presence or absence of a white spot.

Different kinds of fusion rule have been proposed such as OR rule, which decides the presence of white shot even if one of the nodes senses in favor of it, AND rule which decides in favor of white spot only if all the users decide in favor of the white spot. Recently some more detection criterion's have been suggested which given weights to the decisions based on the SNR's of the decision making nodes While cooperative approaches provide more accurate sensing performance, they cause adverse effects on resource-constrained networks due to the additional operations and overhead traffic.

Conclusion

The long-touted scarcity of radio spectrum in the future may be replaced by a surplus of available frequencies. Rather than a cell phone needing a minute to upload a compressed megapixel-size image, it might be able to handle 10 such images a second. Just as the emergence of cell phone technology has led to wide social and business consequences, cognitive radio's adoption will induce similar changes as advanced devices exploit the wireless Web to displace now traditional cell phones. The growth of cognitive radio will take some time to occur, but the effect on all our lives will be significant.

(Rohit Bahl, is a 4th year B.Tech student of ECE Department.)

TCP/IP - An Insight

B. S. Sasikanth

Until recently, the Internet speed in our hostels was pathetic and all of a sudden, the speed is much better without any reduction in the effective user database! Of course we all are happy. But did you not wonder how this happened? Leave that for a fact. Most of us have never been a part of a LAN before coming to the campus but after coming here, we cannot live without it! *DC++* and *'Sharing on Run'*, as we popularly call it, are things which make our day. Even though we manage without knowing how all this works, it's always better to find out …

What is TCP/IP ?

This is a common question that you would like answered before reading an article on it. Fully known as *Transmission Client Protocol / Internet Protocol,* TCP/IP is an understanding between computers connected in a network as to how they must call upon each other for effective two-way data transfer. True we do many other things on a network nowadays other than just send and receive data, but data transfer is the essence of all tasks. The rest of this article will give you an idea of how this actually happens.

Transmission Client Protocol / Internet Protocol version 4 (TCP/IPv4)

This is the protocol which makes everything from Networking to Internetworking possible. The protocol has been prevalent for over two decades with changes being made to it to suit the dynamic needs of the community but it is set to be replaced by its successor, IPv6, reasons for which will be clear as you read further.

The protocol works on the simple fact that every Network interface is identified by a 32 bit word called its IP address. Now let us get one thing straight. A Network Interface and a Network Device are not necessarily the same. The Network Interface is the way the network sees a device and it is possible for a single device to have more than one Network Interfaces. A simple example would be you changing your computer's IP Address. The device remains the same but its Network Interface has changes because the Network sees you as a different device.

Now that we have got that straight, every Network Interface is characterized by an IP Address. This is like the name of the Interface in that Network. This address will be used for all transactions involving the Interface and any other device. As already mentioned, the IP address is a 32 bit word like the one shown below.

IP Address: 11100101011101011000101001000111

But using such an address would only cause utter confusion. Hence this 32 bit word is first split into 4 equal parts and then, they are expressed in decimal making it easier to work with.

IP Address: 11100101.01110101.10001010.01000111

IP Address: **229.117.138.071** usually written as **229.117.138.71**

That is the usual IP address that we see. Since each section has 8 bits, the decimal can extend from 0 to 255. Hence we have IP Addresses ranging from 0.0.0.0 to 255.255.255.255. That gives us a total of 255^(4) IP Addresses.

This may appear a big number at first sight, but taking into consideration the gigantic number of clients all over the world, this is hardly enough. Then how is it, that we manage to survive today with this system? Well, just keep reading to find out!

When TCP/IP was originally implemented, it was split into different classes for different uses. To understand these classes, we need to know about Network and Host Ids.

Network ID (NID): The part of the IP which identifies the network.
Host ID (HID) : The part of the IP which identifies the host.

The following table illustrates the different classes of Ipv4:

Class A	N.H.H.H	**229**.117.138.71
Class B	N.N.H.H	**229.117**.138.71
Class C	N.N.N.H	**229.117.138**.71
Class D	Multicast	Multicast

Addressing based on these classes is popularly known as **classful addressing**. For Example, a company having less number of computers, say 200, will opt for a Class C solution as it offers them 256 host Ids. Their Network will be characterized by a 24 bit word. Similarly, a larger company having 60,000 hosts would opt for a Class B solution as it offers them 256*256, ie, 65536 Host IDs. Their Network's ID is characterized by a 16 bit word.

All this was fine in the earlier stages as it served the purpose. After all, IPv4 was started as a project of the Department of Defense of the United States. But as the computer world evolved, the Internet grew on this infrastructure and soon there were problems. The number of IPs being offered was not enough. Also, the concept of classful addressing led to the wastage of many addresses. A company needing 2000 IPs would opt for Class B hence wasting more than 60,000 addresses! This was indeed unacceptable. Hence came the concept of classless addressing.

Classless Addressing

This works on the concept of splitting the classes into further *subnets* which would be allotted to the different companies. Hence, the concept of a 'Subnet Mask' was introduced. The Subnet Mask's sole purpose is to identify the line dividing the NID and the HID. Let us see how it does that.

Consider the following configuration. We will be seeing the Addresses in binary form for clarity of understanding.

IP Address: **11100101.01110101.1000**1010.0100 0111 (229.117.138.071)

Subnet Mask: 11111111.11111111.11110000.00 000000 (255.255.240.0)

The digits in the Subnet which are '1' refers to the positions in the IP Address which are a part of the NID. Hence, ideally the subnets of classes would be as follows:

Class A	255.0.0.0
Class B	255.255.0.0
Class C	255.255.255.0

The Subnet mask now gives us extra control. Each Class can be further divided into sub-classes and allotted with minimal waste.

Though so many steps were taken to stretch the life of IPv4, some of its shortcomings were inevitable and hence, during the 90's, it was decided that IPv6 had to be introduced. Now it's 2009 and we are not yet seeing IPv6 being implemented. Why? The answer to this would be clear once we have a look at what IPv6 exactly is.

Transmission Client Protocol / Internet Protocol version 6 (TCP/IPv6)

Also popularly known as IPng (IP next generation), the main reason to introduce this new version was to increase the number of available addresses and divide them hierarchically so that, the whole infrastructure can be more organized. So the initial guesses were an address of 48 bits or 64 bits. But finally, a 128 bit address was decided for the system. Now naming a 128 bit word even in decimal will not make it much smaller or easier to comprehend. Take a look for instance: 128.91.45.157.220.40.0.0.0.0.252.87.212.200 .31.255

How easy would that be to remember? Hence instead of splitting it into 16 8-bit words, it is split into 8 16-bit words which are in turn represented by hexa-decimal notation which would look something like 805B.2D9D.DC28.0000.0000.FC57.D4C8.1FFF

Classifying this huge set of numbers into different sections for allocation to different sectors has presented itself as a challenge. Many formats have been proposed some of which, have been accepted to a further extent than the others. Which would be final is something we'll have to wait to see, though the wait doesn't seem a long one.

Now, we have the space that we need and we have the versatility that we need. What is it that stops us from advancing to IPv6? It is the huge infrastructure based on IPv4 which we cannot leave behind and proceed. Hence, to make the transition as smooth as possible, the change is planned to be slow and steady with suggestions of 'embedding' the old IP Addresses into the new ones at the end so as to maintain the existing logics. This concept is popularly known as **IP embedding**. For Example, 805B.2D9D.DC28.0000.000 0.FC57.**212.200.31.255**

This way, the earlier system's profile is maintained in the last 32 bits and its hierarchy is implemented in the earlier bits.

Ipv6 is a very powerful infrastructure which will bring with it many new measures of security, configurations and of course problems! In case any of you haven't noticed, Microsoft has extended features for IPv6 from Windows Vista and has added extensive features for it in the latest release, Windows 7 Beta 1. Along with them, the other companies, including hardware manufacturers of routers and gateways have taken steps towards the transition so the day is not far from today!

(B.S. Sasikanth is a second year B.Tech Student in E.C.E. Department)

Solar Cells

Harpreet Singh

In the previous issue, we talked about the origin of solar cells, their modifications and how they evolved over 3 generations. We saw how, after their invention in 1893, solar cells got better and better and cater the energy needs of the modern world. Now, for the concluding part, let's take a peek into the modern designs of solar cells and their modifications ensure maximum efficiency.

That being said, let's not forget the fact that the major driving force behind the solar cells is that, Sun is their source, so it's a never ending source of energy. Solar cells started with an efficiency of 1% and the new techniques developed have taken the efficiency to nearly 25%. Sounds trivial, but when weighed along the far reaching consequences and benefits, 25% does seem a commendable job. With all the aspects almost covered, researchers are stressing upon increasing the efficiency of the solar cells even higher.

High efficiency cells

High efficiency solar cells are a class of **solar cells** that can generate electricity at higher efficiencies than the conventional solar cells. While high efficiency solar cells are more efficient in terms of electrical output per incident energy (watt/watt), much of the industry is focused on the most cost efficient technologies (cost per watt or $/watt). Still, many businesses and academics are focused on increasing the electrical efficiency of cells, and much development is focused on high efficiency solar cells. That in perspective, its understood that on a large scale, cost does come into picture.

Over several years, scientists have tried to break boundaries of solar cell efficiency. Here is a list of some of the notable contributions that stand apart from others.

Monocrystalline Si

In 1994, the University of New South Wales (UNSW) reported the highest silicon solar cell efficiency of 24.7% with their PERL (Practical Extraction and Report Language) cell technology. This record has been valid until 2008.

UNSW's ARC Photovoltaic Centre of Excellence has reported the first silicon solar cell to achieve the milestone of 25 per cent efficiency. Its worth mentioning that PERL is a high level computer language that was developed in 1987 by Larry Wall as a general purpose UNIX scripting language to make report processing easier. Polycrystalline Si

Multiple junction solar cells

The record for multiple junction solar cells, however, is disputed. A team lead by the University of Delaware, the Fraunhofer Institute, and NREL all claim the world record title at 42.8, 41.1, and 40.8 percent, respectively. With each party hard hitting on the other for the top spot, claims and blames seem to occupy the center stage between these three rivals. NREL claims that the other implementations have never been put under any standardized tests and, in the case of the University of Delaware project, represents only hypothetical efficiencies of a panel that's never been fully assembled. However, NREL claims it is one of only three laboratories in the world capable of conducting valid tests. Whatever the case maybe, as long as they are committed to excellence, we are going to get more efficient and cheaper solar cells.

Thin film solar cells

In 2002, the highest reported efficiency for solar cells based on thin films of CdTe was 18%, which was achieved by the research group of Prof. I.M.Dharmadasa at Sheffield Hallam University in the United Kingdom. The US National Renewable Energy Research facility NREL achieved an efficiency of 19.9% for the solar cells based on copper indium gallium selenide thin films, also known as CIGS. These CIGS films have been grown by physical vapour deposition in a three-stage co-evaporation process. In this process In, Ga and Se are evaporated in the first step; in the second step it is followed by Cu and Se co-evaporation and in the last step terminated by In, Ga and Se evaporation again.

With these three record breaking discoveries being put forward, another method fast catching up with the solar cell industry is the development of organic solar cells.

Organic Solar Cells

In recent experiments conducted by Greg Scholes and Elisabetta Collini of University of Toronto's Department of Chemistry, it was apparently shown that inexpensive solar cells, vastly improved medical imaging techniques and lighter and more flexible television screens are among the vast applications that organic electronics could have. Out of this, the inexpensive solar cells are considered to be a ground breaking discovery. Due to their high installation costs, solar cells are more often than not, disliked but with this kind of inexpensive cells, the view is all set to change.

The University of Toronto team - whose work is devoted to investigating how light initiates physical processes at the molecular level and how humans might make better use of that fact -- looked specifically at conjugated polymers. These conjugated polymers are considered to be one of the most promising candidates for building efficient organic solar cells. The conjugated polymers are very long organic molecules that possess properties like those of semiconductors and therefore can be used to make transistors and LEDs. When these conductive polymers absorb light, the energy moves along and among the polymer chains before it gets converted to electrical charges. This was the property that was exploited to pave way for a more convenient and easily realizable solar cell.

It isn't a cakewalk either. Out of the many problems which were faced, the biggest obstacle to organic solar cells is that it is difficult to control what happens after light is absorbed: whether the desired property is transmitting energy, storing information or emitting light. Here quantum mechanics comes to rescue, as with experiments, it has been shown that using quantum effects, we can control whatever goes on inside the organic solar cell.

Scholes and Collini's discovery opens the way to designing organic solar cells or sensors that capture light and transfer its energy much more effectively. It also has significant implications for quantum computing because it suggests that quantum information may survive significantly longer than previously believed.

New techniques may increase the efficiency of the solar cells, no doubt, but there is a limit to how much efficient a solar cell can be. This is called a Thermodynamic Efficiency Limit. Solar cells operate as quantum energy conversion devices, and are therefore subject to the aforesaid "Thermodynamic Efficiency Limit". Photons with energy below the band gap of the absorber material cannot generate a hole-electron pair, and so their energy is not converted to useful output and only generates heat if absorbed. For photons with energy above the band gap energy, only a fraction of the energy above the band gap can be converted to useful output. When a photon of greater energy is absorbed, the excess energy above the band gap is converted to kinetic energy of the carrier combination. The excess kinetic energy is converted to heat through phonon interactions as the kinetic energy of the carriers slows to equilibrium velocity.

Solar cells with multiple band gap absorber materials are able to more efficiently convert the solar spectrum. By using multiple band gaps, the solar spectrum may be broken down into smaller bins where the thermodynamic efficiency limit is higher for each bin. So, as more and more energy is getting used up in creating kinetic energy, multiple band gaps may provide a solution to the efficiency limit problem.
These days more and more stress is laid on solar powered devices as these certainly provide a back bone to the ongoing "Alternative source" of energy search. In the space missions where the sun is the only unending source of energy, solar energy plays a big role in keeping the equipment running. Wide research that is being done in this field includes Silicon processing, thin film processing, metamorphic multijunction solar cell, polymer processing, nano-particle processing etc.

Contrary to the general functioning of solar cells, Japan's National Institute of Advanced Industrial Science and Technology (AIST) has succeeded in developing a transparent solar cell that uses ultraviolet light to generate electricity but allows visible light to pass through it. Most conventional solar cells use visible and infrared light to generate electricity. However, the innovative new solar cell uses ultraviolet radiation. This cell can be used to replace conventional window glass, the installation surface area could be enlarged, leading to potential uses that take advantage of the combined functions of power generation, lighting and temperature control.

So, as we see, solar cells have come along a long road to provide us with a clean, eco-friendly, efficient and low running-cost method of energy. Advent of new machines and materials will ask for energy to sustain them and with the fuel reserves limited, we can certainly rely on solar cells to take us safely through dark patches of energy scarcity. The source that the cells use – Sun- is a never ending source and hence with more advancement, if we are able to harness Sun's energy to a much better extent, who knows we might even have solar powered cars in each neighborhood.

(Harpreet Singh 3rd year B.tech ECE)

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Tutorial on LT Spice

Karan Sikka

*L*tspice is one of the handiest tools for electrical engineers for simulating electrical circuits and studying input/output and transfer characteristics. Moreover, it also enables one to develop new models for devices for the purpose of analyzing their characteristics and incorporating them in your projects. LTspice is known for its simplicity and can be learned without much effort. The use of spice or to add it best feature is that, it allows the user to view the current and voltages in circuits without physically designing the circuit. It even helps in understanding and optimizing circuits which would hours to solve for the purpose of analyzing. It is actively employed by circuit manufactures to test the correctness of the design without actually building and testing the circuit on a board. Ltspice can be downloaded for free from Linear Technologies (LT) website www.linear.com/software/.

The purpose of this tutorial is to provide the readers with a basic overview of spice, running simulations and brief into how to add models for new devices not initially available in Spice.

Once you install Ltspice, open a new schematic using File->NewSchematic. This schematic will define your workspace over which different electrical components can be placed. On the main toolbar you will see some basic circuit elements like ground, resistor, capacitor, wire etc, which are required frequently. All these elements can also be accessed through the Edit menu and each have an assigned short-cut key which proves to be extremely helpful while designing a bigger and a complex circuit.

The most important part of Ltspice is the huge component library. You may find all requisite components used in IITg labs like NPN2N222, diodes etc for the purpose of simulating lab circuits. The library list can be accessed through Edit->component or pressing the F2 key. This would show a complete list of components available ranging from voltage sources, npn, diode, nmos etc. You should begin on your circuit by first placing voltages sources on your circuit as shown in Fig. 1.

Once the source has been selected, it would appear along with the mouse cursor and can be placed at an appropriate location with a mouse click. The next step is to configure the properties of this source by a right-click. A voltage source can be used as an AC, DC, PULSE, EXP etc by selecting any mode and entering the different parameters. These parameters might fluster you at occasions; remedy to such a problem is referring to the extensive help of Ltspice which is again easy to comprehend. In the same way you can work with most of the passive components like resistors, capaciotrs, inductors, current sources etc, placing and changing their properties.

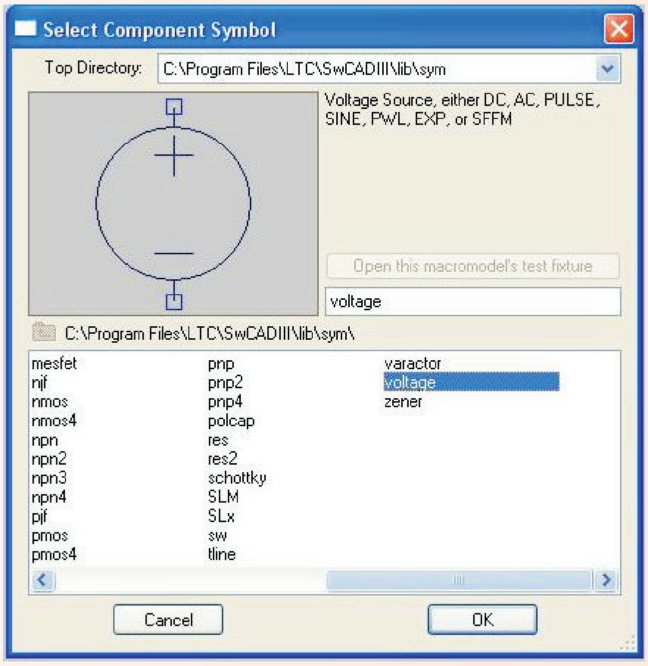

Figure 1

A cardinal rule to remember while designing a circuit is never leaving any voltage source 'floating'. A floating voltage source refers to one without a suitable ground.

The next section of the tutorials highlights how to select active components like bjt, mos etc for your projects and selecting specific models for the same. Open the component window once more and select a npn transistor and place it in your schematic. Right click the transistor and select 'pick up a new transistor' option, which will give you a range of options (models) to select from. This procedure can be repeated for other components as well.

The next step involved in successfully simulating a circuit is to select the type of simulation. Proceed by selecting the 'edit simulation cmd' from the Edit menu. Spice provides a variety of options for simulations:

1. Transient: This is the most widely used option, helping you to plot ac characteristics like transfer functions of amplifiers, input/output characteristics of devices etc. Parameters like start, stop time and timestep are needed to be specified. Timestep is the most important parameter in this simulation, which helps you to control the accuracy of the simulation results. You can also leave this option empty and let the software decided a default value.

2. DC operating point: This provides a dc analysis of the circuit and is extremely helpful for analyzing the transistor biasing.

3. DC transfer: This enables you to perform a DC sweep of a voltage sources for plotting the characteristics of a device.

4. AC analysis: This provides a frequency sweep of a source and used for plotting the transfer characteristics of a filter/system.

Novice users find adding new models into its spice library a daunting task. These days most of the device manufacturers provide spice models along with the datasheet. The model will primarily include a symbol file(.sym), model file (.cir) and an example circuit. These files need to be incorporated into the spice library available in the installation directory, which is C:\Program Files\LTC\SwCADIII\lib by default. The symbol file needs to be place in the sym folder and model file in the sub folder. Once the files have been placed, you will see the new component available in the spice component menu. Select and place it in your project, in order to invoke its library file a spice directive needs to be added. Click on .op in the spice main toolbar and with the spice directive radio button selected enter *.include <path of the .cir file >*.

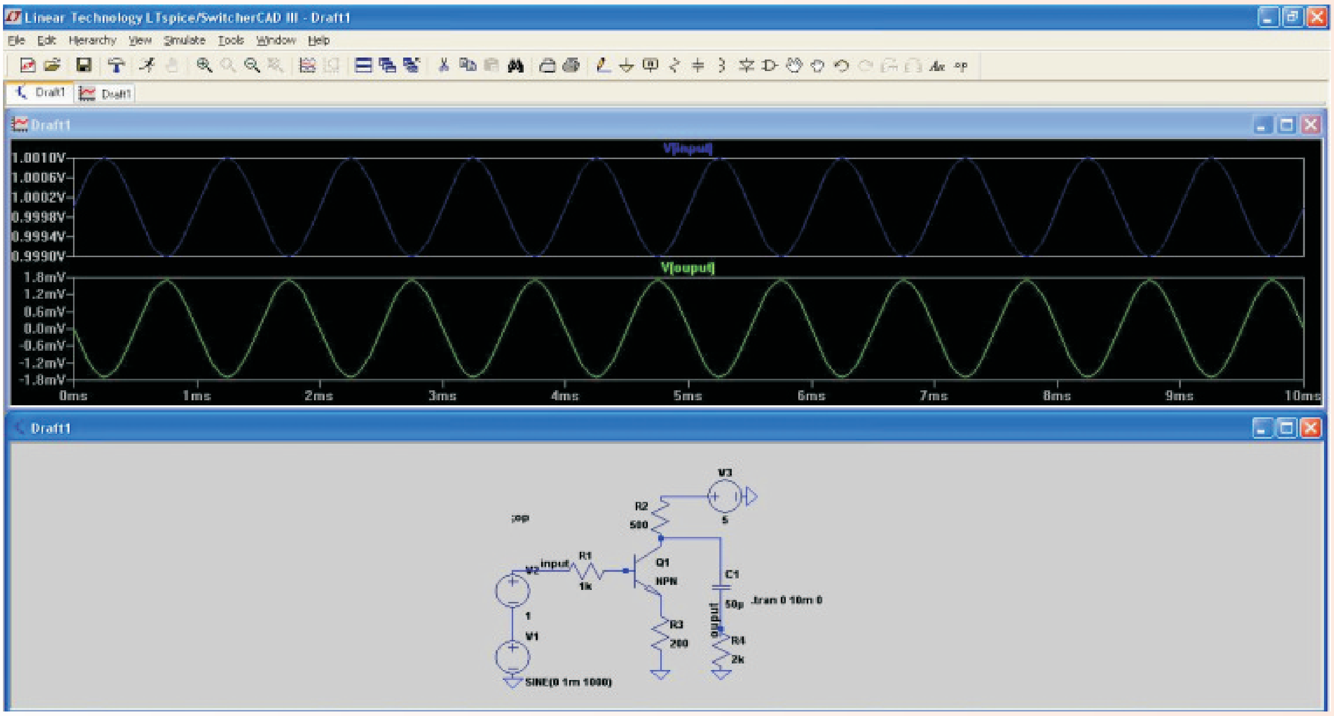

Figure 2

The above would be used from time to time for simulating circuits and in case any parameter is unclear, refer to the Ltspice help. Once a circuit has been designed and a simulation type selected, click on Simulate->Run for viewing the voltage or current graphs by selecting any node (or element) with a mouse click. You will see the mouse turning into a probe when held over a node (wire). Spice provides a plenty of options for viewing graph like plotting in different plot planes or in the same selecting, time base as in an oscilloscope and many more. An example of a simple npn transistor based amplifer is shown with the graphs at the input and output in Fig. 2.

You may find Ltspice Yahoo groups repository quite useful for downloading new spice models.

Many different versions of Spice can be found on the internet like tSpice, hSpice etc., but the best option in terms of user operability is Ltspice. This fact doesn't undermine the importance of other versions, that have better simulation capabilities in different situations like high frequency circuits. A mastery on Ltspice will make the entire course of designing and testing a circuit less severe and would save your time as well.

(Karan Sikka, is a 3rd year B.Tech student of Electronics & Communication Department.)

An Alternate Model for Uplink Interference in CDMA Systems with Power Control

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I. Introduction

Accurately modeling the statistics of the uplink interference power is an important problem in the design and analysis of second and third generation code division multiple access cellular systems. In the uplink, the total interference varies not only because of wireless channel effects such as shadowing and path loss, but also because of the randomness in the number of interfering mobiles and their locations. Conventionally, it has been argued this can be well modeled as a Gaussian distribution, especially in the presence of power control [1]. In this paper, we show that when all the sources of randomness are considered together, the uplink inter-cell interference power is better modeled by a lognormal distribution. Using the well established theory of Poisson point processes to model spatial mobile distributions [2], we extend the moment matching or Fenton-Wilkinson method [3] to determine the parameters of the approximating lognormal. Our results show that our lognormal approximation is several orders of magnitude more accurate than the conventional Gaussian approximation. These results have applications in cell planning and layout and, in general, in cellular system design and analysis.

II. Uplink CDMA System Model Basics

Figure 1 shows the hexagonal cellular layout consisting of a cell 0, which we henceforth refer to as the *reference cell*, and an adjacent interfering cell k. The cell k is served by base station (BS) k, which is located at the cell's center.

When the mobile i transmits a signal with power P_i, the short-term fading-averaged receive signal power at BS k is given by

$$R_i(k) = P_i \left(\frac{d_0}{\|\mathbf{x}_i(k)\|} \right)^{\epsilon} s_i^{(k)}, \quad (1)$$

where d_0 is a reference distance and ϵ is the path loss coefficient, which typically takes values between 2 and 4 [4]. The variable $s_i^{(k)}$ denotes the shadowing of the uplink channel from mobile i to BS k. As mentioned, shadowing is well characterized by a lognormal random variable (RV), and can be written as

$$s_i^{(k)} = 10^{0.1 y_i(k)} = e^{\beta y_i(k)}, \quad (2)$$

where $y_i(k)$ is a Gaussian RV with zero mean and variance $\sigma_i^2(k)$ and $\beta = 0.1 \log_e(10)$. Typically, $\sigma_i(k)$ takes values between 4 and 12. We assume $y_i(k)$ to be independent and identically distributed for different values of i and k.

For a mobile i, let its serving cell, which controls and decodes the mobile's transmissions, be denoted by $C(i)$. In the presence of power control, each transmitting mobile regulates its transmit power (using feedback from the serving BS) so that the receive power equals a preset threshold, γ. Therefore, $R_i(C(i)) = \gamma$. From (1) we get

$$P_i = \frac{\gamma}{s_i^{(C(i))}} \left(\frac{d_0}{\|\mathbf{x}_i(C(i))\|} \right)^{-\epsilon}. \quad (3)$$

Hence, if $C(i) \neq 0$, the interference power received by the reference BS 0 from mobile i equals

$$R_i(0) = \gamma \frac{s_i^{(0)}}{s_i^{(C(i))}} \left(\frac{\|\mathbf{x}_i(C(i))\|}{\|\mathbf{x}_i(0)\|} \right)^{\epsilon}, \quad (4)$$

$$= \gamma e^{\beta(y_i(0) - y_i(C(i)))} \left(\frac{\|\mathbf{x}_i(C(i))\|}{\|\mathbf{x}_i(0)\|} \right)^{\epsilon}. \quad (5)$$

For analytical simplicity, we shall assume that $\sigma_i(k)$ is the same for all users and cells, i.e., $\sigma_i(k) = \sigma$. The method easily generalizes to the unequal $\sigma_i(k)$ case, albeit with the help of some extra book-keeping notation.

Let $I_k\left(N_k; \{\mathbf{x}_i(k)\}_{i=1}^{N_k}\right)$ denote the total inter-cell interference power at BS 0 from users served by BS k, given that the number of interfering users is N_k and their locations are $\mathbf{x}_1(k), \ldots, \mathbf{x}_{N_k}(k)$. Then

$$I_k\left(N_k; \{\mathbf{x}_i(k)\}_{i=1}^{N_k}\right) = \gamma \sum_{i=1}^{N_k} e^{\beta(y_i(0) - y_i(C(i)))} \left(\frac{\|\mathbf{x}_i(C(i))\|}{\|\mathbf{x}_i(0)\|} \right)^{\epsilon}. \quad (6)$$

A. Poisson Point Process Model for Users

The Poisson point process model provides an analytically tractable model for the random user locations in a cell area. Briefly, a homogeneous point process is characterized by an

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intensity parameter λ. The probability that N_k users occur within a cell of area A follows the Poisson distribution with mean λA, and equals

$$Pr(N_k) = \frac{(\lambda A)^{N_k}}{N_k!} \exp(-\lambda A).$$

Furthermore, conditioned on N_k, the geographical locations of the N_k mobiles are uniformly distributed over the cell area.

This implies that with power control, the intra-cell interference power received by any cell of area A from the users it serves is also a Poisson random variable with mean $\gamma\lambda A$ [2]. Therefore, only the probability distribution of the inter-cell interference remains to be characterized, as done in the next section.

III. Alternate Interference Model

The problem at hand is to characterize the distribution of the total interference from cell k, denoted by I_k, when unconditioned on the random number of users and their locations in the cell.

We approximate the distribution of the total inter-cell interference power received by reference BS 0 from BS k by a lognormal RV, I_{eq}. The moment matching method determines the parameters of I_{eq} by matching its mean and variance with those of the total interference, I, that is actually received by the reference BS 0. The approximating lognormal RV can be written as $I_{\text{eq}} = \exp(\beta y_{\text{eq}})$, where y_{eq} is a Gaussian RV with mean μ_{eq} and variance σ^2_{eq}. Then, it can be shown that,

$$E[I_{\text{eq}}] = \exp(\beta\mu_{\text{eq}} + \beta^2\sigma^2_{\text{eq}}/2), \quad (7)$$

$$E[I^2_{\text{eq}}] = \exp(2\beta\mu_{\text{eq}} + 2\beta^2\sigma^2_{\text{eq}}), \quad (8)$$

where E[.] . denotes the expectation operator. Equating these two expressions with the first and second moments of I yields

$$\mu_{\text{eq}} = \log_e\left(\frac{E[I2]}{\sqrt{E[I^2]}}\right), \quad (9)$$

$$\sigma_{\text{eq}} = \sqrt{\log_e\left(\frac{E[I^2]}{E[I2]}\right)}. \quad (10)$$

A. Evaluating First and Second Moments of I

In this paper we derived expressions for the first and second moments of the total interference I, when averaged over the shadowing as well as the spatial Poisson point process model. We showed the following two main results:

$$E[I] \approx 2\gamma N_{\text{ave}}\left(\frac{D_k}{R}\right)^2 e^{\beta^2\sigma^2} \times \frac{1}{W}\sum_{w=1}^{W}\int_{\frac{D_k}{R}}^{\infty}\frac{1}{u^3}\left(1+u^2-2ua_w\right)^{-\epsilon/2} du, \quad (11)$$

and

$$E[I^2] \approx 2\gamma^2 N_{\text{ave}}\left(\frac{D_k}{R}\right)^2 e^{4\beta^2\sigma^2} \times \frac{1}{W}\sum_{w=1}^{W}\int_{\frac{D_k}{R}}^{\infty}\frac{1}{u^3}\left(1+u^2-2ua_w\right)^{-\epsilon} du, \quad (12)$$

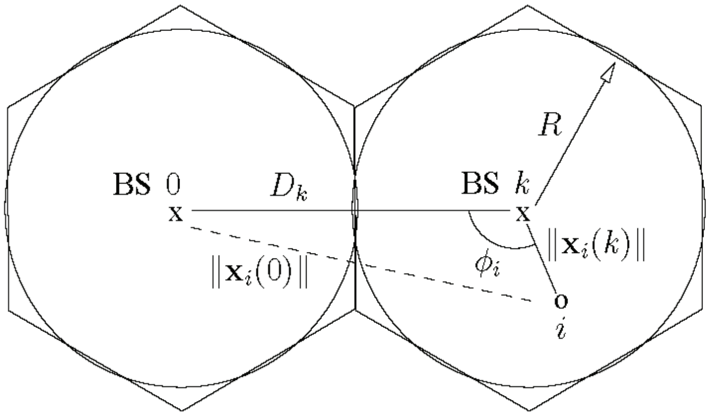

Fig. 1. Hexagonal cellular layout showing the reference cell 0, a first-tier interfering cell k, and the relative position of an interfering user i served by cell k.

where $N_{\text{ave}} = \lambda A$ is the average number of users in the interfering cell of area A, and a_w, $1 \le w \le W$, are the abscissa of Gauss-Chebyshev quadrature [8].

IV. Simulations

We now plot the cumulative distribution function (CDF) and complementary CDF (CCDF) of the measured uplink interference from a first-tier interfering cell. For this purpose, Monte Carlo simulations were used to generate 7×10^6 sample points. Also plotted are the CDF and CCDF of the analytically approximated interference assuming a Gaussian distribution and assuming a lognormal distribution, with parameters derived using the results of the previous section. The mean and variance of the Gaussian distribution are obtained by equating them with the mean and variance of the total interference, along lines similar to that in Sec. III-A.

The following system parameters were used in the simulations: path loss exponent, $\epsilon = 4$, power control threshold, $\gamma = 8$ dB, and lognormal dB standard deviation, $\sigma = 6$. The cell radius was taken to be $R = 400$ m and the first-tier inter-BS distance was $D_k = 800$ m.

Figure 2 plots the CDF when the average number of users per cell is $N_{\text{ave}} = 10$ (which corresponds to $\lambda = N_{\text{ave}}/(\pi R^2)$). Figure 3 plots the same when the average number of users per cell is larger and equals 30. In both figures, the Gaussian approximation is inaccurate by two orders of magnitude. On the other hand, the proposed lognormal approximation method is able to track the observed CDF much better.

Figures 4 and 5 plot the corresponding CCDF curves when the average number of users per cell is 10 and 30, respectively. The lognormal approximation obtained using the moment matching method tracks the actual CCDF very well. This is also in line with the observations made in the literature for the case when the number of lognormal summands is deterministic [5]–[7].

V. Conclusions

In this paper, we developed an alternate characterization of the statistical distribution of the inter-cell interference seen in

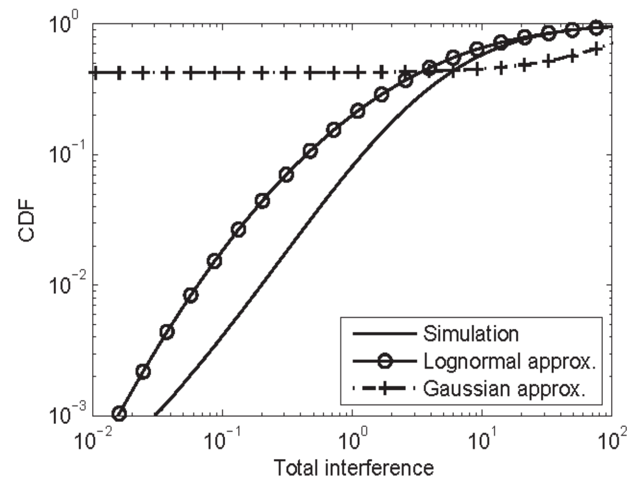

Fig. 2. Comparison of accuracy of CDFs of uplink interference power obtained from the proposed lognormal approximation method and the Gaussian approximation when the average number of users per cell is 10.

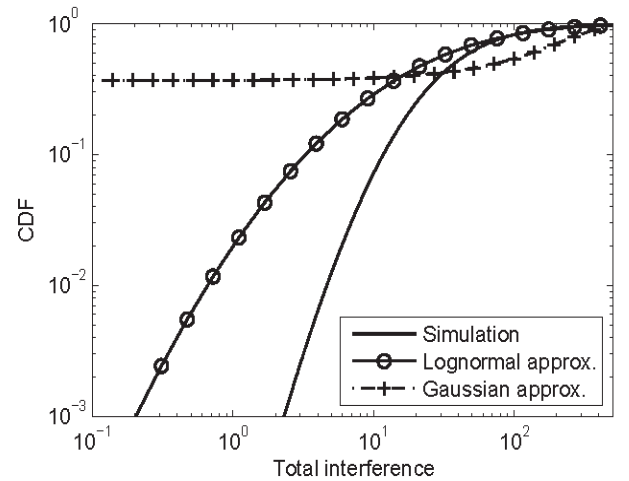

Fig. 3. Comparison of accuracy of CDFs of uplink interference power obtained from the proposed lognormal approximation method and the Gaussian approximation when the average number of users per cell is 30.

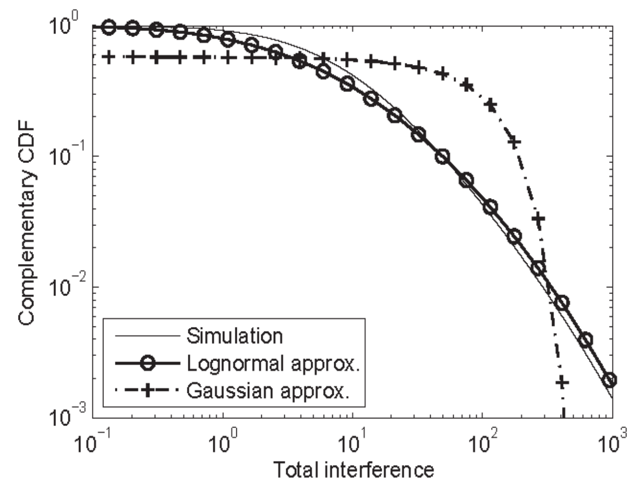

Fig. 4. Comparison of accuracy of CCDFs of uplink interference power obtained from the proposed lognormal approximation method and the Gaussian approximation when the average number of users per cell is 10.

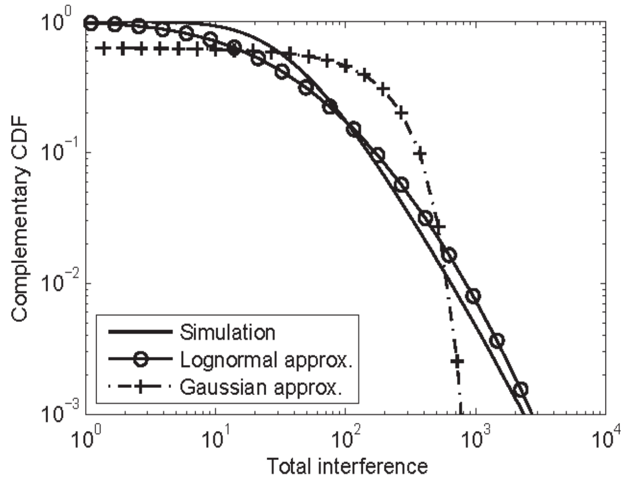

Fig. 5. Comparison of accuracy of CCDFs of uplink interference power obtained from the proposed lognormal approximation method and the Gaussian approximation when the average number of users per cell is 30.

the uplink of CDMA systems that use power control. In the uplink, randomness is introduced in the interference power not only because of lognormal shadowing but also because of random number of users in the cells and their random spatial locations. The moment matching lognormal approximation method turned out to be several orders of magnitude more accurate than the conventional Gaussian approximation even when the number of number of interfering users was relatively large. Both the head portion and tail portion of the inter-cell interference probability distribution were better approximated by a lognormal RV than a Gaussian RV.

The proposed method is easy to implement as the parameters of the approximating lognormal can be written in closed-form in terms of the underlying wireless channel parameters and the parameters of the Poisson point process driving the spatial distribution of users.Future work involves improving the lognormal approximation method to better match CDF and CCDF.

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Final year student Shaurya Agarwal shares his internship experience @ Tubingen University

Almost all of us wait eagerly for the third year intern and what else can you ask for when four students of IITG got internship under the same guide. Three of us from the ECE department along with a CSE batch mate had got our internship calls from the University of Tubingen. All four of us were like on the top of the world when we received the confirmation of our internships. Being in group gave us a feeling of security and confidence in an unknown country. It was all fun right from beginning, be it the Kolkata trip for Visa or Flight Bookings or Baggage packing. Unaware of what awaits us there in Germany, we packed everything we could for us. We stuffed our bags with crockery from a spoon to a pressure cooker, Maggi noodles, spices, pulses, tea bags, sugar, ghee and everything else you get to see in a kitchen.

We had long and tiring flight from New Delhi to Stuttgart. We landed on Stuttgart airport, not sure how we will be reaching Tubingen, as we came out of the airport a pleasant surprise was awaiting us, two young girls standing and holding “IIT Guwahati”. Wow! That was quite a start. We boarded a van and headed to Tubingen. Having reached Tubingen we were welcomed warm heartedly by our guide who is a post-doc at the University of Tubingen. He had a crate full of fruits, chips, biscuits and cold drinks ready for us. We were next taken to our hostels which were situated at the outskirts of city amidst lush green apple orchids. Four well furnished rooms awaited us with a nice and open balcony. Standing in our balcony at thirteenth floor, one could view the whole Tubingen city with its traditional slanted roof houses.

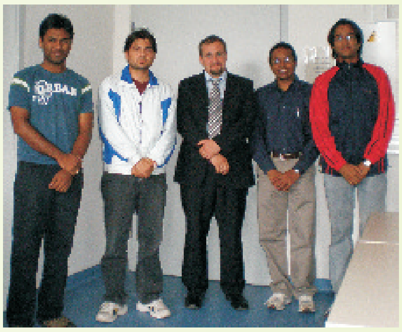
Initial four days were off because of some local holidays and we roamed about in and around Tubingen to get familiarized with local market and bus routes. We were lucky to have found some Indians who are settled there in the city, they helped us to find Indian Shops, helped us with bus routes and ticketing system and gave us a general pulse of the city. Parathe, mattha and paneer curry served in desi style; yes we are talking about langar at Gurudwara, which you can find easily throughout Europe. We often visited the Gurudwara in our town, apart from Indian food, spending time there gave us a feeling of home away from home.

The university was situated few stops away from our hostel, we used to take a local bus to reach lab. We worked till six in the evening. Our guide occasionally visited us to check the progress of our work and discuss the future work. Apart from project work he was always interested to hear stories from India and we discussed football, Euro'08 and stuff like Tata Nano. Somehow our guide had an image of India something as shown in Fevicol add, a mini bus on bumpy Rajasthan road, overloaded with passengers all over and above it. We made him aware of the fact that India is developing rapidly in all aspects and we do have some very good and modern infrastructure coming up. He was really excited to see campus snaps of IITG and said he wanted to visit India soon. There was a Pakistani PhD scholar under our guide, no need to mention a great cricket fan like all of us. The first season of IPL was on and many Pakistani players were playing in it, we always had a lot to discuss and that too in Hindi!! I wonder sometimes how Indians and Pakistanis cannot even coexist but also become great friends in a third country. In spite of so much hatred and tension between the two countries, we never had a problem in getting along with each other. There was a strong feeling of attachment and bonding between us that may have come from the fact we shared same culture, language and ancestors. Its when you get to places like these that you realize the people that are actually close to you and will always be ready for help and it is then you realize the strongest bond is that of humanity rather than religion or nationality.

Getting back to our work there, we were divided into groups of two and allotted a project each. Me and Nikhil (the CSE guy) were assigned to study the Impact of the clock drift on two way TOA Measurements, while Harsh and Akshay were assigned to develop a real-time and efficient algorithm to classify the speech packets in wireless VoIP communication.

Initially Nikhil and I started the work by setting the required hardware in the lab which was well equipped with a couple of robots capable of communicating with Wireless Routers, RFID tags and Bluetooth Devices. The strategically placed wireless routers were used to send ping packets to these robots and the time taken in round trip was used to calculate the exact location of robot. Many factors that affected the accuracy were packet sizes, rate, preamble and hardware used. We tried to find the best set of parameters to get maximum accuracy.

Harsh and Akshay started off by reading parts of a book and some research papers given by our guide and thus getting acquainted with the relevant concepts – Hidden Markov Models (HMMs) and the parameters and Properties of Speech. The objective was to develop a real-time and efficient algorithm to classify the speech packets in wireless VoIP communication, according to their importance. The “importance” here implies the effect on the overall speech quality when the particular packet is removed. Thus, even if only a fraction of the packets, i.e. the most important ones, were transmitted, almost the same speech quality could be achieved. The main benefit of the project would be prolonging battery life of the wireless device as very few speech packets would be transmitted.



Although being thousands of kilometers away from our home we never felt lonely or like in some unknown place. Our hostel mates were very friendly that included students from China, Germany and US. We shared a common kitchen and soon became friends with them. Occasionally we gave them the taste of real Indian spicy food and they offered some delicious German food. We played cards, learnt each other's language and partied together on weekends. Being a university town, Tubingen was flooded with students and hang out places. The city center was a beautiful place situated near Neckar Bridge over laden with flowers. In the evening time all four us would go just walking, enjoying the scenic beauty, sometimes rowing in Neckar River or just sitting, drinking beer and gossiping in Neckar Muller. During the Euro Cup, we witnessed some real fanaticism of Germans. Hours before the match they used to dress in black-red-yellow, face painted, holding flags taking their seats in front of huge screens set up in the town. This was the time that I really got to see the passionate side of the Germans, engrossed in work yes! But they still had their adrenaline pumping as soon as Michael Ballack led the team out every match. Despite not being a football fan, I was totally taken in by the mania that had engulfed Germany during the mega event and chanted along with them *“Auf gehts DEUTSCHLAND schiesst ein Tor!”*(Come on Germany! Score a goal). Backed by the ever so vocal support of the home fans, Germany earned a silver at the Euros, winning match after match en route to the finale which meant the breweries were working extra time!

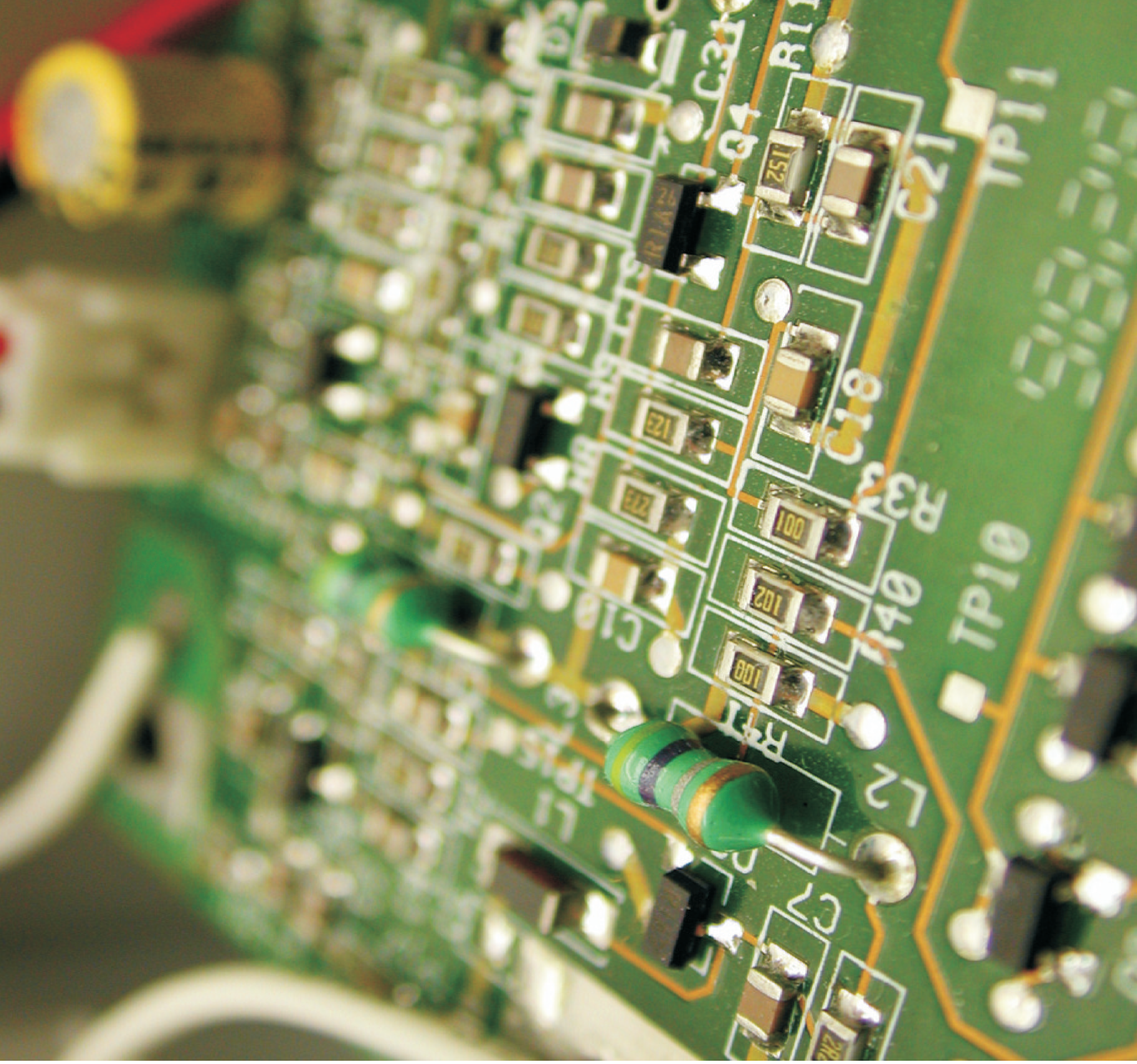
If Euro was a cherish able memory, the best part was of course yet to come. It isn't a big secret how the Eurotrip is the star attraction of our internships, so like all of our batch mates we were really looking forward to our shot at the IITG version of the 'Haj'! and when cities like Paris, Amsterdam and Rome lie within a range of 500 km, it would have been truly unfair had we not paid them a visit! We saved money from our monthly stipend sufficient enough for the 'eurotrip'. It was a great feeling watching the 'City of Lights' from the top of Eiffel Tower, the moonlight boat ride, searching the Holy Grail at Louvre museum. Paris was a sight to behold being an amazing blend of the modern and the imperial age world. If Paris belongs to the art lover, surely the party animals had Amsterdam made for them, void of natural beauty, but as they say in the Netherlands, 'God made the world and the Dutch made Amsterdam', this was one place where you just could not care how much cash you have left with you! These experiences sort of get etched in your memories forever, getting clicked with Johny Depp at Madame Tussauds, trying to straighten the leaning tower of Pisa, romantic river cruise at Seine, paying a visit to the Pope in Vatican City, eating nonstop pizza in Italy and all of a sudden encountering another IITG gang while roaming in streets of Amsterdam besides the canals.

Besides the very frequent weekend escapades to these magical cities, our work was coming along very nicely. It gave us immense pleasure to see that our guide was very happy and impressed by our contributions to the project handed to us. Completing the project in time made sure that he was satisfied with the work that we put in over the weeks and also gave us the sense of pride for re-imposing the lofty standards of our institute in Europe. It was time to say goodbye to Europe, our internship period was almost over. After a very heart felt farewell from our guide and flat mates, we left Tubingen for our flight back to the homeland which was scheduled from Stuttgart and thus ended our summer internship which was a great academic and cultural experience. It was the most beautiful summer ever for all of us!

Placements @ IITG 2009

Peter


CHEAT!
If you can't beat them, join them!
NO GAIN WITHOUT COMPLAIN
PLACEMENT CELL
zzzzz
More Study
CORE JOB
MAA SHARDA ELECTRICALS
B.TECH, IITG, CPI = 8.83
We repair all bulbs etc
G.8
ELECTRICALS
EXAM
L4
Oh Cool!
Its easy this way!
G.8
G.9
HIP HIP HURRAY! WE'RE THE CHAMPS
JOB!
HURRAY!
Yes! We did it!
G.8
G.9
PARTY



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