National Taiwan University

Graduate Institute of Communication Engineering Newsletter

Vol. 2, No. 4 November 2011 http://www.comm.ntu.edu.tw gice_newsletter@cc.ee.ntu.edu.tw

In this issue

Upcoming Events:

Nov. 30
Prof. Natalia K. Nikolova Visit
Department of Electrical and Computer Engineering, McMaster University

Dec. 16
Prof. K.J. Ray Liu Visit
Christine Kim Eminent *Professor of Information Technology, Electrical and Computer Engineering Department, Distinguished Scholar-Teacher, University of Maryland*

Dec. 19
Prof. Truong Nguyen Visit
Department of Electrical and Computer Engineering, University of California, San Diego

Technology Developed in GICE

A New Topology for a Common Mode Choke Based on Metamaterial Concept

from Electromagnetics Group

Differential signaling becomes popular in high-speed digital circuits due to its adaption of low-power-level operation and immunity to crosstalk and EMI. Ideally, it supports balanced signal propagation on the differential interconnects. However, the non-ideal effects, such as unequal rising and falling at the output buffer, bend and length mismatch in the differential pairs, and layout requirement for dense routing, will induce unintended common mode noise coupling to the heat sink or shielding metals and cause serious EMI/EMC problems. To solve this problem, a topology for a common mode choke is presented.

Fig. 1 shows the configuration of the proposed common mode choke. It is a periodic structure and each cell comprises a pair of coupled line, a patch, and a connecting structure shorting the patch to the ground plane. Different from conventional common mode choke, it can be realized without the use of the ferrite material, which is usually applied to produce large inductance. Its equivalent circuit model corresponding to unit cell is established to explain its behavior in different mode operation and can be decomposed into two kinds of half circuit models, the odd and even mode. Odd-mode half circuit model consists of a series inductor and a shunt capacitor and behaves like an equivalent circuit of the quasi-TEM transmission line as shown in Fig. 3 (a). It has well-defined characteristic impedance and can be designed for differential signal transmission. On the other hand, the even mode half circuit model introduces a parallel resonator in the shunt admittance as shown in Fig. 3(b) and produces transmission zero for common mode. That is, common mode noise can be suppressed by the proposed common mode choke at some frequency range.

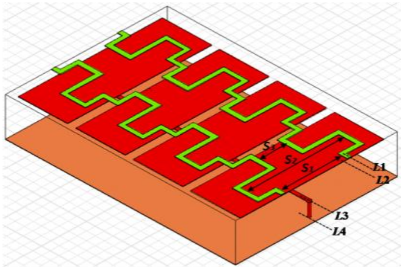


Fig. 1. The configuration of the proposed structure

The proposed common mode choke is fabricated on low temperature co-fired ceramic (LTCC) substrate with dielectric constant of 7.5 to verify its filtering properties for common mode. Only four layers are applied here, which means it can be easily fabricated and embedded on PCB technology. Fig 4 shows its S parameter result. The differential mode maintains below 3 dB up to 10 GHz while common mode noise is reduced over 10 dB from 3.8 to 7.1 GHz. The common mode suppression in time domain is also demonstrated in Fig 5. It shows that the common-mode peak-to-peak voltage is suppressed over 50 % when the 5 Gb/s PRBS with a time skew of 40 ps is injected into a differential pair. Its electrical size is about 0.16 × 0.26 λg2.

In addition, according to the proposed topology in Fig. 1, a component-type common mode choke can be realized using one cell circuit. Fig. 6 (a) and (b) shows its configuration and test sample, respectively and it has a compact size of 1.6 × 1.6 mm2. Instead of

(Continued on page 2)

Technology (continued from page 1)

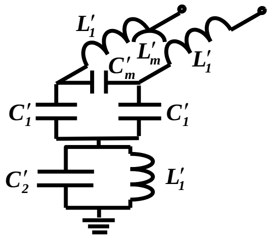
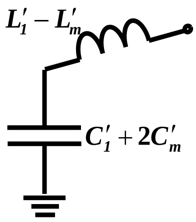
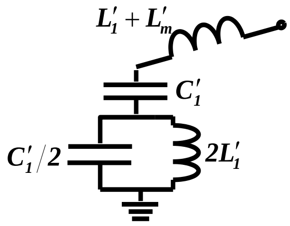


Fig. 2. The distributed equivalent circuit with common-mode suppression



(a)



(b)

Fig. 3. The equivalent circuit models for (a) odd mode and (b) even mode.

simple routing on the top layer,a spiral routings are introduced on the top layer to lower stopband and invoke the two zeros to enhance the common-mode suppression band. Four signal pads and one ground pad are formed for the application of the component. The S parameter result corresponding to the common mode coke incorporating the pad effect is shown in Fig 7. Its differential mode insertion loss keeps below 3 dB up to 8 GHz. It leads in two zeros for common mode at 2.5 GHz and 5.5 GHz, and meanwhile a suppression band over 10 from 2.2 to 6.5 GHz. Based on the proposed topology, two common mode chokes, an embedded periodic structure and a surface-mounted device, were realized on LTCC substrate. The two structures prove that the proposed topology not only preserves a good differential mode transmission but also addresses a wide suppression band for common mode. The most important thing is the proposed chokes without using ferrite materials possess lower cost than conventional one.

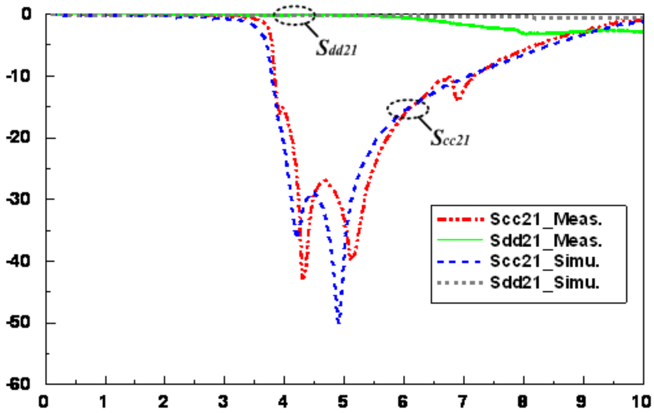


Fig. 4. The S-parameter comparison of the simulation and measurement for the four cells

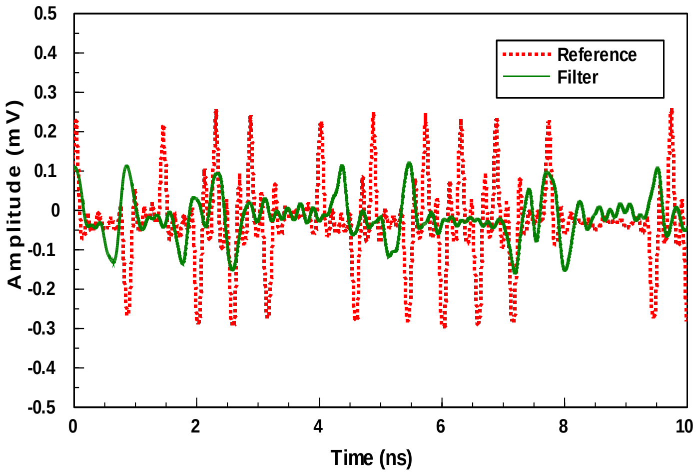


Fig. 5. The measured common-mode noise is reduced by the proposed filter

GICE Honors

Student Winning 2011 IEEE International Workshop on Multimedia Signal Processing – The Top 10% Paper Award

Keng-Sheng Lin

Advisor: Professor Homer H. Chen

Topic: Automatic highlights extraction for drama video using music emotion and human face features

Message from the Director

Kwang-Cheng Chen

Professor &
GICE Director

As time flying, GICE Newsletters is 2 years old. We hope the readers to enjoy our research results, while GICE covers research areas in communications, signal processing and multimedia, networks, EM waves and circuits. We also look forward to feedback and comments from readers. Finally, on behalf of GICE, let me express

Merry Christmas and Happy New Year!

Technology (continued from page 2)

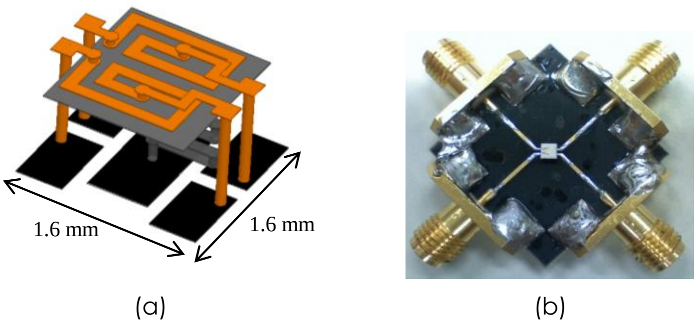


Fig. 6. (a) The configuration and (b) test sample of the proposed component-type common mode choke

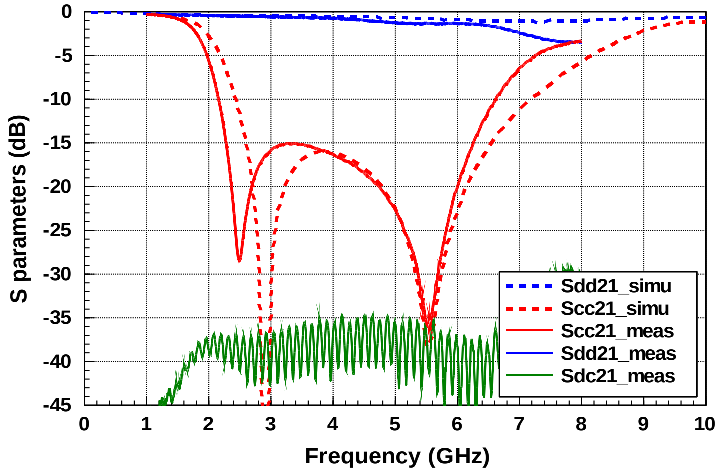


Fig. 7. The simulation and measurement results of the proposed common mode choke

For more information please contact:
Professor Tzong-Lin Wu
Email: wtl@cc.ee.ntu.edu.tw

Antenna Miniaturization Using Zeroth-Order Resonance

from Electromagnetics Group

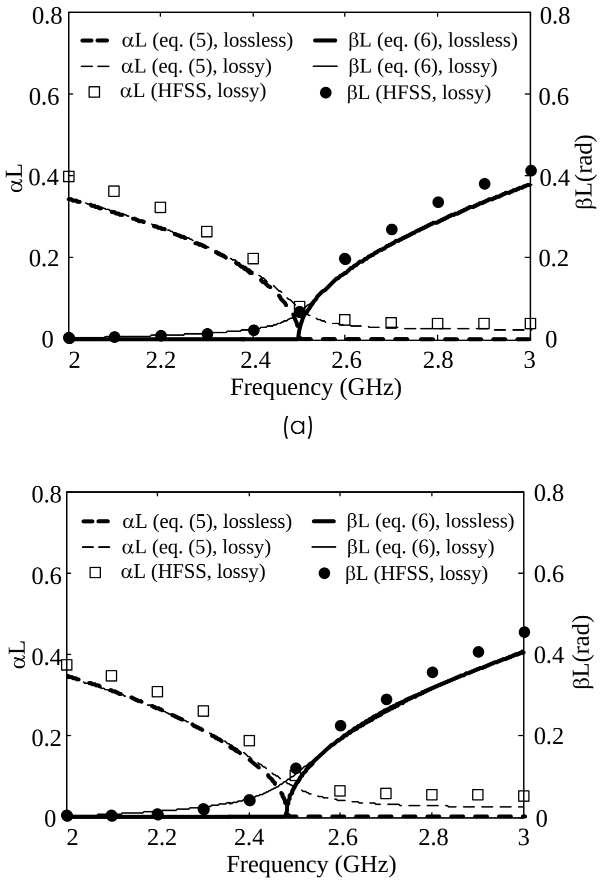
Composite right/left-handed (CRLH) transmission lines (TLs), composed of shunt inductors and series capacitors periodically loaded along the host TLs, have drawn much attention because of several unique properties that they possess. One important property is the zeroth-order resonance (ZOR), which is also known as the infinite-wavelength property. A CRLH TL would have a vanishing phase constant as operating at its ZOR. Unbalanced CRLH TLs possess two distinct ZORs, namely the shunt and series resonances (ωsh and ωse). When terminated by an open/short circuit, the CRLH TL would become a shunt/series zeroth-order resonator. Both resonator types can be exploited to design electrically small antennas since the resonant conditions are independent of their physical lengths. However, only one is feasible because the CRLH TL should be terminated by either open or short circuit. Consequently, the unused resonance may be removed to decrease the design complexity of CRLH TLs, leading to inductor-loaded (IL) TLs and capacitor-loaded (CL) TLs. Both IL and CL TLs are still periodic wave-guiding structures. The unit cell of an IL TL is composed of two identical short sections of the host TL and a shunt inductor in between, while the unit cell of a CL TL has a series capacitor in between instead. The former sustains the shunt ZOR, while the latter supports the series ZOR. Applying the periodic boundary condition and taking into account the losses of host TL, we have derived the closed-form formulas to calculate the propagation constants of IL and CL TLs. The dispersion diagrams thus obtained are shown in Fig. 1, where coplanar waveguides (CPWs) were chosen as the host TLs. Note that only one ZOR (either ωsh or ωse) is observed.

Among the various kinds of TLs, we chose CPW as the host TL because of its uniplanar structure with only one metallic and dielectric layer and ease of shunt connection between the signal trace and bilateral ground plane. Using CPW as the host line, the shunt inductor and series capacitor can be realized by using a pair of folded shorting stub inductors and interdigital capacitor, respectively, to keep the unit cell as compact as possible. Based on the aforementioned formulas and the resonant condition for ZOR, we have also derived a set of formulas, which can be utilized to determine the values of the shunt inductance and series capacitance once the dimensions of the host CPW and the resonant frequency of the ZOR are given. These formulas greatly simply the design and analysis of IL and CL CPWs, and more importantly, they can easily be generalized to IL and CL wave-guiding structures using other host lines, such as microstrip lines or striplines.

The associated ZOR of the IL and CL CPWs can be exploited to realize electrically small antennas. To ensure a compact antenna size, both of the proposed designs are formed by only two unit cells. Photographs of the two fabricated prototypes are shown in Fig. 2. Both antennas have been designed using our derived formulas, and the predicted performance agrees very well with those obtained via measurements and full-wave simulations. The measured peak gain and simulated efficiency of the miniaturized ZOR antenna using CL CPW are 1.1 dBi and 55%, respectively, while for the IL case, they are

(Continued on page 4)

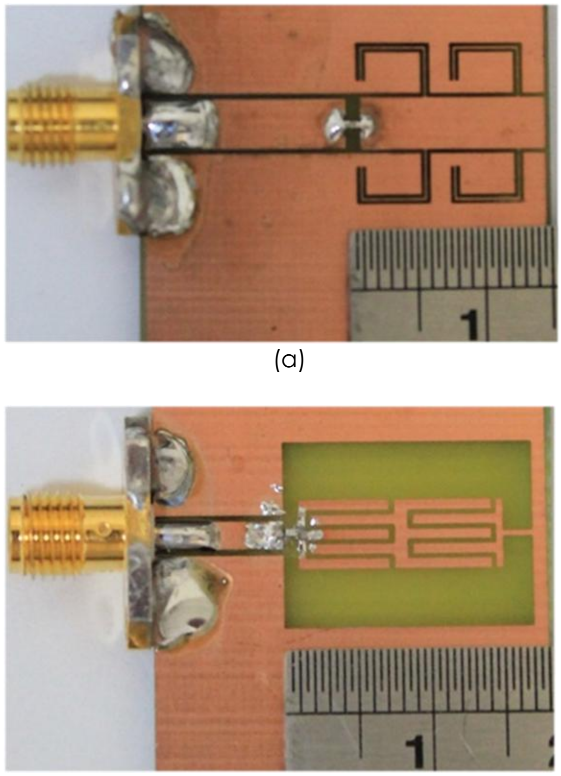
Technology (continued from page 3)



(a)

(b)

Fig. 1. Dispersion diagrams of (a) IL CPW and (b) CL CPW. [1]



(a)

(b)

Fig. 2. Photograph of the two prototype antennas. (a) IL case and (b) CL case.

-5.2 dBi and 27%, respectively. The difference between them may be attributed to the fact that the series ZOR is less susceptible to the dielectric loss within the substrate as the field is loosely confined by the CL CPW due to the larger gap width used. Besides, the proposed design using CL CPW outperforms other ZOR antennas in the open literature. Currently, we are working on the termination condition that can sustain the series and shunt ZORs simultaneously and developing several electrically small antennas for dual- or multi-frequency operations.

References

[1] C.-P. Lai, S.-C. Chiu, H.-J. Li, and S.-Y. Chen, "Zeroth-Order Resonator Antennas Using Inductor-Loaded and Capacitor-Loaded CPWs," IEEE Transactions on Antennas and Propagation, vol. 59, no. 9, pp. 3448-3453, Sept. 2011.

For more information please contact:
Professor Shih-Yuan Chen
Email: sychen@cc.ee.ntu.edu.tw

Co-author of the article:
Chien-Pai Lai, Ph.D. candidate of NTU GICE.

Physical Layer Security Using Artificial Noise Assisted Beamforming

from Communication and Signal Processing Group

Due to its inherent open and broadcast nature, wireless communication is highly susceptible to eavesdropping and attack. As a result, security issues become more and more important with the extensively used wireless technology in our daily life. There are two main streams in the research of security. One is cryptography; the other is information theoretic security. Unlike the former, the latter does not assume limited computation power at the attacker or eavesdropper. Thus it is more suitable for the security of the post quantum era. Since its publication, Wyner's seminal wiretap channel [1] has usually been used for the purpose of discussing the information theoretic security, which is also referred to as the physical-layer security. There are three terminals in this channel: a sender (Alice), a legitimate receiver (Bob), and an eavesdropper (Eve). Alice tries to transmit to Bob as much as possible secure message, which is concealed from Eve. Thus the measure of secrecy is the message equivocation rate at the eavesdropper, defined as the entropy (or the randomness) of the message at the eavesdropper, given the eavesdropper's observation.

(Continued on page 5)

Technology (continued from page 4)

In practice, it is unlikely that the sender knows the correct channel gain of the eavesdropper's channel. Thus we consider a relaxed version of Wyner's wiretap channel [2] as shown in Fig. 1. That is, the sender only knows the statistics of Eve's channel **g** and fully knows the main channel **h**. For such a channel, the capacity (i.e., the maximum achievable rate) of the main channel with perfect secrecy (i.e., message completely undecodable by the eavesdeopper) is unknown. Instead of deriving the capacity, we propose a generalized artificial noise (AN) assisted beamforming scheme to obtain an achievable secrecy rate. This generalized AN scheme allows the AN to be transmitted in all directions, instead of only the null space of the main channel as restricted in [3] which first introduced the use of AN. We prove that for a multiple-input, single-output, single-eavesdropper antenna system, the optimal transmission scheme is a beamformer which is aligned to the direction of the main channel. After characterizing the eigenvectors of the covariance matrices of the desired signal and AN, solving the resultant achievable rate becomes a non-convex power allocation problem. We develop an algorithm to efficiently solve this problem.

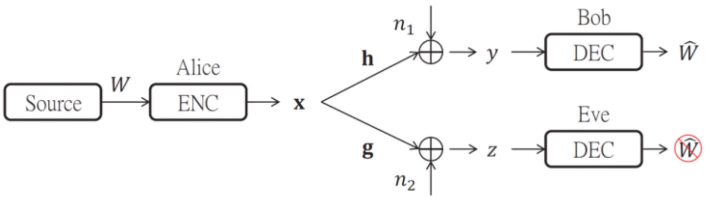


Fig. 1: The considered system model.

We use a 4 by 1 by 1 channel as an example. Assume the noise variances of Bob and Eve are normalized to 1. The norm of the main channel states we use in the simulation is $||\mathbf{h}||^2 = 0.03$ and the eavesdropper channel satisfies $E[\mathbf{g}] = [1, 1, 1, 1]^T$. We compare Goel and Negi's scheme [3] to our proposed scheme with generalized AN. In Fig. 2, the blue and black curves correspond to the optimized achievable secrecy rate using exhaustive search (for the power allocation) and the proposed iterative algorithm, respectively.

From this figure, we can easily find that the proposed scheme indeed provides apparent rate gains over Goel and Negi' s scheme at moderate signal-to-noise ratio (SNR). In particular, the range of SNR with non-zero secrecy rate is enlarged, which means significantly improved connectivity of the secure network when AN assisted beamforming is applied.

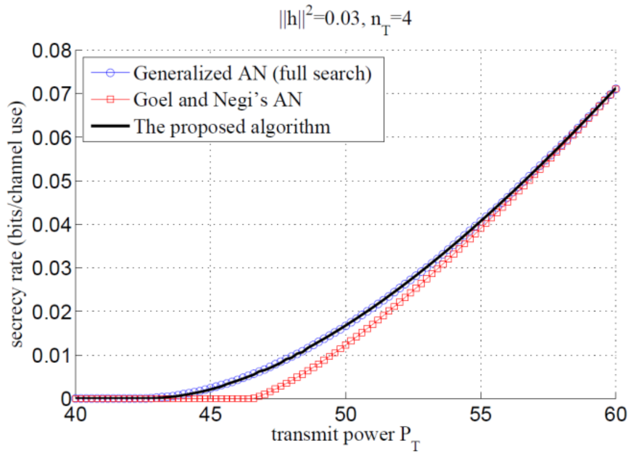


Fig. 2: Comparison of the achievable secrecy rates.

References

[1] A. D. Wyner, "The Wiretap Channel," Bell Syst. Tech. J., 54:1355–1387, 1975.

[2] S.-H. Lai, P.-H. Lin, S.-C. Lin and H.-J. Su, "On Optimal Artificial-Noise Assisted Secure Beamforming for the Fading Eavesdropper Channel," IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Sept. 2011

[3] S. Goel and R. Negi, "Guaranteeing Secrecy Using Artificial Noise," IEEE Trans.Wireless Commun., 7(6):2180–2189, Jun. 2008.

For more information please contact:
Professor Hsuan-Jung Su
Email: hjsu@cc.ee.ntu.edu.tw

Co-author of the article:
Pin-Hsun Lin and Szu-Hsiang Lai
Communications, Signal and Information Processing Lab., BL-508, NTU GICE.

Stimulation of Cooperation in Cooperative Spectrum Sensing for Cognitive Radio

from Communication and Signal Processing Group

Spectrum sensing is an important step towards enabling dynamic spectrum access, where secondary users are allowed to opportunistically fill in the spectrum hole of the primary network. Due to the stochastic nature of channel fading and background noise, however, the signal detector at the secondary user may make inaccurate decision in terms of false alarm and missed detection. To operate the detector in the desirable region of probabilities of false alarm (P_{FA}) and missed detection (P_{MD}), sensing

(Continued on page 6)

Technology

(continued from page 5)

parameters such as the energy detection threshold for an energy detector need to be properly designed.

Specifically, to ensure that the primary user is properly protected from undesirable interference by the secondary user, the probability of interfering with the primary user (P_I) due to missed detection should be limited to a tolerable threshold (ε) such that the interference temperature limit at the primary user is not violated. The objective of spectrum sensing for cognitive radio can thus be written as follows:

$$\text{Minimize } \mathbb{P}_{\mathrm{FA}}, \ \text{ subject to } \mathbb{P}_{\mathrm{MD}}\mathbb{P}_{\mathrm{I}} \le \epsilon.$$

Therefore, a secondary user with a lower probability of interference (P_I) should ideally be allowed to operate the detector with a larger probability of missed detection (P_{MD}) in exchange for a lower probability of false alarm (P_{FA}) for better spectrum utilization. While such an interference-aware spectrum sensing strategy [1] allows for better spectrum utilization, challenges arise in applying the concept in cooperative spectrum sensing for achieving further performance gain.

In cooperative spectrum sensing, a group of secondary users as shown in Figure 1 cooperates with each other to make the transmission decision through fusing the local decisions of individual signal detectors. A secondary user is allowed to transmit in the ensuing time slot if its interference constraint is not violated. In such a scenario, since different users may incur different levels of interference on the primary user, there is a conflict among secondary users in setting local sensing parameters for operating the detector with the desired probability of missed detection. If secondary users are allowed to adjust their parameters for maximizing individual performance without considering other users in the group, the final decision may preclude some users from transmission (e.g. the resultant P_{MD} is too large for those with a larger P_I), thus voiding the potential performance gain of cooperative sensing.

To understand and address this "selfish" problem in cooperative sensing, we first model the parameter negotiation process in a frame as a stage game where secondary users act as players to determine the desired probability of missed detection for maximizing individual payoffs (i.e. achievable link capacities). Furthermore, we design four different roles for players to choose from as the best action strategy (response) in the stage game as follows:

(1) **Egalitarian:** An egalitarian assumes equal responsibility from all players, and hence the sensing parameter is set to achieve the same probability of missed detection among all players.

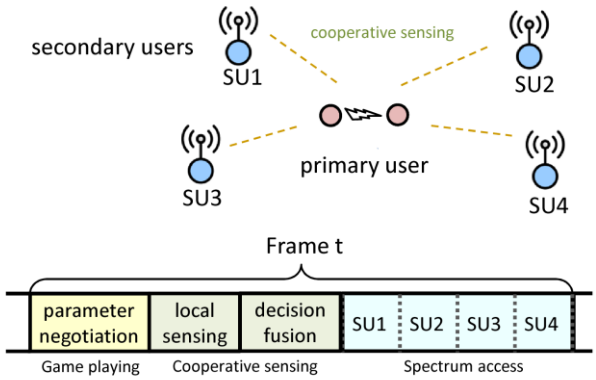


Figure 1: Network scenario and operations

(2) **Glutton:** A glutton is a greedy and myopic player that aims to maximize its payoff in the stage game, and hence it "eats" up the constraint margin based on the sensing parameters used by other players.

(3) **Follower:** A follower simply uses the value it overhears from other players instead of coming up with the "best" decision for itself.

(4) **Solitary:** A solitary takes a conservative strategy in consideration of the potential payoff loss due to cooperation with selfish players, and hence the parameter is set as in single-node sensing.

The stage game is played repeatedly from frame to frame to form a repeated game. Initially, a player selects any of the four roles from A={E, G, F, S} with equal probability. As the game proceeds in repetition, a player increases the probability of adopting the role that can bring more payoff than any other roles. Based on the *theory of evolution* for modeling the population of a species under Nature selection, we apply the following replicator equation to govern the dynamic increase and decrease of the probability distribution of roles:

$$\dot{\mathbb{P}}_{\mathrm{r}} = [\phi_{\mathrm{r}} - \bar{\phi}]\mathbb{P}_{\mathrm{r}}, \qquad \forall \mathrm{r} \in A = \{\mathrm{E}, \mathrm{G}, \mathrm{F}, \mathrm{S}\},$$

where $\mathbb{P}_{\mathrm{r}}, \forall \mathrm{r} \in A$ is the probability (time ratio) of choosing role r as the best response, $\dot{\mathbb{P}}_{\mathrm{r}}$ is the time derivate, ϕ_{r} is the fitness of role r, and $\bar{\phi}$ is the mean fitness averaged over over all roles. Clearly, if a role has larger fitness (by yielding better payoff) than the mean fitness, the rate of change is positive. Otherwise, the role becomes less preferred.

As we mentioned earlier, such a spectrum sensing game usually results in a Nash equilibrium that deviates from the social optimum for the group. To

(Continued on page 7)

Technology (continued from page 6)

address the problem and stimulate cooperation, we design of a special role called **Avenger** to punish non-cooperation of players in addition to the four regular roles. Briefly, if the final result of the negotiation fails to satisfy the interference constraint of a player (thus preventing it from spectrum access), the "unsatisfied" player deviates from the regular role and sets the local sensing parameter to prohibit any transmission of the whole group. In this way, since no players in the game can get non-zero payoff, it is possible that in the next repetition non-cooperative players will be less "selfish" and "myopic" for maximizing individual payoffs.

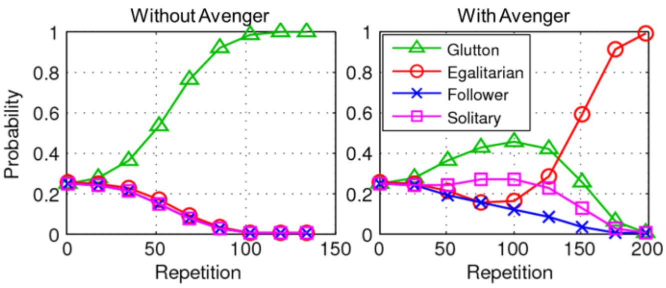


Figure 2: Role evolution with and without **Avenger**

To see the impact of the avenger, we consider a scenario with one primary transmitter and 4 secondary users. Figure 2 shows the evolution of roles adopted by one player as the game proceeds. It can be observed that without the avenger role, the player gradually converts to a glutton. In fact, being a glutton is an evolutionarily stable strategy (ESS) for the game since a glutton chooses the best response in each repetition to bring the maximum payoff. Such a game, however, eventually results in sub-optimal performance where the group of users falls back to single-node sensing without exploiting the benefits of cooperative sensing. After the role of the avenger is introduced, on the other hand, the player becomes a less-selfish egalitarian. Figure 3 shows the overall performance when the cooperative set varies from 2 to 6 users. The right Y-axis shows the total expected throughput of all secondary users, and the left Y-axis shows the price of anarchy (PoA) defined as the achieved value over the socially optimal value (solved using a centralized algorithm in [1]). It can be observed from the figure that in all cases the total expected throughput in the proposed game approaches the optimal performance and outperforms the Nash equilibrium. Therefore, the proposed game does achieve the desirable performance for cooperative spectrum sensing in dynamic spectrum access.

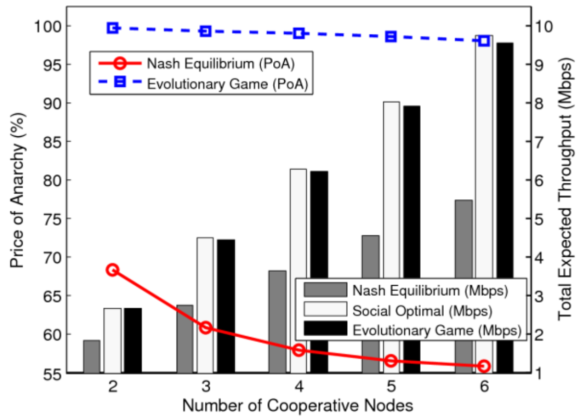


Figure 3: Performance of the proposed game model

References:
[1] Y.-E. Lin, K.-H. Liu, and H.-Y. Hsieh, "On using interference-aware spectrum sensing for dynamic spectrum access in cognitive radio networks," IEEE Transactions on Mobile Computing, to appear.
[2] Y.-E. Lin and H.-Y. Hsieh, "Evolution of cooperation: A case with interference-aware cooperative spectrum sensing in cognitive radio networks," in Proceedings of ICST International Conference on Game Theory for Networks (GameNets), Shanghai, China, April 2011 (Invited Paper).

For more information, please contact:
Professor Hung-Yun Hsieh
Email: hyhsieh@cc.ee.ntu.edu.tw

Co-author of the article:
You-En Lin, Ph.D. candidate,
TONIC Lab., BL-521, GICE, NTU

Activities

Professor Victor Zue Speech

NTU GICE invited Prof. Victor Zue, the Director of MIT Computer Science and Artificial Intelligence Laboratory (CSAIL), also a Distinguished Research Chair Professor of NTU, to give a lecture on October 17, 2011. In his lecture, "Innovation: An MIT CSAIL Perspective," Prof. Zue talked about the factors contributing to the innovation-rich research environment in CSAIL from his point of view. Illustrating his points with examples from his past research experiences, Prof. Zue attracted professors and students by his informative and inspiring talk.

(Continued on page 8)

Activities

(continued from page 7)

Professor Chenming Hu Speech

Prof. Chenming Hu, the TSMC Chair Professor at UC Berkeley and a recipient of the 2011 NTU Distinguished Alumni Award, was invited to give a talk on "What I Know about Innovation" at NTU on November 14, 2011. In this talk, Prof. Hu held an informal discussion on the illusive art of innovation with professors and students from NTU, and he shared his experience of learning, teaching, and practicing innovation.

International Corner

by Sofiane Aloui, postdoctor, NTU GICE

Right after earning my doctoral degree at the laboratory of Integration, from Materials to Systems (IMS) in Bordeaux, France, I decided to explore new research methods and enhance my background in microelectronic field outside France. But, why did I choose Taiwan?

For me, a country of 36000 km^2 which the Taiwan Semiconductor Industry Association (TSIA) represents approximately 60% of worldwide IC foundry, package and testing revenue, that is just magic! However, I never met any Taiwanese before! So I have to discover the secret of the magic by myself. Choosing Taiwan is not only for scientific reasons. Understanding and appreciating intercultural differences ultimately break down barriers, build trust, open horizons and yield tangible results in all domains. Since I have been interested in Asian culture for a while, my professional and personal motivations converge toward Taiwan.

Coming in Taiwan was not possible for me without the help and the trust of Professor H. Wang, Doctor J.J. Kuo and GICE administrative staffs. Since August 2011, I became a member of Professor Wang's research team as a post doctoral research fellow in GICE department of NTU.

I am assigned to conduct a research project that aims at designing millimeter wave embedded automotive radar. The automotive radar will be capable to perform different functions such as obstacle and turn detection, collision anticipation and adaptative cruise control. Since Safety and security issues in transport are gaining more and more importance, the Taiwanese government is getting involved in exploring solutions to manufacture competitive smart cars, as though the cars are equipped with sixth sense. The design of multifunction and reconfigurable circuits is certainly the keys factor of the project success. Moreover, for this project, a low cost CMOS technology is adopted for the design to target mass market products. Besides the technical aspects, the significant benefits of joining in the project are to learn about a new way of working and to drive some student tasks with new relationships and new social communications codes.

In my spare time, I take a Chinese language class to experience Taiwanese culture and I visit local villages outside Taipei city. Every day, I discover something new: a culinary dish, a landscape, a plant, a smell, but one thing that impresses me from Taiwanese people is the pleasant look that they have all the time. Taiwanese philosophical life style is what I am interested. Finally, I would like to underline that Taiwan is not really well known for western people. In the future, I hope to see more students participating in exchange programs and more foreign researchers building broad partnership for middle and long terms.

National Taiwan University
Graduate Institute of
Communication Engineering

No.1, Sec.4, Roosevelt Road,
Taipei 10617, Taiwan

Phone
+886-2-3366-3075

Fax
+886-2-2368-3824

E-mail
gice_newsletter@cc.ee.ntu.edu.tw

Visit us at:
www.comm.ntu.edu.tw

Editors
Wei-Chen Lin
Hsin-Jung Huang
Shin-Yu Chen