## 6. A Summary of the Post-Program Plan

The next five years are the second phase of the Center for Information and Electronics Technologies (CIET), with a goal of continuing the effort and great achievements of the first-phase program, while further teaming up the very strong faculty members and students of the Center and putting together a more focused research theme, with a hope to accomplish even better achievements in the next 5 years. This is implemented by vertically integrating 6 major research areas or subprojects (optoelectronics and components, integrated platform for intelligent sensing chips, millimeter-wave and system-in-package technologies, seamless connectivity, cloud computing, and intelligent medical care), with a research theme of "Broadband Sensing Cloud Computing and Its Applications in Medicine". The basic idea is that the components sense the message, integrated and processed by chips, with millimeter-wave and system-in-package technologies through seamless connectivity, and finally all information and solutions are accessible in the cloud, with medical care as one application.

### 6.1 Subproject 1 (SP1)

NTU microwave group has been globally leading in the mmW MMIC and advanced packaging, and also actively involved in the IEEE 802 standardization process. To keep Taiwan's momentum, the master piece of the group research is to develop the key components in the mmW multi-channel transceiver system, including the Gbps wireless system-on-chip (SoC) and system in package (SiP) for higher integration, lower power consumption, and the exploration of system applications with WPAN/WLAN/WiMax compatibility.

Continuing this momentum, the group has proposed to work on development a system with an ultra-high speed of 28 Gbps wireless transmission using 4 by 4 MIMO (4 input channels and 4 output channels) technique. The subproject will tackle several technical challenges, such as 60GHz antennas with 20% bandwidth, transceiver IC chips with low power consumption and high linearity, module packaging/integration, participation in the IEEE standard organization, and in cooperation with subproject 4 for the study of multi- path environment and 60 GHz MIMO protocol simulation. Major research topics will cover MMIC designs, miniaturized multi-antenna system, and SiP and EMC.

With investigators of excellent achievements, abundant students of talents, equipments of broad coverage, and the full support in the manufacture from the local industry, the subproject has already established the world leading position in this area. Coped with the development trend in the world, the wireless communication with Gbps data rate is a must. The mmW technology will mature and shift to practical applications, while the main research base of the microwave R&D will move from Europe/USA to Asia. If steadily and constantly supported, it is highly predictable that the subproject will end up with a great success and develop the group as a world center of electromagnetic research.

## 6.2 Subproject 2 (SP2)

In the past five years, we have worked extensively on multimedia (media computing), user interface (attentive computing), social network and information mining (social computing) for the era of Web 2.0. Following Web2.0, cloud computing becomes the next generation of computing platforms and has been recognized as the next giant and innovation for IT industries. Cloud computing adopts reliable distributed service model that allows users to acquire wide range of services and computational powers from data centers. Such a platform provides great distributed computing power and data access capability. However, at the same time, privacy, security and ultra-large-scale data become issues and challenges. For the next five years, we would like to extend our researches on multimedia, user interface, social network and information mining to cloud platforms. More specifically, we will address the following research challenges: (1) efficient and scalable data structures and algorithms for cloud computing, (2) Chinese language learning system with real-time machine translation capability, (3) scalable Multimedia recognition, manipulation, transcoding, and enhancement, (4) ultra-large-scale and social network-aware multimedia search and mining and (5) mobile cloud integration and natural cross-device user interface.

## 6.3 Subproject 3 (SP3)

This SOC sub-project will extend the current achievements in video technology, software defined radio with MIMO, broadband wireless communication system, energy-efficient real-time task scheduling, energy-efficient real-time operating system on multi-core platform, and profiling, optimization, synthesis, and analysis of SoC tools to the next level of excellence.

For advanced SoC hardware design, we will continue to disseminate the research achievements in top international publications, increase the impact to industry and academia as well, and license our developed technologies to industry. Some key future plans are summarized below:

- A power-efficient transmitter using the RF digital-to-analog converter will be designed, the key performance specs of the transmitter using RF digital-to-analog converter for the WCDMA and 802.11g system will be analyzed, and novel algorithms of PA linearization will be developed and verified by using commercial PAs. An all-digital frequency synthesizer using bandwidth calibration will be stuudied. Also, Hybrid ADC architecture is another potential research to combine several techniques to achieve further design optimization of data converters. Passive analog signal processing, like SAR architecture, will be investigated to optimize the performance. As for the CTDSM, in order to optimize the power consumption of the modulator, a scalable integrator structure can be further incorporated where the opamp gain-bandwidth is programmable according to the operation modes. In addition, low-power quantizer architectures will be investigated. This is particularly important when multi-bit quantization is adopted in the modulator. All these techniques will facilitate an energy-efficient software-defined radio.
- For the coding system design, multi-view/3D video became very popular in the year of 2010.

We plan to design a multi-function decoder to support high-definition applications. On the other hand, the role of video/image analysis becomes more and more important in a real-time intelligent video processing system, where machine-learning based classifiers become the mainstream. Therefore, in the next year, we are going to enhance our image/video analysis engine with stronger machine learning engines. A new direction of intelligent video system is a bio-inspired recognition processor whose datapath and operations are designed based on the similar concepts of human brain. We have some preliminary results in this year and will try to implement some chips to prove our design concepts.

- Our main target on the coding system will turn to the next-generation free-viewpoint 3DTV. We plan to design a 3DTV set-top box SoC to support not only the 3D video decoding, but also the virtual reality. For video analysis research direction, we will design some hardware engines for smart cameras with more complete functionalities. Based on our experiences, reconfigurable computing architecture may be an effective candidate architecture. Moreover, bio-inspired algorithms/architectures are also possible candidate architectures to be explored.
- We will investigate the performance of CMOS for the mm-wave applications. This project will focus on two different directions. High performance silicon technology can be expanded for medical applications once it can efficiently operate in the THz frequencies. The other direction will focus on the high speed communication that offers a drastically increase in the data transfer speed compared to the systems available today. In order to reach these goals, mm-wave systems have to be considered such as phase-array architecture and circuit angles. Therefore, some chips for W-band passive imager system for demonstrating the feasibility using the advanced CMOS technologies will be planned. On the circuit side, high performance low power circuits operating at the sub-THz will be studied.

For the advanced SoC software design, we propose three major future research directions in advanced SoC software design. First, we would like to extend the research on embedded operating systems. The topics include designs of energy-efficient system components, like task scheduling algorithms and implementations, and I/O subsystem designs with dynamic power management, designs with system configurability that focuses on system booting and dormancy, and finally the designs of storage systems, like flash-memory system components. Second, we will focus on application-oriented energy-efficient designs, which include application layer like voice over IP, IP and driver layers, codec algorithms and FPGA prototypes, and system layer like energy-efficient scheduling of H.264 workloads. Finally we will develop tools in analysis and designs, which will focus on system profiling and hardware and software co-designs.

### 6.4 Subproject 4 (SP4)

- We will continue our research effort in effective high resolution video streaming. New techniques will be introduced such as cloud computing and social networking. We will also study the advanced techniques for multimedia networking to improve our proposed system.
- We will develop a complete solution to smoothly realize developed novel technologies such as cognitive radio resource management, Game theory and Gibbs sampler to LTE/LTE-A

without significant impact on system architecture and operation of LTE/LTE-A.

- Based on the feature detection technique and coordinated quiet period scheme developed earlier, we will develop a multi-channel medium access control (MAC) protocol for dynamic spectrum access. The MAC protocol ensures distributed, weighted share of available spectrum resources and guarantees two communicating devices to discover each other in bounded time, even in an asymmetric DSA channel environments.
- The main purpose of 「Green Communications」 is to reduce the energy consumption during the transmission of communications to increase the efficiency of the resource usage. The goal can be achieved by the following perspectives: (A) Reducing the Interference (B) Power saving under the QoS Constraints (C) Cooperation Mechanism. we will focus on the subjects of「Femtocell on Energy Saving」and「Cooperation for Relay and Network Coding」to accomplish our goals. Instead of maximizing the total throughput without considering the energy consumption, we want to minimize the total energy consumption under QoS throughput constraints . Through the techniques of 「relay transmission」and「cooperation communication」, the error rate can be reduced and the redundant energy consumption owing to retransmission can be prevented.
- Because the existing orthogonally precoded CP-OFDM and CP-OFDMA signals with spectral sidelobes decaying as $f^{-2L-2}$ for $L>1$ require very high complexity in implementation. The design of a low-complexity orthogonal precoder that can construct CP-OFDM or CP-OFDMA signals with spectral sidelobes decaying as $f^{-2L-2}$ for $L>1$ is an interesting and important research topic. Therefore, a systemetic procedure will be conceived in future study to construct a low-complexity orthogonal precoder with desirable sidelobe suppression capability. The implementation complexity of this new precoder will also be analyzed.

## 6.5 Subproject 5 (SP5)

With the advances of various fabrication technologies in our laboratories, including silicon-based devices, crystal fibers, MEMS, etc., the members of this sub-project will be continuously working on new device fabrication techniques and novel devices with international competitivenes in the following years. These members have recently achieved several related device technologies that not only were in the lead in Taiwan but also attracted international recognition. These technologies have great potentials of being further innovated and found practical applications.The research directions meet those of the key industry development in Taiwan and match important state-of-the-art topics pursued in international photonics academic communities.

The following five topics will be pursued: (1) solar energy devices, emphasizing on low-cost devices; (2) light source devices, including glass-clad crystal fiber based broadband light sources for use in 3D optical tomography from visible to near infrared wavelength, and amorphous and non-stoichiometric silicon carbide based light emission photonics; (3) display devices, emphasizing on realizing thin, light-weighted, rugged, ubiquitous and possibly low-cost displays; (4) Sensing devices, including MOS photo sensors compatible with CMOS process

and MEMS-based physical sensors; and (5) new interface structures and device applications, such as photonic crystals, plasmonic structures, and metamaterials, which have been relatively new and active research areas in recent one or two decades, and have successfully been applied to improve performance in all relevant devices investigated in this sub-project.