2. Breakthroughs and Major Achievements

Major achievements and breakthroughs are summarized here, including: 2.1 Integration effort across subprojects and 2.2 Breakthroughs and Major Achievements for each individual subprojects.

2.1 Integration Effort across Subprojects

Here we briefly report the work of two integration tasks across subprojects. The first is a 60 GHz Wireless Multimedia System with a Novel User Interface, which is hardware-oriented and was an integration effort across subprojects 1, 2, 3, and 4. The second is on Cloud Computing for Elder-care, which is software-oriented and was an integration across subprojects 2, 3, and 4.

2.1.1 60 GHz wireless Multimedia System with a Novel User Interface (Hardware-oriented, Integration among SP1, 2, 3, and 4)

The complete work of this integration effort is reported here.

2.1.1.1 Objectives of Integration

This task is to integrate the outcomes of research topic of Sub-projects 1, 2, 3, and 4 into a 60-GHz wireless multi-media system with a novel user interface. The team members are Prof. Huei Wang, Prof. Tian-Wei Huang, Prof. Shey-Shi Lu, Prof. Tsung-Hsien Lin, Prof. Hen-Wai Tsai, Prof. An-Yeu Wu, Shao-Yi Chien and Prof. Yi-Ping Hung.

im-Top is a novel application scenario of map viewer, and is an important outcome of Sub-Project 2. From feature of human visual system, a multi-resolution map shown in Fig. 1 is displayed on a table. This table improves the resolution of the area which user is interested. Furthermore, a mobile device is used to show the 3D scene, dependent on the user's position and direction. Therefore, the interaction between user and map can be improved. To obtain the view-dependent 3D scene, a pair of an infrared (IR) projectors and a camera are used to recognize the position and direction of mobile device and the related 3D scene is reconstructed. Since the reconstruction of the 3D scenes requires heavy computation, the 3D scenes are processed using a server and transferred via wireless communication system to the mobile device.

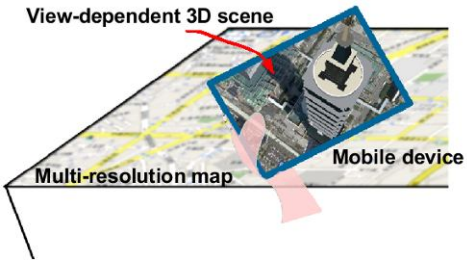


Fig. 1 Scenario of *im*-Top

There are several IEEE standards to transfer multi-media. Fig. 2 is the scenario of IEEE 802.15.3c which is the wireless communication system to transfer high data rate signals with 60-GHz carrier frequency. The development of key components of this standard is an important outcome of Sub-project 1, 3 and 4. In Fig. 2 an HDTV data is transferred from set top box to the displayer. Due to the wide unlicensed bandwidth (57 ~ 66 GHz), the data rate can be improved and the signal can be transferred without compressing. The transfer distance is 10 m, therefore, IEEE 802.15.3c is a suitable standard for the transferring of 3D scene to the mobile device in the *im*-TOP.

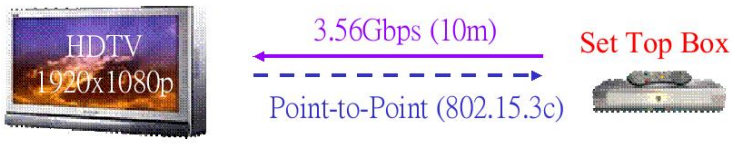


Fig. 2 Scenario of 802.15.3c

The objective of this integration is illustrated in Fig. 3. We plan to integrate *im*-Top and the 60-GHz transceivers. Therefore the processed 3D scene can be transferred from content server to the mobile device.

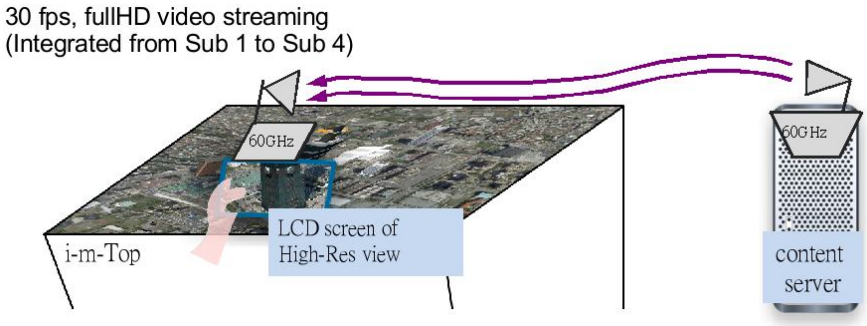


Fig. 3. The objective of this integration

The tasks of each Sub-project are listed below:

* Sub-project 1: 60-GHz transceiver
* Sub-project 2: interactive multi-resolution tabletop
* Sub-project 3: IF, AD/DA and video coding/encoding circuits
* Sub-project 4: baseband circuits

2.1.1.2 Plan of Integration

This integrated system contains the physical level of the communication to user-end multi-media application. We have planned two phases for the integration project execution. Phase I is a prototype system with existing components. In Phase II, we plan to develop a new chip set for 60-GHz transceiver with the ultimate integration goals of the system-on-chip (SoC) and/or the system-in-package (SiP).

The main reason for this Phase I effort is to establish a prototype system timely so that we can figure out bottle necks and the critical parts of the system. Fig. 4 shows the block diagram of the Phase I tasks.

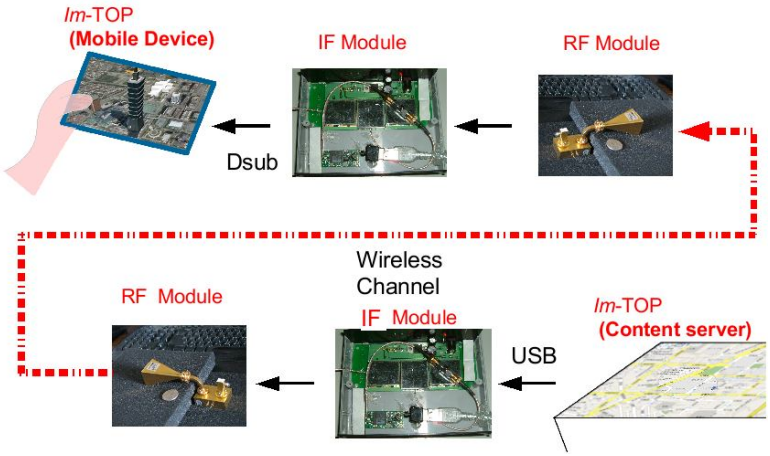
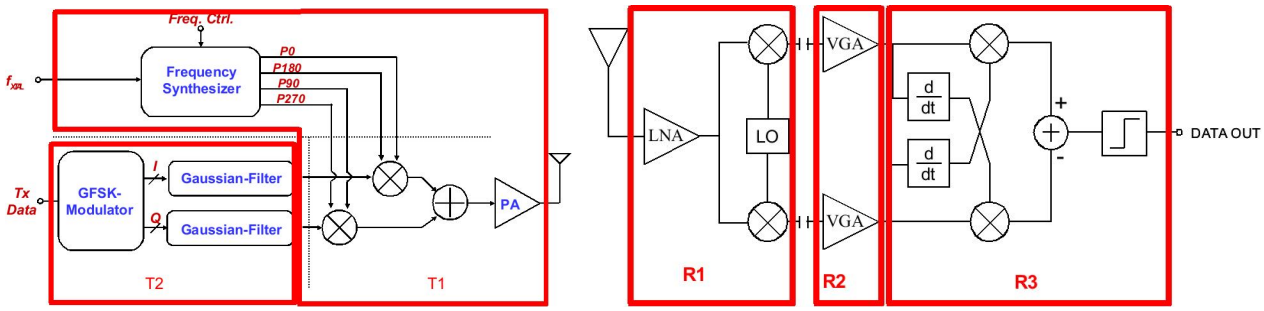


Fig. 4 System block diagram of Phase I.

The RF module converts the 60-GHz signal to 5 GHz and a commercial baseband solution (Wisair solution) is applied to transfer the 5-GHz signal to multi-media signal for the content server and the mobile device. The interface between the content server and the IF module is selected to be USB and the interface between the IF module, while the mobile device is D-sub which is the most popular video output port of computer. The Phase I tasks have been completed in March 2011.

The system block diagram of the Phase II is shown in Fig. 5. Each component is designed by the team members from Sub-projects 1, 3, and 4. TSMC 90-nm CMOS is selected to implement the chip set for the possible future SOC integration. The chips will be sent for fabrication through the Chip-Implementation Center (CIC) of Taiwan. To reduce the cost and the complexity in baseband, GFSK modulation is used for data communication. Fig. 5(a) illustrates the block diagram of our GFSK transmitter. The transmitted data is modulated to GFSK I-Q signal in T2 and than transferred to 60 GHz RF signal in T1. Fig. 5(b) is the block diagram of the receiver. To enhance the sensitivity, we added the VGA (R2) between the RF receiver (R1) and the GFSK demodulator (R3). The chips and their functions are listed are listed in Table I.



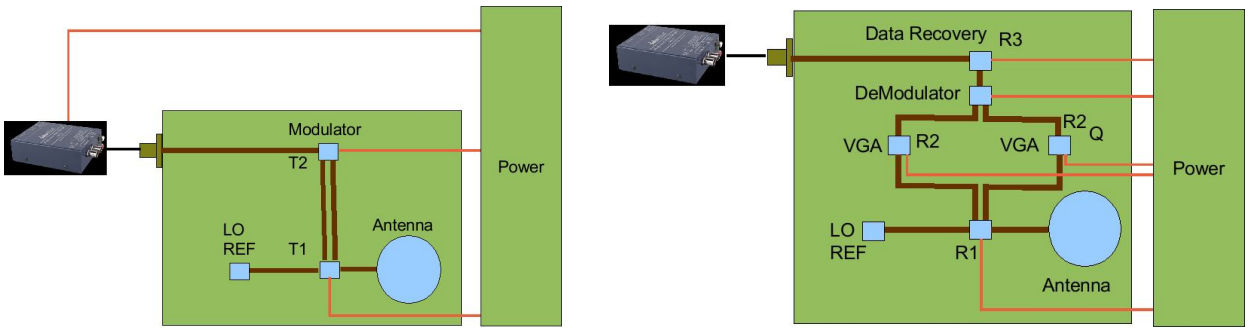
(a) (b)

Fig. 5 System block diagram of (a) receiver, and (b) transmitter in Phase II.

Table I. Chip list of the system in Phase II

Chip Name	Function	Sub-Project
R1	RF Rx	Sub-Project I
R2	Limiting Amplifier & Discriminator	Sub-Project III
R3	Equalizer & De-modulator	Sub-Project IV
T1	RF Rx	Sub-Project I
T2	Tx IQ filter & DAC	Sub-Project III

After verifying the performance of each component, the system will be integrated via SiP and/or SOC approaches. Fig. 6 illustrates a plan for SiP. Each component is mounted on carriers and then connected via bond wires. The HD-SDI to HDMI module is used to transfer parallel HDMI signal to serial HD-SDI signal. Finally, the system will be integrated on a single chip as illustrated in Fig. 7. Obviously, the space and the complexity of the integrated system will be reduced significantly, but the verification of each component will have to be completed first. To now, all the components have been fabricated and under testing. The SiP prototype is planned to complete in 2011/10 and the final SoC is planned to complete in the end of 2012.



(a) (b)

Fig. 6. System block diagram of (a) receiver, and (b) transmitter in SiP of Phase II.

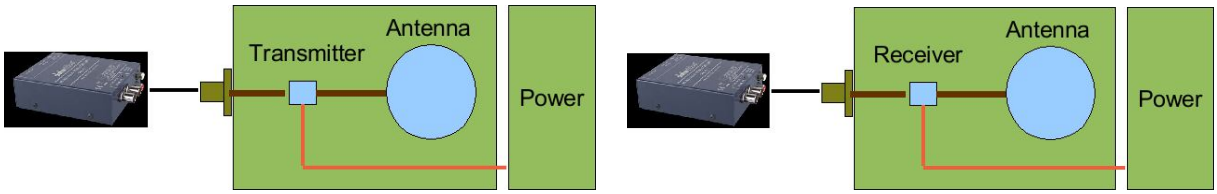


Fig. 7. System block diagram of (a) receiver, and (b) transmitter in SOC of Phase II.

2.1.1.3 Integration Outcomes Including Testing Results

The integration of Phase I has been completed in March 2011. Fig. 8 illustrated the photo of the system demonstration for the 60-GHz transceiver in Phase I. The transceiver is operated in a classroom and the contents on notebook screen are transferred to the projector. The data rate is measured to be 150 MB/s in a distance of 5 m.

Fig. 8. The system demonstration of the 60-GHz transceiver in Phase I.

Fig. 9 illustrated the integration of the 60-GHz transceiver and *im*-TOP. The 3D scene is successfully transferred via the 60-GHz transceiver.

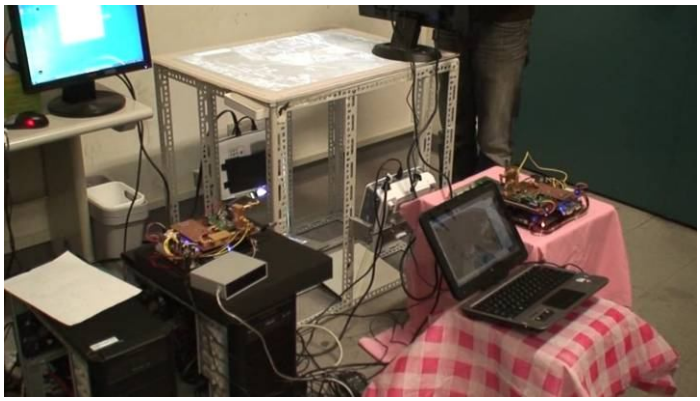


Fig. 9. The integration of 60-GHz transceiver in Phase I and the *im*-TOP

In order to investigate the performance of the platform in Phase I task, the data rate of each component is illustrated in Fig. 10. The 1.2-Gbps video source is compressed using DisplayLink solution to 480 Mbps USB signal first and than modulated to a QPSK signal in 5 GHz, and finally up-converted to 60 GHz. Since the theoretically limit of the QPSK modulator is 1000 Mbps and the bandwidth of the up-converter are much wider than the QPSK modulator, the bottle neck is the overhead from system operation system (OS) to USB and the speed limit of the USB. Therefore, the connection between OS and USB and the modulator will be simplified in Phase II to avoid the overhead.

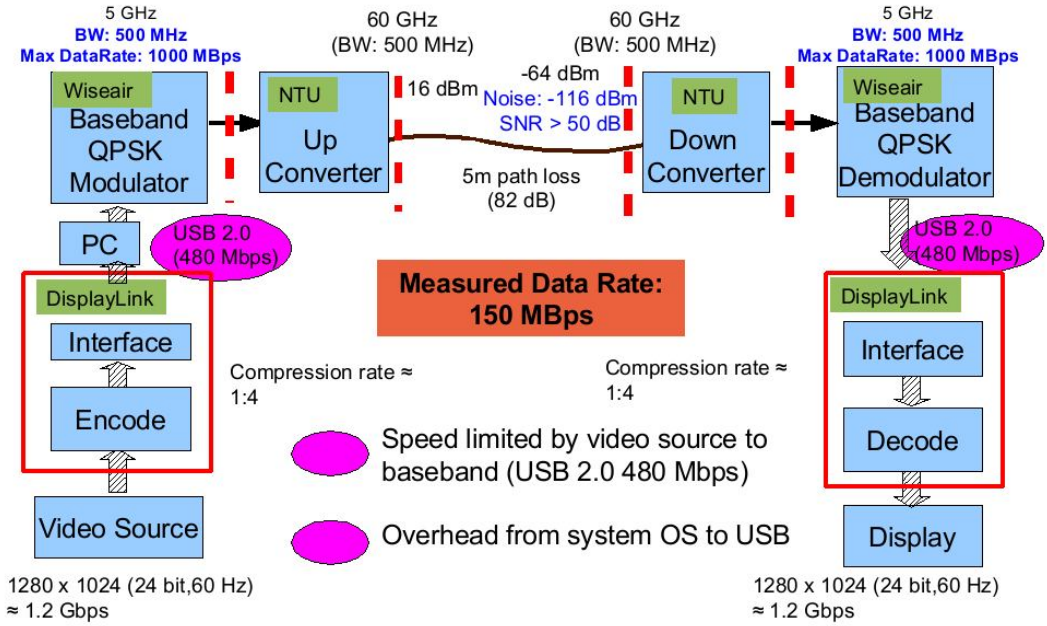


Fig. 10. Data rate of each component in the 60-GHz transceiver.

Fig. 11 illustrates the signal power and gain budget of the transceiver in Phase II. In this transceiver, the modulator and demodulator are all realized in analog circuits in order to avoid the limitation from digital signal processing. Furthermore, the video signal is directly output from the HDMI port of content server. Thus, there is no overhead from system OS to interface. The SNR are better than 40 dB with 5-m path loss and is sufficient for GFSK demodulation.

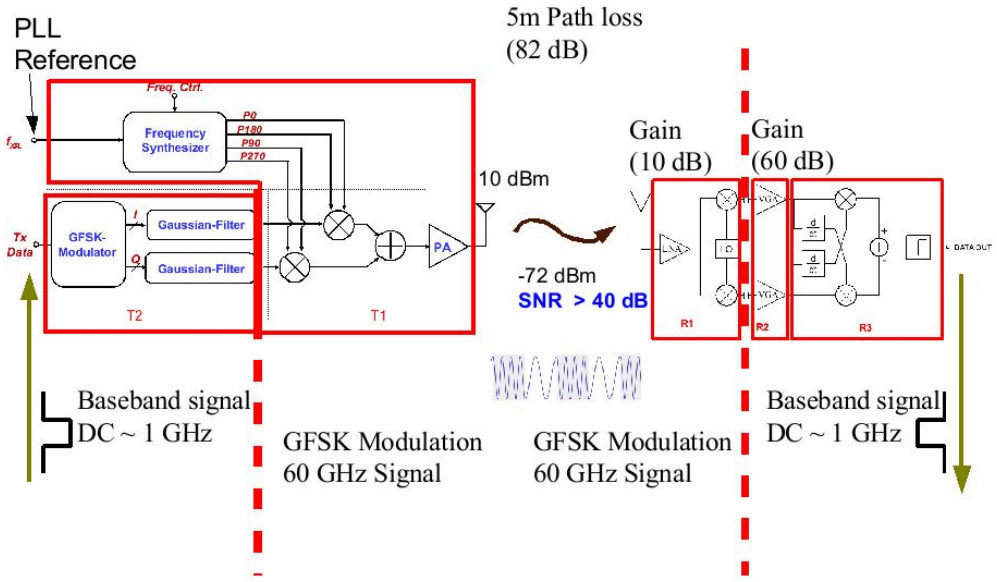


Fig. 10. Signal budget of the transceiver in Phase II.

2.1.1.4 Conclusion

In this integration, we plan to integrate the *im*-TOP and the 60 GHz transceiver. The integration are planned to be two phases. In Phase I, we have realized the system with existing component. In Phase II, the system will be implemented in CMOS process. Table II shows the chip status of Phase II task. The components of receiver (R1, R2 and R3) have been fabricated and all the chips are under testing. The transmitter chips been taped out and currently under fabrication.

Table II The chip status of Phase II.

Item	Function	Chip	Status
SiP 1st run	RF Receiver	R1	Under testing
	VGA	R2	Under testing
	Demodulator	R3	Under testing
SiP 2nd Run	Transmitter	T1	Under fabricating
	Modulator	T2	Under fabricating

Table III shows the schedule of this integration plan. Phase I has been finished in March 2011. Right now, the components are under testing and the 2nd run of the components will be tapped out in July 2011. The Complete SiP system will be finished in Oct. 2011. After completing the SiP system, the chips for the final SoC will be taped out in Dec. 2011. The test and integration of the final SoC is planed to complete by the end of 2012.

Table III Schedule of this integration plan

Date	Phase I	Phase II SiP	Phase II SOC
2011/3	Finished		
2011/7		Tape out of the 2nd run	
2011/8		Verify the components of the 1st run	
2011/10		Complete SiP system	
2011/12			Tape out of the first run
2012/7			On-Wafer Measurement of the system
2012/12			Complete SOC system

2.1.2 Cloud Computing for Elder-care (Software-oriented, Integration among SP2, 3, and 4)

The complete work of this integration effort is reported here.

2.1.2.1 Objectives of Integration

Cloud computing is an emerging technology due to the convergence of computation and network connectivity, and also essential for many services. Basically, it is a virtualization technology in which various distributed computer systems are connected together in order to form a big virtual computer system which can easily manage the computation and large amounts of data.

Meanwhile, it is a vital issue for elder-care in our country since the aging rate of population in our country is the 2nd place in the world according to the data from Council for Economic Planning and Development. Persistent or transient decline of cognitive, nutritional, and physical status was noted in elder patients during hospitalization or six months post hospitalization. Declines of cognition and activity of daily life functions also lead to the increase of average stay days in hospitals, re-admission rate, and the increase of death rate.

Our objective is to utilize NTUCloud's large scale computing power and storage capacity for elderly care in physical and mental health. Figure 11 is the framework of our system which contains two main applications: cognitive stimulation and daily activity recognition. To reduce the computation effort, Subproject 3 and 4 provide the cloud computing techniques such as scheduling and high-dimensional Euclidean lattices in encryption and decryption. Besides, Subproject 3 also studies the power consumption reduction on handheld devices so that it can extend the lifecycle of the above two applications.

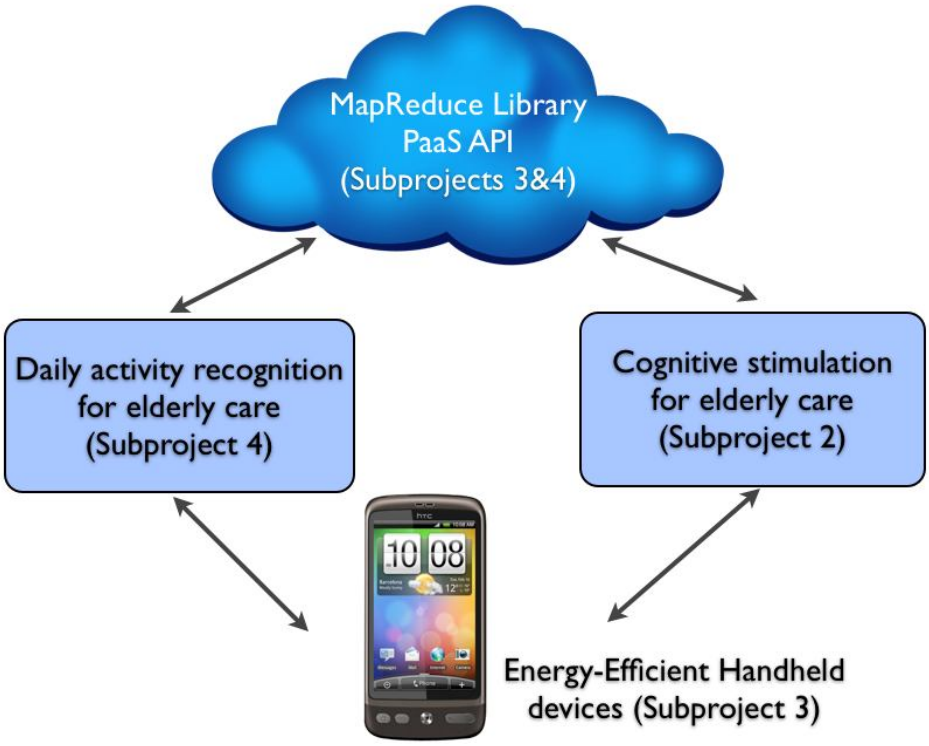


Figure 11. System Framework

2.1.2.2 Plan of Integration

Two cloud systems, *NTUClouds @ BL and BIME* and *NTUCloud@CSIE,* are built to support the intensive computation power and large-scale storage demand in applications for elderly care in this integrated project. First of all, NTUClouds @ BL and BIME is used for cloud security research. It consists of 109 nodes donated by Yahoo! Taiwan and serves as an educational platform for a diverse community of professors and researchers in NTU who are interested in using the latest cloud computing technologies. Currently there are about a dozen of active users, most of whom are not affiliated with the EECS College. NTUClouds @ BL and BIME employs the open-source Eucalyptus system (Elastic Utility Computing Architecture for Linking Your Programs To Useful Systems), a software framework for implementing a private cloud computing environment. It has a friendly user interface that is similar to and compatible with that of the Amazon EC2 and S3 Web Services. As a result, software applications developed on NTUClouds @ BL and BIME can be deployed on Amazon AWS directly without modifications.

On the other hand, NTUCloud@CSIE provides cloud computing resources including computing power, network bandwidth, and disk storage to support the two applications of this integrated project. These resources are provided under the management of the cloud operating system, Roystonea, a prototype cloud operating system developed by the laboratory of Parallel and Distributed Computing, Department of Computer Science and Information Engineering, NTU. It is a research-oriented cloud operating system prototype for studying virtual machine deployment strategies, virtual machine image management, cloud service level auto-scaling, and power conservation. We run Roystonea on a cluster at the Department of Computer Science and Information Engineering. Containing 15 nodes at total, the cluster was donated by TrendMicro

Incorporation. Each machine has two X5570 quad-core CPU running at 2.9 GHz, 24 G memory, and 3T hard disk storage. Roystonea provides various services including Hadoop file system support, MapReduce computation support, and HBase cloud data base support. All of these supports are packaged in the form of virtual machines and then apply in the following elderly-care applications.

To demonstrate the technology of our system for elderly care, we provide two applications considering the physical and mental health. In physical health, we construct a cloud-enabled healthcare platform which bases on a cloud database collecting various kinds of data, including weather information, physiological measurement, and most important of all, activity of daily living data which can be recognized by our home activity inference engine. The data exchanging format now mainly follows the LiveE! standard, which provides higher accessibility of the application. On the top of data are the two main building blocks. One block for adjusting inference engine will add adaptability to our activity inference engine by doing large-scale (over deep time-window of any specified family) sensor data analysis in the cloud using a customized MapReduce-enabled EM algorithm, which is developed by the Intelligent Robot Laboratory, Department of Computer Science and Information Engineering, NTU. Another block was specialized to do even large-scale data mining for user-proposed mining request on demand, which can easily be embedded in many health analysis related services. These health-related service can be implemented by asking the data mining engine for useful knowledge lies in the ADL data collected. For this integrated project, we even develop a possible application which will alert potential chronic illness possibility using the abovementioned data mining engine. It first use the data mining engine to build up its knowledge base for associations between illeness and possible living patterns, then alerts observants who were found matching those living patterns to the ones associated with the specified illness. The mining engine so far supports basic data summarization, clustering, and association rule mining, and it is expected to further expand its functionality by including other data mining core algorithms. For these main building blocks being both computing intensive and storage demanding, the platform leverages the Roystonea as its service bases to improve the scalability, reliability, and availability of its service. Other than these main components, we also distrubute our service by an service portal over proliferating mobile devices such as smart phones or pads. The portal itself provides two types of interfaces to end users and medical professionals. For the end users they can check all their medical record history, current context, and medical advices from the caregivers or medical institutes. Also the portal helps the elder users expand their social involvement by integrating Facebook utility. For the medical professionals the portal gives explicit statistics summarization over every observant by charts, which can be downloadable through highly-exchangeable XML format documents when needed. They are also capable of giving medical advices over the portal after investigating recent conditions of observants. The portal frontpage is illustrated in Figure12(a) and Figure12(b).

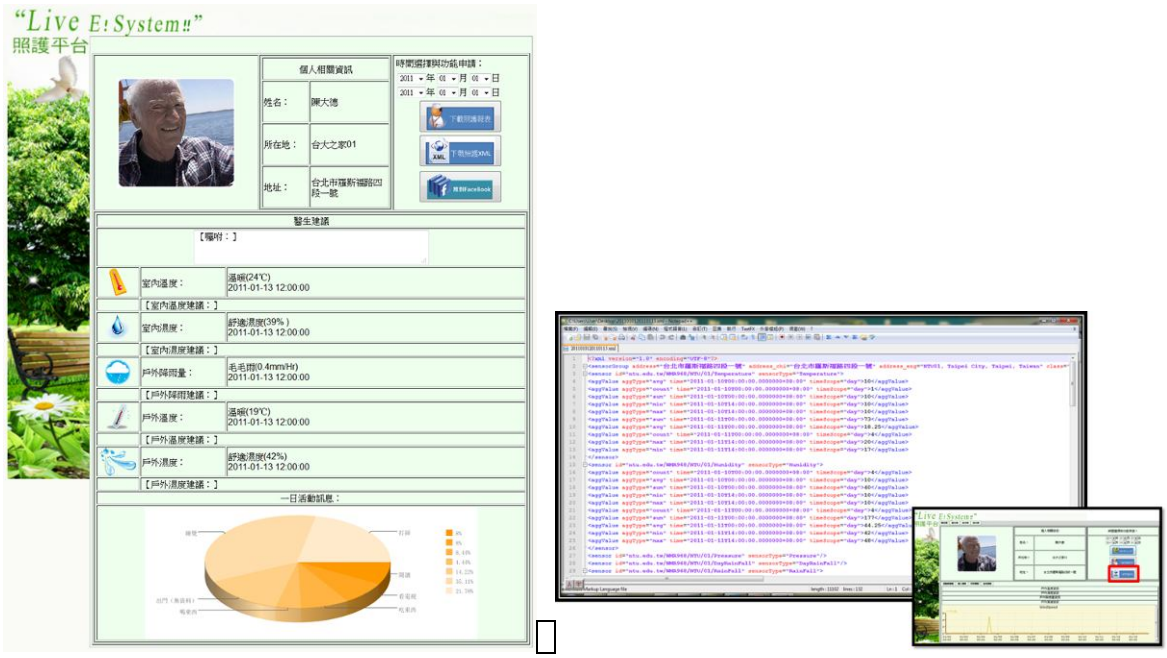


Figure 12. (a) The service portal interface. (b) Downloadable XML history records.

In mental health, we provide an application on cognitive stimulation for elderly care through the interaction with the large-scale photos potentially relevant to his/her past living experiences. Such cognitive-related photos can be further retrieved effectively by keyword-based or content-based retrievals. The scenario is as follows: Mr. Wang is 70 years old and has finished an operation on gastrointestinal surgery. The doctor advises the relatives to talk with Mr. Wang often for fear that his cognitive degradation could result in Alzheimer's disease. Andy, Mr. Wang's only child, studying aboard, and has little interaction with his father. When Andy and his father have time for communication, it usually does not last long for lacking common topics to talk about. In fact, Mr. Wang had been loved to travel and had been to a lot of places when young. In order to have more topics to talk with his father, Andy comes up with the idea that taking the photos of different travel locations and showing to Mr. Wang. Today Andy downloaded some photos of Taipei Confucius Temple from cloud and put it on the TV in the living room. When Mr. Wang sees these photos, he is really exciting and starts to talk about his travelling experiences of that place. At the same time, Andy's cellphone is showing some keywords about the photos so that he can find relevant topics to talk with Mr. Wang. Mr. Wang points at a photo on the wall, a family group picture taken in front of C.K.S. Memorial Hall, and starts to tell the story about the photos. Andy uses his cellphone to take a photo of his best-loved 30-year-ago group picture from the shoe box, and then the TV shows up other photos relevant to C.K.S. Memorial Hall by content-based photo retrieval. When Mr. Wang sees these photos, he starts to think about those great memories.

Figure 13 is an example of the user interface of this application. The end user can utilize the handheld device to control the displaying of the photos. For example, if the user chooses the photo at the left bottom, this photo will expand into a full screen mode. Besides, user can search for the related photos by taking pictures using content-based image retrieval techniques. After browsing these photos, this service also provides the games such as Puzzle Game, Find Error Game and Classify Game to help the cognitive stimulation.

Figure 13. The service of cognitive stimulation for elderly care

The following techniques are needed to achieve these functions:

(1) Automatic Landmarks Generation

In order to automatically mine important locations of an area, we need to handle large enough amount of images from online photo sharing websites. As shown in Figure 14(a), we download geotagged photos in a given geographical area (e.g., Taipei city), separate regions into tiles, and assigning the downloaded photos according to their geolocation. We then cluster images based on their content similarities so that each cluster will be a potential point of interest (POI) in this area. Finally, we extract representative tags and image in each cluster. The processes above require enormous computation (e.g., image feature extraction) and storage and the tile-structure makes it easy to distribute the computations into different computing nodes.

(2) Efficient content-based image retrieval

[1] Object-Level Inverted Indexing

Indexing large-scale image collections helps efficient image retrieval. Inverted file is a popular way to index large-scale data in the information retrieval community. Unlike the traditional methods, we adopt pseudo-objects and store the object information in the inverted file to support object-level image retrieval. Specifically, we construct an inverted list for each visual word (VW) t as follows, <Image IDi, $f_{t,i}$, RID$_1$, ... ,RID$_f$ >, which indicates the ID of the image i where the VW appears, the occurrence frequency ($f_{t,i}$), and the associated object region ID (RID$_f$) in each image. The addition of the object ID to the inverted file makes it possible to search for a specific object even if the object only occupies a small region of an image. We also adopt bit-level coding to reduce memory usage in index compression. Figure 14(b) illustrates the inverted file structure and index compression.

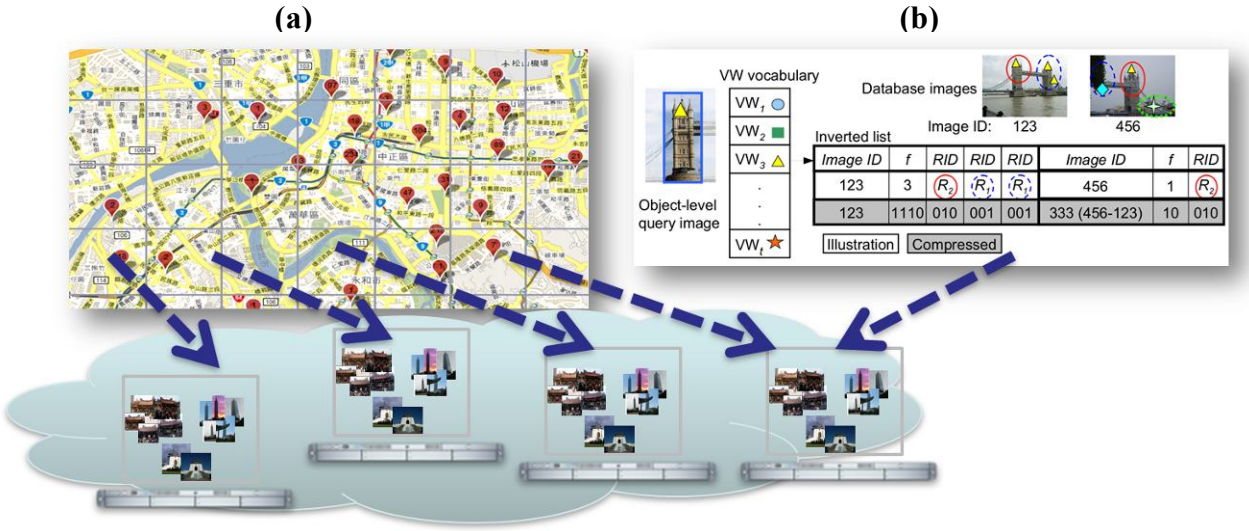


Figure 14. Distributed Computation for Feature Extraction and Indexing

[2] Auxiliary Visual Word (AVW) Discovery

Due to the limitation of VWs, it is difficult to retrieve images with different viewpoints, lighting conditions and occlusions, etc. To improve recall rate, we augment each image with auxiliary visual features and consider representative (dominant) features in its visual clusters and semantically related features in its textual graph respectively. We deploy all the processes in a parallel way by MapReduce. For better efficiency in time and memory we trade off the reduction of the number indexed visual features for each image.

The two elder-care applications abovementioned access the cloud computing resources by proliferating mobile devices such as Android pads and smartphones. They mainly need multiple hardware resources on the mobile phones, such as CPU, screen backlight and 3G for local execution and remote control. Since the services rely on the handheld devices solely for local interaction and access, we have to as possible extend the life of the handheld devices by saving power. That is, it is important to provide an energy-efficient scheme on the side of the handheld devices. Although different applications may have different resource usage patterns, we observed that the usage patterns among the resources have certain relations; in particular, most resources have interplay with the CPU. For example, the resource usage of video streaming applications like YouTube, which mobile users have become increasingly addicted to in recent years. Figure 15(a) illustrates the resource usage when the user is watching a video stream on YouTube. A buffer implemented with the main memory is usually employed to store the video data received from the Internet via the communication component. Whenever a certain amount of data is reached, the video decoder is invoked to decode the video frames, which involves CPU intensive computations. The decoded frames are put into another buffer and, meanwhile, displayed in succession at a constant rate on the screen. Thus, for video streaming applications, besides the computation demand for CPU, 3G connectivity, and LCD should also be busy in receiving network packets and displaying video frames respectively, which also cause frequent access activities to the DRAM.

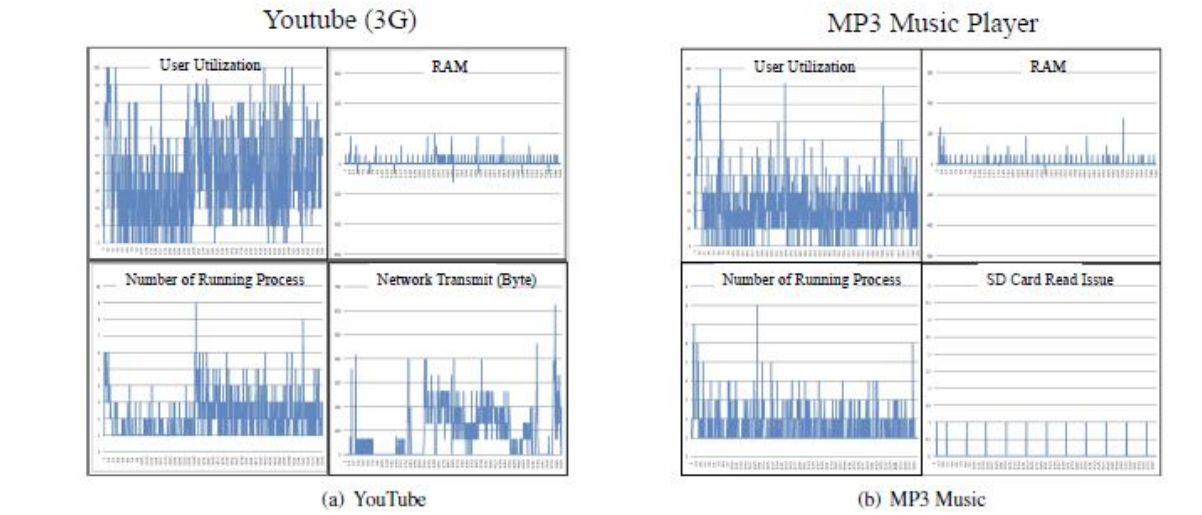


Figure 15. The resource usage patterns

Therefore, we shall propose a series of algorithms to reduce the power consumption of a processor by Dynamic Voltage Scheduling (DVS) algorithms, and utilize the energy-saving states of a peripheral device with Dynamic Power Management (DPM) strategies. These algorithms will largely reduce the power usage of those portable devices, extending the maximum use time and increaseing the service availability, especially for potential emergency conditions.

2.1.2.3 Integration Outcomes Including Testing Results

The integration outcomes can be divided into the following four aspects: (1) Cloud computing adoption. (2) Energy-saving mechanism. (3) Application 1: daily activity recognition for elderly care. (4) Application 2: cognitive stimulation for elderly care.

(1) Cloud Computing Adoption

According to numerous surveys and researches, security has been named the top challenge in adopting cloud computing. Although we can always tighten security by contractual means and security audits, a fundamental issue is that the cloud users no longer have complete control over their own data. Encryption can achieve complete control for the users, but unfortunately it also severely limits data use and may potentially nullify most of the benefits brought about by cloud computing.

Recently, there have been certain theoretic breakthroughs in the cryptologic research community. Via fully homomorphic encryption techniques, it is now possible to encrypt users' data and yet allow cloud servers to perform arbitrary computation on the data without learning any knowledge about the data. The security of such encryption schemes depends on the difficulty of solving several mathematical hard problems. For example, we need to understand how difficult it is to find a short vector in a high-dimensional euclidean lattice. Such a problem is known as the Shortest Vector Problem (SVP).

Using NTUClouds @ BL and BIME, we have advanced the state of the art in solving SVP and hence gained more insights into the security of fully homomorphic encryption schemes. In

the process, we have also found several shortcomings of the Eucalyptus system. First, the scheduling of deployment of virtual machine instances is carried out in a simple round-robin fashion. In addition, once a virtual machine instance is deployed, it cannot be relocated unless being shut down. Such shortcomings often lead to overloading of a number of cloud servers while leaving other machines under-utilized. This motivates us to develop the new Roystonea system, as will be described in more detail below.

NTUCloud@CSIE supports the integration project by providing cloud computing resources. In particular, we have allocated 10 Hadoop servers on 10 virtualized Ubuntu servers, five virtual servers for the subproject "Daily activity recognition for elderly care," and five virtual machines for the subproject "Cognitive stimulation for elderly care." The configuration of these virtual machines is as follows.

- Dual 2.0GHz CPUs
- 4G memory
- 100G hard disk

The CPU-hour usage of these virtual machines, from October 2010 to April 2011, is illustrated as follows.

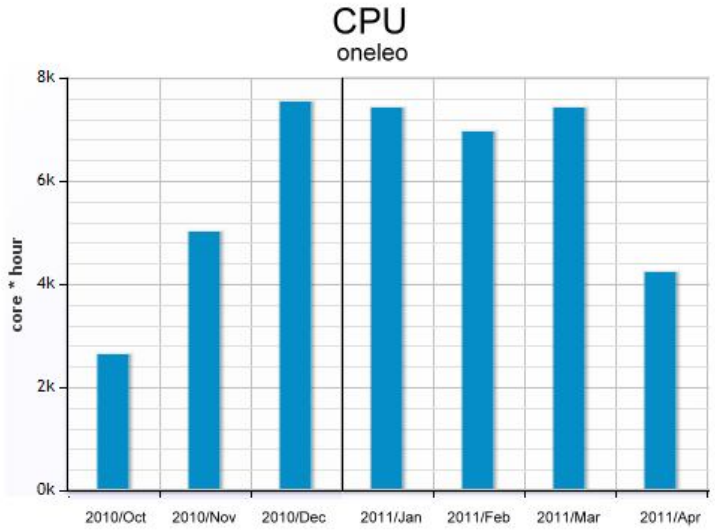


Figure 16. CPU-hour usage of virtual machines

(2) Energy-saving mechanism

To better understand the resource usage patterns of mobile applications, as well as the interplay between the CPU and other hardware resources, we developed a lightweight logging mechanism to log how application programs use the resources mobile devices. Based on the CPU and devices usage patterns, we develop the corresponding algorithms to scale the voltage and/or the frequency of a processor and to adjust the backlight of the screen. The algorithms are also implemented as Linux daemons in the Android environment. The energy-saving results of H.264 decoding over an HTC Hero smartphone is shown in Figure 17. From the figure we could conclude that each mobile application should have some characteristic resource usage patterns, and each resource may have interplay with other resources to a certain degree.

60s HVGA(480*320)		
	with DVS Policy	no DVS Policy
Consumed Energy	1876.14 uAh (14.05%)	2183.07 uAh
Average Power	913.88 mW	1003.45 mW
Average Current	217.92 mA	239.33 mA

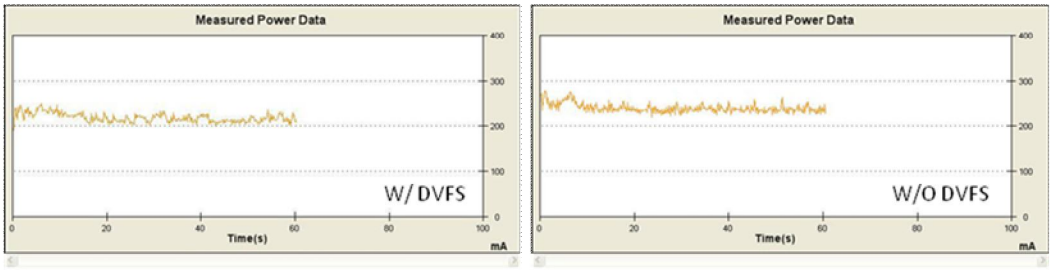


Figure 17. The energy-efficient H.264 decoding

Moreover, in order to implement the energy-saving daemons adapted for the elderly care system, the control registers of the tablet PC should be properly set to adjust the processor frequencies and device states, and the routines should be exported as system calls in the Linux kernel. For Android applications, the system calls are further wrapped by Native Development Kit (NDK). Finally, the energy-saving algorithms are programmed according to the usage patterns. The following table shows the experiment results for the energy-efficient client device of the elderly care applications.

	With DVS and DPM	Without DVS and DPM
Time	609.03 Sec	608.85 Sec
Average Power	538.92 mW	736.31mW
Average Voltage	3.7 V	3.7 V
Consumed Energy	24668.97 uAh	33698.65 uAh

Table IV. The energy saving with the DVS and DPM daemons

(3) Application 1: daily activity recognition for elderly care

The daily activity recognition services have been successfully ported on to the NTU cluster (10 VMs are all in use now for sustaining the whole platform). They also have been worked nicely under the current loading amount. Until now the main reason of service unavailability lies in the service suspension for upgrading (of this application and the Roystonea).

We here discuss the integration result and several testing statistics separately into 2 parts, dedicated to the ADL mining engine and the service portal. The reason not to include the testing result of the inference engine adjustment is that it requires far less efficiency concerns (since the adjustment frequency should not be high). The adaptation ability of the adjustment result has been confirmed but not rigorously experimented.

Focusing on evaluating the performance of the data mining procedure, we have generated a simulated community of population 100K as the experiment environment. For testing the scalability the experiment uses 16 homogeneous virtual machines of 2GB memory and a dual-core CPU. Our

data (mostly ADL data) is distributed evenly as possible on 16 machines for leveraging locality speedup of MapReduce framework. The cluster will be used to analyze over 10 customizable user mining requests of association rule mining over the correlation between dementia (a mental illness which causes intellectual losses) and specified ADL dimensions. The average request completion time under this environment is measured to around 4 minutes (most of which is due to MapReduce startup overhead, which should be further improved). Even if the population is raised to 500K or 1000K, the service completion time only grows sub-linearly to 4 minutes 40 seconds and 5 minutes 30 seconds. It is very likely that we can adequately scale up the computing resource quantity so as to fit required service level. The accuracy of a possible application which detects potential dementia patient, however, is not measured here, for that the result can be largely fluctuated for different simulation distribution setting. Further clinical experiments can be made in order to find more empirically reasonable result.

Of the service portal part, we take another experiment for the power saving performance. The platform environment is HTC Hero for smart phone devices and Samsung Galaxy Tab for pad devices. A list of consecutive operations pre-defined will be played for each test case, which renders the device in fully operative mode (where the LCD backlight keeps on). Compared to the ordinary usage, our platform, combined with the power saving API, saves about 26% power more. This means an extension of 1-hour power life to its original 5 hours, a 20% improvement.

(4) Application 2: cognitive stimulation for elderly care

In application 2, for mining effective auxiliary visual features to improve recall rate in retrieval, we firstly evaluate the effectiveness of the distributed computation framework as listed in Figure 8, where multimodal graphs are required for mining the large-scale photo collections. We measure the pair-wise similarity (graph) construction and show the scalability test of the MapReduce algorithm in different number of computing nodes. The *speedup* is computed by $Speedup = T_1 / T_n$, where T_1 represents the computation time using 1 node and T_n represents the time using n nodes. It shows the proposed algorithm is scalable in a linear manner and can benefit from the distributed platform.

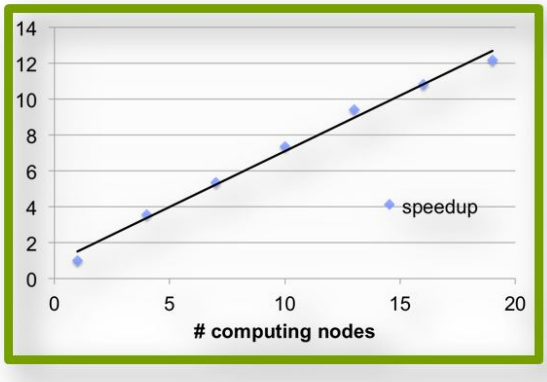


Figure 18. Scalability test of the MapReduce algorithm

Secondly, the performance of AVW discovery in Flickr11K dataset and the overall retrieval accuracy are listed in Table 2. The performance increases when considering the pseudo-relevance feedback (PRF) which takes the top-ranked list as new queries to improve the recall rate. Overall, the AVW improves the prior state-of-the-art BoW model method by 110% and reduces the number of (indexed) features to 1.4%.

	MAP	MAP by PRF (%)	# Feature points
Baseline BoW model	0.245	0.297 (+21.2%)	22M
AVW	0.375	0.516 (+110.6%)	0.3M

Table V. Performance of AVW discovery

For retrieval time consumption, facilitated by object-based inverted indexing, the query time requires 475 milliseconds (ms), while the object-level PRF for 854ms, all of which are sub-second responses even under million-scale photo collections. Overall, we had built a state-of-the-art photo retrieval system considering both retrieval accuracy and efficiency. Meanwhile, we also leverage distributed computation framework for mining the exponentially growing photo collections.

2.1.2.4 Conclusion

In this project, we demonstrated two elder-care applications, daily activity recognition and cognitive stimulation, considering both the physical and mental health.

Daily activity recognition for elderly care constructs a healthcare service portal and provides the end users (e.g., elderly people, caregivers, and medical staff) health-related information such as medical record history, explicit statistics summarization for better understanding in elderly people's health status and giving medical advices in advance. It contains a scalable activity of daily living (ADL) data mining engine to mine useful caring knowledge from collected data and an activity inference engine adjustment module for strenthening activity recognition mechanism.

On the other hand, cognitive stimulation for elderly care integrates an efficient content-based image retrieval system based on the online crowd sourcing social media and will make the elders have better interaction with their accompanies and reduce degradation of their cognitive ability with the help of this multimedia system.

We adopted two cloud systems, NTUClouds @ BL and BIME and NTUCloud@CSIE, to support the enormous computation and storage of data analyzing in these two applications. Moreover, we also investigated the feasibility of greener mobile and cloud computing to provide the energy-efficient service. The experimental results and the demo systems have showed the potential of promoting elder's physical and mental health.

2.2 Breakthroughs and Major Achievements for Each Individual Subprojects

2.2.1 Subproject 1 (SP1)

- Become world leading microwave research group, signified from the publications on prestige IEEE journals - Transactions on Microwave Theory and Techniques (T-MTT) and Microwave Wireless Components Letters (MWCL). NTU ranks number one among universities and research institutes in the number of published papers, total citations, and average citations per paper in MTT for five years (2006-2010) and in MWCL since 2005 (second to KAIST in 2009). Also, MWCL has selected one co-PI to serve as the Editor-in-Chief in 2010-12.

- Developed CMOS-based mmW monolithic integrated circuits using the domestic CMOS technology, including the world first 60-GHz CMOS single-chip low dc power transceiver and got the attention from the entire RFIC domain. In the meanwhile, the individual mmW components such as low noise amplifiers (LNAs), power amplifiers (PAs), switches, mixers, voltage controlled oscillators (VCOs), and etc, were designed and fabricated. The frequency spans from K- (18-27 GHz), V- (50-75 GHz), W-band (75-110 GHz) to even higher frequencies, with many state-of-the-art results. These accomplishments make the fact that using Si-based technology to replace the III-V compound technology comes earlier.

- Demonstrated vast applications of radio-frequency System in Package (RF-SiP) technology by the Low Temperature Co-fired Ceramic (LTCC). Facilitated by the manufacture niche in Taiwan, we have developed various mmW components and antennas, including filters, couplers, transitions, inductors, noise suppression filters, antennas, array, beam former, radar and wireless communication modules over a wide frequency range from X- to Ka-, Q-, and V-bands. As a result, the LTCC-based passive components and antennas has been validated to be a good substitute for the traditional metallic waveguides and cavities. Due to the capability of vertical integration through multi-layer features, the present technology also exhibits salient advantages of compact size, low cost, and diversified design flexibility, e.g., multi-band flexibility, selectivity enhancement in filter design, bandwidth improvement in transition, coupler, and antenna design, among others.

- Become a world renowned research group in the System in Package area, signified from the publications on the IEEE Transactions on Advanced Packaging (T-AdvP). With yearly average publications of more than 4 papers in T-AdvP, NTU ranks world number two in the number of published papers in 2006-2010, only second to GeorgiaTech. In 2010, NTU published 9 papers in T-AdvP, second to GeorgiaTech of 12 papers but outperforming the next KAIST of 5 papers.

- Dedicated to the signal integrity of electronic structures by applying the electromagnetic theory, thus globally pioneering in electrical design for advanced packaging. The series of researches include analysis tools for three-dimensional complicated packaging structures, modeling and design techniques, and signal integirty design and optimization.

Our paper entitled “Fast methodology for determining eye-diagram characteristics of lossy transmission lines,” received the 2009 T-AdvP Best Paper Award to breakthroughs in theory, analysis, design, and experimental validation on the eye-diagram prediction for lossy transmission line in packaging systems.

- Successfully developed technologies for power integrity design, based on the electromagnetic bandgap (EBG) and metamaterial concept. Our co-authored paper entitled “Noise coupling mitigation in PWR/GND plane pair by means of photonic crystal fence: sensitivity analysis and design parameters extraction,” received the 2010 T-AdvP Best Paper Award due to the novel applications of EBG in simulaneously switching noise mitigation in power/ground structures by a photonic crystal fence with minimum use of high dielectric contstant for the rod.

2.2.2 Subproject 2 (SP2)

- At ACM KDD 2011, Prof. Chih-Jen Lin's group won the best paper award. ACM SIGKDD international conference on knowledge discovery and data mining (KDD 2010) is the most prestigious conference in data mining. Among the 578 submissions, only 77 are accepted for full presentation, and 24 for short presentation. The overall acceptance rate is less than 17%. This work was by Prof. Lin and his students Hsiang-Fu Yu, Cho-Jui Hsieh, and Kai-Wei Chang. They studied large-scale linear classification when data cannot fit in memory. Using their results, ordinary users can now train large data using just their laptops. At the KDD conference, the award committee gave the following comments on the paper: “good combination of theory ideas and engineering ideas and a solid evaluation for a very relevant problem,” “address a central task that is specifically a KDD task. Impressive results on large data,” and “can be proved really useful to the community on a wide spectrum of problems.”

- Since 2007, Prof. Chih-Jen Lin's group has been actively developing a software package LIBLINEAR for large-scale linear classification. The software supports different regularizations (L1 or L2) and loss functions (SVM or logistic regression). It is now popularly used in Internet companies and NLP (Natural Language Processing) communities. Prof. Lin's group has published several papers about this software in leading journals and conferences. In particular, the paper "LIBLINEAR: a library for large linear classification" publish in JMLR (Journal of Machine Learning Research) in 2008 has drawn much attention. With 346 Google Scholar citations up to May 2011, it is the most cited JMLR papers published in 2008.

- ACM KDDCUP is the most prestigious annual competition in Data Mining society. The goal is to bridge the gap between theory and practice in machine learning and data mining. The organizers of each year are different, and so are the main themes of the competition. The KDDCUP08 competition is about the early detection of breast cancer using classification techniques. A team lead by NTU CSIE Prof. Shou-de Lin has produced result that outperformed the other 200 world-wide submissions to become the joint-winner of the competition (joint winning with IBM research). In 2009, the KDDCUP competition focused on the predicting the customers’ behavior from a

telecommunication dataset. The National Taiwan University team led by Prof. Chih-jen Lin, Prof. Shou-de Lin, and Prof. Hsuan-tien Lin were ranked the 3rd among 400 participating teams. In 2010, the task is to predict whether a student learned a concept based on the e-learning data. After 4 month's competition, the NTU team led by the same three professors outperforms the other hundreds of teams to become the champion of the competition again. Our team leaders were invited to give the presentations in ACM SIGKDD conference, and to submit papers to describe our winning strategies in three successive years.

2.2.3 Subproject 3 (SP3)

- NTU not only outperformed all other universities in the world in the past six consecutive years (2005-2010) in terms of the number of accepted ISSCC papers, but also ranked first in 2007 among all companies and universities in the world for this premier conference.
- The NTU SoC team's work on efficient provably good optical proximity correction modeling for subwavelength lithography and its applications to interconnect optimization received the Best Paper Award from the 28th IEEE International Conference on Computer Design (ICCD) in October 2010.
- The NTU SoC team ranked the first among all universities/companies for paper publications and best paper nominations in the two premier EDA conferences, ACM/IEEE Design Automation Conference (DAC) and IEEE/ACM International Conference on Computer-Aided Design (ICCAD), and the two premier EDA contests, the annual ACM Physical Design (ISPD) Contest and ACM/SIGDA CADathlon at ICCAD during this period.
- One major challenging issue in the designs of multi-core embedded systems is to tackle the communication problem among tasks with performance requirements and precedence constraints. We show the NP-hardness of the problem in the minimization of the bus cost and the non-existence of any algorithm with an approximation ratio better than 1.5. A polynomial-time optimal algorithm is first proposed for a restricted case in which one multi-layer bus, unit execution time, and chain-based precedence constraints are considered. The results are then extended as a pseudo-polynomial-time optimal algorithm in the considerations of multiple multi-layer buses, arbitrary execution time, non-preemptivity of task execution and communication, and different objective functions. The capability of the proposed algorithm was evaluated to provide more insights in system designs, compared to some popular heuristics. The results appeared in the IEEE 30th Real-Time Systems Symposium and are the best results so far. (2011)
- Flash-Memory Storage Systems: Cost has been a major driving force in the development of the flash memory technology. In this direction, we propose a commitment-based management strategy to resolve the reliability problem of many flash-memory products. A three-level address translation architecture with an adaptive block mapping mechanism is proposed to accelerate the address translation process with a limited amount of RAM usage. Parallelism of operations over multiple chips is also explored

with the considerations of the write constraints of advanced multi-level-cell flash memory chips. We show that the proposed management strategy could significantly improve the reliability and performance of a multi-chipped flash-memory storage system with very limited RAM usage. The lifetime of the storage system under our approach was 4.21 and 7.92 times of those under popular implementations BL and NFTL, respectively. The results appeared in ACM/IEEE DAC in 2009.

- Automatic air pollution sensing system (APS): We propose a distributed and automatic air pollution sensing system (APS). By equipping the sensor on the scooter rider's safety hamlet, APS can dynamically sensing the air quality and provide this information to users. APS also provides a web-based intelligent health path planning system to make each user have the safe and clear environment. (此作品曾獲得微軟 2008 Imagine Cup 軟體設計組台灣區冠軍，而且參與由國科會舉辦的 2008 年台北國際發明暨技術交易展，並獲得展前記者會發表(發表件數共 4 件，台大共 1 件即為本作品。)

- Trusted Volunteer Community System (TVC)
  The TVC system is a social community volunteer system with the Matching and Feedback mechanisms on the mobile networks. With the TVC system, the volunteer can provide the real-time assistant service to the others needing help. The TVC system makes the concept of social community network in the Internet be carried into the real world, especially face-to-face. The TVC system is a complete and mutual trusted platform. (此作品曾獲得微軟 2009 Imagine Cup 軟體設計組台灣區冠軍，並代表台灣參與於埃及舉辦的世界賽，自全世界約 70 個國家中，獲得世界前六強的成績。而且參與由國科會舉辦的 2009 年台北國際發明暨技術交易展。)

2.2.4 Subproject 4 (SP4)

- Current streaming services in mobile networks are subject to the available wireless bandwidth shared among many users and can only provide videos with limited resolutions. In response to the above problem, we bridge the resolution gap between streaming videos and client screens, and propose a novel upsampling-based system architecture to enable high quality video streaming onto mobile devices by upsampling videos with decoded frames and appends a limited amount of metadata to the streaming videos for facilitating high-quality and real-time conversion from low resolution to high fullscreen resolution on the client side.

- Mesh networks with universal frequency reuse is expected to play an important role for future wireless system architecture, to provide ultra high throughput and seamless access via cooperative base stations (BSs), relays, and users. Different from traditional networks with central control, BSs should operate in a self-organizing way. To optimize system performance, we develop the cognitive resource management for wireless mesh networks with self-organizing BSs to utilize entire available spectrum, while BSs collect channel state information of each user by spectrum sensing. Our resource management provides significantly improvement on network throughput, which suggests good potential for many wireless systems such as LTE-A and WiMAX 2 that are adopting mesh network architecture, to achieve universal frequency reuse.

- We proposed a novel approach to building a WLAN based location fingerprinting system. Our algorithm intelligently transforms received signal strength (RSS) into principal components (PCs) such that the information of all access points (APs) is more efficiently utilized. Instead of selecting SPs, the proposed technique replaces the elements with a subset of PCs to simultaneously improve the accuracy and reduce the online computation. Our experiments are conducted in a realistic WLAN environment. Several benefits of our algorithm are demonstrated, such as requiring fewer training samples and enhancing the robustness to RSS anomalies.

- We propose a crowdsourceable framework to quantify the QoE of multimedia content. The advantages of our framework over traditional MOS ratings are: 1) it enables crowdsourcing because it supports systematic verification of participants' inputs; 2) the rating procedure is simpler than that of MOS, so there is less burden on participants; and 3) it derives interval-scale scores that enable subsequent quantitative analysis and QoE provisioning. We conducted four case studies, which demonstrated that, with our framework, researchers can outsource their QoE evaluation experiments to an Internet crowd without risking the quality of the results; and at the same time, obtain a higher level of participant diversity at a lower monetary cost. (ACM Multimedia 2009 – Human-Centered Multimedia Track, pp. 491-500, 2009.)

- Winning ACM Mobicom 2009 SRC contest based on game theoretic research on femtocell.

- We have developed PipeProbe system. PipeProbe is a mobile sensor system that can determine the spatial topology of hidden water pipelines behind walls. PipeProbe works by dropping a tiny wireless sensor capsule into the source of the water pipelines. As the PipeProbe capsule traverses the pipelines, it gathers and transmits pressure and angular velocity readings. Through temporal-spatial analysis on the sensor readings, our algorithm locates all turning points in the pipelines and maps their 3D spatial topology.

2.2.5 Subproject 5 (SP5)

- A Ce^{3+}:YAG DCF based visible emission was used as the light source for optical coherent tomography (OCT). The broadband emission and short central wavelength of this light source enabled the realization of 1.5-μm axial resolution in air. The relatively smooth spectrum reduced the side lobe of its point spread function, and therefore, facilitated the generation of a high quality image with less crosstalk between adjacent image pixels. As a demonstration, an *Aplocheilus Lineatus Gold* fish was experimented on to map out the stroma of its cornea. This work was selected by OCT News (http://www.octnews.org/) as Feature of the Week.

- The micro-structural and micro-spectral characteristics of a vertical-aligned liquid crystal display (VA-LCD) panel were obtained non-invasively for the first time. With 1-μm-axial and 2-μm-transversal resolutions, the cell gap profile beneath the patterned thin-film transistor of the VA-LCD panel can clearly be resolved. The thicknesses of the multiple thin-film layers and the embedded defects can also be unveiled. Spectral-wise, the light transmittance at the layer boundaries can be estimated from the measured

reflectance, which is a crucial information for the design of a highly transmissive panel. The color shift of the VA-LCD panel due to fabrication error was evaluated.

- We report solution-processed ZnO thin film transistors (TFTs) on a flexible substrate, using polymethylmethacrylate (PMMA) as a dielectric layer. The structural and electrical characteristics of ZnO-TFT, which have different channel morphologies produced by various concentrations of the ZnO solution, were investigated. The ZnO trap centers of the ZnO-TFTs were decreased as the concentration of the ZnO solution increased. The ZnO-TFT with the optimized channel morphology exhibited a high field-effect mobility of 7.53 cm^2/Vs.

- Silicon is on the verge of the choice for the photonics industry. Sub-wavelength optical wires fabricated using CMOS (Complementary Metal–Oxide–Semiconductor) materials and techniques will lead feasible and economic integration of optics and electronics. Here, we present a novel method to fabricate circular Si/SiO2 waveguides from bulk silicon using laser reformation technique. High-power excimer laser was used to illuminate pre-fabricated Si ridges. In addition, oxidization of the neck of this reformed structure prevents optical loss due to light coupling from the waveguide to the substrate. This technique allows great flexibility in design and fully compatible with the CMOS circuitry.

- Mode-locking of semiconductor optical amplifier fiber laser (SOAFL) with 50 fs pulses by extracting the clock of an optical non-return-to-zero (NRZ) data injection is demonstrated. The amplified SOAFL pulse can be compressed to 50 fs after nonlinear compression with its spectral linewidth broadening to 64 nm. Nearly transform-limited time-bandwidth product of 0.436 and the maximum pulse compressing ratio of 400 are reported to date.

- Modal characteristics of the THz pipe waveguide, which is a thin pipe consisting of a large air core and a thin dielectric layer with uniform but low index, are investigated. Modal indices and attenuation constants are calculated for various core diameters, cladding thicknesses, and cladding refractive indices. Numerical results reveal that the guiding mechanism of the leaky core modes, which transmit most of the power in the air-core region, is that of the antiresonant reflecting guiding. Moreover, modal patterns including modal intensity distributions and electric field vector distributions are shown for the fundamental and higher order modes. Experiments using time-domain spectroscopy with PMMA pipes also confirm the antiresonant reflecting guiding mechanism.