Personalized Elderly Assistive Home Care Using 3G Networks

B. Fong
University of Hong Kong

K. F. Tsang
City University of Hong Kong

C. K. Li
Neo Mechanics Limited

***Abstract*— Population aging in many metropolitan cities would certainly grow at a rate that far exceeds any expansion to hospital capacity driving an urgent need to reduce the demand for hospital services by elderly citizens. To promote health awareness among those living alone, issuing condition based reminders and alerts, and continual monitoring for those at risk therefore become an important preventive measure where participants will be able to carry out their daily tasks while enjoying their retirement lives with some peace of mind. The system also serves senior citizens with different medication needs for chronic diseases using a prognostics methodology.**

***Index Terms*—Assistive care, remote patient monitoring, smart home technology, telemedicine**

I. Introduction

The combined effect of aging population and lack of financial support for nursing home residency is driving more senior citizens to live alone. Without someone closely keeps an eye on each elderly person's well-being, this increasingly trend will almost certainly drive up the demand on primary care and medical attention.

Elderly people are particularly vulnerable to chronic diseases. Telecare, although not intended to provide a preventive solution for senior citizens, can improvement efficiency and cost effectiveness to serve the elderly [1]. Although current technologies provide assistive care such as off-the-shelf electronic pill reminder and dispensers are readily available for the convenience of organizing drugs for to sort according to the day of the week and the time of day depending on the number of doses needed on a daily basis [2], these devices do not address the fundamental problem that many senior citizens with chronic disease face. Patients with dementia and physical disabilities may have difficulties with getting their prescribed medications replenished. Such weakness in the prescription supply chain is addressed by our proposed prognostics approach.

Assistive technology makes electronic medication dispensary far more capable than organizing medication for rural areas or people with mobility problems. Although medicine must be physically delivered by some means of transportation, it does provide rural areas ease of access to medications and related information. One of the features of electronic drug store is to assist with dispensing of medication securely with automated auditing procedures for quality assurance and to reduce administrative costs. Personalized assistive care entails far more than simply a vending machine selling non-prescription medicine. Another major application is analysis of drugs so that effectiveness and any side effects can be duly recorded in an efficient and organized manner in the process of mixing prescribed medication and other medicine based on specific needs such as cough mixture or pain relievers. The system automatically generates reminders for replenishment and disposal of expired/outdated medications. It keeps patients connected to their caregivers and local pharmacies. Both patients and caregivers can obtain information about possible adverse drug reactions and allergies. Also, any product recall exercise and expiration of drugs or their respective license and registration can be kept up to date. In this paper, we describe a personalized assistive home care system for senior citizens with chronic diseases utilizing a 3G cellular network backbone. This enables caregivers to remotely monitor the well-being of elderly people [3].

In addition to taking care of individual medication needs, the system also serves as a digital guard and provides emergency support around the clock by providing a contact point between the patient and one's caregiver through 3G cellular networks and a range of highly customizable, user-friendly, wearable pervasive health device that is suitable for cognitively impaired persons living alone [4]. A wearable therapeutic device provides general assistance, health monitoring, calling for emergency assistance, alerts and reminders; can provide dementia sufferer with a peace of mind. This solution also links care providers and elderly people, particularly those living alone, so that they can stay in touch.

User-friendliness is an important design consideration since most senior citizens are not familiar with

doi:10.4304/jait.4.3.136-141

technology. Minimal user intervention is therefore an important feature of the system. Another major function

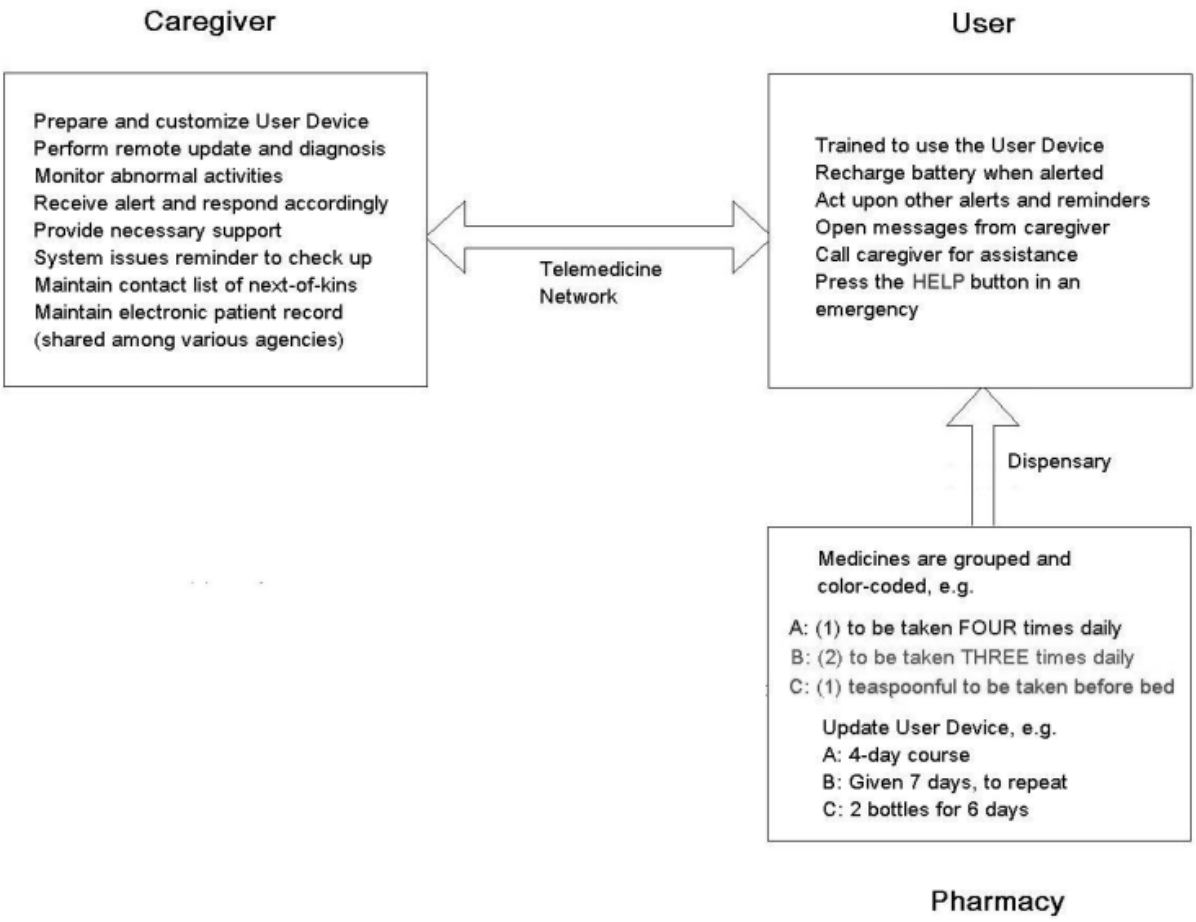

Fig. 1 Personalized assistive care system block diagram

is to collect information about users' health conditions such as blood pressure, body temperature and SpO_2 readings, medication and nutritional intake, and fall history. Such clinical information will be analyzed on a regular basis for monitoring purpose.

II. Objective and Method

A number of techniques can be deployed for continual monitoring of patients in addition to analyzing various vital signs. For example, neural control interaction [5], ingestible substances [6] and affective health [7] can be used to monitor the patient's condition. Condition based health management is necessary since the health state of individual participant can differ by attributes such as daily activities, habits, chronic disease linked to obesity, smoking, and other environmental factors [8]. Condition-based monitoring entails the use of different environmental sensors connected to a console [9]. The console is a standard mobile that runs the Java monitoring application without any modification requirements. Java applications control a number of operations depending on specific requirements of individual patients and the potential health risks, such as:

- Time and frequency of measurement
- Analysis and detection of abnormal readings and data storage
- Automated alert generation in response to abnormal readings, and automatic reports sent to family doctor
- Medication reminders for repeat medication

A combination of sensors that monitor the status of patients listed in Table I can be connected to the console via a zigbee body area network (BAN) for condition-based monitoring [10]. Different sensors can be installed in the mobile device to monitor a wide range of parameters including body and ambient temperature, vibration, shock, pressure, air pollutant concentration, strain and stress [11]; for example, a user that is of higher risk of falling can be equipped with accelerometers that automatically detect a fall and send an alert to a care giver for immediate attention; a user suffering from any form of cognitive impairment can be reminded of various tasks.

The system has two distinctive parts each operates independently and linked together through a backbone 3G cellular wireless network. The system block diagram is shown in Fig. 1, where the caregiver's side is responsible for tasks such as customization of end-user device and acting as a response center. Whereas the End-user side, namely the elderly user's home, can be as simple as just a

pre-programmed mobile phone, to a sophisticated system with comprehensive features that serve users with special needs.

TABLE I
CUSTOMIZABLE WIRELESS ASSISTIVE CARE SENSORS

Sensor Type	Risk Prevention/Detection
Accelerometer	Fall
Air flow	Asthma, COPD, stroke
Optical glucose meter	Diabetes related complications
Pulse counter	Cardiovascular diseases
Shock and vibration	Chronic fatigue syndrome
Thermometer	Cold, hyperthermia

Once the device is prepared, the remaining tasks will be reasonably similar to the regular duties of caregivers such as nurses and social workers. The system is design to assist them with a range of these tasks, including reminder of activities, remote check-up in lieu site visits on certain occasions, automatically alerted to a situation, some necessary support such as consultation can be provide remotely, remotely capture data for analysis or archival, for example, recovery progress tracking, electrocardiography (ECG) of users either diagnosed with cardiopathy or classified as high risk can be monitored and any abnormal activities identified. To minimize the response time in the event of an accident, the system is designed to remotely detect situations such as a fall that can immediately trigger an alarm, this feature is particularly helpful in nursing homes where elderly people may wander around unsupervised.

III. PERSONALIZED MEDICATION SYSTEM

The main objective of this system is to provide an efficient solution for drug delivery to senior citizens with cognitive or physical impairments who may have difficulties with handling medicine for their chronic diseases. Utilization of prognostics and telemedicine technologies enhances the supply chain of medication for senior citizens with chronic diseases by means of an automatic medication dispensary system. The main purpose of this system is to serve as a medication reminder and automated drug dispenser which ensures that only the prescribed dose of medication is dispensed.

The system relies on co-operation from pharmacies when preparing drugs such that a color coded system can be developed. Medications will be packed with appropriate color bags. To serve this purpose, one solution that demands minimal effort would be color printing of labels, so that the drug's name can be printed using a specific color according to its quantity and frequency of intake. Medication information can also be updated to the user device by a Bluetooth link. The information can be embedded to the prescription so that the device can remind the user of when to take the medications. Radio frequency identification (RFID) readers can be installed for a variety of features. For example, when used in the medication console users can be tracked of medication being taken and when repeat or replenishment should be sought,

The major benefit to the patients with e-prescribing is to ensure that they get the best medicine and the risk of drug mix-up is kept to an absolute minimal as technology is available at every step to ensure proper procedures are followed. Electronic patient records are also integrated to ensure that what they have taken is recorded. In addition, electronic link between physicians, pharmacist, and the patient. Patients can collect their medicine after a doctor visit without the need of bringing a prescription form from the clinic since the pharmacy can retrieve this electronically. The idea of an electronic drug store is to employ a remote drug ordering system such that licensed pharmacists can receive e-dispensing orders and patient records irrespective of time of the day. Pharmacists then check and profile the accuracy of each order and authorize the hospital pharmacy system to dispense the medicine. The pharmacists also monitor allergies, drug interactions, correct dosage and each patient's pharmaceutical history before issuing an authorization. Also, the system can check if the medication is covered by the patient's insurance so billing can be made accordingly. The generation and storage process of prescription records are all done automatically. Last but not least, patients can be reminded to take medicine at the right time and to replenish their medicine. For elderly and patients with visual impairments who require long term medication, a small device can be installed at the patient's home as a 'personal medication assistant'. This solution can also be implemented as a software application installed on any home or laptop computer with an RFID reader. It reads the RFID tag attached to each bag containing the drug, information about dosage and time for medication is stored in the tag so the correct type of medication taken at the right time can be assured. A log of which drug was taken at what time is kept to avoid over-medication.

Telemedicine system deployed in conjunction with medicine consumption log not only helps patients get their medications easily and virtually risk free, it also helps inventory up to date at all times. The consumption pattern of certain drugs can also provide information for disease control as shown in Fig. 3. This is particularly important when keeping stock for defending against spreading pandemics, an example of such is the spread of influenza virus [12]. The stock level of seasonal flu vaccine and related drugs must be closely monitored to ensure that at least the most high risk population gets adequate supply. With a communication link between manufacturers and pharmacies, it can serve as a clinical drug order processing system that can initiate the movement of stock to high demand areas swiftly when the rate of dispatch becomes abnormally high in certain areas.

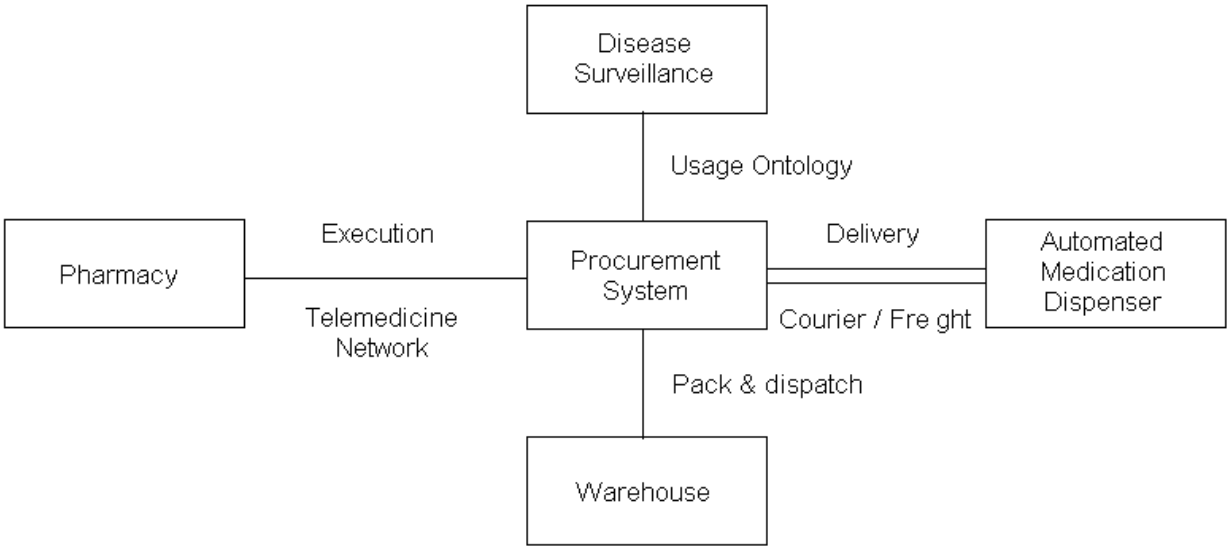

Fig. 3 Medication management

The load data is processed using a fuzzy neural controller [12]. Information about the actual condition of the patient is analyzed and forwarded for electronic patient record (EPR) update. Any sign of abnormality triggers an alert through the assessment framework shown in Fig. 4. A prognostics and health management approach is adopted to assess the actual condition of the patient and detect any signs of abnormal health degradation [13]. A description of the patient's state of health will be generated through an associative classification algorithm [14] and the measurement of various signs will be used to update the EPR. Physiological signs are logged as a sequence of events, where events are tracked by both ontology generation and health personalization for a user. Health ontology is generated through data collection when the abnormality is detected. The context can also be downloaded for analysis [15].

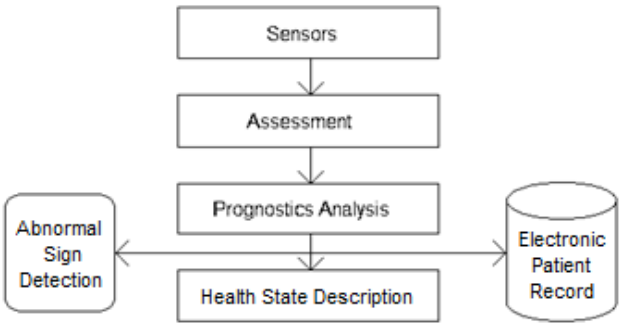

Fig. 4 Health assessment framework

IV. Case Study

The system is capable of serving a user with dementia who is recovering at home after an operation. This particular system consists of both permanently installed sensors and equipment that is installed for post-surgical rehabilitation. The system performance is plotted in Fig. 5. One key design feature is the incorporation of smart clothing technology where a body area network[1], as shown in Fig. 6 where various wireless sensors are adhered, is set up with biosensors embedded on clothing that monitor parameters such as heart rate, blood pressure and body temperature. Different features can be added based on individual needs. In this example, sensors can monitor a range of signs including blood sugar level[2], accelerometers to detect movement and physical activities[3], ECG[4], ambient environment[5]; so that various signs related to the user's health state can be collected and analyzed through processing of various physiological signals [16]. This example shows the following permanently available features with a central control console enabling smart home technology:

- Thermometer to regulate ambient temperature
- Smoke detector for fire hazard
- Gas sensor to ensure safe use of stove and reminds user of activation
- Electronic medication to ensure prescribed medicines are taken on time and first aid kit with reminders for replenishment and alert for expiry[6]

Any abnormal reading that may indicate a potential hazard will be sent to the caregiver for necessary action[7].

The wireless network performance plotted in Fig. 7 shows that sensors with greater mobility suffers significantly lower signal-to-noise ratio (SNR) performance. The patient's BAN has an uncoded E_b/N_o deficiency of nearly 1.2 compared to the reference simulated 3G network at BER of 10^{-5}. The wrist-worn integrated optical sensor for near-infrared blood glucose measurement with comparable condition as described in [17] has a 0.4 E_b/N_o deficiency. Finally, Fig. 7 simulates the interference that adds to the noise floor where it maintains below 6 dB when the patient is within 3 m (10 ft) from the mobile phone that continually collects the signals for analysis. This simulation does not take into consideration any physical obstacles that may affect the signal path [18].

* Subscripts 1-7 correspond to the seven parameters in Fig. 5

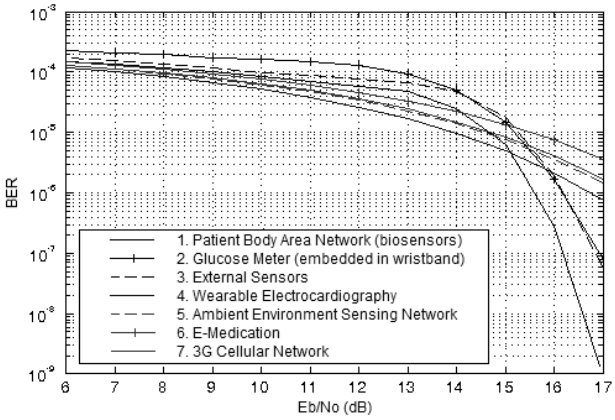

Fig. 5 System performance evaluation

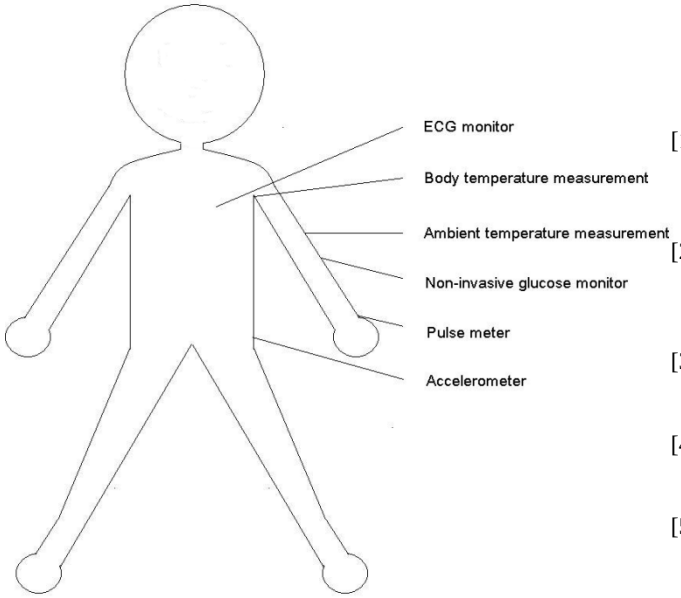

Fig. 6 All-round monitoring with wireless sensors worn by the patient

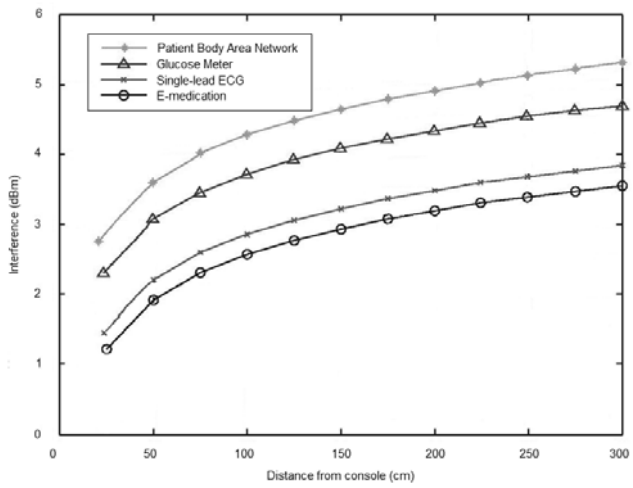

Fig. 7 Simulated performance degradation over distance away from console

V. Conclusions

Senior citizens living alone will benefit most from the personalized assistive care system with advice and assistance readily available. The system also extends to care providers and those who may live with other family members while spending a significant amount of time alone during the day. The system also takes care of users with cognitive impairments. Elderly care has been an important topic to address in many metropolitan cities where the impact of aging population takes up a significant amount of national healthcare resources. The information collected from the personalized medication system not only assists with patients with chronic disease, prognostics surveillance can be applied for disease prediction and control.

References

[1] N. Ansari, B. Fong and Y. T. Zhang, “Wireless Technology Advances and Challenges for Telemedicine”, *IEEE Communications Magazine*, vol. 44, no. 4, pp. 39-40, 2006.

[2] J. P. Ediger, J. R. Walker, L. Graff, et. Al., “Predictors of Medication Adherence in Inflammatory Bowel Disease”, *The American Journal of Gastroenterology*, vol. 102, pp. 1417–1426, 2007.

[3] B. Fong, A. C. M. Fong and C. K. Li, *Telemedicine Technologies: Information Technologies for Medicine*, Wiley, ISBN: 047074569X, 2011.

[4] X. F. Teng, Y. T. Zhang, C. C. Y. Poon and P. Bonato, “Wearable Medical Systems for p-Health”, *IEEE Reviews in Biomedical Engineering*, vol. 1, pp. 62-74, 2008.

[5] M. Moore Jackson and R. Mappus, “Neural Control Interfaces”, *Human-Computer Interaction Series- Part 1*, Springer, pp. 21-33, 2010.

[6] J. L.Gonzalez-Guillaumin, D. C. Sadowski, K. V. I. Kaler, and M. P. Mintchev, "Ingestible Capsule for Impedance and pH Monitoring in the Esophagus", *IEEE Transactions on Biomedical Engineering*, vol. 54, no. 12, pp. 2231 - 2236, 2006.

[7] B. Fong and J. Westerink, “Affective Computing in Consumer Electronics”, *IEEE Transactions on Affective Computing*, vol. 3, no. 2, pp. 129-131, 2012.

[8] R. C. Brownson, D. Haire-Joshu and D. A. Luke, "A Review of Environmental and Policy Approaches in the Prevention of Chronic Diseases", *Annual Review of Public Health*, vol. 27, pp. 341-370, 2006.

[9] G. J. Pottie and W. J. Kaiser, “Wireless integrated network sensors”, *Communications of the ACM*, vol. 43, no. 5, May 2000.

[10] K. F. Tsang, H. Y. Tung and K. L. Lam, *ZigBee: From Basics to Designs and Applications*, Pearson, ISBN: 9810680430, 2009.

[11] B. Ali, M. Ramdane and S. Zaidi., “An Indexing Approach based on a Hybrid Model of Terminology-extraction using a Filtering by Elimination Terms”, *Journal of Advances in Information Technology*, vol. 4, no. 1, pp. 20-21, 2013.

[12] K. S. Li, Y. Guan, J. Wang, et. Al., "Genesis of a highly pathogenic and potentially pandemic H5N1 influenza virus in eastern Asia", *Nature*, vol. 430, pp. 209-213, 2004.

[13] D. Lau and B. Fong, “Prognostics and Health Management”, *Microelectronics Reliability*, vol. 51, no. 2, pp. 251-254, 2011.

[14] T. D. Do, S. C. Hui, A. C. M. Fong and B. Fong, "Associative Classification With Artificial Immune System", *IEEE Transactions on Evolutionary Computation*, vol. 13, no. 2, pp. 217-228, 2009.
[15] P. Y. Lee, S. C. Hui and A. C. M. Fong, "A structural and content-based analysis for Web filtering", *Internet Research*, vol. 13, no. 1, pp.27-37, 2003.
[16] Y. Li, C. C. Y. Poon and Y. T. Zhang, "Analog Integrated Circuits Design for Processing Physiological Signals", *IEEE Reviews in Biomedical Engineering*, vol. 3, pp. 93 – 105, 2010.
[17] M. Z. Poh, N. C. Swenson and R. W. Picard, "A Wearable Sensor for Unobtrusive, Long-Term Assessment of Electrodermal Activity", *IEEE Transactions on Biomedical Engineering*, vol. 57, no. 5, pp. 1243-1252, 2010.
[18] Y. Zhang, N. Ansari and H. Tsunoda, "Wireless telemedicine services over integrated IEEE 802.11/WLAN and IEEE 802.16/WiMAX networks", *IEEE Wireless Communications*, vol. 17, no. 1, pp. 30-36, 2010.