Health Social Networks
Using low-cost RF devices

The total budget for health care in the United States rose to 2.26 trillion dollars in 2007, which translates to $7,439 per inhabitant, and it has been predicted that this trend will continue to rise. Even at this cost, the United States has only the 45th highest life expectancy worldwide, according to the CIA World Fact Book (2007 estimates). As the cost of health care continues to rise, the government struggles to find new, more efficient ways to treat and prevent diseases. A proposed solution described in this article relies on significant use of low-cost, low-power RF devices.

Introduction
According to the World Health Organization, environment is responsible for as much as 24 percent of the total cases of preventable diseases. This means that thousands of people around the world die prematurely because of unhealthy environmental conditions, such as air and water pollution. According to the US Department of Health and Human Services (HHS), personal actions, such as smoking and lack of exercise, along with poor food quality can also lead to unhealthy conditions. Millions of dollars are spent each year treating illnesses that are direct results of these risk factors. By monitoring the risk factors on a regular basis, the government would be able to prevent some diseases and treat others before they developed into more serious and expensive medical conditions.

HHS also states that some of the most common human health risk factors are related to how often people eat in restaurants[1][2], which also can expose them to higher levels of cigarette smoke. Meals eaten outside of the home tend to contain more fat and calories and are served in larger portions. These excesses can lead to serious conditions, such as obesity and type 2 diabetes, which, in turn, can lead to heart disease. In the U.S. alone, a person dies of heart disease every 34 seconds[3]. As of yet there is no completely accurate and affordable way to monitor these different risk factors and the effects they have on the human body.

Cigarette smoke is known to contribute to serious health conditions, including heart disease, respiratory disease and several types of cancer, but there are many other air contaminants that can have adverse effects on human health. People are often unknowingly exposed to these pollutants and over time the toxins from the pollutants can accumulate within the human body.

If all of these risk factors could be monitored and the data compiled, many of the illnesses associated with them could be prevented or even eliminated. One of the main problems in implementing a solution lies in the complexity of monitoring all of these risk factors in the context of a single individual and processing the information in an efficient way. If this could be done, possibly life-threatening diseases could be identified before they reached a critical stage, and preventative measures could be taken to avoid costly health care treatments.

The main risk factors to human health are well-known, but the programs currently in place to gather information about these threats are very expensive and are not adequately accessible to the population. Governments spend large amounts of money each year on health care in an effort to research, treat and prevent diseases caused by these risk factors, but because the risk factors are not effectively monitored, improvements are slow to come. Overall health care could be improved if humans and the risk factors they encounter on a day-to-day basis could be accurately monitored at a low cost.

Wireless sensing and monitoring solution
By monitoring the number of times that a person eats at a restaurant and the amount of exercise performed, and by using exhaust gas sensors and air contaminants sensors to detect air pollution, it’s possible to predict the likelihood of individuals developing certain diseases. Preventative treatments can be administered before these illnesses develop into more serious and more expensive infirmities.
With the current advancements in modern low-power technology, smart wireless devices, such as the Freescale MC13224V Platform-in-Package™ (PIP) with an integrated ARM7™ based microcontroller (MCU), can be used to develop and implement cost-effective and efficient wireless monitoring solutions.

The monitoring solution is based on the fact that a person’s environment can be measured or cataloged at any given moment. This is achievable if low-power wireless sensors are strategically placed to monitor the subjects as much as possible while they go about their daily routines. In order to successfully accomplish this, two types of wireless sensor nodes must be used: static and mobile. It is logical to assume that most people spend the majority of their time either at home, at work or in some cases, in transport between the two. Therefore, a static sensor node could be placed in an individual's workplace, home and mode of transportation to collect information about the quality of the environment, such as cigarette smoke, combustion gases and hazardous chemicals. A restaurant static node could be employed that would simply alert the mobile node that the owner had eaten in a restaurant. This system won’t record how many calories a person has eaten or if the food had sufficient quality, but as stated by HHS, this is enough information to give a general idea of a person’s alimentary habits, which is what the application needs.

There are many ways this kind of solution could monitor an individual. For instance, it could compile the amount of time spent in the restaurant, or a signal could be sent to the individual’s mobile node when the meal had been paid for. Figure 2 illustrates the hardware requirements.

The IEEE® 802.15.4 wireless communications protocol works perfectly for this implementation. This protocol supports a low-power network at moderate data rates (about 250 Kbps), and with proper implementation, can provide years of battery life from a lithium coin cell battery when used in an ultra-low-duty-cycle communications system. The protocol’s IEEE 802.15.4 MAC layer by itself isn’t enough, but a networking layer such as the ZigBee® wireless can provide all the necessary networking services. The proposed stack is shown in Figure 3.
Because of its constraints on power consumption, the static node would have to be a Zigbee coordinator whose main role would be to start and administer the network. The Zigbee layer of the stack would control the administration of the health data by performing different duties, such as timing, incoming data, generating the frame for this layer and processing the recently received data. Because of the application’s orientation, transfers could be performed in period ranges greater than ten seconds. A general frame from a static node should contain such information as the number ID of the monitored person, information about the quality of the environment and if that person has a special message such as a health alert.

Placing sensors in highly frequented locations would not be enough to obtain a complete and accurate data set for each individual. A personal mobile sensor node would be required to collect data related to exercise. This mobile node would be equipped with an accelerometer, such as the 3-axis MMA7361L low-g acceleration sensor from Freescale, giving it the ability to measure the user's level of physical activity. Using simple algorithms, like those mentioned in the Human Fall Detection Using 3-axis Accelerometer reference manual (MMA7260QHFDRM, downloadable from www.freescale.com), specific movements, such as running, walking and jumping, could be recorded. Custom features could also be added to allow the mobile node to log specific information, such as temperature or glucose levels for individuals with special requirements. The mobile node could also have the ability to recognize patterns that indicate an urgent state of medical crisis. It would be able to alert the individual of the critical state of health and he or she would be able to seek immediate medical attention.

A general frame from a mobile node should have the person's ID and statistical information, such as the risk factor measurements gathered in a single day, and special information if that person requires another kind of monitoring.

Both mobile and static nodes would have to be part of the wireless network. They could use the same data transfer software and hardware, which includes the IEEE 802.15.4 wireless protocol and an MCU. Once again, the proposed controller would be the MC13224V PIP because it features a high-performance ARM7 controller and all the IEEE 802.15.4 radio hardware. The design of this mobile node could also include a flexible sensor port capable of supporting three or more different sensors in addition to the accelerometer in order to add custom features for special patients. In this case the mobile node would be a Zigbee end device.

Since the device is mobile and battery powered, energy consumption is very important. The MCU is critical in managing energy consumption, and if a 0.1 percent TX/RX duty cycle is used, the average consumption could be as low as 40 uA.

Using regular AA rechargeable batteries, this would mean years between charges.

Because the mobile nodes would be low power, they couldn’t transmit information over long distances. It would first have to communicate with the static node via the IEEE 802.15.4 wireless protocol, and then the static node would be able to transmit the information to the diagnostic center through the Internet or cellular data network such as the general packet radio service (GPRS). If the Internet is not available, GPRS could send the information via short message service (SMS), providing additional infrastructure flexibility and making it a cost-effective solution for non-Internet data transfers.

The diagnostic center could be programmed to recognize specific patterns of risk factors and would indicate the findings to a specialist if a potential health risk was identified. The specialist would receive the data early enough to be able to analyze it and send a message to the patient in a timely manner.

The system could be flexible enough to facilitate outsourcing overnight data to another location to avoid night shifts. Because each person would have a unique ID, the data could be quickly accessed and reviewed by a specialist who would record the individual’s data and determine if a potential health risk was present. If this were the case, the diagnostic center would communicate back to the static node which would then send an indicator to the individual's mobile sensor via wireless technology. Figure 5 displays the logical path of communication between the sensor nodes and the diagnostic center.

The process of generating a physical health network would be very simple (see Figure 6). A static node would first create a network by itself with no other nodes attached. Then, other static nodes could be added to create a larger wireless network. Once this was accomplished, every new mobile node would join the network by sending a beacon request. Every static node would answer the request, allowing the mobile node to detect the network. Each mobile node would decide which static node to join depending on the quality of the signal. Once the decision was made, an association request would be sent to join that
particular static node. Because every member of the network shares the same environmental conditions, that data would be sent as a broadcast to all members. The static node would also control sending messages to specific mobile nodes but only when the diagnostic center determines that there is a potential risk for a particular mobile node.

Theoretically, a maximum of 65,536 mobile nodes could be connected to a single static node. Because several static nodes can be expected to be placed in the network, there are no real topology issues.

Using low-cost, low-power devices to monitor the most common risk factors would provide a health care agency with a realistic and cost-effective technological platform to provide critical data for preventive and effective medical treatment, particularly for high-risk individuals. The low-power, high-performance MC13224V PIP and its implementation of the IEEE 802.15.4 protocol would be the device of choice for this application, providing a high return on investment to the total health care budget. And, thanks to the minimum number of extra components required, it would still provide huge customization capabilities to suit the different application variants.

**Conclusion**

This type of wireless sensing and monitoring system could help reduce health care expenses and increase individual life expectancy. In addition, the system itself would be a one-time investment, and the devices, once installed, would require little maintenance other than periodic recharging and sensor trimming. On the whole, the health care network could provide preemptive health checks that would reduce the time and economic resources invested in health care while improving the overall quality of life.

**References**

