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Telemonitoring Solutions
A new approach to better patient health

Aging population and chronic degenerative diseases

The aging of the world's population is a fact in our society. Baby boomers are now becoming our senior citizens, fueling the growth of the aged population. To accommodate this dramatic population shift, drastic changes in our health systems are necessary. Today, these changes include new therapies and early diagnostic tools with advanced sensor and microcontroller (MCU) technologies that are accessible by the general population.

Non-communicable diseases accounted for almost 50 percent of the global disease burden, according to the World Health Organization (WHO). Among these, the highest incidences are for chronic degenerative diseases, such as cardiovascular disease, in which hypertension plays a large part (600 million people worldwide), and metabolic diseases like diabetes (90 million people).

A significant issue with chronic degenerative and metabolic diseases is that a patient needs to control the homeostasis or physiological balance for long periods of time, which means developing new habits in their daily lives, like taking blood pressure or glucose measurements. These can be annoying and disruptive tasks that can be forgotten or even purposefully avoided, providing no help to the physician on how the treatment is improving the patient's health.

Chronic diseases such as diabetes and hypertension are becoming worldwide public health problems due to the lack of symptom control and the knowledge to recognize the body's way of letting us know that something is not going well. The prevention and early treatment of the sudden (acute) complications of these kinds of pathologies is vital for reducing any deaths they cause.

In addition, medical costs can become an issue, because long-term pathologies can become a financial burden for the patient. For this reason, it's very important for insurance companies to be aware of how technology and new medical devices can prevent acute complications, since they count for a large number of reimbursement applications.

Enabling physicians or health care providers to access patient monitoring data at any time is one way that doctors can improve patient treatment. For instance, if something is not normal, a monitoring system can start sending data to whoever would make the appropriate diagnostic decisions to avoid a complication. Also, since some problems can be silent complications, a systematic monitoring of vital signs and other readings can prevent further complications.

Telehealth monitoring systems can prevent the acute complications of chronic degenerative diseases

Telehealth solutions directly address the chronic degenerative diseases problem. Intelligent systems that acquire data from endpoint devices, such as blood glucose meters (glucometers), heart rate monitors, blood pressure monitors, digital scales, etc., can advise patients on the proper time for taking new measurements or medication. The telehealth system must also ensure that the data is analyzed and securely transmitted to the health care provider.

A telehealth monitoring system collects, analyzes and monitors a patient's vital signs data and uses telecommunications technology to transfer this information to a remote health provider for further analysis, which can include tracking the evolution of a chronic degenerative disease or monitoring post-operative treatment. This type of telehealth system can be customized by attaching different data acquisition peripherals, such as blood pressure meters, glucometers, pulse oximeters (for measuring oxygen saturation levels in the blood), digital scales and thermometers, among others.

One of the many advantages of this kind of system is the immediate transmission of the patient's vital signs data to a remote medical center. For this purpose, different types of networks can be used, such as wired or wireless Ethernet through a secure virtual private network (VPN) connection or a general packet radio service (GPRS) network for patients living in rural areas without access to a broadband network.

General Telehealth Application Block Diagram

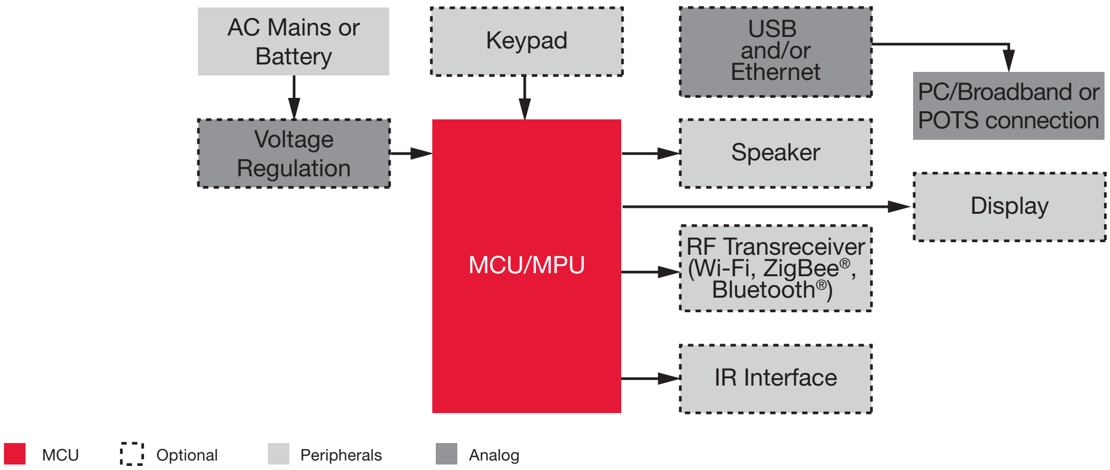

Figure 1

Telehealth Network

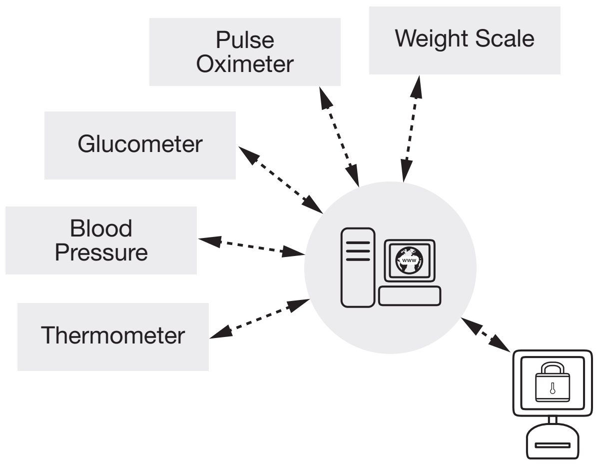

Figure 2

The telehealth monitoring systems are primarily designed for a home-medical environment where a rich graphical user interface (GUI) can help guide patients through the process of measuring vital signs. This article provides an overview of how a telehealth monitoring system can be implemented using Freescale's Solution Enablement Layer to provide portability across Freescale's 32-bit processor portfolio.

It is critical that telehealth devices should be personalized to address a particular disease or condition and cater to the patient's specific needs. This is a challenge for both system designers and OEMs. Scalability, low power consumption and a rich peripheral set are key design considerations for telehealth system design engineers. This article discusses the medical risks of hypertension and diabetes and describes telehealth solutions for patients suffering from these conditions.

Portable Wireless Telehealth System

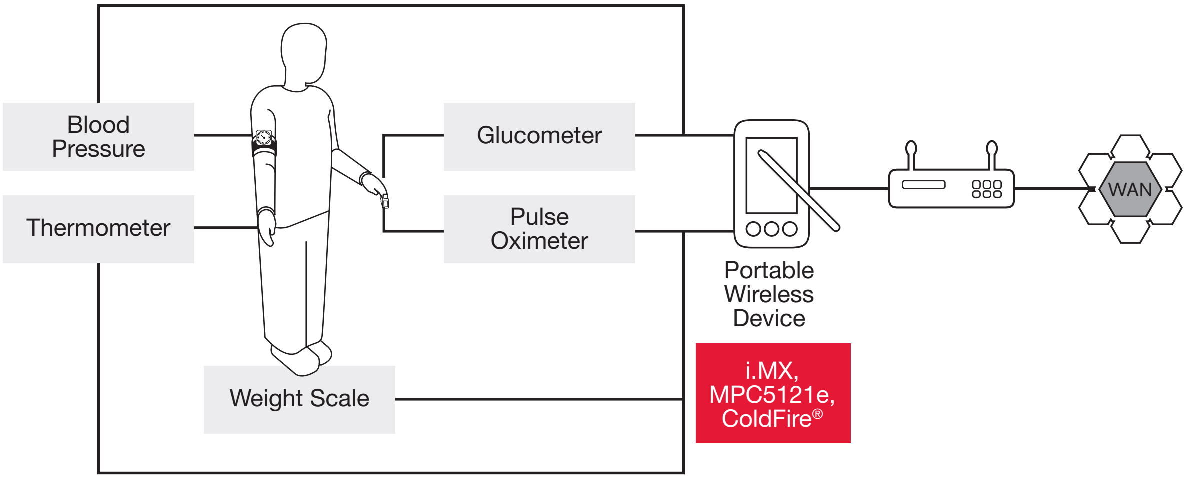

Figure 3

Hypertension and diabetes: medical standards for prevention, detection and evaluation

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) has published some important guidelines regarding hypertension prevention and management. The following are key points taken from the report:

- In persons older than 50 years, systolic blood pressure greater than 140 mmHg is a much more important cardiovascular disease (CVD) risk factor than diastolic blood pressure.
- The risk of CVD, beginning at 115/75 mmHg, doubles with each increment of 20/10 mmHg. Individuals who are normotensive at age 55 have a 90 percent lifetime risk for developing hypertension.
- Individuals with a systolic blood pressure of 120 139mmHg or a diastolic blood pressure of 80–89 mmHg should be considered as prehypertensive and require health-promoting lifestyle modifications to prevent CVD.
- Thiazide-type diuretics should be used in drug treatments for most patients with uncomplicated hypertension, either alone or combined with drugs from other classes. Certain high-risk conditions are compelling indications for the initial use of other antihypertensive drug classes (angiotensin converting enzyme inhibitors, angiotensin receptor blockers, beta-blockers, calcium channel blockers).
- Most patients with hypertension will require two or more antihypertensive medications to achieve goal blood pressure (<140/90 mmHg or <130/80 mmHg for patients with diabetes or chronic kidney disease).
- If the blood pressure is >20/10 mmHg above goal blood pressure, consideration should be given to initiating therapy with two agents, one of which usually should be a thiazide-type diuretic.
- The most effective therapy prescribed by the most careful clinicians will control hypertension only if patients are motivated. Motivation improves when patients have positive experiences with, and trust in, the clinician. Empathy builds trust and is a potent motivator.

Acute complications of hypertension

The most life threatening acute complications are hypertensive urgency and emergency. Hypertensive emergency is characterized by a severe elevation in blood pressure, above 180/120 mmHg, complicated by target organ dysfunction, such as cerebrovascular events, pulmonary edema, coronary ischemia or renal failure among others. Hypertensive urgency does not include progressive target organ dysfunction.

Distinguishing between hypertensive emergency and urgency is crucial to appropriate management. Diagnosis could be done easily by telehealth devices that already have data from the patient's history, including medications the patient is taking. It helps as well to monitor other signs and symptoms that the patient could be experiencing that do not relate to the pathology, such as those in the following table.

Signs and Symptoms of Hypertensive Crises, Urgencies and Emergencies

Signs and Symptoms	Hypertensive Crises, %	Urgencies, %	Emergencies, %	P
Headache	17.0	22.0	3.0	<.001
Epistaxis	13.0	17.0	0.0	<.001
Chest pain	13.0	9.0	27.0	<.005
Dyspnea	12.0	9.0	22.0	<.02
Faintness	10.0	10.0	10.0	NS
Psychomotor agitation	7.0	10.0	0.0	<.004
Neurological deficit	7.0	3.0	21.0	<.001
Vertigo	6.5	7.0	3.0	NS
Paresthesia	6.5	6.0	8.0	NS
Vomitus	2.5	2.0	3.0	NS
Arrhythmia	1.0	6.0	0.0	<.04
Other	5.6	2.0	3.0	NS

Hypertensive Urgencies and Emergencies. Prevalence and Clinical Presentation. Bruno Zampaglione; Claudio Pascale; Marco Marchisio; Paolo Cavallo-Perin

Table 1

Hypertensive urgency is managed using oral antihypertensive drugs as an outpatient or in a same-day observational setting. Hypertensive emergency requires the patient to be taken to an intensive care unit with parenteral medication. For treating hypertensive urgency, the goal is to reduce mean arterial pressure (MAP) by no more than 25 percent in the first 24 hours with oral therapy.

$$\text{MAP} \simeq \text{DP} + \frac{1}{3}(\text{SP}-\text{DP})$$

In a hypertensive emergency, MAP should be reduced by 10 percent during the first hour and an additional 15 percent in the following two to three hours. It's clear to see that automating the data collection under these circumstances is vitally important for the physician to accurately manage this complication.

Diabetes

In diabetics, poorly controlled glucose levels could lead to vascular complications, such as arterial microthromboses, retinopathy, nephropathy and neuropathy. These conditions are primarily caused by superoxide production, the activation of protein kinase C, serum glycosylation and the formation of glycation end products.

Acute complications of diabetes

The most common acute diabetic complication is hypoglycemia (very low blood glucose levels), which can result when patients are concerned about high levels of glucose (hyperglycemia) and over compensate with too much insulin. Hyperglycemia is primarily responsible for chronic complications like diabetic retinopathy, nephropathy, neuropathies, infection and others.

Strict control of glucose is inadvisable in some patients, such as those with short life expectancy, hypoglycemic symptom unawareness or those who cannot communicate the symptoms, like young children. However, by using telehealth solutions with powerful closed loop systems in which glucometers and insulin pumps are merged together, these kinds of situations can be avoided.

One of the most common causes of hypoglycemia in elderly patients is an overdose of antiglycemic drugs. Sometimes they forget they have already taken their dosage and by mistake take another dose of the drugs.

Freescale enables technologies for avoiding acute complications of chronic degenerative and metabolic diseases

Solution Enablement Layer

The Freescale Solution Enablement Layer (SEL)[1] is an embedded software platform running with standard operating systems, such as Linux and uCLinux, to provide application framework capabilities and abstracted hardware drivers (called services). The SEL is designed to support a compile-and-deploy model of software reusability across a range of Freescale 32-bit processors.

The SEL service is the primary abstraction mechanism designed to allow the partitioning of applications into hardware-specific software components. Since services can be written for specific hardware, the application source code can have control and consistent behavior without being tied to a specific processor. Moving from one platform to another becomes as simple as partially re-implementing the service for the new hardware device. Moreover, services are RTOS-agnostic and can be shared by multiple applications. Services are designed to be reusable between applications. In fact, Freescale and third parties can provide suites of services that eliminate the redundant portions of software solutions while still getting the most from specific processor capabilities.

Application frameworks and SEL services are the primary elements of the SEL technology.

- **Application frameworks** define prevalidated application frameworks that exist for rapid prototyping and application development. Most application frameworks are suites of C++ classes designed to interact and define consistent application behavior and look and feel and often implement a rich user interface.
- **SEL services** are application partitioning mechanisms available for partitioning software components from the underlying hardware design, so that applications need only be recompiled to migrate from one platform (HW and RTOS) to another.

Conceptually, the SEL is an extension of the operating system running on the embedded processor that allows another level of application abstraction. SEL services are therefore application subcomponents that are not operating system-specific and can be shared.

SEL services

SEL services are central components in a software solution's implementation. As applications begin to use the SEL, they can start by abstracting only a single service for a particularly complex piece of hardware-specific code while the rest of the application directly calls the operating system. Over time, more and more of the functionality can be divided into services, resulting in the application code becoming more and more abstracted from the hardware without losing any of the underlying hardware functionality. This gradual process allows users to convert to SEL over the life of one or more projects.

SEL services properties

- SEL services insulate the application from both OS and HW differences and are dynamically loaded at runtime
- SEL service interface directly useable from within an application or the command line
- SEL extended services may derive functionality based on existing SEL services

Telehealth monitoring system services

Working down from a software solution through a hardware implementation in a telehealth monitoring system, developers want to write application code that is easy to migrate among hardware devices and RTOS platforms. The SEL allows applications to be segmented to:

- Define the GUIs independent of SEL services
  - Main control with personalized items for vital signs on patient GUI
  - Blood pressure with symptoms for acute complications GUI
  - Glucometer with symptoms for acute complications and prevention of double intake of dosage GUI
  - Pulse oximeter for chronic obstructive pulmonary disease GUI

Medical SEL Services

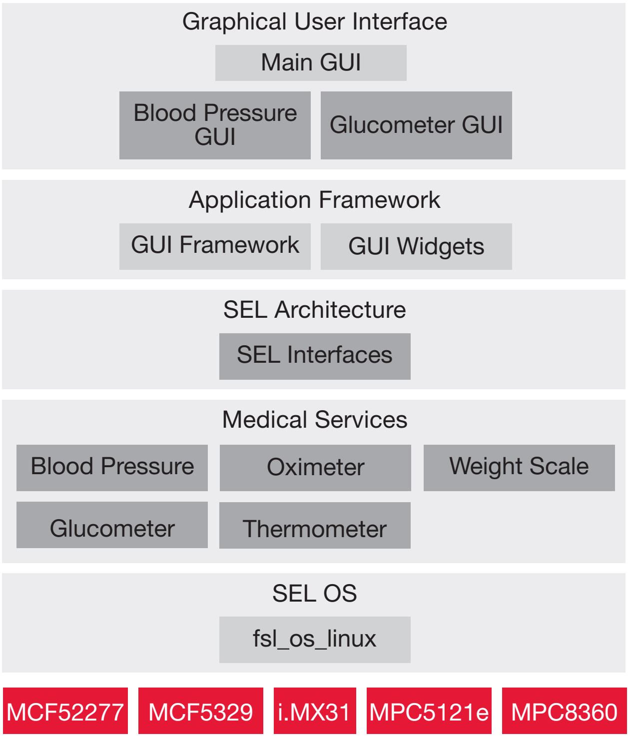

Figure 4

Medical SEL Services in a MCF5329 ColdFire Processor

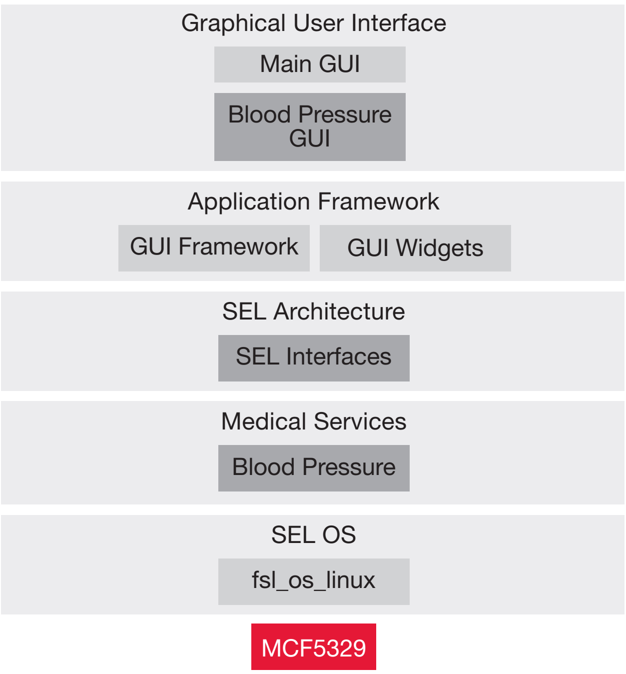

Figure 5

- Define application services that are HW- or RTOS-independent, such that re-implementing part of the service allows the user to easily migrate through the 32-bit processor portfolio
  - Blood pressure service (systolic, diastolic and mean arterial pressure)
  - Glucometer service
  - Pulse oximeter service
  - Thermometer service (infectious disease complications)
  - Digital weight scale service (for monitoring water retained in patients with congestive heart failure)

Following that software partition, a telemonitoring system application could have multiple services running in a high-end processor, such as Freescale's i.MX, MPC51xx or ColdFire® processor, or the application might be tailored to implement a couple of services in a low-end processor. Figure 4 illustrates a complete telemonitoring system using the medical services suite.

Conclusion

Modern society faces public health issues due to the rapidly aging population and their pathologies' demographics. This means providing systems that can remotely monitor vital signs and drug intakes to help avoid acute complications that result in higher costs for patients admitted to a hospital ER facility.

To address these issues, Freescale offers medical equipment designers and OEMs hardware tools and a new software platform (SEL) that enables concurrent software and hardware development and allows hardware designers to deliver their solutions to market faster.

Reusing SEL services and spanning their usage across the 32-bit processor portfolio enables accurate and rapid development of telehealth applications that create a virtual bridge between doctor and patient.

References

[1] Solution Enablement Layer Architecture V1.0 Benedek Aaron, Hemstreet Greg

José Fernández Villaseñor is a medical doctor and electrical engineer who combines his work at Freescale Semiconductor as a medical product marketer and his work as a hospital physician. He has more than eight years of experience working on automotive, industrial and medical engineering systems and applications as well as semiconductor product development. He is currently part of Freescale's Microcontroller Solutions Group. Jesus Gaytan is the software lead for Freescale's Extensible Software Platform team in Guadalajara and has been with the company since 2006. He holds a bachelor's degree in computer science.