# WIRELESS TELEMEDICINE AND SERVICE LEVEL MANAGEMENT ARCHITECTURE SPECIFICATION

Cristina Miyata, Tereza Cristina Carvalho
*Department of Electrical Engineering, University of Sao Paulo, Sao Paulo, Brazil*

Stewart Russell, Akira Kawaguchi
*New York Center for Biomedical Engineering, City College of New York, New York, USA*

Keywords: Wireless Telemedicine, Service Level Management, RM-ODP

Abstract: Wireless telemedicine is a new and evolving area in medical and health care systems, exploiting new developments in mobile telecommunication and multimedia technologies and their integration into new mobile health care delivery systems. A growing body of researchers and manufacturers are working to develop a new generation of wireless technology applications for the medical field. In industry and clinical practice, it is common to outsource services from non-core departments, such as Information Technology (IT) and financial support. Overall business performance depends on these outsourced services, therefore a contractual guarantee of outsourced service performance must be developed, which is then monitored by a Service Level Management (SLM) process. A rigorous approach is needed to specify SLM system architectures that are scalable, flexible, reliable and secure. This paper will discuss the establishment of architecture suitable for the evaluation and measurement of quality of services (QoS) for wireless telemedicine applications. We consider a case-study of a wireless diabetes information management system. The overall methodology and a stepwise specification approach based on the reference model for Open Distributed Processing (RM-ODP) is presented.

## 1 INTRODUCTION

Mobile computing, now a mature and established field, is becoming the dominant computing paradigm (Myers B.A. et al., 2003). The application of this fast developing information technology in heath-care industry will also bring promising economic and technology contribution. As the healthcare industry's transition from paper to electronic medical records continues, another technological revolution is taking place in hospital, clinics, and practitioner's offices. Healthcare delivery itself is being increasingly mobilized through the use of wireless technologies.

Telemedicine is the use of telecommunications to provide medical information and services. Applications can be tailored to meet a need for interactive communication, real-time biometric data transfer, database management, information processing, or some combination thereof (Lin, J.C., 1999) (Tacharka, S. et al., 2001). Providing caregivers real-time access to accurate patient data (clinical histories, treatments, medications, tests, lab results, insurance information) has the potential to reduce medical errors, increase data accuracy, increase efficiency of healthcare personnel, and improve both clinical care, and patient self-care (de Sonnaville, J.J. et al., 1997)(Fund M.M., 1999).

Wireless telemedicine is a new and evolving area in medicine and healthcare systems. It involves the use of a wide array of mobile telecommunication and multimedia technologies and their integration for new mobile healthcare delivery systems (Pattichis C.S. et al., 2002). In fact, wireless solutions could be useful at most patient care points, from clinical monitoring, lab result reporting and medication management, to robotic delivery carts, real-time eligibility verification and claim submission. Examples of wireless applications found in healthcare facilities today are: administration and resource management; wireless pre-hospital care; mobile workstations; medication management; hand-held data assistants; patient monitoring;



Miyata C., Cristina Carvalho T., Russell S. and Kawaguchi A. (2004).
WIRELESS TELEMEDICINE AND SERVICE LEVEL MANAGEMENT ARCHITECTURE SPECIFICATION.
In *Proceedings of the First International Conference on E-Business and Telecommunication Networks*, pages 70-78
DOI: 10.5220/0001399000700078

ambulatory and home patient monitoring (Watchter G., 2004).

As current mobile computing limitations are properly studied and addressed, the possibilities for mobile telemedicine applications increase (Chalmers D., 2004). These limitations include: highly variable communication quality due to environmental variations and handoff, management of data location for efficient access, restrictions of battery life and screen size, connection cost, and increased security risks.

The next generation of mobile communication environment should be able to effectively support high-speed wireless applications with proper security mechanisms and Mobile Quality of Service (QoS), which is the set of performance elements associated with the wireless link, such as channel error rate, and with mobile units, such as Handoff-call Dropping Probability (HDP) and New-call Blocking Probability (NBP) (Hu F. et al., 2004). A summary of important QoS characteristics for wired and wireless telemedicine applications is presented in section 4.

In most industries, including healthcare, outsourcing non-core business services and departments, such as IT (Information Technology) and financial departments, is common practice. Since overall business performance depends on services provided by outsourced departments, the company and the outsource service providers establish a contractual guarantee, or Service Level Agreement (SLA), of outsourced services performance.

In order to guarantee the agreed upon service level, charge customers correctly, and improve the service provider's products, the service provider needs a Service Level Management process (SLM) to articulate the SLA. They also can create products, monitor services, measure their service level, and produce Service Level Reports (SLRs) through the SLM. An SLM system, by measuring the quality of monitored services, allows the service provider, to act before an SLA is violated, and will generate an appropriate SLR. A business enterprise may also employ SLM systems to check the actual delivered service level against SLRs generated by service providers (Lewis L., 1999).

Recent work at University of Sao Paulo (USP) introduced an Open Distributed Processing Reference Model (RM-ODP) based method of SLM system architecture specification for telecommunication service providers (Miyata, C.M. et al., 2003). An overview of this method is presented in section 3.

This paper discusses the establishment of an architecture suitable for the evaluation and measurement of the service quality of wireless telemedicine applications. The goal of this research is to develop a systematic approach to specify SLM system architectures that are scalable, flexible, reliable and secure. A case model considered for the study is a wireless diabetes information management system described in section 2. Recently, several wireless systems for the management of data and reports for self-test blood-glucose meters have been developed (Kawaguchi A. et al., 2003) (Vigersky R.A. et al., 2003). Each of these systems has the potential to reduce the administrative burden to the patient significantly. As promising as these systems are, without appropriate design consideration, interoperability with each other and with existing computer systems will be severely limited. Section 5 presents an ODP reference model based method of SLM system architecture specification for wireless telemedicine systems, as exemplified with the Wireless Blood-glucose Management system.

## 2 WIRELESS BLOOD GLUCOSE MONITORING: A CASE STUDY

The New York Center for Biomedical Engineering and Department of Computer Science at City College of New York (CCNY), in conjunction with the Bayer Corporation, have been developing a system, called the Wireless Blood-glucose Monitoring System (WBgM), that will automatically transfer blood-glucose readings from a hand-held glucose meter to a wireless personal digital assistant, and then to an Internet database (Kawaguchi A. et al., 2003) (Vigersky R.A. et al., 2003). The data will then be represented to the diabetes management team and to the patient in a consistent manner with their needs. Iterative design procedures will result in a product that can lead to more effective management, record keeping, and team development.

A major impediment to the progress towards evidence-based medical practice, shared patient care and resource management in healthcare is the inability to effectively share information across systems and between caregivers. Electronic and paper healthcare records are held in islands of information in independent information systems, each with its own technical culture and view of the healthcare domain. For the need of the public use, system development practice must be based on an enterprise model that encompasses the capabilities required to process medical information by hospital, government, insurance parties, etc.

The objectives of the WBgM system development are (1) to specify a generic and open means for combining healthcare records or dossiers consistently, simply, comprehensibly and securely, to enable the sharing of data between different information systems in different places, and (2) to produce tools and guidelines that can be used in the migration from legacy healthcare systems, as an evolution strategy for a region or Member State, or as an exploitation plan for a healthcare site or commercial company.

The WBgM is essentially a data management system, designed to improve communication between patient and doctor, and encourage participation in self-care. As such, the value added components of the WBgM are not as easy to define as one that is purely technology based. Even with flawless technical performance, the successful implementation of a health care aid must have evaluation criteria based on measurable outcomes to the health or convenience of the user.

## 3 ODP BASED SPECIFICATION METHOD FOR SLM ARCHITECTURE

The RM-ODP based method for SLM system architecture specification introduced by the Polytechnic School of University of Sao Paulo uses TMN network management concepts; TMF definitions of services, service levels and SLM process; ISO/ITU-T concepts related to quality of service; and RM-ODP open and distributed system specification principles.

The method is basically composed by eight phases (Miyata C.M., et al., 2003): (1) Business modelling; (2) Service modelling, (3) Service relevant QoS characteristics identification, (4) QoS and SLA modelling, (5) Proactive monitoring definition; (6) SLRs generation process definition, (7) Accounting management system integration definition, and (8) SLM system architecture definition.

The use of RM-ODP viewpoints (enterprise, information, computational, engineering and technology) organizes the process of specifying SLM system architecture requirements and reduces its complexity. Although the work referred to deals specifically with the specification of SLM systems architectures for telecommunication services providers, the method can be extended and adapted to other service provisioning areas, such as healthcare services.

## 4 QOS IN WIRELESS TELEMEDICINE

The overall satisfaction of users depends on myriad performance elements, all of which must be correctly monitored and evaluated. The collective effect of these performance criteria is termed Quality of Service (QoS). Depending on the service, there are a number of different relevant QoS characteristics, parameters and mechanisms. This section lists important QoS characteristics for wired and wireless telemedicine applications.

In order to guarantee end-to-end QoS in telemedicine solutions, it is necessary to guarantee QoS in all services that comprise the solution: including applications, network infrastructure (wired and wireless) and customer care. QoS related to network performance in IP networks is qualified in terms of latency, jitter, throughput, packet loss, packet error and availability (QoS parameters). Several Internet Engineering Task Force (IETF) groups have been working on standardized approaches (QoS mechanisms) for IP-based QoS technologies.

Next generation wireless and mobile devices will support applications ranging from traditional cellular voice to web browsing and interactive multimedia applications. Efforts have been made to identify new QoS parameters that are exclusive to wireless communications and create Mobile QoS algorithms and mechanisms (Sadeghi, B. et al., 2004). Accordingly, infrastructure and application QoS parameters related to operational performance are: Mean Time To Failure (MTTF), Mean Time To Repair (MTTR) and Mean Time Between Failure (MTBF).

In addition, packet error, packet loss and availability affect the reliability and overall application performance of the telemedicine solution. Multimedia telemedicine applications are sensitive to delay, jitter and throughput. Furthermore, security of patient’s health information and profile must be guaranteed in telemedicine solutions in terms of confidentiality, authentication, data integrity, non-repudiation and access control. Though it is common sense that there is no bullet-proof security solution, security and its risks can be managed. Appropriate security policies and mechanisms—e.g. to choose an appropriate cryptographic scheme and algorithm—must be employed in telemedicine solutions according to the level of security needed (Kawaguchi A. et al., 2003). Performance of many services can’t be measured using objective QoS characteristics. Subjective QoS characteristics usually need end user feedback to be measured. A widely accepted formulation to measure customer satisfaction is the ServQual equation (Parasuraman, A. et al., 1988):

Quality = Perceptions - Expectations

Users judge quality to be satisfactory when their expectations are met. The more their expectations are exceeded, the higher is the perceived service quality. Standards to measure some subjective QoS characteristics such as voice clarity (ex: MOS, PSQM and PAMS) were elaborated. Despite the fact that there is no standard for customer care and helpdesk services performance measurement, several guides provide techniques to obtain customer feedback and analyze collected data (Hill N., 1996) (Vavra T.G. 1997).

# 5 SLM ARCHITECTURE FOR WIRELESS TELEMEDICINE APPLICATIONS

In this section, we present the comprehensive result of the adaptation and application of the SLM system architecture specification, as method mentioned in section 3, to obtain the specification of the architecture of the SLM system that will monitor the quality of the Wireless Blood-glucose Monitoring (WBgM) system.

In order to specify SLM system architectures for wireless telemedicine applications, it is important that professionals with knowledge of business, operations and technology are involved. In this case study, three separate human resource elements must work together in this development, the Diabetes Management Team (DMT), the Health Care Administration Team (HCAT), and the Computer Support Team (CST). Although each organization will differ in the composition of these teams, members of the DMT typically can include the patient, the primary care physician, an endocrinologist, nutritionist, physical therapist, ophthalmologist, cardiologist, and support staff. The HCAT can include office managers, database administrators, accounting personnel, insurance liaisons, and medical ethicists. The CST can include WBgM design, development, technical support teams and data center operations.

## 5.1 Business Modelling

First, it is necessary to obtain a common understanding of the business, services and what goals to achieve with the SLM solution.

The user may input data from his/her meter manually or automatically to a wireless device for upload to a secure cross-platform Internet database. The user may also (1) input service request parameters to view current and historic data on the local device, (2) activate the master Expert System program that runs on the laboratory computer to analyze data, (3) email a report from the Expert system to a recipient doctor's office. The WBgM electronic transactions consist of a simple set of formatted data that represents (a) patient profile such as patient identities, names and contact addresses, (b) biometric data represented with time-stamped blood-glucose reading and coded nutrition characteristics uniformly accepted in the medical practice, and (c) doctor profile similar to patient profile. All the data entries and access to them are coded based on the ANSI SQL standard relational database format.

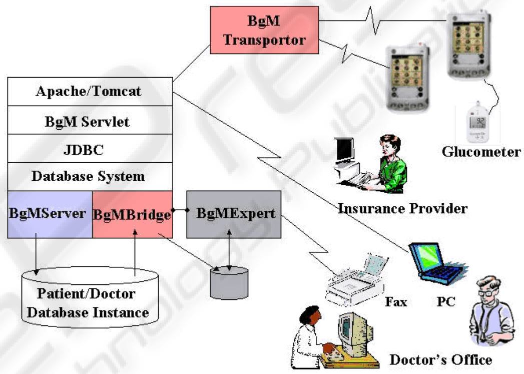


Figure 1: DMT business model

The overall objectives of the DMT are to facilitate the regulation of patient BGL at or near normal levels. Research has shown that the following procedures can help reach this goal:

a) Exchange accurate BGL data between patient and DMT.
b) Increase timeliness and frequency of BGL data exchange.
c) Provide patient interim self-care diagnostic information between office visits.
d) Improve the dynamics of data distribution among members of the DMT.
e) Reduce complexity of equipment connectivity apparatus.
f) Reduce complexity of data analysis software.

The overall objective of the HCAT is to ensure that the WBgM adheres to accepted health care protocol and administrative practices.

WBgM's database architecture allows the registered patient to grant access to her/his profile and blood-glucose readings to a particular set of members of the DMT. The DMT registration is verified by the system administrator. Furthermore, clinical researchers at authorized institutions can access the patient data once given permission from the DMT and patient. This allows the researchers to conduct studies on diabetes across the patients, not bound by a particular doctor or hospital. The certificate method of authentication will build a chain of trust electronically for the clinical studies, and the patient is guaranteed the right to revoke the granted access to the doctors (which in turn revokes associated researcher's access) at any time. The objectives of the HCAT are to:

a) Ensure the security of patient confidential data.
b) Facilitate the addition or removal of members of the DMT.
c) Facilitate the addition or removal of data-access privileges of members of the DMT.
d) Reduce costs associated with diabetes management.
e) Reduce the incidence of fraud and abuse related to patient records.
f) Facilitate inter-institutional data sharing for research purposes.
g) Facilitate compliance with local, state, and federal laws.

The overall objective of the CST is to ensure that industry best practice methods are used. The CST should address the same business objectives listed for the DMT and HCAT above. The specific objectives of the CST are to:

a) Measure services resources utilization and performance
b) Measure service usage time
c) Measure service outage time
d) Deliver usage reports to HCAT
e) Implement new designs and/or configurations based on requests from the DMT and the HCAT

These specific objectives listed above refer to two sets of performance parameters: those of the WBgM system, and those of the CST technical support and development teams. These parameters in turn directly impact the WBgM service level.

In the following sections, an SLM system architecture will be specified that will measure WBgM service level.

## 5.2 Service Modelling

From the business model, it is possible to elaborate a service model. As stated in the previous section, the WBgM service level can be measured by monitoring WBgM system's performance and CST technical support and development teams' performance.

Table 1: WBgM related services resources

| Service | Service Resource |
|---|---|
| WBgM system | WBgM Server application<br>WBgM Expert application<br>WBgM Database system<br>WBgM Apache/Tomcat<br>WBgM Server machine<br>WBgM Expert machine |
| CST helpdesk | Helpdesk system |
| ISP connection | Router |

In order to elaborate an appropriate WBgM services model, it is necessary that CST identify what services that compose the WBgM service needs to be monitored. Table 1 shows a list of services and services resources needed to deliver the CCNY implementation of WBgM.

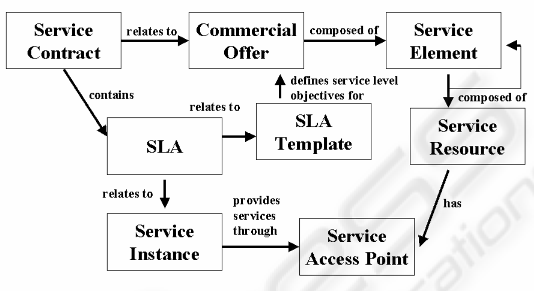


Figure 2: Service model

Figure 2 shows a generic service model. Each service listed in Table 1 is a service element that composes another service element called "WBgM". Each service uses one or more service resources. ISP connection services and outsourced helpdesk services are usually sold with SLAs. It is interesting to the CST that the SLM system also monitors these services to ensure that service providers are respecting the agreed service levels.

## 5.3 QoS characteristics identification

For each service to be monitored, it is possible to identify relevant QoS characteristics to achieve each business objective. DMT and HCAT business objectives identified in the previous section were divided into three areas: communication, clinical utility, and security. This classification is useful for the CST to address these objectives in the WBgM system design. Tables 2 to 4 describe how each of these objectives will be achieved with the CCNY WBgM solution.

Subjective feedback from the DMT, HCAT and the system end users can be used to measure how expectations were fulfilled. DMT, HCAT and CST must decide whether WBgM SLM system will manage end customers feedback or not.

Table 2: Communication objectives

| Objective | How will be achieved |
|---|---|
| Exchange accurate BGL data between patient and DMT | CCNY WBgM solution obtains exact measure of patient. It is also necessary to guarantee the data integrity. |
| Improve the dynamics of data distribution among members of the DMT | WBgM solution with easy GUIs, high availability, efficient technical support and |

| | |
|---|---|
| | 24x7 communication between patients and physicians (ex: leave messages to patients or physicians on the WBgM system or send messages to their email or mobile in case of urgency). |
| Reduce complexity of equipment connectivity apparatus | WBgM solution with easy GUIs (few and simple steps) and apparatus and software configuration. |

Table 3: Clinical utility objectives

| Objective | How will be achieved |
|---|---|
| Increase timeliness and frequency of BGL data exchange | To encourage patients to send their BGL more frequently, the process of sending and measuring BGL must be simple and executable in an acceptable amount of time and cost. |
| Provide interim selfcare diagnostic information to the patient between office visits | BgMExpert module provides patients selfcare diagnostic information and guidelines. |
| Reduce complexity of data analysis software | WBgM solution itself cannot reduce complexity of data analysis software. |
| Reduce costs associated with diabetes management | Patients' quality of live is improved and costs associated with diabetes management will be reduced, because patients are able to have selfcare diagnostic information, contact physicians when needed, the number of patients with hypoglycaemia or other diabetes related complications decreases. |
| Facilitate inter-institutional data sharing for research purposes | Since patient's profile and health information are solely owned by the patient, patients must grant researchers access to his/her information in the WBgM system. Data sharing is also facilitated if WBgM system has open interfaces. |
| Facilitate compliance with local, state, and federal laws | WBgM solution must be designed to comply with existent laws. Solution must be flexible enough to be able to implement new requirements. |

Table 4: Security objectives

| Objective | Security services to be implemented |
|---|---|
| Ensure the security of patient confidential data | Confidentiality, access control, non repudiation, data integrity and authentication |
| Facilitate the addition or removal of members of the DMT | Access control, non repudiation and authentication |
| Facilitate the addition or removal of data-access privileges of members of the DMT | Access control, non repudiation and authentication |
| Reduce the incidence of fraud and abuse related to patient records | Confidentiality, access control, non repudiation, data integrity and authentication |

Table 5: QoS characteristics for CCNY WBgM

| Service Resource | QoS characteristics |
|---|---|
| WBgM Server application | - Availability<br>- Service response time<br>- Number of connected users<br>- User connection time<br>- Number of user operation |
| WBgM Expert application | - Availability<br>- Service response time |
| WBgM Database system | - Availability<br>- Hard disk utilization<br>- Transactions rate |
| WBgM Apache/Tomcat | - Availability<br>- Service response time |
| WBgM Server machine | - Availability<br>- CPU utilization<br>- Hard disk utilization<br>- Memory utilization |
| WBgM Expert machine | - Availability<br>- Service response time |
| Helpdesk system | - Availability<br>- Num of tickets opened<br>- Average time to close a ticket |
| Router | - Availability<br>- CPU utilization<br>- Bandwidth utilization<br>- Memory utilization<br>- Interface errors<br>- Interface discards |

Relevant QoS characteristics to be monitored by the SLM system were listed to achieve CST business objectives (Table 5).

## 5.4 QoS and SLA modelling

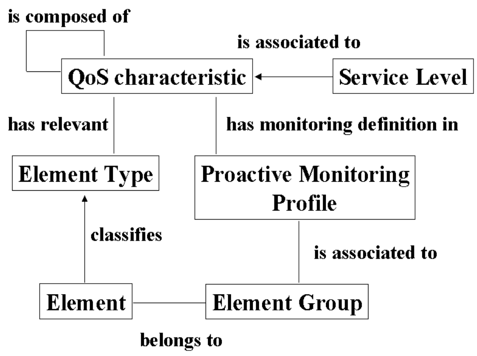


Figure 3: Generic QoS model

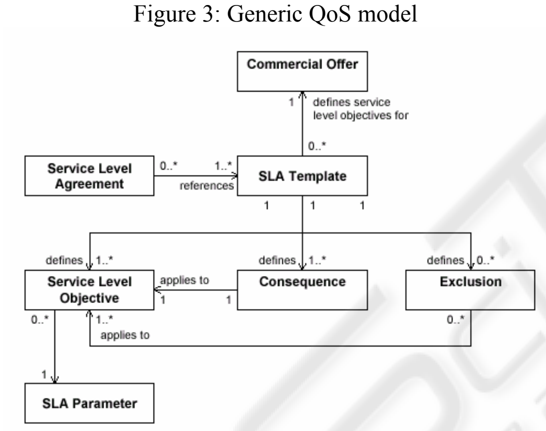


Figure 4: Generic SLA model

The QoS characteristics in terms of specific business goals identified in the previous section will allow two specific models to be generated by the professionals involved. First, the QoS model is shown in Figure 3. It refers to the linkages between services and tuneable quality aspects of the system. In this way, feedback with regard to one or a number of specific service elements may be directly related to a QoS characteristic that may be adjusted to improve user satisfaction. The second, the SLA model shown in Figure 4, represents a configuration that relates services with users. The SLA model is necessary so that the effect on end users of any changes in services resulting from modification of QoS characteristics may be traced.

## 5.5 Monitoring definition

Proceeding from the SLA model, professionals with operational and technology knowledge (HCAT and CST) will then identify appropriate monitoring thresholds for the monitored characteristics. These professionals will then design and develop appropriate monitoring systems that will record and report the status of the key characteristics.

## 5.6 Report generation definition

It is necessary to define what reports and how they will be generated and delivered to users. DMT, HCAT and CST must then define what kind of reports will be generated by WBgM SLM system.

## 5.7 Accounting definition

In order to charge customers according to established SLAs, it is necessary to define the integration of the SLM system with the billing system. WBgM service is not a commercial product yet and some of WBgM service provider's services could be outsourced. WBgM solution users could be charged for its use according to SLAs and WBgM service provider's outsourced services need to be monitored to verify if delivered services adhere to established SLAs. It will be a significant advantage to future development that the WBgM system have open interfaces to facilitate integration with accounting management systems.

## 5.8 SLM architecture specification

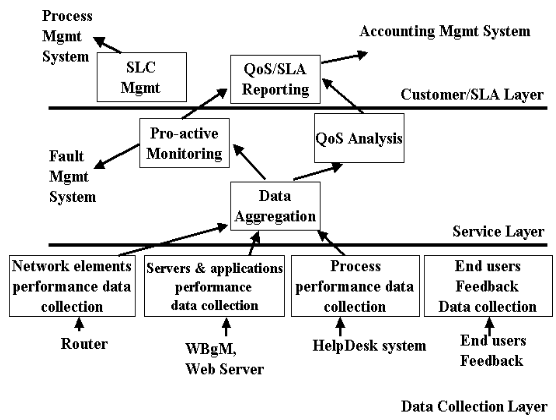


Figure 5: WBgM SLM system architecture

The cumulative result of these 7 steps is the SLM architecture specification. Beginning with the goal of adhering to RM-ODP principles, through identification of QoS characteristics, and establishment of the SLA model, a clear specification for an SLM system architecture is realized. Figure 5 shows an example of an SLM system architecture for the CCNY WBgM solution.

# 6 CONCLUSION

This paper described the detailed study and the use of USP RM-ODP based method of SLM system architecture specification to monitor telemedicine solutions. In particular, the SLM specification for the CCNY WBgM system.

Advances in wireless communications and devices continue to revolutionize our way of living. Wireless telemedicine extends telemedicine application possibilities and promises to benefit a large number of people. In some areas of the globe, wireless telecommunication has been introduced in advance of wired technology. Wireless healthcare applications can have a tremendous positive influence in these developing areas. The development of these wireless telemedicine applications can make use of both wireless and wired infrastructure and services. However, the success of telemedicine applications will have a critical dependence on the overall performance of member services that comprise the solution.

Flexibility, distribution, interworking and interoperability are important features that derive from the ODP-based method of SLM specification and architecture design for telemedicine applications. The fate of a given wireless application will dep end strongly on the designers' ability to adhere to a rigorous and robust ODP design that can be successfully monitored for QoS by the specification of an appropriate SLM system.

# REFERENCES

Myers, B.A., Michael, B., *Handheld Computing.* IEEE Computer, 2003. **36**(9).

Lin, J.C., *Applying Telecommunication Technology to Healthcare Delivery.* IEEE EMB Magazine, 1999. **18**(4): p. 28-31.

Tacharka, S., Istepanian, R., Bansitas, K. *Mobile E-Health: The Unwired Evolution of Telemedicine.* in *Proceedings of HealthComB*. 2001. Italy.

de Sonnaville, J.J., M. Bouma, L.P. Colly, W. Deville, D. Wijkel, and R.J. Heine, *Sustained good glycaemic control in NIDDM patients by implementation of structured care in general practice: 2-year follow-up study.* Diabetologia, 1997. **40**(11): p. 1334-40.

Fund, M.M., *Patients as effective collaborators in managing chronic conditions*, in *Center for the Advancement of Health*. 1999, Milbank Memorial Fund: New York.

Pattichis, C.S., E. Kyriacou, S. Voskarides, M.S. Pattichis, R. Istepanian, and C.N. Schizas, *Wireless telemedicine systems: An overview.* IEEE Antennas and Propagation Magazine, 2002. **44**(2): p. 143-153.

Watchter, G., *Hospital Unplugged: The Wireless Revolution Reaches Healthcare,* retrieved from Telemedicine Information Exchange (TIE) Telemedicine 101 – Telemedicine Technology Topics:, on February 9, 2004, http://tie.telemed.org/telemed101/topics/wireless.pdf

Chalmers D., S., M., *A Survey of Quality of Service in Mobile Computing Environments,* retrieved from IEEE Communications Surveys, on February 9, 2004, IEEE, http://www.consoc.org/livepubs/surveys/public/2q99issue/sloman.html.

Hu, F., Sharma, N.K., *A Priority-determined Multi-Class Handoff Scheme with Guaranteed Mobile-QoS in Wireless Multimedia Networks,* retrieved from IEEE Transactions on Vehicle Technology, on February 9, 2004, IEEE, http://www.ce.rit.edu/%7Efxheec/ieee_veh.pdf

Lewis, L., *Service level management for enterprise networks*. 1999, Norwood: Artech House.

Miyata, C.M., Becerra, J.L. *An ODP Vision of QoS Management: An application in the SLM Architecture*. in *1st International Conference on Software Engineering Research and Practice*. 2003.

Kawaguchi, A., Russell, S., Qian, G. *Developing a Wireless Blood-Glucose Monitoring System: Concept and Practice.* in *7th World Multiconference on Systemics, Cybernetics and Informatics (SCI2003)*. 2003. Orlando, Florida: IEEE.

Vigersky, R.A., E. Hanson, E. McDonough, T. Rapp, J. Pajak, and R.S. Galen, *A wireless diabetes management and communication system.* Diabetes Technol Ther, 2003. **5**(4): p. 695-702.

Sadeghi, B., Knightly, E.W., *Architecture and Algorithms for Scalable Mobile QoS, Wireless Networks 9,* retrieved from Rice University, on February 27, 2004, http://www-ece.rice.edu/networks/papers/SaKnWinet03.pdf

Kawaguchi, A., S. Russell, and G. Qian. *Security Issues in the Development of a Wireless Blood-Glucose Monitoring System*. in *the 16th IEEE Symposium on Computer-Based Medical Systems*. 2003. New York, NY.

Parasuraman, A., L.L. Berry, and V.A. Zeithaml, *SERVQUAL: A multiple-item scale for measuring customer perceptions of service quality.* Journal of Retailing, 1988. **64**(1): p. 12-40.

Hill, N., *Handbook for Customer Satisfaction Measurement.* 1996.

Vavra, T.G., *Improving Your Measurement of Customer Satisfaction: A Guide to Creating, Conducting, Analyzing, and Reporting Customer Satisfaction Measurement Programs*. 1997.