# Chapter 39
# Study of Real–Time Cardiac Monitoring System:
## A Comprehensive Survey

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## ABSTRACT

*Today's healthcare technology provides promising solutions to cater to the needs of patients. The development of wearable physiological monitoring system has reached home-centric patients by ensuring faster healthcare services. The primary advantage of this system is activation of alarms to alert the specialist in a nearby hospital to attend to any sort of emergency. Specifically, cardiac-related problems need special attention when a 24-hour Holter monitors ECG signals and identifies the level of abnormalities under various circumstances. Although several brands of Holters exist in market, there is a huge demand for digitized Holter recorders. These recorders can simultaneously analyse cardiac signals in real time mode and store the data and reuse them for next 24 hours. As home-centric based wearable cardiac monitoring system gains much attention recently, there is a need to design and develop a cardiac monitoring system by establishing a trade-off between the required clinical diagnostic quality and cost. This research study highlights a comprehensive survey of various cardiac monitoring systems under wire, wireless and wearable modes. This provides an insight into the need of the hour in bringing a cost-effective wearable system. The study provides an insight of the technological aspects of the existing cardiac monitoring system and suggests a viable design suitable for developing countries.*

## INTRODUCTION

Due to quality of lifestyle today, there is a huge increase in percentage of young age group (say 18 to 30 years) prone to chronic cardiac-related diseases. Electro cardiogram (ECG), which reflects the continuous cardiac activities, plays an important role in providing the required clinical diagnostic information

for the cardiology community. In the last two decades, Holter recorders have been used to monitor continuous cardiac episodes for 24-48 hours (Erik et al., (2015)). Their dynamic non-invasive monitors store the recordings and are validated later by a cardiologist for arrhythmias detection. Attempts have been made to design digital Holter recorders to overcome certain limitations. Due to the severity level of chronic cardiac-related disorder, there is a huge demand to recognize the related episodes in a real-time mode and to raise an alarm for the patient to consult a specialist immediately. On the other hand, these episodes can be transmitted in a real-time mode through cloud server and the specialist in a nearby hospital can direct the patient based on the severity level. Taking this trait into account, wearable physiological monitoring system has gained much attention in the recent years. Systems that make use these technologies are being introduced in market then and there.

Although wearable technology which is closely associated with home-centric based health care delivery gained popularity, its huge cost restricts its affordability to resource-constrained population. This research study provides an insight into real-time cardiac monitoring system, a comprehensive survey on various systems and signal processing techniques reported in the literature. The salient features and limitations of cardiac monitoring systems are also compared. Finally, a real-time cardiac monitoring system is proposed to overcome all these limitations.

## CARDIAC MONITORING SYSTEM

Recent developments in the miniaturization aspect of sensors has created a huge impact on the wearable physiological monitoring related studies. Such sensing device ensures portability with less power consumption as well as effective energy utilization. The primary advantage of such systems are continuous monitoring of the signals in real-time by clinicians in a monitoring station along with activation of alarms during critical conditions.

In general physiological sensors, such as ECG, demand large energy due to high sampling rate and resolution and also impose limitations due to reduced user wearability. Holter systems are available for patients with cardiovascular diseases to record their cardio activities as demonstrated by Laze et al (1997). In 2001, there has been a notion of telemedicine using mobile phone by NegoslavDaja et al and with power efficient algorithms for Paroxysmal Atrial Fibrillation as proposed by Schreier et al. (2002). Gouaux et al. (2002) proposed a smaller and feasible device for telemedicine. However, it was still insufficient due to lack of processing of raw ECG signals in their devices.

Wireless sensing technology in the recent past decade can enables the healthcare delivery in a better manner and helps in monitoring of patients who are at risk. Although these sensor nodes offer potential low-power operation, the need to limit battery volume to enable a compact package and the need for supporting energy-intensive sensing systems require an energy management method (Winston et al., 2008). This must optimize the operation of sensors and other components further to meet measurement demands while minimizing energy. Energy usage of sensor nodes may be reduced by activating and deactivating sensors according to real-time measurement demand. For better brevity, Table 1 emphasize the various cardiac monitoring system reported in the literature .The report comprises of engineering principles, sensors used, design factor, signal processing and communication modalities adopted and advantage/limitations of each technique.

Table 1 shows a brief report of related literature.

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