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FSM based protocol for wearable and implantable wireless sensors for healthcare

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Abstract— Due to increasing population, shortage of doctors and to lead a better quality of life it is necessary to design a healthcare application as early as possible. This paper proposed the design of finite state machine (FSM) based protocol model for wearable smart devices suitable for monitoring a patient heart based on heart sound. This work present the design, commands, fault tolerance capability, low cost and maintenance free protocol together with taking the advantage of wireless sensor networks (WSNs) which provides environment sensing and data processing capabilities at low cost. FSM is designed in such a way that the system could react to adverse condition and take action (example alert/send SMS to doctor in possibility of stroke). FSM can have a fault tolerance method by moving to an "Oblivion" state and start a new session from "Initial" state instead of blocking due to any undefined event. FSM can also be modified based on future requirement.

Keywords— Wireless sensor network, Finite state machine, healthcare

I. INTRODUCTION

Wireless sensor devices that can be used to actively monitor human activities have garnered great research interest in recent years [1]. Now a day Researchers in WSN and medical fields are working to make the broad vision of smart healthcare possible [2]. Some are devoted to continuous medical monitoring for degenerative diseases like Alzheimer’s, Parkinson’s or similar cognitive disorders [3].Some projects such as “CodeBlue” at Harvard extend WSNs for medical applications in disasters [4]. Some focus on high-bandwidth, sensor-rich environments [5].In recent technology paper the use of Wearable Wireless Body Area Networks as a key infrastructure enabling unobtrusive, continual, ambulatory health monitoring. This technology has potential to offer a wide range of benefits to patients, medical personnel, and society through continuous monitoring in the ambulatory setting, early detection of abnormal conditions, supervised rehabilitation, and potential knowledge discovery through data mining of all gathered information [5]. The design of an integrated electrocardiogram (ECG) beat detector on a personal digital assistant (PDA) platform for the health screening process.

The ECG beat detector module will be supported by the PDA version of personal health information management system (PHIMS) and facilitated accurate referral management system (FARMS) through wireless network infrastructure as a home-based mobile cardiac monitoring solution [6]. Objective of this paper is to show the Finite State Machine (FSM) model together with commands to develop a protocol suitable for monitoring a patient heart rate based on heart sound. Wireless transceiver will do the job of remote sensing and send data. It also sends alert when certain conditions represents undesirable event/threat. Collected data will be processed on the server and take action if limit reaches certain pre set threshold. Second module of this paper defines finite state machine, third module describes the architecture, object discussion has given in fourth module and general condition and conclusion are discussed in module five and six respectively.

II. FINITE STATE MACHINE (DEFINITION)

It is a behavior model [7] composed of a finite number of states, transitions between those states, and actions once the model is implemented. The operation of an FSM begins from one of the states (called a *start state*), goes through transitions depending on input to different states and can end in any of those available, however only a certain set of states mark a successful flow of operation (called *accept states*).

Finite-state machines can solve a large number of problems, among which are electronic design automation, communication protocol design etc.

III. ARCHITECTURE

Majority of the architecture are based on basic structure and set of relationship.

a. Polling based information collection

Take decision based on information.

IV. OBJECT DISCUSSION

We are developing a Finite State Machine (FSM) that will start a new session in case of deviation described in following table (1 and 2) and diagram when any abnormality is detected in heart sound.

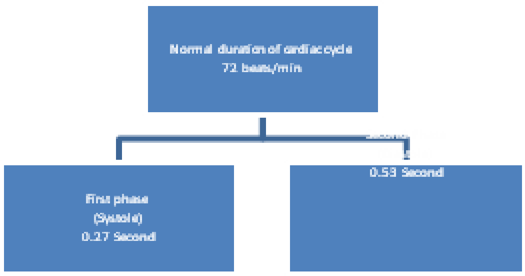

Figure. 1 Normal duration of cardiac cycle.

Initially the device will be in standby/power saver mode when not in use in order to keep the battery life longer. The FSM will save the state so that it can start from the saved state in case of any abnormality. However application of

Wireless Sensor Network (WSN) and design of energy efficient circuitry is beyond the scope of this paper.

Table 1: Heart sound per beat in normal condition

Heart sound	**Quality**	**Duration**	**Conclusion**
First Heart Sound	Long, soft, low pitched like word ‘LUBB’	0.10 to 0.17 sec	Normal (can be heard by stethoscope)
Second Heart Sound	Short, Sharp, High pitched like word ‘DUB’	0.10 to 0.14 sec	Normal (can be heard by stethoscope)
Third Heart Sound	Low pitched	0.07 to 0.10 sec	Can’t be heard by stethoscope
Fourth Heart Sound	Inaudible	0.02 to 0.04 sec	Becomes audible only in pathological condition-studied by phonocardiogram

N.B. Fourth heart sound can’t be heard by any device in normal condition but it is produced in patient with congestive heart failure.

Abnormal heart sound heard by stethoscope along with normal heart sound like ‘*MURMUR’* because of the change in the pattern of blood flow. Streamline blood flow change into turbulent flow. The ‘*MURMUR’* is produced because of valvular diseases, septal defects and vascular defects.

V. GENERAL/NORMAL CONDITION

Table 2: Normal Condition

S.No	**Frequency (Cycle/ Sec)**	**Cause**
1	25-45	Closure of AV valve
2	50	Closure of SL valve
3	1 to 6	Rushing of blood into ventricle
4	1 to 4	Contraction of atrial mausculaturi

Table 3: Finite State Machine (Client) Arrow Indicates- the Initial State Double circle- Indicates the Final State

State	**Event**	**Next State**	**Action**
Arrow-INIT	E_CONN_OPEN	S_CONNECTING	action_connect ( )
S_CONNECTING	E_CONN_COMPLETE	S_CONNECTED	action_conn_establish ( )
	E_TIMEOUT	S_DESTROY	action_cmd_timeout ( )
	E_ERROR	S_DESTROY	action_error ( )
	E_CLOSE	S_DESTROY	action_error ( )
S_**CONNECTED**	E_SERVER_GREET	S_READY	action_greeting_recvd ( )
	E_TIMEOUT	S_DESTROY	action_cmd_timeout ( )
	E_ERROR	S_DESTROY	action_error ( )
	E_CLOSE	S_DESTROY	action_error ( )
S_READY	E_DATA_SEND	S_DATA_SENDING	action_send_data ( )
	E_ERROR	S_DESTROY	action_error ( )
	E_CLOSE	S_DESTROY	action_error ( )
S_DATA_SENDING	E_DATA_SEND_COMPLETE	S_DATA_SENT	action_data_sent ( )
	E_TIMEOUT	S_DESTROY	action_cmd_timeout ( )
	E_ERROR	S_DESTROY	action_error ( )
S_DATA_SENT	E_ACK_RECVD	S_DESTROY	action_data_send_complete ( )
	E_TIMEOUT	S_DESTROY	action_cmd_timeout ( )
	E_ERROR	S_DESTROY	action_error ( )
Double circle DS_DESTROY			

a. All the allocated resources like memory, socket, any open file descriptor etc need to be freed out once DESTROY state is reached.
b. Each session is recognized by a session-id which remains valid until DESTROY state is reached.
c. action_connect ( ) – communicate wirelessly
d. action_send_data () – send the collected data over the connection.
e. action_error ( ) – to indicate error condition in a particular state.
f. action_timeout ( ) – action not finished in designed timeout in a particular state therefore move to DESTROY state and start a new session instead of indefinite waiting (Fault tolerance)

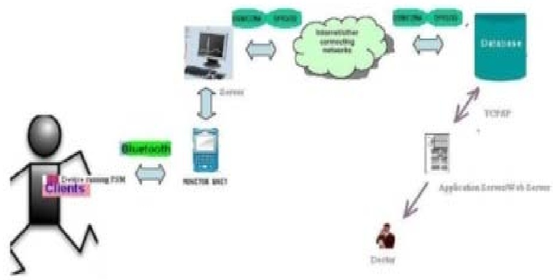

Figure. 2 High level architecture of the model

VI. CONCLUSIONS

The proposed FSM is not complete and not all the possible states and events have been taken into consideration. FSM can be extended according to more complex requirements. However care should be taken to keep it minimal in order to utilize less power. In future similar design can be implemented to support other monitoring capability like Glucose level, BP, cancer detection and depression etc.

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