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Research paper

Performance metrics in wireless sensor networks :a survey and outlook

E. Ramya [1] *, R. Gobinath [2]

[1] *Research scholar, Department of Computer Science, Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai, India*

[2] *Assistant Professor, Department of Computer Science, , Vels Institute of Science, Technology and Advanced Studies (VISTAS)*

**Corresponding author E-mail: ramyaprabakaran28@gmail.com*

Abstract

Data mining plays an important role in analysis of data in modern sensor networks. A sensor network is greatly constrained by the various challenges facing a modern Wireless Sensor Network. This survey paper focuses on basic idea about the algorithms and measurements taken by the Researchers in the area of Wireless Sensor Network with Health Care. This survey also catego-ries various constraints in Wireless Body Area Sensor Networks data and finds the best suitable techniques for analysing the Sensor Data. Due to resource constraints and dynamic topology, the quality of service is facing a challenging issue in Wireless Sensor Networks. In this paper, we review the quality of service parameters with respect to protocols, algorithms and Simulations.

Keywords: *Wireless Sensor Networks; Quality of Service; Performance Parameters; Wireless Body Area Sensor Networks.*

1. Introduction

1.1. Wireless network

The term "Wireless" refers to the telecommunications using radio signals, microwaves (i.e. EM Waves) or infrared waves. The term wireless used to describe the network where is no physical connection between the nodes. Wireless networks are computer networks which uses wireless data connections between the nodes in the network. A wired network connects computer or laptops to the Internet cables. A wireless network connects devices to the network using radio waves. The benefits of a wireless networks are very convenience to access network resources from any location, Mobility, Easy setup, productivity, Expandable and cost reduce.

2. Wireless AD HOC network

This network is a sub type of wireless network mode where network devices communicate with each other. This network is a very small network, which contains temporary connection. This network contains number of mobile nodes or devices that don't depend on the predefined infrastructure. It actually depends on a base station which manages and directs the flow of information been wireless devices. Ad hoc network does not have any central access point. Every node in the network is connected to another node physically.

2.1. Types of wireless AD HOC network

2.2. Wireless mobile AD HOC network

This network contains wireless devices or nodes with short-term network and without any centralized services or standards.

2.3. Wireless mesh network

This network is a local communications network where the nodes structured dynamically, effetely, easily and non-hierarchically with other nodes in a mesh topology. The mesh network ties up with routers and gateways and transmits data to and from the wireless devices.

2.4. Wireless sensor network

This network relies on wireless connectivity. It contains distributed autonomous sensor based devices which observe environmental or physical conditions or signals such as hearing, pressure, climatic changes, and so on. These networks are similar to Ad hoc networks.

Table 1: Performance Analysis in Ad Hoc Networks

TITLE	Author	Measurements	Tools/Parameters/Algorithms/Metrics Used
Capacity, delay and mobility in wireless ad-hoc networks,2003[1][3]	Nikhil Bansal, Zhen Liu	Transmission Delay, Network Capacity and Mobility	Parameters are speed of the mobile nodes and velocity of the mobile nodes. Algorithm is used to achieve a poly-logarithmic factor off.
Capacity and delay tradeoffs for ad hoc mobile networks, 2005,IEEE[2][3]	Michael I Neely, Eytan Modiano	Transmission Delay and Network Capacity	The algorithm used to achieve capacity is a modified version of Grossgslauser-Tse 2-hop relay algorithm and gives O (N)delay(where N is no of users)also results redundancy which cannot increase capacity but significantly improve delay.
The message delay in mobile ad hoc networks, 2005[3]	Robin Groenveh, Philippe Nain Ger Koole.	Transmission Delay	The no of nodes, the time until two random mobile come within transmission are the two Parameters used. Two-hop multicopy and Unrestricted multicopy are the two protocols used to calculate a closed-form expression and an asymptotic approximation of expected message delay.
Performance evaluation and simulations of routing Protocols in ad hoc networks, 2007[4][37]	Li Layuan, Li Chunlin, Yen Peiyan	end-to-end Delay, Throughput and Loss Ratio	Simulation Model Used with an invariable pause time and a dynamic network size. Routing Protocols are Compared with the parameters of Measurements which outturn AODV gives with low delay and the high throughput
Performance evaluation of ad hoc on demand distance vector in manets with varying network size using NS-2 simulation, 2010[5][17]	Nilesh P.Bobade, Nitiket Mhala	Packet Delivery Fraction(PDF), Average end-to-end delay, Routing Load and Throughput	Simulator Ns-2 2.34 Used, AODV Protocol evaluated the network pause time and speed by varying the network size with the Parameters of no of nodes, transmission range, Pause time, Maximum speed, Packet rate, Traffic Type ,Data payload
Improving end-to-end delay in cognitive radio ad hoc networks, 2015	Jing Gao	end-to-end delay	Farthest-node routing (FNR) protocol and Poisson Point Process model used. Numerical and simulation methods used to conclude the upper bound of end-to-end delay based on the local delay.
FP –AODV forwarding mobile ad hoc network, 2015	K.Veeramani, Dr.I.Laurence Aroqiaraj	Packet Delivery Ratio, Throughput and End-to-End dropping.	Compared AODV and DSR with FP-AODV protocol, FP-AODV increases the packet generating, packet sending and packet receiving better than other does. Set of simulation experiments tested to evaluate performance, which indicates FP-AODV decreases the delay per packet.
Delay analysis of ad hoc network using NS 2.34, 2016[6]	Samiksh Nikam,B.T Jadhav	end-to-end delay	DSDV Routing Protocol is used with the Parameters of No of nodes, Pause Time, Speed, and Connection between the nodes in high and low mobility scenario which reduces delay in ad hoc network.

This network contains a collection of such mobile nodes that do not rely on the predefined infrastructure. Table 1 describes about the performance analysis of Ad hoc network. The performance is decided by the speed of the data delivery, efficient algorithms, protocols and simulation models which improves the quality of service. These networks have several advantages and have more flexibility.

The Ad hoc networks classified according to their application as

1) Cellular Ad Hoc networks
2) Vehicular Ad Hoc networks
3) Smart phone Ad Hoc networks
4) Army smart MANETs
5) Wireless Mesh Networks
6) Air Force UAV Ad Hoc networks
7) Wireless sensor networks
8) Hospital Ad Hoc networks

3. Wireless sensor networks

This network contains devices that can communicate the data collected from a sensor field through wireless Network links. The information is transferred via multiple nodes and with the Gateway, the information is connected to other networks like wireless Ethernet.

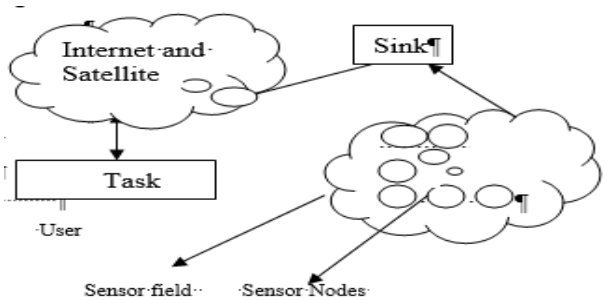

Fig. 1: Architecture of Wireless Sensor Network.

User Sensor field Sensor Nodes

This network contains different and multiple detection stations or sensor fields. Each node in the stations called sensor nodes.

Each node in the network is lightweight, small and portable. Sensor Nodes scattered in a sensor field. Sensor nodes senses data or events and collect the data among the nodes via radio link and route to the Sink.

Sensor field is a scope or area within sensor nodes can detect or collect the senses data. Sink communicates with the task manager or end users via Internet or any network connection or satellite.

This network contains a collection devices called transducers with a transmission infrastructure which monitors and records conditions at different locations. The recorded metrics are humidity, temperature, pressure, wind direction and speed, illumination intensity. Each sensor node in the sensor field is provided with a small computer called microcomputer, transceiver, transducer and power source. The transducer creates different electrical signals depends on sensed physical effects. The microcomputer operates the output comes out from the sensor and stores. The transceiver transmits data by getting commands from a central server.

Table 2: describes the performance metrics in Wireless Sensor Networks. Applications of Wireless sensor networks includes

1) Industrial Automation control.
2) Smart homes system.
3) Virtual security control.
4) Traffic monitoring control.
5) Medical monitoring system.
6) Weather Monitoring conditions
7) Air traffic system control.
8) Robot system control.

The basic differences between Ad hoc networks and Wireless sensor networks are explained in the above Table 3. Wireless sensor network is small, cheap and low power technology developed by using sensor nodes which can gather information and it also helps to transmit.

4. Wireless sensor networks in health care

These are extensively used in the area of Health care. In a hospital health care monitoring system the sensor networks are build to monitor patient's physiological parameters, to control the medication administration path and monitor patients and doctors and inside a hospital. They support fall prevention, insentient detection, vital sign monitoring and dietary or exercise monitoring.

a) BAN-Body Area Network

This network is mainly used to enable the health monitoring. These devices used for communication are located in and around the human body. The extension of awareness in wearable technologies can be worn on the body or implants such as glasses, watches which mainly focused on wireless networking. These networks are mainly designed to mention to the wireless network technology joined with wearable technologies. The main intension of these networks is to communicate data that is produced by wearable device are transferred to the Inter-net. Wearable devices can also exchange the information directly with each other.

Different types of the networks or sensors are created in the networking fields that are used to find the traffic, health in easy way. The out-come of this technology leads many researchers to be conceived to a new technology that is called as body area network. This sensor net-work also allows to monitor the inside activities like chronic diseases.

Table 2: Performance Analysis in Wireless Sensor Networks

TITLE	Year	Authors	Measurements	Tools/Parameters/Algorithm/ Protocols/Metrics Used
Modeling the performance of wireless sensor networks[7]	2004	C.F.Chiasserini, M.Garetto	Network Capacity, Average Delay	Developed Analytical Model with the Parameters of arrival rate of data units, average transfer delay, average number of time slots. This carry data unit from sensor node to sink with active and sleep mode. This permits trade-offs between system performances and energy saving. This showed good accuracy of the proposed.
Sink repositioning for enhanced performance in wireless sensor networks[9][34]	2005	Kemal Akkay, Mohammed Younis	Energy Efficiency, Throughput, Transmission Delay	Algorithms Used For Gateway method for boosting the Energy Efficiency. Relocation Algorithm is used for the gateway with the real Time traffic and with consideration of constrained and unconstrained network traffic. This approach boosts these performance parameters without affecting the consumed energy.
Resource and performance tradeoffs in delay-tolerant wireless networks[10]	2005	Tara Small, Zygmunt J. Hass	Storage-delay and Energy-delay tradeoff	Shared Wireless infestation Model and Algorithm is Used to control the tradeoffs and decreases the used storage in the network without affecting the packet's delay.
Minimizing delay and maximizing lifetime for wireless sensor networks with anycast,[11]	2010	Joohwan Kim, Xiaojun Lin, Ness B. Seroff	Transmission Delay, Lifetime	Anycast forwarding scheme used to decrease the packet delivery delays from the sensor nodes to the sink. Sleep-wake scheduling protocol used to maximize the network Lifetime with the constraints of end to end packet delivery delay.
Delay efficient sleep scheduling in wireless sensor network[12]	2005	Gang Lu, Narayanan Sadagopan	End-to-End Communication Delay	Value-iteration , Local-opt, Hop counting and binary search Algorithms are used and compared to minimize the Transmission delay. Localized and Centralized Algorithms used to calculates delay diameter with graph theoretic problem formulations for arbitrary as well as weighted communication patterns.
Delay performance analysis for supporting real-time traffic in a cognitive radio sensor network[13]	2011	Zhongliang liang, shan Feng,Dongmei zhao	Transmission Delay	Transmission delay achieved for both bursty and poisson traffic by Simulation Parameters total no of channels, scheduling Interval, No of sensors, Packet Transmission time, duration of reserved time interval, probability for bursty time with packet service time(PST) and transmission service time(TS)
Performance analysis of delay in wireless sensor networks[14][50]	2012	Jayashree Pasalkar, Vivek S. Deshpande	Transmission Delay	Protocols DSR,DSDV and AODV compared for 802.15.4 standard which results DSDV increase the end to end delay and Asynchronous sleep-wake scheduling Algorithm and new stop computation reduces the delay.
Delay and throughput performance improvement in wireless sensor and actor networks[15][16]	2015	Shahzad Khan, Fazlullah khan, sher afzal khan	Transmission Delay, Throughput	Transmission Delay and Throughput achieved by Repositioning of Actor nodes, based on Euclidean distance with the Parameters like Field size, no of grid region, channel data rate, transmission range, connection type, packet size.

Table 3: Basic Comparisons between Ad-Hoc Wireless Networks and Wireless Sensor Networks.

Parameters	Ad-hoc Wireless Network	Wireless Sensor Network
Node Size	Large	Small
Node Density	Low	High
Node Coverage Area	Medium	Low
Topology	Fixed for a long time	Changes Frequently
Failure Rate	Low	High
Bandwidth Requirement	High	Low
Communication	Point-to-Point	Broadcast
Cost	High	Low

Table 4: Performance Analysis on Wireless Sensor Networks in Medical Applications

Title	Authors	Measurements	Tools/Parameters/Algorithm/Protocols/Metrics
Performance analysis of the IEEE 802.15.4 based ECG monitoring network, 2007[17]	Xuedong Lian, Ilangko Balasingham	Transmission Delay, End-to-End Delay, Packet Delivery rate	CSMA/CA mechanism used. Parameters for Delay: transmission backoff time, packet transmission time, transceivers transmitting , turnaround time, time of Inter frame space Parameters for End-to-End latency: sampling time, packet transmitting delay. Parameters for Packet delivery rate: packet collision probability, packet delivery rate. By Varying the payload size, sampling and transmitting cycle, the performance of ECG monitoring Network is analyzed.
Transmission delay of multihop heterogeneous networks for medical applications, 2012[16]	M.M.Yaqoob, I.Isar, N.Javid	Transmission Delay	Multihop wireless channel is used. Technologies: Zigbee, WLAN, UMTS Access Protocol: CSMA/CA WLAN, WiMAX, UMTS are three paths connected with ZigBee and calculated each path of delay.
Analyzing delay in wireless multihop heterogeneous body sensor network, 2013[18]	M.Y.Khan, M.A.Khan, A.Javaid	Transmission Delay	Parameters: Transmission backoff time, transmission data time, transmission ack time. WLAN,WiMAX,UMTS are three paths connected with ZigBee and evaluated the overall transmission delay..
Performance evaluation of a wireless body area sensor network for remote patient monitoring,2008[19]	Jamil Y.Khan, Mehmet R. Yuce	end-to-end delay	OPNET simulation model is used and which results to analyze a remote patient monitoring using WBAN without reasonable delay. CSMA/CA random access protocol used to transmit information to the root node provides lower cost system, simple implementation, and a low delay, reliable data transmission.
An experimental performance evaluation and compatibility study of the Bluetooth low energy based platform for ECG monitoring, 2015	Farid Touati, ochirkhand Erdenen-ochir	Throughput, End-to-End Delay, Packet Error Rate	Proposed a BLE based platform for ECG data health monitoring with BLE112 sensor node from Bluegigato measure ECG data and transmit to a BLE dongleconnected to Cubox through WiFi which evaluated the performance metrics like throughput, End-to-End delay, and packet error rate using the below parameters. Parameters used: No of nodes, Data rate, payload, transmission power, transmission time, no of iterations.
Delay, reliability and throughput based on Qos profile: A MAC layer performance optimization mechanism for biomedical applications in wireless body area sensor networks, 2016[20]	Muhammed Sajjad Akbar, Hongnianyu, Shuang Cang	Delay, Throughput, Reliability	WBASN MAC Protocol explored. OMNET++ simulator used. CASTLIA 3.2 framework Validation and simulation followed by three steps: Validation of the proposed DRT profile by comparing statistical results of maximum throughput, comparison in terms of packet deliver ratio of the proposed DRT profilevalues, Delay computation of the DRT profile with different packet sizes which results maximum throughput, improved reliability and produces less delay.
Employing IEEE 802.15.4 for quality of service provisioning in wireless body area sensor networks, 2010[21]	Huasong Cao, Sergio González-Valenzuela and Victor C. M. Leung	Average Queuing Delay, Throughput, Energy consumption	Proposes a QOS provisioning framework for BASN traffic. IEEE 802.15.4 super-frame structure is used in beacon-enabled mode. Parameters: Packet rate or Sampling rate, Payload size or resolution, No of traffic flows. Algorithm: the admission controller algorithm, super frame scheduler, CFP Scheduler algorithms are used with a time constraints compliance ratio for traffic in contention access periods.

b) Components of Body Area Network

This classic network requires dynamic sign detecting sensors and monitoring sensors. The motion detectors are used to detect the motions of any object of human beings. The monitored data are separated and transmitted to the medical practitioners. A body area network contains sensors, battery, processor and a transceiver. The physiological sensors such as ECG, SpO2 sensors and others sensors like EEG, PDA and BP sensors are under development.

The main component of the BAN network contains the following.

- Various types of devices like motion detectors and monitoring sensors.
- Different types of accelerometers are used to transmit vital sign are used as the component in the body area sensor network.

Various kinds of sensing technologies are used in the body area sensor network like physiological sensors (EOG, ECG or EEG) [23]-[29].

Table 5: Types of Medical Sensors

Medical Applications	Description
Electrocardiogram (ECG)	Measurement of heart rate
Electromyogram (EMG)	Measurement of skeletal muscles
Electroencephalogram(EEG)	Measurement of brain activity
Magnetometer	Measure magnetic induction intensity
Temperature	Measures the temperature of the body
Accelerometer	Measures the body movement

c) Challenges of BAN

The various challenges of BAN include

- Quality of Data.
- Managing the datasets

- Validation of sensor devices
- Privacy and security
- Constant monitoring
- Accurate performance

Table 6: Challenges between Wireless Sensor Networks and Wireless Body Area Sensor Networks

Challenges	Wireless Sensor Network	Wireless Body Area Sensor Network
Node Size	Small	Very Small
No of Nodes	High	Low
Lifetime of Nodes	Several months/years	Several months/years
Node Replacement	Easy	Difficult
Power Supply	Accessible and easy to replace	Inaccessible and difficult to replace
Security Level	Lower	Higher
Network Topology	Fixed and Static	Dynamic due to body movement

Wireless sensor Network and Wireless Body Area Sensor Networks have their own characteristics which are different from others. They are characterized into some categories such as Node size, Node density, Node Replacement, Power Supply, Security Level and Network Topology and some more. These challenges are compared with Wireless Sensor Network and Wireless Body Area Sensor Network.

After the performance analysis of Wireless Body Area Sensor Networks we found that the performance metrics for WBAN technology are:

- Minimizing network Lifetime
- Maximizing network Capacity
- Minimizing end-to-end delay
- Maximizing reliability
- Decreasing Energy Consumption

d) Objectives and Observatories of Quality of Service

The Performance is decided by the speed of the data delivery. An efficient algorithm, Protocols, Simulation models improves the performance and the Quality of services. The efficiency of algorithms and protocols are decided by evaluating different performance parameters like delay, throughput, Routing Load, Packet delivery ratio, Packet drop . The delay is measured in high and low mobility scenario by changing various parameters of networks such as no of nodes, pause time, speed connections between the nodes. Redundancy packets through multiple paths improve delay of increasing overall network congestion. Redundancy can easily improve delay performance [6].

5. Conclusion

The Wireless Body Area Sensor Networks has been highlighted a specific Quality of Service requirements like Transmission Delay, Network Capacity, Throughput and Energy Consumption. This survey paper analysis the works carried out in Wireless sensor networks which are specifically focus to analyse Wireless body area sensor networks with Time Delay. The end–to-end delay is one of the most important performances metric. It plays a major thing in deciding the Quality of Service. Future work includes the calculation of overall end–to-end delay in wireless body area sensor network.

References

[1] Bansal, Nikhil, and Zhen Liu. "Capacity, delay and mobility in wireless ad-hoc networks." *INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies*. Vol. 2. IEEE, 2003.

[2] Neely, Michael J., and Eytan Modiano. "Capacity and delay tradeoffs for ad hoc mobile networks." *IEEE Transactions on Information Theory* 51.6 (2005): 1917-1937.

[3] Groenevelt, Robin, Philippe Nain, and Ger Koole. "The message delay in mobile ad hoc networks." *Performance Evaluation* 62.1 (2005): 210-228.

[4] Layuan, Li, Li Chunlin, and Yaun Peiyan. "Performance evaluation and simulations of routing protocols in ad hoc networks." *Computer Communications* 30.8 (2007): 1890-1898.

[5] Bobade, Nilesh P., and Nitiket N. Mhala. "Performance evaluation of ad hoc on demand distance vector in manets with varying network size using ns-2 simulation." *International Journal on Computer Science and Engineering (IJCSE)* 2.08 (2010): 2731-2735.

[6] Nikam, Samiksha, and B. T. Jadhav. "DELAY ANALYSIS OF ADHOC NETWORK USING NS 2.34." *International Journal of Current Research and Review* 8.9 (2016): 7.

[7] Jabeen Q, Khan F, Khan S, Jan MA. Performance improvement in multihop wireless mobile adhoc networks. the Journal Applied, Environmental, and Biological Sciences (JAEBS). 2016;6:82-92.

[8] Chiasserini, C-F., and Michele Garetto. "Modeling the performance of wireless sensor networks." In *INFOCOM 2004. Twenty-third AnnualJoint Conference of the IEEE Computer and Communications Societies*, vol. 1. IEEE, 2004.

[9] Akkaya, Kemal, Mohamed Younis, and Meenakshi Bangad. "Sink repositioning for enhanced performance in wireless sensor networks." *Computer Networks* 49.4 (2005): 512-534.

[10] Small, Tara, and Zygmunt J. Haas. "Resource and performance tradeoffs in delay-tolerant wireless networks." *Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking*. ACM, 2005.

[11] Kim, Joohwan, et al. "Minimizing delay and maximizing lifetime for wireless sensor networks with anycast." *IEEE/ACM Transactions on Networking (TON)* 18.2 (2010): 515-528.

[12] Lu, Gang, et al. "Delay efficient sleep scheduling in wireless sensor networks." INFOCOM 2005. 24th Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings IEEE. Vol. 4. IEEE, 2005.

[13] Liang, Zhongliang, et al. "Delay performance analysis for supporting real-time traffic in a cognitive radio sensor network." *IEEE Transactions on Wireless Communications* 10.1 (2011): 325-335.

[14] Pasalkar, Jayashree C., Vivek S. Deshpande, and Dattatary Waghole. "Performance analysis of delay in wireless sensor networks." *Trends in innovative computing* (2012): 192-195.

[15] Khan, Shahzad, Fazlullah Khan, and Sher Afzal Khan. "Delay and throughput performance improvement in wireless sensor and actor networks." *Information Technology: Towards New Smart World (NSITNSW), 2015 5th National Symposium on*. IEEE, 2015.

[16] Yaqoob, M. M., et al. "Transmission delay of multi-hop heterogeneous networks for medical applications." *Broadband, Wireless Computing, Communication and Applications (BWCCA), 2012 Seventh International Conference on*. IEEE, 2012.

[17] Liang, Xuedong, and Ilangko Balasingham. "Performance analysis of the IEEE 802.15. 4 based ECG monitoring network." *Proceedings of the 7th IASTED International Conferences on Wireless and Optical Communications*. 2007.

[18] Javaid, Nadeem, et al. "Analyzing delay in wireless multi-hop heterogeneous body area networks." *arXiv preprint arXiv:1304.1059* (2013).

[19] Khan, Jamil Y., Mehmet R. Yuce, and Farbood Karami. "Performance evaluation of a wireless body area sensor network for remote patient monitoring." *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE*. IEEE, 2008.

[20] Akbar, Muhammad Sajjad, Hongnian Yu, and Shuang Cang. "Delay, reliability, and throughput based QoS profile: A MAC layer performance optimization mechanism for biomedical applications in wireless body area sensor networks." *Journal of Sensors* 2016 (2016).

[21] Cao, Huasong, Sergio González-Valenzuela, and Victor CM Leung. "Employing IEEE 802.15. 4 for quality of service provisioning in wireless body area sensor networks." *Advanced Information Networking and Applications (AINA), 2010 24th IEEE International Conference on*. IEEE, 2010.

[22] Al Masud, Shah Murtaza Rashid. "Qos taxonomy towards wireless body area network solutions." *International Journal of Application or Innovation in Engineering & Management (IJAIEM)* 2 (2013): 221-234.

[23] Hema.C.R, Paulraj.M.P & Ramkumar.S, "Classification of Eye Movements Using Electrooculography and Neural Networks", International Journal of Human Computer Interaction, Vol.5(4), pp.51-63, 2014.

[24] Hema, C. R., Ramkumar, S., & Paulraj, M. P. , “Idendifying Eye Movements using Neural Networks for Human Computer Interaction”, International Journal of Computer Applications, 105(8), pp 18-26, 2014.
[25] S.Ramkumar, K.SatheshKumar, G.Emayavaramban, ”EOG Signal Classification Using Neural Network for Human Computer Interaction”, International Journal of Computer Theory and Applications, Vol.9(24) , pp.223-231, 2016
[26] Ramkumar, Dr.K.Satheshkumar and G.Emayavaramban” Nine States HCI using Electrooculogram and Neural Networks”, IJET, Vol. 8(6), pp. 3056-3064 , Jan 2017.
[27] S.Ramkumar, K.Sathesh Kumar G.Emayavaramban,” A Feasibility Study On Eye Movements Using Electrooculogram Based HCI” IEEE- International Conference on Intelligent Sustainable Systems, pp.384-388, Dec-2017.
[28] G.Emayavaramban, S.Ramkumar, A.Amudha and K.Sathesh Kumar “Classification Of Hand Gestures Using FFNN And TDNN Networks”, International Journal of Pure And Applied Mathematics, Vol.118(8) Pp. 27-32, Jan 2018.
[29] S.Ramkumar , K.Sathesh Kumar, T.Dhiliphan Rajkumar, M.Ilayaraja, K.Shankar, “A review-classification of electrooculogram based human computer interfaces”, Biomedical Research, 29(6), Pp. 1078-1084, April 2018.