MQMS - An Improved Priority Scheduling Model for Body Area Network Enabled M-Health Data Transfer

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Abstract. Mobile health is a new area of technology that gives the health care system a new face and place in the world. With the support of Body Area Network the m-health application has to make a lot of changes in the area of health support. There are so many research works has been conducted to make the application efficient. As in the case of any network traffic the m-health application also suffers problems. The paper put forward a new idea of scheduling the vital signals from the body with the help of queuing theory. It uses some analytical modeling, by considering the signal packets from sensors are following poisons distribution and the packets are arriving randomly. From the queuing theory uses some equations to find the average waiting time, maximum number of packets waiting for the service, efficiency of the system etc. Here the major issues while incorporating BAN with m-health is the number of nodes and distance from the patients to the receiving station, Number of servers in the receiving station, Priority of the signals etc.

Keywords: Body Area Networks · M-health · Queuing theory
Poisons distribution

1 Introduction

M-health the novel application of technology and new trend in the health care system, incorporated Body Area Network (BAN) as a supporting infrastructure to make the entire system so efficient and easy to handle. The assistance of BAN in m-health make the diagnosis clearer and give opportunity to change the design of m-health from mere mobile phone conversation from the patients to doctor to capturing signals from various body parts and sending it to a receiving stations. Here the paper introduces an analytical approach to find the efficiency of the queuing system by reducing delay time and finding the average number of signals in the queue. The architecture has a two-layered structure one is the internal BAN and other is the external network between the BAN and receiving station. The existing studies focused on variety of priority scheduling models in wireless sensor networks. The proposed study applies queuing models for considering the priority of vital signals.

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The major objectives of this paper are scheduling the signals from BAN according to their priority, finding the delay in processing of signals and determine the efficiency of queuing service.

2 Related Work

The review has conducted on focusing on the popularity of m-health application, problems related with it and various scheduling methods adopted for efficient transfer of signals from BAN to receiving station. The BAN is key factor in the architecture of m-health. The vital signals from different sensors flows to the outside network. Whenever the number of signals arriving increases and they are not processed there will be severe traffic problem in the network. The vital signals from the sensors not reached in the receiving centre properly then the diagnosing of health problems could not be accurate. The recent surveys on m-health, web reports reveal the wide acceptance of this application as well as the view of people and society about the health care system. In Refs. [1–3] the latest applications of m-health were described. Now day M-health is a part of IOT so the acceptance of the application is increasing more and more. At the same time the anxiety of both the patients and physicians were also mentioned in the paper. The papers not mentioned any solution for the authenticity or security of data transfer. Reference [4] deals with the technological growth in e-Health services. The recent developments in the area of technology has vital role to make the m-health application popular. But the optimization of secure transmission cannot have achieved also by this technology. Research works are going on in the field of BAN as well as in the area of m-health. Most of the research works are in the area of BAN rather than m-health. The studies by Yankovic et al. [5] proposed semantic authorization model for pervasive healthcare by employing ontology technologies. It is a novel decision propagation model to enable fast evaluation and updating of concept-level access decision. The European countries mostly depend on m-health services in the area of health services. But the developing countries still have precincts in accepting and implementing the applications. The economy and lack of knowledge in technology is one obstruction in this area. In the case of BAN, to improve the quality of service an analytical mode has been designed by Worthington et al. [6] in his work he treated the signals in to different classes and analyze the various metrics like delay, through put, and packet loss rate etc. The paper analyze the queue traffic problem in terms of Markov chain transition probabilities for low latency queuing model. The paper could not give an efficient solution for the considered metrics. The life time and total energy consumed by WBAN were studied by Kumar et al. [7]. The paper proposed an energy efficient and cost-effective network design for WBAN the paper considered the metrics such as low latency, high throughput, guaranteeing multiple services etc. The routing of signals from BAN discussed by Liang et al. [8] in their studies by introducing the concept of collecting tree protocol and analyze metrics like reliability delay and energy conception. The application of queuing principles in health care were discussed by Sayed and Perrig [9] The paper introduced the basics of queuing principles and various queuing models. It explains the various situations in hospitals and prove the improvements in the efficiency by the application of queuing theory. The paper not considering the Body Area Network and their signals. In Ref. [10] Patwari et al. worked on authenticating loss data in body sensor health care monitoring. A network coding mechanism is used to retrieve the loosed packets during transmission. The paper not considering outdoor communication in BAN. The paper considered the packet losses in BAN are bursts, the assumption of point loss is not optimal. The theory of queuing is mathematically complex but the application of queuing theory to the analysis of performance is remarkably straight forward. The study on various scheduling techniques not considered the scheduling of signals based on priority. The paper proposes a new scheduling scheme considering the priority of signals from different sensors. Chang et al. [13] have explained a system architecture for a mobile health monitoring platform based on a wireless body area network (WBAN). They detail the WBAN features from either hardware or software point of view. The system architecture of this platform was three-tier system. Each tier was detailed. They had designed a flowchart of a use of the WBANs to illustrate the functioning of such platforms. They show the use of this platform in a wide area to detect and to track disease movement in the case of epidemic situation. Indeed, tracking epidemic disease was a very challenging issue. The success of such process could help medical administration to stop diseases quicker than usual. In this study, WBANs deployed over volunteers who agree to carry a light wireless sensor network. Sensors over the body will monitor some health parameters (temperature, pressure, etc.) and will run some light classification algorithms to help disease diagnosis. Alameen et al. [14] have stated a wireless and mobile communication technologies it had promoted the development of Mobile-health (m-health) systems to find new ways to acquire, process, transport, and secure the medical data. M-health systems provide the scalability needed to cope with the increasing number of elderly and chronic disease patients requiring constant monitoring. However, the design and operation of such systems with Body Area Sensor Networks (BASNs) was challenging in two-fold. They integrate wireless network components, and application layer characteristics to provide sustainable, energy efficient and high-quality services for m-health systems. In particular, they use an Energy-Cost-Distortion solution, which exploits the benefits of in-network processing and medical data adaptation to optimize the transmission energy consumption and the cost of using network services. Moreover, they present a distributed cross-layer solution, which was suitable for heterogeneous wireless m-health systems with variable network size. Zhang et al. [18] have proposed a way to improve sensing coverage and connectivity in unattended Wireless Sensor Networks. However, accessing the medium in such dynamic topologies raises multiple problems on mobile sensors. Synchronization issues between fixed and mobile nodes may prevent the latter from successfully sending data to their peers. Mobile nodes could also suffer from long medium access delays when traveling through congested areas.

3 Proposed Architecture

The proposed architecture of m-health uses two layered architecture. One is the intranet which is the inter connection of sensors within the body. The second one is the networking of this BAN and external nodes up to the receiving station. As in the case of any network BAN also suffers the problem of security, routing, authenticity, privacy etc. The paper deals with the problem of scheduling of signals from BAN. There is more than one sensor within the body; they capture signals from the different part of the body. The signals are collected to a sink node. From this the signals transmitted out to the external network and it is received by the mobile device in the patient's hand. From the device the signals captured by the intermediate node, from the nearest node the signal captured by the receiving server in the receiving station. The signals from different sensors may be of different types, and according to the priority the processing of signals can be arrange from the diagnosing centre with priority scheduling. This study proposes a multiple queue multiple server scheduling models to consider the priority of signals. The priority of signals is calculated by comparing with the predefined value of vital signals (Fig. 1).

The DFD of the proposed architecture is depicted below.

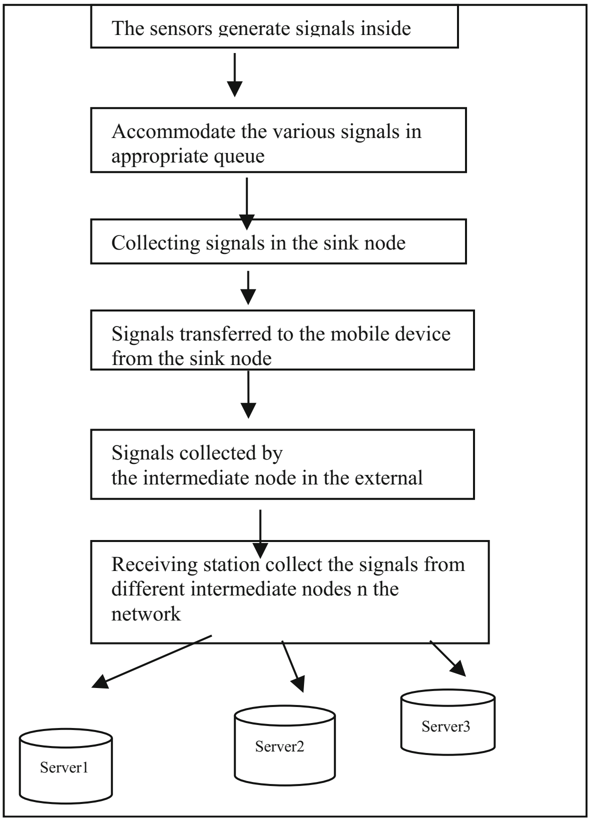

Fig. 1. Architecture of M-health with BAN

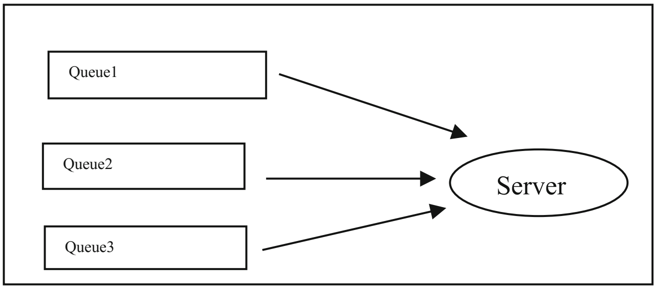

Fig. 2. Queuing of signals from different sensors.

3.1 Queuing Scheduling in BAN

Inside the BAN here we use multiple queue single servers scheduling. The signals from different sensors forms separate queue and collected by the receiving station. While this the arrival time per hour and service rate can be calculated. From this the utilization factor R can be calculated as $R = N/\mu$. It should be <1 for the steady state of the system. Here the arrival of signals as well as service rate follows poisons distribution. If the utilization factor >1, there is a need of additional servers. The queuing model can be shown as in Fig. 3 (Fig. 2).

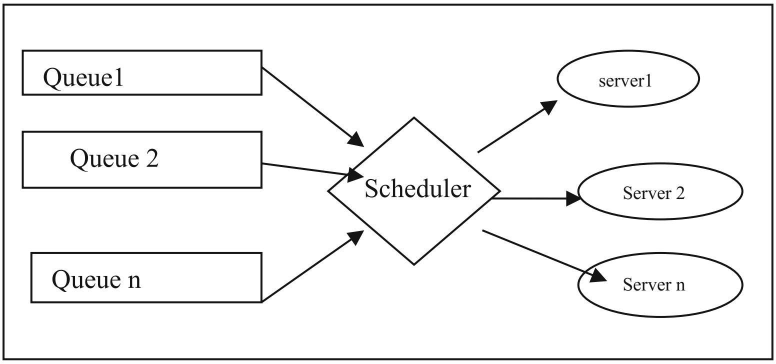

Fig. 3. Queue of signals outside BAN

3.2 Queuing Model in the Network Outside BAN

The above discussed simulation process is for the scheduling inside the patient's body. In the external network there may be more than one collecting node. The node has to determine the signal's priority and send them in to the receiving station. From the receiving center then accept the signal and channelize them in the required doctor's server. Here the scheduling model changes in to multiple queues multiple server models (Fig. 4).

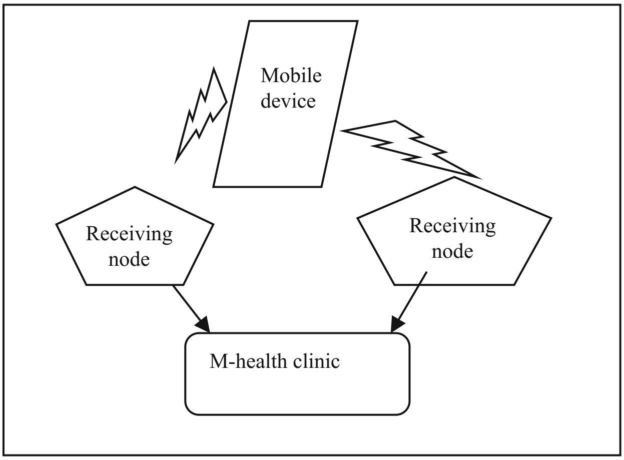

Fig. 4. Architecture of network outside the BAN

The queue model can be shown in Fig. 3.

The nodes collect signals from the mobile devices and arrange them in the queue according to priority. The signals having high deviation from the normal rate are arranged in the high priority queue and having normal rate are in the medium priority queue and the emergency messages are in the low priority queue. The scheduling process in the receiving center is done according to the pseudo code for the above process will be as follows.

```
Method to check priority
Set queue length, emgql, ql1, ql2 = 1
While queue length>=1
If the sigrate>nrate and sigrate<nrate
Emgql++
Goto queue1
Else
If sigrate = nrate
ql1++
Go to queue2
Else
ql2++
Goto queue3
```

```
Method to delivering required server
In server 1
Emgql = n
While emgql>=1
Send the signal in server1
```

In server 2
ql1 = n
While ql1>=1
Send the signal in queue2
In server 3
ql2 = n
While ql2>=1
Send the signal in queue3

The proposed model can be implemented through the multiple queue multiple server. In this model, the incoming signals are arranged in different queues based on priority as high, medium, and low. So it forms different queues and the signals from these queues are sent to different servers for processing and this is the second stage in the architecture. The general form of multiple queues multiple servers is **(M/M/C):GD/ ∞/∞)**.

The parameters are

(a) Arrival rate follows poisson distribution.
(b) Service rate follows poisson distribution.
(c) Number of servers is C.
(d) Service discipline is general discipline.
(e) Maximum number of signals permitted in the system is infinite.
(f) Size of calling source is infinite.

$$\emptyset = \frac{N}{C\mu} \tag{1}$$

For steady state the efficiency should be <1

$$Wq = \frac{Lq}{N} \tag{2}$$

$$Lq = \frac{\emptyset}{c - \emptyset} \tag{3}$$

where $\emptyset/\mathrm{c} \approx 1$

$$Ws = Wq + \frac{1}{\mu} \tag{4}$$

From the intermediate servers the signals transferred to the server in the receiving station. It is the third stage and it follows single queue multiple server queue model.

3.3 Analytical Implementation of Queuing Model

For the implementation of priority scheduling the abnormal readings are arranged in the Tables 1 and 2 The arrival time and service rates are calculated in minutes. We take the readings for 30 min from 20 people. The abnormal readings are arranged in the high priority queue, and the rest of the signals are arranged in medium and low priority queue. The calculations are made with queuing theory principle of multiple queue multiple method. The waiting time of signals in the queue, the number of signals waiting in the queue are calculated. In this calculation the waiting time and queue length are reduced to the maximum. The calculations are represented in the following section.

Table 1. Signal details

Arrival rate in min.	6	7	6	5	9	10	4
Service rate	3	5	7	10	15	12	6

Table 2. Signal details

Arrival rate in min.	4	1	1	4	1	4	2	2	3	3	2	2	3	3	1	4	3	3	6	5
Service rate	3	4	3	3	3	1	2	2	3	2	2	4	3	4	2	2	3	3	3	3

From the table data
The mean arrival rate $\mu = 6.7 = 7$
The mean service rate $N = 8.28 = 8.3$
The inter arrival = 1/7 and inter service rate = 1/8.3
The efficiency $ø = (1/N)/(1/\mu) = 7/8.3 =$ **0.843**
So the efficiency meet the steady state condition i.e., < 1.

The average number of customers in the queue Lq

$$Lq = \emptyset^2/1 - \emptyset = N^2/\mu(\mu - N) = \mathbf{4.54}$$

Around 5 signals are in the queue.
Average waiting time in the queue

$$\begin{aligned} Wq &= N/\,\mu(\mu - N) \\ &= \frac{1}{8.3}\Big/\frac{1}{7}\left(\frac{1}{7} - \frac{1}{8.3}\right) \\ &= 49/1.3 = \mathbf{37.69\ min}. \end{aligned}$$

So each signal has to wait around 38 min in the queue to get the service.

The same set of signals can be implemented through priority queue, While the signals are arriving, arrange them in different queues like high priority, medium priority and low priority queue. Then the queue will be like multiple queue multiple server manner. The calculation can be done using multiple queue multiple server equations as follows and for each level of priority there is a server.

Mean arrival rate = 8.3 implies μ = 1/8.3
Mean service rate = 6.66 ≈ 7 implies N = 1/7
Number of servers = 3

Applying the values in multiple queues multiple server model equations the following results obtained.

$$\emptyset = \mathrm{N}/\mathrm{c}\mu = 7/3 * 8.3 = \mathbf{0.2811}$$

$$p0 = \sum_{c=0}^{2} \frac{1}{c!}\left(\frac{N}{\mu}\right)^{c} + \frac{1}{c!(c\mu - N)/c\mu} * (N/\mu)^{3}$$

$$= 1/0!(7/8.3)^{0} + 1 * (7/8.3)^{1} + 1/2 * 7^{2}/8.3^{2} + 1/3! * \frac{3 * 1/7}{\left(\frac{3}{7} - \frac{1}{8.3}\right)} * \left(\frac{7}{8.3}\right)^{3}$$

$$= 0.4769$$

$$Lq = \frac{(N\mu)(N/\mu)^{c}}{(c-1)!(c\mu - N)^{2}} * p0$$

$$= ((1/7 * 8.3) * (7/8.3)^{3}/\left(2 * (3/7 - 1/8.3)^{2}\right)0.4769$$

$$= \mathbf{0.1304785}$$

$$\mathrm{Wq} = \mathrm{Lq}/\mathrm{N}$$

$$= 0.1304785/1/8.3$$

$$= \mathbf{0.108297155}$$

Table 2 represents the second set of data in priority queue and calculate the waiting time and queue length in multiple queue multiple server manner and single queue single server manner.

Inter arrival rate = 1/2.9 = 0.3448
Service rate = 1/2.7 = 0.37037

For single server

Ø = 0.93096
lq = 12.5705
Wq = 35.32

For multi-server

Ø = 0.31032
lq = 0.1987
Wq = 0.5764

4 Parameter Evaluated

The proposed model considered the various metrics like arrival rate of the signals in the queue, waiting time in the queue, service rate and overall efficiency of the system. It is obvious from the result that the queue length, waiting time can be reducing to the maximum such that around 1 signal is in the queue for processing. That is, by applying the queuing equations to calculate the parameters, the result is too much better and it has proved by equations. In the normal case the priority is not considered and it follows the single queue single server manner. In the proposed model the queue length, waiting time and efficiency are calculated, by considering the priority of signals, in multiple queue multiple server manner. By analyzing the result, it is clear that average waiting time of signals in the queue, and number of signals in the queue can be reduced, such that no signals are waiting in the queue and the average waiting time is very less, i.e. 0.182. The graph 1 shows the comparison between single queue single server and priority-based scheduling. The Table 3 shows the comparison between various metrics evaluated. The results show that the priority-based scheduling using multiple queues multiple servers is more efficient than the normal scheduling.

Table 3. Comparing results of SQSS and MQMS

Metrics evaluated	Single queue single server	Multiple queue multiple server
Efficiency	Case 1 = 0.843 Case 2 = 0.93096	Case 1 = 0.2811 Case 2 = 0.31032
Average queue length	Case 1 = 4.54 Case 2 = 12.5705	Case 1 = 0.1304785 Case 2 = 0.1987
Average waiting time	Case 1 = 37.69 min. Case 2 = 35.32	Case 1 = 0.108297155 Case 2 = 0.5764

5 Result and Discussion

The paper tries to explain the scheduling scheme for signals coming out from the BAN with an analytical model using queuing theory. Here the scheduling uses multiple queue multiple server. In each case the average waiting time in the queue, average queue length and the utility factor all lies as per the steady state condition with the collected values. The values are calculated for single queue single server (SQSS) manner also for comparison so the study compare the proposed MQMS model with the FCFS (single queue single server) model. The results are shown below in the Table 3 and in Figs. 5 and 6.

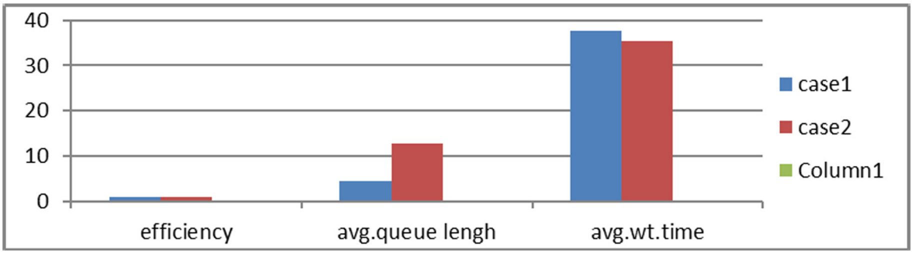

Fig. 5. Results in MQMS

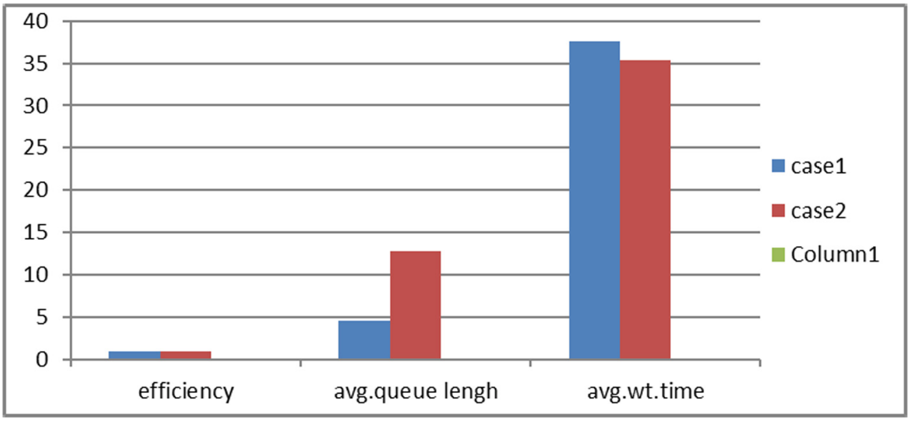

Fig. 6. Results in SQSS

6 Conclusion

The paper deals with the scheduling of signal from body sensors in m-health application. There is no research work in this area based on queuing theory. Here the network is considered as a two-layered architecture, one is the internal BAN architecture and the other is the external network. The signals are collected to the receiving station from there the scheduling begins. According to the recorded readings by applying the proposed algorithm the parameters like waiting time, number of packets in the queue are analyzed. The results are tabulated in Table 1. The study proved the efficiency of MQMS scheduling algorithm. In the present health care system, the mobile health can do much more in the public health care system. So, the future work in this study is focused on designing a frame work for pubic health care system with M-health by considering the prioritized scheduling of vital signals and emergency messages.

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