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Toward Energy-efficient Communication Protocol in Wireless Body Area Network: A Dynamic Scheduling Policy Approach

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ABSTRACT

Wireless body area network (WBAN) is an emerging technology that has been able to provide a better experience of mobility and flexibility for humans using tiny and low power sensors inside, outside, or around the body compared to the traditional wired monitoring systems. Due to numerous constraints in size, energy consumption, and security of implant devices in the human body, it is still a significant research challenge to design these systems in a reliable and energy-efficient fashion. To provide quality of service, timely and secure delivery of real-time data needs to be done without any loss. This paper attempts to provide a communication protocol in order to upgrade QoS levels in WBANs and reduce energy consumption in sensor nodes. To do so, the earliest deadline first (EDF) real-time scheduling algorithm and its combination with the least laxity first (LLF) scheduling algorithm were employed to prioritize sensor nodes for sending data packets. The proposed method could optimize the system performance when it is in the event of an overload and tasks miss their deadlines in a row. The OMNET++ simulation environment is used to evaluate the proposed solution's efficiency which checks packet delivery rate and mean-power consumption evaluation criteria in the sink and sensor nodes. This is done with different numbers of nodes in the network. The results show that the proposed strategy could provide an appropriate improvement in sending and receiving packets for body area networks.

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1. INTRODUCTION

Body sensor networks (BSNs) or wireless body area networks (WBANs) are an emerging technological field for many human-centered applications, including medical monitoring, sport performance monitoring, social networking, etc. WBANs consist of low power, smart, micro- or nanotechnology sensors and actuators, which are placed on the human body or planted inside the body. Sensor nodes measure important physiological parameters such as body temperature, heart rate, body movements, blood glucose, and oxygen saturation as well as transmitting them to a local processing unit called sink node. The sink node sends information to the hospital or any health care system for diagnosis and permanent records [1]. WBANs reduce health care costs by eliminating the need for expensive monitoring of patients in hospitals. However, many social and technical challenges need to be addressed to allow for the practical acceptance of these networks [2].

Human health monitoring programs are considered critical in many cases and require low delays as well as immediate transmission of information in emergency cases. Therefore, WBANs have to provide immediate

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emergency assistance to the patient in case of abnormalities in the physiological and vital signals. An important challenge of WBANs is the provision of quality of service (QoS), which must guarantee the timely and reliable delivery of real-time and non-real-time data without losing data packets [2]. Continuous patient monitoring not only requires a technological platform, but it also needs time-sensitive algorithms that prevent data packets from colliding in wireless environments and minimize energy consumption in WBANs [3].

One way to reduce energy consumption and improve the quality of service in WBANs is to prioritize data as some biological signals are more important than others. Different data collected by body sensors may differ in importance. The urgent data with the highest priority needs to be sent to the destination with the least delay. In addition, the presence of different amounts of data traffic in WBANs increases the importance of sequencing performance in coordinator nodes.

This paper attempts to offer a strategy for real-time embedded systems operating in WBANs, which includes optimizing message scheduling. Through scheduling in the transmission layer, the proposed approach not only could solve the problem of packets collision, but it could also provide a better chance of receiving higher priority data. In the proposed method, higher priority will be allocated to the nodes that are more important, for example, for the heart patient, the heart sensor has a higher priority than other sensors, so it get more priority. The proposed algorithm presents a combined EDF and LLF scheduling policy, which is used for real-time scheduling applications. The EDF scheduling algorithm is used, because the priority of information sent by nodes is not the same in WBAN.

One of the important features of EDF algorithm is its priority-orientation. This means that the algorithm schedules and prepares existing tasks based on their priority. The main advantage of EDF's strategy is that it allows the optimal utilization of the communication channel, ensures the delivery of the message within a specific time, and avoids the packet collisions. However, one of the problems with the EDF algorithm is that it is unable to manage the system in the event of an overload. This means that when one system task misses a deadline, it is likely that other subsequent tasks miss their deadlines in a row as well. In order to tackle this issue and optimize the system performance, a combination of EDF algorithm with LLF scheduling algorithm is proposed. Since the LLF scheduling algorithm is an optimal priority-based scheduling algorithm, it could be used to solve the problems caused by the application of the EDF algorithm.

This paper attempts to show that by using the real-time scheduling algorithms and queuing the nodes based on their priority, the packet collision rate in the network is reduced and consequently the percentage of packet delivery rate in the sink node is increased. The results of the study demonstrate that the proposed method outperforms the method in which packets are sent randomly. Accordingly, the contributions of this paper is as follows:

1. Providing a method to prevent the collision of data packets sent from sensor nodes in WBANs.
2. Providing an approach to prioritize data packets before sending to enhance the QoS in WBANs.
3. Providing a solution to reduce the energy consumption of the sensor nodes in WBANs.

2. RELATED WORK

Gambhir et al. [4] proposed a protocol based on occupying the queue, along with the loss of packets to control congestion in physical sensor networks. They assumed that the nodes do not lose their functionality due to the low battery life. In this method, congestion control consisted of two phases: the fast start phase and the phase of the congestion control module. Simulation results were compared with the conventional TCP method, which indicated performance improvement in throughput and reducing the impact of congestion in the system based on the proposed method. This procedure was done after the congestion to control it in WBANs and consequently increase the throughput and networks lifetime. The current work however, aims to schedule the sending of the packets in the sensor nodes before occurrence of congestion in order to prevent it. Indumathi and Santhi [5] proposed a dynamic multilevel priority (DMP) for Wireless Sensor Networks (WSNs) where the sensor nodes were organized in a hierarchical structure. The real-time data traffic with the same priority would be processed using the shortest job first (SJF) scheduling scheme, as it is very efficient in the average waiting time of the task. It ensures the minimum end-to-end data transmission for the highest data priority while exhibiting acceptance fairness towards lowest data priority. Their experimental results showed that the proposed DMP packet scheduling scheme had better performance than the existing first come first served (FCFS) and multilevel queue scheduler in terms of the average task waiting time and end-to-end delay. Caccamo and

Zhang [6] suggested a network architecture appropriate for sensor networks along with media access control protocol based on EDF scheduling. Their main idea was to utilize the alternating feature of the sensor network traffic, so that the prioritization was used instead of control packets. As a result, they provided lower delay and more throughput. This approach was implemented through utilizing the cellular network features in the WSN network, where most of the messages are duplicate data and differ from WBANs in terms of the importance of the data sent. Facchinetti et al. [7] proposed a novel MAC layer protocol, where nodes can enter or leave the communication space while avoiding collisions caused by simultaneous transmission. The algorithm, used to access the communication channel in this protocol, was based on EDF, which not only ensured time constraints on uninterrupted messages but also provided optimal utilization of the communication channel. In this approach, the collision in the transmission of messages was prevented, because each node sent messages at different times according to the order set by EDF. In this work, however, the problem of equal deadlines (domino effect) was not considered in using EDF algorithm, which might miss other deadliness in a row with the loss of one deadline. Almeida et al. [8] proposed a MAC layer protocol for scheduling real-time communications in a network of mobile robotic units in the wireless media which used implicit EDF to guarantee the real-time network traffic. By executing and replicating the implicit EDF scheduling in parallel in all nodes, the collisions were prevented in a highly synchronized way. In this strategy, the EDF is combined with an adaptive method to support dynamic resource reservation and topology management. The simulation results showed the effectiveness of the proposed protocol, even with the transmission and mobility errors of the nodes. Here, the implicit EDF scheduling is used in MANET networks that do not have excessive physical limitations and can generally use powerful processors, radio transmitters, and batteries. WBANs, on the other hand, have many limitations in these cases. Chéour et al. [9] developed a non-exclusive multiprocessor and dynamic management policy for periodic tasks. The EDF scheduling algorithm was used to handle complex applications such as video processing. In this method, the scheduling algorithm is used as a set of rules to select the task to be executed. Moreover, it investigates deadlines, restrictions, and dependencies of each task. The EDF provides the optimal utilization of the CPU and consequently, enables energy efficiency. Additionally, the task scheduling and managing CPU time help to improve the performance of sensor networks and predictive capabilities. Here, a real-time scheduling policy was implemented under the Linux operating system that saved significant energy. Therefore, in the proposed method, this useful feature of EDF is used to schedule the sending of packets of each sensor node in the body networks in which the energy challenge is of great importance. Wu et al. [10] proposed new techniques to limit the communication delays which were caused by collisions in the channel and sending conflicts in a wireless sensor and actuator network (WSAN). They also provided a method to reduce the disadvantages of accept control that uses the repetition of minimizing the limit of the delay for data flows with short deadlines. Their paper presented a new delay analysis for periodic streams in which transmissions are scheduled based on EDF policy. The experimental results showed that this delay analysis creates a safe limit for the real end-to-end delay. Simulation results demonstrated that EDF has a better real-time performance over static priority scheduling, and also leads to less computational cost. Ayele et al. [11] proposed a novel scheduling algorithm for hard real-time systems, reducing the amount of context switching and average waiting time, which in turn boosts the system performance. This method was a combination of EDF and LLF scheduling algorithms. The simulation results indicated that the proposed system reduces the context switching and the probability of overhead occurrence. In the current work, we used the same method to schedule the packets sending of each sensor node in physical networks. Zandvakili et al. [12] proposed a new task scheduling algorithm based on discrete pathfinder algorithm (DPFA) and modeled the objective function based on five parameters (i.e. make span, power consumption, tardiness, resource utilization and throughput). The results showed that this algorithm performs well in case of increasing the number of tasks. Yousefipour et al. [13] proposed a method for task scheduling improvement of cloud computing through an improved particle swarm optimization algorithm. In this method, selection of a proper objective function has led to balanced workload of virtual machines, decreased time of all tasks as well as maximum utilization of all resources and increased productivity in addition to dynamic placement of virtual machine on physical machine. Samal and Kabat. [14] proposed a traffic prioritized load balanced scheduling (TPLBS) algorithm for load balancing in different priority queues in WBANs. This work is to minimize packet drop in the queues to improve throughput of WBAN.

3. BASIC CONSEPTS

3. 1. WBANs A WBAN is a wireless network that consists of tiny bio-medical nodes distributed on the body surface, underneath the skin, inside the body, or in the vicinity of the body [15]. The sensors detect physiological data and transmit it, using an access point, to the medical server. Figure 1 shows three tiers of the architecture of WBANs. When the data is received in the server, it is analyzed by medical staff to detect the patient status.

One of the most important points is to pay attention to energy consumption in sensors. Small size and, in some WBAN cases, irreplaceable batteries in the sensors must operate for multiple years. Therefore, providing a communication protocol to minimize energy consumption levels is the goal when using tiny batteries in WBAN [16]. This is while a real-time transmission protocol with guaranteed performance is required for the critical data in WBAN. In real-time WBAN applications, sensors should instantaneously sense and transmit feedback to the medical staff to process the obtained information while achieving a bounded delay latency. With the recent advances of WBAN systems, real-time applications have attracted prominent attention from researchers. In real-time WBAN applications, the criticality level of a sensor is determined based on the nature of measured data. According to the criticality level of a sensor, its priority level is determined. The priority level is used for scheduling data to minimize data collisions. Critical data should be transmitted with high priority. It means high-reliability level and minimum delay are two prerequisites for transmitting it [16].

3. 2. Real-Time Systems A real-time system is a time-bound system that has well defined fixed time constraints. Processing must be done within the specified constraints, or the system will fail. Generally, computing systems involve one or more processes that is required to allocate a set of resources to these processes, such as computing resources, to perform user requests. These processes are divided into tasks. Tasks communicate with each other to achieve the goal of a process [17]. A task is real-time if the moments in which the results are produced are important as much as the logical accuracy of those results. A real-time system can consist of several real-time tasks. Regarding task period, real-time systems can be categorized into periodic or aperiodic tasks. In periodic tasks, a job is activated every T unit of the time where T equals its period. Aperiodic tasks are tasks in which there is no fixed time interval between consecutive activations [17].

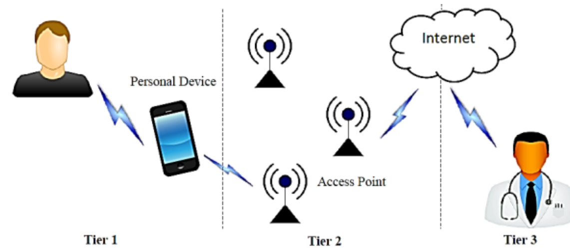

Figure 1. Three-tiers WBAN architecture

3. 3. Task Model In one of the simplest task models, periodic and aperiodic tasks are described by certain parameters namely execution time, deadline, and the period. The worst-case execution time (WCET) is shown as “C”. It is the maximum time that a task needs a processor to finish its computation. The corresponding deadline indicated as “D” is the last moment of counting that starts from the process activation in which the calculation results are still useful. The period or the minimum time between activations is indicated by T. These features are bundled together to describe a task [18]. Equation (1) shows the model of a task, which is indicated here by the letter τ.

$$\tau = (C, T, D) \tag{1}$$

3. 4. Priority Assignment Priority assignment of tasks in real-time systems is divided into static and dynamic modes. In static mode, the priority of tasks does not change during their execution, but in dynamic mode, this priority changes during task execution.

3. 5. Real-Time Scheduling Algorithms

3. 5. 1. RMS Scheduling Algorithm Rate monotonic scheduling algorithm (RMS) is a static scheduling algorithm based on priority in which processes are assigned priorities as a monotonic increasing function of their rates. Equation (2) is used to determine the priority of processes in the RMS algorithm, in that the letter "τ" indicates the desired task, the letter "T" demonstrates the period of the task, and the letter "P" also shows the priority of the task. This means that for the two tasks, i and j, a higher priority is given to the task with a lower period [19].

$$\forall \tau_i, \tau_j \in \tau, T_i < T_j \Rightarrow P_i > P_j \tag{2}$$

3. 5. 2. FCFS Scheduling Algorithm In the first come first serve (FCFS) scheduling policy, whenever a process is activated, the smallest priority is assigned to it. Over time, the age of the process and its priority increases. The process that has the highest priority is scheduled as the next process to run. A set of tasks is schedulable by FCFS if and only if all the tasks are simultaneously queued, (regardless of re-entry). Equation (3) represents this condition [20].

$$\forall_{i:\tau_i \in \tau} \sum_{j:\tau_j \in \tau} C_j \leq D_i \quad (3)$$

which "τ" indicates the desired task, "C" demonstrates the worst-case execution time of the task, and "D" shows the corresponding deadline of the task.

3. 5. 3. EDF Scheduling Algorithm The algorithm earliest deadline first (EDF) is a dynamic priority-based algorithm. It means that the priority of a request is assigned to it upon its arrival, and a higher-priority request can stop a lower priority request execution. In EDF, the higher priority is assigned to a request with the closest deadline. The utilization of this system, with the assumption that all deadlines are equal to their periods, has a limitation. Equation (4) indicates this limitation [21].

$$\mathrm{U} = \sum_{\mathrm{i}:\tau_\mathrm{i} \in \tau} \frac{\mathrm{C_i}}{\mathrm{T_i}} \leq 1 \quad (4)$$

which "τ" indicates the desired task, "T" demonstrates the period of the task, and "C" shows the worst-case execution time of the task.

In this case, EDF is an optimal scheduling policy among priority-based scheduling algorithms in which the deadlines are equal to their periods because the utilization value of no scheduling policy cannot reach above one [21].

Moreover, if EDF cannot schedule a set of tasks on a single processor, another algorithm cannot do this either [22]. The main disadvantage of the EDF scheduling algorithm is that it cannot manage the processor under overload conditions. After losing one of the deadlines, the following tasks will also miss their deadlines. This problem is known as a domino effect. It occurs when Equation (5) is valid [23].

$$\sum_{i=1}^{n} \frac{C_i}{T_i} > 1 \quad (5)$$

which "n" indicates total number of tasks, "T" demonstrates the period of the task, and "C" shows the worst-case execution time of the task.

3. 5. 4. LLF Scheduling Algorithm Algorithm least laxity first (LLF) is another optimal scheduling algorithm based on dynamic priority assignment. The laxity of a process is the deadline of process minus the remaining execution time. Equation (6) defines the laxity of a process., which "L" indicates the laxity of a process, "D" shows the corresponding deadline of the process, and "C" shows the remaining execution time of the process.

$$\mathrm{L_i} = \mathrm{D_i} - \mathrm{C_i} \quad (6)$$

In other words, it is the maximum time that the execution of a process can wait so that it does not miss its deadline. The algorithm assigns the highest priority to the process with the smallest laxity. Then, the process that has the highest priority is executed. So long as the process is running, it is possible to be stopped by another process with a smaller laxity than the running process. The problem occurs when the two processes have the same laxities. One process will be executed for a short period, and then will be preempted by another and vice versa [24].

One of the advantages of this algorithm is the fact that there is no other analysis except the schedulability test, namely the static priority assignment that should be made at the time of creation. Also, the task that is losing its deadline is detected at the same moment with the task that is not currently being performed. At that moment, the deadline is not still finished and emergency measures can be taken to cover the loss of the deadline. These advantages are associated with the issue of performing computational operations during scheduling. In addition, the LLF algorithm performs poorly when more than one task has the least laxity. In such a situation, at any unit of time, the content of the system switches from one task to another until they are finished (context switching). This behavior is referred to as the "thrashing" effect, which makes the system perform so many unnecessary switching between tasks. This high amount of context switching means loss of computing time [25].

4. PROPOSED METHOD

In this research, to support the need for real-time communication in body area networks and the energy constraints of sensor nodes in these networks, attempts are made to reduce the collision rate of packets in the network using scheduling algorithms of real-time systems and subsequently reduce energy consumption in the sensor nodes. For this purpose, the EDF scheduling algorithm and its combination with the LLF scheduling algorithm are used. In the proposed method, it is required to assign concepts such as the period, deadline, and the worst case of execution time to the sensor nodes in order to schedule the sending of packets.

The general trend of the proposed method consists of two phases, (1) EDF prioritizing phase, (2) Correction of prioritizing phase using LLF algorithm. In this way, the EDF scheduling algorithm is executed simultaneously and in parallel on all network nodes to identify them for sending their packets. In this case, if the turn of the two nodes equals, then to refine the algorithm from the arisen problems, the laxity parameter, which is used to determine the priority in the LLF algorithm, will be used to specify the higher priority node.

4. 1. EDF Scheduling Phase In this phase, to take advantage of the features of the EDF algorithm, it is necessary that the parameters, which are used for scheduling in real-time systems, to be allocated to the sensor nodes. For this purpose, a period, a deadline, and the worst case of execution time are determined for each node. The worst case of execution time here is the number of packets to be sent at each period. Initially, to run the EDF algorithm, nodes must send their parameters to other nodes with the broadcasting method. All nodes have a table in their memory that stores the parameters obtained from other nodes. After completing these tables, the EDF algorithm is executed on all nodes in parallel, and their turn for sending packets will be determined. Figure 2 shows the pseudo-code of the EDF algorithm.

4. 2. Correction of Prioritizing Phase Using LLF Algorithm As previously mentioned, in the EDF algorithm, if two deadlines happen to be equal, a domino effect may occur which leads to the loss of the next deadlines continuously. To remedy this problem, it is tried to use the laxity parameter, which is used to determine the priority in the LLF algorithm, to assign priority to the nodes to send their packets.

```
Insert(q,N)  //insert the node into the EDF queue
 {
   For each node Ni in queue //i=1 to N( number of current nodes in the queue)
     {
       If ( N.deadline < Ni.deadline)
         {
           queue_insert (q,N,Ni)  //insert N before Ni
         }
     }
       If (not inserted)  //all nodes in the queue have less deadline than node N
         {
           queue_app end(queue,N)  // add N to the end of queue
         }
 }
```

Figure 2. EDF algorithm pseudo code

The correction of the scheduling phase is such that, at first, the laxity parameter is calculated for nodes with the same deadlines. Then, the sending priority is allocated to the node which has less laxity. In this case, it is determined that if the laxity value of the two nodes are equal, then the node that is currently sending packets will continue its sending. Figure 3 illustrates the complete flowchart of the proposed method.

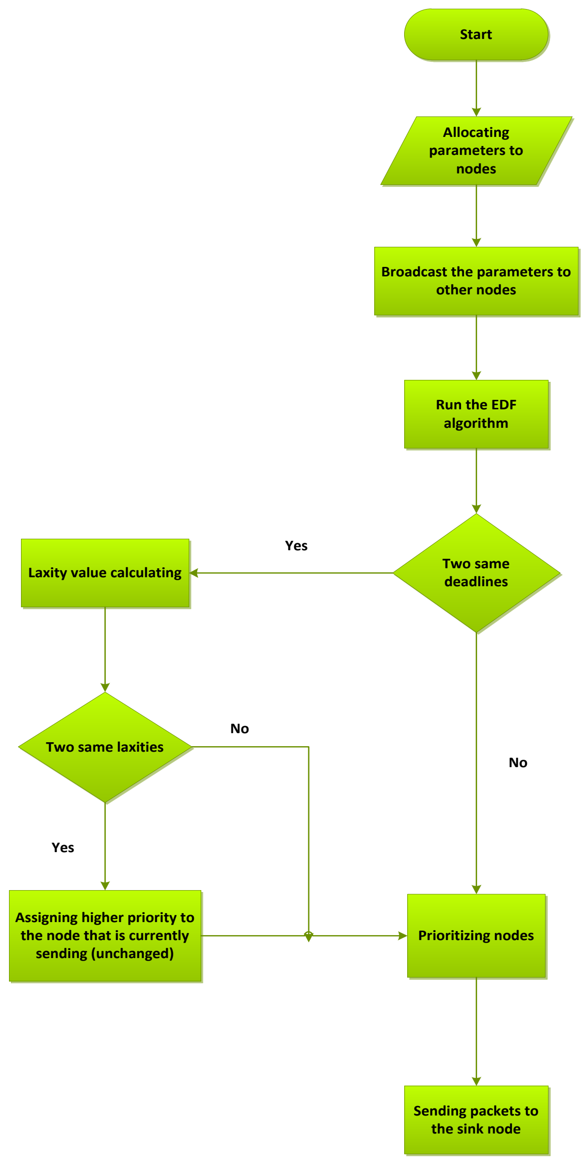

Figure 3. Complete flowchart of the proposed method

4. SIMULATION RESULTS

To simulate the proposed method, OMNET ++ simulator environment is used. Three different situations (random, EDF, proposed method) are used to simulate the body area network all of which are tested with 4, 10, 20 and 50 number of sensor nodes, and one sink node. The experimental results show that in case of dynamic scheduling, deadline based algorithms have supremacy over laxity based [26]. For this reason, the proposed method is not compared with LLF algorithm. The performance of each of the mentioned situations are evaluated in terms of two evaluation criteria; the percentage of packet delivery rate in the sink node and the average energy consumption in the sensor node. In the random scenario, whenever a node has a packet to send, it sends it to the sink node immediately without considering any time constraints. In the EDF scheduling scenario, the required parameters to execute the EDF algorithm, i.e. periodic, deadline, and the number of sent packets per period (capacity), are randomly assigned to the nodes. These parameters are stored in a table in the node's memory. Then, the nodes send their parameters to each other by broadcasting. Therefore, all nodes are aware of the parameters of the other nodes, and store this information in their table. After the tables are completed, the EDF algorithm is run simultaneously and in parallel on all nodes. According to this algorithm, the node with the smallest deadline has the highest priority. In this way, the priority and the order of the nodes to send the information packets are specified and the sending process starts.

At each period, the packet transmission at each node begins again, and this transmission must be done in a specified deadline. In this scenario, when the two nodes have the same deadlines, the algorithm randomly selects one of the two nodes.

In this case, the domino effect is likely to occur. For this reason, the algorithm is combined with the LLF scheduling algorithm in the third scenario. The hybrid scenario (EDF-LLF) behaves like the EDF scenario and the EDF scheduling algorithm runs on all the nodes in parallel and determines the nodes' turn to send packets. (EDF scheduling phase). Only when the deadlines of the two nodes are equal, it is determined that the node whose laxity parameter is less has higher priority. At this time, if the laxity of the nodes is equal, the algorithm selects the node that was sending its packets from before (unchanged). The values of characteristics assigned to each node in the EDF and EDF-LLF scenarios are randomly assigned, and attempts are made only to establish Equation (7) between these features. In this relation, P_i is the period specified for node i and D_i, is the deadline specified for node i, and C_i, is the capacity, or the number of packets that node i sends in each period.

$$C_i \leq D_i \leq P_i \tag{7}$$

Figure 4 shows the percentage of packet delivery rate in the sink node for all three random, EDF and EDF-LLF scenarios, as a linear graph, where n = 4, and n represents the number of sensor nodes in the network and t is the simulation time.

As it can be seen, when there are 4 nodes in the network, the proposed situation works slightly better than the other two scenarios in terms of percentage of packet delivery rate in the sink node and this is due to the scheduling in packet delivery and the reduction in collisions between them.

Figures 5, 6 and 7 show that the performance of the proposed scenario, and the EDF scenario, maintain this percentage of packet delivery rate even by increasing the number of nodes in the network while the random scenario has poor performance with an increased number of nodes in the network, and its percentage of delivery rate decreases.

For a better comparison of the performance of the three scenarios in terms of the percentage of packet delivery rate in the sink node, Figure 8 shows this criterion for all three scenarios at t=150.

As it can be seen, the percentage of packet delivery rate in the sink node, for the random scenario, decreases sharply as the number of nodes increases. Because in this scenario, whenever each node has a packet to send, it sends it, which by increasing the number of nodes and consequently increasing the number of sends, the

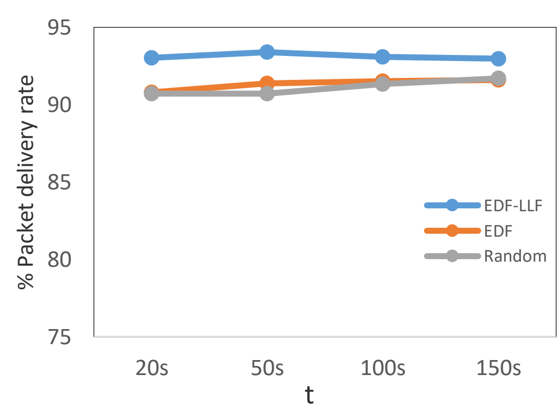

Figure 4. Packet delivery rate in the sink node, n = 4

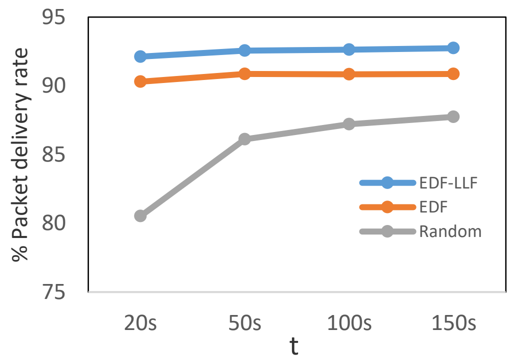

Figure 5. Packet delivery rate in the sink node, n = 10

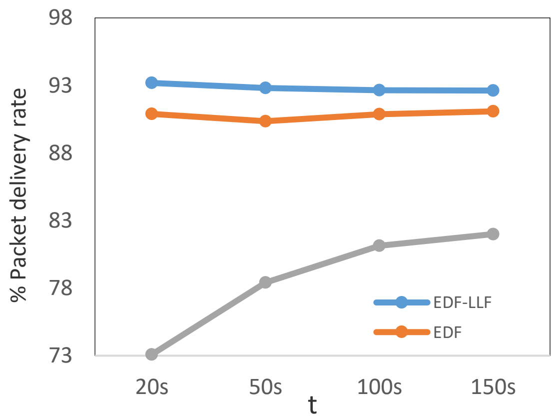

Figure 6. Packet delivery rate in the sink node, n = 20

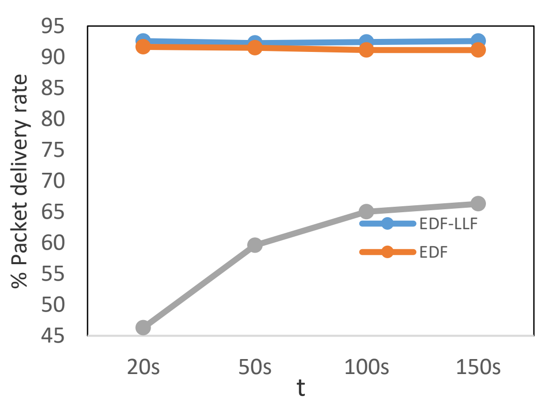

Figure 7. Packet delivery rate in the sink node, n = 50

number of collisions between sent packets also increases. This reduces the percentage of packet delivery rate in the sink node. While this case for the other two scenarios, even with increasing the number

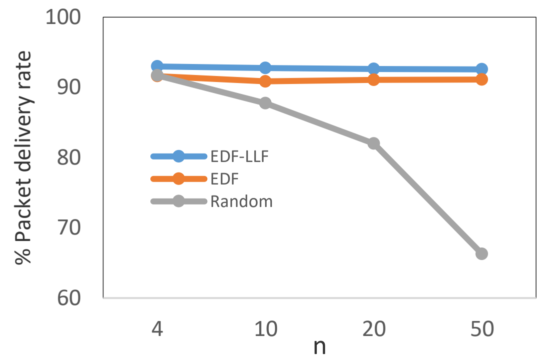

Figure 8. Packet delivery rate in the sink node at t = 150

of nodes is almost constant. As the scheduling of sending packets by real-time scheduling algorithms causes each node to send its packets in its turn, this causes the increase in the number of nodes in the network to have little effect on the percentage of packet delivery rate in the sink node. The proposed situation, by combining the two real-time scheduling algorithms and collision reduction, performs better, even compared to the EDF scenario. This is due to the better management of packet sending using the LLF algorithm. Figure 9 shows the evaluation criterion of the average energy consumption at node zero, with n= 4, for the three random, EDF, and EDF-LLF scenarios, as in linear graphs. (n represents the number of sensor nodes in the network.)

It is observed that the average energy consumption in the proposed method is higher than the random scenario in the node (0) at t=20. However, it is much less than the random scenario in continue of simulation. This is because at the beginning of the simulation, the proposed EDF-LLF algorithm has to be implemented in the nodes to specify their turn. This processing increases energy consumption at the beginning of the scenario. In continue the nodes can send their packets based on the specified order. This will reduce the average energy consumption in later times. Also, according to Figure 9, at t = 20, the average energy consumption for the EDF scenario is lower than the EDF-LLF. This is also because the EDF algorithm does not calculate the laxity parameter for prioritizing the nodes. That's why, although the energy consumption rate is low at the beginning of the scenario, it has a lower delivery rate than the EDF-LLF scenario. The same is true for the different number of sensor nodes in the network. Figure 10 shows the average power consumption at node (0) at t = 150, for all three scenarios, and all numbers of nodes. Figure 10 proves

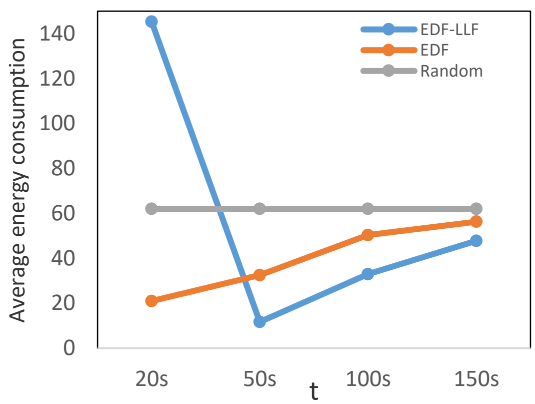

Figure 9. Average energy consumption at node zero, n = 4

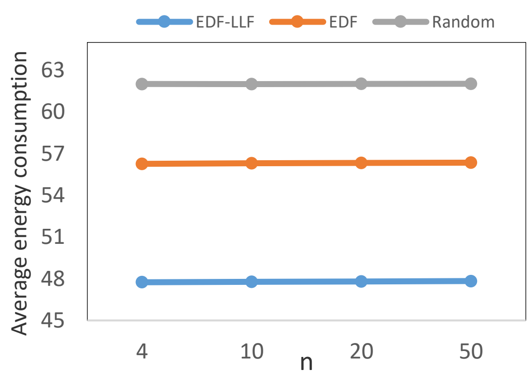

Figure 10. Average energy consumption at node zero at t = 150

that the proposed method performs better in terms of average power consumption than the other two scenarios by increasing the number of nodes.

5. CONCLUSION

This paper aims to show that using real-time scheduling algorithms and queuing nodes based on their priority could reduce the packet collision rate in the network and consequently increase the packet delivery rate in the sink node. Reduced collisions would also lead to reduced packet retransmission, which in turn reduces energy consumption in sensor nodes. This paper also shows that by combining two scheduling algorithms EDF and LLF, the problem of domino effect could be avoided and as a result, data with higher priority will have a better chance of timely reception in the sink node. Future studies are recommended to focus on how to automatically assign priorities to the sensed data in sensor nodes.

6. ACKNOWLEDGMENTS

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Persian Abstract

چکیده

شبکه‌های حسگر بدنی (WBANs) یک فناوری نوظهور هستند که با بهره‌گیری از حسگرهای کوچک و کم توان در داخل، خارج ویا اطراف بدن، توانسته‌اند تجربه‌ی بهتری از تحرک و انعطاف‌پذیری را برای انسان نسبت به سیستم‌های نظارتی سیمی سنتی فراهم کنند. به‌دلیل محدودیت زیاد در اندازه، مصرف انرژی و امنیت دستگاه‌های کاشتنی در بدن، طراحی این سیستم‌ها به‌طوری‌که قابل اطمینان و از لحاظ انرژی کارامد باشند، هنوز یک چالش تحقیقاتی بزرگ است. برای ارائه کیفیت خدمات در این شبکه‌ها، می‌بایست تحویل به موقع و مطمئن داده‌های بی‌درنگ، بدون از دست دادن بسته‌های داده، فراهم شود.در این مقاله، یک پروتکل ارتباطی به منظور ارتقای سطح کیفیت خدمات در شبکه های بدنی و کاهش مصرف انرژی در گره های حسگر، ارائه خواهد شد. برای انجام این‌کار، از الگوریتم زمانبندی بی‌درنگEDF و ترکیب آن با الگوریتم زمانبندی LLF، جهت نوبت‌بندی گره‌های حسگر در ارسال بسته‌های اطلاعاتی استفاده خواهد شد. به منظور بررسی کارایی راهکار پیشنهادی، از محیط شبیه‌سازی OMNET++ استفاده شده است که معیارهای ارزیابی درصد نرخ تحویل بسته در گره چاهک و میانگین مصرف انرژی در گره حسگر را با تعداد مختلف گره در شبکه بررسی می‌کند. نتایج بدست آمده، نشان می‌دهند که راهکار پیشنهادی، بهبود مناسبی در ارسال و دریافت بسته‌ها، برای شبکه‌های حسگر بدنی ایجاد می‌کند.