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Clustering algorithms for energy efficient lifetime in HWSN

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***Abstract*— Wireless Sensor Network (WSN) is a collection of spatially distributed sensor nodes in order To acquire information from locally collected data. Those nodes have to communicate wirelessly to form a network and should collaborate amongst themselves to perform any common task. Heterogeneity and Mobility of the sensor nodes have imposed new research challenges and demand for new energy efficient solutions in order to increase network lifetime. In this paper, we focused on one of basic issues in WSN, which is energy consumption. We also present a performance evaluation study for a healthcare system given three handover mechanisms (MAEB, H-MOHRA and CCPE-PSO). A simulation was performed using several scenarios with different sizes of network. The results show that EECP-PSO is the best solution to ensure lower energy consumption.**

***Keywords*— Healthcare, Routing protocol, Clustering, WSN, Energy consumption.**

I. Introduction

Nowadays, Healthcare aware Wireless Sensor Networks (HWSNs) have received a great attention due to the properties of WSNs such as reliability, interoperability, efficiency, wearability, low-power consumption and inexpensiveness.
Healthcare cost crisis and growing death rate motivates researchers and the healthcare service providers to devise new, cheap and smarter way of providing remote healthcare to people suffering from such diseases which require long term and continuous monitoring. The use of WSNs in healthcare is a sort of optimization of operations related to patients' monitoring tasks. In a classic health system, sensors as well as EMG, ECG, EEG, body temperature, and motions/positioning are forwarding their data via wireless interface to a base station or Sink. This data is then streamed to the hospital via a wide coverage network such as 3G, GPRS/SMS, U-Health, LAN or WLAN to a medical doctor, hospital, telemedicine or to ambulatory service in emergency cases.

In WSNs, clustering is an important technique applied in order to improve the lifetime of a sensor network and scalability [1]. In clustering, WSN network is divided into clusters and each one of them has a cluster head (CH). Each CH is responsible to collect the sensed data from his cluster and transfer it to the sink [2]. The routing protocol needs to transfer data to their destination which is sink in the best conditions which are associated with metrics such as highest throughput, lowest delay, best link quality, smaller hop count, minimum energy consumption and maximize lifetime of the system [3]. CH consumes more energy to perform the collection and transmission of cluster data. However, other cluster nodes still have more than 90% of their initial energy. This is a normal situation happened because of the unbalanced energy assumption which causes more drain of energy in the network [4]. To solve this issue, many energy efficient routing protocols and algorithms have been propose recently, including power-aware routing [5] [6], cluster based protocols [7], and multi-level transmission radio routing [8]. In this paper, we are interesting to cluster based routing protocols, as shown in the next section.

In the following, we will quote some examples of the researchers' work, particularly for the algorithms based on clustering.
The idea of BEENISH [9] is that sensor nodes having higher residual energy will always be the CH. The probability of choosing ultra-super sensor nodes as CH, in the successive rounds, is very high. BEENISH performs uniform energy distribution throughout the network and improve the lifetime of the system. Also, LEACH [10] is one of the most popular self-organizing, distributed cluster based routing protocols. The problem of this protocol is that the cluster heads are selected without considering the residual energy or the other properties. In addition, the random mechanism of cluster heads selection does not guarantee the clusters distribution over the network. Another distributed clustering protocol that is an extension of LEACH is HEED [11]. Cluster formation is realized with an iterative approach. The selection of CH in this protocol is based on two parameters: residual energy and communication cost. The authors in [12] perform a modification on LEACH protocol, in which the new algorithm improves the selection process of CH. It takes into consideration the residual energy of nodes and adopts its probability outcome to determinate next round threshold value. EEHC [13] respect residual energy of each node and its weighted probability to become CH. In this protocol, not only consumption of energy resources of the sensor network is improved, but also the process of election of CH due to

heterogeneity. Energy-Efficient and Distance-based clustering (EEDC) is a similar proposed algorithm based on distance condition and cluster head election [14]. In EE-SEP [15] more network stability and energy efficacy are supplied. This algorithm considers standard sensor nodes and advanced nodes. A non-cluster node is elected as a CH based on the percentage of CH demanded with a given population of sensor, the number of current round and set of nodes those, in the previous round, were not CH. A new protocol called RMCHS (Ridge Method Based Cluster Head Selection for Energy Efficient Clustering Hierarchy) [16] was proposed. It performs energy efficient cluster head selection which distributes reasonably the cluster heads, balances efficiently the levels of energy consumption of nodes and extends the network lifetime. In [17], Authors propose a routing protocol named Mobile Data Collector-based (MDC). It uses three-tier network architecture and multi-hop communication to provide potential energy savings due to the long and the multi-hop communication.

The remainder of the paper arranged as below: section II describes the studied network model, section III offers a description of three routing protocols, namely MAEB, H-MOHRA and EECP-PSO, section IV introduces result analysis of simulation and Section V concludes the work.

II. Studied System

Health telematics is a growing up question that is becoming a major improvement on patient health, especially in disabled, elderly and chronically ill. Recently, communication technologies improvements and information, guaranteeing anytime and anywhere connectivity, play an interesting role on modern healthcare solutions. A wearable system has a key function in ubiquitous healthcare and is characterized by the biomedical sensors deployment, on human body or implemented in, to collect physiological data and transmit them to the base station for processing. Fig.1. presents some sensors attached to patients being able to sense patient information.

The architecture of the healthcare systems is depicted in Fig. 2. It is composed of the WSNs and a system of telemedicine. It can service hundreds or thousands of patient users. Each patient wears a number of body sensor nodes which are placed on or in his body. We considered that every patient form a cluster of sensor nodes in which one is chosen as a Cluster head. This cluster head (CH) is responsible to broadcast to information about his cluster to the base station and then to the telemedicine system.

In this paper, a hospital infirmary, presents in Fig. 3 was emulated by a network scenario to evaluate the performance of the handover mechanisms in HWSNs. Our infirmary area was considered as being a size about 100.0 m by 40.0 m. It was supposed that each CH could cover an area of 10 m radius to ensure bidirectional communication with others CHs. The definition of this value was based on Shimmer technical characteristics platform used for medical applications [18].

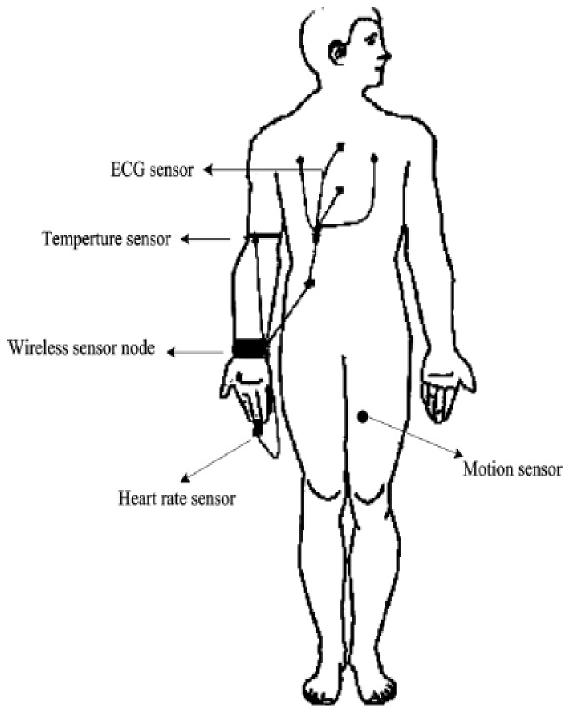

Fig. 1 Different sensors attached to patients

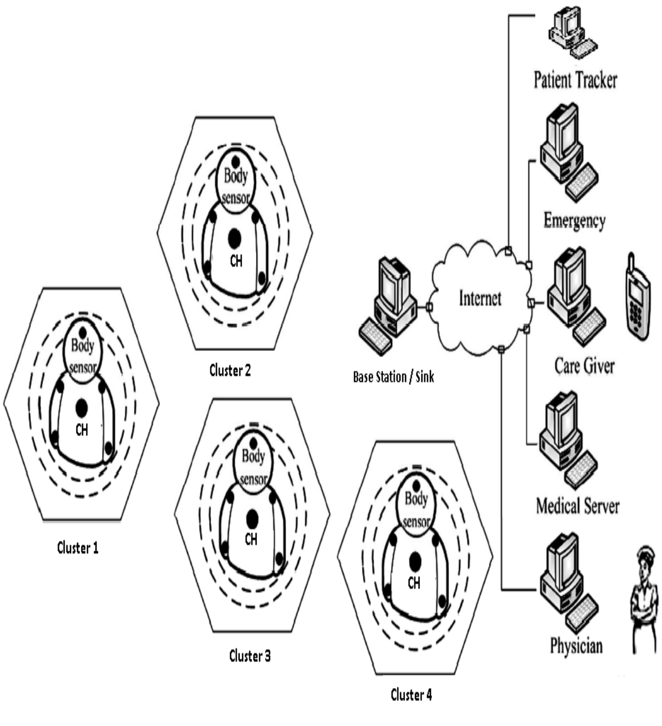

Fig. 2 Architecture of healthcare systems

Our assumed network is composed of 10 patients so 10 clusters and 10 CHs. In this network, sensor nodes were compliant with IEEE 802.15.4 communications. To simulate the movement of patients around the infirmary, a random strategy was followed.

For simulation needs, it was considered that all the elements of communication in this scenario were prepared with a CC2420 radio transceiver [19].

To aggregate data, we used a routing protocol taking into account energy consumption. We will perform a comparative study between 3 protocols to select the more adequate one.

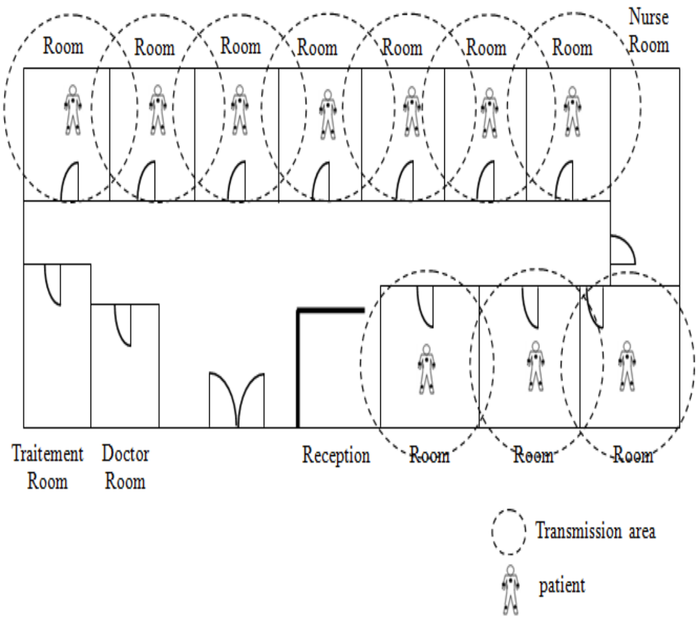

Fig. 3 Illustration of a hospital infirmary used in the simulation scenario

III. Energy Loss Causes

Battery-powered nodes have limited energy reserves, therefore, applications and protocols used for WSNs, should be designed, concerning the optimized energy consumption in order to prolong the network lifetime. Data reception and transmission are the main energy consuming operations and they are regulated by the network layer, hence the routing protocol plays very important role in network optimization.

MAC sub-layer plays a key role in the coordination between the nodes and minimizing energy consumption, since nodes share the same transmission medium.

Therefore the main causes of energy loss are:

- Retransmission of lost packets can cause a significant loss of energy. Indeed, the sensor nodes have usually only one radio antenna and same transmission channel. So that, simultaneous data transmission from multiple sensors may create collisions and consequently a loss of transmitted information.
- Overhearing is occurs when one node receives packet that is not addressed to it.
- Sitting idly and trying to receive when no other node is sending.
- Many MAC layer protocols function by exchanging control messages (overhead) for diverse functions: connectivity, signaling, collision avoidance and establishment of plan. All these messages require additional energy.
- Overemitting occurs when a sensor node sending data to another who is not ready to receive them.
- The size of messages exchanged on the network has an influence on the energy consumption of nodes.

IV. Considered Routing Protocols

In this section, we describe the chosen protocols and present how it minimizes the energy consumption.

A. *MAEB Protocol*

The main goal of the Movement-Aided Energy-Balance (MAEB) [20] is to increase energy efficiency for deliver the data. In this protocol, energy information and the movement of the neighbor coordinators are collected and stored in the procedure of neighbor discovery. The MAEB forwarding is used to pick out the most adequate neighbor CH to forward the data. For each cluster, the HC has more energy organizes the entire network. Sink and CHs transmit periodic signaling frames for synchronizing the nodes in the network. Step one of the MAEB is neighbor discovery procedure which leads by the CH of the cluster. After the CHs get information about their neighbor, they send their packet data to the sink according to a forwarding rule, in which the velocity and distance to the sink and the remaining energy is considered to choose the neighbor CH. Neighbors selection mechanism affects the energy consumption and packet delay of the whole network. CH scans the strength of received signals and finds the neighbors in its transmission area and then establishes a neighboring table to store its information. By calculating K, we can know the most appropriate neighbor coordinator to transmit the packet (which has the smallest k):

$$k = a\frac{D_N}{D_S} + b\frac{V_N}{V_S} + c\frac{E_T}{E_R} \quad , \quad 0 \geq a,b,c \geq 1 \qquad (1)$$

Where D_N is the distance between the neighbour CH and sink, D_S is the distance from CH itself to sink, V_N is the relative velocity of the neighbor CH and sink, V_S denotes the relative velocity of CH itself and sink, E_T is the data packet transmission energy, E_R denotes the residual energy of the neighbor CH. $a, b,$ and c are three weighting parameters, which are between 0 and 1. They can be adjusted depending on the application scenario. Fig. 4 describe MAEB neighbour CH discovery.

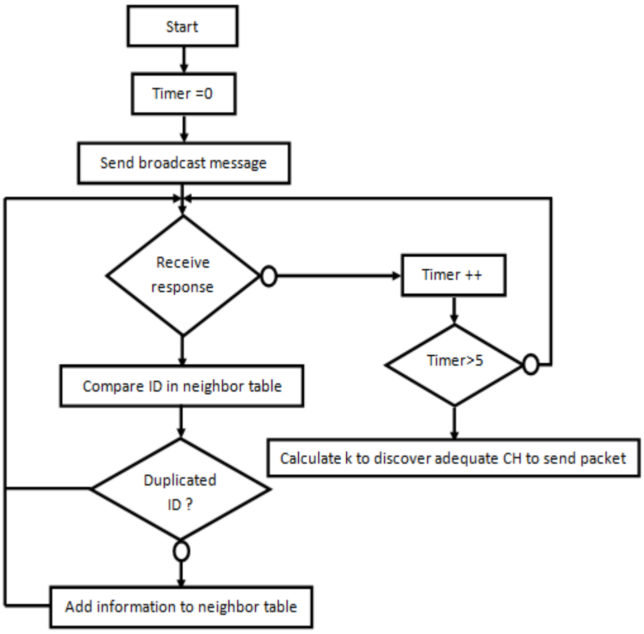

Fig. 4 Flowchart of MAEB neighbour CH discovery

B. *H-MOHRA Protocol*

In this protocol [21], the sensor nodes are responsible for detecting the events in the vicinity. The sensing area is divided into small groups called clusters. The cluster is divided into cluster head (CH) and cluster member (CM). In every cluster, the CMs will elect the CH. The CM and CH arranged in the Binary Heap Tree (BHT) [21]. This procedure is repeated for all the elected CH at second level. The CH election depends the weighted average of many parameters which are Mean Energy Utilization, Control Overhead, Connection Quality Measure, Response Time and HOPs. At second level, CM with largest weighted sum is selected as CH. H-MOHRA consists of three phase: cluster formation, CH election and data communication. The Cluster formation phase relies on the broadcasted Hello message by all the CMs and then the response from the neighbouring nodes. The CH election based on $f\left(n_{ij}\right)$ which is a global parameter as presented in Eq (2) [22]:

$$f\left(n_{ij}\right)=\alpha.m_{energy}\left(n_{ij}\right)+(1-\alpha).\left[\begin{array}{l}\beta.m_{overhead}\left(n_{ij}\right)+(1-\beta).\\ \left[\begin{array}{l}\gamma.m_{rtime}\left(n_{ij}\right)+(1-\alpha)\\ \left[\begin{array}{l}\delta.m_{lqi}\left(n_{ij}\right)\\ +(1-\delta)\left[\eta.m_{hops}\left(n_{ij}\right)\right]\end{array}\right]\end{array}\right]\end{array}\right] \quad (2)$$

Where $0\leq\alpha,\beta,\gamma,\delta,\eta\leq1$ are factors of weighting.

CMs will evaluate the global parameter and will update the routing table referring to new values of the cost. In order to update the routing table, CMs disseminate the updated information to all their neighbours. The CMs make a BHT and the CM with minimum weighted average will be the next CH for the next iteration. The sender node transmits a data packet to its parent node, as can be obtained from the routing table. The parent node will send the package to his immediate antecedent node from BHT. It repeats until the data packet reaches the sink node. Fig. 5 show the H-MOHRA algorithm which is used for intra and inters cluster communication.

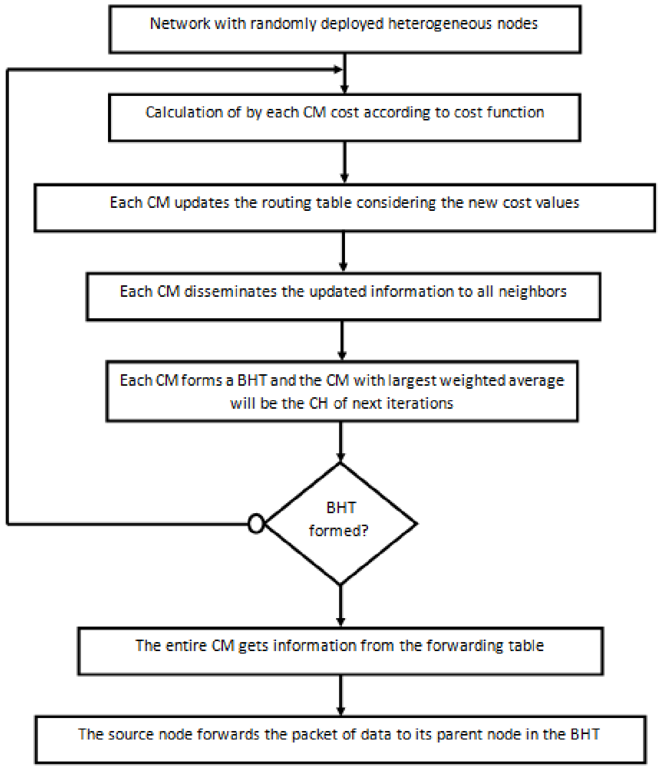

Fig. 5 Flowchart of H-MOHRA

C. *EECP-PSO Protocol*

In Energy Efficient Clustering Protocol for WSN using PSO [23], the establishment phase starts with neighbour discovery where each sensor node in the network transmits a hello packet that includes its ID. Neighbour table will be updated with the ID included in this packet and the Received Signal Strength Indicator (RSSI) value. Then, the protocol used the flooding method to transfer the control data to the sink. After that, sink run PSO algorithm to find suitable CHs. This algorithm selects only node having enough energy.

To minimize the number of active CHs during each round, in order to save more energy, we have to minimize the following function:

$$EE1_p=\frac{K}{D} \quad (3)$$

The sink uses the following sub-objective to equilibrate the energy consumption between nodes:

$$EE2_p=\sum_{k=1}^{K}\frac{initial\left(CH_{p,k}\right)}{E\left(CH_{p,k}\right)} \quad (4)$$

The process of neighbour discovery is illustrated by fig. 6.

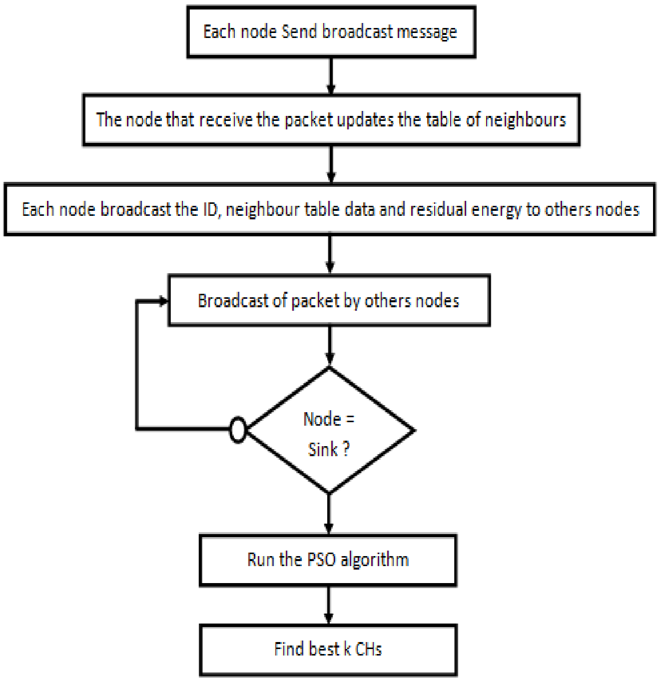

Fig. 6 Flowchart of EECP-PSO neighbour discovery

V. Simulation Results

The simulations were performed on ns2 [24] simulator using 5 different network sizes ranging from 20 to 100 sensor nodes, and each network was tested using 5 different random seeds and the initial energy of a standard node is set to E = 18720 Joules. In the table below, we can found parameters of the simulation used for CC2420 operation [25].

TABLE I
Parameters of Simulation

Parameter	Values
Target area (m)	100 * 40
Experimentation time (s)	200
Initial energy of nodes (J)	18720
Data rate	0,2
Packet length (byte)	512
Number of nodes	20 – 100 in step of 20
Radio	CC2420
Rx power (mW)	52,2
Tx power (mW)	56,4
Idle power (mW)	1,28
Sleep power (mW)	0,003

We compared MAEB with H-MOHRA and EECP-PSO in terms of the energy consumption and packet delivery ratio. Firstly, the energy consumption means the average quantity of energy consumed by sensor nodes. Secondly, the packet delivery ratio denotes the ratio between the number of data packets received by the sink and the number of data packets delivered by source mobile node.

A. Average Energy Consumption (AEC)

It is clearly shown from Fig. 7 that Average Energy Consumption of EECP-PSO is less than H-MOHRA and MAEB thanks to using less number of CHs and balancing the energy consumption as insured by two equations above. Indeed, using a number of nodes between 20 and 100, we note that with EECP-PSO, the network consume less quantity of energy than MAEB, which is better than H-MOHRA except when we used 80 nodes.

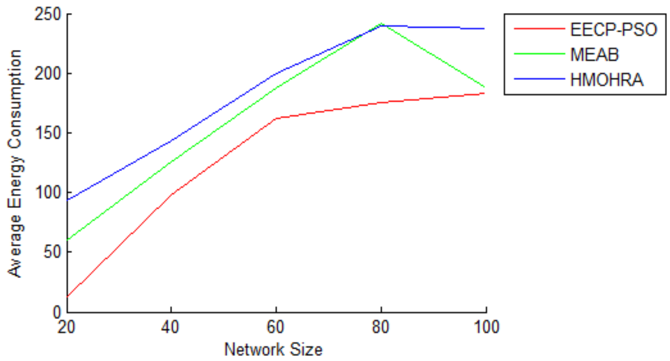

Fig. 7 Average Energy Consumption

B. Packet delivery ratio

PDR is the correlation along with the number of packets received by the sink, as against the number of packets send from all the nodes by the senders.

Fig. 8 demonstrates the PDR of MAEB, EECP-PSO and H-MOHRA. We observe that when using 20 or 100 sensor nodes, MAEB is the most efficient protocol in terms of packets delivery. For the three others network sizes (40, 60 and 80), EECP-PSO is the most efficient. When the network is composed of 80 nodes, H-MOHRA deliver almost 77% of packets, whereas MAEB deliver only 70%.

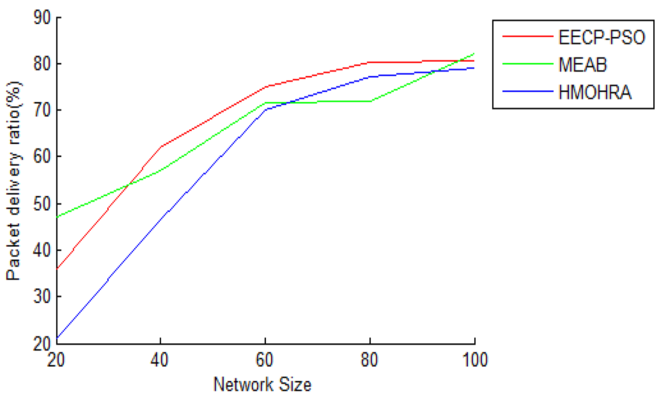

Fig. 8 Packet Delivery Ratio

We conclude that for EECP-PSO, PDR is higher because of the fact that the best route is chosen quickly and correctly.

Referring to the simulation results of Average Energy Consumption and Packet Delivery Ratio, we can considerate that the adequate protocol to use in our system network in EECP-PSO.

VI. CONCLUSIONS

Extending the lifetime of wireless sensor networks is one of the most critical issues.

In some fields such as telemedicine, network lifetime must be increased because of the very important temporal services to perform like continuously monitoring capacity of vital signs such as electrocardiogram (ECG), blood pressure.

We compared three routing protocol in term of energy consumption and we have shown that EECP-PSO is more efficient than two other protocols. These results encouraged to use the EECP-PSO mechanism in a real hospital.

The evaluation of those three promising approaches was performed by simulation encouraging enhancing and evaluating it in real scenarios.

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