A New QoS-Aware and Stable Opportunistic Routing Protocol for Mobile Wireless Networks

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ABSTRACT:
Due to the specific nature and various limitations in the architecture and resources of mobile wireless networks, AD HOC networks are highly challenging and risky in terms of quality spheres and maintaining such systems. Opportunistic routing provides the opportunity to improve these issues and enhance the network performance appropriately. Meanwhile, due to unspecified exchange routes in this strategy, it is more difficult to support the quality of routing. In this type of routing, decision-making and candidate prioritization are done based on a criterion named "opportunism" in such a way that this method of prioritization and selection leads to increased instability in intermediate routes. Accordingly, in order to improve this issue, this research introduces a new routing protocol, named "QoS-Aware and Stable Opportunistic Routing Protocol (QSORP)". The QSORP is a three-stage protocol that is based on the performance of its stages, this protocol tries to provide quality together with stability in opportunistic routing, depending on the necessities and requirements of this type of routing. The QSORP protocol supports the capability of reducing the complexity of candidate management in addition to effectively support the quality and stability of links. In order to evaluate the QSORP's performance and efficiency, this protocol is simulated using the OPNET simulator and then the protocol is compared with two other protocols; ORAC and QEOR. The simulation results indicated the superiority of the proposed protocol based on the following criteria: unstable intermediate routes, the rate of the received data, and network throughput.

KEYWORDS: Ad-hoc Networks, Opportunistic Routing, Quality of Routing, Stability of Candidates.

1. INTRODUCTION

For the first time, AD HOC networks emerged in the United States in an attempt to monitor battlefields and military facilities, but over time, with the advancement of electronics and telecommunications, and their easy installation and application in different situations, they were introduced and used in various areas such as transportation, industry, medicine [1]. The category of quality and stability in AD HOC networks have always been subject to unwanted factors, and are considered the most challenging topics in the networks [1], [2]. The importance of these topics is doubled due to the applications of AD HOC networks in sensitive and critical areas such as military, medical and other sensitive applications (in a way that the quality and stability are considered the most fundamental issues of these types of applications) [2[, [3].

Among the most important characteristics of AD HOC networks are their applicability in different areas, the absence of a fixed infrastructure, dynamic network connectivity, wireless connections, self-organization, and multi-hop communications [1]. These unique characteristics have caused issues raised in other networks such as quality and supporting the stability of service providing to be put forward differently in this category of networks from those in other networks [2], [4]. Among the most important of these differences are securing and supporting the quality and stability of routing and intermediate routes.

Accordingly, many studies have so far been conducted to improve this fundamental area of AD HOC networks based on expanding the variations of routing strategies. In traditional routing protocols, in case of failure in the optimal route towards the destination, the source will need to repeat the routing process in order to continue data sending. Opportunistic routing desirably improves this issue and enhances the performance of AD HOC networks through its capability of candidate prioritization. On the one hand it is more difficult to support the quality due to unspecified exchange routes, on the other hand the complexities and problems, decision-making and candidate prioritization, and intensified issues associated with the instability of routes are existed. Also, it doubled the importance of supporting quality and stability.

In this paper, we introduced a new mechanism to protect and secure the stability and quality of routing, named the “QoS-Aware and Stable Opportunistic Routing Protocol (QSORP)”. QSORP is developed and designed based on three stages: candidates’ limitation, qualitative evaluation of candidate sensors, and evaluation of candidates’ stability. Focusing on developed opportunistic routing and the performance of its stages, QSORP creates the capability of desirably protecting and securing the quality and stability in AD HOC networks. This will eventually create the capability of securing the quality and stability of candidates in the steps of intermediate routes.

This paper consists of the following sections: Section II: A Review of Research Literature, Section III: An Introduction to the QSORP Protocol, Section IV: Simulating and Analyzing the Performance of QSORP, and Finally Section V: Summarizing the Paper

2. A REVIEW OF THE LITERATURE

According to the introduction, opportunistic routing has many complexities and challenges for supporting quality and stability. Taking into account challenges on the one hand, and the high importance of quality and reliability in the routing process of AD HOC networks on the other hand, many methods have been presented, focusing on the quality and stability. In what follows, we will review and discuss the performance of some of the most important methods.

A[1] protocol named “D-MACE” has been introduced in [5] (Darehshoorzadeh et al., 2014) aiming at finding the optimal number of transmission candidates in each round of routing. Compared to traditional protocols, most opportunistic routing protocols choose equal numbers of transmission candidates for each intermediate step. D-MACE introduces this as the complexity of these protocols, thus determining and assigning a variable number of candidate nodes in each intermediate step based on their distance to the destination. The results of the simulation of this protocol indicate the optimization of the complexity of opportunistic protocols based on this strategy. However, the instability of candidates depending on their distances and its intensification due to the strategic planning, and the lack of support for the quality of routing are among the fundamental limitations of this research.

Reference [6] (Budyala et al., 2014) has introduced a protocol named “QARA”[2], which focuses on supporting the quality of routing. QARA expands its performance based on three criteria: transmission rate, latency, and bandwidth. Candidate nodes are first selected on an opportunistic basis, and then the priority of the candidates is determined based on the functional criteria mentioned. Intermediate nodes in this protocol, are prioritized and selected based on logic and fuzzy sets. Thus, the afore-mentioned criteria are applied as inputs to the fuzzy set, and the outcome or output of the set will be the selection of the best node with the highest priority level for routing and exchanges. The increase in overheads and the instability of candidates in intermediate exchange routes are among the limitations of this research.

Reference [7] (Qin et al., 2015) has introduced a protocol named “ORAC”[3] in order to support the quality of opportunistic routing. ORAC acts in order to improve opportunistic routing based on directing the variations of transmitted flows according to the most important quality indices. The protocol proposed in this research first specifies a flow-acceptance control scheme to select candidate nodes based on the opportunistic index, bandwidth, the rate of flows entering the node, and the energy left in the node; and accordingly selects the candidate nodes in opportunistic routing. The use and combination of the functional criteria of the proposed protocol is in a way that in addition to supporting the quality of candidates, it supports the control of congestion as well. The simulation results are indicative of the increased quality of exchanges in the network based on the performance of the proposed protocol. However, in the limitations of this research, we can refer to the instability of candidates along intermediate exchange routes.

[4]A protocol called “EE-ARP” has been proposed in [8] (Sandhya et al., 2016) to support instant services. EE-ARP is a three-stage protocol, whose three stages are as follows: 1- Identification and removal of delayed packets: This process is carried out based on estimating a criterion called expectation latency (based on the distance between the current node and the source, and the current node and the destination) and the Packet Removal Decision Rule Algorithm such that packets delayed. 2- The Comparative Transmission Power Algorithm: This algorithm estimates the comparative power for packet transmission based on the geographic distance between adjacent nodes aiming to improve the rate of received packets and optimize energy consumption. 3- Forwarding: In this step, suitable candidate nodes are identified based on the opportunistic index, and are prioritized accordingly. Eventually, the node with the highest priority level is selected as the main candidate for exchanges, and the information is transmitted based on the selected node. Among all

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[1] Distance-based Maximum number of Candidate Estimation

[2] QoS anycast routing agency

[3] Opportunistic Routing scheme which considers Admission Control

[4] Energy-Efficient Adaptive Routing Protocol

capabilities of EE-ARP, we can refer to preventing useless and delayed data exchanges, but, among all important limitations of this research, we can refer to the instability of candidates in intermediate exchange routes.

Reference [9] (Tiab et al., 2016) has introduced a [5] protocol called “QEOR” based on the criteria: opportunism, latency, energy, and the received rate to improve candidates’ elections. The criteria are evaluated and combined through the variable valuation capability to protect and secure the adaptability of the protocol in different applications under different conditions. It gives importance and value to each criterion in calculations proportionally to the value of that criterion. The quality support in relation to candidate nodes is one of the important capabilities of this protocol, resulting in step by step quality support, and ultimately end-to-end quality support. Other limitations are as follow: the instability of candidates during the exchanges of intermediate nodes, the increased number of failures in intermediate routes, and instable exchanges.

So far, we have introduced some of the most recently developed and offered protocols in order to improve the performance. Subsequently, some of the other most important protocols in this field in the form of survey studies are reviewed, as presented in Tables (1) and (2), and discussed from the perspective of key indices in opportunistic routing and the category of quality and reliability [5-33].

Table 1. Categorization of opportunistic protocols from the perspective of the functional strategy and the operational state.

Opportunistic protocols				
Geographical	Connection aware	Probabilistic	Optimization-based	Interlayer
QARA [6]	Economy [14]	ORAC [7]		
POR [10]	Slide OR [15]	EE-ARP [6]	Profit-based	Physical-layer aware
TLG-OR [11]	CCACK [16]	QEOR [8]	D-MACE [5]	Parallel-OR [25]
CORMAN [12]	O3 [17]	EBR [18]	Consort [20]	TLG-OR [11]
COR [13]		Max Opp [19]	O3 [17]	SPOR [26]
			TOUR [21]	CORMAN [12]
				COR [13]
			Learning-based	HS-OR [27]
			AdaptOR [22]	EEOR [28]
			ORL [23]	MAC aware
				ORPL[29]
			Tree-based	QOR [30]
			LOR [24]	ORCD [31]
				ORW [32]
				Physical-layer-and-MAC aware
				CL-EE [33]

The lack of desirable support for the quality and stability of candidates are among the most important challenges facing the methods and protocols of opportunistic routing. In this paper, we try to provide a protocol which has the capability of supporting the stability and quality of candidates in response to the needs of opportunistic routing. And we believe that the limitations and challenges in the previous studies are well covered and improved by the performance of the desired protocol.

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[5] QoS aware and Energy efficient Opportunistic Routing protocol

Table 2. The analysis of indices and capabilities in the previous studies in the field of opportunistic routing.

Protocol	Year	Index	Coordination strategy	Timing	Network coding	Rate control	Mobility	Stability of candidates
POR [10]	2010	Geo. distance	Timer	IEEE 802.11	-	-	✓	Medium
Economy [14]	2010	ETX	Token	Token-based	-	-	-	Poor
SlideoR [15]	2011	ETX	ACK	-	Intra-flow	-	-	Poor
CCACK [16]	2012	ETX	NSB-ACK	-	Intra-flow	✓	-	Poor
O3 [17]	2012	ETX	Timer	-	Intra/Intra flow	✓	-	Poor
Consort [20]	2012	ETX	Overhearing	Collision-Free MAC	Intra-flow	✓	✓	Medium
TOUR [21]	2014	Delivery Delay	Overhearing	-	-	-	✓	Medium
AdaptOR [22]	2012	PDR	ACK	Duplicate-Free MAC	-	-	-	Poor
ORL [23]	2013	PDR	Overhearing	Duplicate-Free MAC	-	-	-	Poor
LOR [24]	2013	Link Quality	Overhearing	-	-	-	✓	Medium
ORCD [31]	2010	Queuing Time	ACK	-	-	-	-	Poor
EBR [18]	2010	Delay-Goodput	Overhearing	-	-	-	✓	Poor
MaxOpp [19]	2010	ETX	Overhearing	IEEE 802.11	-	-	-	Poor
EEOR [28]	2012	Energy	Overhearing	-	-	-	-	Poor
CL-EE [33]	2014	Energy	ACK+ Overhearing	-	-	-	-	Poor
ORPL [29]	2011	ETX	Timer	IEEE 802.15.4	-	-	-	Poor
QOR [30]	2012	Link Quality	ACK+ Overhearing	Preamble MAC	-	-	-	Poor
ORW [32]	2014	Link Quality	ACK+ Overhearing	Duty Cycle+LPL	-	-	-	Poor
SPOR [26]	2011	Interference Aware PDR	ACK+ Overhearing	RTS/CTS based	-	-	-	Poor
CORMAN [12]	2012	Hop Count+RSSI	Overhearing	-	-	-	✓	Poor
COR [13]	2014	Link Quality	Timer-based	CSMA	-	-	✓	Medium
HS-OR [27]	2013	Link Quality	ACK+Timer	-	-	✓	-	Poor
TLG-OR [11]	2013	LQI,Energy,Geo distance	Timer+ Overhearing	-	-	-	✓	Medium
Parallel OR [25]	2013	SINR-based	ACK	TDMA	-	-	-	Poor
D-MACE [5]	2014	Geo. Distance	ACK+ Overhearing	CSMA	Medium	Medium	Medium	Medium
QARA [6]	2014	Link Quality	Overhearing	IEEE 802.11	-	-	✓	Medium
ORAC [7]	2015	Link Quality	Overhearing	IEEE 802.11	-	-	✓	Medium
EE-ARP [8]	2016	Energy	ACK	CSMA	-	✓	-	Poor
QEOR [9]	2016	Link Quality	Overhearing	IEEE 802.11	-	-	-	Poor

3. INTRODUCTION TO THE QOS-AWARE AND STABLE OPPORTUNISTIC ROUTING PROTOCOL (QSORP)

The proposed protocol has appropriate conditions for implementation in the IP layer. It is also implementable on opportunistic routing protocols in networks, and is highly compatible with these protocols. The operational diagram of the proposed protocol QSORP along with its relevant operational components has been illustrated in Fig. 1.

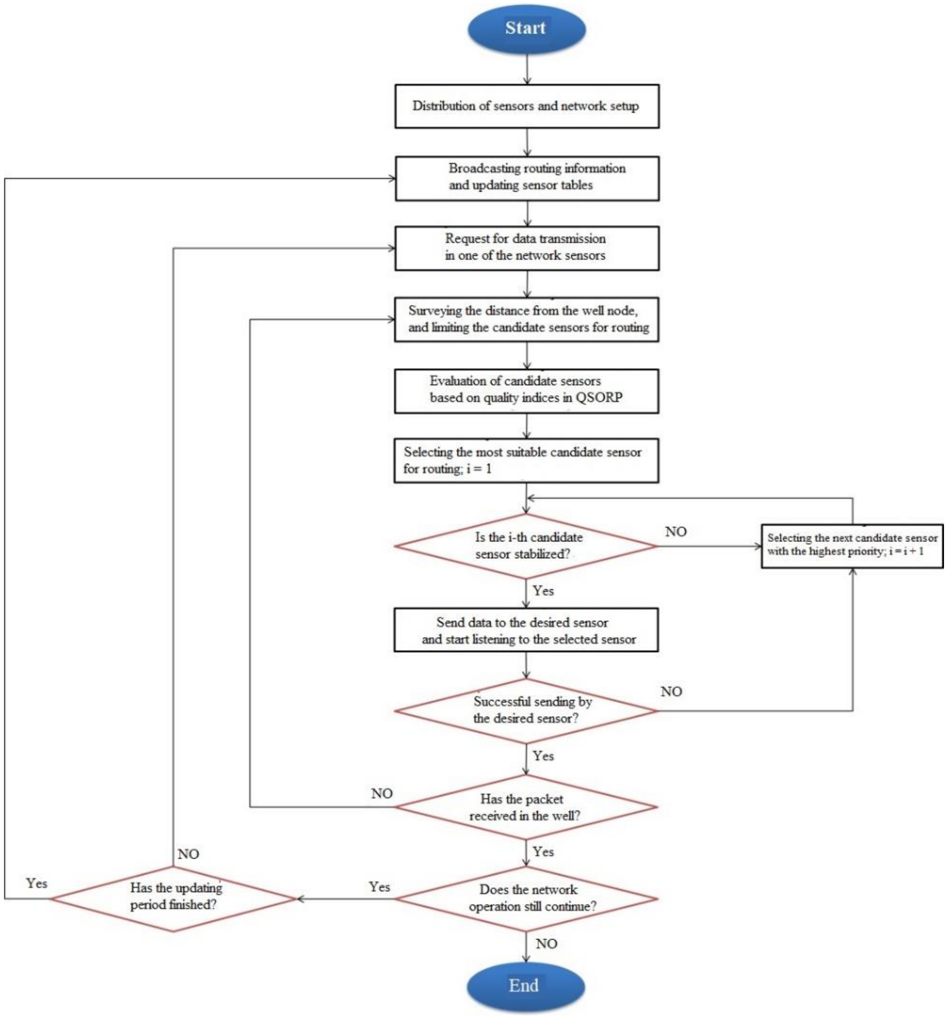

Fig. 1. The activity diagram of the proposed protocol QSORP.

In order to protect the stability and quality of opportunistic routing, QSORP is divided into the following three stages followed by a review and discussion about each stage.

1- Qualitative evaluation of candidate nodes
2- Evaluation of candidates' stability
3- Limitation of candidates

Following the distribution of sensors and setting up the network, single-step periodic releases routing data in the network in order to update the information in the node routing tables. These releases are done in a single step form and only between neighboring sensors, and are repeated in consecutive periods. The shared routing data contains the quality and stability indices of the proposed protocol, which are shared in order to develop the QSORP quality-oriented routing and to evaluate the stability of nodes. Whenever a node requests the network to send data, it benefits from this shared information to evaluate the candidate sensors; and based on the result of this evaluation, a sensor with the highest priority and stability level will be selected as a router node.

Before describing the principles and details of QSORP protocol, we will introduce the functional symbols of the proposed protocol in Table (3), and then, we will review and discuss the operational framework.

Table 3. The functional symbols of the proposed protocol.

Functional symbols	Description
$\text{Eng Eff}_{\text{Ci}}$	The energy efficiency of the i-th candidate node
EC_{Ci}	The energy consumed by the i-th candidate node
IE_{Ci}	The initial energy of the i-th candidate node
$\text{Services Eff}_{\text{Ci}}$	The service efficiency of the i-th candidate node
p	The number of variations in the rate of exchange services on the network platform
q	The total available data bits of one type of service in the i-th candidate node
$\text{Capacity}_{\text{i}}$	The buffer capacity of the i-th candidate node
n	Total accesses of the i-th candidate node to the communication media
Nonsucc acc (j)	The non-success the j-th access of the i-th candidate to the communication media
$\text{Success Rate}_{\text{Ci}}$	The link quality of the i-th candidate
k	Total transactions between the sender node and the candidate node
Success (r)	Success in the i-th transaction; success (1) and non-success (0)
time_{r}	Time of performing the r-th transaction
Delay_{Ci}	The delay of the i-th candidate
$\text{No. of PK Buff}_{\text{Ci}}$	The buffering rate of the i-th candidate
Delay_{Ci}	Processing delay for each packet
P_{L}	Length of the packet
C_{C}	Capacity of the channel
$\text{Dist}_{\text{Snd to Dist}}$	The distance of the sender from the final destination
$\text{Dist}_{\text{Ci to Dist}}$	The distance of the i-th candidate from the final destination
$\text{Dist}_{\text{Snd to Ci}}$	The distance of the sender from the i-th candidate
OE_{Ci}	The position of the i-th candidate node relative to other candidates versus the opportunistic index
EE_{Ci}	The position of the i-th candidate node relative to other candidates versus the energy efficiency index
SE_{Ci}	The position of the i-th candidate node relative to other candidates versus the serviceability index
SR_{Ci}	The position of the i-th candidate node relative to other candidates versus the link quality index
DE_{Ci}	The position of the i-th candidate node relative to other candidates versus the delay index
RM_{Ci}	Hybrid routing factor for priority assignment
RR	The radio range of the nodes
ρ	Valuation index for the mobility of neighboring nodes in decision making, (having a value between 0 and 1)
Sp Ci	The speed and mobility degree of the i-th candidate
$\text{Mb history}_{\text{Snd and Ci}}$	The mobility history of the i-th candidate in relation to neighboring nodes
ω	Valuation index for the mobility history of the i-th candidate versus the current mobility relative to time
$(\text{x}_{\text{Snd}}, \text{y}_{\text{Snd}})$	Coordinates of the sender node
$(\text{x}_{\text{Ci}}, \text{y}_{\text{Ci}})$	Coordinates of the candidate node
$(\text{Cos}\theta_{\text{Sender}}, \text{Sin}\theta_{\text{Sender}})$	The movement angle of the sender node
$(\text{Cos}\theta_{\text{Ci}}, \text{Sin}\theta_{\text{Ci}})$	The movement angle of the candidate node
Ncand(k)	Frequency of candidates in relation to the k-th sender node
MaxCand	The highest frequency of candidates in intermediate steps
Max Sp	The highest speed of nodes in the network platform

3.1. Qualitative Evaluation of Candidate Nodes

Qualitative indices are one of the factors exchanged between neighboring nodes during sharing control data. This sharing is done aiming at developing the quality-oriented routing. In the following, we will present functional quality indices and discuss the position of each index in the proposed routing.

- **Opportunism in routing**

Opportunism in routing is considered the most fundamental index associated with the opportunistic routing strategy. Also it refers to the concept of nodes' positions and the implementation of routing based on it. The reduced latency and increased speed of transactions are among the most important benefits of using this index. Accordingly, the selected candidate nodes with the highest priority were the most distant nodes from the sender node and the closest to the destination node (Fig. 2). Algorithm (1) provides an evaluation of neighboring nodes to determine eligible candidates based on the concept of opportunism.

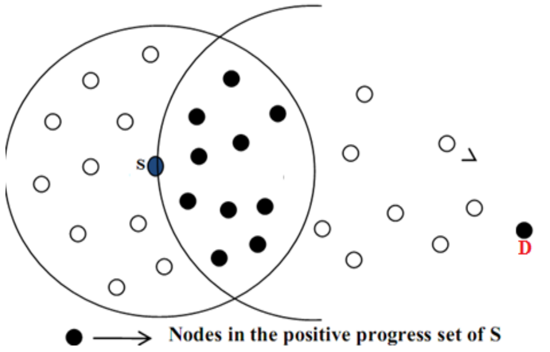

Fig. 2. A demonstration of the evaluation of eligible candidate nodes based on opportunism in routing.

Algorithm 1. The analysis and identification of eligible routing candidates based on the concept of opportunism

```
Evaluation in Source and Intermediate Nodes;
For i= 1 to Total neighbor node    {
  If ($\sqrt{(Snd_i - Dist_x)^2 + (Snd_y - Dist_y)^2} > \sqrt{(Ngb_x - Dist_x)^2 + (Ngb_y - Dist_y)^2}$)
        Then  $neighbor\ node_i$ insert to Candidate List
     Else Discard the Node;    }
```

- **Energy efficiency**

Due to the nature and characteristics of AD HOC networks, the energy efficiency is one of the most important functional indices in various topics. It is also related to these networks, especially in relation to routing and data exchanges. This index refers to the energy efficiency of nodes in a network. Relation (1) shows how to calculate and evaluate this index.

$$Eng\ Eff_{Ci} = 1 - \left(\frac{EC_{Ci}}{IE_{Ci}}\right) \tag{1}$$

- **Serviceability**

Serviceability is one of the other important indices associated with routing and data exchanges in AD HOC networks. It refers to the level and volume of traffic loads in the nodes of a network relative to the involvement of the communication channel (for service providing). This development-based index [7] is evaluated with the relativity of the traffic load rate relative to the access levels, thus it supports the performance of the proposed protocol with more capabilities. Relation (2) shows how to calculate and evaluate the index.

$$Services\ Eff_{Ci} = \frac{1-\left(\frac{\left(\sum_{a=1}^{p}\sum_{b=1}^{q} Traffic_a^b\right)}{Capacity_i}\right)}{1+\left(\frac{\sum_{j=1}^{n} Nonsucc\ acc\ (j)}{n}\right)} \tag{2}$$

- **Link quality**

The link quality refers to the category of the packet loss rate, which is considered as an undeniable factor in AD HOC networks. It is sometimes referred to as one of the characteristics of these networks. The rate of a variable is depended on different conditions in a network including the characteristics and limitations of AD HOC networks. Moreover, it will increase and decrease depending on these conditions. Accordingly, the link quality index has been introduced and presented to evaluate the quality of links between intermediate candidate nodes. Therefore, it takes into account the calculation of an appropriate evaluation. Relation (3) shows how to calculate and evaluate this index.

$$Success\ Rate_{Ci} = \frac{\sum_{r=1}^{k} Success\ (r) \times time_r}{\sum_{r=1}^{k} time_r} \tag{3}$$

- **Delay**

It refers to the time needed for data exchange by the desired candidate node, known as a critical factor, especially in relation to some exchange services in AD HOC networks. This index has been proposed considering the delay of candidates. It is defined depending on the delay of the communication media, the buffering rate of candidates, and their processing power. Relation (4) shows how to calculate and evaluate this index.

$$Delay_{Ci} = (No.of\ PK\ Buff_{Ci} * Pro\ Delay_{Ci}) + \left((P_L/L_C)\right) \tag{4}$$

Accordingly, whenever a node requests the network to send data, it calls the qualitative evaluation process for routing elections and data transmission. To this end, the source node and the intermediate sender nodes will act for routing elections based on the shared quality indices. Algorithm (2) demonstrates how the qualitative evaluation of candidate sensors works in the proposed QSORP protocol. The routing process of the QSORP protocol is applied and developed step by step based on an opportunistic routing strategy. This process is repeated in intermediate sensors until the sent packet is received at the final destination.

Algorithm 2. The way of evaluation and routing elections in the proposed QSORP

```
QoS Routing Process in QSORP;
    For i = 1 to n    {            /* n is all Candidate Sensors */
    If ($Dist_{Snd\ to\ Dist} \le Dist_{Ci\ to\ Dist}$)
    Then    {
        $OE_{Ci} = 1 - \left(\frac{Distance_{Candidate\ (i)\ to\ Sink}}{Distance_{Sender\ to\ Sink}}\right)$;
        $EE_{Ci} = \frac{Energy\ Efficiency_{Ci}}{Best\ \ Candidate\ Energy\ Efficiency}$;
        $SE_{Ci} = \frac{Services\ Efficiency_{Ci}}{Best\ \ Candidate\ Services\ Efficiency}$
        $DE_{Ci} = 1 - \left(\frac{Delay\ Efficiency_{Ci}}{Max\ Delay}\right)$;
        $SR_{Ci} = \frac{\sum_{r=1}^{k} Success\ (r)\ \times time_r}{\sum_{r=1}^{k} time_r}$
        $RM_{Ci} = \left((\alpha.OE_{Ci}) + (\beta.EE_{Ci}) + (\tau.SE_{Ci}) + (\sigma.DE_{Ci}) + (\omega.SR_{Ci})\right)$;
        }
    Else            $RM_{Ci} = 0$;
        }
```

3.2. Evaluation of candidates' stability

It is proposed in an attempts to examine the stabilization of candidates, which is considered the most fundamental step of the QSORP. Therefore, the conditions of the two mobile nodes are evaluated in relation to each other and based on the mobility degree of nodes during the exchanges. The results demonstrated that the precision and efficiency of the proposed performance of the protocol are doubled in terms of controlling and managing. Algorithm (3) depicts how this step of the proposed protocol works. The stability evaluation process in the QSORP protocol will be performed based on three fundamental factors as follows:

1- Evaluating the stability of the link between the two nodes relative to the speed of mobility, the manner of mobility, and the motor angle
2- Screening the candidates based on their geographical position in relation to the sender and the mobility degree
3- Evaluating the motor history of the two mobile sensors along each other

Algorithm 3. An evaluation of the stabilization of candidates based on the proposed QSORP

```
Evaluation Candidate Stability in the QSORP;
    For i = 1 to n    {
```

```
    If $\left( Dist_{Snd\ to\ Ci} \le \left( RR - \left( \rho * \left( RR * \frac{SP\ Ci}{Max\ Speed} \right) \right) \right) and\ (Mb\ history_{Snd\ and\ Ci} < 0) \right)$
     Then        Discard the Candidate Node (i);
/*$Mb\ history_{Snd\ and\ Ci} = \omega . DD_{Snd,Ci}(t, t-1) + (1-\omega). \omega . DD_{Snd,Ci}(t-1, t-2) + (1-\omega)^2 . \omega . DD_{Snd,Ci}(t-2, t-3) + \cdots + (1-\omega)^n . \omega . DD_{Snd,Ci}(t-n-1, t-n)$    */
/* $DD_{Snd,Ci}(t, t-1) = Dist_{Snd,Ci}(t) - Dist_{Snd,Ci}(t-1)$    */
/* $SP_{Ci} = \frac{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}{time_2 - time_1}$    */
    Else If $\left( \left( \frac{(-A+\sqrt{B})}{C} \right) < time_{Sending} \right)$        {
     Then        Discard the Candidate Node (i);
/*$A = \left( \left( (Sp_{Snd} . Cos\theta_{Snd}) - (Sp_{Ci} . Cos\theta_{Ci}) \right) * (x_{Snd} - x_{Ci}) + \left( (Sp_{Snd} . Sin\theta_{Snd}) - (Spe_{Ci} . Sin\theta_{Ci}) \right) * (y_{Snd} - y_{Ci}) \right)$    */
/*$B = \left( \left( (Sp_{Snd} . Cos\theta_{Snd}) - (Sp_{Ci} . Cos\theta_{Ci}) \right)^2 + \left( (Sp_{Snd} . Sin\theta_{Snd}) - (Sp_{Ci} . Sin\theta_{Ci}) \right)^2 \right) * RR^2 - \left( \left( (Sp_{Snd} . Cos\theta_{Snd}) - (Sp_{Ci} . Cos\theta_{Ci}) \right) . (y_{Snd} - y_{Ci}) - (x_{Snd} - x_{Ci}) . \left( (SP_{Snd} . Sin\theta_{Snd}) - (Sp_{Ci} . Sin\theta_{Ci}) \right) \right)^2$ */
/*$= \left( (SP_{Snd} . Cos\theta_{Snd}) - (Sp_{Ci} . Cos\theta_{Ci}) \right)^2 + \left( (Sp_{Snd} . Sin\theta_{Snd}) - (Sp_{Ci} . Sin\theta_{Ci}) \right)^2$  */
/* $time_{Sending} = \frac{Total\ PK\ per\ Flow * Size\ of\ PK\ (Bit)}{Channel\ Capacity}$    */
```

3.3. Limitation of candidates

This step of the QSORP protocol has been designed and developed based on the development in Reference [5], aiming at reducing the complexity of managing the candidates. Among many topics associated with opportunistic routing is the topic of candidate's nodes management. This topic refers to the multiplicity of candidate nodes at each intermediate step, and the relevant challenges in the areas of routing tables management and intermediate candidates. In order to tackle this issue, we have benefited from the following criteria: the distance from the end node of the well, and the mobility degree of the mobile nodes. In addition to reducing the complexities associated with candidates, we have been trying to ensure and protect the reliability of exchanges through intermediate candidates based on these two factors. To this end, the multiplicity of candidate nodes at each step is defined and determined through Relation (5).

$$Ncand(i) = \begin{bmatrix} max\left(2, \left(\left(Round\ \left(\frac{Dist_{Snd(k),Dist}}{Dist_{Source,Dist}} \right) * MaxCand \right) * \frac{Sp_i}{Max\ Sp} \right) \right) & i \neq sink \\ 0 & i = sink \end{bmatrix} \quad (5)$$

This limitation in the multiplicity of candidates is constricted to nodes having the highest positions and values which pave the way by supporting the quality and stability of routing in addition to managing the candidates.

Based on what has been mentioned so far, if candidates' nodes meet sufficient requirements to participate in routing operations, they will be prioritized based on Algorithm (4), and will participate in the routing process. This algorithm is repeated in all intermediate nodes; thus the sent data can be received at the final step.

Algorithm 4. Prioritization and routing in the proposed QSORP protocol

```
Selection Candidates Process in QSORP;
$Routing\ Sensor = Candidate\ 1$;
    For i = 2 to k    {  /* k is all Candidate */
    If (($Candidate_i \rightarrow RM_{Ci}$) > ($Routing\ Sensor \rightarrow RM$)) Then  {
    $Routing\ Sensor = Candidate_i$;
    Insert to Routing Table;
    }
Send data to Routing Sensor;
```

4. EVALUATION AND SIMULATION

In order to demonstrate the efficiency of the proposed QSORP protocol, steps have been taken to simulate this protocol using the OPNET simulation software. We simulated an AD HOC network using the physical layer and medium access control (MAC) protocols in IEEE 802.11, designed in OPNET. Table (4) provides details of parameters which is related to the configuration of the simulated scenarios. The performance of QSORP is evaluated and compared with that of the two protocols ORSCAC [7] and QEOR [9]. Finally, the simulated criteria and their relevant details are presented in Table (5).

Table 4. The parameters of the simulated scenarios.

Parameter	Value
The version of the OPNET functional simulator	Version 14.5
The dimensions of the network, and the way the nodes are positioned in the network	1000×1000 (m); randomly in the network environment
The speeds of the nodes and the movement model	0 to 5 m/s; Random Way Point with speed changes
Generation, volume of packets, and type of packets	Exponential (1); 1500 (bytes); CBR
The protocol of the transfer layer, physical layer	UDP، CSMA/CA
The standard of the physical layer, and the transfer rate	Mac/802.11b، Mbps11
The simulation time, and the number of nodes	950 (s); 20, 40, 60
Starting and finishing the simulation	Sec (100); End of Simulation
Initial energy, reception energy, and boosting the transmission	10 Jules, 50×10^{-9} J, 10×10^{-12} J/b
α، β، τ و σ	0.25, 0.25, 0.25, 0.25
ω	0.5

Table 5. The simulation criteria.

Row	The component title	Scientific definition	Way of measurement	Unit
1	Instability of the routes	Inability to send data through the candidate present in the intermediate route	$\frac{\sum \mathbf{No.of\ Route\ Error\ per\ Route}}{\mathbf{Time}\ (\mathbf{s})}$	no./sec
2	The network's received data	The amount and volume of received data to the rate of sent data	$\frac{\sum \mathbf{No.of\ data\ byte\ Received} * \mathbf{8}}{\mathbf{Time}\ (\mathbf{s})}$	bit/sec
3	End-to-end delay	The time required to send the packet from the source until receiving it at the destination	$\frac{\sum_{i=1}^{Number\ of\ Trancation} \mathbf{Delay}\ (\mathbf{i})}{\mathbf{Number\ of\ Transaction}}$	sec
4	Network throughput	The network efficiency based on the protocols being compared	$\frac{\sum \mathbf{No.of\ Byte\ Received} * \mathbf{8}}{\mathbf{Simulation\ Time} * \mathbf{1000}} \mathbf{Kbps}$	bit/sec

- **Instability of the Routes**

Given the characteristics of opportunistic routing (i.e. elections of intermediate nodes based on the opportunistic index), it is believed that the failures and instabilities of exchange routes are among the challenges and complexities facing the routing strategy. QSORP primarily tries to assess guaranteeing the reliability of candidates' links based on evaluating the stability of candidates. Also, it tries to elect sensors having the highest quality levels based on evaluating the quality of candidates. QSORP properly controls and manages the instability of candidates by providing features ranging from evaluating the mobility history of sensors and estimating the duration of the stability of the links to the desired candidates. This along with quality support has reduced the incidence of unwanted issues due to the lack of quality during exchanges. Therefore, it totally promotes the stability of candidates. That is why the two compared protocols do not support specific measures in this regard. Although both protocols, especially ORSCAC, desirably protect and secure the quality of exchange for intermediate candidates, the lack of appropriate measures has resulted in an increased rate of failure. Fig. 3 shows the rate of this tested criterion.

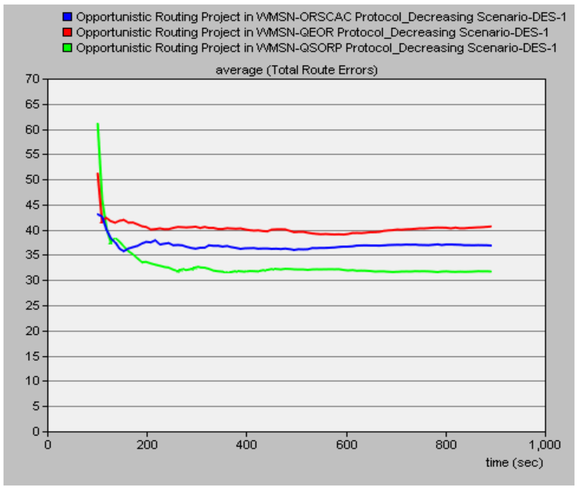

Fig. 3. a. The instability rate of routes in the compared protocols in decreasing scenarios.

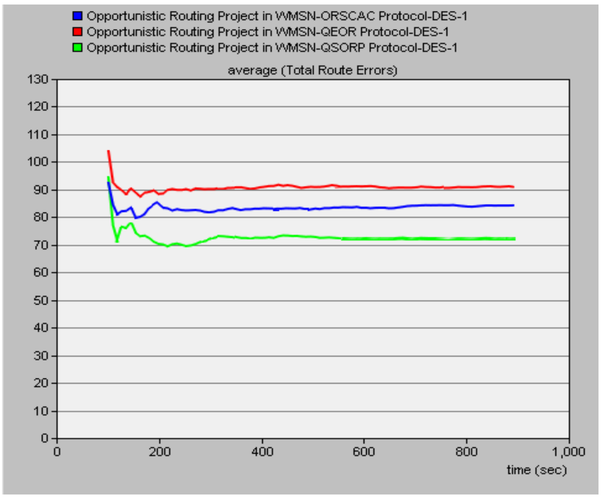

Fig. 3. b. The instability rate of routes in the compared protocols in Normal scenarios.

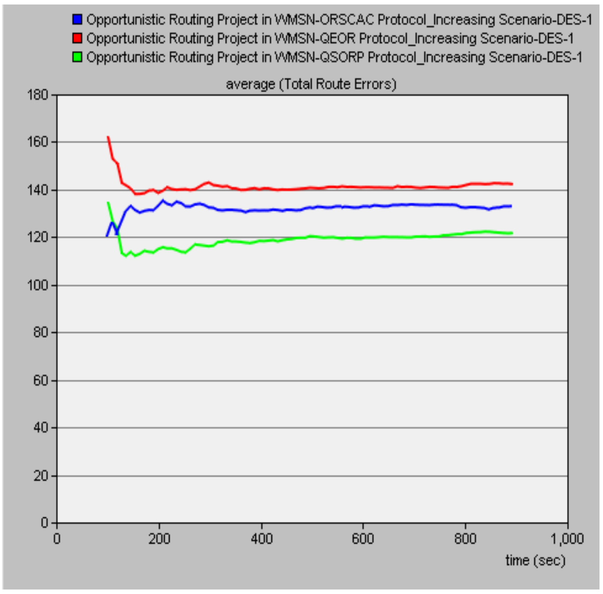

Fig. 3. c. The instability rate of routes in the compared protocols in increasing scenarios.

- **The network's received data**

Due to the sameness and similarity of the simulation scenarios, the rates of sent data are identical in the protocols being compared, However, the rates of received data will be variable depending on the behavioral framework of the protocols. Based on the performance of its algorithm in the evaluation of the stability of candidates, QSORP acts during the prioritization of intermediate candidates which prevents the selection of that node (no matter how efficient it is). This matter has been secured and protected by evaluating the mobility history of a mobile node over time as well as measuring the stability of the desired candidate. On the one hand, it attempts to use nodes of the highest quality levels as intermediate nodes depending on the current status of the nodes and the desired destination. Effective support of both factors affecting successful exchanges in network services has resulted in the improved and increased rate of successful reception in the proposed protocol. Conversely, in these simulations, the ORSCAC and QEOR protocols have improved the rate of success exchanges through effectively protecting the quality. However, it has not led to effective capabilities considering the stability of candidates. Inattention to this issue has increased the instability of routes, and reduced the rate of successful exchanges in this protocol compared to those in the proposed protocol. Concerning QEOR, this protocol has also suffered from inattention to some important qualitative criteria, which has led to a drop in improvement compared to the other two protocols. Fig. 4 shows the rate of this tested criterion.

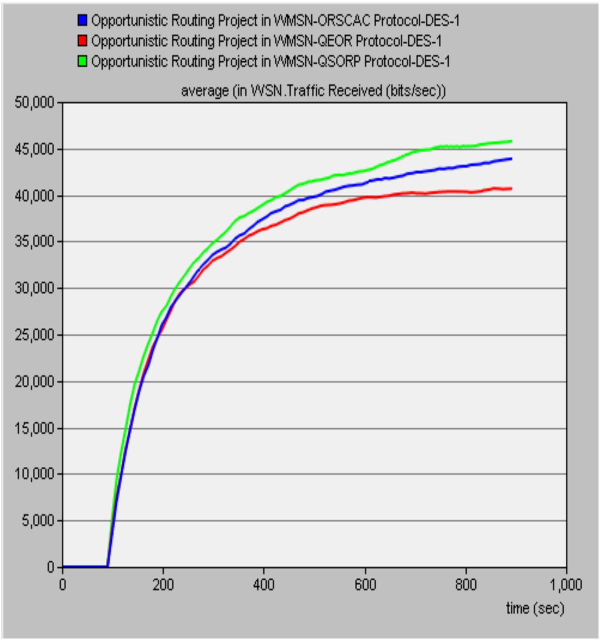

Fig. 4. a. The rate of received data in the compared protocols in Normal scenarios.

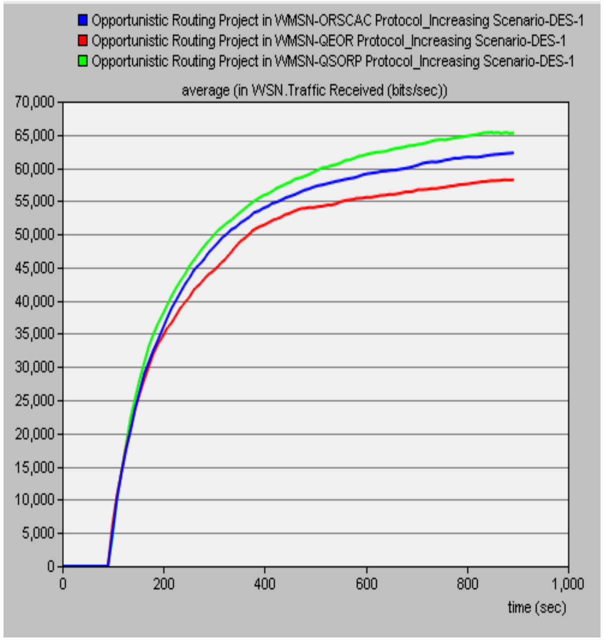

Fig. 4. c. The rate of received data in the compared protocols in increasing scenarios.

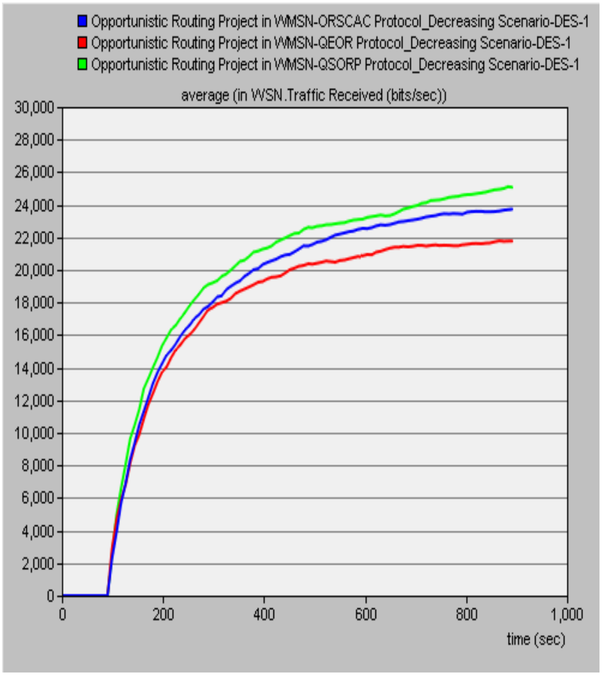

Fig. 4. b. The rate of received data in the compared protocols in decreasing scenarios.

- **End-to-end delay**

Delayed network data exchange is another important index for the evaluation of the performance of opportunistic protocols, receiving the greatest impact from opportunism in routing. Considering this index and its effects, the opportunistic strategy is designed against the opportunistic trait in a way that it reduces the number of intermediate steps; thereby resulting in a delay. In connection with this tested index, we can refer to the limitation of the proposed QSORP. During the routing operations and elections of intermediate nodes, QSORP acts in a way that limits candidate sensors in terms of stability, preventing some sensors from participating in the routing process. This kind of performance, on the one hand, desirably increases the stability, but on the other hand, increases the multiplicity of the presence of intermediate sensors in exchange routes as well as increasing the delay. In this regard, the ORSCAC protocol has been accompanied by a greater improvement than the other two protocols. This protocol acts in the routing operations in such a way that it reduces the delay, and that prevents the occurrence of disorders which increases the delay as far as possible. On the other hand, QEOR has also provided a desirable performance in this regard, but this improvement is lower than that of ORSCAC. Fig. 5 shows the rate of this tested criterion.

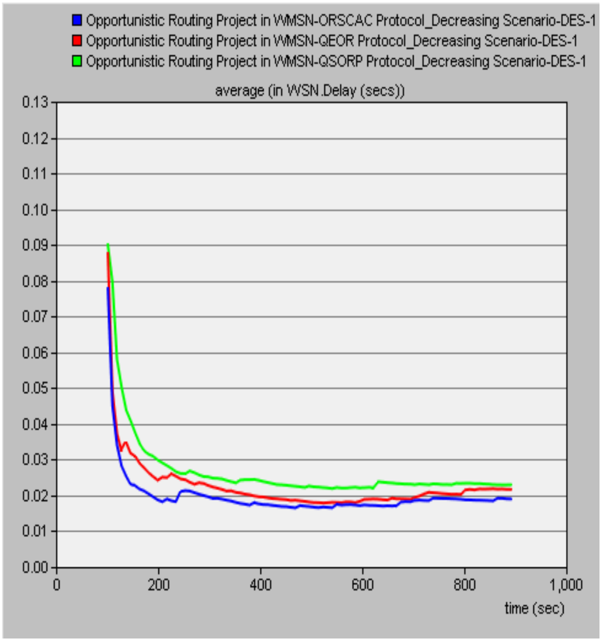

Fig. 5. a. The results corresponding to the rate of delayed exchanges in the compared protocols in decreasing scenarios.

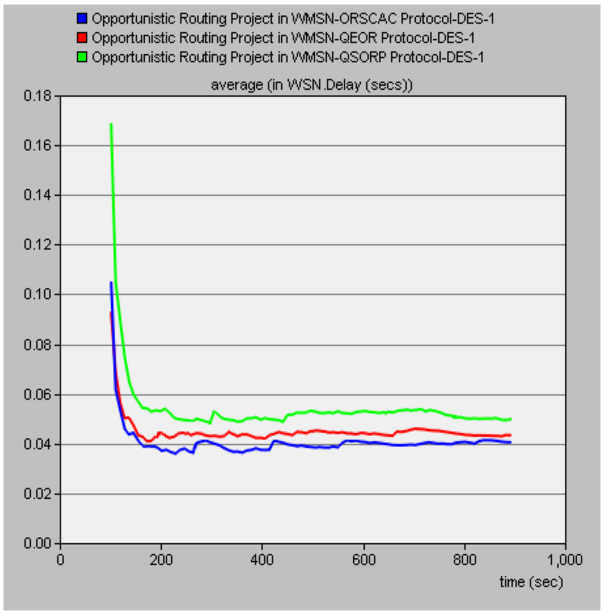

Fig. 5. b. The results corresponding to the rate of delayed exchanges in the compared protocols in normal scenarios.

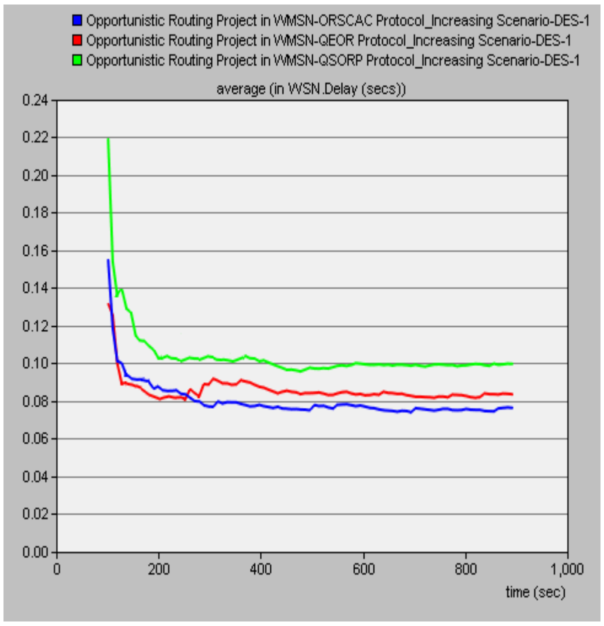

Fig. 5. c. The results corresponding to the rate of delayed exchanges in the compared protocols in increasing scenarios.

- **Network throughput**

The network throughput refers to the network's actual transfer rate or operational power versus the performance of protocols. It is suggested that the Network throughput improves the rate of successful exchanges. It is measured and initialized based on various factors such as turbulences, collisions, disorders, and particularly the performance of protocols during routing and opportunistic data exchanges. However, given the similarity of the simulation conditions, these effective factors are identical for the two intended protocols, and the different results in the output of the simulators are the result of the performance of the compared protocols. The proposed QSORP supports the improvement in the stability and quality of candidates during exchanges in intermediate routes. Moreover, it improves the rate of successful reception in the network as far as possible. It also prevents disorders associated with the challenges in opportunistic routing. Undoubtedly, it will reduce the adverse effects resulting from opportunistic routing, and has led to the improved quality of intermediate candidates' exchanges and the increased network throughput. Similarly, the other two protocols, particularly the ORSCAC protocol, have appropriately supported the quality, but have been vulnerable in terms of the stability and protection of it, resulting in the reduced network throughput in comparison to that in the proposed protocol. Compared to the other two protocols, the QEOR protocol does not appropriately support the quality in terms of the congestion rate and traffic load, and suffers from inattention to some important qualitative criteria. The presence of these issues has resulted in a more severe drop in the throughput in this protocol than in the other two protocols. Fig. 6 shows the rate of this tested criterion.

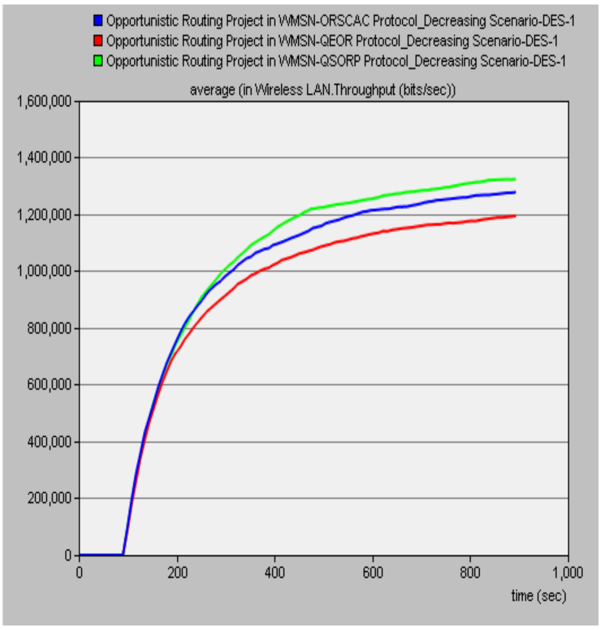

Fig. 6. a. The rate of received data in the compared protocols in decreasing scenarios.

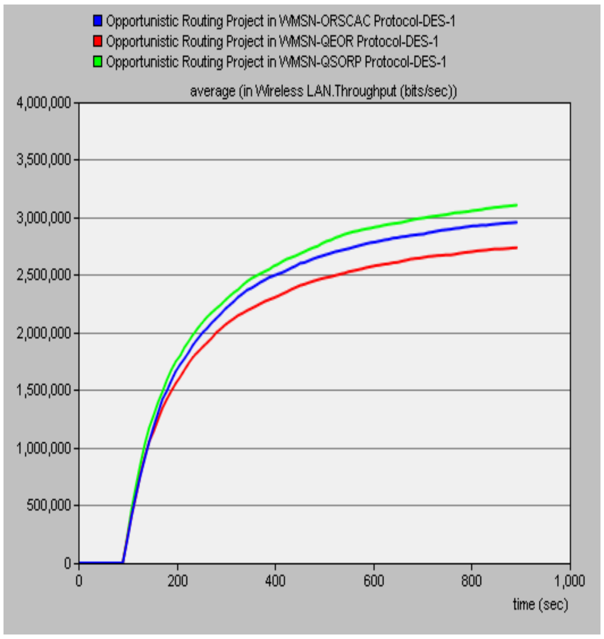

Fig. 6. b. The rate of received data in the compared protocols in normal scenarios.

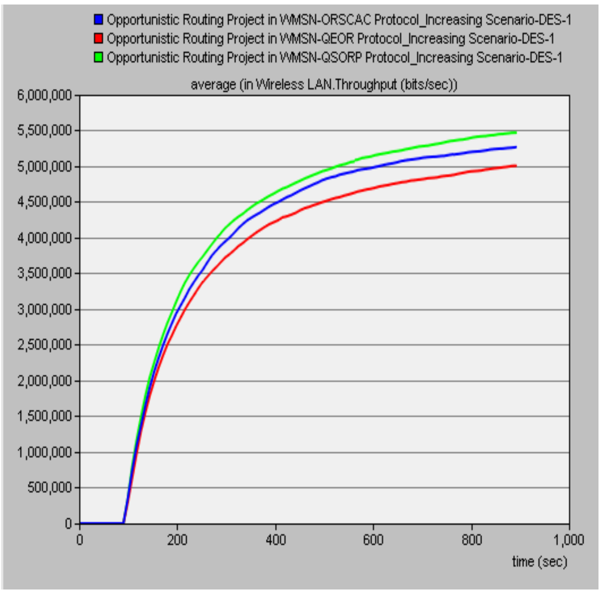

Fig. 6. c. The rate of received data in the compared protocols in increasing scenarios.

5. DISCUSSION OF RESULTS

Instability of the Routes in QSORP is achieved by evaluating the stability and the instability of candidates. These factors choose sensors with the highest quality. And also ensure the good connections of the candidates are met.

The network received data by evaluating the mobility history over time as well as by evaluating the results of the stability of the desired candidate along with a transmitted flow.

Prevention of the occurrence of disturbances is achieved by limiting candidate sensors in terms of stability in QSORP and leads to an increase in delay.

Improvement in Network throughput is achieved by enhancing the rate of successful reception and improvement in the stability and quality of candidates, which has ultimately reduced the negative impacts of the opportunistic routing protocol.

6. CONCLUSION

In this paper, we introduced a new quality-oriented routing mechanism, called QSORP with the aim of supporting and protecting the stability and quality of opportunistic routing. Focusing on important qualitative indices and through evaluating and analyzing the stability of candidates, QSORP appropriately supports quality proportionally to the needs and requirements. The simulation results and the way the proposed protocol works are indicative of the improved criteria of the network compared to those in previous studies in terms of supporting the quality of opportunistic routing. Considering the results of simulations in scenarios with greater numbers of nodes, this improvement is more dramatic and prominent. In upcoming works, we will try to improve the performance of the proposed protocol in terms of resistance to connectivity changes using prediction mechanisms such as the Markov chain, analyzing methods, and connectivity evaluation.

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