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ALQARM: An Ant-Based Load and QoS Aware Routing Mechanism for IoT

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Abstract

According to the conditions and characteristics of Internet of Things (IoT), routing and data exchange in these networks are facing with many challenges such as high delay and overhead, congestion and lack of data. The ants-algorithm as a bio-inspired heuristic technique is an intelligent heuristic algorithm that also provides quality in addition to effective optimization. This algorithm distributes computing among the elements of network and can be easily implemented on the internet of things. In this paper, a new method called ALQARM based on the development of ants-algorithm is proposed to improve the IoT routing problems. ALQARM uses special parameters during its operation to support routing quality, congestion control and overhead optimization. To cover the concepts mentioned above, ALQARM focuses on ant-agent exchanges, pheromone updates and learning-enhancing topics. ALQARM is essentially a three-step approach in such a way that in the first and second steps, parent elections and child belong are determined and the network graph is created. In the final step try is to optimize the overheads in terms of reinforcing learning. To evaluate ALQARM, this method is implemented based on the development of RPL protocol in the Cooja simulator and has been compared with previous researches. The simulation results show the superiority of ALQARM in the metrics of network successful receipt rates, control overheads and interaction delays compared to similar methods.

Keywords: Internet of Things, Ants-Algorithm, Routing, Quality

1. Introduction

The IoT introduces a world where all physical objects are able to interact with each other by internet or other communication platforms. In this network, everything (all objects can be a member of this community) has its own digital identifier whereby computers are able to manage, organize, and communicate with the intended thing [1]. Given the unprecedented popularity and advancement of this technology, researchers believe that in the very near future a large number of things will join to this unique technology [2]. In recent years, IoT has greatly expanded in terms of its capabilities and benefits. The most important application areas of this technology can be introduced to smart cities, smart transportation, aerospace industry, smart building and industrial applications [3-5]. This rapid development of the IoT has problems due to the lack of complementary communication technologies, coordination algorithms, and application standards [6, 7]. Routing and service are the most important issues in this communication technology.

Final Approval

In IoT, network members are unable to communicate directly with each other or with the knowledge base due to limitations. Therefore, in such a situation where direct communication is not possible, service is provided through routing and in collaboration with other members of their network [8]. However, resource constraints, network topology changes, network scalability and heterogeneity of host types introduce the design of appropriate routing techniques as a serious problem [8-10].

In IoT, according to the features mentioned, routing and supporting quality of this category has been associated with various issues and has always been one of the challenging topics [10]. The importance of this issue is doubled in light of the important application areas of IoT (in sensitive and often important areas) [5]. Therefore, IoT has been associated with new issues (due to the lack of technology) that have made traditional methods (methods used in other networks) be ineffective for this technology [11]. On the other hand, the application areas of this technology require high quality services to perform their activity in an acceptable manner [8]. Therefore, effective support for routing and quality of service is an undeniable necessity in this technology.

Based on the concepts outlined above and given the importance of routing and servicing in IoT, extensive researches have been presented in this critical area. Most past researches have been based on the RPL protocol [10-24]. But recent studies have revealed some fundamental unsolved problems with past researches, which make it necessary to conduct more extensive researches in this area. It is worth noting that the focus of this paper's approach focuses on improving these challenges. In general, these challenges can be addressed as follows.

A) Lack of optimism: As mentioned, most researches are based on RPL. The RPL protocol imposes a large amount of overhead on the network to create and update the DADOG (network graph) structure. This volume of overheads requires high memory consumption in addition to occupying network capacity and bandwidth [12-21]. Their lack of management and optimization can severely affect network performance.

B) Lack of effective support for the quality of service: In the past researches, parent choices are made based on the result of objective function (expected transfer rate) [12-22]. Although elections evaluate on the basis of expected transfers is effective but not sufficient. Because considering other issues including energy, congestion and quality of links can also be very effective in making an effective choice and improving service.

C) Imbalance in DADOG graph: Given that the parent selection in the RPL is based on the evaluation of certain criteria in the objective function. This topic has led to the majority of nodes at each level tends to have a number of specific nodes as parents. This will lead to an imbalance in the structure of DADOG graph and increase the congestion [13,15-18,29,30].

In order to cover the aforementioned issues, this paper proposes a new method based on the development of an ant algorithm called ALQARM (An Ant-Based Load and QoS Aware Routing Mechanism for IoT). ALQARM is designed based on the concepts associated with bio-inspired heuristic algorithms, and strives to improve service based on the capabilities of these methods. This targeted performance, with the ability to control the child of parents, in addition to improving the quality of service, also improves the problem of graph congestion and imbalance.

The remainder of the paper will provide an overview of the research background in the second section. The proposed ALQARM will be introduced in Section 3. Section 4 of ALQARM will be evaluated based on the development of the RPL simulation and its performance and will conclude at the end of the article in Section 5.

Final Approval

2. Review of Research Background

Due to the importance of routing and supporting the quality of IoT services, there is a great deal of researches to improve this fundamental topic. Much of these researches has focused on critical qualitative criteria and has sought to improve the objective function and choice of parent nodes [12-21]. Another part of researches has focused on improving fault tolerance and has therefore attempted to improve the stability of interactions [22-28]. Researches have also been developed on the basis of nonlinear techniques and based on the use of concepts related to this area; efforts have been made to improve service [19-22]. Further researches have investigated end-to-end of intermediate routs and attempted to make decisions accordingly [19-22]. According to the studies, the methods developed based on the improvement of the objective function based on the evaluation of qualitative criteria have better results than the other methods. In the following we will analyze some of the most important of these studies and more precisely methods based on qualitative criteria. Finally, the importance of ALQARM will be outlined and discussed in the light of previous researches.

Researches carried out in [12-21] are important researches focused on improving objective function based on qualitative criteria. In most of these studies, the objective function, in addition to the expected transfer rate, is evaluated on the basis of broader qualitative criteria (such as energy and delay) and based on these evaluations, parent choice and routing are done. In fact, based on the results of this evaluation, if the node has the best condition in the evaluated factors, the node's preference for selection is high. The results of this research show that the quality of service is improved and the transmission delay is reduced. But these methods are often not optimal, and the network is associated with an increase in the amount of control overhead. On the other hand, in most of these methods, the parent selection is done in a way that causes the DADOG graph imbalance problem, which leads to the aggravation of the congestion issues.

The methods proposed in [22-28] were important researches focused on improving error tolerance and maintaining service stability. To this end, the methods presented in this research have investigated various aspects related to the domain of error tolerance and stability and have therefore tried to increase the reliability of communication. In this regard, some methods have attempted to use backup routs, some have focused on evaluating the mobility and stability of nodes connections and some have attempted to evaluate important issues related to error tolerance (such as prevention of energy finalization and loss of nodes efficiency). So, based on the results of these evaluations, routing choices are made and exchanges are done through the desired routes. Overall, the purpose of these researches is to increase the error tolerance of data exchanges and to ensure service stability as far as possible. But these methods are not optimized due to increasing the rate of exchange of control data to enhance their performance. In addition, some of these methods that are introduced in this domain are based on overheads (such as multi-rout routing, multiple parent selection instead of one parent, etc.) that exacerbate the problem of lack of optimism, reduce bandwidth and impress on other consumables.

Other researches have been developed based on the application of nonlinear techniques and the productivity of concepts related to this field [29-33]. In these researches, evaluations and choices of parent nodes are based on nonlinear techniques, especially fuzzy logic, and according to the results of this decision data exchange is done. To this end, the desired factor after considering is applied as input to the fuzzy

Final Approval

and the fuzzy outcome or output distinguishes final election. The purpose of most researches in this area is to improve the accuracy of calculations, elimination of heterogeneity and variety of decision factors. The simulation results show improvement in decision making accuracy, routing efficiency and network interactions. But these methods aren't optimally and often having high complexity.

As mentioned in the previous articles, each of these studies relying on different measures has sought to improve the service of IoT. But as it turns out, most of the investigations reviewed work to develop their proposed methods based on high volume exchange of control messages. Furthermore, previous studies have not provided effective measures to maintain the DADOG graph equilibrium. This paper focuses on the development of ants- algorithm and uses the capabilities of this technique to introduce a method that improves as much as possible the issues and enhances the quality of service.

3. Communication and Energy Consumption Model

As mentioned earlier, the proposed method is organized on the basis of the RPL protocol and accordingly the communication model of the proposed method follows this protocol. The RPL protocol supports three types of communication algorithms. The three patterns are point-to-point (P2P), point-to-multipoint (P2MP) and multipoint-to-point (MP2P). In P2P communications, routing and exchanges between both nodes are in DODAG. In P2MP type, traffic is sent from root to leaf node, and MP2P is related to data collection and transmission from leaf node to root node, which mainly DODAG root is destination.

In order to design an energy efficient routing protocol, it is necessary to determine the energy consumption status of nodes. Nodes need to spend energy in exchanging to send and receive messages. The amount of this energy is defined as a function of distance between the sender and receiver nodes. In addition, nodes require energy consumption to listen to the media in order to receive data as well as sleep. In IEEE 802.15.4 WSNs, the MAC layer controls the communication modes. In this standard the energy consumption for the node i on the link e (i, j) ∈E is to process a packet equivalent to the relation (1) [34]. So that E_l^i ،E_{tx}^i ،E_{rx}^i and E_{sl}^i are equivalent to the consumed energy during listening, sending, receiving and sleeping periods respectively. I_{tx} ،I_{rx} ،I_l and I_{sl} are in the transmit, receive, listen and sleep modes, respectively. t_l^i and t_{sl}^i are the listening time and the sleep state, respectively. U is the battery voltage, L the packet length, and R the bit rate of the media transfer.

$$E_c^i = E_l^i + E_{tx}^i + E_{rx}^i + E_{sl}^i = \left(t_l^i I_l + (I_{tx} + I_{rx})\frac{L}{R} + t_{sl}^i I_{sl}\right)U \quad (1)$$

In terms of introduced concepts [39], the values of t_{sl}^i and t_l^i are equivalent to (2) and (3), respectively. Such that BI is equivalent to Beacon Interval, SD Super-frame Duration, aBaseSD = aBaseSuperframeDuration = 960 symbols, symbol = 16µs (defined by CSMA-CA [34]), t_{tx}^i and t_{rx}^i respectively the time of send and receive successfully for L bits at the R transfer rate.

$$t_{sl}^i = BI - SD = aBaseSD \times (2^{BO} - 2^{SO}) symbols \quad (2)$$

Final Approval

$$t_l^i = BI - \left(t_{tx}^i + t_{rx}^i + t_{sl}^i\right) \quad (3)$$

According to the concepts, the energy consumption for sending and receiving is the relation (4) and the remained energy is the relation (5). So that $E_r^i$and E_0^i are the remained and initial energy equivalents, respectively.

$$E_c^i = \begin{cases} \left(\left(t_l^i I_l + I_{tx}\frac{L}{R} + t_{sl}^i I_{sl}\right) U \ \ if\ i\ is\ Tx\right) \\ \left(\left(t_l^i I_l + I_{rx}\frac{L}{R} + t_{sl}^i I_{sl}\right) U \ \ if\ i\ is\ Rx\right) \end{cases} \quad (4)$$

$$E_r^i = E_0^i - E_c^i \quad (5)$$

4. Assumptions

Some of assumptions to develop ALQARM are as follows.

- Network nodes are heterogeneous and all nodes operate in user mode.
- Nodes are limited in terms of energy and consumption sources .
- Network topology is variable.
- Nodes in the network are fixed and not mobility.
- Network traffic algorithm is considered as a many-to-one algorithm.
- Network nodes are not equipped with any overhead tools such as positioning (such as GPS).

5. Paper Approach

In ALQARM, according to the challenges of past researches, the proposed method provides the expected capabilities to cover existing issues. For this purpose, ALQARM is designed based on the development of ant heuristic algorithm. ALQARM is very compatible with IoT and especially the RPL protocol for implementation. The proposed method is divided into three steps in order to develop its performance.

1- Parent Selection and early graph formation
2- Selecting child and formation of final graph
3- Data Exchanges

Before discussing how ALQARM works and its proposed steps, first some basic discussions about the principles of designing the proposed method based on the ant heuristic algorithm will be presented. Then we will discuss the steps involved.

5.1 Practical concepts related to ALQARM design based on ants algorithm

This section describes some of the practical concepts associated with the ALQARM design based on the ants algorithm, and some important topics will be discussed around them.

- Topics related to the ant algorithm

Final Approval

The ants algorithm is one of the bio-inspired heuristic techniques that provides quality support in addition to effective optimization. Some practical concepts associated with the design of ALQARM are based on this algorithm and in particular with regard to applied ant agents that are described in the following.

• Forward ant agents (FA)

These agents are the ant agents that are sent periodically to the network for awaring of the network structure (DADOG tree). Nodes in the network receive FA periodically and use this agent stack information to update the network structure or to add to the DODAG tree. In fact, each node of receiving FA selects its parent based on its stack information. This work is done in the RPL protocol by exchanging DIO (DAG Information Object) messages. It is noteworthy that in ALQARM, unlike the RPL, FA emissions are variable. Also, based on abilities of ant agents learning try to manage the propagation of these agents with the aim of optimizing overheads. For this purpose, the ALQARM uses ant agents learning and control counter. With regard to the concept of learning, if the learning of node be reached to the stable state, the desired node will be able to select its parents without the need for exchanges of factors. In relation to the control counter topic, whenever the node receives an FA agent from the network nodes that is consistent with its current state (no change or looping occurred in DADOG), it adds one value to the counter. In this regard, the higher value of counter led to the longer period of time for sending FAs. Based on this, release of FA will be controlled and optimized in accordance with DADOG update requirements. Figure (1) shows an outline of the FA format. Functional fields in FA are according to RPL protocol [35], with the exception of adding some ALQARM fields as follows: Rel (reliability), QoS (quality), CL (Parent adn child rate) and ETX (expected transfers), FA sender node and stack on node to be visited. The details of these fields will be provided below.

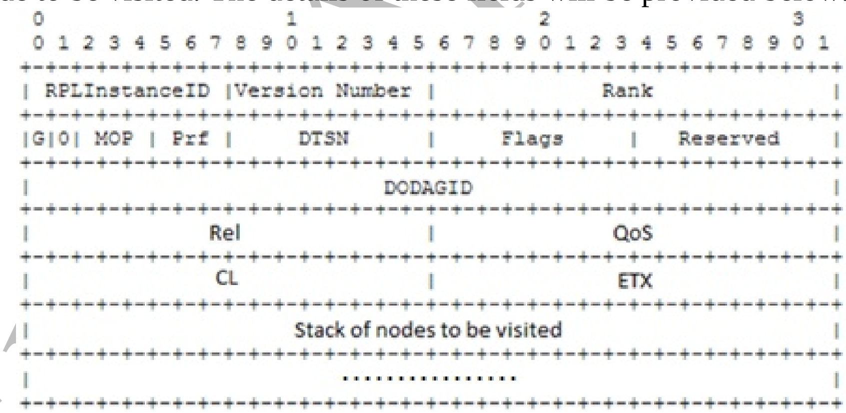

Fig 1. Overview of FA agent.

• Backward ant agents (BA)

These ant agents are sent from the leaf nodes to the root (up of the DADOG tree) in order to find out the destination status and update the parent routing tables. This is done in the RPL protocol based on the exchange of DAO messages. In ALQARM, unlike RPL, each BA has a stack that stores the information of nodes and pheromones in itself. Figure 2 shows a summary of the BA format. Applied fields in the BA agent comply with the RPL protocol [35], with the exception of adding some ALQARM fields as follows: Pheromone Deposited (evaluated pheromone for each node), and Stack of node to be Visited (nodes met by BA). The details of these fields will be provided below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| RPLInstanceID |D|  Reserved    |  DAOSequence  |    Status     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           DODAGID*                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Pheromone deposited                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Stack of nodes to be visited                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       .................                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 2. Overview of BA agent.

•Request ant agents (RA)

These ant agents are used to request FA sending from a present node in DODAG (present in network topology). In this case, if the node is newly added to the network or has require of FA, based on RA sending, it requests FA sending from other nodes in DODAG to distinguish and update its status on the network after receiving this agent. This is done in the RPL based on the DAO message exchange. However, in ALQARM the quality status of nodes is also reported. Figure 3 shows an overview of the RA format.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags     |   Reserved    |   Option(s)...                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Rel              |              QoS              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 3. Overview of RA agent.

Pheromone: This concept is related to the learning ability of ALQARM for the use of concepts related to the ant algorithm. Pheromone in ALQARM is evaluated by sending and receiving ant agents.

In this section, practical topics related to the design of ALQARM based on the ant algorithm are presented. In the following we will review the steps of ALQARM.

5-1- Parent selection and initial graph formation

This step is introduced as the first step of ALQARM and its aim is to form the initial network topology. As stated, the basic architecture of ALQARM, like RPL, is based on the creation of the DODAG tree that its root node is at its origin. In ALQARM after this step, each node present in the network topology will have a set of parents and ultimately a selected parent. Note that the rank of parent nodes must be lower than that of the lower child.

The formation of DADOG graph in ALQARM starts from the root and covers all of the network nods. In ALQARM, each node calculates its rank and sends it to its neighboring nodes when selecting its parent on the basis of FA information. The details of how to create a grid graph based on ant agents and ALQARM functional concepts are presented below.

- Creating a DODAG graph in ALQARM

In ALQARM, in order to create a network graph, at first the root node sends an FA to the network in a pervasive way. Based on the forwarding of this agent, the node identifies the root of the corresponding DODAG ID and reports its rank to other nodes in the network. After sending the FA, each node received the sending agent stores the ant agent sending node as its parent. It then evaluates and calculates the gal function and rank for itself, and then it adds the result of calculations to the FA stack along with the other criteria given in Figure (1). It then sends the intended agent again to the network and its neighborhood. This process is repeated in order to all nodes receive the sent FA agents. In addition to receiving the FA and storing the ant stack information, each node in its parents set will make the top node as main parent. So that in the first time the node with the lowest rank value will be selected as the parent and in the next time based on the result of the objective function (presented below), the top node will be selected as the main parent. The main parent is the node that through it data is sent to the root. During the graph creation process when a nod receives duplicate FA if the FA sender node (according to the ant agent stack information) is superior to the other parent, the receiving node will update its routing table against the FA stack information and resends the target agent in the network. Otherwise the received FA will delete without any additional operations. Relationship (6) provides a general overview of this concept. In the presented relation Rank is acceptance factor of the progressive ant agent (such that $Rank_{AF1}$and $Rank_{AF2}$are respectively equivalent to the rank denoted in the first FA and duplicate FA and δ equals the coefficient of acceptance index variable valuation such a way that $\delta \geq 1$). This component determines the severity of acceptance of repetitive factors and is an interaction between the reduction of overheads and the number of routs discovered.

$$Rank_{AF2} \geq \delta \times Rank_{AF1} \tag{6}$$

It is noteworthy that if a node receives an FA that indicates a reduction in the node rank in the DODAG graph, in this case the intended node must remove all of its parents that have higher rank than their current rank from their parent list.

Final Approval

Algorithm (1): A routine associated with sending FAs and updating its stack

Notation
//$Rank_{AF1}$ and $Rank_{AF2}$: Given rank in first and second FA respectively.
//δ: The variable valuation coefficient of acceptance index of repetitive ant agents.
//Rel_i, QoS_i, CL_i and ETX_i are equivalent in reliability, quality of service, number of children, expected transmission rate of FA sender node i.
//RE_i, CE_i and PE_i: Remain energy, consumption energy and primary energy of node i, respectively.
//Err_i: The number of errors that occurred during node i interactions with other nodes.
//C_i: Equivalent to node capacity i.
//BF_i and BS_i: Equivalent to free space and total space of buffer node i, respectively.
//d_f and d_r: The probability of successfully in packet correct sending and the probability of receiving correctly of the ACK packet [12]
 	
Forwarding Ant Process;
While (All Network Node not Received Forwarding Ant) {
After Received Forwarding Ant;
IF (Received Forwarding Ant is Repetitive) Then
IF $(Rank_{AF2} \leq \delta \times Rank_{AF1})$ Then
Discard Received Forwarding Ant;
Else {
Evaluation Criterias;
$Rel_i = RE_i \times \frac{1}{1+Log(Err_i)}$; $RE_i = 1 - \left({EC_i}/{PE_i}\right)$
$QoS_i = C_i \times \frac{1}{1+DS_i}$;
$DS_i = \sum No. of Message in Buffer_i \times PD_M$; $C_i = \frac{BF_i}{BS_i}$
$CL_i = \sum No. of Child node$;
$ETX_i = \frac{1}{d_f \times d_r}$; [12]
Insert Criterias to Forward Ant Stack;
ReBroadcast Forward Ant;
}
}

· Parent selection

Purposeful selection is nodes equivalent to improvement of routing and service in IoT. Because the task of routing and sending data of children of each node is performed by its parent. Detection and determination of parent node sets in ALQARM are based on node rank. For this purpose, when the node sends the FA agent root to the network, it gets an initial value (for example 256) to its rank in the FA stack and sends it along with the intended agent. The nodes receiving the FA store the sender node as their parent,

Final Approval

and evaluate their rank based on the father's rank. They then replace the rated rank with the parent rank in the FA and resend the agent to their neighbors. During the release of FAs, each node becomes aware of its parent set. In addition, the main parent is selected from the sum of the parent nodes. In the RPL, parent selection is based on the objective function and the expected transmission count (ETX). This method of selection is not appropriate and will lead to issues such as loss of service quality, graph imbalance, congestion event and overall performance loss. In order to improve this issue in ALQARM, evaluations are carried out in terms of the proposed pheromone (the same improved objective function). Relationships (7) to (9) provide details of calculating the objective function and ranking of nodes in ALQARM in terms of pheromone evaluation. In relation (7), $CPhn_i$ is the pheromone equivalent at the present moment for node i, and β_1, β_2, β_3 and β_4 are equivalent to the evaluation coefficients of evaluation criteria. Based on the result of relation (7), the value of objective function for node i will be equivalent to relation (8). So that γ equals the current moment pheromone value coefficient compared to the previous pheromone and has a value between zero and one. So that by increasing it the value of the current pheromone will be increased in the final pheromone evaluation; $TPhn_i$, $CPhn_i$ and $goal_i$ are equivalent to the pheromone value at the present moment, the pheromone value at the preceding moment, and the final value of the objective function for the nth node. According to the result of the relation (8) the node with the highest value is selected as the parent.

$$CPhn_i = \frac{(Rel_i)^{\beta_1} \times (QoS_i)^{\beta_2} \times \left(1 - \frac{1}{CL_i}\right)^{\beta_3} \times \left(\frac{1}{ETX_i}\right)^{\beta_4}}{\sum_{i \in all\ Father}\left((Rel_i)^{\beta_1} \times (QoS_i)^{\beta_2} \times \left(1 - \frac{1}{CL_i}\right)^{\beta_3} \times \left(\frac{1}{ETX_i}\right)^{\beta_4}\right)} \quad ,\beta_1, \beta_2, \beta_3, \beta_4 \geq 1 \tag{7}$$

$$goal_i = \gamma . CPhn_i + (1 - \gamma) . TPhn_i \tag{8}$$

Relation (9) shows the details of node rank evaluation. $Rank_i$ is rank of i node, CR fixed component of rank increase (256), $Father_{Rank}$ parent rank of intended node.

$$Rank_i = \frac{(Rel_i)^{\beta_1} \times (QoS_i)^{\beta_2} \times \left(1 - \frac{1}{CL_i}\right)^{\beta_3} \times \left(\frac{1}{ETX_i}\right)^{\beta_4}}{\sum_{i \in all\ Father}\left((Rel_i)^{\beta_1} \times (QoS_i)^{\beta_2} \times \left(1 - \frac{1}{CL_i}\right)^{\beta_3} \times \left(\frac{1}{ETX_i}\right)^{\beta_4}\right)} + CR + Father_{Rank} \tag{9}$$

As described above, the network graph is formed from the root node to the leaves. Next, to create routs from the leaf nodes to the root node and update the parent tables, the leaf nodes create a BA agent and send it to the root. In this case, each parent node on the rout to the root node with receiving the BA stores the received message information and updates the pheromone in term of relation (7). It then replaces its pheromone and ID in the BA stack and then sends the BA back to the root node. This process continues until the BAs receive by the root.

Ant colony routing is based on the concept of reinforcement learning in which positive feedback is given to the system in terms of pheromone deposition. Whereas, negative feedback is introduced in terms of pheromone evaporation. Pheromone evaporation refers to a decrease in pheromone values. In fact, pheromone deposition is a solution to enhance learning while pheromone evaporation allows old pheromones to be forgotten. The pheromone evaporation for all nodes in the network is modeled according to (10). Such that τ is equivalent to the control component of pheromone evaporation which has a value between zero and one, and it determines the intensity of evaporation.

Final Approval

$$Phn_j = (1 - \tau).Phn_j, \quad Phn_j \in [0,1] \tag{10}$$

According to the two processes described, the child nodes learn about their parents, the pheromones attributed to their parents and their status in the network, and the parents and roots learn about the architecture topology and rout state.

5.2 Children selection and the final graph formation

As a result of the objective function, each node selects the parent with the highest value as main parent and announces it membership. But in ALQARM, unlike the RPL, the parent node will only accept the child node membership if its child nodes set do not exceed more than k by accepting this child. However, if a parent has multiple requests from child nodes and exceeds the number of children in order to accept them, then it will only accept the highest priority children. In this regard, children will have a higher priority that their pheromone values are more. Algorithm (2) presents child selection in ALQARM.

Algorithm 2: child selection in ALQARM.

```
Child Accrue in ALQARM;
After Evaluation;
  Every node Selecet Father base on Objective function;
  Send Request to Seleceted node;
  After Received Request by Father;
  IF (Father_No.of Child < k) Then
        Child Acceptance;
      Else
        Not Acceptance and Send Reply to Child;
  ElseIF      ((No.of Child < k) and (Received m Request))
Then
      IF ((m + No.of Child) < k) Then
          Childs Acceptance;
      Else
          Childs by best CPhn_j Acceptance;
```

5.3 Data exchanges

At this point, whenever the node intends to send data, it starts the data exchange in terms of graph and the selected parent. Until there is not a change in the network topology, the data exchange will take place in the form of a graph. If the network graph is changed, the parent update and election it will be in accordance with what was mentioned in the previous step. Then the exchanges will be done according to the new graph.

According to what has been presented, routing and data exchange are performed for ALQARM performance. In the next section we will evaluate the performance of ALQARM in the simulator context and compare similar methods.

6. Performance Evaluation

To evaluate and demonstrate the performance of ALQARM, this method has been simulated with Cooja method, and compared with OFQS method [13]. In the simulations we used the Contiki IPv6 / 6loWPAN model and the open source implementation of the RPL protocol called ContikiRPL [36 and 37]. The tool of

Final Approval

simulation was Cooja that is a discrete event simulator in Contiki operating system. In experiments, methods compete with each other in the presence of a number of different nodes. The parameters for the simulation scenarios are as shown in Table (1).

Table 1: Simulation parameter.

Parameter	Value
Operating system	Contiki master version (2.7)
Loss Model	) UDGM(Radio model
Sensors	Tmote Sky
Communication protocol	CSMA, RDC contikimac, IEEE 802.15.4, ContikiRPL, IPv6
OF	OFQS ALQARM (Proposed OF)
The number of sensors	20,40,60,80,100
Network invirnment	) 200M*200M (
Microcontroller unit	ARM Cortex M3, 32-bits, 72 MHz, 64 kB RAM
Packet size	30 kb
Send of data	1 packet every 1 to 60 s
Transmission layer standard	UDP
Initial energy of sensors	210J
Buffer size of nodes	40 Packet
Radio waves	CC2420
Message volume of FA .BA and RA	16, 16 and 4 bit
Simulation time	30 m
Resuls	15 round

- Network successful receipts

This criterion is evaluated against the rate of sink node successful receipts relative to all produced and sent data, and it is defined as (11).

$$PDR = \frac{\sum \text{No.of Packet Received in Root}}{\sum \text{No.of Packet Send}} \tag{11}$$

•Network interaction delay

This factor is related to average time of data send from source to root. It is introduced as (12).

$$Delay = \frac{\sum_{j=1}^{\text{No. of send data}} \text{Arrival Time}_j - \text{Send Time}_j}{\text{No.of send data}} \tag{12}$$

•Control overheads

This factor shows control data exchanges in relationship (13).

$$OvearHead = \sum \text{No. of Control bit Send} \tag{13}$$

•Congestion

This factor is about control of parent child. It is evaluated by relationship (14) in the most congestion of parent nodes.

$$Congestion = \text{Maximum packet in Father node Buffer} \tag{14}$$

•Network consumption energy

This factor is related to sum of energy consumption of sensors and is evaluated by (15).

Final Approval

$$\text{Netwotk Energy Consume} = \sum_{i=1}^{n} \frac{\text{Energy Consume}_i(\text{mj})}{\text{Time }(s)} \quad (15)$$

The tests used Contiki Power trace to measure the power consumption of nodes and network. The output of the Power trace routine provides the total amount of time that all sectors are active [42]. To check energy, based on the 6LowPAN network with duty cycle where the radio unit is often inactive (except for sending and receiving) is operated. Contiki MAC's default settings are also used, with 8-bit wake-up per second and 6% of the time is active in traffic-free radio mode.

Based on the discussion above, the average energy consumption over time will be per relationship (16).

$$\text{Netwotk Energy Consume}_i(\text{mj}) = \text{Transmit} \times 19.5\text{mA} + \text{Recieved} \times 21.8\text{mA} + \text{Cpu} \times 1.8\text{mA} + \text{Lpm} \times 0.0545 \quad (16)$$

•Network consumption energy

The performance of methods is considered in terms of two concepts of effective network data exchange and performance optimization. ALQARM, by examining various indicators in the parent elections, on the one hand, prevents from issues that led to increase of consumption (such as data loss and re-sends) and on the other hand for data exchange uses optimal routs (optimizing send and receive). The proposed method is also effective in optimizing the overheads and energy consumption for their interactions in order to utilize the learning capabilities and design of the counter compatible with the topology changes. This effective performance with the capability of covering both areas has led to energy optimization. OFQS has been successful with the first concept (using optimal routs and data appropriate interactions). But this approach has not been effective in the second case. Figure (4) shows the results of energy consumption.

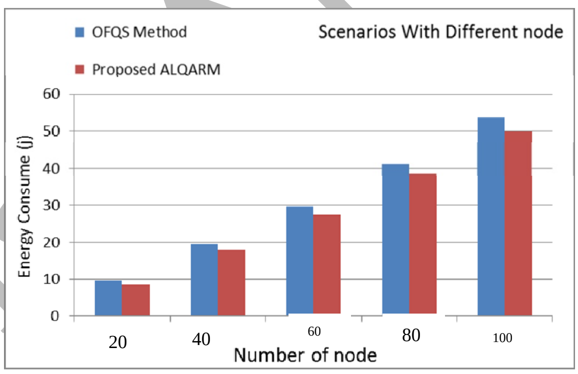

Fig 4. Network energy consumption.

•Network successful receipts

This criterion is related to the percentage of received data of root node correctly relative to the sum of sensors sent data. In this regard, when a method operates more desirable in choosing main parent and supporting quality and reliability of service, the service is better and the quantity of correct receipts will increase. ALQARM has supported services in a way that based on measures in line with anticipates of analysis and selection of parents, services are exchanged through higher quality and reliability parents and more appropriate intermediate routs. Therefore, quantity of network end-to-end receipts has been associated with greater improvement. The OFQS results in a much weaker performance. In this mechanism there are not the capability of analyzing the intermediate routs as well as measures to check the reliability of nodes and in this

Final Approval

respect has been associated with the relative decline of network successful receipts. Figure (5) shows the results of the percentage of successful receipts.

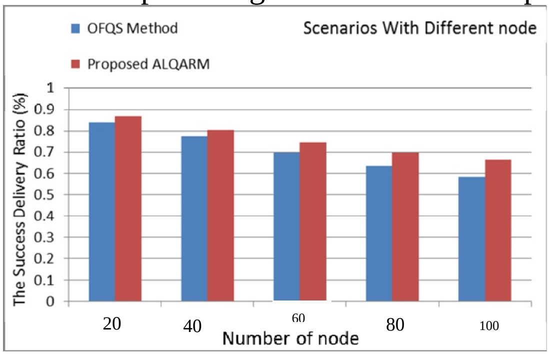

Fig 5. Network successful receipts.

• Transaction delay

This factor depends on the both of the quality of service and congestion control. Because each of these concepts has a direct impact on delay improvement. ALQARM has attempted to select the main parents and follow-up transactions in such a way as to support quality as much as possible in its effective performance. This ability along with bilateral decision-making with the ability to control allocation of children to parents and subsequent congestion control has doubled the capabilities of ALQARM to improve delay. This targeted design has resulted in improved service quality and effective prevention of congestion issues that ultimately results in delay optimization. OFQS has adopted appropriate measures in terms of quality of service and consideration of factors affecting the improvement of interaction delay. However, this approach has not been able to balance parent nodes traffic load and congestion management, and has been associated with increased delay. Figure 6 shows the delay results.

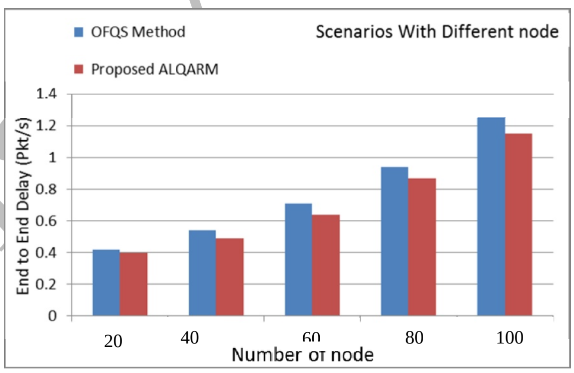

Fig 6. Network delay

•Congestion

This criterion is evaluated in maximum number of waiting packets for service in the parent node buffer and accepts the most impact from the parent child balance. Most past researches have suffered from the problem of graph imbalance and have not provided the capability to cover it. ALQARM has acted in a twofold design and activity (decision-making on both the parent and child side) as well as practical measures to limit the children that provides enable children of parent balancing and prevents congestion in different situations. This capability is a result of anticipated measures to limit children of parents and the ability of ALQARM to maintain graph balance. OFQS

Final Approval

has no capacity in this area, and is not efficient in this regard. This inefficiency has led to increased congestion for some parents and eventually the network. Figure 7 shows the results of the percentage of successful receipts.

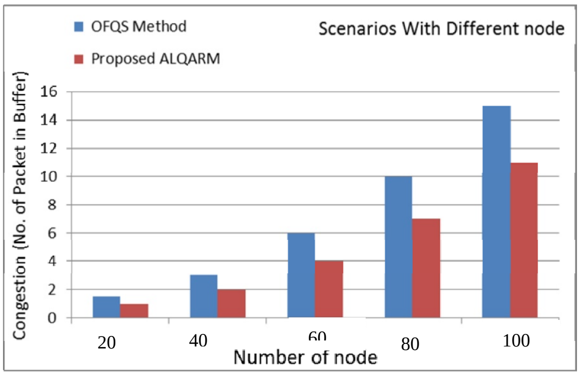

Fig 7. The most rate of parent congestion.

•Control overheads

This criterion is related to the sum of control data exchanges. In this regard, the more efficient method for optimizing and controlling message interactions, the lower overhead rate. ALQARM provides measures based on the benefits of learning pheromones and using compatible counters with topology, the capability to analyze network topology changes and accordingly controls overheads adapted to the needs and requirements. The OFQS has not provided a specific capability in this regard and has been associated with an increase in overhead. Figure (8) shows the results of overheads.

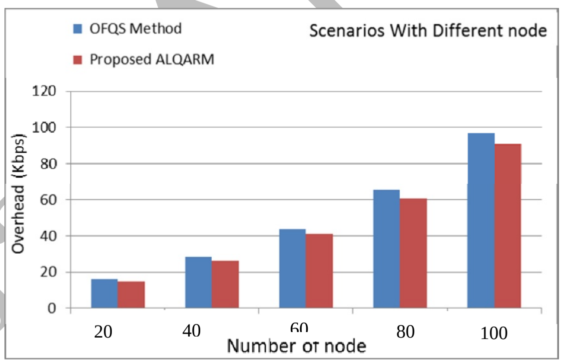

Fig 8. Results of data loss rate.

7. Conclusions and Future Works

In this paper, a new method called ALQARM is introduced for routing and exchanging data on the IoTs. ALQARM is based on exploration methods, and more precisely it is developed based on the ants algorithm. It is programmed in such a way that to maximize quality and optimize overheads. ALQARM has also been effective in controlling congestion based on examining and controlling parent-child attachment. The ALQARM was implemented based on the RPL protocol and the results of its simulation show congestion improvement, delay in data interactions, successful receipts and optimization of control overhead compared to similar methods. However, although ALQARM offers acceptable performance in terms of expanding routing, it still faces

Final Approval

with some challenges in optimizing and balancing energy consumption. In future research, we will attempt to cover these challenges by developing an ant algorithm based on the factors influencing optimization and energy consumption balance. It also attempts to develop and test the proposed method on the basis of other heuristic algorithms and based on results functions be evaluated.

Reference

[1] Madakam, Somayya, R. Ramaswamy, and Siddharth Tripathi. "Internet of Things (IoT): A literature review." Journal of Computer and Communications 3.05 (2015): 164.

[2] Srinivasan, C. R., et al. "A review on the different types of Internet of Things (IoT)." Journal of Advanced Research in Dynamical and Control Systems 11.1 (2019): 154-158.

[3] Alaa, Mussab, et al. "A review of smart home applications based on Internet of Things." Journal of Network and Computer Applications 97 (2017): 48-65.

[4] Talari, Saber, et al. "A review of smart cities based on the internet of things concept." Energies 10.4 (2017): 421.

[5] Philip, Vinu, et al. "A Review on latest Internet of Things based Healthcare Applications." International Journal of Computer Science and Information Security 15.1 (2017): 248.

[6] Ng, Irene CL, and Susan YL Wakenshaw. "The Internet-of-Things: Review and research directions." International Journal of Research in Marketing 34.1 (2017): 3-21.

[7] Stojkoska, Biljana L. Risteska, and Kire V. Trivodaliev. "A review of Internet of Things for smart home: Challenges and solutions." Journal of Cleaner Production 140 (2017): 1454-1464.

[8] Poluru, Ravi Kumar, and Shaik Naseera. "A Literature Review on Routing Strategy in the Internet of Things." Journal of Engineering Science & Technology Review 10.5 (2017).

[9] Čolaković, Alem, and Mesud Hadžialić. "Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues." Computer Networks 144 (2018): 17-39.

[10] Dhumane, Amol, Rajesh Prasad, and Jayashree Prasad. "Routing issues in internet of things: a survey." Proceedings of the international multiconference of engineers and computer scientists. Vol. 1. 2016.

[11] Silva, Bhagya Nathali, Murad Khan, and Kijun Han. "Internet of things: A comprehensive review of enabling technologies, architecture, and challenges." IETE Technical review 35.2 (2018): 205-220.

[12] Lamaazi, Hanane, and Nabil Benamar. "RPL enhancement using a new objective function based on combined metrics." 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC), pp. 1459-1464, 2017.

[13] Nassar, Jad, et al. "Multiple Instances QoS Routing in RPL: Application to Smart Grids." Sensors 18.8 (2018): 2472.

[14] Taghizadeh, Seyedreza, Hossein Bobarshad, and Halima Elbiaze. "CLRPL: context-aware and load balancing RPL for IoT networks under heavy and highly dynamic load." IEEE Access 6 (2018): 23277-23291.

[15] Nassar, Jad, Nicolas Gouvy, and Nathalie Mitton. "Towards Multi-instances QoS Efficient RPL for Smart Grids." Proceedings of the 14th ACM Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, & Ubiquitous Networks, pp. 85-92, 2017.

[16] Sousa, Natanael, et al. "ERAOF: A new RPL protocol objective function for Internet of Things applications." 2nd International Multidisciplinary Conference on Computer and Energy Science (SpliTech), pp. 1-5, 2017.

Final Approval

[17] Shakya, Nikesh Man, Mehdi Mani, and Noel Crespi. "SEEOF: Smart energy efficient objective function: Adapting RPL objective function to enable an IPv6 meshed topology solution for battery operated smart meters." Global Internet of Things Summit (GIoTS), pp. 1-6, 2017.

[18] Lamaazi, Hanane, and Nabil Benamar. "A Novel Approach for RPL Assessment Based on the Objective Function and Trickle Optimizations." Wireless Communications and Mobile Computing 2019.

[19] S. Santiago, & L. Arockiam. "ELT-EAPR: Expected Life Time of Energy Aware Parent Routing for IoT Networks," International Journal of Pure and Applied Mathematics, 118, 8, pp. 243-249, 2018.

[20] Kharrufa, Harith, et al. "Dynamic RPL for multi-hop routing in IoT applications." 2017 13th Annual Conference on Wireless On-demand Network Systems and Services (WONS), pp. 100-103, 2017.

[21] Alvi, Sheeraz A., Fakhar ul Hassan, and Adnan Noor Mian. "On the energy efficiency and stability of RPL routing protocol." 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC). IEEE, 2017.

[22] Muhammed, Thaha, et al. "HCDSR: A Hierarchical Clustered Fault Tolerant Routing Technique for IoT-Based Smart Societies." Smart Infrastructure and Applications. Springer, Cham, 2020. 609-628.

[23] Lin, Jenn-Wei, et al. "Efficient Fault-Tolerant Routing in IoT Wireless Sensor Networks Based on Bipartite-Flow Graph Modeling." IEEE Access 7 (2019): 14022-14034.

[24] Boudaa, Abdelghani, and Hocine Belouadah. "Fault-Tolerant Communication for IoT Networks." International Conference Europe Middle East & North Africa Information Systems and Technologies to Support Learning, pp. 245-255, 2018.

[25] Takahashi, Ryuichi, Mitsumasa Ota, and Yoshiaki Fukazawa. "Fault-Tolerant Topology Determination for IoT Network." International Conference on Ubiquitous Information Management and Communication, pp. 62-76, 2019.

[26] Somaa, Fatma, Ines El Korbi, and Leila Azouz Saidane. "Braided on demand multipath rpl in the mobility context." IEEE 31st International Conference on Advanced Information Networking and Applications (AINA), pp. 662-669, 2017.

[27] Hasan, Mohammed Zaki, and Fadi Al-Turjman. "Optimizing multipath routing with guaranteed fault tolerance in Internet of Things." IEEE Sensors Journal 17.19 (2017): 6463-6473.

[28] Lin, Jenn-Wei, et al. "Efficient Fault-Tolerant Routing in IoT Wireless Sensor Networks Based on Bipartite-Flow Graph Modeling." IEEE Access 7 (2019): 14022-14034.

[29] Aljarrah, Emran. "Deployment of multi-fuzzy model based routing in RPL to support efficient IoT." International Journal of Communication Networks and Information Security 9.3 (2017): 457-465.

[30] Sankar, S., and P. Srinivasan. "Fuzzy Logic Based Energy Aware Routing Protocol for Internet of Things." International Journal of Intelligent Systems and Applications 10.10 (2018): 11.

[31] Fabian, Philippe, et al. "Fuzzy-based Objective Function for Routing Protocol in the Internet of Things." 2018 IEEE Global Communications Conference (GLOBECOM). IEEE, 2018.

[32] Thangaramya, K., et al. "Energy aware cluster and neuro-fuzzy based routing algorithm for wireless sensor networks in IoT." Computer Networks 151 (2019): 211-223.

[33] Santiago, S., and L. Arockiam. "A novel fuzzy based energy efficient routing for Internet of Things." International Conference on Algorithms, Methodology, Models and Applications in Emerging Technologies (ICAMMAET), pp. 1-7, 2017.

[34] Nguyen, Thien Duc, Jamil Yusuf Khan, and Duy Trong Ngo. "A distributed energy-harvesting-aware routing algorithm for heterogeneous IoT networks." IEEE Transactions on Green Communications and Networking 2.4 (2018): 1115-1127.

Final Approval

[35] J. Ko, J. Eriksson, N. Tsiftes, S. Dawson-Haggerty, A. Terzis, A. Dunkels and D. Culler, ”ContikiRPL and TinyRPL: Happy Together”, Proceedings of the workshop on Extending the Internet to Low power and Lossy Networks (IPSN), April 12-14, 2011, Chicago, Illinois.

[36] N. Tsiftes, J. Eriksson, and A. Dunkels, ”Low-PowerWireless IPv6 Routing with ContikiRPL”, Proceedings of the workshop on Extending the Internet to Low power and Lossy Networks (IPSN) ACM Conference, Stockholm, Sweden, April 2010.

[37] Dunkels, Adam, et al. "Powertrace: Network-level power profiling for low-power wireless networks." (2011).

Final Approval