Cross-Layer Routing Based on Semantic Web Services Discovery with Energy Evaluation and Optimization in MANET

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***Abstract*:** The web services discovery process in mobile ad hoc networks is considered as a very difficult challenge due to the continuous change in the topology of the network and also the lack of a fixed central directory for publishing web services. Several approaches have been proposed which are based on either keywords or identifiers representing the service to be searched or by using a specific scenario of discovery. All of those proposed solutions try to respect the constraints of mobile ad hoc networks MANET such as energy, bandwidth, throughput, etc. In this paper we present our new proposed model for measuring the cost of the overall energy consumption in ad hoc networks depending on the web services discovery protocols. We also present a new optimized web services discovery protocol in MANET based on cross_layer routing techniques with the dissemination in the routing process at the same time the semantic web services information and a DISCOVERY_DIAMETER parameter that we have proposed to limit the area of discovery in the network. Finally, we present simulation results of our defined approach showing a significant optimization of the energy consumption level and the average throughput.

***Keywords*:** Ad hoc, Energy consumption, MANET, Semantic web services discovery, Average Throughput, Routing protocols.

1. Introduction

A web service is a technology that makes any application or software available over Internet. Nowadays web services are widely used by companies due to their efficiency and their security; besides this they are based on internet standards. Web services are described in a WSDL (Web Services Description Language) form, specifying the methods that can be invoked; those methods are accessible via SOAP (Simple Object Access Protocol). Furthermore, Web services are published in a common fixed repository UDDI (Universal Description Discovery and Integration) in order to facilitate their research. However, in a mobile environment without infrastructure such as MANETs (Mobile Ad Hoc Networks), where the topology of the network changes all the time, we cannot use a fixed directory for publishing web services, because this situation makes the process of finding web services a difficult challenge, especially if we take into consideration the limits of ad hoc networks, such as bandwidth and energy. In that regard, several approaches and protocols have been developed.

In this work we have first proposed a model to calculate, verify and validate protocols of web services discovery in mobile ad hoc networks depending on the global energy consumed. Moreover, we have proposed an optimized protocol that has two main objectives: The first one is to create a new mechanism for semantic web services discovery in mobile ad hoc networks, otherwise, to perform a semantic discovery based on functional parameters (Inputs and Outputs) present in the semantic descriptions OWL-S (Ontology Web Language-Service) of web services without the intervention of the client in the selection phase of the discovered services; this means achieving an automatic and precise discovery of the desired services. The second objective is to develop a new strategy which simultaneously elaborates the routing and the web service discovery using cross-layer techniques over a modified AODV protocol with dissemination in the routing process of some semantic web services information and the DISCOVERY_DIAMETER parameter that we have proposed to limit the area of discovery in the network. This technique will greatly minimize bandwidth and energy consumption in the network.

This paper is organized as follows, a presentation of some related works, then our proposed model to evaluate protocols of web services discovery in mobile ad hoc networks depending on the global energy consumption, our new optimized protocol. Finally, an illustration and a discussion of the obtained simulation's results.

2. Related Works

Research in the field of ad hoc networks focused initially on routing, and several routing protocols such as DSR, AODV, TORA, OLSR, etc., have emerged. However, the initial assumption of those routing protocols is that the packet destination address is known to the source node at the beginning. Applications in ad hoc networks often use resources or services that are present in another mobile node, it is important for applications to discover in a transparent manner those remote services. Existing routing protocols are not suitable for services discovery process, since in the latter case the destination address is not initially known. To remedy this situation, several approaches and protocols have been proposed.

The first approaches of services discovery in ad hoc networks were based on the aspects related to the architecture of discovery. These approaches include: SLP (Service Location Protocol) [30], Salutation [28], JINI [27], UPnP [35], Bluetooth Service Discovery Protocol [29], etc. However, most of these solutions are not suitable for mobile ad hoc networks, since they were not designed for networks with mobile nodes, also they do not take into consideration the technical constraints and limitations of ad hoc networks.

There is a second category of services discovery approaches that focus on the description language of services, like XML (Extensible Markup Language) and DAML (DARPA Agent Markup Language). These approaches include: SSDP (Microsoft's Simple Service Discovery Protocol) [31], DReggie [32], GSD (Group based Service Discovery) [36], Konark [20], Web Service Discovery Replication and Synchronization in Ad-Hoc Networks [19], etc.

However there are other studies as in [15], [33] and [34] which showed that, proposing an approach of service discovery based on cross-layer (Interaction between the application layer and network layer) using existing ad hoc routing protocols is much more efficient in terms of optimizing the network performance compared to traditional approaches.

There is also another type of works that aims to optimize the services discovery protocols using QoS or more specifically based on the trust to servers that respond to the client request, this trust is assessed through a set of parameters such as energy, response time and mobility of servers. Among these works we find [1], [2], [3], [4], [5] and [6].

In another category of works on web service discovery in mobile ad hoc networks there are those who focus on the Sensor Web Services field (SWS) which emerged from the need to offer data captured by the Wireless Sensor Networks (WSN) via the web, especially works in [8], [11], [12], [13], [14] and [7]. In the same category there is also an interesting work in [10] where the authors carried out a comparative study on the impact of mobility between the PDP, SDP, UPnP and TinySDP protocol proposed in [9].

3. Evaluating the Energy Consumption

The problem of energy consumption represents the center of interest for the research community of mobile ad hoc networks (MANET) and wireless sensor networks (WSN) like works in [38], [39], [40], [41], [42] and [43], this led us to study the impact of the web services discovery protocols on the energy consumed in MANET. After our study of some existing works we have noticed that each one of those approaches violates one or more technical constraints that should be respected in ad hoc networks such as bandwidth and storage resources, etc. As a result a significant consumption of energy occurred. Also, we have noticed that the proposed discovery approaches are based on the identifiers of the services or their names and their types with the client intervention to select the services which satisfy their needs.

The Table 1 shows a comparison between five different services/web services discovery approaches (protocols): KONARK [20], SEDIRAN [15], WSDRS [19], TrustSD [1] and TinySDP [9] that we have chosen to propose our cost evaluation model of the consumed energy by any service discovery protocols, depending on a set of elements which influence in direct or indirect manner on the overall energy consumed in MANET.

In Table 1, we collected several constraints C_i that influence in a direct or indirect manner on the main technical constraints to be respected in mobile ad hoc networks, where:

C_i = *{Bandwidth, Resources, Discovery_Mechanism, Energy}*

We used all these specific constraints as well as the results of works in [17] and [37], to propose a formula for measuring and evaluating the overall energy consumed according to any web services discovery protocol in MANET.

The formula (1) for measuring the cost of energy consumed in each node depending on constraints C_i is given as follows:

$$\mathrm{Cost}_{enr} = \mathrm{Cost}_{ack} + \prod_{i=1}^{3} \mathrm{Cost}_{C_i} \quad (1)$$

Where:

Cost_{enr} : *Cost of energy consumed in each node.*

Cost_{ack} : *Cost of energy consumed in the transmission or reception of control packets.*

Cost_{Ci} : *Cost of energy relative to each constraint C_i in each node.*

To calculate $Cost_{C1}$ that represents the cost of influence on the electrical energy consumed in each node depending to the number, size and type of packets circulating in the network, we are interested in the work proposed in [17] who presented several results of the measuring energy consumption; they identified four states of energy consumption:

- Transmission: the transmission of packets.
- Reception: the reception of packets.
- Waiting: waiting for a packet transfer.
- Sleeping: the state of lowest energy consumption when the node cannot receive or transmit.

The energy cost associated with each packet to each node is represented by the total incremental cost ***m*** proportional to the packet size, and a fixed cost ***b*** associated with acquisition channel. The formula (2) below is used to calculate the energy cost of each packet in each node on the network.

$$\mathrm{Cost} = m \times size + b \quad (2)$$

The formula (3) is the formula that we have proposed to calculate $Cost_{C1}$

$$\mathrm{Cost}_{C1} = \mathrm{Cost}_{E_{adv}} + \mathrm{Cost}_{E_{disc}} + \mathrm{Cost}_{E_{sync}} + \mathrm{Cost}_{E_{resp}} \quad (3)$$

Where:

$\mathrm{Cost}_{E_{adv}}$: *Cost of energy consumed by the transmitting and receiving services advertisements packet.*

$\mathrm{Cost}_{E_{disc}}$: *Cost of energy consumed by the transmitting and receiving services discovery packets.*

$\mathrm{Cost}_{E_{sync}}$: *Cost of energy consumed by the transmitting and receiving nodes synchronization packets.*

$\mathrm{Cost}_{E_{resp}}$: *Cost of energy consumed by sending response packets by the provider.*

The formula (4) is the proposed formula to calculates Cost_{C2} which represents the cost of influence of the used resources and the stored information on the overall energy consumed.

Table 1. Comparison between existing approaches

C_i	Parameters	Protocols				
		KONARK [20]	SEDIRAN [15]	WSDRS [19]	TrustSD [1]	TinySDP [9]
Bandwidth	Advertisement Packets	Broadcast	Broadcast	Broadcast between areas	No	Broadcast
	Synchronization Packets	No	No	Between UDDIs	No	No
	Discovery Packets	Unicast	Broadcast	Unicast	Broadcast	Unicast
	Response Packets	Broadcast	Broadcast	Broadcast	Broadcast	Broadcast
Resources	Replication of Information	All services between all nodes	Only the special Services between all Nodes	All services between UDDIs	No	All services between all nodes
	Routing Table	Routes to all network providers	Routes to all providers of special services + Routes to the ordinary Services desired	Routes to UDDIs	Routes to all network providers	Routes to all network providers
	Services Storage	Database 'tree' of all existing services	Database of all special services + Cache of ordinary services	UDDI Database in every area	Cache of discovered services	Cache of all services in the network
Discovery Mechanism	Discovery Elements	Name or Service Type (Uncertain Discovery)	Services Identifiers (Uncertain Discovery)	Services Identifiers or Service Name (Uncertain Discovery)	Service Name (Uncertain Discovery)	Unique services Identifiers + QoS (Certain Discovery)
	Search and Selection	Client intervention	Client intervention	Client intervention	Automatic	Client Intervention
Energy	Energy Consumed	Important	Important	Important	Average	Important

$$Cost_{C2} = Cost_{Rrepl} + Cost_{Rrout} + Cost_{Rstor} \quad (4)$$

Where:

$Cost_{Rrepl}$: *Cost of replication of the same information between nodes.*

$Cost_{Rrout}$: *Cost relative to routes stored in the network nodes.*

$Cost_{Rstor}$: *Cost relative to the structure of service's directory.*

The formula (5) represents the proposed formula to calculate $Cost_{C3}$ which represents the cost of influence on the energy consumed in each node depending to the proposed discovery mechanism.

$$Cost_{C3} = Cost_{M\,resr} + Cost_{M\,client} \quad (5)$$

Where:

$Cost_{M\,resr}$: *Cost relative to the discovery elements proposed.*

$Cost_{M\,client}$: *Cost relative to the involvement of the client in the discovery process.*

The proposed formula to calculate the cost of influence on the overall energy consumed in all the network depending on the discovery approach is represented as follows:

$$Cost = \sum_{j=1}^{nb\_nodes} \left(Cost_{ack} + \prod_{i=1}^{3} Cost_{C_i}\right) \quad (6)$$

Figure 1 represents the comparison between the different discovery approaches studied according to the cost of energy calculated from the proposed formula, where the axis NODE represents the number of nodes in the network and the axis ENERGY_COST represents the cost of energy calculated from the proposed formula.

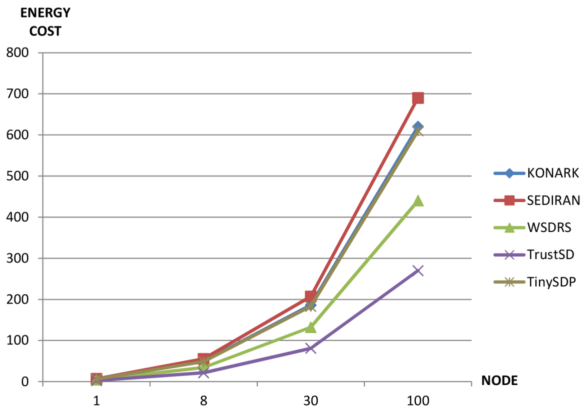

Figure 1. Comparison between discovery approaches

As shown in Figure 1 after evaluation of the studied approaches by our formula, the approach proposed in TrustSD [1] is less greedy in terms of the overall energy consumption compared to other approaches, this is due to the mechanism proposed, because the authors have proposed a cross-layer protocol and also a Trust parameter calculated according to a set of characteristics of the servers (energy of the server, response time and the mobility of server) which are added into the provider's reply packet. The Trust parameter ensures a QoS and an automatic provider's selection.

4. The Proposed Optimized Approach

Due to the limitations of ad hoc networks we propose a new protocol where we assume that each provider node is the advertisement's directory of its own services in order to avoid overloading the network with the announcement packets of services such as the works in [15], [19], [20], [32], [36] and [9]. This assumption is justified with the permanent change of the topology because in the studied existing approaches we have noticed that at every movement in the topology of the network there is a new election of publication directories, re-execution of the synchronization mechanism inter-directories or a re-execution of the announcement mechanism of services across the network. Our approach is based on the interconnection of the application layer and the network layer because using a cross-layer approach in service discovery as presented in [33] and [34], increases the performance of the network in terms of bandwidth and the overall energy consumed, also in [17] the author proved that there is a direct relation between number of the packets, the bandwidth and the energy consumed.

In our protocol we have modified and adapted the existing AODV protocol to satisfy our needs. The choice of the routing protocol AODV is justified by its simplicity of implementation, also it does not require a lot of computing power, and most importantly, it is a reactive routing protocol, which means that it does not look for routes only on demand. The proposed architecture is shown in Figure 2.

In our new approach, we have added two new types of packets to AODV protocol, RREQSSD (Route Request Semantic Services Discovery) and RREPSSD (Route Reply Semantic Services Discovery), they are similar to the existing packets RREQ (Route Request) and RREP (Route Reply) but with more fields that correspond to the REP and REQ messages, where REQ represents the query containing the necessary information to discover routes to the desired service by the Client and REP represents the response of the provider that offers the desired service.

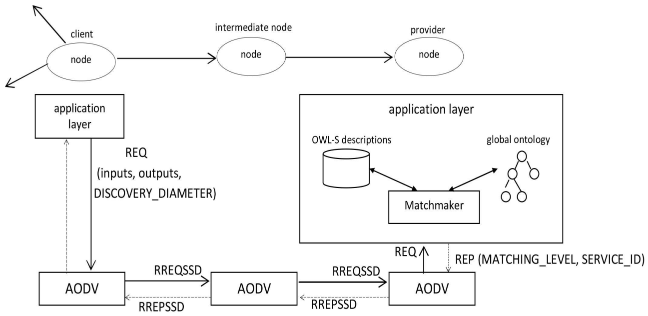

Figure 2. The proposed architecture

4.1 The discovery packet RREQSSD

To search a service in our approach, the Client at the Application layer enters all the information concerning the desired service (information about the Client, service name, functional parameters such inputs/outputs, etc.). He specifies also the value of the field DISCOVERY_DIAMETER, this value is used to control the distance of research according to the client needs. This will lead us to an important reduction in the number of research packets flowing through the network, therefore an important optimization of the total energy consumed in this discovery process. After validation by the Client, a REQ packet containing the functional concepts INPUTS/OUTPUTS of the desired service and the distance of discovery DISCOVERY_DIAMETER, will be sent to the AODV protocol of the network layer (the choice of INPUTS/OUTPUTS parameters is justified in section The Matchmaker Module), to be integrated into the routes discovery process to the desired destination via the new RREQSSD packet that we have proposed (Figure 3).

Type	J	R	G	D	U	Reserved	Hop Count	**REQ: DISCOVERY_DIAMETER**
REQ : SERVICE_INPUTS								
REQ: SERVICE_OUTPUTS								
RREQ ID								
Destination IP Address								
Destination Sequence Number								
Originator IP Address								
Originator Sequence Number								

Figure 3. Structure of RREQSSD

RREQSSD will be sent in broadcast mode to all neighbors depending on the DISCOVERY_DIAMETER field that indicates the number of nodes that the packet can pass. The flowchart in Figure 4 shows the behavior of the network nodes at receiving the RREQSSD packet.

In the case where the intermediate node is a services provider, the AODV protocol of the network layer will send the REQ packet encapsulated in RREQSSD packet to the Matchmaker module of the application layer. The Matchmaker extracts the descriptions SERVICE_INPUTS and SERVICE_OUTPUTS in the Client request REQ and by using a global ontology he will match them with the inputs/outputs in the descriptions of the services offered by the provider according to the principle proposed in [21] presented in section The Matchmaker Module. Otherwise in the case where the provider does not find any match with the request of the source node, it will check whether the hop_count+1 is less than the DISCOVERY_DIAMETER if so it forward the packet RREQSSD.

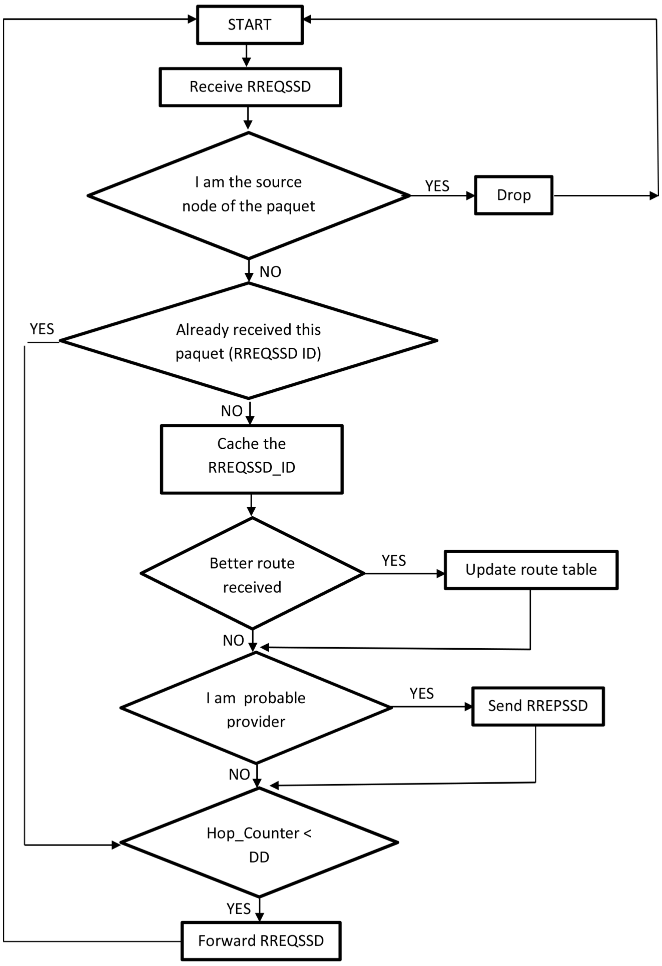

Figure 4. The flowchart of RREQSSD reception

The Algorithm 1 represents the new actions executed by AODV protocol, upon receipt of the new RREQSSD packet.

> ***Algorithm 1***: *RREQSSD_Reception( )*
> ***if*** *New RREQSSD_ID* ***then***
> *Save RREQSSD_ID( );*
> *Extracting DISCOVERY_DIAMETER ( );*
> ***if*** *DISCOVERY DIAMETER ≥Hop Count* ***then***
> *SendTo_Application_Layer(REQ) ;*
> ***else***
> *Drop_RREQSSD( ) ;*

The Algorithm 2 represents the actions performed by the application layer at the reception of REQ packet.

> ***Algorithm 2***: *Application_Layer(REQ)*
> ***if*** *Provider()* ***then***
> ***if*** *Matchmaker(REQ)* ***then***
> *Generate_REP(MATCHING_LEVEL, SERVICE_ID);*
> *SendTo_AODV_Network_Layer(REP);*

The parameter REP packet contains: the degree of matching MATCHING_LEVEL of the service found by the Matchmaker module relatively to the inputs/outputs of the client request and the inputs/outputs in the OWL-S descriptions of the services offered by the provider. The message REP contains also the identifier SERVICE_ID of the service found.

The Algorithm 3 represents the new actions performed by the AODV protocol of the destination at the reception of the REP packet from the application layer.

> ***Algorithm 3***: *AODV_network_layer(REP)*
> ...
> *Update_Routing_Table(REP);*
> *Generate_New_RREPSSD(REP);*
> *Send(RREPSSD);*

4.2 The matchmaker module

The main role of Matchmaker module is based on the principle of semantic matching. There are several approaches of semantic web services discovery [16], [18], [21], [22] and [23]. We can say that, although the principle proposed by Paolucci et al. is limited to the use of functional attributes inputs/outputs to adapt their system of web services semantic discovery in an environment with infrastructure, it remains the most simple and effective approach to solve this problem, because, the authors based on the modeling language DAML-S that provides a rich, simple and detailed description of web services, also they have integrated their solution over the known standards such as UDDI and WSDL. This leads us to exploit the principle proposed by *Paolucci et al.* in our approach.

The detailed architecture of the Matchmaker module in our system is shown in Figure 5.

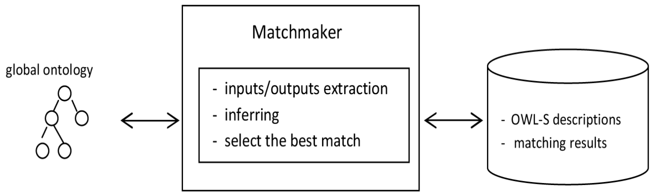

Figure 5. Architecture of the Matchmaker module

As illustrated in Figure 5 the Matchmaker module in the application layer performs several actions, it takes the inputs/outputs from the OWL-S descriptions of the services offered by the provider, then with the help of a global ontology which describes the ontological relationships between all concepts that exist (by theoretical definition of ontology), the Matchmaker will calculate and save the degrees of matching between the inputs/outputs of the user query with those of the services proposed by the provider. This research of the services which may correspond to the demand of the user is based on the following definition.

Definition: Let *inR* and *outR* are the inputs offered and outputs required by the client request *R*. let *inS* and *outS* are the inputs required and the outputs offered by a web service *S*, a web service *S* can respond the request *R* if inputs required by *R*, are equivalent or include (according to the global ontology) those offered by *S*, and if the outputs offered by *S* are equivalent or include those required by *R*. [21]

Concerning the degrees or levels of matching, there are four levels [21] shown in Figure 6 those levels depend to the relationship between the concepts associated with each input/output of the request *R* and the service *S*.

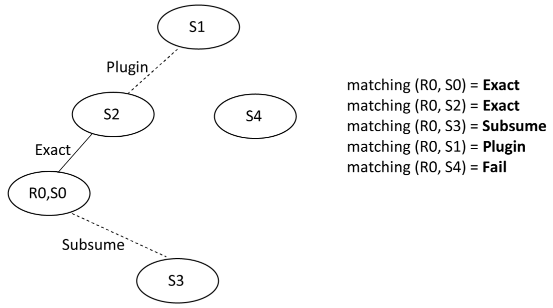

Figure 6. Degrees of matching

Exact match: The Matchmaker recognizes an Exact match between the service *S* and the request *R*, when *outR* = *outS*. Such service responds to the exact needs of the request. Also the matching can be Exact when outR is an immediate subclass of *outS*.

Plugin match: The Matchmaker recognizes a Plugin match, if *outS* superclass of *outR*. This rule recognizes that there is a weak relationship between *outR* and outs.

Subsume match: In the case of Subsume match, the request is more generic than the service found. In other words: *outR* is a superclass of *outS*. In this case, the service *S* can be chosen, but this service may or may not satisfy the query, it may be that another service may be sought to complete the lack (Web services composition).

Fail: If no one of the previous matching were identified it means that the service *S* and the request *R* are incompatible.

Once the Matchmaker finishes the matching process, he begins to sort the results found, knowing that the Exact match is the preferred then the Plugin match and finally comes the Subsume match. The main element in the sorting process is to select the highest degree of the outputs matches. The Inputs Matching is used secondarily to separate the outputs matches with the same degree.
If no match was found then the Matchmaker will not return any results, otherwise it sends a REP packet containing the identifier of the service found and the calculated matching degree, to the AODV protocol in the network layer.

4.3 The response packet RREPSSD

The Figure 7 shows the structure of the new RREPSSD packet according to our approach.

Type	R	A	Reserved	Predix Sz	Hop Count	**REP: MATCHING_LEVEL**
REP: SERVICE_ID						
Destination IP Address						
Destination Sequence Number						
Originator IP Address						
Lifetime						

Figure 7. Structure of RREPSSD

After receiving the REP packet from the application layer, the AODV protocol will encapsulate it in the new RREPSSD packet and sends it to the client. The traversed nodes will update their routing tables; they add also the content of MATCHING_LEVEL field. The AODV protocol of the source node, after receiving the first RREPSSD packet, saves it for a waiting period WAITING_TIME which corresponds to the time to wait for other RREPSSD packets from other providers, once all packets are received it calculates the route with the smallest MATCHING_LEVEL, after that the network layer sends to the application layer the SERVICE_ID of the service found to begin data transfer.
In case of link failure during data transfer, the end node sends a packet RERR (Route Error) to the source node to prevent that the destination is now unreachable. If the source node always needs a route to this destination to complete the data transfer it will launch a route discovery process using only the classic packets RREQ and RREP.
The flowchart in Figure 8 shows the behavior of the network nodes at receiving the RREPSSD packet.

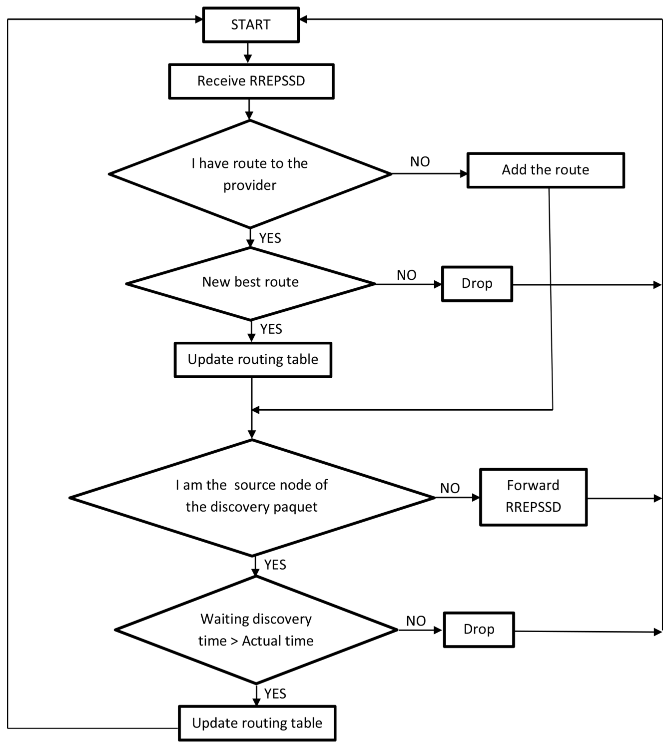

Figure 8. Flowchart of RREPSSD reception

4.4 An optimized routing discovery

We assume a scenario of disaster (earthquake), in which is deployed an ad hoc network of emergency, and in order to rescue and give the first aid to the injured before bringing them to the hospital, the ambulance man must first verify medical information about the patient, to check whether he has a chronic disease for example, or if he is allergic to a given injections. In this case the ambulance man will fetch a web service published by a specific hospital or medical center that provides access to a medical database that contains all the necessary medical information about the injured persons. In our case of study, for example, we assume that the information about the service sought are:

- Service name: Heart Disease.
- Inputs: Surname; Firstname; Identifier.
- Outputs: Hypertension
- DISCOVERY_DIAMETER = 2

In our scenario we assume that there are five medical centers in the area, The following Table 2 represents the functional parameters and other information about these Web services collected from the OWL-S semantic descriptions of the offered services.

Table 2. Web services offered

Medical Centers	Acronym	Service Name	Inputs	Outputs
Hospital	H	S1	Surname; Firstname; Identifier;	Disease
Cardiovascular Diseases Center	CDC	S2	Surname; Firstname; Identifier;	Chronic
Clinic of Diabetology	CD	S3	Surname; Firstname; Identifier;	Diabetes
Pharmaceutical Center	PC	S4	Medicines	Quantity
Medical Center	MC	S5	Surname; Firstname; Identifier;	Disease

Figure 9 shows the execution of our proposed approach depending on the above scenario.

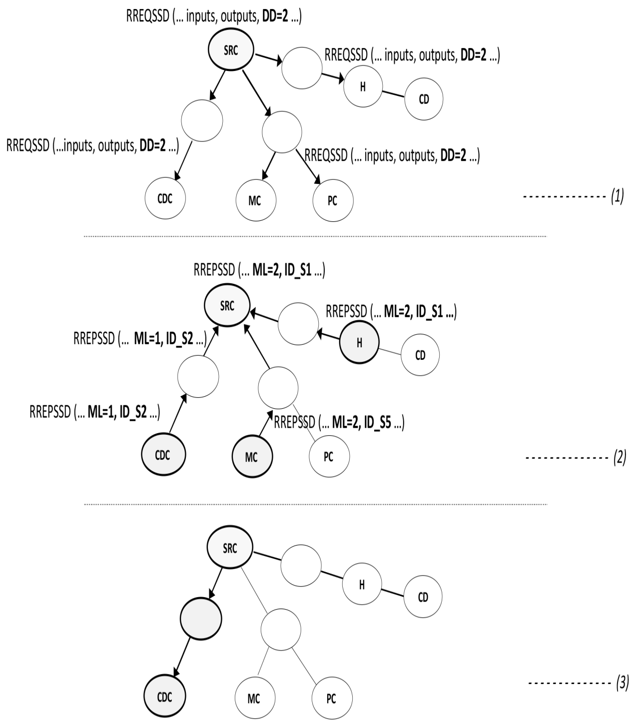

Figure 9. Routes discovery process

The Part (1) in Figure 9 illustrates the result of RREQSSD broadcasting process to all nodes in the network. As illustrated, the providers that correspond to DISCOVERY_DIAMETER (DD=2) are the nodes [H, CDC, PC and MC].

Then as illustrated in Part (2), the providers [H, CDC and MC] send a response packets RREPSSD with an ML (MACHING_LEVEL) equal to [2, 1 and 2] successively, (2: means that the degree of match = Plugin and 1: means that the degree of match = Exact); the provider PC did not send any response packet because it did not detected any degree of match it means a case of Fail. The results of the matching process are illustrated in Table 3.

Table 3. Results of matching

(Request, Service)	Service Provider	Output Request	Output Service	Match Degree
(REQ, S1)	H	Hypertension	Disease	Plugin
(REQ, S2)	CDC	Hypertension	Chronic	Exact
(REQ, S3)	PC	Hypertension	Quantity	Fail
(REQ, S4)	MC	Hypertension	Disease	Plugin

The degrees of matching in our case of study are calculated from the following domain ontology.

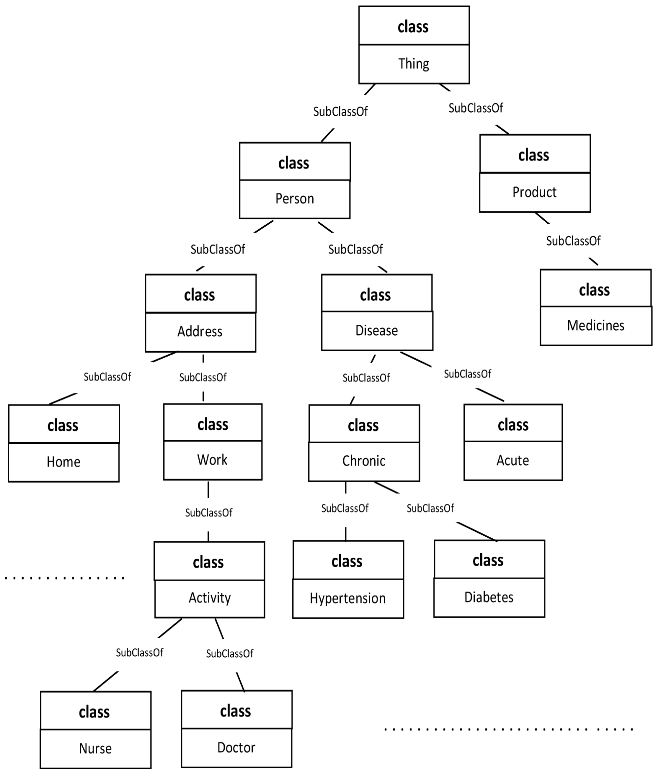

Figure 10. Domain ontology

Finally as illustrated in Figure 9 Part (3), the modified AODV protocol in the client node, will automatically select and save route to the provider CDC because it has the best match.

4.5 Validation of the proposed approach

To validate our approach according to the desired challenges presented in the introduction part, we have used the formula (6) to compare our approach with other existing works against the global consumed energy in the network during the discovery process.

Table 4 presents the challenge of our proposed approach depending on the C_i parameters proposed and presented above.

The graph in Figure 11 shows the positioning of our proposed web service discovery approach compared to other discovery approaches (KONARK, SEDIRAN, WSDRS, TrustSD and TinySDP) according to the energy cost calculated by the proposed formula (6).

Table 4. The challenge of our proposed approach

C_i	Parameters	Proposed Approach
Bandwidth	Advertisement Packets	No
	Synchronization Packets	No
	Discovery Packets	Broadcast
	Response Packets	Unicast
Resources	Replication of Information	No
	Routing Table	Route into the selected provider and only during the period of activity
	Services Storage	No
Discovery Mechanism	Discovery Elements	Functional parameters inputs/outputs (Certain discovery)
	Search and Selection	Automatic
Energy	Energy Consumed	Low

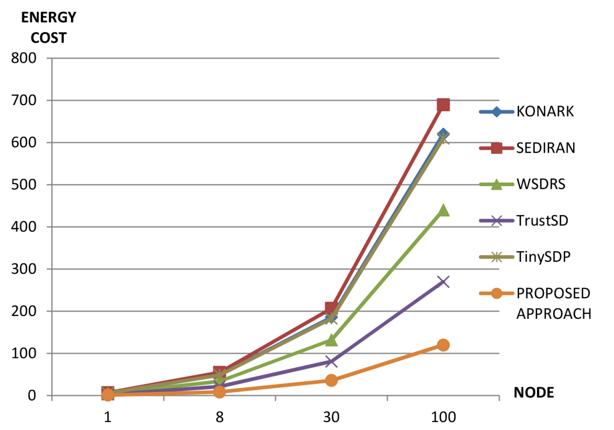

Figure 11. Energy cost of our proposed approach.

As illustrated in the Figure 11 our proposed approach offers an important gain in term of energy consumption in the network.

5. Experimentations

To analyze and evaluate our protocol, we have implemented it under the Network Simulator NS2. Table 5 below summarizes the proposed setup for this experiment.

In the proposed scenario we assumed five clients looking for services at different time intervals: [Client1: 0.1 → 2 sec], [Client2: 3 → 5 sec], [Client3: 3.3 → 5.3 sec], [Client4: 8 →10 sec], [Client5: 8 → 10 sec]; Also a data transfer with an FTP stream of 1500 bytes which represents the data services transfer, then we have measured and evaluated: the total energy consumed and the average throughput with and without using the DISCOVERY_DIAMETER parameter.

5.1 Energy consumption

Figure 12 illustrates the impact of DISCOVERY_DIAMETER parameter on the overall energy consumed in the network.

Table 5. Configuration of the simulation

Parameter	Value
Simulator	NS2.35
Simulation time	10s
Number of nodes	100
Simulation field	850*850
Number of clients	5
Number of providers	20
Number of probable providers	10
Propagation model	Tworayground
Energy in each node	3.4
Energy consumed during transmission	0.33
Energy consumed during reception	0.1
Energy consumed during the rest	0.5
Energy consumed in standby mode	0.3
Mobility	100

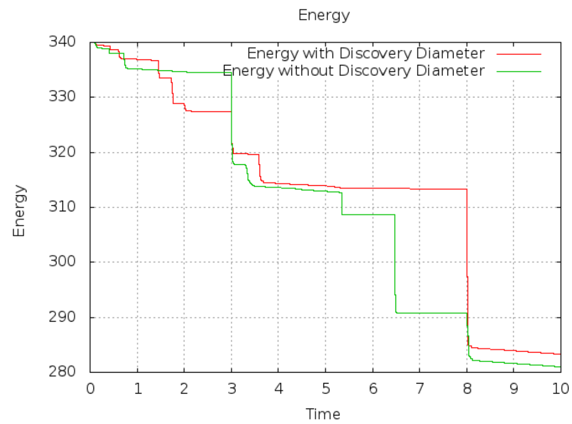

Figure 12. Energy Consumption

By using the DISCOVERY_DIAMETER parameter we have noticed an optimization in the energy consumed due to the limitation of the broadcast domain. We have also noticed logic in the energy consumption according to the proposed scenario because there is stability in the time intervals of no activity [2 → 3 sec] and [5 → 8 sec]. However, in the case where we did not use the DISCOVERY_DIAMETER, the energy consumption is more important and random over time which is explained by the limitless dissemination of the discovery packets.

5.2 Average throughput

The average throughput ***A*** is calculated by dividing the sum of the discovery packets sizes on the average transmission time.

$$A = \frac{\sum_{i=1}^{nb\_disc} S}{T} \quad (7)$$

Where:
A: Average throughput.
nb_disc: The number of all the discovery packets.
S: The packet size.
T: The average time of packets transmission.

Figure 13 shows the average throughput consumed during the proposed scenario with and without using the DISCOVERY_DIAMETER.

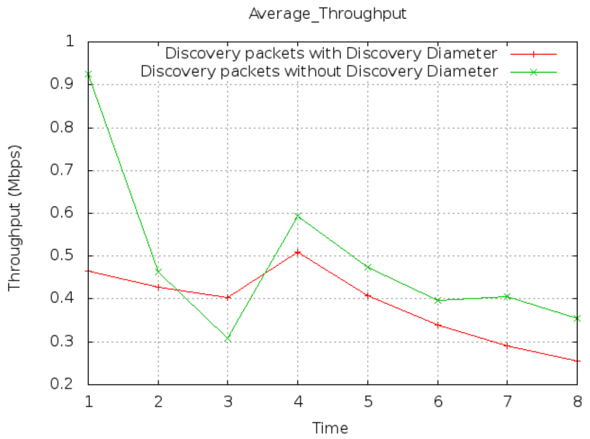

Figure 13. Average throughput

The optimization and stability of the average throughput using the DISCOVERY_DIAMETER parameter is clearly illustrated in Figure 13, where for example in the time interval [0 → 2sec] throughput is reduced to half.

Figure 14 shows a comparison between the average throughput calculated according to the discovery packets (RREQSSD + RREPSSD) and the average throughput consumed by all generated packets in the network (Discovery packets, Control packets and DATA packets), this allows us to see the impact of the discovery on the bandwidth in with our proposed approach.

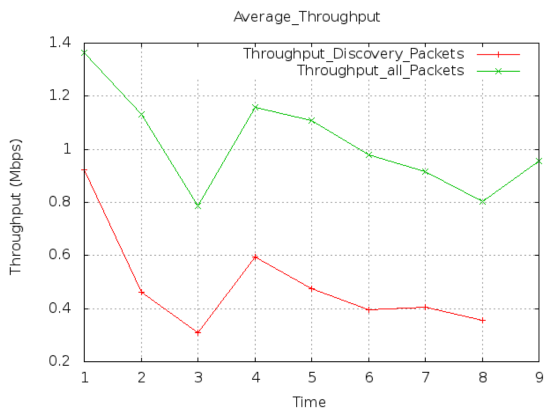

Figure 14. Service discovery packets throughput Vs All network's packets throughput

6. Conclusion and Future Works

In this paper, we have presented a new formula to calculate the cost of the energy consumed in MANET depending on the approaches of web services discovery. The formula is based on C_i parameters that we have taken from our comparative study between different existing discovery approaches. This new model will allow us to evaluate any web services discovery protocol depending on the global energy consumed by the nodes of the network. In addition, we have presented a new optimized approach of web services discovery in MANET which has the following characteristics:

- A decentralized architecture where each node in the network maintains its own services and it does not depend on a central directory.
- A routing discovery based on the diffusion of functional parameters of services.
- An automatic discovery and a best selection of services and routes to the destinations.
- A semantic discovery of web services.
- A significant reduction of energy consumed and of throughput in the discovery process.

To conclude we have presented the simulation results obtained where we have noticed that using the dissemination of the semantic web services information and the DISCOVERY_DIAMETER parameter proposed in the routing process, gives a significant optimization of the energy consumption level and the average throughput.

Further work would be to review the proposed evaluation formula of web service discovery protocols in an environment connected to Internet such as IoT (Internet of Things), where there will be an ad hoc network with gateways to Internet which means an access to existing UDDI directories where we can publish and find existing web services. Furthermore, it would propose the most appropriate approach for this network configuration.

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