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Energy of Bandwidth and Storage Routing Protocol for Opportunistic Networks

Salem Sati
IT Factuality, Misurata University, Libya
Email: salem.sati@it.misuratau.edu.ly
Abubaker Alhutaba
Department of Electronic Engineering, CIT Factuality, Libya
Email: alhutaba_a_abu@yahoo.com
Ibrahim Abutalag
Department of Electronic Engineering, CIT Factuality, Libya
Email: ibrahim_abutala@cit.edu.ly
Mohamed Eshtawie
Department of Electronic Engineering, CIT Factuality, Libya
Email: eshtawie@yahoo.com

ABSTRACT

Opportunistic Networks is communication environment which has no stable path. Therefore, in this environment, the routing algorithms are partitioned into two main classes which are metric-based and contact-based. Essentially, contact based algorithms target for a high routing performance and small delay at the same time. However; these protocols consume high resources in terms of Energy, Bandwidth and Storage. Practically, opportunistic nodes such as smart phones and tablets suffer from the limitation of the energy and physical memory. In addition, the environment connectivity instability leads to low bandwidth links. This work proposes a resource concentrate routing protocol for opportunistic networks, named Energy of Bandwidth and Storage Routing Protocol (EBSRP). The energy is considered as a main factor calculated as a function of bandwidth and storage. The proposed EBSRP has its queuing policy calculated as a function of energy ratio. The Simulation results are used to analyze the performance of EBSRP and it is compared with Epidemic using different replication and dropping policies based on energy, bandwidth, and storage. The results show that the proposed protocol has better performance than Epidemic in terms of delivery ratio, delay, and overhead.

Keywords **- Resource Concentrate, Epidemic Routing, Routing Performance, Controlled Replication, Message Information.**

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I. INTRODUCTION

The Opportunistic Networks commonly consist of nodes which are carried by people, these nodes or devices, in reality, suffering from resources of storage, bandwidth, and energy. The main property of such environment is unstable link and connectivity, As result of mobility and radio coverage, the bandwidth of the link between every two encountered nodes is insufficient, this low bandwidth comes from the mobility of both source and destination. Therefore, the messages are handled between source and destination using hop-by-hop mechanism. Due to absence of connectivity that might be long in some cases, the messages is carried out in the node buffer while the node moves around. This delay increases till the relay node meets the final destination. Essentially, both source and relay nodes store the message or its copy in their buffer, the time of buffering increases based on mobility pattern. While the message is stored in the buffer, it has the chance to be replicated which leads to increase hop count. The opportunistic routing protocols in general, are mainly divided into two main types. These types are contact-based routing and metric-based routing.

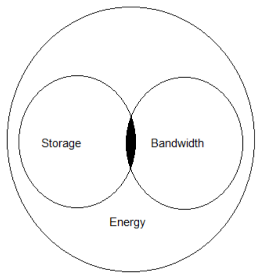

Figure1. Relationship Between Resources

Epidemic [1] routing protocol known as the simplest contact-based routing. The main idea of the Epidemic protocol is that the mule replicates the message to every encountered node. This mechanism is based on the assumption of routing design. The epidemic supposes that the buffer space of nodes is unlimited, however, if the buffer space is physically limited, the replication of uncontrolled message copies considered as traffic bandwidth which leads to high overhead. Both of limited storage as a reason of physical buffer and limited bandwidth as the reason for mobility leads to consuming the nodes energy. The energy is main criteria of such environment as shown in Figure 1. To overcome the problem of delivering message cost and node's resources consumption, several energy concentrate protocols have been proposed, Spray & Wait [2] which is considered as storage-bandwidth routing protocol, there are two types of Spray & Wait which are Source Spray & Wait (SSW) and Binary Spray & Wait (BSW). The Binary Spray & Wait partially improves the disadvantage of the storage and bandwidth, but it is still consuming energy from the node by long message storage. The idea of Spray & Wait to shape the bandwidth and storage with same value, the protocol eliminates the extra bandwidth and storage by fixing the traffic as number of copies, but Spray & Wait does not look at the energy consumed by the fixed traffic, where the protocol suffering from the long buffering time which is energy function. In this work, we propose a resource concentrate routing protocol for opportunistic networks, named Energy of Bandwidth and Storage Routing Protocol (EBSRP). This proposed routing protocol considers the energy as the function of storage and bandwidth. The copy and evict criteria of the proposed EBSRP protocol are calculated depending on the local information. EBSRP considers the bandwidth and storage as variables of energy consumption function, the bandwidth and storage show how much energy are consumed by the node. The idea of EBSRP relies on that the energy consumption can be estimated when the bandwidth adapted to the energy rate. Therefore the proposed routing protocol consider the bandwidth which is considered as storage function, Furthermore, both storage and bandwidth are variables of the energy function. Our proposed routing protocol EBSRP differs from the existing based contact epidemic routing protocols in three important points. First, it is considered the storage as a function of the bandwidth, Furthermore, it calculates the energy based on storage and bandwidth. Second, the proposed EBSRP protocol calculate the replication criteria based on the energy ratio which is computed based on the multiple of storage and bandwidth as the capacity of traffic. Third, the function is dynamic and locally where it considers hop count as storage and replication count as bandwidth. Furthermore looks to buffer time as energy time of the current node.

II. RELATED WORK

Routing in Opportunistic Networks designed on view of resource concentrate issues with trying to achieve a high delivery ratio. Therefore, most of the routing designers focus on one of the three issues of resource concentrate which are storage, bandwidth, and energy. The resources in such environment considered as criteria based on the node physical construction as storage or the mobility pattern of the node. where mobility impact on the bandwidth and makes energy impossible to recharge of powered handled devices. Thus, the messages delivery process is related on one hand to the routing as mission, where on the other hand it also related to the node limited resources, Therefore, Epidemic with greedy replication process, it increases the delivered messages and minimizes the delivery delay as a positive sign. But it consumes resources of bandwidth, storage, and energy as a negative sign. The epidemic routing algorithm should consider the energy as the main design issue. Several research papers suggest a rule of minimize the number of messages to make a balancing between the energy and the delivery. Optimal Probabilistic Forwarding [3] this paper maximize the number of delivered messages depending on the message storage and life time. Therefore, this paper considers one issue of the resources which is a physical buffer space limitation. In probability epidemic routing [4], messages are replicated based on a probabilistic mechanism. The two probabilities variables are used to calculate the probability of forward/replicate the message. Jia Xu suggests in his work [5] an Optimal Joint Expected Delay Forwarding (OJEDF) approach. The idea of the paper is to minimizes the expected storage of the message based on the bandwidth rate of the contact. As observed from this paper it looks to the storage and bandwidth of the message replication process. In the paper [6], the authors suggest a quota-based scheme (GAR) The GAR aim to minimize the replication cost, where GAR limits the number of message copies allowed to disseminated on the network. Wi-Fi broadcast mechanism is used for message replication process. The authors of the paper [7] consider the message replication process as a heuristic problem to determine the optimal replication criteria. This decision taken depending on the resource constraints. The paper suggests RPRS scheme that can solve the problem depending on bandwidth and storage as message information. The paper [8] suggests the RAPID as resource allocation of the opportunistic environment. This routing protocol optimize a metric of the storage time or the ratio of messages energy. This routing considers the energy as overhead which comes from finite storage and bandwidth. MaxProp [9] , which considered as vehicular routing protocol. This routing protocol assumes that storage and bandwidth are both limited. Therefore. It considers the hop count and message replication rate. Lo and Liou suggest in their work [10] a quota-based routing protocol for minimizing message overhead. This routing has the controlling feature of bandwidth and storage. This mechanism has a positive impact on nodes a network energy resources. Some theoretical researches such as [11]. The authors of this work derive closed-form function for average message replication probability and a number of message copy in the system. This function which calculated based on a number of messages and nodes with considering the mobility patterns. Finally the contribution of our proposed routing protocol that it considers the storage and bandwidth as variables of the energy function.

III. SYSTEM MODEL

This section will describe our model and its assumption, where this model consists of a set of mobile opportunistic nodes. The nodes transmit the message to encounter node when both nodes within radio range of each other. During this message copy process, the originator or mule node copy the message while keeping the original message in the buffer of the node. A node may deliver a message to its destination directly or indirect using cooperation with other nodes. Based on the mobility and physical construction of the node, there are limited storage and link bandwidth. These two resources are a function of availability of the message at the current node. The message availability is a function of node energy. In Table I, we summarize our model symbols and variables that we use throughout our routing protocol design and implementation. From the modeling of our proposed routing protocol EBSRP, we can write the bandwidth as function of storage with following equation.

Table I
USED SYMBOLS AND QUANTITIES

No	Parameters	Description
1	N	Total number of nodes in the entire network
2	b_t	single message copy generated by the node
3	S_t	Number of current stored messages in the system
4	Bt	Number of message copies generated by current node
5	E_T	Total Energy consumed by encountered nodes from system energy
6	E_B	Energy consumed by bandwidth
7	E_S	Energy consumed by the stored messages in the entire network
8	T_s	Storage and buffering time at the current node
9	Etr	Energy of transmitted message copy at the current node
10	Erc	Energy consumed by receiving the message at an encountered node
11	$E_{\%}$	Energy ratio
12	Ebs	Energy consumed by bandwidth and storage at the current node
13	Dp	Utility function of evict policy

$$b_t = S_t + 1 \quad (1)$$

From equation (1), we can calculate the number of infected nodes in an instant time. This infection process which done by the node when the condition is applied. The node disseminated the message during the buffering time as bandwidth as:

$$B_t = \sum_{n=1}^{N} (b_t)_n = Nb_t \quad (2)$$

In addition, we can calculate the energy consumed by every node as a component of storage and bandwidth in the system as follows:

$$E_T = E_B + E_S = E_{tr} + E_{rc} + E_S \quad (3)$$

From Eq. (3), we know that $E_{tr} > E_{rc} > E_S$. Moreover, depending on our energy model which consider the energy budget of the node as local information. Therefore, we can cancel the value of E_{rc} because it related to the encountered node energy budget. Then, we can calculate the node energy depending on bandwidth and storage as follow

$$E_{bs} = E_B + E_S = E_{tr} + E_S \quad (4)$$

Furthermore, our model and infection decision of proposed routing consider the energy as a ratio, instead of finding different state values such as the energy values of send, scan, and storage, our model consider the energy as the ratio of bandwidth and storage to the total message energy. Therefore, we can find the energy ratio based on Eq. (3) and Eq. (4) as follow

$$E_{\%} = \frac{B_t S_t}{T_s} \quad (5)$$

The proposed EBSRP routing protocol consider the storage cost and bandwidth cost which have an impact on the energy of the node. For example, the bandwidth impact on storage and the energy of the encountered node at the same time. The delivery probability of the proposed routing protocol depends on the energy ratio based on Eq. (5) of the relay node, the message with minimum energy ratio has a high priority to replicate. In an opportunistic network environment, mobile nodes missing the global information of future contact prediction with next encountered nodes. Therefore, our proposed protocol delivery probability has to be based on local information of the node. The EBSRP routing protocol executes when two nodes are encountered each other. The proposed routing protocol is considered the local message information to calculate the energy consumption ratio. EBSRP routing protocol also adapts to storage and bandwidth restrictions for the opportunistic environment, where messages with the maximum energy consumption are deleted first by the evict policy. Now from Eq. (5) we can calculate the delivery probability of a single message at the node by the following equation:

$$send-queue = \begin{cases} replicate & \min(E_{\%}) \\ stop & E_{bs} = \infty \end{cases} \quad (6)$$

This Eq. (6) shows that the replication decision is based on the energy ratio of the node, this equation shows that our proposed routing protocol is calculated per message bandwidth and storage in addition to per node energy budget. Now from Eq. (5), we formulate EBSRP routing protocol replication criteria, where this replication probability as a function of the energy variables. This replication function considers the resource concentrate based on storage and bandwidth. The drooping and evict function of implemented routing protocol consists of three parts. The first one considers the cost of the storage S_t, this function computes the storage metric based on the buffer time of the message. As the second part, it computes the cost of the bandwidth B_t based on the number of infected nodes, moreover, the storage cost S_t impact by the cost of bandwidth. The drop policy considers the energy consumed by the message as the third part. where, as the message stored in the buffer in the node, it impacts on energy of the node. This leads to the policy D_p finds its criteria as follow

$$D_P = Max(B_t + S_t) \cap E_T = Max(E_{\%}) \quad (7)$$

The drop mechanism is related to Eq. (5) of our implemented routing protocol EBSRP as we mentioned in Eq. (6). Where the forwarding policy is based on $E_{\%}$ function with the storage and bandwidth costs. Also the drop policy is based on $E_{\%}$ as shown in Eq. (7). The intersection area as shown in Figure 1 of black area

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considered as the relationship between both costs with energy.

IV. EXPERIMENT AND RESULTS

The evaluate of the implemented routing protocol EBSRP conducted by simulation scenarios, this evaluation will consider metrics related to resource consumption for deep analyze, the evaluation consider the energy metric as the main indication of the performance. Furthermore, we will focus on the main components of energy function which are bandwidth and storage at relayed nodes. The comparison of the performance will use metrics related to an application as delay/storage metric and energy consumption as bandwidth/overhead metric. The performance metrics which used for comparison are

1) ***Delivery Ratio*** is the ratio of successfully delivered messages to the total number of created messages.
2) ***Overhead Ratio*** is the average number of intermediate nodes used for one delivered message.
3) ***Average Delay*** is the average wasted time of all messages delivered successfully.

The performance of EBSRP protocol compared with the simplest type of contact-based opportunistic routing protocols, This greedy epidemic routing protocol copy message to every encountered node. This evaluation compares epidemic routing protocol combined with different replication and dropping policies. Where the implemented EBSRP protocol uses the message priority as decision of

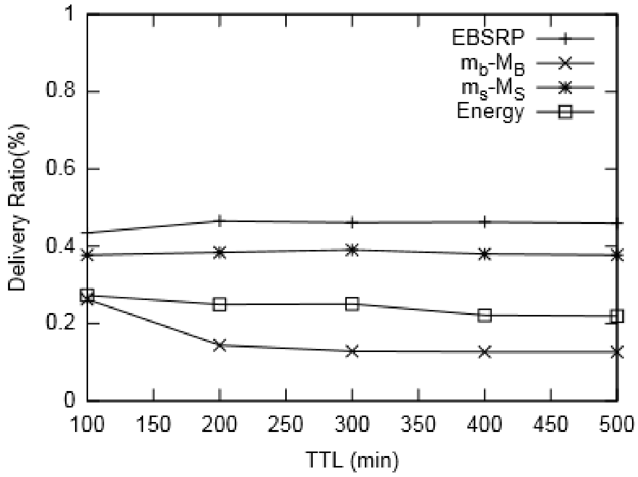
Table II
SIMULATION SETTINGS VALUES

No	Settings	Value
1	Simulation time	43200 s
2	Number of nodes	126
3	Group Type / Speed	80 Pedestrians (0.5-1.5 km/h) 40 Cars (10-80 km/h) 6 Trains (10-50 km/h)
4	Simulation area	3400 X 4500 m2
5	Routing applied	EBSRP , Epidemic
6	Interface type	Simple Broadcast
7	Transmission range	250 m
8	Bandwidth	250 KBps
9	Drop policies used	Energy, MS; MB; ms; mb
10	Message size range	0.5-1 MB
11	Message creation interval	25-35 s
12	Time-to-live (TTL)	100, 200, 300, 400, 500 min
13	Default buffer size	Pedestrians: 5 MB Cars, Trains: 50 MB

send queue priority depending on the Eq. (6). Also the evict policy which is applied depending on the Eq. (7). The stopping function which implemented by Eq. (6) used by EBSRP. This function determines when the message copy should be done or neglected. For comparison and deep investigation, we select different replication and evict policies, the sleeted policies depended on the idea of implemented EBSRP routing variables. Obviously, the selection of the policies was depending on the dissemination variables. These variables are replication/bandwidth counter and hop/storage counter of the message. Furthermore, we consider the evict policy which depends on the buffer/energy time as main energy ratio indicator. Therefore, the selected strategies of epidemic routing protocol depend on the three information of the message. From the suggested policies of those message variables, we select Energy which is selects the message of the maximum buffer time, we choose the buffer time as function time of energy because as the message stays at the node buffer as it consumes the energy of storage or even energy of bandwidth. Also, we consider M_S, this policy selects the message of the maximum storage/hop count. Furthermore, we apply M_B which considers the maximum bandwidth/copy of the message. Furthermore, regarding mentioned previous policies, we use the m_s which selects the message of the minimum storage/hop count. Also, m_b which considers the minimum bandwidth/copy of the message. We use those different policies as replication or drop policies for the comparison of the implemented EBSRP routing protocol with the epidemic as a greedy and contact-based routing protocol. The implemented EBSRP routing protocol uses its replication probability based on the ratio of the energy $E_{\%}$ which depends on bandwidth and storage. We run all different strategies using epidemic routing protocol with the listed parameters in Table II . Also, we compare the performance with regards to the above mentioned metrics. The evaluation and comparison of EBSRP with epidemic conducted by using two scenarios under different message TTL values. The different two scenarios were simulated with the default settings of the ONE Simulator [12], [13]. For extending our routing protocol evaluation, we also compare the performance of the implemented EBSRP protocol with different replication and dropping policies based on the three variables of the EBSRP routing protocol. For evaluation our proposed protocol, we apply different scenarios, these scenarios consider the resource concentrate as an idea of the proposed EBSRP protocol, The resources basically depends on the energy metric criteria as bandwidth metric and storage metric. For the comparison of the implemented EBSRP routing protocol with epidemic, we apply two different scenarios, where for the two scenarios, we consider the implemented $E_{\%}$ which consider the two energy function variables as shown in Eq. (5). Therefore we compare the epidemic with different replication and drop policies.

1) Delivery Ratio: The proposed EBSRP protocol takes its replication decision depending on the value of the energy ratio $E_{\%}$. This function used for send queue to order the messages Also the energy used for evicting policy when the node buffer is full . In general the drop or evict policy D_p depended on the energy of bandwidth and storage value E_{bs}. We compare our proposed routing protocol EBSRP with flooding or blind routing protocol. We consider epidemic because the idea of this routing protocol supposes that node resources infinity. In our comparison, we apply epidemic which uses different policies. Namely Energy, M_S, M_B, m_s and m_b as shown in Figure 2 and Figure 3. From scenario 1 we can observe that the delivery ratio of EBSRP routing protocol is better than the delivery ratio of the epidemic when epidemic uses different policies, the scenario 1 Figure 2(a) shows that the delivery ratio of the epidemic with m_s-M_S polices is the closest graph to the performance of proposed EBSRP delivery graph, especially when the message TTL= 100 min the proposed EBSRP has ratio better than epidemic with a gain of 3% . Furthermore, when the message TTL= 500 min considered as the greatest gain achieved by the proposed routing protocol, Moreover, the proposed EBSRP is has a higher delivery ratio compared with the epidemic which is 5 %. The traffic pattern generated as shown in Table II with different TTLs Values. With different replication and dropping policies. The high delivery ratio of EBSRP can also seen in scenario 2 of Figure 3(a), which have the epidemic protocol with a different replication and drop policies. These policies combined based on the three resource elements which are bandwidth, storage, and energy. The delivery ratio of EBSRP has better performance in comparison to the other policies for an epidemic routing protocol. At scenario 2, we can observe that epidemic with both m_b-Energy and m_s-Energy have lower values compared to EBSRP, but it is clear from the Figure 3(a) that both m_b -Energy and m_s-Energy policies are have lower values of 5% and 10% at TTL=500 min respectively compared with delivery ratio results by the proposed EBSRP. From Figure 3(a), we can see that the delivery ratio efficiency is low, when using m_s-Energy compared with m_b-Energy policy, because the energy consumption mostly based on the transmission of the message rather than the energy consumed in the storage. when selecting the message with bandwidth impact this decision related to storage and energy, therefore, the criteria of bandwidth more efficient as suitable energy criteria compared with storage decision. Where the energy of bandwidth of the message will conduct the energy at the message carrier and encountered node, also it will include the storage cost of the encountered node. Clearly, we consider that by using the message bandwidth and storage as variables of energy for the implemented EBSRP routing protocol. Therefore , the proposed EBSRP replication probability function $E_{\%}$ consider both variables B_t and S_t.

2) Overhead Ratio: The fundamental performance metric to compare EBSRP routing protocol with epidemic is the overhead ratio. Our evaluation uses a different buffer management policies, the overhead metric is related to the energy of both a bandwidth and the storage. Due to the unlimited messages replication behavior of the epidemic, the epidemic routing protocol is suffering from the consumption of bandwidth and storage resources. epidemic impacts directly on the node energy. Therefore, EBSRP considers the resource consumption regarding storage and bandwidth as variables of energy consumption. Figure 2(b) shows that EBSRP routing protocol has the lowest overhead when compared with epidemic, the epidemic protocol uses a different buffer management policies of queuing and evict. As the replication probability, depends on the value of energy ratio $E_{\%}$ of the EBSRP routing protocol. The energy function is considered the overhead variables which are S_t and B_t. Also, the node infection controlled by the copy probability function $E_{\%}$ which is stopping rule function. The message replication probability calculated as a function of storage and bandwidth of the message. Furthermore, those two variables S_t and B_t implies the energy resource consecrate. Hence, from Scenario 1 of Figure 2(b), we notice that EBSRP routing protocol has a stable and minimum overhead ratio when compared with epidemic using different buffer management policies. This stability derives from that the mathematically modeled optimal of both the applied queuing policy $E_{\%}$ and the evict policy D_P. The Scenario 1 shows that the minimum overhead results by the implemented EBSRP routing protocol between 40 to 50 %, where an epidemic of Energy policy reaches to 100% at TTL= 500 min. Even in Scenario 2 of Figure 3(b), we observe that EBSRP still has a lower overhead ratio, where it is in the range of 50-55 %. Also, we found that epidemic using m_s-Energy has a higher overhead, because it considers the storage rather than the bandwidth which consumes more energy. The implemented EBSRP has lower overhead compared to epidemic with m_s-Energy at TTL=100 min with about 7% and it reaches 12% at TTL =500 min. Simulation results of Figure 2 and 3 show that EBSRP protocol satisfies the energy and overhead depending on Eq(6) and Eq(7). It has been observed from simulation that EBSRP outperforms the epidemic protocol in terms of node lifetime, message delivery ratio, storage capacity. Therefore, EBSRP can provide minimum energy and overhead while at the same time achieving much higher message delivery ratio than the epidemic protocol.



(a) Delivery Ratio

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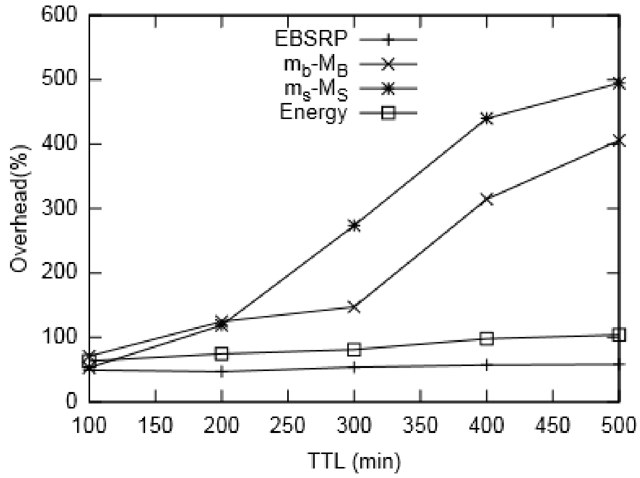
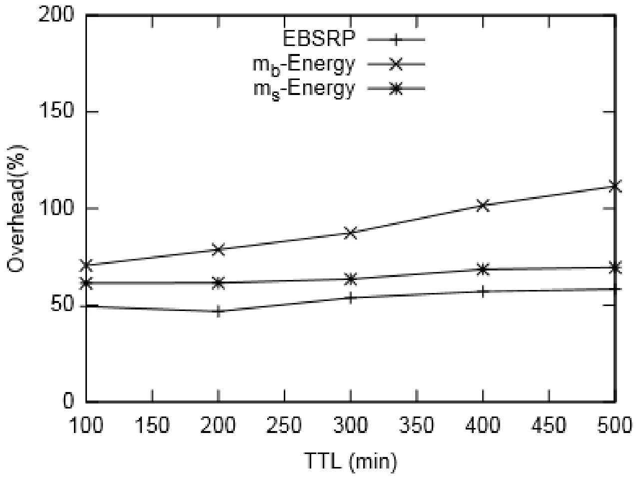
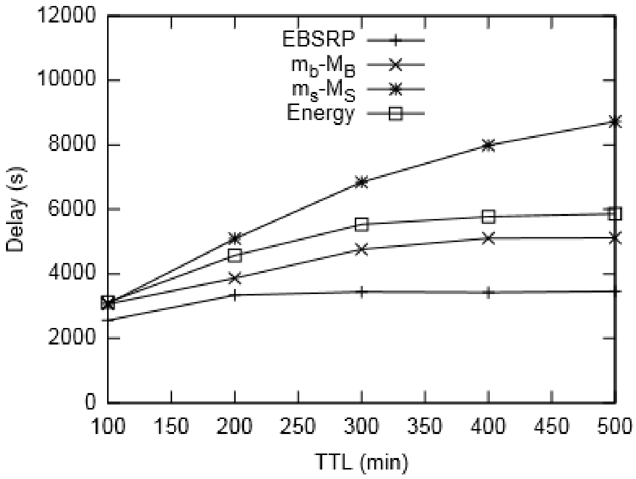


(b) Overhead Ratio

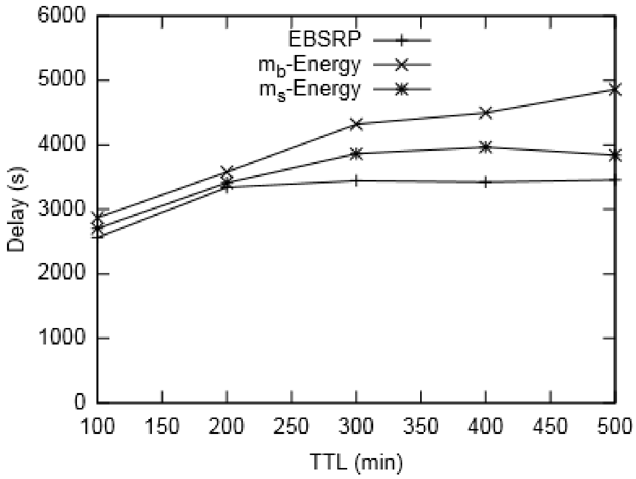


(b) Overhead Ratio



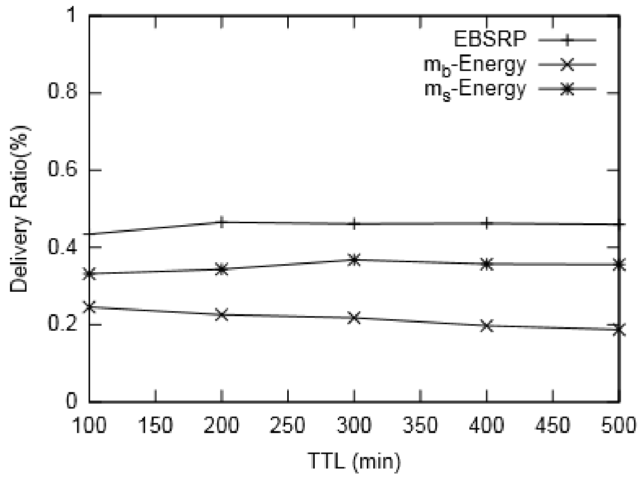
(c) Delay

Figure 2. Scenario 1



(c) Delay

Figure3. Scenario 2



(a) Delivery Ratio

3) Delay: The average end-to-end delay is performance metrics indicates how much storage energy consumed for message delivery, this performance metric indicating the storage cost which impacts on transmission or bandwidth costs. The proposed EBSRP routing protocol consider the delay as the main component of the energy function, whereas the message stays in the system as it consumes the energy of storage or may of bandwidth when the node encountered another node. The evict function D_p uses the storage time as energy variable to choose the drop message when the physical buffer is full. Also, the replication probability $E_{\%}$ consider the time as energy ratio to the energy of bandwidth and storage. Scenario 1 of Figure 2(c) shows that EBSRP routing protocol has a delay, this delay is less than that results from the epidemic routing protocol using a different buffer management policies. As we see from the Figure 2(c) the delay results from the proposed EBSRP ranges from about 2416 to 3363 s. Where the closest epidemic configuration using m_b-M_B. This epidemic replication and drop policies lead to delay ranges from 3064 to 5118 s. The implemented EBSRP has delay lower than epidemic using m_b-M_B with rang of about 25 % to 53 % with different message TTL values. This reduction of delay for the proposed routing protocol results from that, the implemented EBSRP consider the storage time as the main energy variable for drop policy D_p and a ratio of the replication probability of the message. The message life can be estimated as it is the sum of all storage and message transmission times. Therefore, we consider the storage time as the highest impact variable on the energy of the node and delivered message delay. Furthermore, we consider the message buffering life as main criteria for the storage and bandwidth costs. We can see that as shown in Scenario 2 of Figure 3(c), EBSRP routing protocol has a lower delay when compared to the epidemic router using m_s-Energy as buffer queue and drop criteria. Where the implemented EBSRP routing protocol has a lower delay with 1 % at TTL = 100 min and also it has a delay at TTL = 500 min which is less than 4 %.

V. CONCLUSION

This paper studies the replication issues in opportunistic environment by formulating the problem of energy as resource concentrate issues of bandwidth and storage. The paper here considers the energy ratio as a function to obtain the optimal infection decision which taken depending on the resource concentrate. We solve the energy problem of epidemic greedy infection using three message information which are bandwidth counter, storage counter and buffering time. The implemented EBSRP routing protocol considers the infection decision based on the energy ratio in opportunistic networks. EBSRP decision for the message copy taken depending on the energy ratio regardless the value of different states of node activity such as scan, send and receive. Our proposed EBSRP routing protocol has better performance regarding delivery ratio, overhead and energy. For future work, we aim to extend our proposed routing protocol to be as gradient routing protocol which may consider the energy budget and buffer space of encountered node.

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Authors Biography

Salem Sati has a PhD in computer science from HHU University in Dusseldorf, Germany (2017), and an MSc degree in computer engineering from Higher Industrial Institute in Misurata, Libya (2008). Also he completed his BSc in computer engineering in Higher Industrial Institute in 1997. Dr. Sati has contributed to several local conferences in Libya, Also International IEEE conferences in North America. Asia and Europe in the fields of computer networks. He has many publications in IEEE conferences. He is currently a Doctor at the Faculty of Information Technology in Misurata University.

Abubaker Alhutaba has received the Bachelor's degree since 1998 in computer department of Electronic Engineering, from The College of Industrial Technology, Misurata, Libya. He currently is an engineer at the College of Industrial Technology, Misurata, Libya and he is interested in wireless communications and routing protocols.

Ibrahim Abutalag has received the Technical Master's and Bachelor's degrees since 2010, 2004 respectively both in Electronic Engineering, communication-section from The College of Industrial Technology, Misurata, Libya. Ibrahim currently is an assistant lecturer at The College of Industrial Technology, Misurata, Libya and he is interested in mobile communications and networks.

Mohamed Eshtawie has received the BSc in computer engineering 1990 from the Engineering AcademyTajoura, Libya. In 1999 he obtained the MSc in Computer Engineering from University Putra Malaysia. In 2008 He received his PhD in the field of signal processing and communication from the National University of Malaysia (2008). Currently he is an Associate Professor at the Engineering Academy Misurata, Libya.