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Energy Transmission and Equilibrium Scheme in Data Communication Opportunistic Networks

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Received: 29 October 2020; Accepted: 1 December 2020; Published: 3 December 2020

Abstract: In data communication, a good communication scheme can improve the transmission of data packets among nodes. The opportunistic network is a convenient wireless communication network and its model is easily applied in data communication. Energy consumption among nodes in the opportunistic network is an important parameter. The over-consumption of energy may cause the nodes to be dead, and then many useful data packets would be lost. Especially in data communication, this tendency is obvious. However, many researchers rarely consider energy consumption in the opportunistic network. This paper suggests a scheme in which data packets are transmitted among nodes. Energy supply and equilibrium is found in opportunistic networks. This scheme not only supplies energy to active nodes, but also considers inactive nodes to energy supply objects. Then, this scheme accomplishes data packets transmission and improves energy utilization in the opportunistic network. With the evidence of simulation and comparison of the epidemic algorithm, the direct delivery algorithm, and spray and wait algorithm in the opportunistic network, this scheme can be an equilibrium for energy consumption, for improving the delivering ratio, and the size of the cache time.

Keywords: opportunistic social network; overhead; multi-copy forwarding strategy; adaptive allocation

1. Introduction

In recent years, with the rapid development of the wireless network, a new type of wireless network called the opportunistic network was integrated into people's lives and has attracted the attention of domestic and foreign researchers. The opportunistic network originated from delay tolerant networks (DTN), a network of nodes connected wirelessly. The communication range between two connected nodes is not further than walking distance. Nodes are connected only temporarily, and the network topology may change due to the node movement or node activation and node deactivation, respectively. Nodes in the opportunistic network cooperate to forward the routing messages of other nodes in a coordinated manner and realize the communication hop-by-hop through the opportunities of encounters caused by the node movement [1–4]. The opportunistic network has been widely used in post-disaster communication, animal tracking, vehicle network, and other fields, with the rapid development of 5G wireless communication technology and IoT [5–8]. The model in the smart city in IoT, such as the energy supply bus [9], unmanned aerial vehicle with an energy supply [10], and the opportunistic network, has shown a broad application prospect.

With the explosive growth of data in wireless communication networks, the transmission load increases massively. However, nodes do not have enough capacity to transmit such a large amount of data. At the same time, the nodes also need to do a computation to perceive the information of the neighbor nodes and choose the most appropriate node for message transmission [11–17]. To get the lowest delay average and the highest delivery ratio in the information transfer process, the multi-copy policy is widely used.

According to the difference of the copy processing method for the transmission process, policies can be divided into the copy-based policy and the forwarding-based policy. Direct delivery [18], epidemic [19], spray and wait [20] are typical copy-based policies. They spread messages by sending multiple copies to the network to achieve a higher success delivery ratio. Although flooding or controlled copy dissemination can improve the delivery probability of messages, there is still the blindness of message dissemination, especially in the network with limited network resources [21]. The consumption of the copy has a great impact on the network performance. Bubble rap [22] uses the strategy based on "forwarding", which does not copy messages in the information transmission process. This kind of strategy selects the most appropriate next-hop node by analyzing the location, node intimacy, movement history, and other environmental information [23–25], and predicting the encounter of nodes. Although it can reduce the energy consumption, it causes a large number of messages to flow to the nodes with high activity, resulting in a heavy load and network congestion.

Although the multi-copy strategy effectively improves the delivery ratio and reduces the delay, it does bring more network overhead, especially when spreading the copies blindly by the flooding method [24,25]. Therefore, to reduce the congestion of nodes and improve the delivery ratio, we must calculate the proper number of copies, and deliver messages as accurately as possible. To achieve the above goals, the algorithm design must take node intimacy, reliability, congestion, and energy consumption into consideration.

This paper introduces the priority selection delivery routing algorithm (PSDRA), which ensures the accurate delivery of the message and effectively reduces the system overhead. The contributions of this paper mainly include:

(1) Estimating the extent of message dissemination based on the message dissemination and the characteristics of node movement.
(2) Estimating the delivery ratio of message copy by combining the dissemination of message copy and node connection strength.
(3) Combining the message delivery ratio and the size of the cache, this paper optimizes the message forwarding queue by using the 0–1 knapsack strategy and achieves the adaptive control of the number of message copies.

2. System Model Design

In opportunistic networks, nodes carry different data packets in communication. They transmit data packets by moving and creating communication areas. However, some nodes carrying a great number of different important data packets have high transmission frequency when transmitting messages; the other nodes may carry a few data packets and take part in communication rarely. Therefore, active nodes which have a high transmission frequency when transmitting messages consume energy very soon; inactive nodes carry energy but take part in communication rarely.

In data communication, the effective energy equilibrium of active and inactive nodes may improve the quality in transmitting and energy supply. Moreover, in the IoT communication application, active nodes can be supplied with energy from inactive nodes, and then extend their life-times. Inactive nodes also have more of an opportunity to join in the communication.

In order to solve this problem, the scheme PSDRA considers three problems.

(1) Active nodes need to supply enough energy to guarantee that data packets transmit data communication.
(2) Inactive nodes must be utilized effectively. They can transmit energy to active nodes and join the active nodes.
(3) The energy for each node should become an equilibrium when the node transmits data packets.

If these problems can be solved, the performance of the opportunistic network will be improved.

The epidemic algorithm is a kind of typical opportunistic network algorithm. It can acquire maximal exclusive data packets. Therefore, when two nodes A and B transmit data packets, node A can acquire data packets which node A has not carried but node B has. Then, node B transmits these packets to node A. The same condition is applied to node B, which is similar to an epidemic. This algorithm may acquire maximal effective data packets in communication. Especially in data communication, effective data packets transmission is important, since it can improve the delivery ratio and reduce energy consumption.

However, this algorithm has a problem in which no energy can be supplied among the nodes. In this algorithm, nodes become dead very soon in data communication, since more data packets transmit and over consume energy.

A new method which is applied in data communication is energy supply and equilibrium. In order to extend the nodes life-times when there are a great number of nodes transmitting data packets and consuming energy, the scheme is designed as follows:

(1) Set the transmission threshold. In Figure 1, node A and B send request A and request B to each other. When they receive a request, they can send data packets which they carry while its neighbor has not.

In communication, the average transmission data packets p_{ave} between A and B are:

$$p_{ave} = \frac{p_{<A,B>} + p_{<B,A>}}{2} \tag{1}$$

where p is the transmission data packet, $p_{<A,B>}$ are the data packets transmitted from A to B. Node A sends the data packets $p_{<A,B>} = p_A \cap \overline{p_B}$. At the same time, node B receives $p_{<A,B>}$ and sends data packets $p_{<B,A>} = p_B \cap \overline{p_A}$ to node A. Then, node A receives data packets $p_{<B,A>}$. Additionally, node B receives data packets $p_{<A,B>}$. Where the average transmission data packets act as a threshold. Especially in data communication, the average transmission threshold can control the over-selection and over-transmission among nodes.

(2) Difference in transmitting data packets. If the transmission of data packets p and threshold p_{ave} have the relationship $p - p_{ave} \geq 0$. For a node, it indicates that sending packets is more than receiving; otherwise, $p - p_{ave} < 0$. Nodes can judge how many new data packets they gain and send and how many data packets are by themselves. It is important for the nodes to calculate the energy consumption.

(3) Energy consumption. When two nodes meet, they establish a communication area in the opportunistic network. Especially in data communication, nodes are easy to find the communication areas by moving. Then, the data packets can be transmitted.

Energy consumption happens when transmitting data packets. If each data packet is transmitted by consuming the e energy unit. Then, the data packets transmitted from A to B consuming energy are:

$$E_{<A,B>} = e \times p_{<A,B>} \tag{2}$$

From B to A are:

$$E_{<B,A>} = e \times p_{<B,A>} \tag{3}$$

(4) Energy supply. According to step 2 and 3, if $p - p_{ave} \geq 0$, the sending data packets are more than receiving, this node needs to supply energy from its neighbor; if $p - p_{ave} < 0$, the receiving data packets are less. For a node, in the condition of $E \geq E_{\mathrm{lim}it}$, this node should transmit energy to its neighbor. $E_{\mathrm{lim}it}$ is the carrying energy with the least threshold. It ensures the energy lower limit for the node.

In the transmission model, if node A sends more data packets than node B, at the same time, node B carries energy $E_B \geq E_{\text{lim}it}$. Therefore, node A consumes more energy and it needs to acquire energy from its neighbor. Hence, node B is a neighbor, it has enough energy to supply. Therefore, node A acquires energy supply from B. The supply energy is:

$$\Delta E_{<B,A>} = e \times (p_{<A,B>} - p_{ave}) \tag{4}$$

$\Delta E_{<B,A>}$ is the energy supply from B to A. $p_{<A,B>} - p_{ave}$ is the difference in the transmission of data packets. The more $p_{<A,B>} - p_{ave}$, the more node A transmits data packets, then node A acquires more energy from neighbor B. Formula (4) suggests that node A acquires energy from the neighbor, and then node B can keep enough energy transmitting data packets.

Nodes A and B complete the energy equilibrium when they transmit data packets. Node A avoids energy over-consumption; node B acquires more data packets and supplies redundant energy to node A.

After they finish the data packets and energy transmitting, node B acquires more effective data packets from node A. At the same time, node A not only receives data packets, but also has been supplied energy.

In data communication, nodes must transmit more data packets, since they have high frequency founding communication areas. According to the energy equilibrium, active nodes extend their life-time and transmit more data packets to others; inactive nodes have more opportunity to improve communication when they supply energy.

(5) Iteration energy supply in data communication. In data communication, there are a great number of nodes. A node can acquire or supply energy to its neighbors.

For node A in data communication, it has many neighbors when it moves and establishes the communication area. At the beginning, node A carries energy E_0. When it meets neighbor B_1, they transmit data packets to each other. At this time, node A carries energy:

$$E_1 = E_0 - \Delta E_{<A,B_1>} \tag{5}$$

Next time, node A transmit data packets, its energy is:

$$E_2 = E_1 - \Delta E_{<A,B_2>} \tag{6}$$

When node A is in the data environment, after many transmissions, the iteration formula can be found as Equations (2), (5) and (6):

$$E_n = E_{n-1} - \Delta E_{<A,B_n>} = E_{n-1} - e \times (p_{<A,B_n>} - p_{ave}) \tag{7}$$

E_{n-1} represents the energy node carried the last time, $\Delta E_{<A,B_n>}$ is the supply energy between the nodes. If $p_{<A,B_n>} - p_{ave} > 0$, node A has enough energy and supplies energy to its neighbors; if $p_{<A,B_n>} - p_{ave} < 0$, node A acquires energy.

The iteration formula can judge how many energies a node carries and estimates its lift-time in the big communication. Moreover, the iteration formula can judge the average energy in the data environment.

(6) Extend the communication life-time for nodes. In data communication, the energy equilibrium can extend active nodes, which take part in communicating high frequency life-times and avoiding energy over-consumption. It is important to guarantee that data packets are transmitted by nodes.

In the data environment, there are a great number of inactive nodes in network communication. They can supply energy to active nodes and send a request to acquire data packets. When they have enough data packets in communication, they also become active nodes.

This process guarantees that data packets can be transmitted among the nodes. Especially in data communication, it avoids important data packets from being lost when the nodes die.

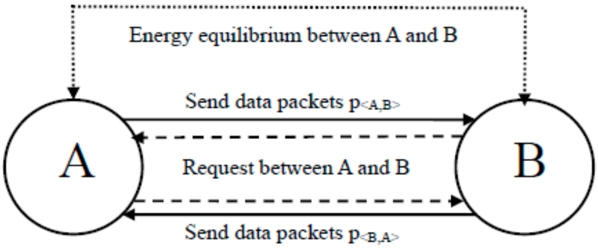

Figure 1. Data packets transmission and energy equilibrium in the epidemic algorithm.

3. Simulation

The simulation adopts the simulator ONE (opportunistic networking environment) [10] and extends the model in the opportunistic network to compare energy consumption in these algorithms. Parameters can be settled based on the random model in opportunistic networks. Parameters adopted in the experiment are set as follows. The simulation time is 12 h; the simulation area is 4500 m × 3400 m in the map of Helsinki; the involved nodes are 100 to 400; the transmission pattern is broadcast; the maximum transmission area of each node is 10 m^2; the sending frequency of a data packet is 25–35 s; the type of data packet is a random array; a node consumes one unit of energy when it sends a data packet; each node carries 10 data packets and 100 units of energy; the energy lower limit for each node is 30 units; the transmission pattern of the nodes is a social model; the transmission speed of the node is 0.5~1.5 m/s; and the cache of each node is 5 MB.

In the simulation, each one of the 600 nodes is recorded to show the energy exchange in the opportunistic network. The simulation time and energy consumption are recorded and compared with the epidemic algorithm, direct delivery algorithm, spray and wait algorithm, and PSDRA. The simulation is as follows.

Figure 2 shows the node and delivery ratio. The nodes are from 100 to 600 in with all the algorithms. The epidemic algorithm and direct delivery algorithm are shown as the low delivery ratio. Since energy has no supply and consumption, PSDRA is better than others as the nodes can acquire energy supply. Moreover, the nodes in the communication can send messages.

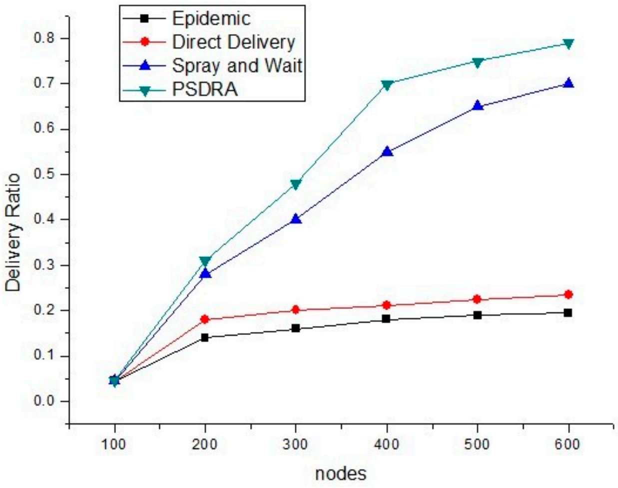

Figure 2. The delivery ratio with algorithm.

Figure 3 shows the cache time in the communication. The nodes are from 100 to 600 in with all the algorithms. The direct delivery algorithm needs a lot of cache time to solve the data transmission.

PSDRA is also better than the others algorithms, since the energy supply improves the activity of the nodes. Moreover, additional nodes can be added to deliver data.

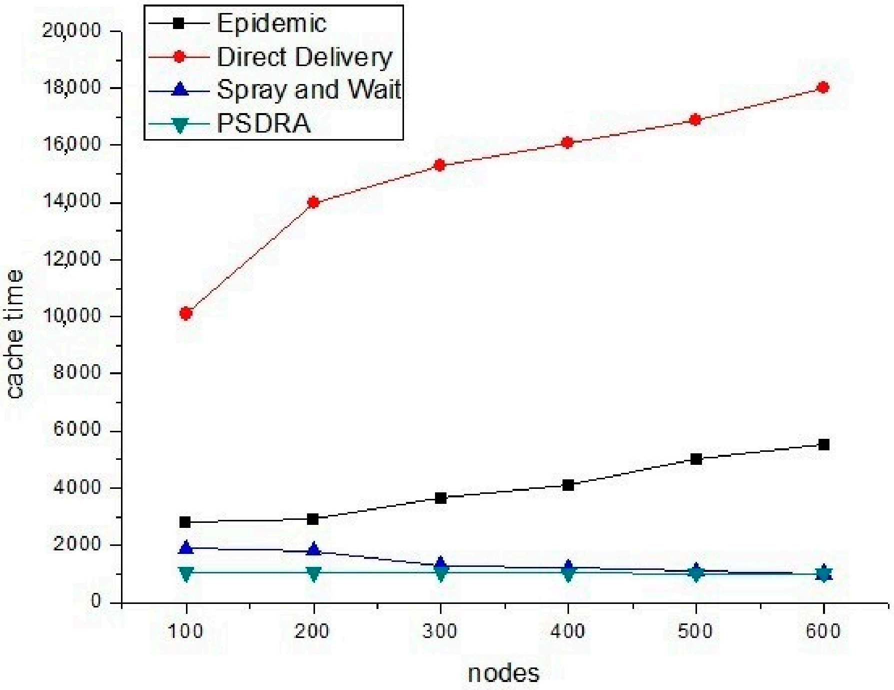

Figure 3. The cache time with algorithm.

Figure 4 shows the node energy expended in the communication. The direct delivery algorithm does not consume energy due to its direct transmission. PSDRA is better than the epidemic and spray and wait algorithms. According to the energy supply in the communication, the node can expend less energy and deliver more data between nodes.

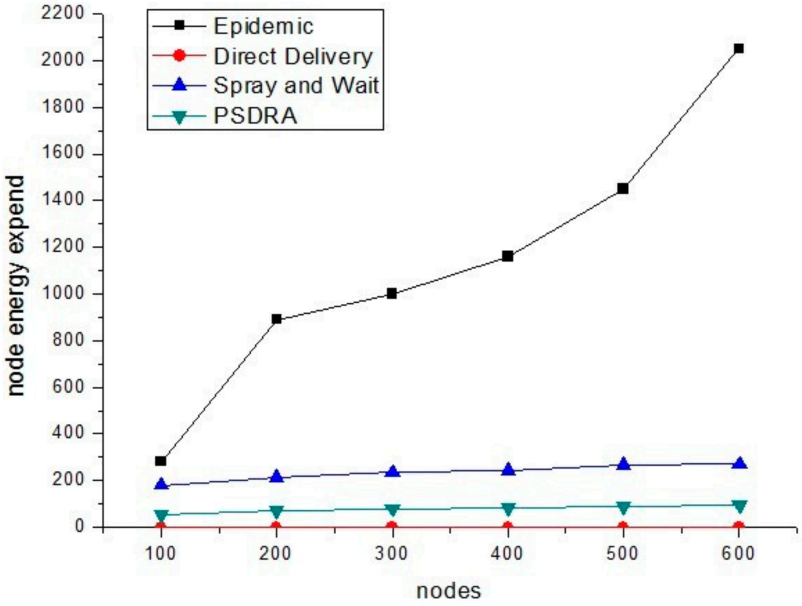

Figure 4. The expended node energy.

In data communication, extending life-times is important to keep the active nodes transmitting data packets. The simulation result shows that PSDRA can guarantee nodes to acquire energy to transmit data packets. It avoids node death when the nodes join in communication.

4. Conclusions

This paper analyzes the energy consumption and supply for the epidemic algorithm model and establishes an effective energy equilibrium scheme. In the scheme, many opportunistic network algorithms can be used and extended. It gives a good condition for mobile device communication to work. Especially in future data communication, the energy equilibrium scheme can be applied in different research areas. In the future work, additional methods and usage in data communication may be discovered.

Author Contributions: All authors contributed to the design of this work. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hunan Provincial Natural Science Foundation of China (2018JJ3299, 2018JJ3682).

Conflicts of Interest: The authors declare no conflict of interest.

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