TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 05/09 pp389–399
Volume 22, Number 4, August 2017

Optimization-Based Fragmental Transmission Method for Video Data in Opportunistic Networks

Peng Li, Xiaoming Wang*, Junling Lu, Lichen Zhang, and Zaobo He

Abstract: Multimedia data have become popularly transmitted content in opportunistic networks. A large amount of video data easily leads to a low delivery ratio. Breaking up these big data into small pieces or fragments is a reasonable option. The size of the fragments is critical to transmission efficiency and should be adaptable to the communication capability of a network. We propose a novel communication capacity calculation model of opportunistic network based on the classical random direction mobile model, define the restrain facts model of overhead, and present an optimal fragment size algorithm. We also design and evaluate the methods and algorithms with video data fragments disseminated in a simulated environment. Experiment results verified the effectiveness of the network capability and the optimal fragment methods.

Key words: opportunistic network; communication capabilities; fragment; video data

1 Introduction

For the past few years, wireless communication has undergone rapid development. Phones, tablets, and reading tools connect to networks wirelessly. With the promotion and popularization of wireless communication terminals, researchers have proposed many methods to create a self-organized network without an infrastructure, such as Mobile Ad hoc NETwork (MANET). MANET is a network topology that can automatically establish a connection through wireless communication components between nodes. However, before the data are transmitted between traditional MANET nodes, end-to-end routing needs to be established to forward data packets according to the routing table. An issue is that, in actual applications, networks may not be connected all the time because of the movement of nodes, the closure of radio, or obstacles to radiation. Delay/disruption-Tolerant Networks (DTN) is a network that connects nodes occasionally and periodically without needing to establish end-to-end connection and disseminate data by joining mobile nodes. Opportunistic Networks (ON) were developed based on MANET and DTN[1]. ON is a new network model that does not need a firm link between the source and the destination nodes. It transfers information from one node to another when the nodes are encountered opportunistically and make contact. Moreover, ON uses a storing-carrying-forwarding routing model to communicate with other nodes. As a novel network model, ON has adapted to a large number of practical applications for on-site wireless communication. Many related studies have been conducted to determine the effective methods of satisfying node communication requirements[2]. In the age of big data, when everyone wishes to produce, process, and share data, ON has an important application value in many fields.

Another point we should focus on is that large amounts and various types of heterogeneous data

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- Peng Li, Xiaoming Wang, Junling Lu, and Lichen Zhang are with the Key Laboratory Modern Teaching Technology, Ministry of Education, Xi'an 710119, China, and School of Computer Science, Shaanxi Normal University, Xi'an 710119, China. E-mail: lipeng@snnu.edu.cn; wangxm@snnu.edu.cn; jllusnnu@gmail.com; zhanglichen@snnu.edu.cn.
- Peng Li and Zaobo He are with Department of Computer Science, Georgia State University, Atlanta, GA 30303, USA. E-mail: zhe4@student.gsu.edu.

$*$ To whom correspondence should be addressed.

Manuscript received: 2016-11-20; revised: 2017-01-24; accepted: 2017-02-12

resources continuously maintain a high-speed growth among networks. The increasing data include many multimedia types, such as image, audio, and video. The Cisco Visual Networking Index[3] shows that the average amount of traffic per smartphone in 2016 was 1614 MB per month. The increase in the amount of data has greatly enriched and satisfied the interactive requirements of users. However, large-scale data takes up a considerable amount of network resources when they are transmitted through new-generation cellular networks, thereby significantly increasing network communication costs when users enjoy 4G or 5G high-speed bandwidth[4].

Smart-phone users or users of other mobile terminals take photos and short videos and then share them with other nodes in the network space or their social network[5]. When WLAN is unavailable or the mobile flow cost is unaffordable, transmitting video data is difficult. Related research[6, 7] has shown that the number of strong connections between social network nodes is limited, and the strongest connection nodes often stay in the same activity area, which is frequently the expected data sharing range. Considering this circumstance, direct sharing between nodes becomes a choice[8]. However, given the limited transmission bandwidth between nodes, video data may not be transferred completely at one time in an opportunistic connection. When the communication is dropped, previously transmitted data may become unavailable, or contain only a part of the beginning of the video, which cannot be shared with other related nodes[9]. Frequent unsuccessful transmission will result in considerable energy consumption of the nodes. How frequent interruptions between nodes can be overcome and how large-scale data can be transmitted effectively in a more pervasive or spontaneous manner without affecting human activities have become essential problems.

The main contributions of this study are summarized as follows: First, we define a general ON node movement and communication model without a fixed communication infrastructure. Second, in Random Direction (RD) mobile model conditions, we utilize mathematic and probability theory to convert regular and obvious parameters into essential features of ON transmission capacity, such as expected communication duration and average expected communication frequency. Third, based on the above-mentioned key features, we propose a fragment size analysis and calculation method in which an optimal fragment size is deduced. If video data in a source node are divided into several fragments with the optimal size, then the shortest transmission time and best efficiency can be achieved. Finally, simulation experiments are conducted to verify the proposed approach.

The paper is organized as follows: In Section 2 we survey the state-of-the-art works on ON, especially on the topic of network communication capability evaluation and large content data transmission. In Section 3, we establish a basic model for dynamic data transmission in ON and analyze the key problems to be solved. In Section 4, based on the mathematical and probabilistic method, we create a calculable framework for ON communication capacity in the RD mobile model. In Section 5, we analyze the relationship between fragment size and transmission efficiency. We also propose an optimal fragment size calculation algorithm. In Section 6, we conduct an experiment and verification through simulation of the above models and methods. The paper is summarized in Section 7.

2 Related Work

Many novel research achievements have been made with regard to ON, which is a new research area. Such achievements include mobile modeling routing scheduling energy or a cache management nodes social feature analysis, and encryption security[10]. The research content of this paper mainly addressed the question of fragmented video data dissemination among nodes.

Transmitting a video message during one-time contact is difficult. A commonly used method is to divide the data in the source node into several fragments with the same size[11]. Each fragment is treated as a separate message to be delivered between nodes. At the destination node, all the fragments would be gathered and merged into an integrated video data.

The network communication capacity needs to be calculated to achieve effective video data transmission, increase the disseminative efficiency, and improve user experience between mobile nodes. Specifically, how to quantify the basic and essential parameter characteristics of ON is the main problem. Some network parameters, such as mobile area, number of nodes, and communication bandwidth, are easy to obtain. However, some parameters are not fixed values; rather, they change with time[12]. We usually need to count the long-term parameter values and analyze the distribution to determine the significant features[13], such as the contact duration between nodes and node contact frequency. Multiple factors influence node communications[14]. With the increase in the node communication radius and the decrease in the node mobile velocity, the contact duration will be extended. Even if both characteristics are the same during different contacts, whether the two contacts have the same and fixed communication durations is still uncertain because of the different entry angles[15]. Therefore, the mobile probability mode of nodes is necessary to depict the mobile rules and to calculate the expected contact duration and frequency.

Based on the fragment transmission framework, some new approaches have been proposed. Lin et al.[16] explored the effect of node velocity diversity on the performance of mobile ONs while keeping the average velocity of nodes consistent with each other. Their findings indicate that greater node velocity diversity always corresponds to a longer average communication and fewer communications within the constant total communication time. Furthermore, a node contact analysis method was proposed. Based on their research, they presented an entire node contact calculation framework.

After determining the crucial characteristics of ON capacity, another issue is fragment size[17]. Network terminals produce various data with different sizes. When these data are transmitted in the challenging network, a firm delivery ratio is difficult to obtain. For instance, data with a relatively small size could be transmitted within a short amount of time at a specific contact duration and frequency. By contrast, data with a large size are difficult to transmit during one-time contact because of the restricted connection duration and bandwidth. Disruptions normally take place during transmission. The partly delivered data cannot always be used in the receiving node and are usually discarded after a certain time. Moreover, the communication between nodes fails.

Wang et al.[18] explored a general framework to describe the random node mobility, and derived a new contact rate between nodes, which is closely related to mobility properties of nodes. Such opportunistic networks rely on wireless communication to support a decentralized model of communication where nodes can store, carry, and forward data directly to others.

Belblidia et al.[19] investigated the issue of piece size selection. They theoretically defined the global goodput of the system that defines the tradeoff between the size of the shortest contact that can be considered useful and piece overhead. Then, they presented the design and evaluation of the prevalence-aware content spreading method and selected pieces to transfer based on their popularity. Their results showed the effectiveness of the methods when the nodes were distributed intensively.

Belblidia et al.[20] also designed a specific protocol called EPICS to quickly exchange large content in ONs. By using gray relational analysis, EPICS can balance the distribution of content with different sizes and creation times, thereby providing fairer delay distribution and faster dissemination.

Pan et al.[21] proposed a transmission scheme to help social selfish nodes to forward multimedia messages to other nodes. In the proposed scheme, priority is given to a message according to the cooperation degree. Afterwards, a cache management strategy is applied to guide nodes to select other better nodes as their relays. The research focused on the users social attribute of the node and also discussed the multimedia data processing method.

The above studies indicate the importance of fragment size. In addition, we argue that the fragment size must adapt to the communication capacity of ON, especially according to the majority nodes contact duration and transmission bandwidth.

To address the above-mentioned problem, video data could be divided into fragments with the same small size. After a period delay, the destination node receives all fragments and then combines them into a complete video content. How to calculate the capacity of ON and how to determine the optimal fragment size are thus the key problems in video data transmission. Therefore, a calculable model of ON is needed.

3 Network Model Definition

Maintaining end-to-end paths in ON to communicate between nodes is unnecessary. Such communication relies on the mobile opportunities of nodes to build a self-organized network to transmit data from one node to another. Figure 1 shows an illustration of ON. The source node S intends to transmit data to the destination node D at t_1 time, but S and D are located in different domains without a communication path. Therefore, S packs the data into a message and sends it to neighbor node 3. Considering that node 3 does not have a suitable opportunity to forward data to the next-hop node, it keeps the message in the local storage and waits for a transmission opportunity. After a period of time, node

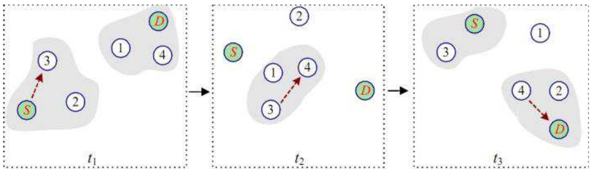


Fig. 1 Illustration of ON.

3 has the opportunity to move into the area where node 4 is located at time t_2. Then, the message is forwarded to node 4. At time t_3, node 4 transmits the message to destination node D. Finally, data transmission is completed.

Based on the ON transmission process, we define some terms to model the ON accurately and study the research strategy to improve the opportunistic communication quantitatively. $N = \{N_0, N_1, ..., N_{n-1}\}$ is the set of the nodes in ON, and each node can move in the same specified scenarios. We also assume that each node has the same structure, mobile velocity, amount of energy reserves, buffer space, and communication range and that each node has enough energy to maintain the communication and mobile activities within a specified time. The related variables and parameters are shown in Table 1.

The scene of node movement and information transmission is shown in Fig. 2.

Considering the nodes are moving with the RD mobile model, each node moves in an RD and with the same velocity in scene s. When the distance between any two nodes is less than the radius of the communication range, the communication begins and the data may be transferred. When the data are relatively large, successful one-time transmission is difficult. Frequent failures result in low delivery efficiency. Thus, quantifying the communication capacity based on the definition of ON is important.

Table 1 Defined variables in ON.

Variable	Definition
s	Nodes mobile area
N	Node
n	Number of nodes
T	Total simulation time
R	Communication radius of node
V_0	Node movement velocity
B	Communication bandwidth between nodes
t_{ave}	Expected contact duration of nodes
C	Expected contact times of all nodes
F	Nodes contact frequency
c_{ave}	Expected contact times between two nodes
M	Video data size
m	Size of video data fragment

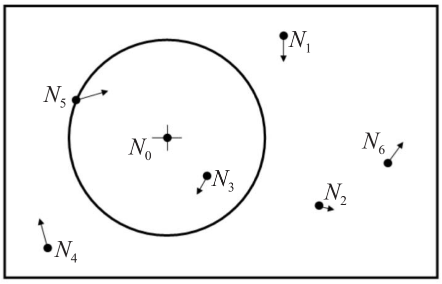


Fig. 2 Scenario of node movement.

4 Contact Duration Analysis and Calculation

4.1 Relative movement analysis method

As defined above, N mobile nodes move with the RD model in scene s within the time duration T. All nodes move in an RD and at a steady velocity V_0. In the mobile process, nodes do not stop, rather, they change their directions intermittently, thereby ensuring contact and communication among nodes in accordance with the contact opportunities.

To quantitatively describe the contact duration, we select a specific node, such as N_0 to simplify the problem. Node N_0 could be regarded as a relatively stable node. Accordingly, other nodes move at a relative velocity between 0–$2V_0$ in scene s. Within the communication range of node N_0, other nodes always enter and leave. When all nodes are moving in a sufficiently large scene, the movements of other nodes, such as N_i could be approximately regarded as a straight line in the communication range of N_0, as shown in Fig. 3.

Circle N_0 denotes the communication range of node

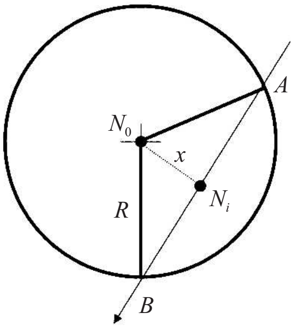


Fig. 3 Calculation of contact duration.

N_0, and segment $\overline{AB}$ denotes the moving path of node N_i within the communication range of N_0. Segment $\overline{AB}$ intersects circle N_0 at a random angle and position, there is always a line x located at the radius perpendicular to $\overline{AB}$. Now, the location and direction of $\overline{AB}$ are random. Thus, the length of x is between $0 \sim R$ and has a uniform distribution.

4.2 Expected length of segment *AB*

When the scene s runs for a certain time, the node contact duration presents a stable statistical feature, for the known $x \sim U\,(0, R)$.

$$\overline{AB} = 2\sqrt{R^2 - x^2} \tag{1}$$

The lengthen expectation of line $\overline{AB}$ is calculated as follows:

$$\begin{aligned} E(\overline{AB}) = &\int_{-\infty}^{+\infty} 2\sqrt{R^2 - x^2} \cdot f(x)\mathrm{d}x = \\ &\int_0^R \frac{1}{R} \cdot 2\sqrt{R^2 - x^2}\mathrm{d}x = \\ &\frac{2}{R}\int_0^R \sqrt{R^2 - x^2}\mathrm{d}x = \\ &\frac{2}{R}\left(\frac{R^2}{2}\arcsin\frac{x}{R} + \frac{x}{2}\sqrt{R^2 - x^2}\right)\Bigg|_{x=0}^{R} = \\ &\frac{\pi R}{2} \end{aligned} \tag{2}$$

4.3 Expected relative velocity calculation

The absolute values of the velocities of nodes N_0 and N_i are the same as that of V_0. The movement direction of the two nodes are random during the contact.

The relative velocity of the two nodes is calculated as follows:

$$V_{0i} = \sqrt{V_0^2 + V_0^2 - 2V_0^2\cos\theta} = \sqrt{2(1 - \cos\theta)} \cdot V_0, \quad \text{s.t.}\ \ 0 \leqslant \theta \leqslant \pi \tag{3}$$

Given that we know the relative velocity of the nodes, the contact duration of N_0 and N_i is

$$t_{0i} = \frac{\overline{AB}}{V_{0i}} = \frac{2\sqrt{R^2 - x^2}}{\sqrt{2(1 - \cos\theta)} \cdot V_0}, \quad \text{s.t.}\ \ 0 \leqslant x \leqslant R;\ 0 \leqslant \theta \leqslant \pi \tag{4}$$

where θ is the mobile direction angle of N_0 and N_i. When θ tends to zero, the nodes of N_0 and N_i are relatively static, the contact duration tends to be $+\infty$ or to the whole running time T. The contact duration of the two nodes is shown in Fig. 4, the range of θ is limited to $(0.2, \pi)$.

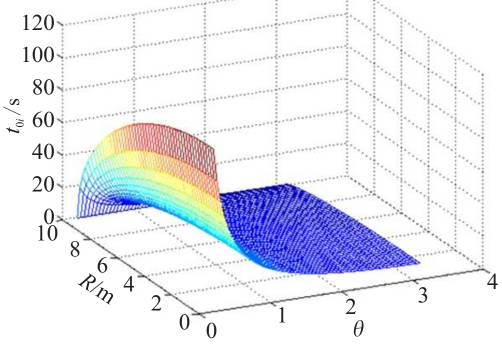


Fig. 4 Distribution of contact duration between two nodes.

Before calculating the expected value of relative velocity, we first need to analyze the probability density function of θ. Assuming that N_0 moves in an RD θ_1, $\theta_1 \sim U\,(0, 2\pi)$, and N_i moves for θ_2, $\theta_2 \sim U\,(0, 2\pi)$, the moving direction angle is $\theta = \theta_1 - \theta_2$.

Let $\theta_2' = \theta_2$, then $\theta_2' \sim U\,(-2\pi, 0)$, and the density function is

$$f_2'(\theta_2) = \begin{cases} \dfrac{1}{2\pi}, & -2\pi < \theta_2 < 0; \\ 0, & \text{otherwise} \end{cases} \tag{5}$$

$\theta = \theta_1 + \theta_2'$, then the density function of θ_1 is

$$f_1(\theta_1) = \begin{cases} \dfrac{1}{2\pi}, & 0 < \theta_1 < 2\pi; \\ 0, & \text{otherwise} \end{cases} \tag{6}$$

The probability density function of θ is

$$f(\theta) = \int_{-\infty}^{\infty} f_1(\theta_1) f_2'(\theta - \theta_1)\mathrm{d}\theta_1 \tag{7}$$

The non-zero area of $f_1(\theta_1) f_2'(\theta - \theta_1)$ is

$$\begin{cases} \theta_1 \in (0, 2\pi), \\ \theta - \theta_1 \in (-2\pi, 0) \end{cases} \tag{8}$$

Therefore,

$$f(\theta) = \begin{cases} \displaystyle\int_0^{\theta+2\pi} \frac{1}{4\pi^2}\mathrm{d}\theta_1 = \frac{1}{4\pi^2}(\theta + 2\pi), & -2\pi < \theta \leqslant 0; \\ \displaystyle\int_\theta^{2\pi} \frac{1}{4\pi^2}\mathrm{d}\theta_1 = \frac{1}{4\pi^2}(2\pi - \theta), & 0 < \theta < 2\pi; \\ 0, & \text{otherwise} \end{cases} \tag{9}$$

Then, we calculate the expected relative velocity of two nodes:

$$E(V_{0i}) = \int_{-\infty}^{\infty} V_0\sqrt{2(1-\cos\theta)}\cdot f(\theta)\mathrm{d}\theta = \int_{-2\pi}^{0} V_0\sqrt{2(1-\cos\theta)}\cdot \frac{1}{4\pi^2}(\theta+2\pi)\mathrm{d}\theta + \int_{0}^{2\pi} V_0\sqrt{2(1-\cos\theta)}\cdot \frac{1}{4\pi^2}(2\pi-\theta)\mathrm{d}\theta = \frac{4}{\pi}\cdot V_0 \tag{10}$$

Obviously, the expected relative velocity of any two nodes is only in accordance with the known value V_0, because of the randomness of N_0.

Probability density function of velocity angle is shown in Fig. 5.

4.4 Expected contact durations and frequencies

Based on the above calculations, the expected contact duration is

$$t_{\mathrm{ave}} = \frac{E(\overline{AB})}{E(V_{0i})} = \frac{\frac{\pi R}{2}}{\frac{4}{\pi}\cdot V_0} = \frac{\pi^2 R}{8V_0} \tag{11}$$

The expected contact duration is influenced by node communication radius and moving velocity, whose distribution is shown in Fig. 6.

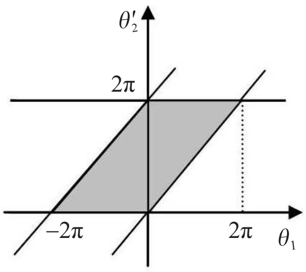


Fig. 5 Probability density function of velocity angle.

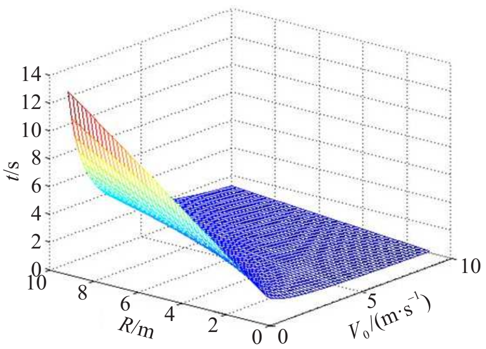


Fig. 6 Distribution of expected contact duration.

Aside from contact duration, contact frequency is another crucial parameter that can depict the communication capacity. Contact frequency affects the delivery delay in a fragmented transmission scenario. Data transmission in ON relies on communication opportunities. Increasing the communication opportunities between nodes can effectively shorten transmission delay. A qualitative analysis of the higher velocity of the moving nodes indicates that having more nodes corresponds to a larger node communication radius and thus more communication opportunities. Specifically, during the scenario running period T, node N_0 is still assumed to be relatively stable. Then, any specified node such as N_i is either inside or outside the communication range of N_0. In the long run, the locations of N_i in scene s have a uniform random distribution. Thus, some parts of the N_i's mobile traces are included in the range of N_0, others are not, and the distribution probability is identified with the rate of the two areas. The average values of the cumulative communication durations between N_i and N_0 are as follows:

$$t_{0i}' = T\cdot\frac{\pi\cdot R^2}{s} \tag{12}$$

And we could calculate the cumulated communication times between N_0 and N_i based on the result of contact duration and total contact duration.

$$c_{\mathrm{ave}}' = \frac{t_{0i}'}{t_{\mathrm{ave}}} = \frac{T\cdot\frac{\pi\cdot R^2}{s}}{\frac{\pi^2 R}{8V_0}} = \frac{8V_0\cdot T\cdot R}{\pi\cdot s} \tag{13}$$

Both N_0 and N_i are all randomly selected nodes. If there are N nodes in the scene, the global contact times expectation can be deduced as follow:

$$C = 4n\cdot(n-1)\cdot\frac{V_0\cdot T\cdot R}{\pi\cdot s} \tag{14}$$

The contact frequency is

$$F = 4n\cdot(n-1)\cdot\frac{V_0\cdot R}{\pi\cdot s} \tag{15}$$

Based on the above possibility analysis and calculation, we obtained the key parameters that can accurately depict the communication capacity of ON.

5 Confirmation of Data Fragment Size

As explained above, neither an excessively large fragment nor a small one will result in high transmission efficiency in ON. We argue that the optimal fragment size should match the ON's communication capacity and features well. Obtaining the optimal fragment size is necessary. The transmission bandwidth of two nodes is an important factor that affects fragment size. Combined with the expected contact duration, we can define the suitable size of fragments as follows:

$$m = \alpha \cdot t_{\text{ave}} \cdot B, \quad \text{s.t. } 0 < \alpha \leqslant 1 \tag{16}$$

where t_{ave} is the expected contact duration, B is the transmission bandwidth, and α is the adjust coefficient. When $\alpha = 1$, approximately half of the communication opportunities cannot be used, and in the other communication opportunities, at least one fragment could be transmitted during contact. During one time contact duration, the last-remaining duration that is less than t_{ave} will also not be used. Theoretically, a smaller fragment corresponds to a higher utility that will be gained.

However, large scales of small fragments cause low calculation efficiency of routing algorithms or schedule algorithms, thereby resulting in low communication efficiency. Label information needs to be added to each fragment. With regard to the video data, the label may be of a considerable size compared with the fragment, because they have to contain the new head part of the fragment media.

The video data could be separated into a number of fragments with the same size before transmission without producing a fragments new head file if all the fragments could be received and gathered in the destination nodes. If any number of the fragments is missing, then the original video file cannot be reconstructed, especially for compressed data, which are now used widely. Attaching every head file in each fragments label information is a necessary procedure to ensure that the incomplete fragments could be reassembled and played by users in the destination nodes even though some parts of the video are lost.

Rich label information is contained in every fragment, such as the IDs of the video file, fragments, source node, destination node, the start and end times of the video fragment, lifetime size of the video, and fragment coding and compression information. Obviously, excessively small fragments mean an excessively larger number of fragments, thereby resulting in a large amount of label information, high overhead, and low dissemination ratio. Therefore, we built the network goodput calculation model to analyze the optimal fragment size.

Let h be the size of label information, and m be the original fragment data size. Thus, the new fragment size is $h + m$. When the bandwidth is completely used, the actual goodput is

$$\xi_i = B \cdot \frac{m}{m+h} = B \cdot \left(1 - \frac{h}{m+h}\right) \tag{17}$$

When the data size m declines, the label information proportion is increased, thereby resulting in a low goodput ratio. Consequently, the actual global goodput ratio is

$$\begin{aligned}\xi =& \frac{(t_{\text{ave}} - t') \cdot C \cdot B}{T} \cdot \frac{m}{m+h} = \\ & \left(\frac{\pi^2 R}{8V_0} - \frac{(m+h)}{2B}\right) \cdot 4n \cdot (n-1) \cdot \\ & \frac{V_0 \cdot T \cdot R}{\pi \cdot s} \cdot \frac{B}{T} \cdot \frac{m}{m+h} = \\ & \frac{n \cdot (n-1) \cdot \pi R^2 \cdot B}{2s} \cdot \left(1 - \frac{h}{m+h}\right) - \\ & \frac{2n(n-1) \cdot V_0 \cdot R \cdot m}{\pi \cdot s} = \\ & \frac{n \cdot (n-1) \cdot \pi R^2 \cdot B}{2s} - \\ & \frac{n \cdot (n-1) \cdot \pi R^2 \cdot B}{2s} \cdot \frac{h}{m+h} - \\ & \frac{2n(n-1) \cdot V_0 \cdot R}{\pi \cdot s} \cdot m\end{aligned} \tag{18}$$

To obtain the maximum global actual goodput, we calculate the derivative of ξ, and let it equal 0. Thus, we could obtain the optimal size of fragment data m.

$$\begin{aligned}\xi' =& -\frac{n \cdot (n-1) \cdot \pi R^2 \cdot B}{2s} \cdot h \cdot (-1) \cdot \\ & \frac{1}{(m+h)^2} - \frac{2n(n-1) \cdot V_0 \cdot R}{\pi \cdot s} = 0\end{aligned} \tag{19}$$

$$\begin{aligned}& \frac{2n(n-1) \cdot V_0 \cdot R}{\pi \cdot s} = \\ & \qquad \frac{n \cdot (n-1) \cdot \pi R^2 \cdot B \cdot h}{2s} \cdot \frac{1}{(m+h)^2}\end{aligned} \tag{20}$$

$$m = \frac{\pi}{2} \cdot \sqrt{\frac{R \cdot B \cdot h}{V_0}} - h \tag{21}$$

So far, we have built the communication capacity calculation model of ON and optimal algorithm of fragment size in fragmented dissemination based on the RD mobile model. We expect the methods are certified and are able to bring high delivery efficiency in ON transmissions. So, we carry out the experiments in simulation circumstance.

6 Simulation-Based Evaluation

We present the simulation-based evaluation of network communication capacity calculation and the optimal fragment size analysis below.

Based on the Opportunistic Network Environment (ONE) simulator, the network capacity and the optimal fragment size algorithms are used, and the simulation is completed.

6.1 Verification of expected contact duration and time

In the first part of the experiment, we verified the network capacity calculation. The proper value of the parameters needs to be set initially. We can use the ONE simulator to build a similar scene for verification. The default setting of basic parameters is shown in Table 2. Some parameters will change in specific experiment.

We ran the simulator based on the parameters, built the corresponding scene, and obtained every specific node communication log which includes the contact duration information. We also calculate the related values of contacts by using algorithms. We compare the simulation value with the algorithm value for expected contact duration in Table 3, and the total expected contact time is shown in Table 4.

The figures indicate that the algorithm values are very close to the corresponding simulation results of all six experiments. Given the randomness of every specific experiment, there also exist some minimal differences between the reasonable values in a small range. Another situation needs to be explained. The total contact time represents the times during which the nodes move into each other's communication range. We assume that the communication begins as soon as they enter each other's range. However, in practical applications, communication appliances in some nodes are unable to support multi-communication with certain nodes synchronously. In this case, the total contact time may be less than the algorithm values at some special parameter settings.

Table 2 ONE simulator configuration in default.

Parameter	Value
Node movement area	$s = 250\,000\,\text{m}^2$
Number of nodes	$n = 100$
Node communication radius	$R = 10\,\text{m}$
Node mobile velocity	$V_0 = 1\,\text{m/s}$
Communication bandwidth	$B = 250\,\text{kbps}$
Source node number	1
Destination node number	1
Data size	$M = 1\,\text{MB}$
Node mobile model	RD
Routing algorithm	Epidemic
Total time	4000 s

Table 3 Contact duration verification.

Node radius (m)	Node velocity (m/s)	Contact duration (s)	
		ONE	Algorithm in this paper
10	1	13.08	12.34
10	5	3.32	2.47
10	10	2.17	1.23
5	1	6.58	6.17
5	5	1.37	1.23
5	10	0.62	0.62

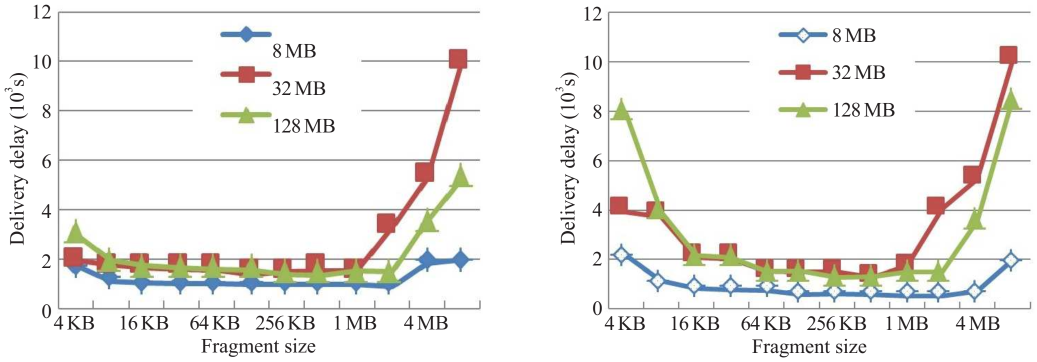
Table 4 Contact time verification.

Node radius (m)	Node velocity (m/s)	Contact duration (s)	
		ONE	Algorithm in this paper
10	1	2127	2016
10	5	10 127	10 084
10	10	20 432	20 168
5	1	1104	1008
5	5	5045	5042
5	10	10 247	11 102

6.2 Verification of optimal fragment size

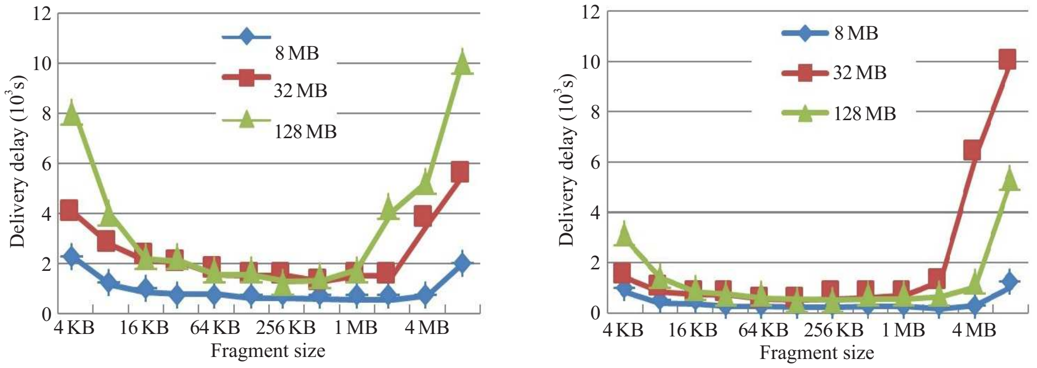
The second part of the experiment involves verifying the optimal fragment size. We defined a serial configuration of the ONE simulator as the key parameter that includes the communication radius $R = 10\,\text{m}$, bandwidth $B = 128\,\text{KB/s}$, the node velocity $V_0 = 1\,\text{m/s}$, and the label information size $h = 1\,\text{MB}$. Also, we assume that three types of data with sizes of 8, 32, and 128 MB should be disseminated. With this configuration, the factors that affect the optimal fragment size calculation in the algorithm are all constant. We can compare the known optimal size with several manually defined fragment sizes to verify our proposed method. We split the big data into fragments in the range of 2 KB to 32 MB to run the simulator. All the fragments are attached with label information with the same sizes (1 MB). The simulation running time is sufficiently long and is mainly 10 000 s.

The statistics of delivery delay at different data and fragment sizes are shown in Figs. 7 and 8.



(a) Epidemic

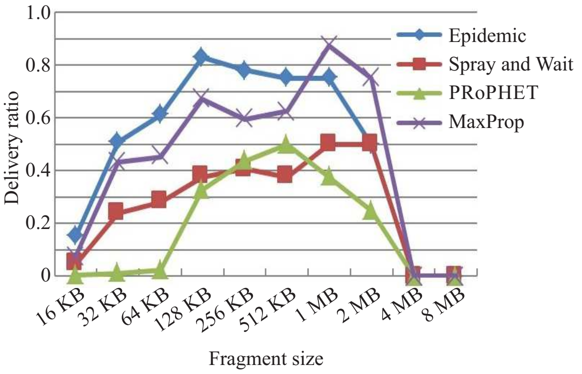
(b) Spray and Wait



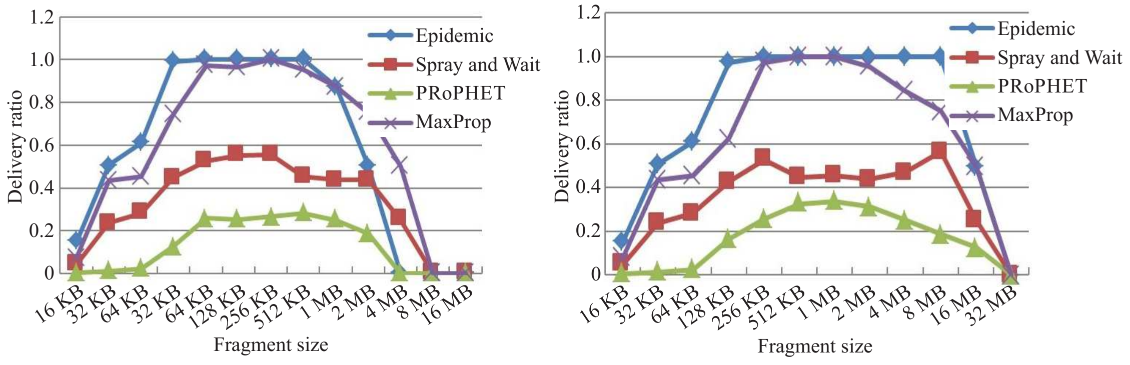
(c) PRoPHET

(d) MaxProp

Fig. 7 Statistics of delivery delay at different data and fragment sizes.



(a) 8 MB, 1500 s



(b) 32 MB, 5000 s

(c) 128 MB, 10 000 s

Fig. 8 Delivery ratio in different data sizes and times.

From the figures we can conclude that the delivery delays vary with different routing algorithms. Some routing algorithms are less aware of excessively small fragments such as Spray and Wait, whereas others are not. However, all the routing algorithms are aware of the larger fragments. When the fragment size is outside a reasonable range, the delay increases dramatically. The optimal fragment size could be easily calculated with certain constant parameters. In these experiments, the optimal size result could be deduced using Eq. (21). The value is 252.3 KB, which is always located at the position of low delivery delay and high delivery ratio.

7 Conclusion

In this paper, we analyze the challenges of video data transmitted in ON. Given intermittent communication, video data may not be delivered during most contact opportunities of nodes. Fragment transmission is reasonable as long as we obtain the contact features or communication capacity first. Therefore, we propose a novel communication capacity calculation model of ON based on the classical RD mobile model. Then, we observe that different fragment sizes represent different delivery delays, and that the video fragments should include the additional head-part. We define the restrain facts model of overhead and present an optimal fragment size algorithm. Finally, we design, implement, and evaluate the methods and the algorithms in a simulated ON. Experiment results show that the contact duration and total contact times analyzed from the log are all in accordance with the expected contact duration and times calculated from the algorithms. The optimal fragment size is located at the optimal position of the fragment size sequence.

In the future, we will conduct further analysis of other mobile models and intend to propose effective routing algorithms at different types of fragment delivery or for heterogeneity analysis of fragments. We will also explore social relation nodes in certain mobile communication areas.

Acknowledgment

The authors would like to thank Tengjiao Zhu and Dan Zhang for their help. This work was supported by the Shaanxi Natural Science Foundation Research Plan (No. 2015JQ6238), the China Scholarship Council, the National Natural Science Foundation of China (Nos. 61373083 and 61402273), the Fundamental Research Funds for the Central Universities of China (No. GK201401002), the Program of Shaanxi Science and Technology Innovation Team of China (No. 2014KTC-18), and the 111 Programme of Introducing Talents of Discipline to Universities (No. B16031).

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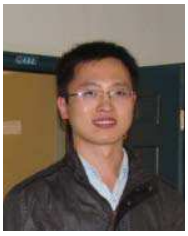
Peng Li received the PhD degree from Beijing Normal University in 2010 and the MS degree from Northwest University in 2007. He is now doing research and teaching work in School of Computer Science at Shaanxi Normal University. He is also a visiting scholar at Georgia State University in USA. His research interest includes wireless sensor networks, multimedia analisys, and mobile social networks.

Junling Lu recieved the PhD degree from Shaanxi Normal University in 2013 and the MS degree from Northwestern Polytechnical University in 2003. He is now doing research and teaching work in School of Computer Science at Shaanxi Normal University. His research interest includes privacy preservation and wireless networks.

Zaobo He is now a PhD student at Georgia State University, studying security and privacy. He received the MS degree from Shaanxi Normal University, China in 2014, and the BS degree from Yanan University, China in 2011. He interests in privacy preserving, particularly in privacy preserving for big data. He also studies big data aggregation and capacity analysis for wireless networks.

Xiaoming Wang received the PhD degree in computer theory and software from Northwest University, China, in 2005. He is currently a professor with School of Computer Science, Shaanxi Normal University, and he was a research professor (visiting scholar) from 2007 to 2008 at Georgia State University, USA. His current research interests include network security, access control, pervasive computing, wireless sensor network, workflow management system, and system dynamics. His research has been supported by the National Science Foundation of China (NSFC), Key Research Project of Ministry of Education of China. He has authored and coauthored more than 40 publications in journal, books, and international conference proceedings.



Lichen Zhang received the PhD degree and the MS degree from Shaanxi Normal University, China in 2011 and 2005, respectively. He is currently an associate professor with the School of Computer Science, Shaanxi Normal University. He was a visiting scholar with the Department of Computer Science, Georgia State University, USA, from 2013 to 2014. His main research areas focus on networking and privacy preservation.