A Buffer Management Strategy on Spray and Wait Routing Protocol in DTNs

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Outline

- **1. Introduction**
- 2. Model Description
- 3. Scheduling and Drop Strategy
- 4. Evaluation
- 5. Future Work

1. Introduction

1.1 Motivation

- **The dramatic change of topology and the frequent interruption of connections make it difficult to forward the message to the destination in DTNs**

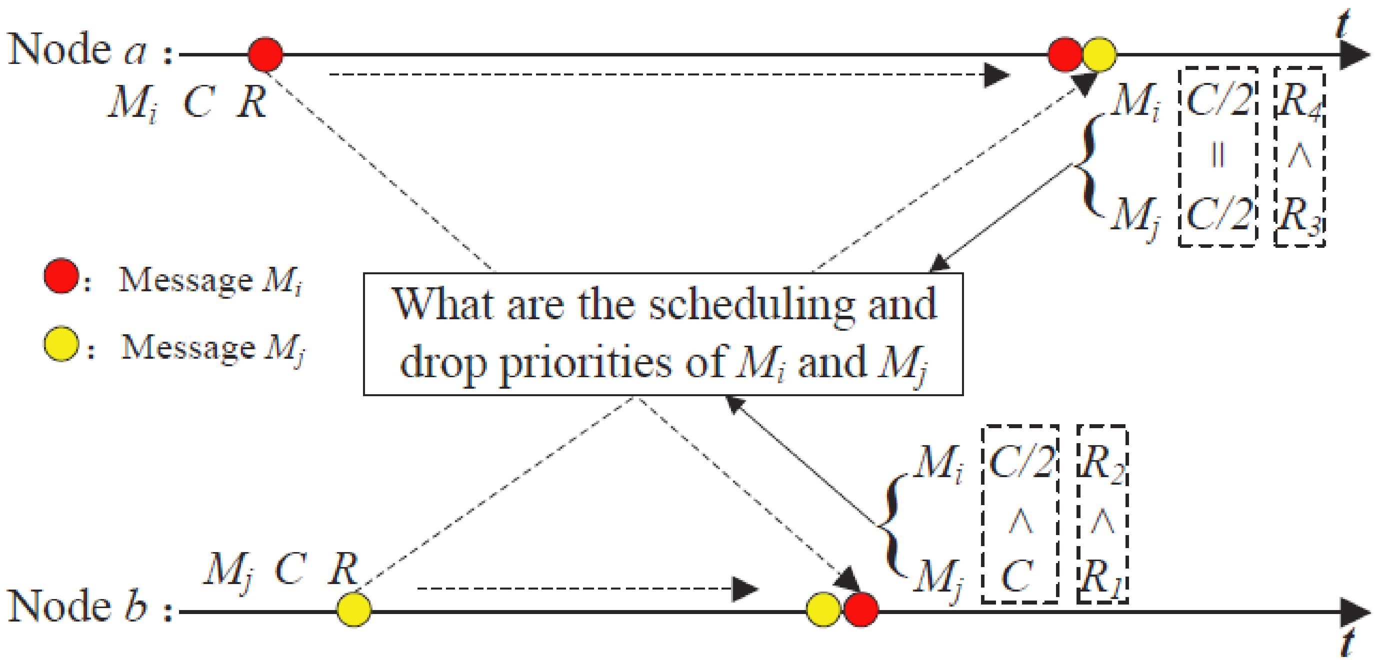
- **To maximize delivery ratio, while reducing the network congestion, Spray and Wait adopts a binary splitting method to distribute a set number of copies into the network**

- **However, there is still partial congestion due to the limited buffer size, even in the Spray and Wait routing protocol.**

1. Introduction

1.2 Problem

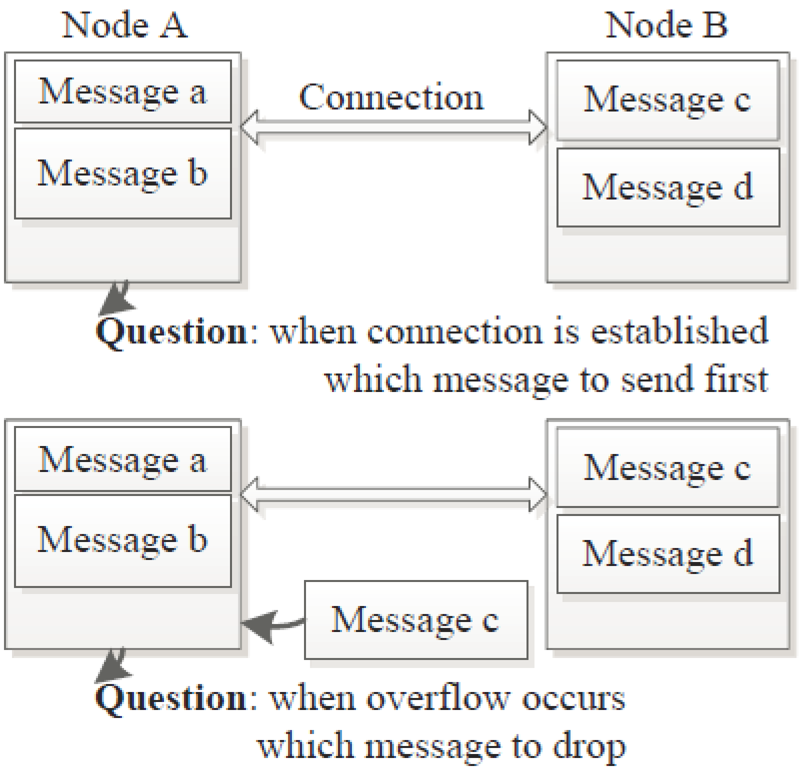
- **How to address the message scheduling and drop problem in Spray and Wait routing protocol (*M*: message id, *C*: message copies number, *R*: message remaining TTL).**



1. Introduction

1.2 Problem

- **When a connection is established, which message to send first**
- **When overflow occurs, which message to drop**



1. Introduction

1.3 Challenge

- **In order to optimize the delivery ratio, how to decide the message priority.**

- **How to map the number of copies (C_i) and remaining TTLs (R_i) into message priority**

- **How to address message scheduling and drop problem according to the priority.**

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2. Model Description

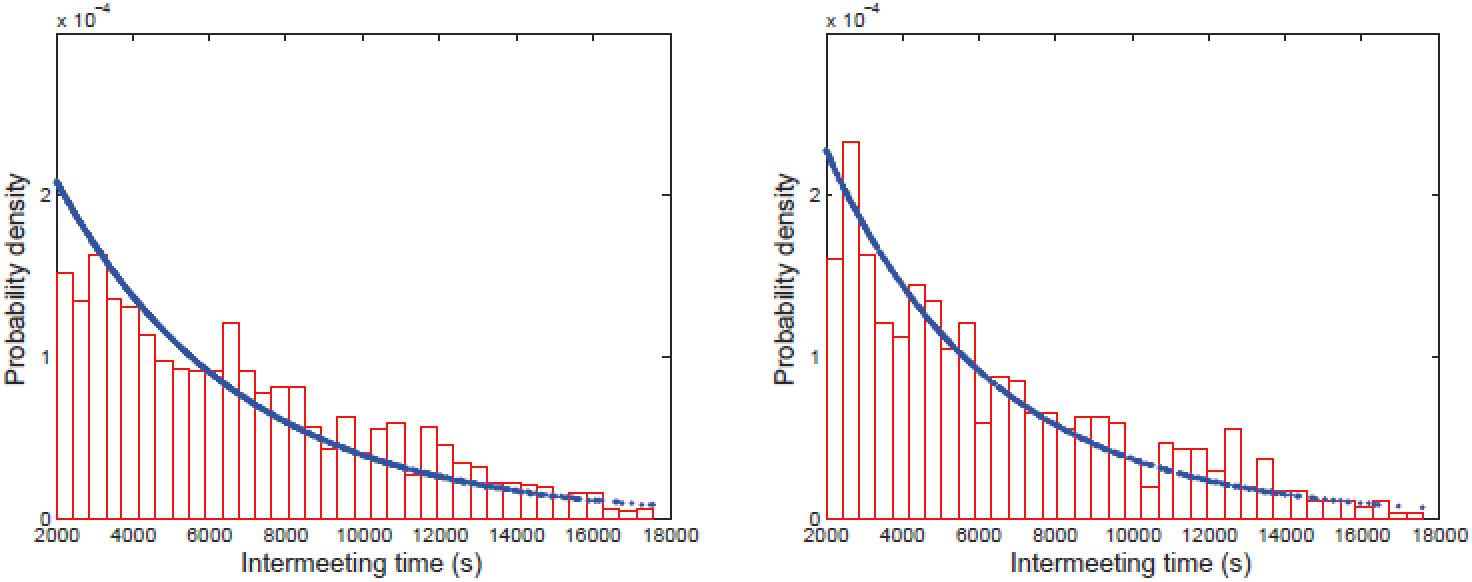
2.1 Mobility Model

- ***Definition 1*: Intermeeting time: the elapsed time from the end of the previous contact to the start of the next contact between nodes in a pair**
- ***Definition 2*: Minimum intermeeting time: the minimum elapsed time for a specific node from the end of the previous contact to the start of the next contact with any other node.**
- **Intermeeting times are exponentially distributed under many popular mobility patterns such as random walk, random waypoint, and random direction.**

$$f(x) = \lambda e^{-\lambda x} \quad (x \geq 0)$$

2. Model Description

2.1 Mobility Model: the random-waypoint (a) and the real trace EPFL (b)



(a) (b)

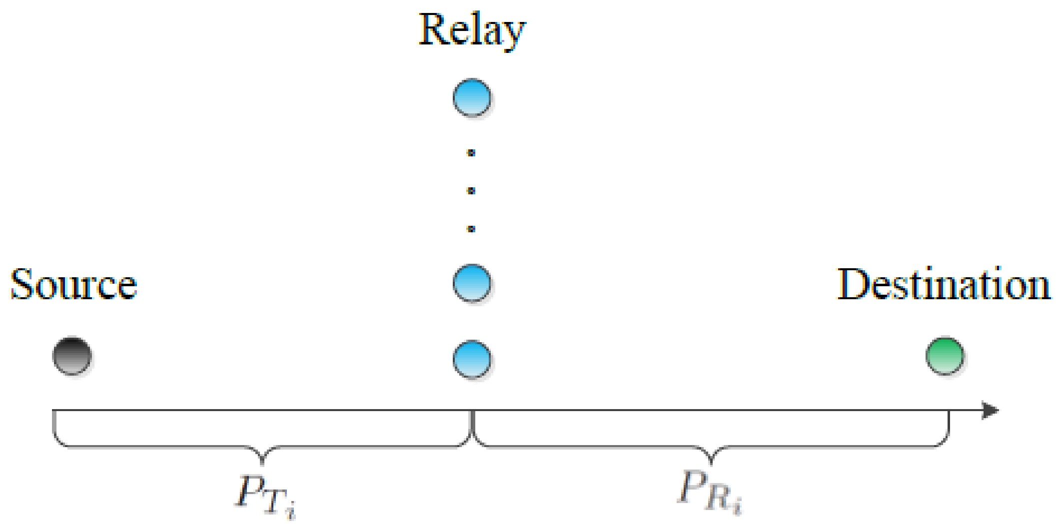
2. Model Description

2.2 Utility Model

Symbol	Meaning
N	Total number of nodes in the network
$K_{(t)}$	Number of distinct messages in the network at time t
TTL_i	Initial time-to-live (TTL) for message i
R_i	Remaining time-to-live (TTL) for message i
T_i	Elapsed time for message i since its generation ($T_i = TTL_i - R_i$)
$n_i(T_i)$	Number of nodes with message i in buffer after elapsed time T_i
$m_i(T_i)$	Number of nodes (excluding source) that have seen message i after elapsed time T_i
$d_i(T_i)$	Number of nodes that have dropped message i after elapsed time T_i ($d_i(T_i) = m_i(T_i) + 1 - n_i(T_i)$)
$E(I)$	Mathematical expectation of intermeeting times
λ	Parameter in the exponential distribution of intermeeting times ($\lambda = \frac{1}{E(I)}$)
$E(I_{min})$	Mathematical expectation of the minimum intermeeting times
λ_{min}	Parameter in the exponential distribution of minimum intermeeting times ($\lambda_{min} = \frac{1}{E(I_{min})}$)
C	The initial number of copies of message i in source node
C_i	The copies number of message i in the current node
U_i	Priority of message i
$P(T_i)$	Probability that message i has been successfully delivered after elapsed time T_i
$P(R_i)$	Probability that undelivered message i will reach the destination within time R_i
P_i	Probability that message i can be successfully delivered
P	Global delivery ratio

2. Model Description

2.2 Utility Model



- **The probability of message *i* being delivered is given by the probability that message *i* has been delivered and the probability that message *i* has not yet been delivered, but will be delivered during the remaining time R_i**

$$P_i = (1 - P_{T_i})P_{R_i} + P_{T_i}$$

2. Model Description

2.2 Utility Model

- **Due to the reason that all the nodes including the destination have an equal chance of seeing the message *i:***

$$P(T_i) = \frac{m_i(T_i)}{N-1}$$

- **Probability that undelivered message *i* will reach the destination within time *R*$_i$*:***

$$P(R_i)=1-\prod_{k=0}^{\log_2^{C_i}} e^{-\lambda n_i(T_i)[R_i-kE(I_{min})]}$$

$$=1-e^{-\lambda n_i(T_i)[(\log_2^{C_i}+1)R_i-\frac{1}{2(N-1)\lambda}\log_2^{C_i}(\log_2^{C_i}+1)]}$$

2. Model Description

2.2 Utility Model

- **We obtain the final expression for P_i as follows:**

$$P_i = \frac{m_i(T_i)}{N-1} + (1 - \frac{m_i(T_i)}{N-1})$$
$$(1 - e^{-\lambda n_i(T_i)[(\log_2^{C_i} + 1)R_i - \frac{1}{2(N-1)\lambda} \log_2^{C_i}(\log_2^{C_i} + 1)]})$$

- **Note that the global delivery ratio P equals the sum of P_i:**

$$P = \sum_{i=1}^{K_{(t)}} [\frac{m_i(T_i)}{N-1} + (1 - \frac{m_i(T_i)}{N-1})$$
$$(1 - e^{-\lambda n_i(T_i)[(\log_2^{C_i} + 1)R_i - \frac{1}{2(N-1)\lambda} \log_2^{C_i}(\log_2^{C_i} + 1)]})]$$

2. Model Description

2.2 Utility Model

- **Three cases：**

$$\begin{cases} \Delta(n_i) = 1 & \text{If replicate message } i \text{ during contact.} \\ \Delta(n_i) = 0 & \text{If no action for message } i \text{ is taken.} \\ \Delta(n_i) = -1 & \text{If drop an already existing message } i. \end{cases}$$

- **Therefore, the utility of message *i* is precisely the derivative of the delivery ratio P_i, which is defined as U_i.**

$$U_i = (1 - \frac{m_i(T_i)}{N-1})\lambda[(\log_2^{C_i}+1)R_i - \frac{1}{2(N-1)\lambda}\log_2^{C_i}(\log_2^{C_i}+1)] e^{-\lambda n_i(T_i)[(\log_2^{C_i}+1)R_i - \frac{1}{2(N-1)\lambda}\log_2^{C_i}(\log_2^{C_i}+1)]}$$

- **The higher U_i indicates that the message *i* is more important**

2. Model Description

2.2 Utility Model

- **Estimation of $m_i(T_i)$ and $n_i(T_i)$:**

$$n_i(T_i) = m_i(T_i) + 1 - d_i(T_i)$$

- **$d_i(T_i)$ is achieved as follows:**

Data Structure:

Node ID	Dropped List	Record Time

Node A		
A	Messages:1, 3, 5	300
C	Messages:2, 7, 8	250

encounter

Node B		
B	Messages:1, 4, 6	350
C	Messages: 2, 8	200

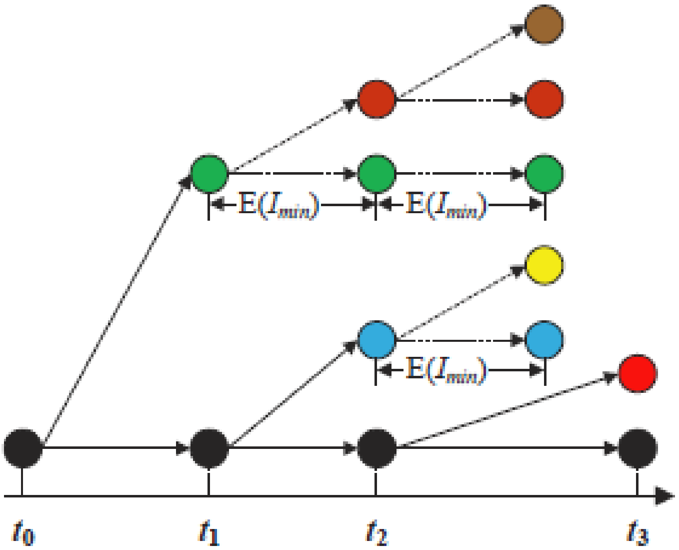
Node A		
A	Messages:1, 3, 5	300
B	Messages:1, 4, 6	350
C	Messages:2, 7, 8	250

Node B		
B	Messages:1, 4, 6	350
A	Messages:1, 3, 5	300
C	Messages:2, 7, 8	250

2. Model Description

2.2 Utility Model

- ***$m_i(T_i)$* is estimated as follows:**



$$m_i(T_i) = \sum_{k=1}^{n-1} 2^{\lfloor \frac{t_n - t_k}{E(I_{min})} \rfloor} + 1$$

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3. Scheduling and Drop Strategy

3.1 Strategy

Algorithm 1 SDSRP

Input:

Copies number: C, Remaining TTL: R,
Number of messages in the buffer: n
The ID of new coming message: m

Output:

Scheduling message: ID_S, Dropping message: ID_D

for i =1 to n **do**
    map C_i, R_i to $Priority_i$
Sort $Priority_i$ incrementally
Find highest $Priority_h$, and assign h to ID_S
Find lowest $Priority_l$, and assign l to ID_D
if connection up **then**
    return ID_S
if buffer overflows **then**
    map C_m, R_m to $Priority_m$
    if $Priority_m < Priority_l$ **then**
        assign m to ID_D
    return ID_D

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4. Evaluation

4.1 Simulation parameters (random-waypoint)

Parameter	Random-Waypoint
Simulation Time	18000s
Simulation Area	4500m × 3400m
Number of Nodes	100
Moving Speed	2m/s
Transmission Speed	250Kbps
Transmission Range	100m
Buffer Size	2MB,2.5MB,3MB,3.5MB,4MB,4.5MB,5MB
Message Size	0.5MB
Message generation rate	[10,15][15,20][20,25]· · · [35,40][40,45][45,50]
TTL	300mins
Initial Copies Number	16,20,24,28,32,36,40,44,48,52,56,60,64

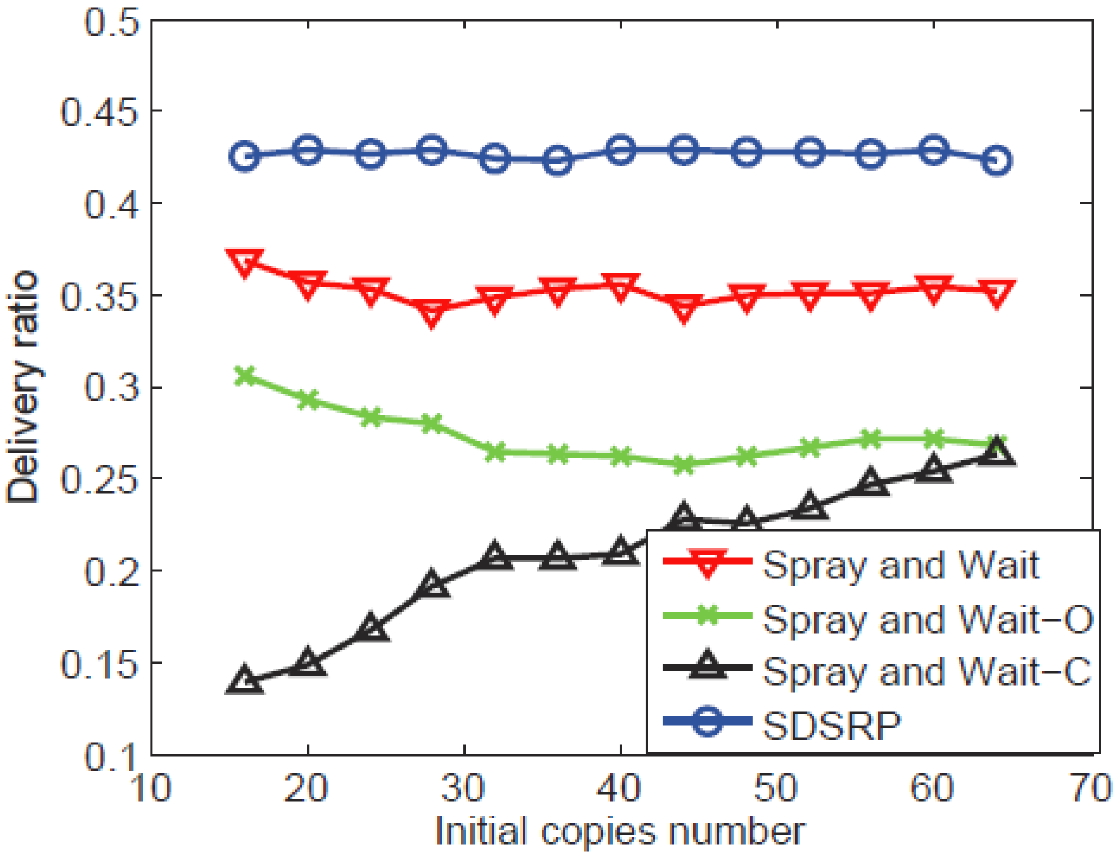
4. Evaluation

4.2 Four buffer management strategies

- **1. Spray and Wait adopts the FIFO (first in first out) buffer management strategy.**
- **2 . Spray and Wait-O regards the ratio between the remaining TTL and initial TTL as the priority.**
- **3 . Spray and Wait-C treats the ratio between the current message copies number and initial copies number as the priority.**
- **4 . SDSRP is our method, use Ui as the priority.**

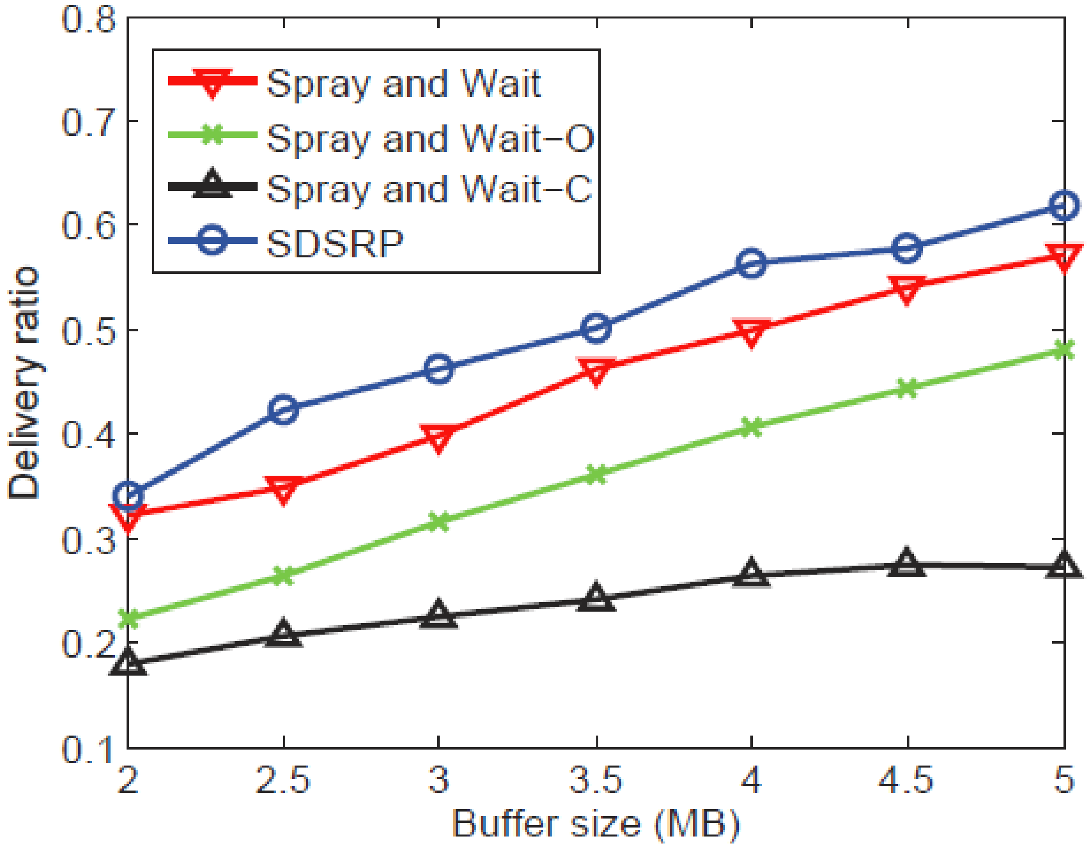
4. Evaluation

4.3 Simulation Results



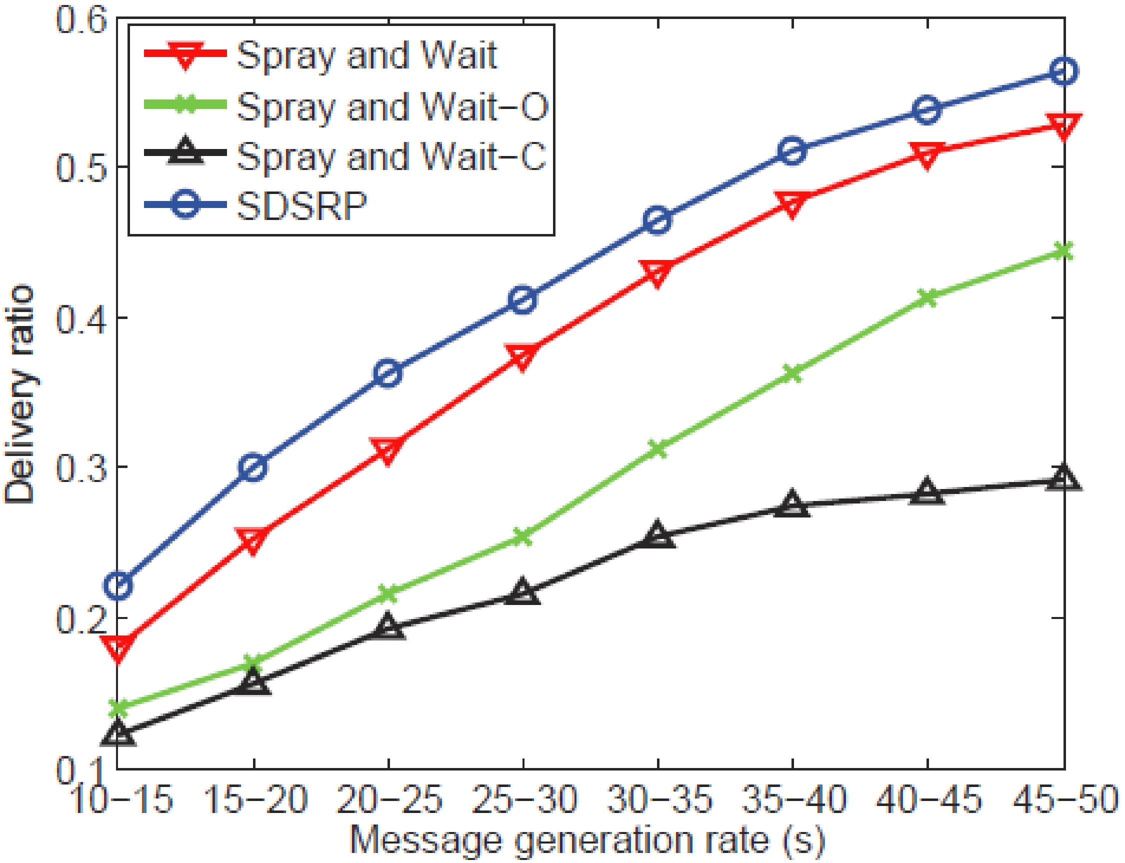
4. Evaluation

4.3 Simulation Results



4. Evaluation

4.3 Simulation Results



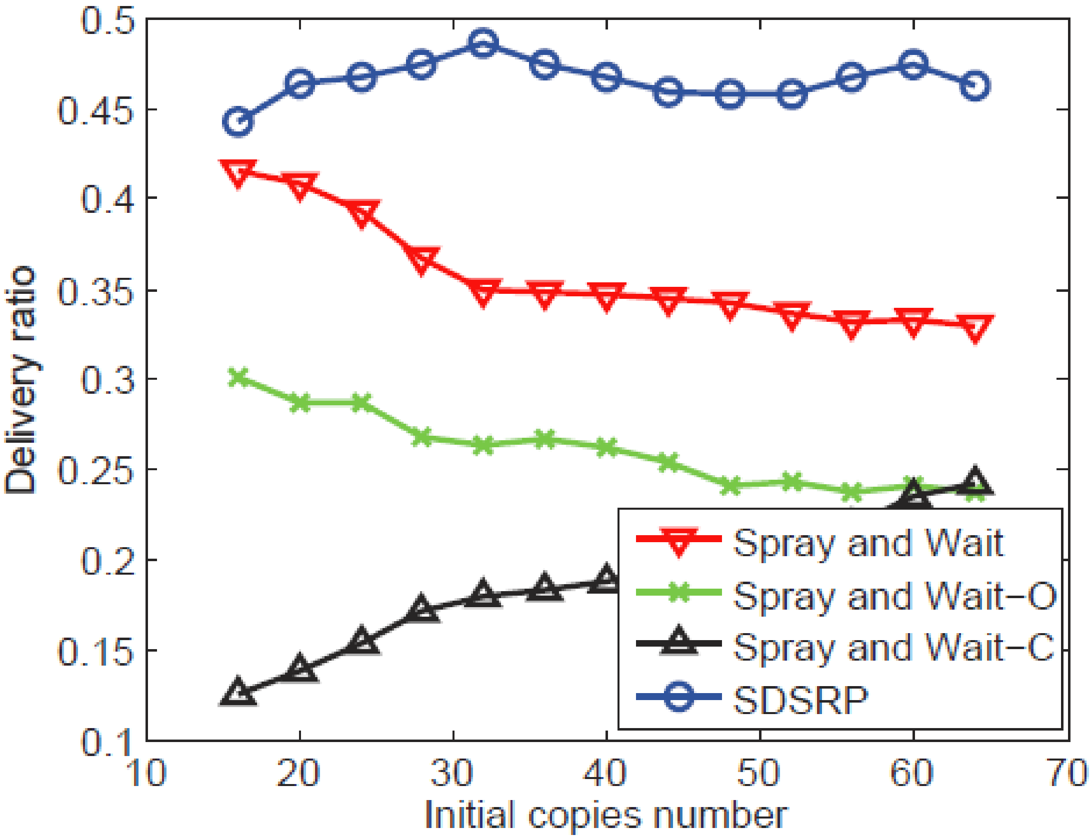
4. Evaluation

4.4 Simulation parameters (EPFL)

Parameter	EPFL-Dateset
Simulation Time	18000s
Number of Nodes	200
Transmission Speed	250Kbps
Transmission Range	100m
Buffer Size	2MB,2.5MB,3MB,3.5MB,4MB,4.5MB,5MB
Message Size	0.5MB
Message generation rate	[10,15][15,20][20,25]· · · [35,40][40,45][45,50]
TTL	300mins
Initial Copies Number	16,20,24,28,32,36,40,44,48,52,56,60,64

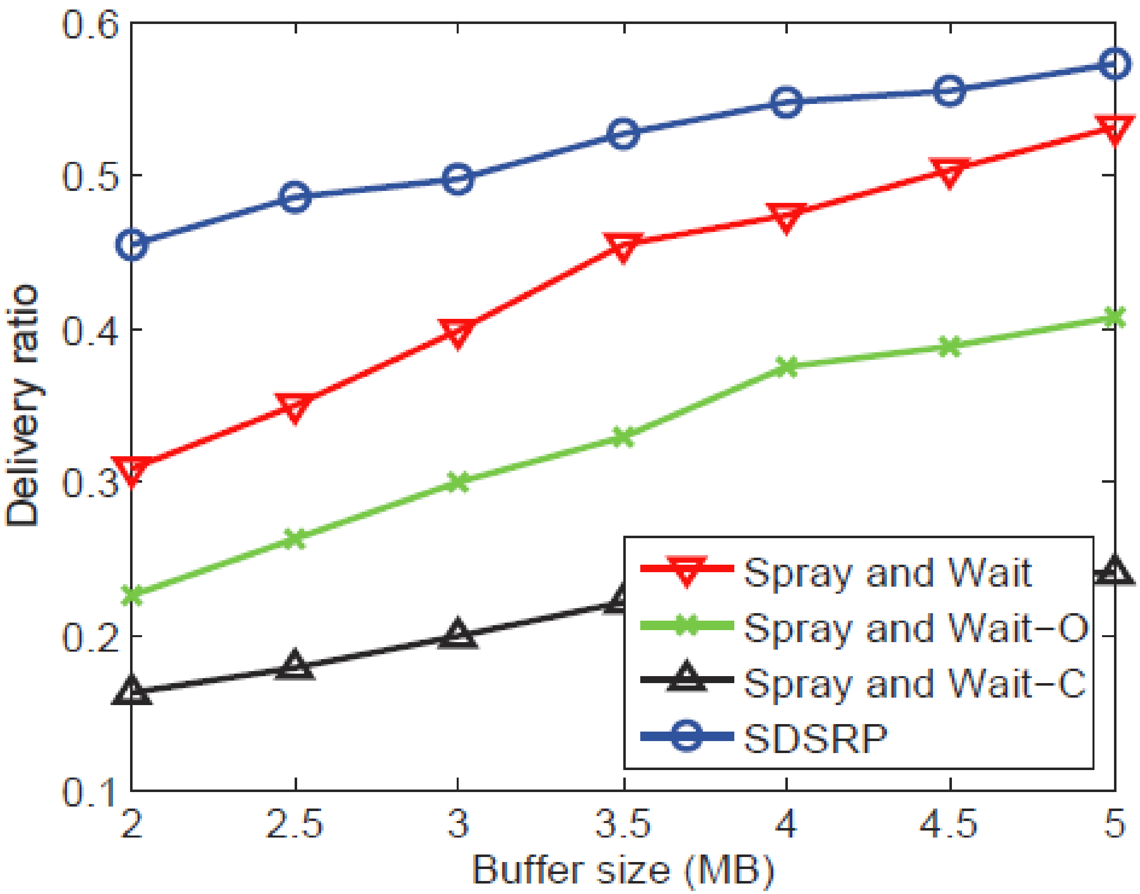
4. Evaluation

4.5 Simulation Results



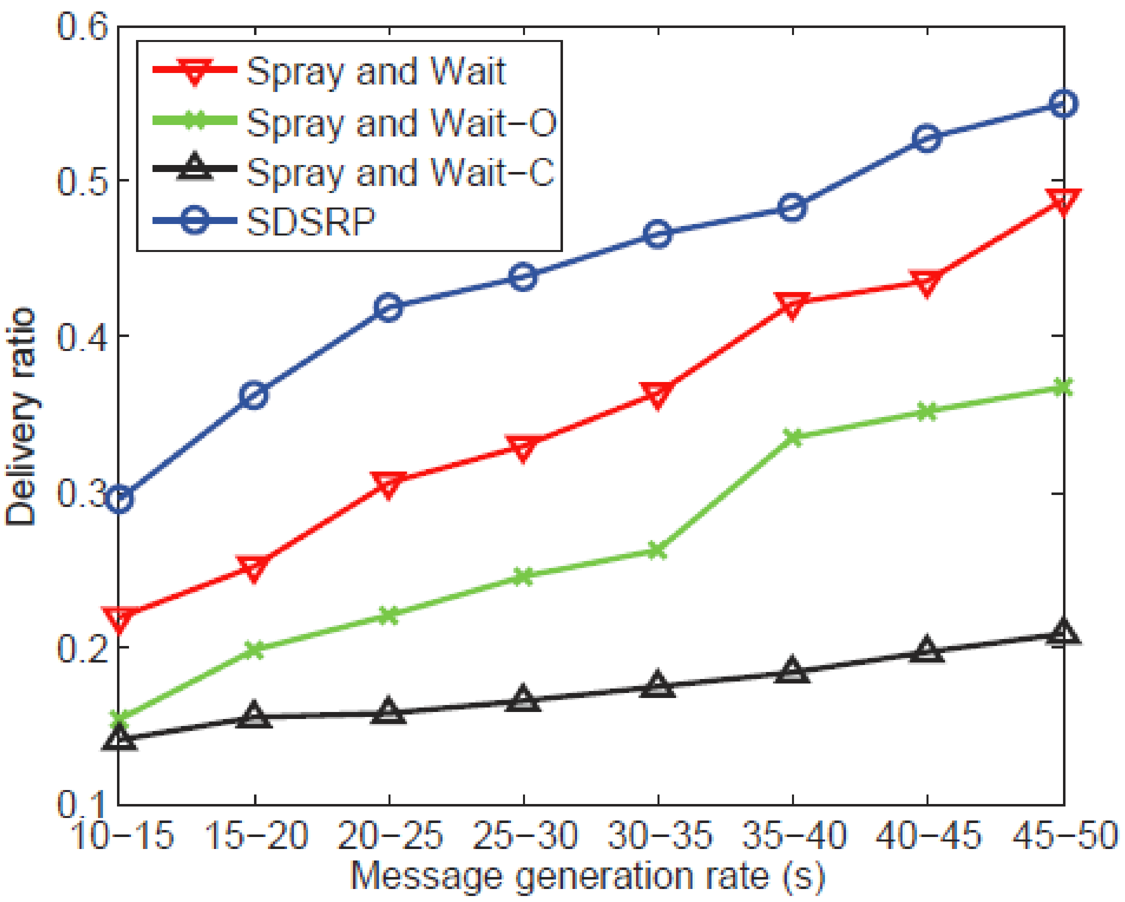
4. Evaluation

4.5 Simulation Results



4. Evaluation

4.5 Simulation Results



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1. Future Work

- **Other replication-based routing schemes**
  - **delegation forwarding, etc**

- **The problem of messages in different sizes**

Thank You