

# **Towards the Development of a Modified Token based Congestion Control with Adaptive Forwarding for Opportunistic Networks**

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## **ABSTRACT**

In opportunistic networks the accessible network resources such a storage capacity, bandwidth, etc., are limited, and simply be consumed over time. This always result to network congestion, which has substantial impact on the overall network throughput. Due to the distinctive features of the network and the implementation of custody transfer mechanism, the conventional TCP congestion control mechanism fails in OppNets. The congestion control in OppNet has attracted the attention of the researchers because it attempts to establish network in an extreme environment where infrastructure is not obtainable, and when it succeeds, the message should not be dropped instantly since it has serious impact on the objective of OppNet. Instead, the message should be rerouted to the next best neighbor whose buffer is not full because some of the application areas are extremely sensitive. Some congestion control strategies have been considered compared and modified token-based congestion control algorithm is proposed by examining them.

## **General Terms**

Opportunistic networks, Congestion control strategies and routing protocols

## **Keywords**

Epidemic routing protocol, token-based congestion control and modified token-based congestion control

## **1. INTRODUCTION**

Opportunistic Networks (OPPNets) are subclass of delay tolerant network where communication opportunity are intermittent and connected paths rarely exist between the source node and the destination node. The link performance in an OppNets is always subject to frequent disruption. Thus, the traditional networks, such as transmission control protocol and internet protocol (TCP/IP) will fail in this type of extreme environment because contemporaneous end-to-end path between the source and the destination node may only exist briefly and unpredictable period[1].

The OppNets lack the potential to provide contemporaneous end-to-end connectivity between the nodes and extreme latencies because of long propagation delay and intermittent connectivity demands for mechanism to control the network, which are essentially different from what is obtainable on the Internet [2]. In fact, the control function provided by the Internet's (TCP) are all accomplished at the connected path

over a logical connection built between the sender and the receiver. Since OppNet has 'connectivity challenged' issues, network control in OppNets ought to be implemented on hop-by-hop platform. This necessitates for custody transfer [3] and store-carry-and-forward[4] approaches that have been proposed for OppNet. This demands that OppNet nodes ought to buffer the packets in persistent storage for unpredictable period and move about until best next hop is discovered. In view of this, congestion control is considered fundamental to ensure that OppNet nodes are free from congestion and can serve as relays to aid in message delivery process. OppNets have attracted much research efforts in the area of security and routing[5]. Meanwhile, one can understand that the convergence layer for OppNets still depends heavily on TCP. Therefore, the congestion control techniques contained in the TCP cannot adapt to the dynamic evolving topology presented by the OppNets. Thus, finding an appropriate congestion control measure for OppNet is deemed a critical issue. The following sections discuss about the literature survey, comparison between congestion controls strategies. Followed by the modifying token –based congestion control and the flowchart provided. Subsequently, is the conclusion and directions for future works in the fields.

## **2. LITERATURE SURVEY**

In OppNets, to transmit packets several routing techniques are proposed, and a lot of research efforts are taking place in this domain, among which are broadly classified as flooding strategies and forwarding strategies[6]. However, unlike other traditional protocols implemented in TCP, assume link is already established before forwarding the packet. In OppNets, epidemic routing protocol[7] is widely utilized due to its features of transmitting non-fragmented packets in First-In-First-Out fashion. This has enabled the epidemic router to have an optimal delivery probability and low latency as a function of buffer size as well as bandwidth. Thus, it performs better in terms of QoS. Despite the fact that it has this distinguishing feature to transmit packets to either single or several destinations[8], it has a substantial drawback of overloading a neighboring node with redundant amount of duplicated packets and making it vulnerable to congestion. Consequently, drop a significant any incoming packets. To conquer this condition, different congestion control techniques have been proposed and the implementation of congestion control mechanism that is routing protocol independent, among which some are highlighted as follow:

## 2.1 Congestion Control Strategy for OppNet Based on Message Value[9]

It is a reactive congestion control strategy based on Message Deleting and Transferring (MDAT), which is triggered after the occurrence of congestion within a node. It operates in a manner that the congested node computed the storage value of each message as a function of forwarding probability and

message time-to-live. The message with the least storage value is erased. The relay node determined the receiving value of the message based on the forwarding probability and its free buffer capacity. Thus, prompting the congested node to transfer the packet with maximum receiving value. Spray and Focus routing is used for forwarding packets between contacting nodes. The flow chart for message deleting and transferring algorithm is shown in fig.1.0

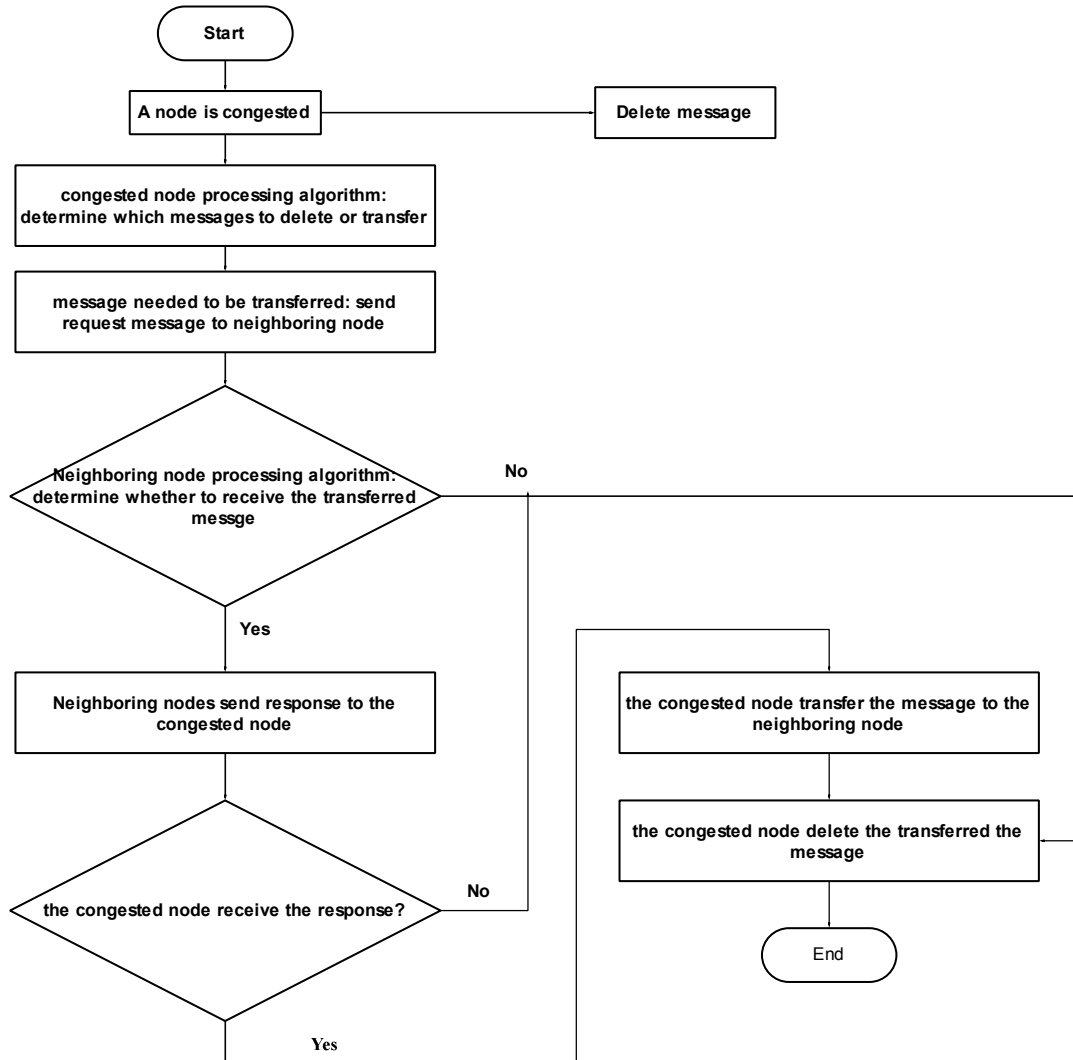


Fig 1: flow chart for MDAT algorithm[9]

A node accepts the messages if it has maximum receiving value for all incoming messages or else it checks for congestion. At this point, the Authors focused on congested node processing algorithm and neighboring node-processing algorithm. Packets are discarded if it has least storage value and minimum receiving value in the buffer of the congested node and the receiving node in order to address congestion. The flow chart of this strategy is shown in fig.1.0

## 2.2 Exploiting social preference for congestion control in OppNet [10]

In line with the message deleting and transferring, exploiting Congestion Control with Adjustable Fairness (CCAF) algorithm is also a reactive method built on any utility-based routing protocol to enhance maximum delivery rate and minimize end-to-end delay at the disbursement of a sensible decrease in fairness. The algorithm used normalized utility and normalized residual space to determine the relay node to

forward the message, taking cognizance of the remaining memory capacity as the node contacted each other. This approach has the potential to dynamically adjust the tunable parameter through the social preference of the nodes to provide the trade-off between efficiency and fairness, which matched the desired network performance.

The essence is that in OppNets, there is exceedingly unbalanced dissemination of traffic load among the nodes. Thus, it is conceivable for some nodes to exhaust their constrained buffer capacity and energy resources. Hence, the best approach for addressing the problem is to optimize the fairness in the network, through disseminating the traffic load among all the nodes in the network. This achieves significant decrease in packet discards.

### 2.3 Token based congestion control for DTNs[5]

Different from the above congestion control strategies, TBCC is a congestion Avoidance technique, which is a proactive method. It is only the node holding a valid token can injects message into the network, which is somehow alike to Token Ring. The tokens are initially circulated evenly and then randomized. The essence of TBCC is matching the quantity of data entering the network with the network capacity and this indicates that any network or nodes should accepts as much data as it could forward. Contrast to Token Ring, TBCC only requires token to put data into the network and is recovered when the message leaves the network in favorable or unfavorable manner. The amount of tokens to be disseminated in the network differs; beside it has means of sharing the extra

tokens with the neighboring nodes. The TBCC is routing algorithm independent compared with MDAT and CCAF. When simulated through discrete event simulator (DES), it showed better performance in terms dropped message and network transit time, which is directly proportional to the connectedness between the nodes via the greatest connected component (GCC) metric. It outperforms other congestion control mechanisms considered so far because it avoid congestion before it happens. Dropping message when a node's buffer is full has significant impact on the network performance and some nodes could be stressed, while others may not actively take part in message delivery process. This could results to ineffectiveness in resource utilization and unfairness in the network, which is not favorable. Figure 2, illustrates the TBCC flow chart.

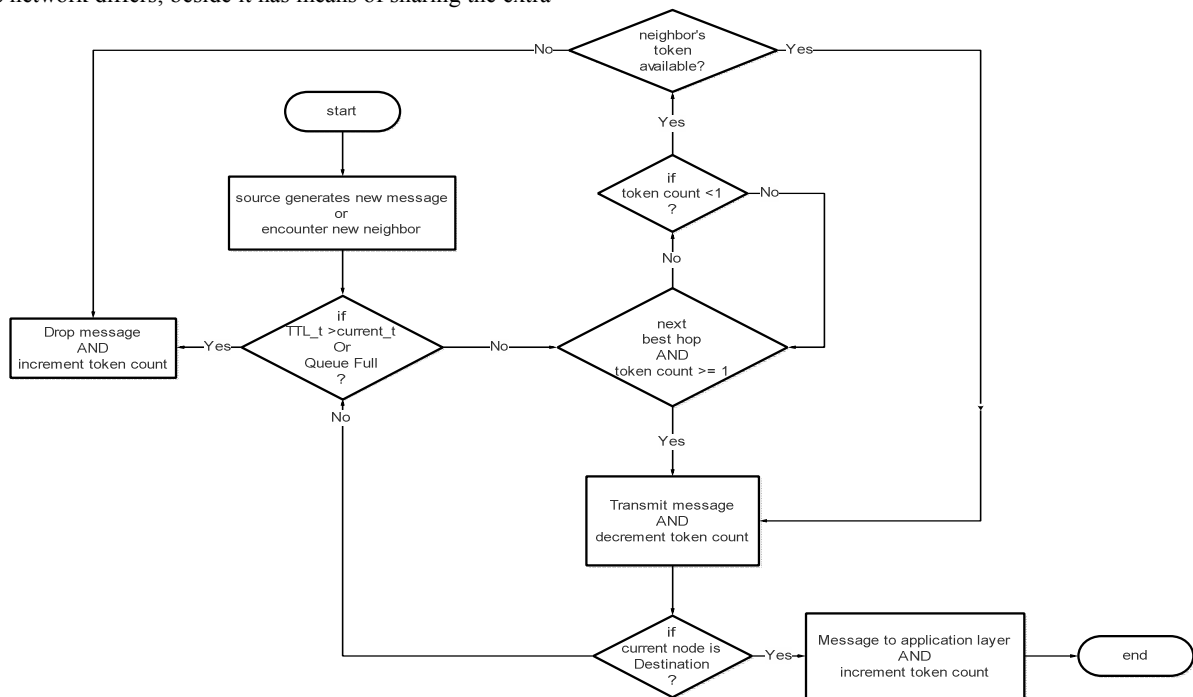


Fig.2: Flow chart for TBCC algorithm[11]

Parameters

TTL\_t: Time to live timer  
 Current\_t: Current timer

### 3. COMPARISON BETWEEN THE STRATEGIES CONSIDERED

The conversed strategies are compared, and brought together in tabular form as depicted in Table 1, which are categorized and elucidate the difference inferred between them. The categories are expounded as follows:

Table1: Comparison between the strategies considered

| Strategies | categories         |           |  |
|------------|--------------------|-----------|--|
|            | Type               | Method    | Establish on?  |
| MDAT       | Congestion control | Reactive  | Determine the storage value of each message and delete the message with the least storage value and forward the message with maximum receiving value |
| CCAF       | Congestion control | Reactive  | Used normalized utility and normalized residual space to define the rely node to forward message   |
| TBCC       | Congestion control | Proactive | Matching the amount of data entering the network to the total network capacity   |

### 3.1 Established on strategies

These mechanisms are triggered when the node suffers from congestion during storage management. Else, it buffers the message until opportunistic contact exist to forward the packet to the destination. These are useful in optimizing the delivery rate of packets without any issue. Due to substantial drawback of OppNet Epidemic Routing Protocol, several OppNets protocols are developed to route packets from source to destination successfully. CCAF operates on the dynamically adjusting the tunable parameters through the social preference of the nodes to provide the trade-off between efficiency and fairness, that matched the desired network performance. MDAT works on congested node processing algorithm and the receiving node-processing algorithm. Likewise, TBCC is a technique where by a node ought to have valid token in order to put message into the network or another neighboring node. In essence, it attempts to monitor the amount of traffic entering the network to the network capacity. Tokens are initially circulated and then randomized.

### 3.2 Established on Type and Method

Fundamentally, there are two kinds of congestion control techniques[11]: 1) Congestion control is a reactive method that permits the occurrence of congestion and attempts to eliminate it after detection. 2) Congestion Avoidance is a proactive method that attempts to avoid congestion prior to its occurrence. CCAF and MDAT congestion control strategies belong to the reactive method while TBCC is proactive method.

## 4. MODIFIED TOKEN BASED CONGESTION CONTROL (mTBCC)

Any networks losing packets during communication is a serious problem that deserve urgent attention. Considering the issue of OppNets, where congestion leads to packet drops, is vital as establishing connection between nodes where connected routing is not guaranteed. To overcome the limitation of epidemic routing protocol, which is overloading the neighboring nodes with redundant packets. There is every need to try to avoid packet drop in the network as much as possible by utilizing more active congestion control method. To strengthen the development of modified token-based congestion control mechanism, hybrid technique is employed comprising of TBCC and Adaptive Forwarding approach to address congestion within a node.

In the event of congestion in a node and the node has to discard the incoming message(s) that can be based on any one of those congestion control strategies, will impede the network performance. In addition, network performance depends greatly on the effectiveness of resource utilization and fairness in the network. Therefore, before dropping packet, especially in one copy forwarding protocol (PHoPHET), the incoming message should be rerouted from the congested node to congestion-free node taking into account of the largest available free buffer space and migration cost. This brings the message closer to the destination in the absence of end-to-end connectivity between the source and destination node. The conclusion drawn from the comparative study is that congestion avoidance method is favored over the congestion control method as pointed out in TBCC[5], since it maintains the network in a safe state, and do way from congestion through appropriate action before it happens.

Fig.3, discusses the proposed development of the modified token-based congestion control with adaptive forwarding

mechanism (mTBCC) algorithm to avoid as well as control congestion in OppNet node taking cognizance of the largest available free buffer space and migration cost. Equations 1 and 2 describes the buffer threshold and the migration threshold respectively.

$$MCth = TC + SC \quad (1)$$

$$BSth = Li(\max) + lc \quad (2)$$

Where

MCth: migration cost threshold, TC: transmission cost, SC: storage cost

Li (max): maximum message length, lc: packet overhead length

BSth: buffer size threshold

The node can be source, destination or relay forwarding node between the source and destination node. The following algorithm describe how message enters into the network and the action taken when message leaves the network. Coupled with the flow chart of Fig.3, can be utilized to avoid and control congestion in OppNet as follows:

- 1) Source node encounters new neighbor(s)  
Source queries routing protocol to determine if one of the new neighbors is the best next hop for message held in the application queue.  
if best next hop  $\neq$  NULL AND my token count  $\geq$  1 then  
    decrement token count and transmit message to best next hop  
else if token count  $<$  1 then  
    query neighbors for extra token  
if extra token is available then  
    decrement neighbors token count and transmit message to best next hop  
    end if  
end if
- 2) Source node generates new message  
Source queries routing protocol to determine if one of the new neighbors is the best next hop for message held in the application queue.  
if best next hop  $\neq$  NULL AND my token count  $\geq$  1 then  
    decrement token count and transmit message to best next hop  
else if token count  $<$  1 then  
    query neighbors for extra token  
if extra token is available then  
    decrement neighbors token count and transmit message to best next hop  
    end if
- 3) Message dropped in the network  
Upon receiving message node checks  
if queue State = FULL then  
    Redirect the traffic from congested node to congestion free node. If buffer of all nodes is full, drop the message AND increment token count.

end if  
 4) Message TTL timer expires  
 Upon routing beacon update receipt for each message in the queue check  
 if  $TTL\_timer > Current\_timer$  then  
 Drop message AND increment token count  
 end if

5) Message reaches destination  
 Upon receiving message node checks  
 if message Destination = this then  
 Pass the message to application layer AND increment token count  
 end if

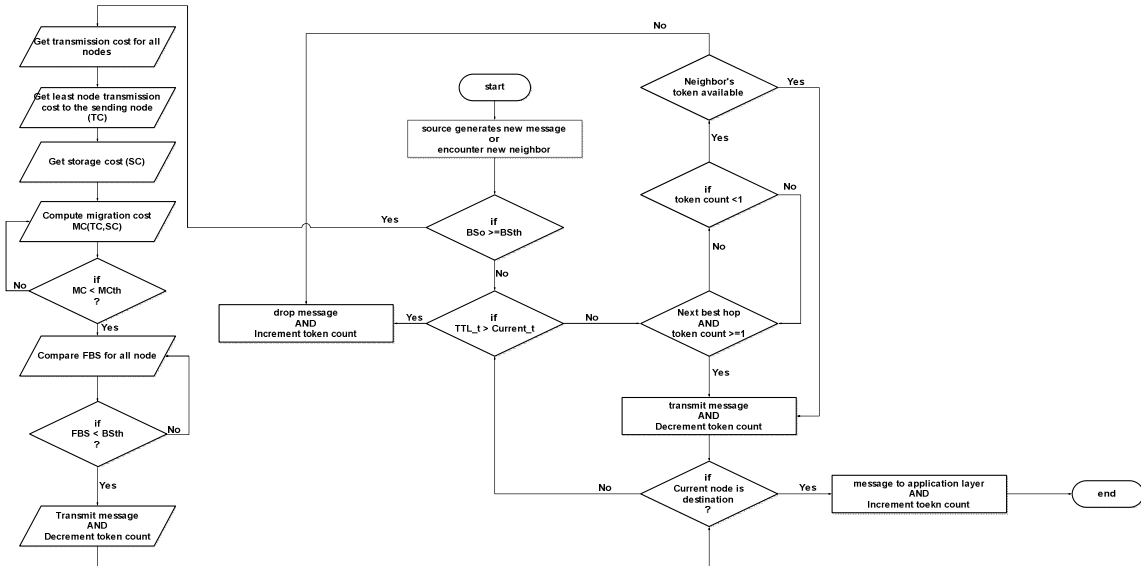


Fig.3: flow chart for mTBCC algorithm

Parameters

|                                |
|--------------------------------|
| BSo: Buffer size over          |
| BSth: Buffer size threshold    |
| TTL_t: Time to live timer      |
| Current_t: Current timer       |
| MC: Migration cost             |
| TC: Transmission cost          |
| SC: Storage cost               |
| MCth: Migration cost threshold |
| FBS: Free buffer space         |

Table 2: Simulation Parameters

| Parameter                 | Value                         |
|---------------------------|-------------------------------|
| Simulation area           | 4500x3400m                    |
| Transmission range        | 5m                            |
| Transmission speed        | 2Mbps                         |
| Total number of nodes     | 60                            |
| Message size              | 5KB-3MB                       |
| Message creation interval | 25-35s                        |
| Simulation time           | 43200s                        |
| Node movement speed       | 4.5 -5m/s                     |
| Node buffer size          | 5MB, 20MB, 60MB, 200MB, 300MB |

4.2 Environment Setup and Discussion

The networks of interest are generated from the greatest connected component mobility model comprising of sixty mobile nodes in addition to the random waypoint mobility model operating in a Helsinki region (4500x3400m) with a range of 5m. Nodes move within this region with speed of 5m/s. the routing protocol is based on predictability probability. Nodes update their routing table with predictability metric and compares neighboring predictability metric values for the destination with the node's value. The node with maximum value for predictability metric is considered the next best hop. The main simulation parameters are presented in table 2.

5. CONCLUSION AND FUTURE WORK

OppNets are one type of DTNs where communication opportunity occurs intermittently and contemporaneous end-to-end connectivity rarely exists between the source and destination node. OppNets are vulnerable to recurrent link disruption, yet still capable to establish connections between the nodes, which is challenging and expensive. Thus, it has several application areas that is broadly researched, developed and implemented. There are different routing techniques in OppNets, amongst which is epidemic routing that is widely used due to its performance features. However, it congests communication node easily and extreme packet dropping. Meanwhile, some congestion control strategies have been

developed using different routing protocol to overcome the limitation of the epidemic routing protocol. These are considered and compared. The mTBCC algorithm is proposed to avoid and control congestion in OppNets. In future work, we will study dynamic creation of token and deletion using localized detection. The concept of token scheme is associated to the network capacity and there has been little efforts in determining the OppNets capacity.

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