

Cross Layer Optimization of Dynamic Source Routing Protocol Using IEEE 802.11e Based Medium Awareness



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ABSTRACT: The inception of multimedia applications, the Mobile Adhoc Networks has created multi-disciplinary challenges for researchers in the field of network engineering. These applications on one hand consume extensive bandwidth and battery power and on the other hand require special treatment by the network entities to experience minimum delay by the traffic they generate. Due to some inherited limitations in MANET like low processing capabilities and limited transmission power, the multimedia traffic will require careful attention to route along the network from the source to destination. The legacy Dynamic Source Routing (DSR) protocol was designed in 1994 for simple data transmission. For transmission of multimedia traffic over DSR, many newer schemes are proposed in the last decade to meet the quality of service requirements. However the proposed scheme in this paper utilizes the Enhanced Distributed Channel Access (EDCA) based medium access mechanism as defined in IEEE 802.11E standard. The EDCA works on the principle of traffic prioritization into four access categories, thus allowing higher priority traffic more chances to access medium and transmit on the network. The proposed scheme uses cross layer technique to take EDCA parameters from the MAC layer on real time and calculate routing metric. OPNET Modeler is used to implement the scheme and evaluate results. The performance comparison shows the significance of the proposed scheme over the standard DSR routing.

Keywords: MANET, DSR, Delay, EDCA, IEEE 802.11E

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1. Introduction

Routing in Mobile Ad-hoc Networks (MANET) is a complex function due to the various limitations of the network including dynamic network topology, limited battery power, low processing speed and limited transmission capabilities of mobile devices. The impact of these limitations is more obvious and severely affects the performance of the routing protocol when multimedia applications are deployed over the network. These applications are bandwidth extensive and also drive more processing power from the mobile nodes. Since these applications are inception in the mobile networks, the research community has focused on the optimization of routing protocols. Many researchers urged on the cross layer design and optimization of protocols in wireless scenario due to its different nature from the fixed wired networks. [1]

The researchers using this paradigm proposed a variety of schemes to optimize the performance of many routing protocols and succeeded to a greater extent. [2] [3] [4] [5] [6] [7] [8].

Our proposed scheme is following the approach of cross layer design to optimize DSR protocol for quality of service enhancement required by delay sensitive multimedia traffic. The main goal is to minimize the routing delay for quicker transmission of voice and video traffic. We have used the EDCA [9] parameters in our proposed scheme to enable prioritized channel access for delay sensitive traffic. The approach is to modify the default routing metric and find routing paths which have least delay associated.

2. Dynamic Source Routing Protocol

Dynamic Source Routing is a reactive routing protocol proposed by IETF. [10] The specifications are defined in RFC 4728. [11] The protocol uses source routing i.e. the whole routing path is defined the source node and inserted into the packet's header before transmission. The default routing metric is hop count. The protocol's operation is divided into two parts, route discovery and route maintenance.

2.1 Route Discovery

The first step in protocol's operation is to find out the route to the remote destination. The process is accomplished by two messages, Route Request (RREQ) and Route Reply (RREP). The source node before sending packets initiates the route discovery by broadcasting RREQ to its neighbors using broadcast address 255.255.255.255. All the neighbors receive RREQ and check if it has an entry in the route cache for the destination node or either it itself is the destination node. If both cases are false, it will rebroadcast the packet until it reaches the actual destination. The destination will return a RREP message to the source node for each individual RREQ messages received. The source node on receiving multiple RREP will saves all routes discovered to the same destination in its route cache.

2.2 Route Maintenance

The route maintenance is initiated when a route on the path is broken. The source node is notified by Route Error (RERR) message which are returned on the same path of RREQ message in the reverse direction and finally received by the source node. The source node will then use an alternate path to send its transmission for the destination. In the absence of alternate path, it will again initiate route discovery procedure.

3. Enhanced Distributed Channel Access

The EDCA is a distributed, contention based channel access mechanism defined in IEEE 802.11E standard [9]. The standard defines it as "*The prioritized carrier-sense multiple access with collision avoidance (CSMA/CA) access mechanism used by quality of service (QoS) stations (QSTAs)*". [9] The EDCA categorizes traffic into four Access categories called AC_BK, AC_BE, AC_VI and AC_VO. Each AC has different priority assigned by the application layer. Table 1 shows the AC to UP mapping. [9]

AC	CWmin	CWmax	AIFSN	TXOP FHSS	Limit DSSS
AC_BK	CWmin	CWmax	7	0	0
AC_BE	CWmin	CWmax	3	0	0
AC_VI	(CWmin + 1)/2-1	CWmin	2	6.016ms	3.008ms
AC_VO	(CWmin + 1)/4-1	(CW + 1)/2-1	2	3.264ms	1.504ms

Table1. Access Category to User Priority mapping [9]

EDCA defines different contention window size and AIFSN values. The values are smallest for voice thus voice has highest priority and more chances to access medium. Our proposed scheme will exploit this feature to meet the required quality of service for voice traffic.

4. Literature Review

The major shortcomings in DSR protocol are listed. [12] The points which we have focused are optimizing the routing metric, to

find out least-delay paths and reduce longer route discovery delay and routing overhead.

The proposed scheme is formulated after thoroughly studying the protocol's operation [11] and a variety of research. [2] [4] [5] [6] [7] [8] [13] [14] [15] [16] [17]. These papers are work from different authors to optimize various MANET routing protocols using different cross layer designs schemes. The cross layer design principles and methodology [1] is explained by the Rappaport.

The basic idea of medium awareness to reduce routing delay is explained in [4]. The paper proposed a modified DSR routing metric which is based on MAC delay instead of hop count. The optimization scheme calculates the expected delay at the MAC layer, which is the sum of transmission delay, queuing delay, contention delay, transmission delay and propagation delay. The total MAC delay is calculated and transferred to routing function. The RREQ message of DSR route discovery function takes this information in a separate field to the next node and calculates accumulative delay. Finally the total path delay is calculated and returned to the source node using RREP message. The significance of EDCA mechanism over traditional DCF is evaluated [18].

5. Validation of EDCA

The EDCA mechanism was first tested to check its performance and the significance of traffic priorities mapped to the four access categories. The results are validated using a simple and short time simulation. A client-server model is deployed (figure 1). The server runs four applications namely, Database, FTP, Video and Voice mapped with the AC_BK, AC_BE, AC_VI and AC_VO respectively, to provide services to the client. All the applications are started at the same time and runs till the end of the simulation. The expected simulation results are that voice will experience minimum delay.

The result in figure 2 is a clear validation of the fact that the AC_VO have least media access delay while the AC_VI has greater than AC_VO. The AC_BK have maximum delay.



Figure 1. Client Server Model for EDCA validation

6. Proposed Scheme

6.1 Overview

The main idea of the proposed scheme is to produce medium awareness in the routing function. The hop count approach is no longer used in our scheme. The route discovery procedure is accomplished by the same RREQ and RREP messages. The format of the messages is altered to carry information of the link layer to the routing function for appropriate decision. Some features of the protocol's operation are disabled including stale cache and automatic route caching.

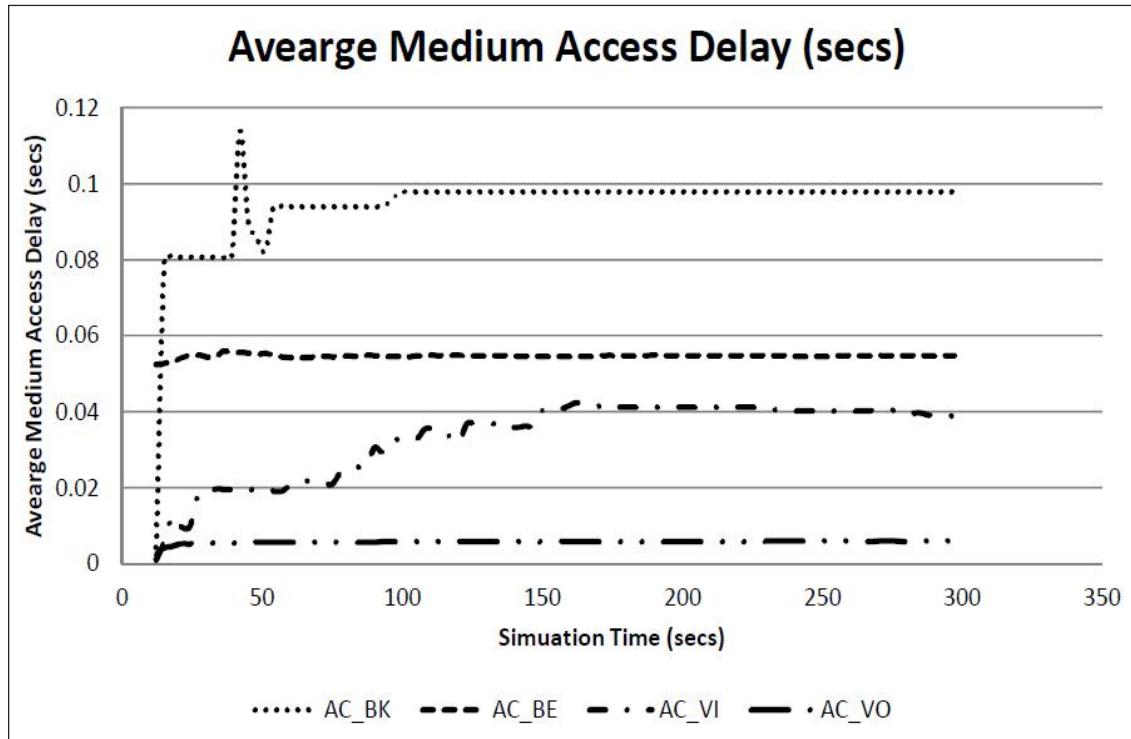


Figure 2. EDCA Access Categories Delay comparison

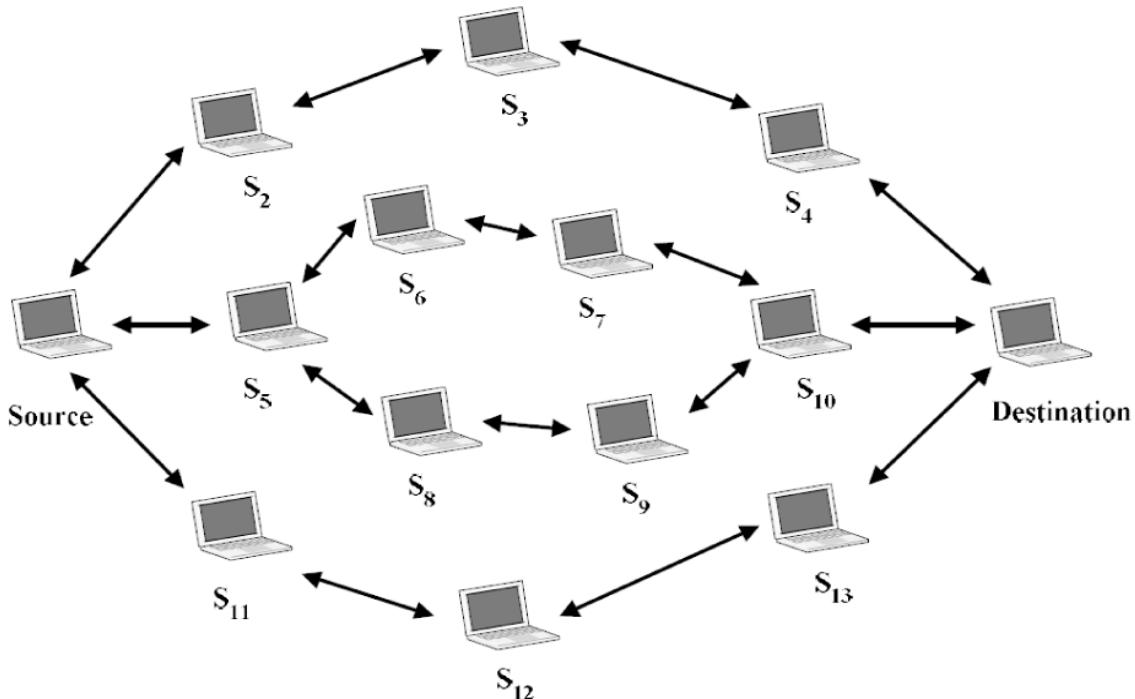


Figure 3. Simulation Scenario

6.2 Route Request

The modified RREQ message is shown in figure 2.1 along with the original RREQ message of DSR protocol. The four extra fields AC_BK_Delay, AC_BE_Delay, AC_VI_Delay and AC_VO_Delay are inserted in the message format. These fields contain delay

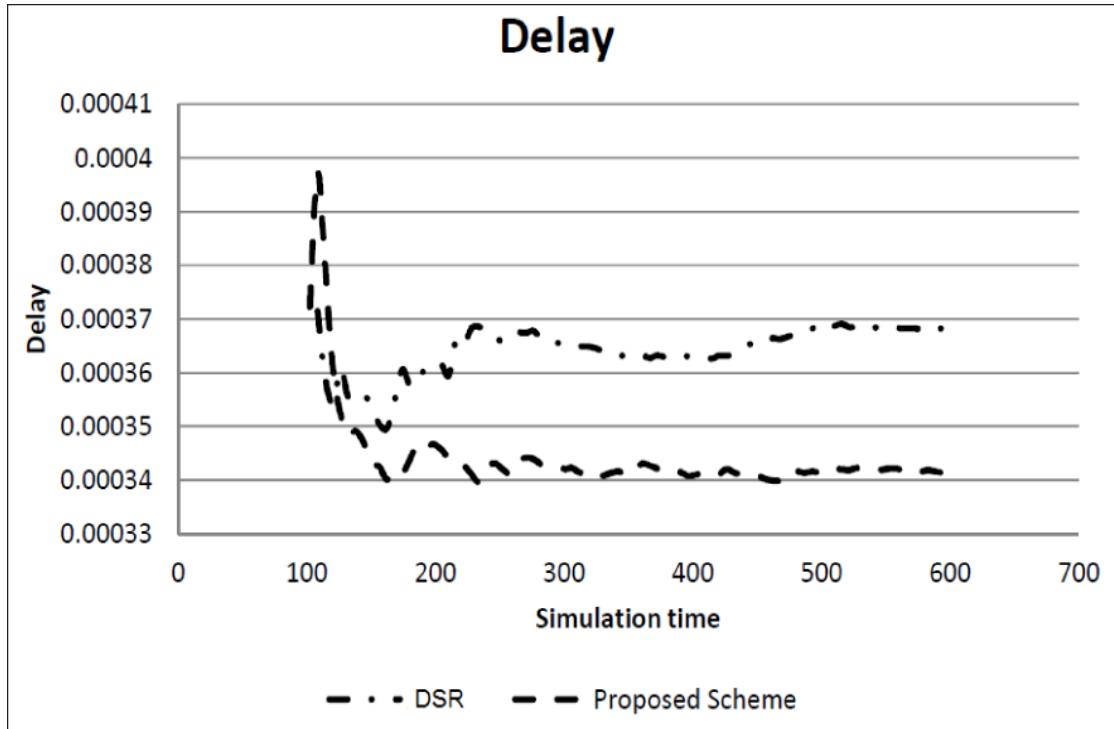


Figure 4 (a). Delay Comparison of DSR and proposed scheme

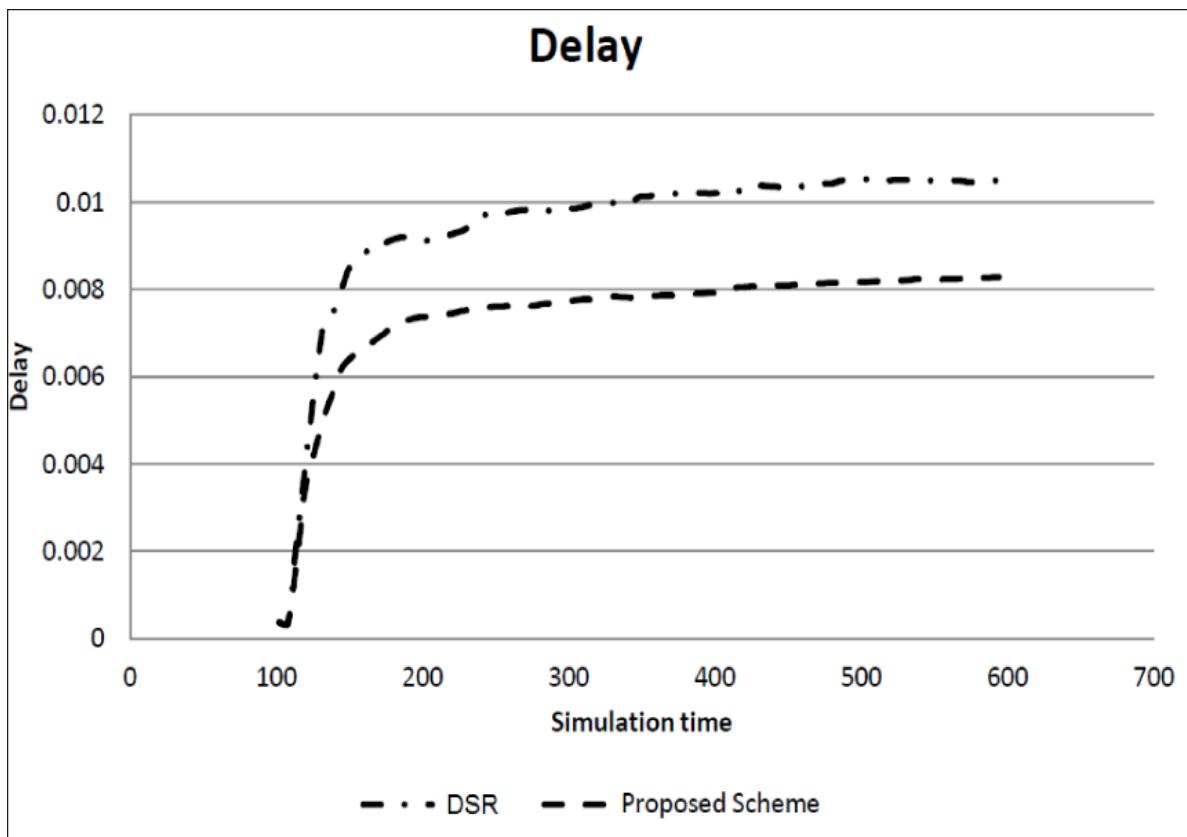


Figure 4 (b). Delay Comparison of DSR and proposed scheme

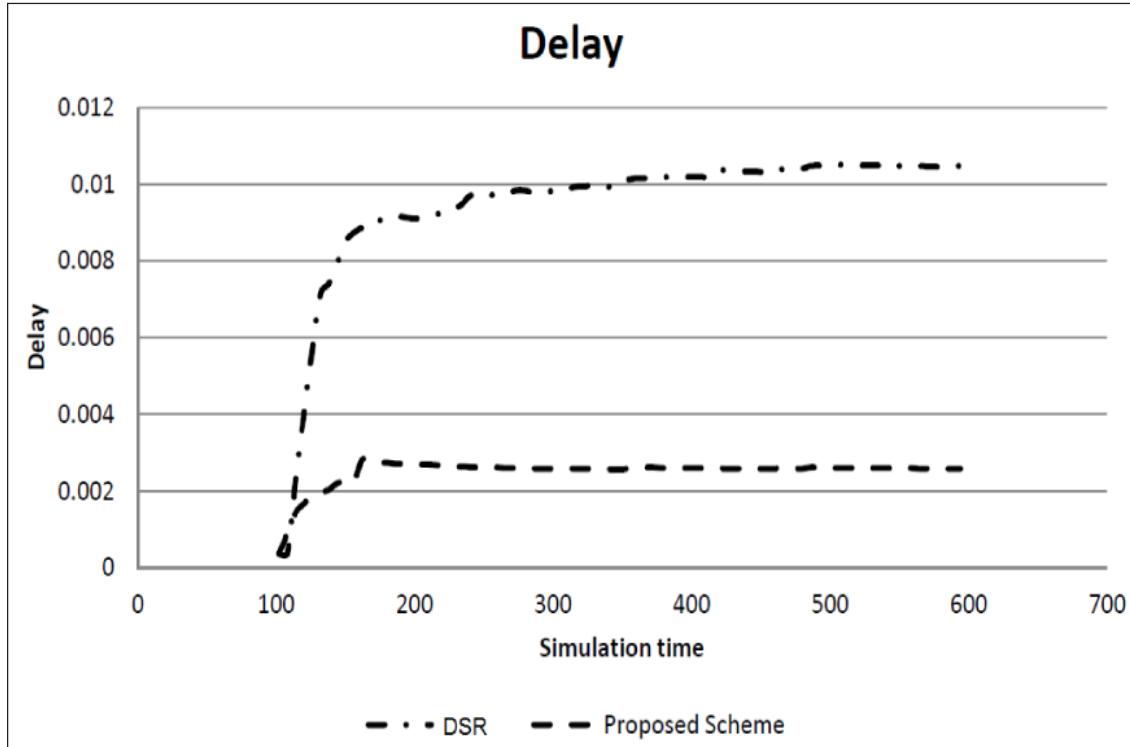


Figure 4 (c). Delay Comparison of DSR and proposed scheme

values associated with each AC at the MAC layer. The transfer of these parameters from MAC layer into the routing function is OPNET's mechanisms “*Global Attributes*” and ICI mentioned in next section.

6.3 Route Reply

The modified RREP message along with original RREP message is shown in figure 2.2. The four extra fields are the same and just copied from the RREQ message when it reached the destination node.

6.4 Route Cache

The route cache function is also modified in the proposed scheme. The route cache now stores at least four routes per destination, each for every individual access category with the associated delay information. The No. of hops field is no longer used and is eliminated to save memory.

7. Implementation

The proposed scheme is implemented in OPNET Modeler. [19] The OPNET Modeler supports IEEE 802.11E and implements all features of EDCA. The DSR protocol's implementation is defined at various levels including main process model and external C files. The functional block in the process model implements the operational steps of DSR protocol using Proto C language and OPNET defined kernel functions while the external files implements route discovery, route maintenance, route cache, send buffers, packet support and logs. The process model of DSR dsr_rte is located as a child process of manet_mgr which is the child process of ip_dispatch process model.

The cross layering is implemented using “*Global Attributes*” feature of OPNET Modeler with the help of OPNET defined kernel procedures. The mac_delay parameter is calculated by MAC layer in wlan_mac_hcf process which is the child process of wireless_mac.

The per HCF Access category MAC delay value once available to the DSR process model can be used in the routing function. The value is updated at the routing layer in real time. The next step is to change the RREQ and RREP messages.

The modified format of the RREQ message code is given below.

```
typedefstruct
{
    longint identification;
    InetT_Address target_address;
    List * route_lptr;
    Double hcf_ac_bk_delay;
    Double hcf_ac_be_delay;
    Double hcf_ac_vi_delay;
    Double hcf_ac_vo_delay;
} DsrT_Route_Request_Option;
```

The modified format of RREP message code is given.

```
typedefstruct
{
    Boolean last_hop_external;
    List * route_lptr;
    Double hcf_ac_bk_delay;
    Double hcf_ac_be_delay;
    Double hcf_ac_vi_delay;
    Double hcf_ac_vo_delay;
} DsrT_Route_Reply_Option;
```

There are also major changes in route cache and the external source files and the DSR function block as well which cannot be included in this paper.

8. Performance Evaluation

The proposed routing scheme is then evaluated to check its performance. The only performance metric which is our target is delay constraint. The network scenario used for our performance testing is shown (figure 3).

There are four routing paths between a pair of source and destination nodes. The two paths are four hops and two are five hops. We configured voice traffic on source node destined for destination. One of the two four-hop path has heavy AC_BK traffic configured on it. The standard DSR will always sense congestion on the path with heavy background traffic and send all traffic through the alternate four-hop path. Using single route followed by the voice traffic will cause delay for voice traffic and thus degrade its performance. Our proposed scheme will select route with lowest delay for AC_VO irrespective of the congestion caused by any other AC because the EDCA automatically gives highest priority to AC_VO. Thus we can also achieve load balancing on alternate paths which improves performance of our scheme. The simulation results are shown in figure 4 (a), 4 (b) and 4 (c). The three results exhibit performance comparison when different kind of traffic is configured on one of the path.

9. Conclusions

The proposed routing algorithm which calculates routing metric based on EDCA medium access delay shows a clear edge over the traditional DSR metric in terms of delay performance of the protocol for multimedia transmission. The overhead of the scheme may be greater than standard DSR operation.

10. Future Work

In this thesis we modified only the route discovery procedure and get performance improvements in static environment. As the nodes moves randomly and topology changes, the route maintenance is a mandatory portion of the protocol which still needs to be modified and optimize based on the modification done in the route discovery procedures.

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