

A Review of Gateway Load Balancing Methods in Connecting MANET into Internet

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Abstract—Interconnection of wired Internet and Mobile Ad hoc Network (MANET), called Integrated Internet-MANET can expand the network coverages and services. In this type of networks, the gateway acts as a bridge between MANET and wired Internet. As all data packets must pass through gateway, which is likely to be congested due to uneven traffic distribution. Thus, gateway load balancing become one of the most important issues in MANET. When the gateway is transmitting a large number of packets, load Balancing is the process of improving the performance of a network through a distribution of load among different gateways. If a gateway is heavily loaded without any load balancing capability, it degrades the performance by causing congestion, delay and resource loss in network. Recently, the key issue of gateway load balancing has been addressed by researchers in various ways, but now there aren't systematic analysis and comparison among different strategies. This paper provides the complete survey on load balancing solutions and proposes a gateway load balancing strategy comparison framework.

Keywords—MANET, Integrated Internet-MANET, Gateway Load Balancing, Strategy Comparison, Dynamic Gateway

I. INTRODUCTION

Wireless mobile ad hoc network (MANET) is a kind of special network that each node in this network serves as a router or ordinary host, and can join or leave the network freely [1]. Due to its self-management and easy-deployment, it is widely used in many applications such as disaster recovery, search and rescue operations, military service, and vehicular networks [2]. Although MANET is a promising technology that can be applied in many fields, there are yet many issues and challenges that need to be resolved, which mainly arise from the unreliability of multi-hop communication and the network's dynamics topology. These challenges require that the networking protocols must be modified or optimized, in order to adapt to the wireless environment. In recent years, a growing number of efforts has gone into the study of the network construction as well as maintenance, routing protocols in MANET has been proposed [3]. The routing protocols are classified into three categories: proactive routing protocols, reactive routing protocols and hybrid routing protocols. In proactive routing protocols, each node maintains routing information to reach other nodes in the network and updates its

routing table periodically. The reactive routing protocol creates routes only when nodes are needed. The hybrid routing protocols are a combination of the best features from proactive and reactive routing protocols. When MANET is connected to the wired Internet, the Mobile IP is one of the most popular and widely used protocol for allowing nodes to obtain single hop network connectivity [4]-[5]. Foreign agent as an Internet gateway to integrate MANET with the wired Internet in some solutions, however, deploying gateway between foreign agent and mobile nodes is a well solution [6]. Before all mobile nodes within the ad hoc network can communicate with other foreign nodes, they must be registered with a gateway in order to obtain Internet connectivity. The node registration process mainly includes three phases: gateway discovery, gateway selection and gateway registration. Specifically, the gateway discovery and selection mechanism are very key to connect MANET with Internet. The registration of mobile nodes in the Internet gateway can be done in one of three ways [7]. In order to realize gateway load balancing, strategies with load balancing mechanism have been proposed by some researchers. we have found that different strategies have very diverse effects on overall network performance by deeply researching these strategies. Given the need for gateway load balancing in MANET and its importance, in this paper, we briefly introduce these strategies and analyse routing protocols, gateway discovery, gateway selection and load balancing. Finally, we summarize the performance characteristics, application scenarios of various strategies, and the further research directions in this field.

The rest of the paper is organized as follows. Section II introduces gateway discovery methods. Section III briefly presents the main gateway load balancing strategies. Section IV compares the solutions proposed in section III. Section V concludes the paper

II. GATEWAY DISCOVERY METHOD

Currently, in order to access the Internet, nodes first obtain global connection information through the gateway discovery process and establish a connection to the gateway. During the gateway discovery process, gateways actively or passively issue gateway advertisement message (GWADV) to announce their service information. Nodes receive and parse the

GWADV to obtain global connection information and thus initiate a global connection or the node actively releases a gateway request to indicate that it needs to make a global connection.

Researchers have proposed a number of different gateway discovery strategies for MANET interconnected with the Internet, which can be broadly categorized shown in Figure 1.

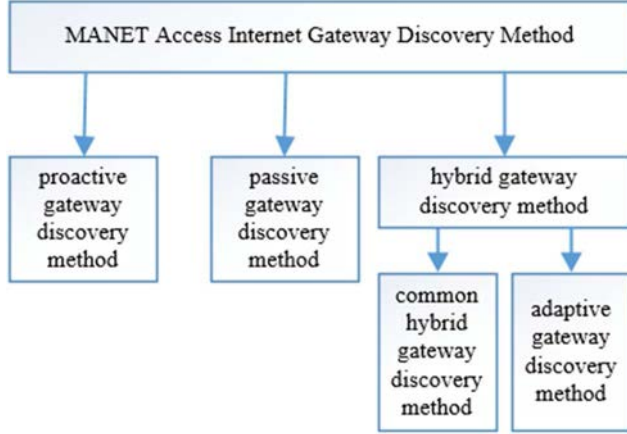


Figure 1. Gateway discovery methods

A. Proactive gateway discovery

The gateway periodically broadcasts gateway message (GWADV) to all mobile nodes within transmission range of the gateway message. A mobile node receives the GWADV message and creates a route to the gateway in its routing table if the node does not have a route to the gateway, otherwise, the node updates its previously saved routing table. The node then forwards the GWADV to neighbour node [8].

B. Passive gateway discovery

When a mobile node has an Internet demand and there is no default route to the gateway in its routing table, or the gateway information stored by the mobile node needs to be updated, the mobile node initiates the gateway discovery process by broadcasting gateway request to the multicast address of the gateway, and the intermediate node forwards the received gateway request information. Upon receipt of the request, the gateway unicasts the gateway message to the source node so that the mobile node can obtain the corresponding information [9].

C. Hybrid gateway discovery

The hybrid gateway discovery method is an integration of proactive and reactive gateway discovery methods. When a node is within a range of h hops from the gateway, the gateway node periodically broadcasts GWADV gateway information, and all nodes within the gateway transmission range can receive GWADV. when a node is out of range from the gateway h -hop, if the node wants to get gateway information, adopting a passive method, broadcasting the gateway request to the gateway's multicast address, and when the gateway receives the request unicast GWADV to the source node [10].

III. REVIEW OF RELATED WORK

Till now, in literature, load balancing techniques are based on a procession of gateway discovery and gateway selection, but they cannot completely eliminate or prevent the occurrence of load imbalance. In the previous research efforts, many approaches have been proposed to address how to improve load balancing from different aspects in MANET. The main contributions in this section are the investigation and the proposals of different solutions for gateway load balancing.

The LB-AODV routing protocol [11] is a combination of the AODV routing protocol and the concept of Load-Balancing (LB). The mechanism reduces the number of unnecessary retransmissions of routing messages, prevents heavy network congestion by separating source nodes into different groups and allows source nodes to relay packets generated only by their own group members. In order to realize load balance of each groups, the load balance index B is proposed. If the balance index B can be maximized by accepting this new source node into one of its serving groups, then this intermediate node will send a RREP message to the source node. Using LB-AODV routing discovery, the total number of source nodes between groups and groups can be minimized dynamically, but the determination of group number is critical for the efficiency of LB-AODV routing protocol. The appropriate number of groups can balance the network connectivity and routing control overhead. However, the optimal number of groups is not pointed out in this scheme, which will provide a direction for future research.

The dynamic gateway acts as an interface between MANET and the Internet [12]. These dynamic gateways can use Mobile IP and DSDV protocol when they communicate with the internet and interact with MANET, respectively. The MANET nodes accessing Internet will register with dynamic gateways, the registration includes two parts. The registration from gateway to foreign agent is proactive, from mobile node to gateway is passive. Whether it is active or passive, the advertising messages sent by foreign agents and gateways contains some important information. The algorithm of the dynamic gateway and foreign agent can be expressed as follows:

$$GWExp = DS \times n\% + NN \times m\% + QL \times k\% \quad (1)$$

$$GW = \text{Min} \left\{ \sum_{i=1}^j GWExp \right\} \quad (2)$$

$$FAExp = DS \times n\% + NN \times m\% + QL \times k\% \quad (3)$$

$$FA = \text{Min} \left\{ \sum_{i=1}^j FAExp \right\} \quad (4)$$

- NN : the node number of foreign agent and dynamic gateway.
- DS : The Euclidean distance between two nodes.
- QL : The queue long of data packets delivered on dynamic gateway and foreign agent.

This solution abandons the previous static gateway method and adopts a bottom-up method to adjust load balancing, which can optimize the performance of the entire system and improve

the reliability of the system, but it will increase the complexity of the registration process.

In this strategy [13] proposes a hybrid Internet gateway selection index to achieve load balancing of internal / external traffic in MANET. The load balancing metric consists of three components. The first component is the shortest Euclidean distance (in terms of hop-count) between the MANET nodes and the selected IGWs. The second component is the inter-MANET traffic load via each IGW, which is represented as the number of registered MANET nodes sending/receiving traffic to/from internet via that IGW. The final component is the intra-MANET traffic load within the network topology managed by each IGW. The information of three components is attached to the agent advertisement in the form of $((L_j, w_j), N_{reg}(j), N_j)$, where (L_j, w_j) is the internal traffic load of the MANET nodes managed by the gateway, $N_{reg}(j)$ is the number of registered nodes, and N_j is the number of nodes managed by the gateway. The mixed load index can be expressed as:

$$W(i, j) = a1 \times D(i, j) + a2 \times L_{internet}(j) + a3 \times L_{BMANET}(i, j) \quad (5)$$

$$a1 + a2 + a3 = 1 \quad (6)$$

In previous studies, the internal and external load balancing of the ad hoc network was considered separately. However, in this solution, the load balancing mechanism is part of the gateway selection process, and a hybrid gateway index is proposed to improve the performance of system, but it will increase the cost of control messages to a certain extent.

Aiming at the influence of gateway location and network topology on load balancing, a solution based on radio load (RLLB) is proposed [14]. The RLLB is a measure for how busy the medium around a node is. If the radio load is high, it indicates that the local node is transmitting a large amount of traffics, or nodes within the sensing range of the local node are sending lots of traffics. Defining the radio load as the amount of time T_{busy} within a time window T_{window} where the local channel is monitored busy. To estimate the average load L the strategy uses the exponential moving average as follows:

$$L_{new} = a \times L_{previous} + (1 - a) \times \frac{T_{busy}}{T_{window}} \quad (7)$$

where a is the weighting factor defined as a is $[0, 1]$. The strategy is part of the gateway selection process for two gateways, but theoretically, the strategy is also applicable to the case of multiple gateways.

In this paper [15], the network architecture consists of three tiers. At first tier, internet gateway (IGW) nodes which are directly connected to the wired network. At second tier, Access Points (Aps) or Mesh Routers (MRs) that forward each other's traffic in multi-hop fashion towards the IGW. This forms the lower layer, Mobile Nodes or the end users connected to the

MRs for accessing the wired network services. AS the gateways are responsible for forwarding all network traffic, they may become a potential bottleneck in the WMN. In order to overcome gateway congestion, this strategy proposes a clustering method based on k-means. This method divides the network into k clusters, calculating the gateway value of all available gateways in each cluster and selecting the maximum value as the cluster head. This strategy reduces the overall load of the WMN by dividing the network into k clusters and performing small-scale load management on the network, which helps to improve network bandwidth utilization, simplify routing, and improve network performance.

In this paper [16], the network architecture consists of Internet gateways and mobile nodes. The strategy uses an improved WLB-AODV routing protocol for communication, which is based on four parameters: hop count (HC), aggregate interface queue length (AIQL), aggregate routing table entry (ARTE) and latency parameter (Latency). Route selection according to the following equation:

$$M_1 = a \times HC + b \times AIQL + c \times ARTE + d \times Latency \quad (8)$$

$$a + b + c + d = 1 \quad (9)$$

Where a , b , c and d are the weights given to the respective parameters HC, AIQL, ARTE and Latency. In previous studies, the weights are all set statically, and the best weight value cannot be obtained. Aiming at the problem, this strategy proposes a weighted load balancing mechanism based on fuzzy control and genetic algorithm. This strategy optimizes the weights and has better performance than existing solutions.

Aiming at the intermittent connection caused by the high mobility of vehicles, a multi-criteria gateway selection method for load balancing of vehicle Internet is proposed [17]. The purpose of this strategy is to select a suitable gateway within the transmission range based on parameters such as gateway direction, received signal strength, distance, speed, and data rate. The vehicle broadcasts a request message (REQ). After the gateway receives the request message, it sends a response message (RESP) with gateway parameters. The vehicle searches for the list of available gateways from the received RESP message. For each parameter value, the gateway is assigned a location value. The location value of the gateway is assigned by sorting the gateways according to each parameter value. Each parameter has a predefined priority, as shown in Table 1:

TABLE 1. PRIOSITY LIST

Priority	Parameter
1	Load
2	Direction
2	Speed
3	Signal strength
3	Distance
4	Data-rate

Priority of vehicles based on the above information and parameters. Use the following formula to calculate the total load of each gateway, $SUM_i = \sum (\text{priority of parameter } 1 \times \text{position value of parameter } 1 + \text{priority of parameter } 2 \times \text{position value of parameter } 2 + \dots + \text{priority of parameter } j \times \text{parameter } j \text{ position value})$. Select the gateway with the smallest sum value for communication. This method uses real-time data to dynamically determine the gateway to improve connection stability, gateway load balance and minimize transmission delay.

In connection with the problem of uneven load distribution in wireless mesh network (WMN) which leads to an inefficient use of the network resources, increases latency in some routes, and decreases the average packet delivery ratio [18]. To tackle this problem, this paper proposes two WMN load balancing algorithms based on the AODV routing protocol, named AODV average queue (AODVMQ) and AODV weighted average queue (AODV-WMQ). The main idea is to select the route to the destination according to the average load of the node or the weighted average load of the node in a time interval. When the RREQ packet reaches a node, if the node is the destination and the RREQ number is not duplicated, the node sends back a Route Reply (RREP) to the source using the returning path. For intermediate nodes, if the node is gateway and the value of the variable gateway goes beyond a specific threshold g associated with the buffer size and waiting time of routers, it rejects that request, otherwise, the conventional AODV protocol is performed. In order to select the low-congestion path as the data transmission path. In this strategy, load balancing is built into the process of gateway discovery. By considering the different buffer capacity of gateway and grid nodes, the threshold is set to achieve load balancing.

In terms of the problem of unbalanced gateway load, this paper proposes a new load-sensitive optimization gateway selection scheme [19], which mainly includes $D_{\max}$ hop adjacency matrix, gateway selection, cluster formation and load-sensitive optimization. Defined as a $N \times N$ matrix of the graph $G(V, E)$, considering two MNs as neighbours to each other if they are within $D_{\max}$ hop distance to each other. The $D_{\max}$ matrix is represented by Eq (14). In Eq (15) $d(i, j)$ is the shortest distance between two nodes v_i

$$D_{\max(G)} = \begin{bmatrix} b_{11} & \dots & b_{1N} \\ \vdots & \ddots & \vdots \\ b_{N1} & \dots & b_{NN} \end{bmatrix} \quad (11)$$

$$b(i, j) = \begin{cases} 1 & \text{if } d(i, j) \leq D_{\max} \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

To ensure the maximum coverage of the MNs and the minimum distance between gateway and MNs, the Coverage Capacity to Distance Ratio (CCDR) is the appropriate matrix

for gateway selection. For a node v_i , the CCDR for gateway selection can be defined as h_i in Eq (16).

$$h_i = \frac{\min\left(\sum_{j=1}^N b(i, j), S_{\max}\right)}{\sum_{v_j \in NR(i)} d(i, j)} \quad (13)$$

Where $NR(i)$ represents all the neighbours of node v_i . The numerator of CCDR represents the coverage of the node while the denominator represents the sum of hop count of all its neighbours whose distance is less than the $D_{\max}$. After the gateway selection, the rooted tree is formed by selecting a gateway as a root node and assigning MNs to the gateway using the Breadth First Search (BFS) technique. When a node is selected as a gateway or attached to the root tree, it will be removed from the graph and a residual graph will be updated. After selecting the gateway, perform load balancing on each gateway. Check whether the current load of the gateway exceeds its maximum capacity $T_{\max}$. If this is the case, the node is transferred from a cluster with a heavy load to a cluster with a light load. After the shift operation, the current load of the two gateways is updated. The algorithm has better performance, can reduce ETE delay and reduce packet loss

Aiming at the problem of gateway load in hybrid MANET networks, this strategy [20] proposes a hybrid mobile ad hoc network gateway selection scheme based on bio-inspired. The scheme introduces the attractor selection model, which enables nodes to choose the appropriate gateway dynamically in a cooperative way. In this strategy, Assuming that the connections to all available gateways are represented by the state vector X , and each gateway is marked with the state variable X_i , the connection from the node to the available gateway can be defined as $X = [X_1, X_2, \dots, X_N]$, where N is the node's number of available gateways. After the gateway is discovered, the node periodically unicasts the detection packet to each available gateway. When the gateway receives the detection packet, it uses performance parameters (hop count, routing robustness, routing available capacity, and gateway availability Capacity) unicast a confirmation packet to enable the node to obtain the status information of the corresponding gateway. When an acknowledgement packet arrives at a node, the gateway selection preferences are calculated based on the performance parameters of the gateway, and the attractor selection model evolves driven by the gateway selection preferences. The attractor selection model updates the corresponding state values for all available gateways whenever the eminence value changes. By indirectly interacting between the gateway selection processes in a potentially cooperative manner, the attractor selection model can induce each node to adaptively select the optimal gateway in a dynamic environment, using the merit values as feedback. Since the superiority of gateway selection is based on statistical information about network performance, source nodes are able to adjust their gateway selection decisions accordingly based on state vectors.

IV. COMPARISON OF GATEWAY LOAD BALANCING STRATEGIES

In this section, a framework based on gateway load balancing strategies are proposed by considering network architecture, routing protocol, gateway discovery and load balancing parameters in MANET. This framework can be broadly divided into two parts, the first part is gateway

discovery, the second part is gateway load. In Table I, the network architecture of the load balancing strategy can be either two-tier or three-tier. In Table II, the gateway load balancing mechanism can be part of the gateway discovery or gateway selection process.

TABLE 2. GATEWAY DISCOVERY PARAMETERS

Load Balancing Strategy	Gateway Discovery Parameters		
	Network Architecture	MANET Routing Protocol	Gateway Discovery
LB-AODV [11]	Two tiers	LB-AODV	Passive
Dynamic Gateway [12]	Three levels	DSDV	Hybrid
Hybrid Metric [13]	Two tiers	AODV	Proactive
RLLB [14]	Two tiers	OLSR	Passive
K-WMN [15]	Three tiers	AODV	Passive
WLB-AODV [16]	Two tiers	WLB-AODV	Proactive
MCMGSA [17]	Three tiers	AODV	Passive
AODV-MQ AODV-WMQ [18]	Two tiers	AODV	Passive
LSOGS [19]	Two tiers	AODV	Proactive
Bio-inspired Gateway Selection [20]	Two levels	AODV+	Proactive

TABLE 3. LOAD BALANCING CRITERIA

Load Balancing Strategy	Load Balancing Criteria	
	Load Balancing Mechanism	Load Balancing Parameters
LB-AODV [7]	Gateway Discovery	Number of nodes, Number of groups
Dynamic Gateway [8]	Gateway selection	Number of registered nodes, Queue length
Hybrid Metric [9]	Gateway selection	Node to gateway distance, Network topology
RLLB [10]	Gateway selection	Radio load, Routing table
K-WMN [11]	Gateway selection	Node energy, Gateway average queue length
WLB-AODV [12]	Gateway selection	Hop count, Interface queue length, Routing length,
MCMGSA [13]	Gateway selection	Direction, Signal strength, Distance
AODV-MQ AODV-WMQ [14]	Gateway Discovery	Average queue
LSOGS [15]	Gateway selection	Distance, Node coverage capacity
Bio-inspired Gateway Selection [16]	Gateway selection	Hop count, Routing robustness

V. CONCLUSIONS

The interconnected technology of MANET and Internet have attracted increasing attention in recent years, and it is still in the developmental stage. This paper discusses, compares and analyses ten strategies for gateway load balancing and provides good insights for researchers for reference and further modification. We argue that diverse gateway load balancing schemes have different scenarios of application. From the perspective of gateway discovery, with an active gateway discovery approach, the gateways periodically broadcast advertising messages which causes a lot of overhead and is suitable for small-scale scenarios. With a passive gateway discovery approach, nodes initiate routes to the gateway on demand, which reduces routing overhead and is suitable for large scale scenarios. The Hybrid gateway discovery is a compromise between active and passive, and is suitable for large-scale scenarios. From the perspective of load balancing, when the gateway load balancing mechanism is based on the

gateway discovery process, the load balancing depends on the gateway to achieve, considering only the load of the current gateway, which will cause network performance degradation, suitable for small-scale scenarios. When the load balancing mechanism is part of the gateway selection process, the load balancing mechanism relies on mobile nodes to select an optimal gateway from the list of candidate gateways, which is suitable for large-scale scenarios. The comparison of the above various strategies only qualitatively analyses the gateway discovery and load balancing, and does not quantitatively analyse the performance overhead of the strategy implementation process. There are many more issues that need to be investigated in the future such as the gateway number in a dynamic gateway environment, QOS guarantee and Communication security.

REFERENCES

[1] Pham V. Performing Gateway Load Balancing in MANETs.[Z]. 2012.

- [2] Patel, R.S. and P. Kamboj. An Efficient Delay-Based Load Balancing using AOMDV in MANET. 2020. Singapore: Springer Singapore.
- [3] A M A, A T W, B E D. A review of routing protocols for mobile ad hoc networks[J]. Ad Hoc Networks, 2004,2(1):1-22
- [4] Perkins C E. Mobile networking through Mobile IP[J]. IEEE Internet Computing,1998,2(1):58-69
- [5] Khan K U R, Zaman R U, Reddy A V G. Integrating Mobile Ad Hoc Networks and the Internet:challenges and a review of strategies: International Conference on Communication Systems Software & Middleware & Workshops, 2008[C].
- [6] Zaman R U, Khan K U R, Reddy A V. A review of gateway load balancing strategies in Integrated Internet-MANET, 2009[C]. IEEE, 2009.
- [7] Kim Y, Lim Y, Ahn S, et al. Load Balancing Mechanisms in the MANET with Multiple Internet Gateways.[J]. 2006.
- [8] Kim Y, Ahn S, Yu H, et al. Proactive internet gateway discovery mechanisms for load-balanced internet connectivity in manet[C]//International Conference on Information Networking. Springer, Berlin, Heidelberg, 2007: 285-294.
- [9] Xi J, Bettstetter C. Wireless multihop Internet access: gateway discovery, routing, and addressing[J]. Proceedings of 3GWireless, 2002, 2.
- [10] Ruiz P M, Gomez-Skarmeta A F. Maximal source coverage adaptive gateway discovery for hybrid ad hoc networks[C]//International conference on ad-hoc networks and wireless. Springer, Berlin, Heidelberg, 2004: 28-41.
- [11] Song J, Wong V W S, Leung V C M. Efficient on-demand routing for mobile ad-hoc wireless access networks.[Z]. 2003558-563.
- [12] Zhao J H, Yang X Z, Liu H W. Load-balancing Strategy of Multi-gateway for Ad hoc Internet Connectivity.[Z]. 2005592-596.
- [13] Trung Q L, Engelstad P E, Skeie T, et al. Load-balance of intra/inter-MANET traffic over multiple internet gateways.[Z]. 200850-57.
- [14] Pham V, Larsen E, Kure O, et al. Gateway load balancing in future tactical networks[J]. 2010.
- [15] Das B, Roy A K, Khan A K, et al. A New Approach for Gateway-Level Load Balancing of WMNs through k-Means Clustering: 2014 International Conference on Computational Intelligence and Communication Networks (CICN), 2014[C].
- [16] Zaman R U, Alam H M, Khan K U R, et al. Amelioration of load balanced gateway selection protocol in integrated Internet-MANET: International Conference on Contemporary Computing & Informatics, 2017[C]
- [17] Bhore A K, Sharma A, Bhattacharya U. Multi-criteria mobile gateway selection approach in vehicular internet: International Conference on Communication & Signal Processing, 2017[C].
- [18] Pourbarmany J, Mirjalily G, Abouei J, et al. Load Balanced Ad-Hoc On-Demand Routing Based on Weighted Mean Queue Length Metric: 2018 Iranian Conference on Electrical Engineering(ICEE), 2018[C].
- [19] Kushwah R, Tapaswi S, Kumar A. Enhanced Gateway Deployment Scheme for Load Balancing in Heterogeneous Networks.[Z]. 20181-7.
- [20] Xu H, Zhao Y, Zhang L, et al. A Bio-Inspired Gateway Selection Scheme for Hybrid Mobile AdHoc Networks.[J]. IEEE Access, 2019,7:61997-62010



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