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# Cross Layer Optimization Routing Algorithm for Wireless AD HOC

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***Abstract***

*Throughput maximization is one of the main challenges in ad hoc networks, where the availability of local spectrum resources may change from time to time and hop by hop. For this reason, a cross-layer opportunistic routing algorithm for ad hoc networks is proposed, which is called the multi channel (MCPEF) algorithm. Through local control actions, MCPEF aims to maximize the network throughput by performing joint routing, scheduling, and transmit power control. Specifically, the algorithm dynamically allocates spectrum resources to maximize the capacity of links without generating harmful interference to other users, while guaranteeing bounds bit error rate (BER) for the receiver. In addition, the algorithm aims to maximize the weighted sum of differential backlogs, and which can stabilize the system by giving priority to higher capacity links with a high differential backlog. The proposed algorithm is distributed, computationally efficient, and it has bounded BER guarantees. MCPEF is shown through numerical model-based evaluation and discrete-event packet-level simulations to outperform baseline solutions; it will obtain a high throughput, low delay, and fair bandwidth allocation.*

***Keywords:*** *AD HOC, opportunistic routing, cross-layer, Qos*

## 1. Introduction

With the wide application of wireless Ad Hoc network, the data in the network business diversification, the proportion of multimedia services in wireless communication service increases unceasingly, these services often require the network to have enough bandwidth to support multimedia data transmission service [4].The traditional wireless Ad Hoc network routing technologies are difficult to meet the new demand, on the other hand, in recent years there have been many advanced communication theory and technology, such as OFDM, MIMO and cognitive radio, these new technologies improve the utilization of the spectrum, combined with new communication technology to provide quality of service guarantee has become a current wireless Ad Hoc network routing technology important research content of [5]. Wireless channel is open to bring the mutual interference between channels and the wireless channel quality time variability makes the design of wireless network routing mechanism is very complex. Traditional routing often ignores the channel quality and inters node interference factors, find out the route to meet the needs of users of the service quality. In order to reduce interference and improve network performance in the wireless network nodes, routing should consider

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topology and channel quality in wireless network. Wireless Ad Hoc network topology and the relative dynamic link quality is not stable, in the layered system under the network layer cannot be timely access to the underlying information to select an appropriate routing, hierarchical thinking seriously affect the performance of the system of wireless communication network, the cross layer optimization enhance the performance of the network has already become an important way for the design of wireless network protocols. In order to make full use of multi-channel resource in multi-channel Ad Hoc networks provide bandwidth guarantee end-to-end user business needs, dynamic channel allocation and optimal route this chapter combined with multi-channel Ad Hoc network options for cross layer optimization, multi-channel QoS interference aware routing establishment. This paper is organized as follows: in Section 2 describes related work routing algorithm and channel allocation algorithm in wireless multi interface multi-channel Ad Hoc network in the wireless Ad Hoc network; introduced the intra flow interference and inter stream interference in the Section 3 , put forward the remaining estimation method with wide wireless network and first dynamic channel switching and passive joint optimization of QoS routing is proposed for QoS multi-channel path; through the simulation experiment, Section 4 will discuss the performance of the routing algorithms; finally the conclusion is given out in Section 5.

## 2. Related Work

In recent years, due to falling hardware costs, multi interface (such as a plurality of wireless network card) multi-channel (such as multiple orthogonal channels) techniques are frequently used in wireless Ad Hoc network [15].Through the channel allocation properly can make multiple wireless links in the interference range while parallel data transmission, which can improve the throughput of wireless networks in the network, meanwhile, how to reasonably allocate channel to enhance the network performance that has attracted extensive attention of researchers. Channel allocation and network layer routing in wireless multi interface multichannel networks are closely related, on the one hand, channel distribution will affect the network topology, and affect the routing choice; on the other hand, routing will affect the distribution of network traffic and the channel allocation. Channel allocation is generally divided into static and dynamic allocation, dynamic channel allocation in initializing the network pre assigned fixed channel assignment is completed no longer switch; dynamic channel allocation corresponds to make adjustment according to the changes of the elastic flows in the internet. Dynamic channel allocation in a wireless network can be divided into two categories: one category is weakening the interference of local area network for the purpose of [10], another is balance the local network load for the purpose of [13]. In the first scheme, the detection of external interference nodes periodically through broadcast is sent to the neighbor node, while minimizing the external interference can improve network performance by reducing the total interference of the networks, but it does not consider the traffic load on the links; in the second kind of scheme, each node periodically measure their link load, when the load exceeds the link capacity link capacity, switching channels seek better channel switching scheme from a link point of view, it is difficult to guarantee the end-to-end bandwidth requirements of multi hop routing. Wireless Ad Hoc network source sends data streams often need to pass forward reach the destination node multi hop, how to choose a suitable routing is the main research content of the wireless Ad Hoc network [1]. The basic Ad Hoc network layer protocol and data link layer protocol in order to support QoS guarantee, when the network needs to provide quality of service to be extended as 802.11QoS mechanism by priority scheduling and fair allocation to provide differentiated service QoS [11]. Looking to meet bandwidth constrained routing problem is NP hard [2] in multi hop wireless networks, some intelligent algorithms such as the ant colony algorithm is used to solve the multi constrained [11] routing problem. But most of the current model assumes that the link capacity is fixed, ignores the coherence between the wireless links, and is not consistent with the actual environment of wireless network. QoS routing is present mainly in the single interface for single channel networks, routing key to provide quality of service in interference limited wireless Ad Hoc networks is to estimate and residual bandwidth on the path of call admission control in [9]. In IEEE 802.11DCF networks, due to random access MAC layer makes very difficult for QoS routing in the network, this is mainly because it is difficult to accurately estimate the remaining bandwidth on the route, if the residual bandwidth is overvalued, it may lead to more through allowing access to data and produce congestion; if estimated too low and it may result in waste of bandwidth and reduce the network performance. Literature [7] presented residual available bandwidth estimation scheme, load parallel transmission through double carrier sense, more accurately estimate the residual bandwidth by using RTS/CTS mechanism, calculation of the new arrival data stream bandwidth needed by the call admission control to decide whether the data access new flow request. Document [14] uses hidden terminal and channel information to estimate the residual bandwidth and available bandwidth, it not only is through jamming decision within communication range and it will also receive the communication outside the scope of hidden terminal interference effects by using the load of neighbor nodes can estimate the available bandwidth. The scheme is mainly applied to single channel Ad Hoc networks. In the multi- channel network, consider allocating different channels on the link conditions need to be in the process of routing setup, Draves *et al.*, proposed a routing scalar called WCETT in [6], to reflect the interference condition of different channels in a multi-channel network routing, WCETT reflects the cumulative end-to-end delay and flow interference, but they put forward routing cannot provide QoS support; in order to provide to meet the bandwidth requirement of routing, in search of the routing process priority link residual bandwidth maximum may improve for satisfaction into power index of QoS routing. Literature [8] presented a fixed channel allocation of multi interface multi-channel QoS route mechanism, through the control message information carrying channel utilization rate of OLSR, each node can obtain the topology of the whole network and the residual bandwidth path information, source node can find the maximum available bandwidth is built QoS routing, this approach does not consider the channel switching, and each node is obtained all the information of the whole network requires a large amount of broadcast. Literature [9] presented QoS routing in wireless multi- channel network IEEE based on 802.11DCF, taking into account the interference among the nodes and link access random competition, they proposed scheme is firstly estimated residual bandwidth through the interference range node and its data flow occupancy time to compute the residual available bandwidth, then integrated access provide QoS route control mechanisms. Selected routing not only considers the residual bandwidth, but also considers path cost. These routing mechanisms consider the channel diversity, but they did not consider the channel assignment, network all channel in initializing the network ahead of static allocation and channel allocation network initialization will affect the performance of the network. In the aspect of dynamic channel allocation, according to the two hop neighbor in literature [15] queue accumulation calculated load condition to dynamic selection of channel, reduce the interference of nearby nodes, without considering the access control, it is difficult to solve the problem of network congestion. Document [3] first consider dynamic channel allocation of QoS routing table routing path, use good, then the path does not meet the link switching QoS channel, so that the path can provide QoS guarantee. But the routing table needs to obtain the latest state of the whole network real time switching, and they put forward are too complex, only discussed from a general mathematical model, without considering the network IEEE 802.11DCF this competition channel. [12] research literature IEEE 802.11DCF network QoS channel assignment and routing optimization based on the reference [3], channel estimation of residual bandwidth carrying neighbor information using routing table OLSR HELLO message and TC message, and then according to the optimal path topology information and residual bandwidth information, routing table with global information, easy to realize, but frequently in the control message in a distributed network update will produce a large amount of communication overhead. At present, in the research of multi-channel QoS still exist the following problems: (1) the majority of research results is the fixed channel allocation; (2) study on the model of a few dynamic allocation is too simple, it is difficult to effectively guarantee QoS, communication of multi-channel QoS routing table needs periodic broadcast a lot of produce more based load; (3) dynamic channel routing scheme into new data stream, may produce ripple phenomenon, this led to a rapid increase in complexity of channel switching produced; hence the need for further research of dynamic channel assignment in QoS routing problem. In this paper, the QoS passive routing and dynamic channel allocation combined with consideration on the basis of existing research, the multi- channel QoS an interference aware routing scheme.

## 3. Problem Formulation

Hypothetical scenarios is a static N network of wireless nodes, node arrangement will no longer move or position changed little, between nodes self-organize into a network through multi hop, not the destination node in the emission range using multi-hop relay routing and forwarding data. Having a plurality of channel in the system, each node has a plurality of radio frequency interface, wherein a fixed channel assignment as a common control channel, the other radio interfaces assigned data channel to transmit data. Separate channel is considered as a common control channel, which is benefit: thus can ensure that the network connection and avoid different channel allocation to lead to network partitioning; to provide QoS access control and maintain mechanism; reduce network strict synchronization requirements, network synchronization in a multi hop network is very difficult. In addition, the residual bandwidth control channel can be used to provide best effort data flow. The IEEE 802.11 DCF wireless Ad Hoc network based on RTS/CTS is considered, which adopts the reservation channel mechanism. All data channel has the same transmission range (Transmission Range, TR) and the interference range (Interference Range, IR), the general assumption interference distance is two times of the transmission distance. The presence of K is unrelated to orthogonal channel in the system, the interference between different channel system can be ignored. WMN measurement report points out PHY layer in wireless networks, link capacity is stable and predictable, its capacity is mainly affected by the wireless interference limits. Through the RTS/CTS mechanism the network can avoid interference, the link capacity is stable. In multiple channel networks, link (I,J) using the K channel capacity can be expressed as ($K_i$, $J_C$). The actual available capacity of the network is not only determined by the channel capacity, but also the interference of adjacent nodes are limited, the following will introduce interference model in wireless network, and design of multi- channel estimation method remains available link capacity.

### 3.1. Dynamic Channel Allocation Interference Aware QoS Routing

Wireless Ad Hoc network routing is mainly divided into routing, on-demand routing and hybrid routing *etc*. On demand routing does not need to synchronize the whole network, distributed build initiated by a source node, suitable for large-scale wireless self-organizing network. On-demand routing approach is designed based on QoS multi-channel routing in this section.

### 3.2. Routing Process

Suppose a source node $n_i$ needs through the network to objective end points DN launched *f* data stream, data stream needs to meet certain bandwidth guarantee. A source node first checks the routing table, if there is such a routing directly accept, or to initiate the route request. In order to find the appropriate routing of data flow of F, the source node needs to request broadcast routing on a control channel. Intermediate nodes based on the received route request packet to decide whether to forward or discard, when reaching the destination node exists and meet the QoS routing, the path back up. In order to facilitate the intermediate node to make a routing request message RREQ generation, the need to carry part of the path has been information, these information and update with the RREQ in the forwarding per hop node. Assumptions in the current routing forwarding node in a $n_x$, a source node $n_1$, each node of $i$ can be transmitted using multiple channel request message need to record channel $C_i$ and the corresponding $If_i$ interface. When the front through the part of the path can be represented as ($n_1$, $n_2$) $C_1$, $If_1$, ($n_2$, $n_3$)$C_2$, $If_2$, ($n_3$, $n_4$) $C_3$, $If_3$, ......,($n_{x-1}$, $n_x$) $C_{x-1}$, $If_{x-1}$, wherein $C_i$ represents the $i$ nodes by letter Road, $If_i$ represents the I nodes using the interface, the information at each hop update and with the request message. In order to facilitate the intermediate node routing, request message still need to carry through each channel node interference neighbors set on the remaining available link bandwidth $ni_n$ and each link $CA^t_\phi$ ( $n_i$, $n_{i-1}$, $f$). The main process route is established for the:

(1) Started the RREQ stage

If the node will need to initiate the flow request, and the current routing table has no corresponding routing or does not meet the current demand, the node initiates a RREQ. The initial node ID, use interface, channel and interference neighbors set to join message, adding bandwidth demand flow and maximum life cycle of TTL RREQ set. Message waiting routing should be cached (*e.g.*, in RREQ transmission after waiting for RREP), start the timer for timing, in excess of timer time, did not receive any RREP information to the high-level failed to establish sends a route.

(2) prior to the routing stage

In the forward routing phase, the source node to node ID add their own into the request message as the path nodes, by request to the broadcast neighbor nodes, when an intermediate node receives requests from the RREQ after treated as follows: when a node receives a RREQ, first to determine whether the current node appears on the part of the path of the RREQ, if the current node appears in the path, the description of the RREQ loop is generated, the node discards the newly received RREQ to prevent routing loops. In preventing the emergence of loop, judging a node $n_{i-1}$ to the residual bandwidth of the current node $n_i$ whether meet the bandwidth requirement of stream F. First determine the two node whether has the common data channel, if there is residual available bandwidth judgment in the channel on K whether meet the requirements that $n_{i-1}$ interference will not bring, that is $k_f < CA^t_\phi(n_i, n_{i-1}, f)$ and select the link after the destruction of link bandwidth constraints of existing path constraints, if meet the node and the corresponding information is added into RREQ to continue routing operation, if there is no match for a carry out the following link operation: to determine the existence of free interface, if not then refused to accept the request to drop RREQ, otherwise the remaining free channel list $Unused_{channel}$ ($I$). If you cannot find the available channel the RREQ is discarded, otherwise it will channel the node and choose as the quasi switching channel, corresponding to the free interface ID No. If $i$ is added to RREQ, and add the node in each A set of $N_{Ik}$ interference channel (I). If the same precursor link channel is used in the interference and range $N$ ($i$, $j$) is not empty, the remaining available bandwidth will update precursor link. The existence of available link will be identified in the nodes after the routing mechanism will be performed, determine the current path is the need for further forwarding.

(3) Routing mechanism

The shortest path mechanism will not consider the differences between traditional wireless network link capacity and adopts the minimum hop count as the criterion in the network, some long link capacity are few chance of being selected for routing, which leads to the low capacity in end-to-end path. This does not consider the network shortest path interference diversity and link capacity is not suitable for multi-channel network environment. In order to improve the success rate of QoS routing, path finding residual bandwidth most wide to the low success rate of reduce the link prediction is not accurate to bring QoS's shortcomings, but also may lead to find the path that is too long, excessive consumption of resources (need multi hop or multi interface). Route selection should not only consider the residual bandwidth link, but also the choice of the link interference on the size of the network. Considering the network in general there are a plurality of flow, need to produce balanced bandwidth and path interference, interference of this paper chooses the path generated by the minimum bandwidth according as current path and the path set ratio as a measure of standards. Let $W(P)$ represents the current all links on the path $P$ minimum residual available bandwidth, *i.e.*,

$$W(p, f) = minca^{t}_{\phi}(i, j, f) \quad (1)$$

where routing decision is expressed with $M(p, f)$ :

$$M(p, f) = W(p, f) / INC(p, f) \quad (2)$$

Routing decision is to choose the best bandwidth path interference: as is shown in formula (2), The minimum bandwidth reaction path bandwidth, and $INC(p, f)$ show that the path of $P$ space-time link flow $f$ occupancy ratio and interference neighbors by product quantity, the value the more interference is produced on the network. The intermediate node routing scalar calculations before forwarding, only when the node receives a better routing or received for the first time to the node RREQ to forward, otherwise discarded directly without forwarding the route. If the destination node receives the RREQ and determine feasible after, to return to sponsor the RREQ node of RREP, the intermediate nodes need to carry out corresponding treatment after receipt of the RREP. The specific process of pseudo code as shown in algorithm 1:

(4) RREP returns processing

After the timer delay, the target node to choose the best path to construct a routing message RREP returned along the original path back to the target node, intermediate nodes receive after check whether there is a channel switching, if there is, will be replaced by settings for the selected channel and broadcast channel. The path of each node receives the RREP containing the selected, each intermediate node using the path through the control channel sprang forward routing and forwarding RREP, after the establishment of forward and reverse path forwarding path.

(5) Channel initialization and maintenance

The network initialization stage all data channel and data interface is in the idle state, when the two nodes ($I$, $J$) channel and there is no corresponding data flow in the above transmission, after a long time after the release of the interface and the channel nodes, the release of the interface can be used in distribution channel of good quality to enhance the probability of finding the right route. Table release channel also broadcast notice neighbor node updates the neighbor nodes corresponding.

(6) Channel exchange and negotiation

When the request packet in the forwarding process needs to switch channel, through a channel selection mechanism to select the appropriate channel, because the channel selection mechanism considering the end nodes on the link the current channel condition, so the channel selected can be switched. When the link receiving routing to return message RREP, channel switching, after the switch announcement neighbor node update.

Algorithm 1: MCPEF algorithm

**if** node *x* in path *p* **then**
  RREQ packet is discarded;
  **exit**;
**else** channel *C* ← **used channel *f* or node *x*;**
**while** *C* is not empty **do**
  Updates every time △*t*;
 end while
**if** *C* is empty **then**
 **For** each channel k in common channel
  **if** *k* is not empty **then** *C* ← ***C* U *k*;**
  **else** RREQ packet is discarded;
 **For** each node *i* cache *j* cache message
   **if** $D_{xi} > D_{xj}$ **then**
    Node *x* to forward this message to *j*;
    Delete the message from node *i* in the cache;
   **else**
    Node x continue to carry the message;
 end for
end for
end if

## 4. Performance Evaluation

This section will use the NS2 network simulator to evaluate the routing algorithm. Simulation of all nodes in the stationary distribution in the 1000 * 1000$m^2$ two-dimensional plane, grid is divided into regular network topology and random distribution. Data transmission channel distance of each node is 250*m*, the distance of 500*m* interference. Control channel transmission distance is two times the data channel. Each of the channel capacity of 2Mbps, each node has 5 interface, at network initialization, an interface distribution control channel, the other interface randomly assigned data channel. There are 11 channel systems, of which one is a common channel. With the RTS/CTS IEEE in the MAC layer of 802.11 DCF collision avoidance mechanism. In a grid like uniform arrangement of the 5*5 node in the regular network, in the scene 30 nodes randomly distributed random distribution, node arrangement will no longer move. In order to measure the performance of routing scheme proposed in this paper, firstly selected by multi-channel multi interface wireless networks are commonly used in WCETT routing strategy as a comparison object, WCETT only considered without considering the inter stream interference flow; choose another interference aware in literature [9] multi letter road by strategy of PEF (Path efficiency factor) routing as the object of comparison. This paper presents the algorithm named MCPEF (Multi channel path efficiency factor) routing. According to Table 1 configuration parameters, each experiment was performed multiple analog averaging as criterion, each simulation are independent of each other, in the network initialization data channel randomly distributed over the nodes on the interface when the interface assignment, channel no neighbors same distribution channel is to re select the channel assignment. Figure 1-2 show the system throughput in different network environment (Grid environment and Random environment). The system throughput increases when flow number of access network increases. It is also easy to see that MCPEF our proposed has higher throughput in both two environments. This main reason is MCPEF adopt the adaptive switch method to achieve the success transferring, while WCETT and PEF just consider disturbing of in-flow and out-flow, so the performance is lower. In Figure 3-4, the delay of these algorithms are presented, we can see the delay is increasing when flow number of access network increases, the delay of WCETT is the maximum, MCPEF has lower delay, which adopt the method with fastest finding the best routing hop and can use less time to transfer data, so MCPEF our proposed can obtain the few delay.

**Table 1. Experiment Setup**

| Parameter | Value |
|---|---|
| MAC Protocol | 802.11 |
| Speed | 0.5-1.5 |
| Transmit Ratio | 250 |
| Node Buffer | 3 |
| Simulate Time | 12 Hour |
| Queue Length(k) | 70 |

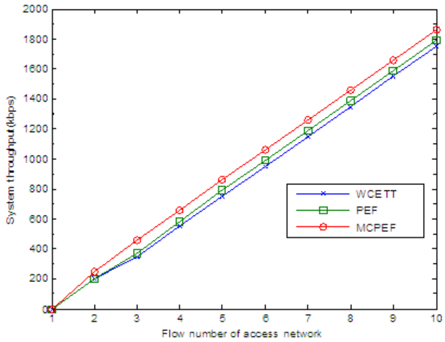


**Figure 1. System Throughput in Grid Environment**

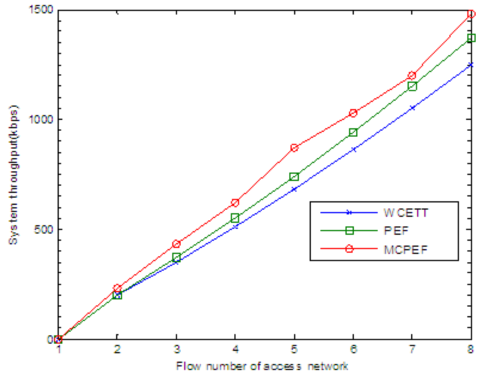


**Figure 2. System Throughputs in Random Environment**

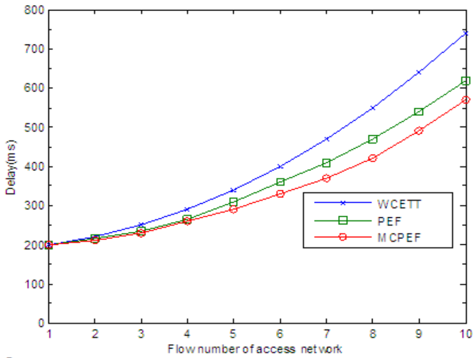


**Figure 3. Delay in Grid Environment**

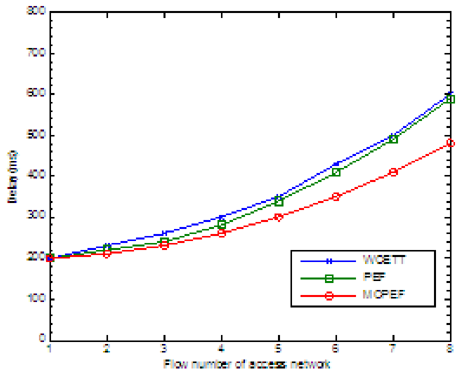


**Figure 4. Delay in Random Environment**

## 5. Conclusion

In order to effectively use the wireless multi interface multi-channel cyber source to meet the growing require for wireless bandwidth, channel allocation and routing combined with optimization by scholars, the most researches in this field mainly aim to reduce the interference channel assignment, in order to provide QoS for routing, which will adopt TDMA scheduling method to solve the a problem, while distributed characteristics and TDMA mode is not suitable for Ad Hoc network. In order to provide multi-channel 802.11 for QoS routing in the network environment, the number of fixed channel routing and cross layer multi-channel routing table based design scheme are proposed, and existing research findings are different, this paper considers QoS scheme of passive routing dynamic channel allocation algorithm, which not only can improve the

QoS satisfaction rate, but also can avoid routing table periodically broadcast message updates from the network overhead. In a wireless network interference model and presented a dynamic channel allocation algorithm for QoS routing. In this paper, the design of routing algorithm considering the wireless Ad Hoc network interference with the flow, in the process of building the routing, according to the path cannot meet the constraint of link bandwidth, in order to reduce the interference between wireless Ad Hoc network node, through the channel link channel switching on the search for poor quality to meet the bandwidth constrained routing, dynamic channel allocation algorithm to achieve a balance between link residual bandwidth and other nodes of the network interference. Simulation shows that this algorithm can improve the QoS user's acceptance rate, and reduce the network between the same frequency channel interference, improve the network performance. Through the analysis of dynamic channel switching mechanism, this paper proposes relative to the static channel allocation, which is beneficial to improve the network performance. Of course, the interference model proposed in the protocol layer just is considered, it is a relatively simple, without considering some special relation between the nodes in the network, the estimation of residual bandwidth in this paper using the accuracy still needs to be improved.

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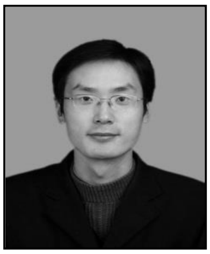

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