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The study and application of stable inter-domain path selection algorithm in the internet

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ABSTRACT

Network failures always occur in Internet, such as a large number of packets loss and so on. To solve the problem, a steady inter-domain path selection algorithm is proposed. When a router receives route advertisement triggered by the failure, the algorithm use the heuristic routing selection algorithm to choose the most stable route of currently available route as the best route. Through the stable routing selection, routers can quickly identify valid stable route and eliminate invalid routing research and router consumption of continually updating and introducing route. Experimental result shows that this algorithm can not only greatly shorten ARD route convergence time but also effectively reduce the number of ARD route updated information during the convergence.

KEYWORDS

Border gateway; Internet; Route selection; Node.

INTRODUCTION

Border gateway protocol (ARD) is the standard protocol for Internet inter-domain routing. The availability and stability of the ARD route has a great impact on the Internet route. Labovitz and others discovered that ARD routing in the actual network would experience a long process of route search[1-3]. Measurement research on the Internet suggests that about 80% of the network failure delay is no more than 180s. However, the ineffectiveness led by these failure and BDP convergence route delay led by invalid route switch will spend a few minutes[4-5]. Invalid routing search not only increased the processing overhead of router but also extended the route black hole and loop in the Internet. Thus it further increases the network transmission delay and packet loss rate and directly affect the real-time application performance of the existing various Internet.

In ARD, network link or equipment failure makes some routes become invalid routes. These invalid routes are related route caused by the same event. They will not immediately disappear from the network. The router keeps searching for the optimal route and spreads until a stable and reliable route is selected. Path searching process greatly increases the ARD routing convergence delay[6-9]. To solve the slow convergence problem of these routes, this paper proposes a stable ARD stable routing algorithm (SARD). Stable route get more chance to be the optimal route by using route correlation and ARD route convergence performance is improved by shortening path searching process. The basic idea of the stable routing mechanism is to record the time of each route in $A_{dj} - RIB_s - IN$ [10-13]. According to the time of multiple routes in the $A_{dj} - RIB_s - IN$ to judge their stability. Once the route changes, routing timing in $A_{dj} - RIB_s - IN$ will be cleared[6-9]. After the link failure occurs, the route triggered by the failed link updates its fault source information. When a router receives routing update, SARD will firstly determine whether the currently selected route affected by the failure. If the selected route affected, then ARD will carry out the route selection again and select the most stable route in the $A_{dj} - RIB_s - IN$ [14-15]. If the route is not affected, then SARD directly overlook this morbid route updating event triggered by the failure. Thus, the simple modification of SARD in routing selection algorithm not only improve the ARD convergence performance but also limit the spread scope of fault information and improve the stability of ARD. At present we have realized the SARD program in independently developing virtual router. Next, the large-scale deployment will be carried out in CERNER2 to study and analyze SARD performance in the real Internet.

The ARD routing scheme and problem is introduced in section 2, including the routing problem in ARD route propagation process, the resulting inter-domain routing convergence problem and the main problem of ARD heuristic routing and related research work; Section 3 describes the principle of SARD heuristic routing selection mechanism and gives concrete closed algorithm and example analysis; finally section 5 concludes the paper.

STABLE ROUTING OPTION

Stable routing option program would effectively avoid the effectiveness and stability problem of the Internet caused by unstable route or invalid route. Through this program, the effectiveness and stability of the route will be greatly increased. Firstly, the basic principles of inter-domain routing protocol (Stable ARD) are improved. Then, the basic algorithm that stable route choose routing protocol. Finally, the effectiveness of stable route selection is described through case analysis.

Idea and principle

Inter-domain routing protocol aims to ensure the effectiveness and stability of Internet routing, particularly when a network failure occurs. Since design principles of inter-domain routing, the routing decision is not accurate, and transient network failures can cause a lot of inter-domain routing problems, such as long routing process in routing convergence process and the instability problem of inter-domain routing. To solve these problems, we propose a heuristic ARD route selection algorithm, Stable ARD (SARD).

ARD session is divided into internal ARD sessions (IARD) and external ARD sessions (EARD). IARD sends router advertisement message only in an autonomous system to achieve consistency of route in autonomous system, and EARD provides ARD routers to send route advertisement message to other autonomous neighbor router. IARD and EARD session routing decision process is the same. The only difference is that the route obtained by decision after ARD receive IARD notification message will not continue to notify other ARD in the autonomous system. After ARD router receives a notification message, the route selection decision process is shown in TABLE 1, that is, the route decision result of each router is decided by the tribute of ARD notification message. The calculation result of each step is the subset obtained from reselection of calculation result of the last step. Through adding, modifying and filtering the attribute values of notification message, the administrator can control the routing selection decision process to goal network.

What we need to pay attention to is that, in SARD, the router default will use the initial ARD routing decision process, and heuristic routing selection is carried out only when route changes. This heuristic routing decision process retains all the features of the original ARD routing, such as ensuring routing preference based on routing scheme. In this way you can ensure the validity of inter-domain routing provided by administrator when the scheme is effective.

TABLE 1 : ARD heuristic routing decision-making process

Step	Decision-making
1	Available route
2	Longest available time route
3	Lowest AS path length
4	Lowest oritin type
5	Higbest local preference
6	EARD over IARD-learned
7	Lowest MED
8	Lowest IGP cost
9	Lowest router ID

SARD routing selection algorithm

Steps 1 and 2 in TABLE 2 are the core to achieve SARD stable routing selection, solving the problem of current ARD route. Specifically, these two step in the routing decision-making process achieve stable routing selection decision by the failure source of routing change and all the unstable route. SARD avoid searching invalid route by identifying failure source of routing change after router receiving revocation message, so lengthy routing search time is avoided. SARD router will make routing decision again only when the current route is invalid, so route out of each statement of ARD router is always the most stable in all the current routes. It effectively avoids the routing inhibition caused by the repeated statement of route. Similarly, since SARD router will make routing decision again only when the current route is unavailable and only the most stable optional route is selected in the decision-making process, so routing non-convergence problem cause by routing scheme will not occur in SARD.

In SARD routing decision step 2, if the effective time of route is less than τ, then a new received declaration routing is adopted. τ is used for stable routing selection judgment. Specific algorithms is shown as Algorithm 1. The route with longest running time is selected and the effective time of this route is longer than τ. If the effective time of all the routing is not longer than τ, then the new declaration received route is selected and the route chosen at this moment is stable route. This principle is also the selection scheme of ARD stable route as SARD have the following theorem.

Algorithm 1 SARD routing decision algorithm
Avail(r): return the available time of route γ
Contains(u,v): return if the route contains the failed link
Input: Route γ is withdrawn or replaced, which is caused by
link failure between AS u and AS v
Output: the best route γ'

1)// AS determines the current route γ^* is impacted by the failed link or withdrawn
If γ . contains(u,v) == FALSE Then
Return
Else //AS needs to recomputed the best routers
choose r in RIB-IN with the longest available time
while $(\gamma != null)$ {
If γ . contains(u,v) == FALSE THEN
8) $\gamma' = r$
bread
Else
re-choose γ in RIN-IN with the sub-longest available time
End if
13)}
If $(avail(\gamma) \prec \tau)$ Then
// Available time of all routes in RIB-In is less than τ
If exists announced route γ Then
select the announced route γ'
End if
End if

20) End if

Theorem 1 In SARD, as the new declaration route is the available route of the longest time route that the neighbor router adopts, so when no available locally stable route to be selected, to select the declaration received route is also a selection strategy of stable route.

In SARD, when the AS receives the stable route from upper AS, then the stable time of this route in network is longer than τ. So, when the route changes and there is no local optional stable route (that is, the effective time of route is longer than τ), SARD can choose stable route selected by upper as their stable routes.

To improve ARD

Because the feature of path vector routing of inter-domain routing protocol ARD and the flexibility of scheme configuration lead to the slow convergence or even non-convergence of the entire Internet route, the synchronous network model B- group (B-cique4) network routing convergence process is used to analyze these issues. As it shows in Figure1, six AS compose fully connected B-group topology. After AS0 network device fails, the route arrived at destination node will experience path search process in AS_1, AS_2, AS_3 and AS_4. In Figure 1, the underlined AS route represents the optimal route of currently selected route;[1205] represents the route that not arrive the destination node; The route in solid-line box indicates the route to the neighbor in this AS routing round; The route without the solid-line box represents the route to neighbor in the last round; w indicates that the routing cancellation is sent. To make easy analysis, a synchronous network model is used to describe the convergence process that the route reach the destination node. Synchronous network has three meanings: (1) Propagation delay between any AS is a fixed value. The example in this paper is set to be 1s; (2) AS in network receives the routing message sent from the last round by neighbor simultaneously, selecting the new optimal route and spreading out; (3) AS prefer choosing high priority route. The route in ARD $A_{dj} - RIB_s - IN$ Routing has been ordered by priority level.

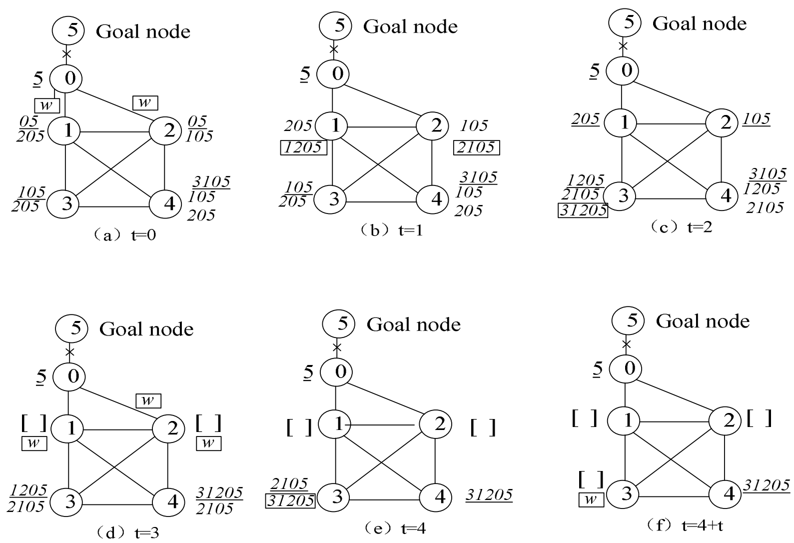


Figure 1 : Group topology routing search process

When the link between ASO and AS5 fails, at the moment $t=1$, AS_1 and AS_2 cancel all the route from AS_5. Routes that arrive destination address exist in AS_1, AS_2, AS_3, AS_4 and the paths respectively are［205］,［105］,［105］,［3105］. Although the three routes become invalid route because of the link failure of AS5 and AS0, but AS1 and AS2 cannot know this message. Then the respectively selected [20] and [105] is used as a new route and send [1205] and [2105] to the neighbor. At the moment t=2, all the AS receive the routing statement sent by neighbor at the moment $t=1$, updating the corresponding $A_{dj} - RIB_s - IN$ and choosing route again. Because the route from AS 1 and AS_2 is received, [1205], AS3 that receive AS1 select [1205] as the optimal route and inform the neighbor. Similarly, at the moment t = 3,when the loop is formed because of receiving the route from AS_3 and AS4,AS1 will no longer have the route that reach the destination address any more and send cancellation notification. In the same way, AS_2 also detect loop and cancel route. Since AS_3 receive the route cancellation notification of AS_1 firstly, AS_3 will choose [216]. However, due to MARI restrictions, AS_3 does not immediately send [32105] to the neighbor. Until the $t = t + 4'$ moment, AS_3 receive the route cancellation notification sent by AS_2 before MARI clock overtimes. Meanwhile, AS_4 receive the cancellation notification of AS_2 to delete the route in $A_{dj} - RIB_s - IN$ and send the cancellation notification to neighbor. AS_4 receive the cancellation notification and delete all the route in $A_{dj} - RIB_s - IN$, then the route convergence process ends. It can be seen that each AS will keep searching, selecting and disseminating invalid route in all neighbors' $A_{dj} - RIB_s - IN$ until all the AS $A_{dj} - RIB_s - IN$ will no longer have any route.

In general, several problems of the inter-domain routing protocol ARD in the following result in the slow convergence or even no convergence of the entire Internet routing:

(1) Error detection of failure. In the ARD protocol, the router detect neighbors router through Keepalive messages of TCP-based reliable connection, but the abnormal termination of TCP session will result in unnecessary routing recalculation of ARD router. The unnecessary route recalculation will lead to a global recalculation of associated ARD route and then the instability of the network.

(2) The route calculation time is too long. Unlike domain protocol, as a path vector protocol, ARD may experience longer path search process when the route is canceled or switches. In the route recalculation process, some routes that ARD routers often choose some routes may no longer be available, and such search process lead to long time of ARD route convergence of the entire Internet.

(3) Routing propagation delay is too long. Some improvement mechanisms in ARD protocol have a direct impact on the routing update propagation in ARD. For example, the minimum time interval value that ARD router send the neighbor to reach the same destination network route is limited to a determined value MSRI (Minimum Route Advertisement In-terval). Although, to a certain extent, MARI can reduce communication overhead, but it also increase the routing convergence time.

(4) ARD routing does not converge. The flexibility and concealment of ARD scheme setting may result in no convergence of route. Different AS are managed by different organizations or institutions. They have great flexibility as they set different ARD routing schemes according to their own needs. In addition, for security and other considerations, ARD routing scheme of each AS is usually not open to the public, and it is highly covert. This feature of ARD scheme make each AS can not get all the Routing scheme information and determine scheme conflicts. It may eventually lead to no convergence of the route.

Many improved ARD scheme ease or solve the above four questions, but, due to the shortcomings of these programs' design itself, they can not be actually deployed to effectively improve ARD convergence performance. RCN and EPIC speed up the convergence through increasing the resource information of routing change in the ARD notification message, but their improved performance is heavily dependent on the network topology, and these programs do not support incremental deployment. CA program accelerate routing convergence by detecting invalid route in advertisement routing, but this proposal adds a lot of computational load to the router. GhostFlushing program accelerate routing convergence through withdraw the old route before advvertise a new route, but it can not avoid invalid search process of route. Furthermore, Ghost Flushing program adds a lot of ARD notification message, and this program will worsen the convergence performance during failure recovery.

Example

In order to facilitate comparison with the traditional ARD and analysis, we also use the synchronous network to analyze SARD performance. As it shows in Figure 2, AS_5 and AS0 link fails, AS_0 release withdrawal route advertisement to AS_1 and AS_2 route. Since withdrawal advertisement contains the faulty link information, AS_1 and AS_2 will choose a route that not affected by the failure. However, AS_1 and AS_2 have no available route, so at the moment $t=1$ they respectively publish the route withdrawal with a link failure information. At the moment $t=2$, AS_3 and AS_4 respectively receive the route withdrawal from AS_1 and AS_2. Similarly, AS_3 and AS4 have no available stable routes. Until the moment $t=3$, all AS delete all faults routes and reach steady state. Compared with conventional ARD (as it shows in Figure 1), SARD shorten convergence time $2+t'$ in this topology.

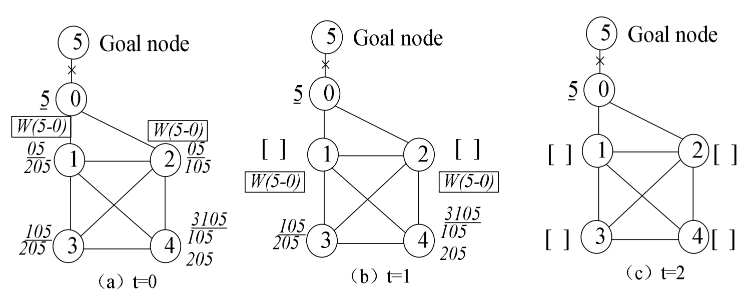
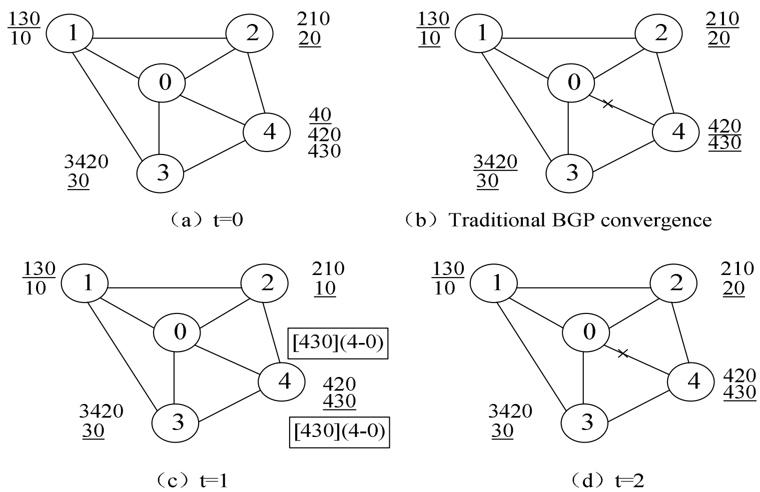


Figure 2 : SARD convergence process in the B-group topology

SARD use a stable routing selection strategy after a failure, which can effectively avoid route non-convergence problem caused by failure. The topology and configuration examples in the document"The stable paths problem and inter domain routing"to make analysis and comparison[14]. As it shows in Figure 3, if AS_0 and AS_4 link fails, the traditional ARD selection route will cause that each AS keep selecting route in $A_{dj} - RIB_s - IN$, which lead to route non-convergence. SARD have a good solution to this problem. When a link fails, at the moment $t = 2$, AS_2 and AS_3 respectively receive a new route advertisement, AS_2 and AS_3 route do not change because the current route is not affected by the failure, then the route converges this time.



Figutre 3 : The representation of traditional ARD and SARD convergence

EXPERIMENTAL SIMULATION AND ANALYSIS

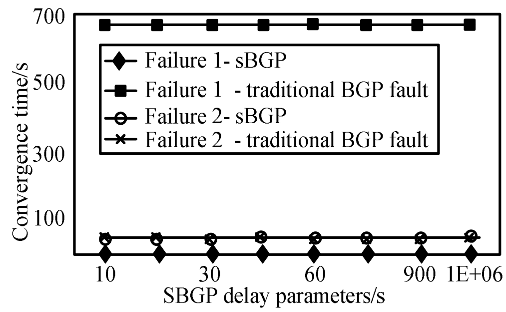
Experimental environment and setup

In order to evaluate the performance of SARD, SARD is achieved in the ARD code of the simulation software *SSFNet* . A simple network topology and the real Internet topology provided by the *SSFNet* is used in the experiment. Simple topology uses several typical topologies, including 15AS topology of binary tree, 5AS ring topology, 32AS B-group topology, 5 AS line topology, 6AS group topology, 16 AS network topology and so on. The real Internet topology uses the topologies including topology of 6AS, 30AS, 113AS and 209AS, in which the last three topologies is proposed and built based on the route information in the real Internet. In routing simulation, every AS inform its prefix information. Because Ghost Flushing program and Consistency Assertions program can not effectively avoid invalid path search, so this paper will not analyze and evaluate these two types of program. On different topology, traditional ARD, RCN program and SARD is simulated respectively and the convergence time and update message number of different program is analyzed and evaluated.

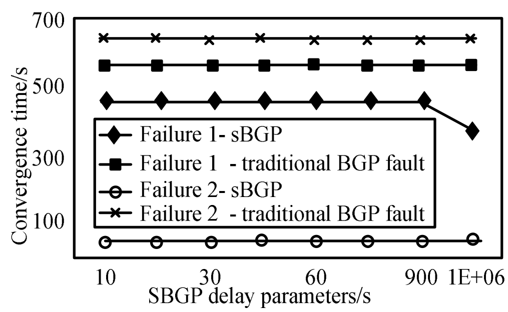
Performance evaluation

Firstly, to analyze the performance of stable routing, different τ values is respectively used to stimulate on 32AS B-group topology and 110AS real topology. Since the analog environment can not accurately portray the failure characteristics of the Internet, and thus the optimal values of τ can not be accurately learned. As it shows in Figure 4, respectively only one failure performance is affected by τ setting in simple topology and real topology, but influence of convergence is less than 1%. This is because all stable route is more in $A_{dj} - RIB_s - IN$ after failure occurs. Thus, according to the simulation experiment, the selection of τ have little effect on SARD convergence performance. In this experiment, we take τ as 45s.

Figure 5 respectively stimulate different simple topology convergence and updated information number. As it shows in Figure 5 (a), RCN and SARD in the B- group topology eliminates invalid path search, and convergence time improve by 96% and 95%. In the network topology, because failure link do not introduce invalid search, RCN gain the same performance as traditional ARD. But SARD effectively eliminate invalid route calculation, thus the convergence performance is improved by 21%. There is no valid route in other topology and there are not many effective routes in the topology, thus the convergence performance of RCN, SARD and the traditional are similar. Figure 5 (b) the updated number of each topology. In B-group topology, the number of messages in RCN and SARD are reduced by 76%. In other topologies, the updated number of three kinds of program is similar. Figure 6 shows the performance of different network size. In 6AS and 29AS topology, there are not many optional stable routes. RCN, SARD and traditional ARD performance is similar. But, as the network size becoming large, the convergence performance of SARD improves more. For example, in 112AS and 209AS network topology, SARD get relatively good performance improvement. RCN get similar performance of conventional ARD. This is because that the part of the failed link do not introduce a large number of invalid route searching. In 110 AS topology, compared with the RCN and traditional ARD, SARD convergence performance improves by 78 % and 79% and the number of the updated message respectively reduce by 1% and 33%. In 208AS topology, the convergence time of SARD improves by approximately 65 % and the number of updated message reduce by 36%. It can be seen that, with the network size increases, the performance improvement of SARD becomes better. Therefore, SARD can improve the performance of existing Internet routing convergence, deal with network failures and improve convergence performance.

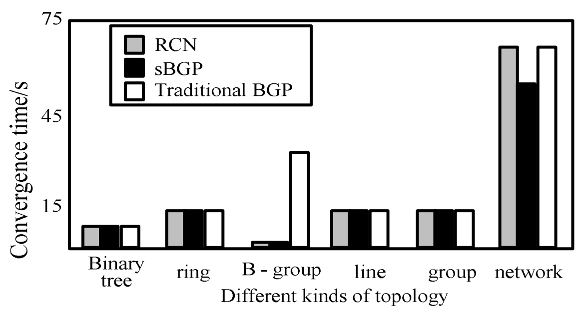


(a)32 AS the convergence of the network

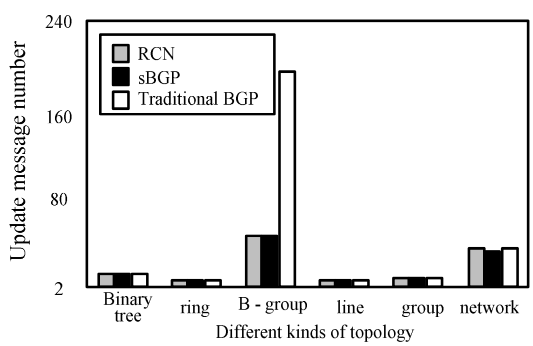


(b)110 AS the convergence of the network

Figure 4 : The delay parameter of SARD

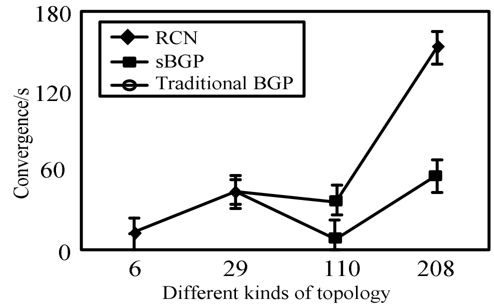


(a)convergence

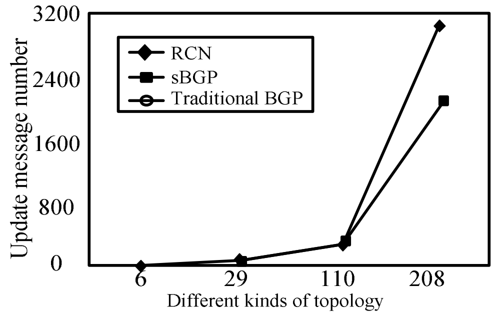


(b)Update number of messages

Figure 5 : ARD performance comparison of simple topology



(a)convergence



(b)Update number of messages

Figure 6 : Network topologies GDP of different sizes

CONCLUSION

The slow convergence problem of ARD routing directly affects the performance of Internet routing. A stable routing selection (SARD) algorithm is proposed to improve the ARD routing convergence. Firstly, the effectiveness of algorithm routing is detected. Only when the currently selected route is affected by the failure will the SARD select route again. Unlike traditional ARD, SARD select the most stable alternative routes as the best choice. Model analysis and simulation experiment result show that SARD can greatly shorten the convergence time of ARD routing and effectively reduce the number of ARD routing update message in the convergence process.

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