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Link State protocols SPF trigger and delay algorithm impact on IGP micro-loops

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Abstract

A micro-loop is a packet forwarding loop that may occur transiently among two or more routers in a hop-by-hop packet forwarding paradigm.

In this document, we are trying to analyze the impact of using different Link State IGP implementations in a single network in regards of micro-loops. The analysis is focused on the SPF triggers and SPF delay algorithm.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

Status of This Memo

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Table of Contents

1. Introduction

Link State IGP protocols are based on a topology database on which an SPF (Shortest Path First) algorithm like Dijkstra is implemented to find the optimal routing paths.

Specifications like IS-IS ([RFC1195]) propose some optimizations of the route computation (See Appendix C.1) but not all the implementations are following those not mandatory optimizations.

We will call "SPF trigger", the events that would lead to a new SPF computation based on the topology.

Link State IGP protocols, like OSPF ([RFC2328]) and IS-IS ([RFC1195]), are using multiple timers to control the router behavior

in case of churn: SPF delay, PRC delay, LSP generation delay, LSP flooding delay, LSP retransmission interval...

Some of those timers are standardized in protocol specification, some are not especially the SPF computation related timers.

For non standardized timers, implementations are free to implement it in any way. For some standardized timer, we can also see that rather than using static configurable values for such timer, implementations may offer dynamically adjusted timers to help controlling the churn.

We will call "SPF delay", the timer that exists in most implementations that specifies the required delay before running SPF computation after a SPF trigger is received.

A micro-loop is a packet forwarding loop that may occur transiently among two or more routers in a hop-by-hop packet forwarding paradigm. We can observe that these micro-loops are formed when two routers do not update their Forwarding Information Base (FIB) for a certain prefix at the same time. The micro-loop phenomenon is described in [I-D.ietf-rtgwg-microloop-analysis].

Some micro-loop mitigation techniques have been defined by IETF (e.g. [RFC6976], [I-D.ietf-rtgwg-uloop-delay]) but are not implemented due to complexity or are not providing a complete mitigation.

In multi-vendor networks, using different implementations of a link state protocol may favor micro-loops creation during the convergence process due to discrepancies of timers. Service Providers are already aware to use similar timers for all the network as a best practice, but sometimes it is not possible due to limitations of implementations.

This document will present why it sounds important for service providers to have consistent implementations of Link State protocols across vendors. We are particularly analyzing the impact of using different Link State IGP implementations in a single network in regards of micro-loops. The analysis is focused on the SPF triggers and the SPF delay algorithm.

This document is only stating the problem, and defining some work items but its not intended to provide a solution.

2. Problem statement

```
                      A ---- B
                      |      |
                   10 |      | 10
                      |      |
                      C ---- D
                      |  2   |
                      Px     Px
```

Figure 1 - Network topology suffering from micro-loops

In Figure 1, A uses primarily the AC link to reach C. When the AC link fails, the IGP convergence occurs. If A converges before B, A will forward the traffic to C through B, but as B as not converged yet, B will loop back traffic to A, leading to a micro-loop.

The micro-loop appears due to the asynchronous convergence of nodes in a network when an event occurs.

Multiple factors (and combination of these factors) may increase the probability for a micro-loop to appear:

- the delay of failure notification: the more B is advised of the failure later than A, the more a micro-loop may have a chance to appear.

- the SPF delay: most of the implementations supports a delay for the SPF computation to try to catch as many events as possible. If A uses an SPF delay timer of x msec and B uses an SPF delay timer of y msec and x < y, B would start converging after A leading to a potential micro-loop.

- the SPF computation time: mostly a matter of CPU power and optimizations like incremental SPF. If A computes its SPF faster than B, there is a chance for a micro-loop to appear. CPUs are today faster enough to consider SPF computation time as negligeable (order of msec in a large network).

- the RIB and FIB prefix insertion speed or ordering: highly implementation dependant.

This document will focus on analysis SPF delay (and associated triggers).

3. SPF trigger strategies

Depending of the change advertised in LSP/LSA, the topology may be affected or not. An implementation may avoid running the SPF computation (and may only run IP reachability computation instead) if the advertised change is not affecting topology.

Different strategies exists to trigger the SPF computation:

1. An implementation may always run a full SPF whatever the change to process.

2. An implementation may run a full SPF only when required: e.g. if a link fails, a local node will run an SPF for its local LSP update. If the LSP from the neighbor (describing the same failure) is received after SPF has started, the local node can decide that a new full SPF is not required as the topology has not change.

3. If the topology does not change, an implementation may only recompute the IP reachability.

As pointed in Section 1, SPF optimizations are not mandatory in specifications, leading to multiple strategies to be implemented.

4. SPF delay strategies

Implementations of link state routing protocols use different strategies to delay the SPF computation. We usually see the following:

1. Two steps delay.

2. Exponential backoff delay.

Those behavior will be explained in the next sections.

4.1. Two steps SPF delay

The SPF delay is managed by four parameters:

- Rapid delay: amount of time to wait before running SPF.

- Rapid runs: amount of consecutive SPF runs that can use the rapid delay. When the amount is exceeded the delay moves to the slow delay value .

- Slow delay: amount of time to wait before running SPF.

o Wait time: amount of time to wait without events before going back to the rapid delay.

Example: Rapid delay = 50msec, Rapid runs = 3, Slow delay = 1sec, Wait time = 2sec

```
   SPF delay time
       ^
       |
       |
   SD- |             x xx x
       |
       |
       |
   RD- |   x  x   x                    x
       |
       +---------------------------------> Events
           |  |   |  | || |            |
                          < wait time >
```

Figure 2 - Two steps delay algorithm

4.2. Exponential backoff

The algorithm has two modes: the fast mode and the backoff mode. In the fast mode, the SPF delay is usually delayed by a very small amount of time (fast reaction). When an SPF computation has run in the fast mode, the algorithm automatically moves to the backoff mode (a single SPF run is authorized in the fast mode). In the backoff mode, the SPF delay is increasing exponentially at each run. When the network becomes stable, the algorithm moves back to the fast mode. The SPF delay is managed by four parameters:

o First delay: amount of time to wait before running SPF. This delay is used only when SPF is in fast mode.

o Incremental delay: amount of time to wait before running SPF. This delay is used only when SPF is in backoff mode and increments exponentially at each SPF run.

o Maximum delay: maximum amount of time to wait before running SPF.

o Wait time: amount of time to wait without events before going back to the fast mode.

Example: First delay = 50msec, Incremental delay = 50msec, Maximum delay = 1sec, Wait time = 2sec

```
   SPF delay time
       ^
   MD- |               xx x
       |
       |
       |
       |
       |
       |             x
       |
       |
       |
       |          x
       |
   FD- |   x  x                        x
   ID  |
       +---------------------------------> Events
           |  |   |  | || |            |
                           < wait time >
          FM->BM -------------------->FM
```

Figure 3 - Exponential delay algorithm

5. Mixing strategies

```
                              S ---- E
                              |      |
                           10 |      | 10
                              |      |
                              D ---- A
                              |  2
                              Px
```

Figure 4

In Figure 4, we consider a flow of packet from S to D. We consider that S is using optimized SPF triggering (Full SPF is triggered only when necessary), and two steps SPF delay (rapid=150ms,rapid-runs=3, slow=1s). As implementation of S is optimized, Partial Reachability Computation (PRC) is available. We consider the same timers as SPF for delaying PRC. We consider that E is using a SPF trigger strategy that always compute Full SPF and exponential backoff strategy for SPF delay (start=150ms, inc=150ms, max=1s)

We also consider the following sequence of events (note : the time scale does not intend to represent a real router time scale where jitters are introduced to all timers) :

- o t0=0 ms: a prefix is declared down in the network. We consider this event to happen at time=0.
- o 200ms: the prefix is declared as up.
- o 400ms: a prefix is declared down in the network.
- o 1000ms: S-D link fails.

Time	Network Event	Router S events	Router E events
t0=0	Prefix DOWN		
10ms		Schedule PRC (in 150ms)	Schedule SPF (in 150ms)
160ms		PRC starts	SPF starts
161ms		PRC ends	
162ms		RIB/FIB starts	
163ms			SPF ends
164ms			RIB/FIB starts
175ms		RIB/FIB ends	
178ms			RIB/FIB ends
200ms	Prefix UP		
212ms		Schedule PRC (in 150ms)	
214ms			Schedule SPF (in 150ms)
370ms		PRC starts	
372ms		PRC ends	
373ms			SPF starts
373ms		RIB/FIB starts	
375ms			SPF ends
376ms			RIB/FIB starts
383ms		RIB/FIB ends	
385ms			RIB/FIB ends
400ms	Prefix DOWN		
410ms		Schedule PRC (in 300ms)	Schedule SPF (in 300ms)

710ms		PRC starts	SPF starts
711ms		PRC ends	
712ms		RIB/FIB starts	
713ms			SPF ends
714ms			RIB/FIB starts
716ms		RIB/FIB ends	RIB/FIB ends
1000ms	S-D link DOWN		
1010ms		Schedule SPF (in 150ms)	Schedule SPF (in 600ms)
1160ms		SPF starts	
1161ms		SPF ends	
1162ms	Micro-loop may start from here	RIB/FIB starts	
1175ms		RIB/FIB ends	
1612ms			SPF starts
1615ms			SPF ends
1616ms			RIB/FIB starts
1626ms	Micro-loop ends		RIB/FIB ends

Route computation event time scale

In the table above, we can see that due to discrepancies in the SPF management, after multiple events (of a different type), the values of the SPF delay are completely misaligned between nodes leading to long micro-loops creation.

The same issue can also appear with only single type of events as displayed below:

Time	Network Event	Router S events	Router E events
t0=0	Link DOWN		
10ms		Schedule SPF (in 150ms)	Schedule SPF (in 150ms)

```
   |        |                     |                  |                  |
   | 160ms  |                     |    SPF starts    |    SPF starts    |
   | 161ms  |                     |     SPF ends     |                  |
   | 162ms  |                     |  RIB/FIB starts  |                  |
   | 163ms  |                     |                  |     SPF ends     |
   | 164ms  |                     |                  |  RIB/FIB starts  |
   | 175ms  |                     |   RIB/FIB ends   |                  |
   | 178ms  |                     |                  |   RIB/FIB ends   |
   |        |                     |                  |                  |
   | 200ms  |      Link DOWN      |                  |                  |
   | 212ms  |                     | Schedule SPF (in |                  |
   |        |                     |      150ms)      |                  |
   | 214ms  |                     |                  | Schedule SPF (in |
   |        |                     |                  |      150ms)      |
   |        |                     |                  |                  |
   |        |                     |                  |                  |
   | 370ms  |                     |    SPF starts    |                  |
   | 372ms  |                     |     SPF ends     |                  |
   | 373ms  |                     |                  |    SPF starts    |
   | 373ms  |                     |  RIB/FIB starts  |                  |
   | 375ms  |                     |                  |     SPF ends     |
   | 376ms  |                     |                  |  RIB/FIB starts  |
   | 383ms  |                     |   RIB/FIB ends   |                  |
   | 385ms  |                     |                  |   RIB/FIB ends   |
   |        |                     |                  |                  |
   | 400ms  |      Link DOWN      |                  |                  |
   | 410ms  |                     | Schedule SPF (in | Schedule SPF (in |
   |        |                     |      150ms)      |      300ms)      |
   |        |                     |                  |                  |
   |        |                     |                  |                  |
   | 560ms  |                     |    SPF starts    |                  |
   | 561ms  |                     |     SPF ends     |                  |
   | 562ms  |    Micro-loop may   |  RIB/FIB starts  |                  |
   |        |   start from here   |                  |                  |
   | 568ms  |                     |   RIB/FIB ends   |                  |
   |        |                     |                  |                  |
   |        |                     |                  |                  |
   | 710ms  |                     |                  |    SPF starts    |
   | 713ms  |                     |                  |     SPF ends     |
   | 714ms  |                     |                  |  RIB/FIB starts  |
   | 716ms  |   Micro-loop ends   |                  |   RIB/FIB ends   |
   |        |                     |                  |                  |
   | 1000ms |      Link DOWN      |                  |                  |
   | 1010ms |                     | Schedule SPF (in | Schedule SPF (in |
   |        |                     |       1s)        |      600ms)      |
   |        |                     |                  |                  |
   |        |                     |                  |                  |
   |        |                     |                  |                  |
```

```
|        |                    |                  |                  |
| 1612ms |                    |                  |    SPF starts    |
| 1615ms |                    |                  |     SPF ends     |
| 1616ms |   Micro-loop may   |                  |  RIB/FIB starts  |
|        |  start from here   |                  |                  |
| 1626ms |                    |                  |   RIB/FIB ends   |
|        |                    |                  |                  |
|        |                    |                  |                  |
|        |                    |                  |                  |
|        |                    |                  |                  |
| 2012ms |                    |    SPF starts    |                  |
| 2014ms |                    |     SPF ends     |                  |
| 2015ms |                    |  RIB/FIB starts  |                  |
| 2025ms |  Micro-loop ends   |   RIB/FIB ends   |                  |
|        |                    |                  |                  |
|        |                    |                  |                  |
+--------+--------------------+------------------+------------------+
```

Route computation event time scale

6. Proposed work items

In order to enhance the current Link State IGP behavior, authors would encourage working on standardization of some behaviours.

Authors are proposing the following work items :

- o Standardize SPF trigger strategy.

- o Standardize computation timer scope: single timer for all computation operations, separated timers ...

- o Standardize "slowdown" timer algorithm including its association to a particular timer: authors of this document does not presume that the same algorithm must be used for all timers.

Using the same event sequence as in figure 2, we may expect fewer and/or shorter micro-loops using standardized implementations.

```
+--------+--------------------+------------------+------------------+
|  Time  |   Network Event    | Router S events  | Router E events  |
+--------+--------------------+------------------+------------------+
|  t0=0  |    Prefix DOWN     |                  |                  |
|  10ms  |                    | Schedule PRC (in | Schedule SPF (in |
|        |                    |      150ms)      |      150ms)      |
|        |                    |                  |                  |
|        |                    |                  |                  |
| 160ms  |                    |    PRC starts    |    PRC starts    |
```

```
   | 161ms  |                    |     PRC ends      |                  |
   | 162ms  |                    |  RIB/FIB starts   |     PRC ends     |
   | 163ms  |                    |                   |  RIB/FIB starts  |
   | 175ms  |                    |   RIB/FIB ends    |                  |
   | 176ms  |                    |                   |   RIB/FIB ends   |
   |        |                    |                   |                  |
   | 200ms  |     Prefix UP      |                   |                  |
   | 212ms  |                    | Schedule PRC (in  |                  |
   |        |                    |      150ms)       |                  |
   | 213ms  |                    |                   | Schedule PRC (in |
   |        |                    |                   |      150ms)      |
   |        |                    |                   |                  |
   |        |                    |                   |                  |
   | 370ms  |                    |    PRC starts     |    PRC starts    |
   | 372ms  |                    |     PRC ends      |                  |
   | 373ms  |                    |  RIB/FIB starts   |     PRC ends     |
   | 374ms  |                    |                   |  RIB/FIB starts  |
   | 383ms  |                    |   RIB/FIB ends    |                  |
   | 384ms  |                    |                   |   RIB/FIB ends   |
   |        |                    |                   |                  |
   | 400ms  |    Prefix DOWN     |                   |                  |
   | 410ms  |                    | Schedule PRC (in  | Schedule PRC (in |
   |        |                    |      300ms)       |      300ms)      |
   |        |                    |                   |                  |
   |        |                    |                   |                  |
   |        |                    |                   |                  |
   |        |                    |                   |                  |
   | 710ms  |                    |    PRC starts     |    PRC starts    |
   | 711ms  |                    |     PRC ends      |     PRC ends     |
   | 712ms  |                    |  RIB/FIB starts   |                  |
   | 713ms  |                    |                   |  RIB/FIB starts  |
   | 716ms  |                    |   RIB/FIB ends    |   RIB/FIB ends   |
   |        |                    |                   |                  |
   | 1000ms |   S-D link DOWN    |                   |                  |
   | 1010ms |                    | Schedule SPF (in  | Schedule SPF (in |
   |        |                    |      150ms)       |      150ms)      |
   |        |                    |                   |                  |
   |        |                    |                   |                  |
   | 1160ms |                    |    SPF starts     |                  |
   | 1161ms |                    |     SPF ends      |    SPF starts    |
   | 1162ms |   Micro-loop may   |  RIB/FIB starts   |     SPF ends     |
   |        |  start from here   |                   |                  |
   | 1163ms |                    |                   |  RIB/FIB starts  |
   | 1175ms |                    |   RIB/FIB ends    |                  |
   | 1177ms |  Micro-loop ends   |                   |   RIB/FIB ends   |
   +--------+--------------------+-------------------+------------------+
```

Route computation event time scale

As displayed above, there could be some other parameters like router computation power, flooding timers that may also influence micro-loops. In Figure 4, we consider E to be a bit slower than S, leading to micro-loop creation. Despite of this, we expect that by aligning implementations at least on SPF trigger and SPF delay, service provider may reduce the number and the duration of micro-loops.

7. Security Considerations

This document does not introduce any security consideration.

8. Acknowledgements

Authors would like to thank Mike Shand for his useful comments.

9. IANA Considerations

This document has no action for IANA.

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