Kyland Redundant Ring Technology

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Preface

Industrial Ethernet switch has been widely used in the fields of electric power distribution network, digital power substation, wind power plant, rail transit, high speed railway, industrial control. And it has been also applied more and more in the areas of important communication and control systems.

Industrial field communication requires for reliable communication, redundancy, and fast recovery. In some areas, it also requires data bypass flow and isolation, load balance insurance and etc. For these reasons, all kinds of redundancy protocols including STP, RSTP, PVSTP and MSTP appear since 1990's. However, all these redundancy protocols are designed for commercial networks, and while they are used in industrial Ethernet networks, they have obvious disadvantages on long recovery time and limited supported topology.

Kyland has been devoting itself in developing such kinds of redundancy protocols especially for the field of industrial Ethernet. These protocols include K-RSTP, DT-Ring, DT-Ring+, DT-VLAN and DT-Ring-E, which can ensure the redundant backup, fast recovery time, and load balance for industrial Ethernet switches.

K-RSTP (Kyland RSTP)

Although RSTP offered a significant performance improvement compared to the legacy STP, it still had several weaknesses:

1) Even the failover and recovery time of a few seconds was not good enough for mission critical industrial Ethernet applications
2) RSTP doesn't support LANs with a bridge diameter greater than 40

Kyland developed an enhanced version of the RSTP algorithm referred to as K-RSTP which is fully compatible with the IEEE 802.1w RSTP protocol while enhancing it in several aspects:

1) K-RSTP reduces failover and recovery times to just a few milliseconds (5ms per a pair of bridges involved in the topology change)
2) K-RSTP is able to operate in larger LANs with a bridge diameter greater than 20

Being a proprietary enhancement, the K-RSTP algorithm was never published.

In order to calculate the ring failover times, we can use the following formula:

$\mathbf{T_L + (N - 3)*T_{PA}}$, if **N** is even
$\mathbf{T_L + (N - 2)*T_{PA}}$, if **N** is odd

Where:
N - number of switches in the ring
$\mathbf{T_L}$ - time required by a switch to detect a link failure
$\mathbf{T_{PA}}$ - time required by a pair of switches to perform RSTP Proposal-Agreement handshaking; equal to the sum of the BPDU processing times in both switches of the pair.

For Kyland products, these values are:
$\mathbf{T_{PA}}$ = average 2.0ms，max 3.0ms
$\mathbf{T_L}$ = average 6ms and max 11ms for 100Base-TX and 100Base-FX links
= average 17.6ms and max 22.6ms for 1000Base-X links

DT-Ring

DT-Ring protocol is Kyland specially designed communication protocol. This protocol can test the state of ring port and pass few protocol messages to decide the state of port on ring and ensure the redundant ring network work properly, to make the redundant Ethernet fast and stable, and finally meet the needs of industrial communication.

Figure-1 is the typical topology of a DT-Ring network. One of the switches is configured as the Master while others are Slaves.

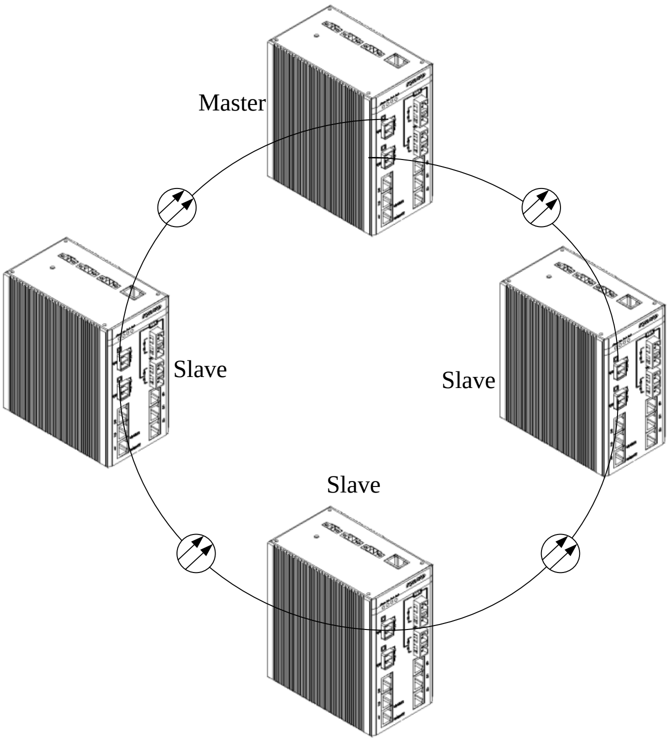

Figure-1: Typical Topology of DT-Ring

Configuration Notes:

1. Multiple domains are supported in one switch so that multiple rings topology can be supported.
2. All switches in the same ring should have same Domain ID and same Domain name.
3. In one ring, only one Master is allowed, and all other switches should be set as Slaves.

Figure-2 displays the DT-Ring with ring closed status. S_0 is the Master while others are Slaves. All links are in the status of LINK UP. The ring is working under closed status. At this time, one of the ports of S_0 named $P_{0\text{-}2N}$ is actually blocked.

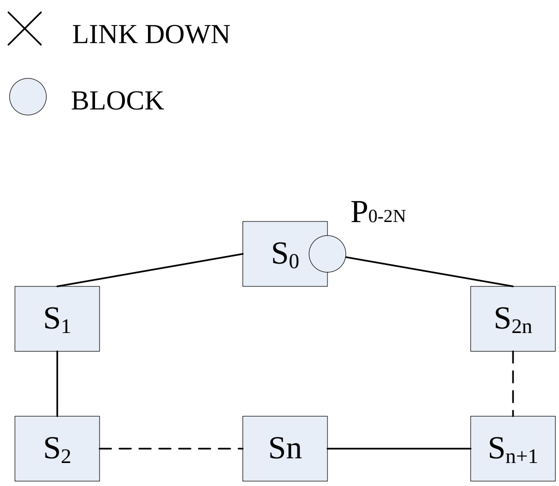

Figure-2: DT-Ring with the ring closed

We will consider on the worst case with the longest recovery time, and for other cases, we only give the result without detail discussion on them.

We assume that the link between S_N and S_{N+1} is down as displayed in Figure-3. S_N and S_{N+1} can both detect the link between them is down, and then, they will block their ports connected to the link which is already down, and forward LINK DOWN PDU to the other side. Other switches will forward the PDU they received and update their own FDB. While the Master S_0 received this message, it will open the blocked port P_{0-2N}, and forward LINK DOWN TC message to other switches from its both ports. Other switches will update their FDB and forward this message.

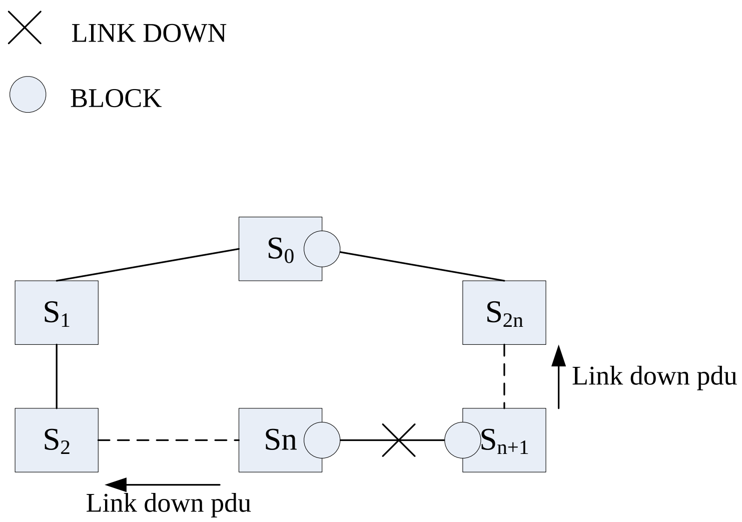

Figure-3: DT-Ring with the ring opened

So, the failover time in the above example will be:

$\mathbf{T_L+N*T_{PA}}$

Where:

N - We assume the failover time will be the worst while there are 2N+1 devices in the ring.
T_L - Time required by a switch to detect a link failure
T_{PA} - Time required by a pair of switches to perform DT-Ring Proposal-Agreement handshaking; equal to the sum of the BPDU processing times in both switches of the pair.

Table1: Link down Failover Time Calculation Table

Link Down	Failover Time Calculation Formula
S_0-S_1	**T_L + N *T_{PA}**
S_1-S_2	**T_L + N *T_{PA}**
S_2-S_3	**T_L + N *T_{PA}**
…	**…**
S_N-S_{N+1}	**T_L + N *T_{PA}**
S_{N+1}-S_{N+2}	**T_L + (N-1) *T_{PA}**
S_{N+2}-S_{N+3}	**T_L + (N-2) *T_{PA}**
…	…
S_{2N-1}-S_{2N}	**T_L + T_{PA}**
S_{2N}-S_0	**0**

The following is another case that the link which has been down recovers, and the slaves forward the LINK UP PDU toward the Master. After the Master receives this message, it will block its port of $P_{0\text{-}2N}$ again, update its FDB, and forward the notification message of topology change through ring port. All Slaves will forward this message and update their own FDB.

Table2: Failover Time Calculation While the Link which is down recovers

Link which is down recovers	Failover Time Calculation Formula
S_0-S_1	**T_L**
S_1-S_2	**T_L + T_{PA}**
S_2-S_3	**T_L + 2 *T_{PA}**
…	**...**
S_N-S_{N+1}	**T_L + N *T_{PA}**
S_{N+1}-S_{N+2}	**T_L + (N-1) *T_{PA}**
S_{N+2}-S_{N+3}	**T_L + (N-2) *T_{PA}**
…	…
S_{2N-1}-S_{2N}	**T_L + T_{PA}**
S_{2N}-S_0	**0**

For Kyland products, these values are:
T_{PA} = average 0.8ms, and max 1.5ms
T_L = average 10ms and max 15ms for 100Base-TX and 100Base-FX links
= average 17.6ms and max 22.6ms for 1000Base-X links

DT-Ring+

DT-Ring can support ring topology, however it cannot offer the redundancy for the links outside the ring. DT-Ring+ realizes the backup redundancy for the links between two rings. DT-Ring+ can set the blocking status of backup port according to the backup device ID, DT-Ring status, backup port status, and ensure the links between two rings could work redundantly.

Figure-4 is the typical topology of DT-Ring+

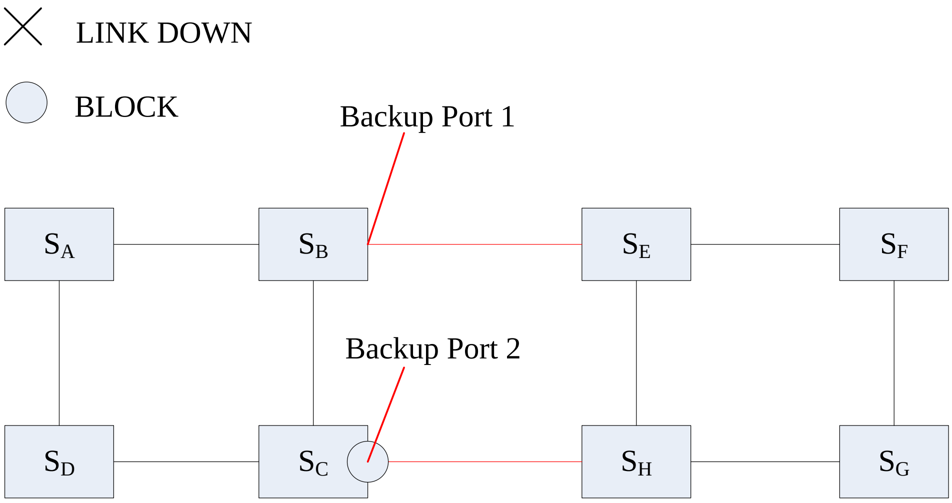

Figure-4: Typical Topology of DT-Ring+

Configuration Notes:

1. One switch can only have one backup port.
2. In one ring, the backup ports can not be more than 2.

In DT-Ring+, the backup port on the switch with a bigger MAC address will be stocked while the ring and backup ports are both working normally. In the Figure-4, the backup port of S_C is blocked. While the link between backup port of S_B and S_E is down, backup port 1 will be set as block, and message informing the block status of this port will be forwarded to other ring ports (S_A, S_D and S_C). Switches received this message will update its ring port FDB and forward this FDB till the message reaches the switch with the other backup port (S_C). This switch (S_C) will open its backup port (backup port 2), and send the notification of topology changes to the other ring network, and require them to update their FDB.

The present status of the DT-Ring+ is displayed in Figure-5

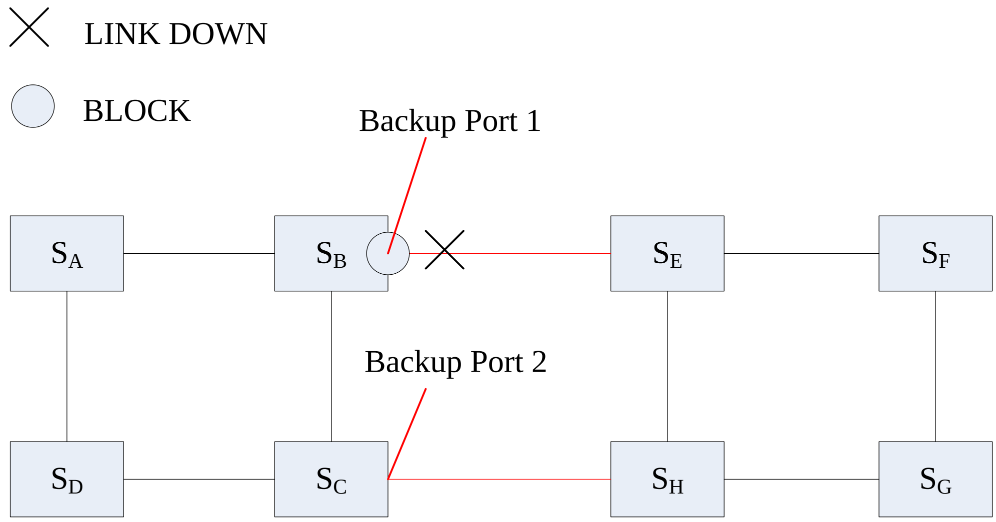

Figure-5: DT-Ring+ Topology While Redundancy Works

In this situation, the failover time in the above example will be:

$\mathbf{T_L+N*T_{PA}}$

Where:

N – The maximum number of switches between the two backup ports in the same ring. (In Figure-5, N=4, S_B-S_A-S_D-S_C)

$\mathbf{T_L}$ - Time required by a switch to detect a link failure

$\mathbf{T_{PA}}$ - Time required by a pair of switches to perform DT-Ring Proposal-Agreement handshaking; equal to the sum of the BPDU processing times in both switches of the pair.

After the backup port 1 has been recovered to LINK UP, since the switch S_B's MAC address is smaller than S_C, the backup port should be switched back to backup port 1. SB will forward the backup port 1 LINK UP message to other ring ports (S_A, S_D and S_C) and request that the backup port 1 be opened instead of blocked. After S_C received this message, it will reply with confirmation message and block the backup port 2. Other switches will again update their FDB table after receive message from S_C and forward the message come from S_C. While S_B receives this message, it will open the backup port 1.

In this case, the failover time in the above example will be:

$\mathbf{T_L+N*T_{PA}}$

Where:

N – The number of switches in the ring.

$\mathbf{T_L}$ - Time required by a switch to detect a link failure

$\mathbf{T_{PA}}$ - Time required by a pair of switches to perform DT-Ring Proposal-Agreement handshaking; equal to the sum of the BPDU processing times in both switches of the pair.

For Kyland products, these values are:
$\mathbf{T_{PA}}$ = average 1ms and max 1.5ms
$\mathbf{T_{L}}$ = average 6ms and max 11ms for 100Base-TX and 100Base-FX links
= average 17.6ms and max 22.6ms for 1000Base-X links

DT-Ring-E and DT-Ring+-E (Coming soon)

DT-Ring and DT-Ring+ have excellent performance on shortening the recovery time. However, the recovery time will grows together with the number of switches connected in a ring.

DT-Ring-E and DT-Ring+-E are next version of Kyland private ring protocols which are to be released in the year of 2010. In this new version, the recovery time will no longer be related to the number of the switches in the ring and be improved a lot.

Comparation of STP, RSTP, K-RSTP, DT-Ring and DT-Ring+ with Proprietary Solutions

For many years, there was no standard redundant LAN solution that would provide short network recovery times sufficient for Industrial Ethernet applications. As a result, some networking equipment vendors offered different proprietary protocols designed to solve the problem for ring network topology. The table on the next page compares some of such proprietary solutions with STP/RSTP and with each other.

Protocol	**Vendor**	**Can be used in multi-vendor environment**	**Max Bridge Diameter**	**Topology**	**Single ring link failover time (for different number of switches)**		
					10	15	20
STP	IEEE Standard	Yes	40	Any	>30s		
RSTP(802.1w)	IEEE Standard	Yes	40	Any	Several seconds		
HiPER Ring [4], [5]	Hirschmann	No	Virtually unlimited	Ring	200-500ms, independent of number of switches		
Turbo Ring [4], [6]	Moxa	No	Virtually unlimited	Ring	<200ms	<250ms	<300ms
S-Ring [8]	GarrettCom	No	Data not available	Ring	<250ms		
RS-Ring [8]	GarrettCom	No	Data not available	Ring	<100ms		
RapidRing™ [7]	Contemporary Controls	No	50	Ring	<300ms		
RSTP(802.1D-2004)	IEEE Standard	Yes	40	Any	<50ms	<75ms	<100ms
eRSTP™	RuggedCom enhuancements to IEEE Standard	Yes	160	Any	<50ms	<75ms	<100ms
K-RSTP	Kyland enhancements to IEEE Standard	Yes	38	Any	<60ms	<150ms	<300ms
DT-Ring	Kyland	No	Virtually unlimited	Ring	<35ms	<40ms	<50ms
DT-Ring+	Kyland	No	Virtually unlimited	Ring	<40ms	<45ms	<50ms