White Paper

An Introduction to Resilient Packet Rings

Metro Ethernet

Metro Ethernet networks extend the boundaries of the LAN environment to encompass the metropolitan and even wide area network. Metro Ethernet solutions allow service providers to seamlessly address the burgeoning increase in demand for bandwidth and strict performance resulting from the proliferation of video-centric applications and services, while maintaining the cost-effectiveness and simplicity that make Ethernet so attractive. Advanced Ethernet capabilities — coupled with the reach, scale and reliability strengths of optical networking products — enable a ubiquitous service plane for profitable, next-generation services such as triple and quadruple play, wireless video and data, and Ethernet business connectivity. With today's networking solutions, Metro Ethernet services can be provided using Ethernet over straight fiber, Ethernet over WDM, Ethernet over SONET/SDH via GFP/VCAT, switched Ethernet over SONET/SDH and Ethernet over Resilient Packet Ring (RPR).

Figure 1. Distributed switching architecture

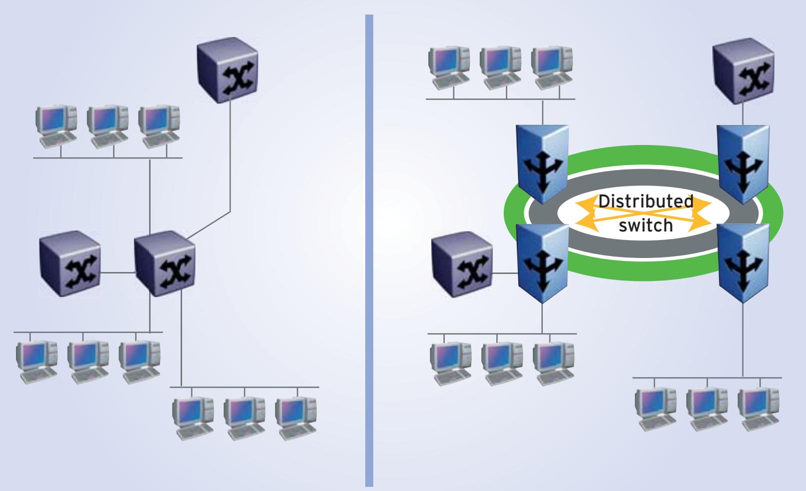
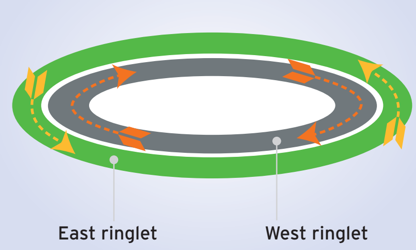


Figure 2. Dual counter-rotating ringlets

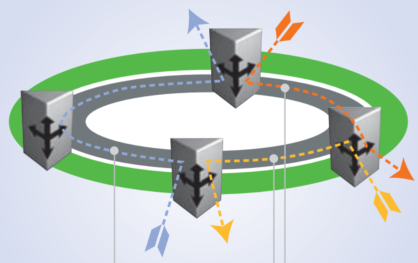


Introducing RPR

Resilient Packet Ring (RPR) is a solution based on standardized technology designed to bring sub-50ms ring-based resiliency to efficient, packet-switched network architecture. As illustrated in Figure 1, RPR is a ring-based technology that provides a geographically separated "distributed switching" architecture that incorporates extensive performance monitoring and network restoration and offers flexible deployment options.

The basis of the RPR architecture is made up of two counter-rotating (east and west) ringlets, as shown in Figure 2, which forward packet-based traffic from Ethernet ports using distributed Ethernet switching. RPR may operate over any

Figure 3. Spatial reuse



Efficiency via reuse of bandwidth on spans for different traffic flows

underlying transport layer such as SONET/SDH, DWDM/OTN or Ethernet. This pairing of technologies enables operators to benefit from traditional transport characteristics (scalability, determinism, resiliency, etc.) and to incorporate addressing, differentiated service levels (Classes of Service) and the ability to deal with bursty traffic that is found in today's networking environments. Standardized in 2005 and defined by IEEE 802.17 and 802.17b, RPR aligns the ubiquity and operational simplicity of the Ethernet protocol with the ring-based, service-oriented nature required in many customer networking strategies.

RPR (IEEE 802.17) technology overview

Packet forwarding

Several of the benefits of RPR are provided by the packet forwarding mechanism, wherein packet traffic can travel in either a clockwise (CW) or counterclockwise (CCW) direction, depending on which ringlet it uses. RPR nodes can use either ringlet to send traffic — the choice is being governed by either a shortest path algorithm based on the number of hops required to reach the destination on either ringlet or via user control. This mechanism supports point-to-point and point-to-multipoint or any-to-any architectures, which are both copied to the local receiver and transmitted to the downstream nodes.

By providing any-to-any connectivity over a Layer 2 architecture, RPR eliminates the need to provision a full mesh of circuits to deliver services, as in legacy technologies like Frame Relay or ATM, or when using point-to-point links. Furthermore, cut-through switching enables this type of efficient packet forwarding to occur with minimal latency and jitter.

Spatial reuse

Spatial reuse is a mechanism defined by the IEEE 802.17b standard whereby the RPR ring has awareness of the amount of traffic on each of the spans and can therefore allow the switching of more traffic on underused spans without impacting the rest of the carrier's traffic, as shown in Figure 3. This functionality increases several-fold the effective bandwidth in the network as compared with circuit-based technologies.

Statistical multiplexing

The "shared pipe" principle of RPR solutions is well suited to facilitate statistical multiplexing of traffic flows, taking advantage of unused or temporarily idle ring bandwidth to transfer other packet traffic over the same path. The bursty nature of data traffic, in combination with an effective traffic prioritization mechanism, enables "sharing" of bandwidth. This means that irrespective of the implementation methodology, a provider can make do with a smaller, more cost-effective "pipe" to deliver the same connectivity requirements versus traditional WAN connectivity methods.

The MAC layer

The Media Access Control (MAC) is the Layer 2 function, and for networks based on a shared medium (i.e., wavelength), it is used to control access to the medium. The MAC layer makes one of three primary decisions for proper transport of traffic:

- **Receive decision** — The MAC layer receives both multicast and unicast data packets with a matching destination address (unicast stripped from the ring).
- **Transit path** — Packets with non-matching destination address or multi-cast packets are passed through to continue to transit the ring.
- **Transmit and bandwidth control** — Controls packet ring insertion prioritization and control.

Solution protection and resiliency

With its defined sub-50ms fault restoration scheme, RPR offers the level of resiliency that is necessary to facilitate mission-critical connectivity and ensure business continuity. There are always two paths between any two nodes on

Figure 4. RPR Layer 2 protection mechanisms

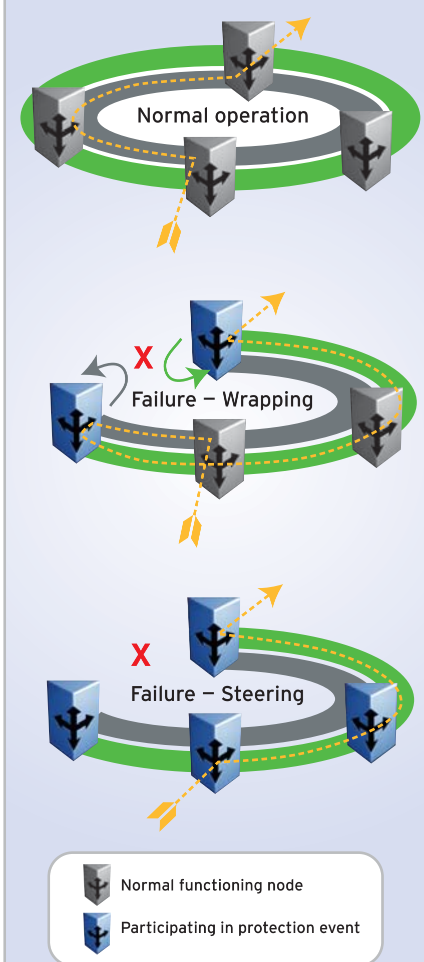
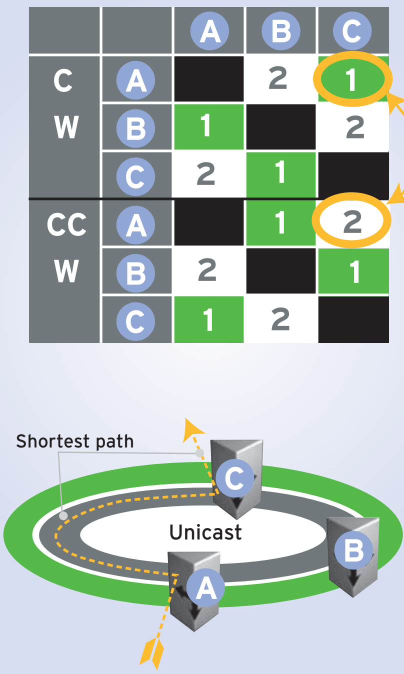


Figure 5. Topology discovery



the ring during normal operation, which offer diverse routes in the event of a failure. There are two specific protection mechanisms specified for RPR as identified in Figure 4 — wrapping and steering.

- **Wrapping** — In principle, this is similar to the SONET BLSR protection mechanism. Nodes at each end of a failed span automatically detect the failure and loop back on the other ringlet.
- **Steering** — This is an intelligent protection strategy designed for RPR implementations which relies on nodes exchanging information on the status of downstream spans. When a failure occurs, nodes reroute their ingress traffic onto the appropriate ringlet to avoid the failure.

Wrapping is simple, but less bandwidth efficient than steering in the sense that it occupies more “normal operations” spans where it may take away some of the throughput being leveraged by other connectivity and potentially impact applications that may not be directly impacted by the fiber fault, etc. The option is up to vendors as to which protection mechanism they implement within their RPR solutions.

Topology discovery

RPR has a built-in topology discovery and management function which allows a shortest path forwarding capability without manual provisioning by the user. The same mechanism is also used for fault detection, ring resiliency and troubleshooting. As illustrated in Figure 5, once the node discovery process is completed, traffic takes the shortest path to its destination.

Quality of Service (QoS)

Since RPR was designed to deliver QoS-aware services, the standard has been defined to deliver a consistent, end-to-end quality user experience. Bandwidth policing and traffic queuing are performed on traffic ingressing the RPR, which manages potential congestion while ensuring that on-ring traffic reaches its destination. The traffic on the ring itself is assigned to one of four different Classes of Service (CoS), providing the ability to prioritize the traffic being added to the ring ahead of traffic already on the ring and vice versa. A backpressure mechanism is provided in order to make the ring lossless and utilize the much larger queues at the ingress of the ring where the added traffic is prioritized.

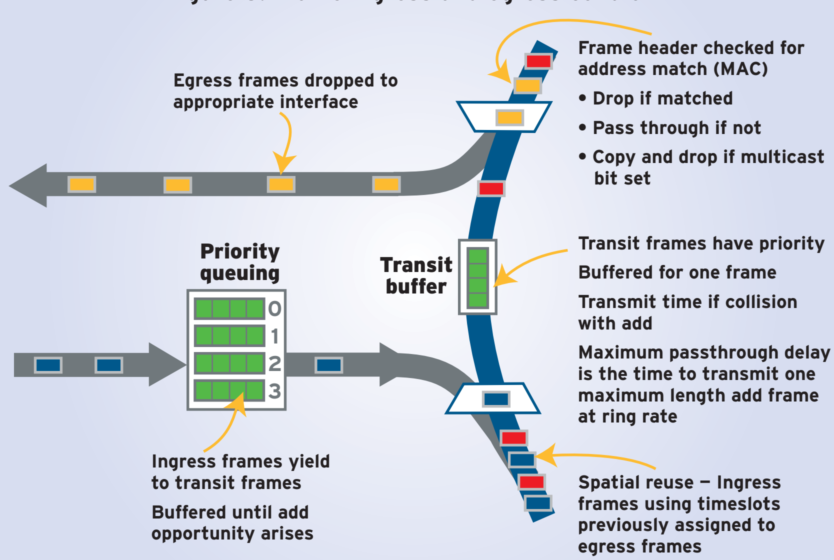
Frame ingress and egress control

There are two sources of frame within an edge RPR node — those being inserted onto the ring from the business unit LAN environment and those transiting through the node on a path to their destination. It must be ensured that frames do not interfere during ingress/egress to the RPR with those frames transiting the node as identified in Figure 6. Priority always rests with transiting frames that are currently on the ring. For the ingress traffic, the prioritization/QoS queue plays a role in the insertion of frames into the ring based on the priority they are assigned.

Efficient network bandwidth utilization

RPR is one of the solutions that can be delivered over next-generation transport networks. RPR leverages connectivity strategies which make more efficient use of working and protect bandwidth on a transport network infrastructure as well as more efficiently allocating ring bandwidth to RPRs.

Figure 6. Frame ingress and egress control



The packet-oriented nature of RPR redefines the working and protection architecture of a more TDM-oriented infrastructure into a common bandwidth; RPR leverages a Layer 2 protection strategy to reroute packets in the event of a failure. This enables RPR solutions to use all available transport bandwidth instead of having 50 percent reserved for protection such as in the case of more traditional SONET/SDH transport; for example, the full 5 Gbps of traffic can be transported on an OC-48 (2.5 Gbps) ring.

Summary

Resilient Packet Ring (RPR) technology addresses the growing need to explode the bandwidth bottleneck found in today's metro access networks. Efficient use of bandwidth and reliability of transmission are targeted at ring topologies deployed in metro areas worldwide. A Resilient Packet Ring combines the low cost and simplicity of packet-based, connectionless networking with the reliability, bandwidth and scalability of optical networks. The result is the best of both worlds — a resilient, packet-oriented, ring-based solution that provides virtual mesh network connectivity.

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