



Doubling Wireless Ring Capacity Protected ABR

Abstract

Native² (“Native Squared”) is Ceragon’s unique, innovative TDM-to-packet migration approach that allows for the forwarding of TDM and packet-based traffic over microwave backhauling links – “natively”, without using expensive encapsulation methods – supported by the Ceragon FibeAir® IP-10 platform.

Ceragon’s native support for TDM traffic leverages the resiliency advantages of wireless SDH rings¹, with their intrinsic Sub-Network Connection Protection (SNCP) path-protection capabilities. In SNCP, information is redundantly transmitted on the ring in both “east” and “west” directions, while the receiver selects which transmission to receive.

In today’s super-competitive mobile industry, many carriers wish to reallocate the redundant protection bandwidth for other uses, such as low-priority, high-volume data transfer. The benefits are clear – exciting sales opportunities arise as newly-generated capacity can be sold to support the interpersonal communications shift to Facebook, as well as the ever-growing demand for YouTube access.

No less importantly, this reallocation of bandwidth from TDM to Ethernet – and back – must be risk-free, with no interruption of revenue-generating services.

For the purposes of this paper, we suggest to differentiate between the terms “**fully protected**” and “**fully reserved.**” While in legacy systems, processing power could not allow the delivery of protected services without fully reserving all the capacity, modern systems, such as Ceragon’s FibeAir IP-10, are capable of protecting TDM services **without** reserving large quantities of bandwidth.

In response to the needs described above, Ceragon proposes a novel approach to improve the efficiency of ring-based protection, using a technique called **Protected Adaptive Bandwidth Recovery (“ABR”)**, which enables full utilization of the bidirectional capabilities inherent in ring

¹ or a detailed discussion on wireless network topologies and a comparison between them, please refer to Ceragon’s publication, “Wireless Backhaul Topologies: Tree vs. Ring.”



technologies. With ABR, the TDM-based information is transmitted in one direction only, while the unused protection capacity is allocated for Ethernet traffic. In the event of a failure, the unused capacity is re-allocated for TDM transmission. In this paper, we take a closer look at this solution, and at the technologies that are used to implement it. This technique extends the Native² approach to dynamic allocation of link capacity between TDM and Ethernet flows to the network level.

Comparing Ring Protection Schemes

Having selected a ring topology for wireless backhauling, a range of alternative protection schemes are available for implementation.

A major drawback of ring topology is the allocation of redundant bandwidth in order to ensure network availability. For example, the widely-implemented SNCP 1+1 unidirectional protection scheme, which requires the simultaneous transmission of information in both directions on the ring, causes a loss of up to 50% of the ring's total bandwidth capacity.

A number of techniques have been devised for recovering and utilizing the lost bandwidth. The techniques are described in the following sections.

Ethernet & Spanning Tree Protocol

The rapid advance in Ethernet-based technologies has made the eventual migration of transport networks from SONET/SDH to packet a foregone conclusion. This move to packet transport has challenged the Ethernet community to exploit the resilience benefits of the physical ring structure, while adhering to the logical tree structure required by Ethernet networks, thus ensuring a loop-free topology and avoiding broadcast storms. These conflicting requirements have led to the development and widespread adoption of the Rapid Spanning Tree Protocol (RSTP) and its variations.

In order to forward TDM-based traffic over Ethernet-based rings, vendors have had to adopt Pseudowire technologies. Pseudowire, the emulation of a native service over a Packet Switched Network (PSN), is used to map Legacy TDM or ATM services (such as E1 traffic), by creating TDM tunnels over the PSN. While Pseudowire helped accomplish the goal of creating an Ethernet infrastructure for TDM services, it significantly raised network cost and reduced total capacity due to the heavy encapsulation requirements.



Some microwave equipment vendors, including Ceragon, are able to provide complete, ring-based transport networks, without the need for external networking equipment such as switches and routers. These networks use a ring-optimized RSTP to form a logical tree over the physical wireless ring. This logical tree topology increases the ring's efficiency, allowing operators to leverage the bidirectional characteristic of the ring in order to double its bandwidth capacity, as illustrated in Figure 1 below.

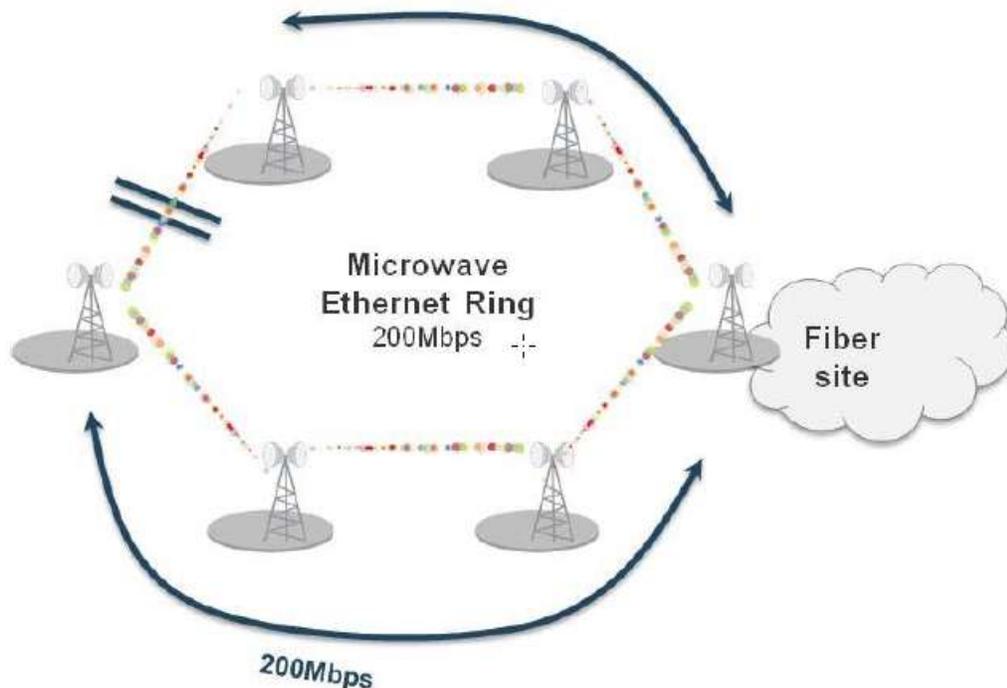


Figure 1: Doubling Ring Capacity using Spanning Tree Protocol

Hybrid TDM & Ethernet Systems

Hybrid systems that support the native transmission of both TDM and Ethernet flows can also be used to reduce wasted protection bandwidth. Ceragon's **Native²** ("Native Squared") migration strategy offers a unique hybrid approach, in which both Carrier Ethernet and TDM traffic are carried natively over microwave links without using expensive encapsulation methods – resulting in significant cost savings, while smoothing the way to a future all-IP network.

Native² allows unparalleled flexibility in the **dynamic allocation** of the link's bandwidth into TDM and Ethernet flows. The bandwidth available to each flow can be easily re-allocated in



real time using Ceragon's PolyView™ Network Management System – **without resetting the link!**

As the volume of data transfer in mobile networks continues to grow, the percentage of time-critical voice & TDM traffic in these networks continues to drop. By limiting native TDM traffic to a minimum, the amount of redundant protection-path bandwidth can be significantly minimized.

Legacy TDM Systems

As the trend toward packet-based networks gains momentum, there remains a huge demand for legacy E1 transport solutions that offer path protection. A variety of protection schemes are listed here:

- **Diverse Path.** Usually involving redundant equipment and/or links, this scheme depends on the availability of alternative ports, cell sites, and base stations.
- **Bidirectional Line Switch Ring (BLSR).** A bidirectional ring, in which logical “working” and “protection” rings forward traffic in opposite directions. Protection switching is performed on a per-link basis (not per E1), and is often wasteful of bandwidth capacity, while possibly increasing delay.
- **SNCP 1+1 Unidirectional Protection.** The most widely implemented of ring-based protection schemes. Each E1 flow consists of a primary path and a protection or standby path, represented in Figure 2 by the blue arrow and the green arrow, respectively.
- **SNCP 1:1 Based.** A protection scheme developed exclusively by Ceragon Networks (and described in detail in this paper). Each E1 flow consists of a primary path, and a protection path whose bandwidth is used for protection signaling and Ethernet traffic, represented in Figure 2 by the blue arrow and the gray-white arrow, respectively.

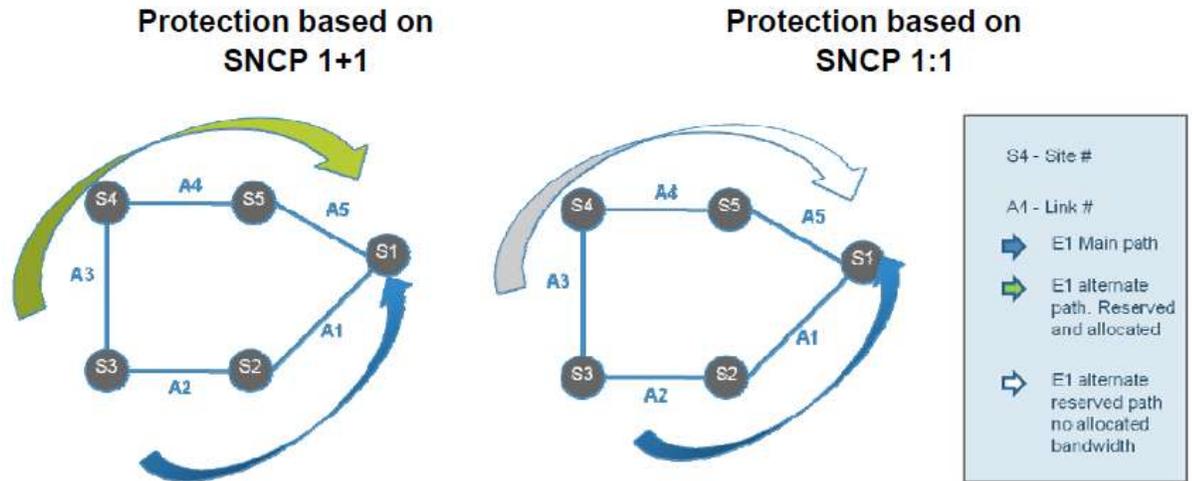


Figure 2: Graphical Depiction of TDM Ring Protection Schemes

Comparison of Protection Mechanisms

The following table compares each of the TDM-based ring protection schemes in regard to resiliency and capacity:

Protection Scheme	Resilience	Capacity Requirements
Diverse Path	Handled at cell site or base station and core sites.	No spare capacity requirement
BLSR	Very Fast. Protection is per-link and not per E1. Risk of increased delay and delay variation.	Some spare capacity is required
SNCP 1+1 Unidirectional	Very Fast. Phone service and synchronization not affected.	For 100% recovery, ring must reserve 50% spare capacity.
ABR (SNCP 1:1 Bidirectional)	Very Fast. Phone and synchronization not affected.	No spare capacity requirement

Table 1: Protection Scheme Comparison

These protections schemes must be able to deal with additional challenges that add complexity to TDM ring protection:



- **Hybrid Fiber/Microwave Rings.** Microwave rings containing fiber segments must be able to propagate E1 frames, fault indications, and other signals vital to the network.
- **Dual Homing.** Protection rings remain vulnerable in situations where a fiber node suffers an equipment failure. In order to ensure network availability, protection schemes must be able to handle the forwarding of primary and standby transmissions from 2 different points of entry, as shown in Figure 3 below.

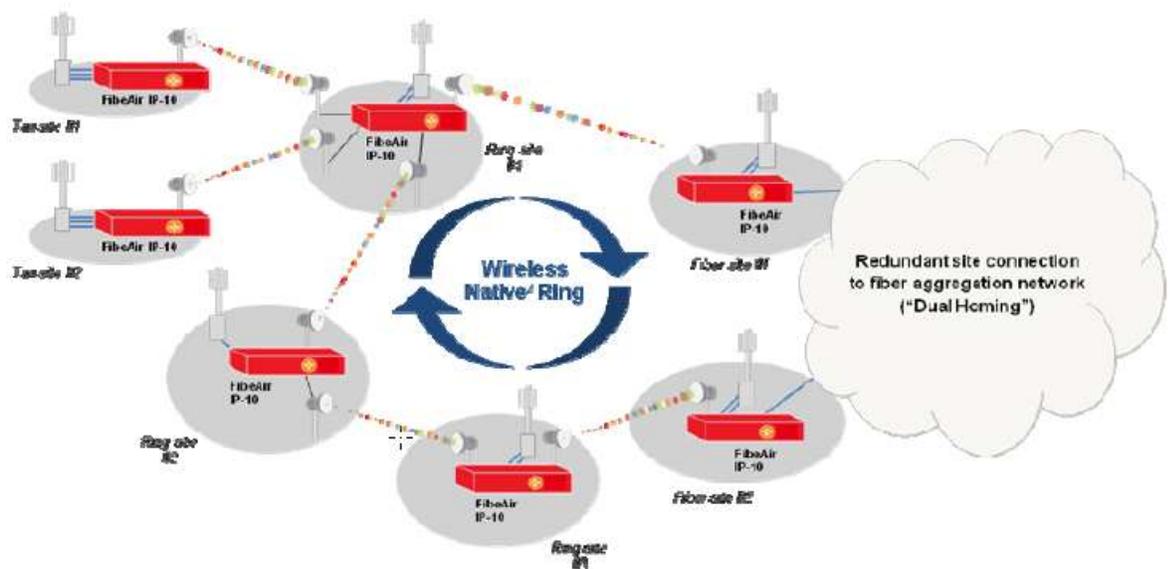


Figure 3: Dual Homing with ABR-based Native²

Novel Approach to Bandwidth Recovery

Ceragon’s Native² hybrid TDM & Ethernet technology, which allows for the transport of both TDM and packet traffic over a unified microwave link, offers additional tools for the optimization of TDM traffic over wireless rings.

In a typical SDH network, the receiving node monitors the transmission quality at its “east” and “west” link interfaces, and selects the direction from which it will receive transmissions. The transmitting node, therefore, sends traffic in both the east and west directions, causing the redundant use of bandwidth. This form of protection is known as **SNCP 1+1 Unidirectional Protection**, and while it can generally provide 50 millisecond protection switching, it does so by reserving large quantities of bandwidth over a very expensive wireless spectrum.



Ceragon's novel approach to the reduction of redundant protection bandwidth involves a change in the role of the transmitting element. In this approach, the transmitting element determines the direction of information transmission – east or west. The decision is based on the monitoring of status information that the transmitting node receives from the network. The receiving node continues to monitor both directions for the arrival of information, as described previously. This method achieves the goal of protecting traffic without wasting capacity on unused reserved bandwidth.

The following section provides technological details on the implementation of this innovative feature, in which **Protected Adaptive Bandwidth Recovery (“ABR”)** is applied to enable better spectrum utilization for Ethernet services.

Protected Adaptive Bandwidth Recovery (ABR)

In Protected Adaptive Bandwidth Recovery (ABR), a protection mechanism based on SNCP 1:1 technology, the transmitting node selects a single direction in which to transmit information. The direction is determined independently for each E1 path, based on status information sent periodically by the receiving node back to the transmitter.

In the standby direction, the transmitting node – along with all the nodes in the standby path to the receiver – removes the E1 bandwidth allocation, and sends periodic signals to the receiver to help it monitor the transmissions from east and west. (Note: This requires special handling in hybrid fiber / microwave networks). The de-allocated (recovered) E1 bandwidth can now be utilized by Ethernet traffic.

The receiving node continues to accept information flows from either the east or west direction, and detects the path in which the E1 payload is actually transmitted.

When a failure occurs in the working direction, the receiving node sends a Reverse Defect Indication (RDI) signal to the transmitter, which automatically switches to the standby path.

ABR can be selected for any number of E1 channels, and the resulting path co-exists with all other paths in the network – be they unidirectional, bidirectional, protected, or unprotected. The case study below describes a real-life example of how ABR delivers normal-state Ethernet capacity that may triple the Ethernet capacity delivered when using SNCP 1+1. While malfunctions under SNCP 1+1 automatically result in network degradation to a worst-case scenario (known as “failure state”), a network fault under **ABR** results in a level of degradation that depends on the exact location of the failure, and worst-case degradation is usually avoided.



Dual Homing

ABR can also be used in a **dual homing** configuration – in which there are 2 possible points of entry into the ring network. This provides added resiliency in case of failure in the transmitting node. In dual homing mode, one transmission node sends the E1 payload, while the other transmission node sends “standby” signaling as mentioned earlier.

Hybrid Fiber / Microwave Networks

In segments of a microwave network that are connected by fiber-optic links, E1 frames must be propagated onto the optical cable, and restored again on the next microwave segment. The same goes for fault indicators. When a wireless E1 is de-allocated and its bandwidth freed for Ethernet traffic, the periodic signals sent from the transmitter to the receiver are also propagated optically and then regenerated on the next microwave segment.

ACM

Ceragon’s Native² technology enables the implementation of highly-efficient Adaptive Coding Modulation (ACM) techniques in order to optimize network availability. When the received Signal-to-Noise Ratio (SNR) degrades to a predetermined threshold, the system will pre-emptively switch to a lower modulation level. When implemented correctly, ACM allows the platform to adjust itself, allocating capacity in favor of high-priority traffic, and reducing the possibility of a total service outage. Ceragon’s implementation enables hitless and errorless operation, and it can be enhanced with QoS mechanisms to ensure that only pre-defined low-priority traffic is dropped. For both TDM traffic and Ethernet traffic, the operator can define traffic priorities based on network planning and on the current stage of migration. For example, in new 3G Node Bs, voice traffic is carried by Ethernet, requiring changes in drop precedence (giving higher priority to some Ethernet flows vis-a-vis TDM), and in path protection as well.

Trail Management

In order to enable full utilization of the FibeAir platform’s networking capabilities, Ceragon offers **PolyView™** - Ceragon’s innovative, user-friendly Network Management System (NMS), designed for managing large-scale wireless backhaul networks. PolyView, a fully integrated radio and networking management platform, provides **complete trail management support**.



PolyView’s efficient trail maintenance capabilities allow network technicians to create, delete, modify, and monitor TDM trails. Trails can be built either automatically, based on user-defined trail endpoints, or manually, according to varying degrees of manual input, with full resource control.

ABR – Case Study

In Figure 4 below, the traffic emanating from 18 cell sites is merged into 4 aggregation sites, making up a metro ring consisting of 28 MHz channels in a 1+0 configuration. In our basic scenario, 2G BTSs support 4 E1s each, yielding a total of 72 E1s. SNCP 1+1 Protection is employed.

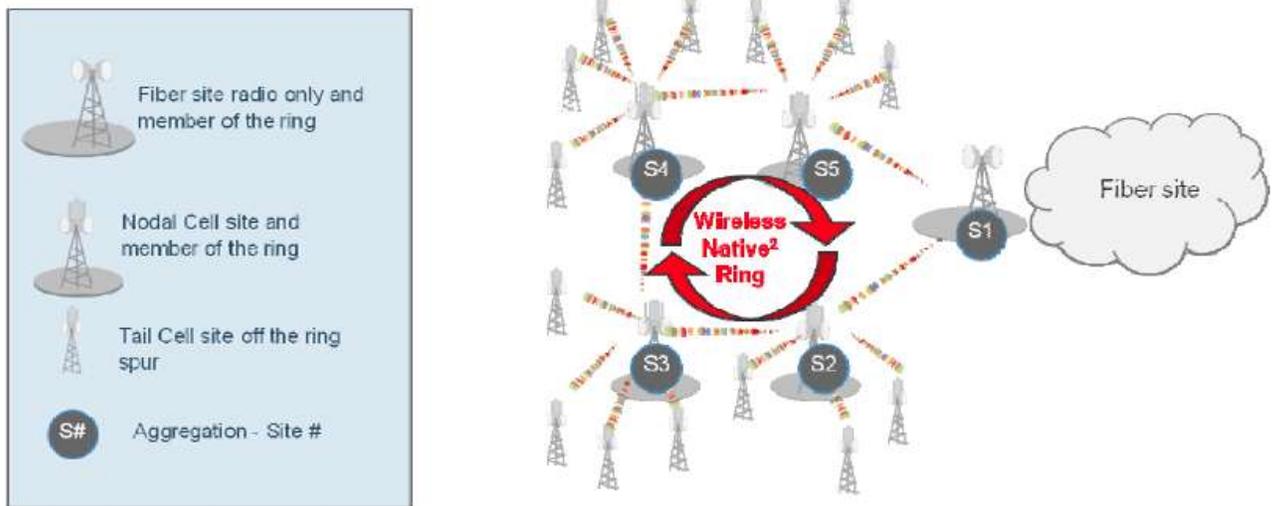


Figure 4: TDM and Ethernet Aggregation Case Study

In this scenario, the main question is how to migrate the network to support 3G-based data services, given the severe spectrum limitations. This common legacy configuration leaves us with almost no capacity for Ethernet traffic – in this case, approximately 1.7 Mbps per site of guaranteed Ethernet traffic.

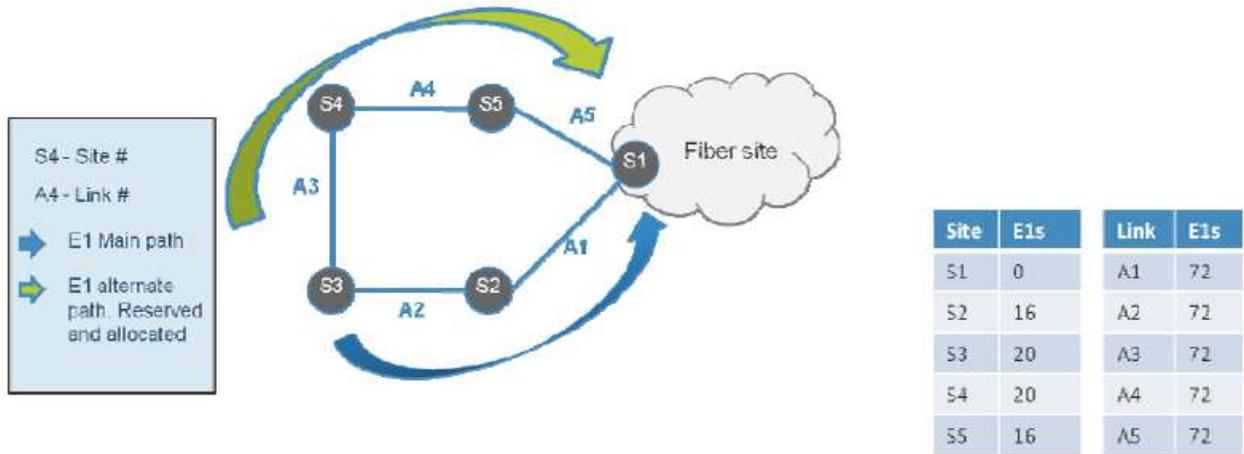
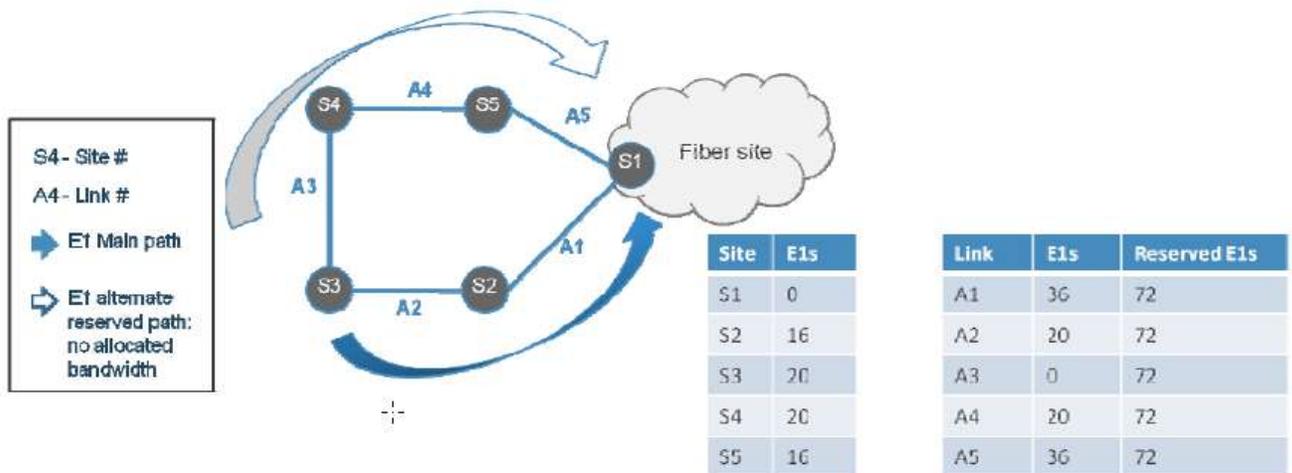


Figure 5: TDM-only Aggregation Ring with 100% Protection Based on SNCP 1+1

In the simple, TDM-only, SNCP 1+1 case presented in Figure 5 above, all E1s flow in both directions, meaning that 50% of the total capacity is reserved for failure states. In case of such a failure, E1s traffic is forwarded in the opposite direction. From a capacity point of view, there is no difference between normal state and failure state.



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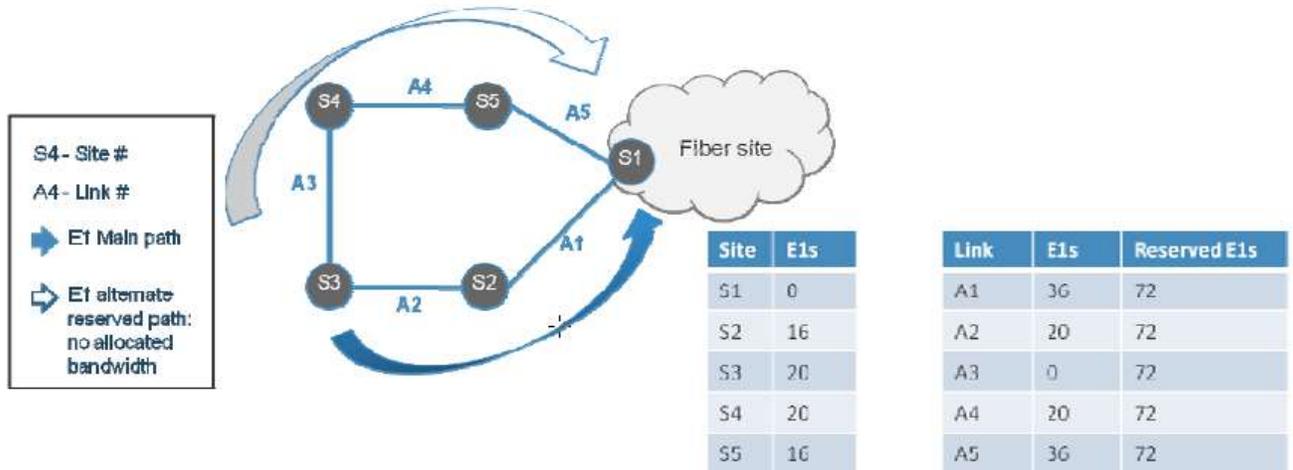
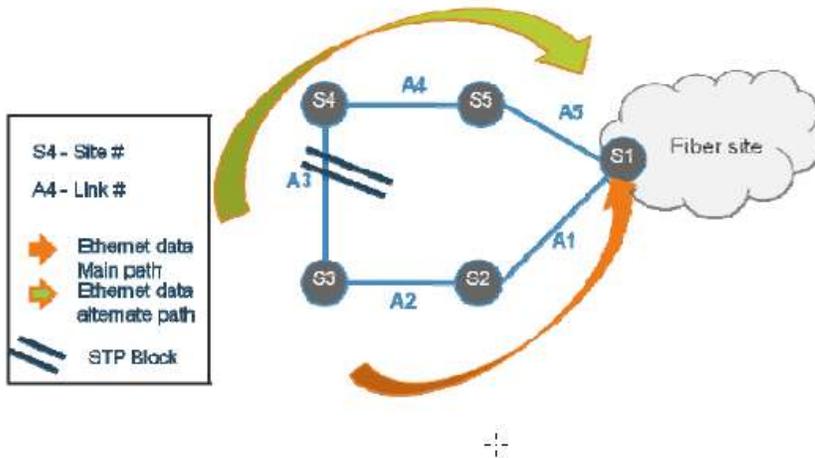


Figure 6: TDM Aggregation Ring - SNCP 1:1 Protection Bandwidth is used for Ethernet

In the **SNCP 1:1** scenario depicted in Figure 6, TDM-only E1s flow only in one direction. An alternate path is reserved, but no capacity is allocated. In case of a failure, E1s are re-routed in the opposite direction over the reserved path, receiving the non-allocated capacity.

When planning a data network for broadband services, one should compute the guaranteed traffic (Committed Information Rate – CIR), as well as the possible upside (Excess Information Rate – EIR). Given the availability of bandwidth for both classes, we can determine the subscriber’s overall Quality of Experience.



100% protection/worst case

Site	Cells	Data
S1	0	0
S2	4	42 Mbps
S3	5	53 Mbps
S4	5	53 Mbps
S5	4	42 Mbps

Use both sides of ring – x2

Site	Cells	Data
S1	0	0
S2	4	84 Mbps
S3	5	106 Mbps
S4	5	106 Mbps
S5	4	84 Mbps

Figure 7: A Native Ethernet Ring with 100% or partial protection based on STP

In the scenario that appears in Figure 7 above, when applying 100% protection – or in case of a worst case failure, up to 10 Mbps of Ethernet capacity are available per site. The whole ring can support 190 Mbps of traffic. So if the 190 Mbps of protected path bandwidth is reserved but not allocated, Ethernet capacity is increased to 21 Mbps per site. In Ethernet, the various failure state scenarios each have a different effect on capacity, as described in the next section.

Ethernet Ring Failure States

Figure 8 below depicts 3 failure states of varying severities:

- Non-Affecting Failure.** The failure in link A3 does not affect traffic, as STP has in any case blocked this link. Ethernet traffic does not traverse this link.
- Medium-Severity Failure.** The link failure at A2 causes some traffic to flow normally, while some traffic uses the reserved alternate path.
- Worst-Case Scenario Failure** – A failure in link A1 causes all traffic to flow over the reserved alternate path

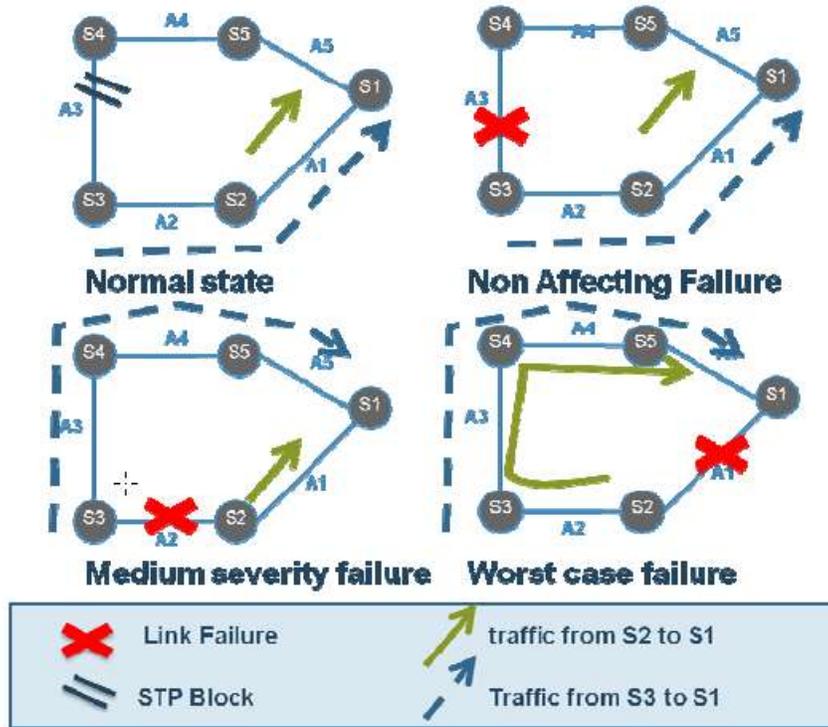
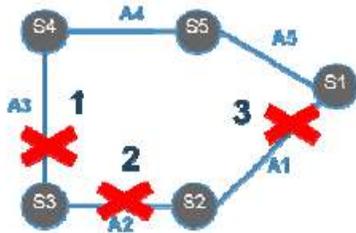


Figure 8: Ethernet rings: Different Severities of Failure States

There no need for an STP block in any of the failure scenarios (1-3), since at least one link in the ring is in any case out of service.

Comparison of Protection Methods – To Allocate or not to Allocate

Traditional protection schemes include bandwidth reservation and actual allocation of capacity for the alternate path. The reasoning for this was simple – in failure state, the network would not be able to restore connectivity in a timely fashion. Today, higher processing speeds and improved network recovery algorithms allow products such as Ceragon’s FibeAir IP-10 to restore connectivity instantly – without pre-allocation of capacity. Therefore, while high-priority E1 traffic is protected, alternate path capacity is reserved, but the unused capacity can be utilized for the delivery of broadband services, allowing data users to enjoy additional capacity when it becomes available. Let’s review an example:



2. Medium severity failure – A2 Failure

Site	# of E1s	Data	Link	# of E1s	Data
S1	0	0	A1	16	154 Mbps
S2	16	154 Mbps	A2	0	0 Mbps
S3	20	23 Mbps	A3	20	145 Mbps
S4	20	23 Mbps	A4	40	101 Mbps
S5	16	18 Mbps	A5	56	65 Mbps

1. Normal state – A3 Block or failure

Site	# of E1s	Data	Link	# of E1s	Data
S1	0	0	A1	36	110 Mbps
S2	16	49 Mbps	A2	20	145 Mbps
S3	20	61 Mbps	A3	0	0 Mbps
S4	20	61 Mbps	A4	20	145 Mbps
S5	16	49 Mbps	A5	36	110 Mbps

3. Worst case Failure - A1 Failure

Site	# of E1s	Data	Link	# of E1s	Data
S1	0	0	A1	0	0 Mbps
S2	16	7 Mbps	A2	16	154 Mbps
S3	20	8 Mbps	A3	36	110 Mbps
S4	20	8 Mbps	A4	56	65 Mbps
S5	16	7 Mbps	A5	72	30 Mbps

Figure 9: A Native² Ring with Protected-ABR at work

While 72 E1s lines are delivered all the time, only the relevant 36 E1s are actually carried on each path. On the Ethernet side, up to 190 Mbps of data are available in normal state, while 30 Mbps guaranteed at failure (in the worst case scenario).

In summary, ABR can provide much higher capacities in all scenarios, with the exception of worst case failures. The increased capacity allows operators to improve customer stratification, and enhance subscribers’ overall Quality-of-Experience (QoE) with better performance in mail delivery, content sharing, backup services, Facebook access, and video streaming.

Risk Free Bandwidth Re-allocation

Ceragon’s ABR feature allows operators to reclaim unused E1 bandwidth and re-allocate it for Ethernet traffic – without putting critical revenue-generating services at risk. Synchronization and other critical signaling systems are preserved.



ABR Benefits

Ceragon’s ABR approach has significant benefits over Pseudowire-based techniques when applied in a 2G-to-3G migration environment. It enables an operator to enjoy the inherent benefits of hybrid TDM and Ethernet Microwave environments:

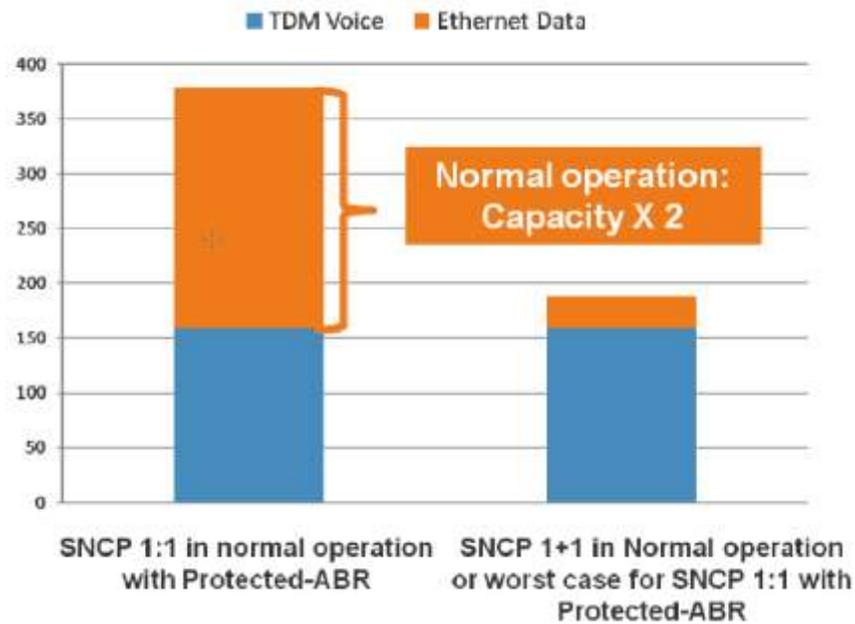


Figure 10: ABR Benefits: Double Data Capacity, with no Impact on TDM in Failure State

- Doubles ring capacity by using the TDM protection path to provide extra capacity for Ethernet services.
- Leaves revenue-generating 2G voice traffic unaffected in the migration process, with no need for protocol conversion.
- Protects network synchronization and clock using currently deployed E1s, without the need to test and verify new clock recovery mechanisms. Clock recovery techniques are sensitive to delay and delay variation, and therefore have a severe impact on the operator’s deployment strategy, often limiting the number of links in a chain or a ring.
- Streamlines the phase-out of legacy E1s in the network, easing the preparation for deployment of all-packet backhaul networks.



- QoS awareness enables the operator to associate the appropriate class of availability and class of service to each traffic type:
 - Protected or not protected
 - Special low delay considerations
 - Low, medium, or high priority – TDM or Ethernet

Summary

Mobile carriers operating wireless backhaul networks are discovering the advantages of deploying ring-based topologies, which include enhanced quality and reduced costs. While carriers can exploit the inherent strengths of such networks – such as unequalled reliability, it is understood that the price to be paid in bandwidth capacity may be too high.

Ceragon offers a range of solutions for capacity recovery, based on its Native² TDM-to-packet migration strategy, and on the Protected Adaptive Bandwidth Recovery (ABR) feature described in the previous sections.

These solutions enable a risk-free migration from 2G TDM-based communications, to a mixed 2G and 3G network carrying both TDM and Ethernet, to an all-packet multi-RAN environment. They can be deployed both in a single link with dynamic allocation of capacity between TDM and Ethernet, and in a ring where a protection scheme such as SNCP 1:1 can be selected to recover capacity for 3G traffic. Ceragon's innovative ABR mechanism maintains TDM protection levels and bandwidth reservation, but performs bandwidth allocation "just in time" when a fault condition occurs. As a result, the cell site bandwidth capacity is significantly increased, while the subscriber's overall quality of experience is enhanced as well. In short – Ceragon's solutions provide the simplest, most cost-effective, and most reliable way to migrate to 3G while doubling capacity at "zero" incremental expense.

The flexibility of Ceragon's FibeAir® IP-10 family allows carriers to implement a wide range of backhauling strategies – whether TDM-based, packet, or a combination thereof. Designed to help carriers reach their IP migration goals, Ceragon's Native² solution is an excellent platform for capacity optimizations – in any topology.

For more information, please visit our web site: www.ceragon.com.



About Ceragon Networks

Ceragon Networks Ltd. (NASDAQ: CRNT) is the premier wireless backhaul specialist. Ceragon's high capacity wireless backhaul solutions enable cellular operators and other wireless service providers to deliver 2G/3G and LTE/4G voice and data services that enable smart-phone applications such as Internet browsing, music and video. With unmatched technology and cost innovation, Ceragon's advanced point-to-point microwave systems allow wireless service providers to evolve their networks from circuit-switched and hybrid concepts to all IP networks. Ceragon solutions are designed to support all wireless access technologies, delivering more capacity over longer distances under any given deployment scenario. Ceragon's solutions are deployed by more than 230 service providers of all sizes, and hundreds of private networks in more than 130 countries. Visit Ceragon at www.ceragon.com.

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