FLEXIBLE WDM AND GMPLS IMPLEMENTATION ON WACS

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Abstract: The West Africa Cable System (WACS) connects 15 sites from South Africa to the UK over more than 14000 km of cable. WACS is a four fibre pair system and with semi-express fibres and O-ADM technology on the omnibus fibre pair, each site can reach both Europe and South Africa with no more than 3 "hops" without the need for signal de-multiplexing in-between.

In order to get the most benefits from WACS' meshed WDM topology, Generalised Multiple Protocol Label Switching (GMPLS) was implemented on the 1678MCC (Metro Core Connect) multiservice nodes deployed in each site. Thanks to the intelligent routing engine running on each node, any single or multiple failure case can be handled by the system as long as some capacity remains free. The different classes of service enable to implement 50 msec fast protection as well as best-effort automatic traffic protection.

A detailed study was conducted by WACS' Network Administrator (NA) to identify the best traffic engineering parameters in line with the capacity utilisation rules put forward by WACS. Following this initial step, network and traffic implementation is simplified by the embedded intelligence of the control plane combined with the network management control and display functionalities. An additional offline planning tool was also made available for failure scenario analysis, capacity planning and to determine future network expansion requirements to meet WACS' capacity demands.

1. GMPLS BASICS

First of all, some information on the main GMPLS elements are necessary:

- GMPLS : Protocol suite defined by the Internet Engineering Task Force (IETF),
- GMRE (GMPLS Routing Engine): The GMRE is the combination of the hardware and software embedded on the Network Element (NE) that implements the GMPLS control functionality,
- Data Plane: Also called Transport plane, represents the transmission resources available to support traffic,
- Control Plane: A set of applications and resources e.g. DCN, links used to support the control of the network,
- LSP (Label Switched Path): This is equivalent to a traditional path in SDH/OTN model but controlled by the set of GMPLS protocols,
- Nominal Route: Route of a LSP that has been assigned during initial implementation. Even if the actual route is switched following network events or operator commands, the system keeps memory of the nominal route.

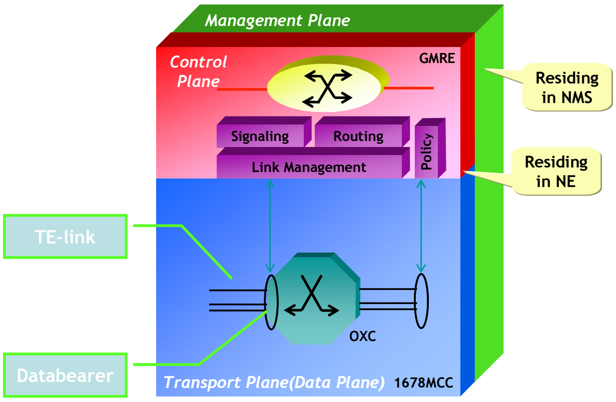

Figure 1: GMPLS network building blocks

Based on these main GMPLS elements, the following protection types can be applied on a per circuit basis across the 1678MCC multiservice cross-connect network elements to define the class of service required:

- Unprotected
- Source Based Restoration (SBR)
  - A nominal route is defined
  - A backup is computed upon failure
- Guaranteed Restoration (GR)
  - A nominal route is defined
  - A pre-calculated backup is available
- Sub Network Connection Protection (SNCP)
- Protection and Restoration Combined (PRC)
  - A main and spare route are defined
  - A backup is available upon failure

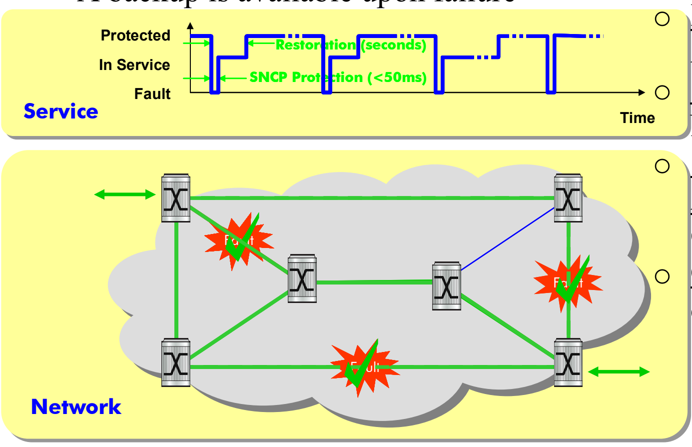

Figure 2: Protection and Restoration Combined (PRC)

2. NETWORK DESIGN AND TOPOLOGY

SDH ring protection mechanisms were traditionally designed on submarine networks at the early stages of the project, by routing fibres to build rings. However, in most cases these transoceanic rings are collapsed in a single cable. The main drawback of such a design, over and above the increase in latency during protection switches, is that half the network capacity has to be reserved for protection capacity around the rings.

The WACS fibre network was designed to connect 14 different countries across 15 main sites between London Global Switch and Yzerfontein (close to Cape Town) in South Africa. To facilitate the lowest latency end-to-end connection between South Africa and London, an express fibre pair was implemented. Connection of the 11 intermediate West African countries along the route is achieved via an omnibus fibre pair and two semi-express fibre pairs.

The different fibre pairs and types of traffic contributes to the WACS networks' meshed and resilient architecture. The four fibre pairs on WACS can be seen in Figure 3 and are defined below:

- Express fibre pair directly links South Africa to Portugal,
- Semi Express#1 fibre pair directly links Nigeria to South Africa and Portugal,
- Semi-express#2 fibre pair linking South Africa, Angola, Congo DRC, Ivory Coast and Portugal,
- Omnibus fibre pair connecting all 13 countries along the African coast.

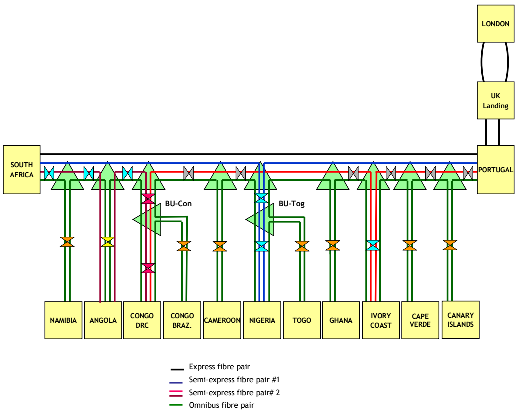

Figure 3 : WACS Fiber Network Topology

In addition, Optical Add Drop Multiplexing (OADM) technology was implemented on the Omnibus fibre pair to shorten the connection from any landing station to Europe and South Africa. Each landing site on the Omnibus fibre pair has a direct Digital Line Segment (DLS) to two sites both connected to a Semi-Express fibre pair.

The combination of Semi-Express fibre pairs and OADM technology increases the meshed network architecture and decreases the number of "hops" necessary to reach Europe and South-Africa. The network can be seen as a logical tree with short and redundant paths to both ends.

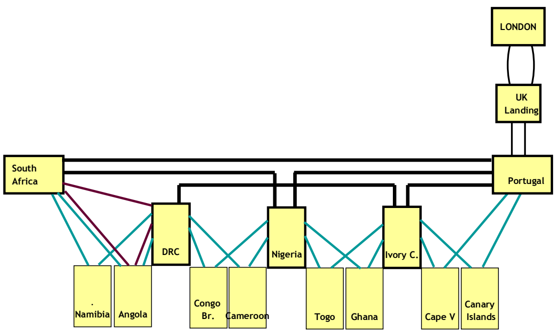

Figure 4: WACS Wavelength Topology

The benefits of this architecture are:

- Reduction of traffic latency,
- Increased Immunity for the rest of the network in case of a branch failure.

This combination of fibre and wavelength topologies forms the basis of the meshed network architecture with at least two routes to connect any site to another, and a maximum of two "hops" from any site to connect to the sites at the end of the network. In addition direct patching of 10 Gb/s tributaries between segments, without crossing SDH nodes, reduces latency and increases route diversity.

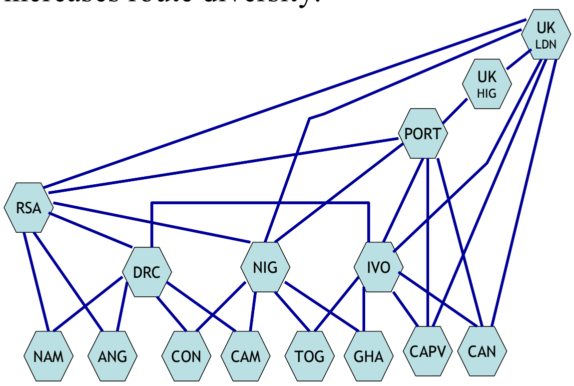

Figure 5: WACS Node Interconnection Diagram

3. RATIONALE FOR THE CHOICE OF GMPLS

In such a relatively large meshed network, multiservice cross-connecting remains the logical choice to combine fast protection mechanisms with traffic grooming capabilities.

Traditionally, submarine networks were implemented with one of the following network protection schemes:

- Linear, MSP 1:N protection which provides a fast and "bandwidth-efficient" protection against any hardware failure between any two sites,
- Ring topologies, more specifically 4F-MSPRING Transoceanic, which provides protection against branch cable failures at the cost of a higher bandwidth (50% of bandwidth reserved for protection),

WACS's decision to implement GMPLS on their network was driven mainly by the following considerations:

- Possibility to protect both against transmission equipment failure and the loss of one or more branches.
- Protection against any double or triple failure, as long as enough resources remain free,
- Shorter protection routes compared to ring protection, the system will always look for the shorter protection route and make use of the semi-express fibres rather than routing through the other end of the system,
- Flexibility in terms of definition of classes of service. Network protection is implemented on a per circuit basis, on request by the customer, thereby eliminating the need to reserve capacity network wide for protection.
- Automated restoration switching to external systems, available on demand, which eliminates the requirement for physical fibre patching.
- No fixed pre-defined ring topologies. The configuration of the system is not based on assumptions on the traffic matrix and there is no need for complex reconfiguration in case traffic between two sites evolves quicker than planned,
- No need for complex ring interconnection schemes.

There are some drawbacks that has to be dealt with by the users:

- Slower protection mechanisms for some of the classes of service,
- Need for careful traffic engineering, as the protection bandwidth is not booked and could be used for some nominal traffic .

However, most of these issues can be limited by the usage of right planning tools and new processes which will be discussed shortly.

4. GMPLS TRANSOCEANIC IMPLEMENTATION

Several specific aspects were jointly investigated, tested and engineered between the WACS NA and the supplier.

- Impact of submarine cable network distance: A lab experiment was conducted, with a test bed of over 12 000 km in length, to demonstrate that the GMPLS switching times over the longest WACS DLS does not have a significant impact on protection switching times,
- Simulation of a N+1 MSP over a single DLS: this is a basic request from all submarine operators, that can be easily fulfilled. One solution is to configure one of the wavelengths with different parameters so that it is kept empty by the provisioning algorithms.
- External traffic restoration: This proprietary feature enables the definition of an external SDH link (VC4-nc across a traditional SDH network) as a possible restoration route.
- Segregation of traffic: Both ports and LSP (traffic) can be flagged with colours, known as resource colouring, to prevent traffic from utilising a particular resource or route unless it has been pre-assigned the correct colour attribute to do so. This feature enables automatic external restoration to be set up to reserve the external restoration routes to “restorable” traffic only from the corresponding site,
- Control plane & DCN (Data Communication Network) Reliability: The control plane status drives the decisions for traffic rerouting, and is therefore important that it’s communication to the network elements be secured both on the internal DCN and Alternate-DCN. The standard practise is to provide an internal backup for the DCN, which normally runs over the SDH DCC (Data Communication Channel), over the SLTE FEC (Forward Error Correction) frame overhead. Alternate-DCN links are also made available externally in cases when it’s not possible to restore this internally. This need to be in place for the proper

operation of the automatic restoration switching to external systems.
- Maintenance activities: Special care has to be taken during maintenance operation not to trigger protection mechanisms in a un-controlled way. Maintenance commands are available to limit rerouting triggers on a port-by-port basis to prevent any un-controlled rerouting to occur during planned maintenance activities.

5. GMPLS MANAGEMENT TOOLS AND SUPPORT

The level of capacity management requirements on a submarine cable system dictates that these systems can't be fully left under the control of its embedded intelligence as compared to the more predictable SDH switching behaviour. The same level of control is therefore expected with the implementation of GMPLS in a submarine cable network.

First key point is that traffic over a GMPLS enabled network keeps all SDH monitoring capabilities i.e. all performance monitoring and overhead bytes usage are still available.

Another important notion that of the nominal route and the possibility to revert any path back to its optimal routing position, before the failure occurred, once the failure condition is cleared.
Another key aspect is the control of the network load to ensure that enough capacity remains available to support the various classes of service in case of failure. As protection resources are only pre-calculated and not pre-booked, the availability of network resources needs to be audited on regular basis To achieve this, Alcatel-Lucent has delivered an external tool to the WACS NA with the capability to collect a snapshot of the network i.e. GMRE databases to analyse and perform the necessary network failure simulations confirming resource availability to sustain the various classes of services that are booked.

6. CONCLUSION

GMPLS is the natural evolution of TDM based submarine networks. With many alternative submarine cables becoming available to support external restoration, few operators want to reserve potential revenue generating network capacity for protection. GMPLS provides this flexibility to deliver the required class of service on a per circuit basis, therefore enabling more efficient usage of the available bandwidth. Due to the complexity of WACS' meshed network architecture, GMPLS provides better resilience and optimised routing to the protected circuits. The proper implementation of GMPLS on WACS, supported by the protection switching times observed, is proof that this technology is suitable for a 15,000 km submarine network with a large number of sites. Involvement of NA and NOC in the early network architecture development phases of the project is key to establish the required traffic engineering parameters to have effective control over network switching behaviour.

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