Designing an Advanced Regional Research Network

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Background

The Spanish authorities are fostering the development of high-speed regional research networks as a better way to guarantee that adequate infrastructures can be built at the regional level to access the Spanish and international research networks. In this context, the government of the region of Madrid imposed on itself the challenge of creating a high-speed regional research network to be one of the most advanced within Europe. It established a collaboration with Universidad Carlos III de Madrid in order to introduce the most advanced technology, yet find a cost-effective solution. This has led to the design and deployment of REDI Madrid, a regional research network for the research and education institutions of the region of Madrid that is under the supervision of a non-profit organization called Fundación Madrimasd para el Conocimiento.

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In this article we share our experience in setting up the requirements and designing this advanced network.

Requirements

After a consensus process with different institutions, the design requirements for the new REDI Madrid network were listed as:

- High performance: Provision of a minimum access speed of 1 Gb/s.
- Reliability: Institutions are day after day more dependent on their data communications to be able to attend to their daily activities, so high reliability was considered crucial.
- Scalability in terms of capacity: Network technology is constantly evolving, and new and more bandwidth-demanding network-based applications are appearing. This means that to be able to keep pace with these developments, the network must provide easy ways to update capacities and access speeds.
- Scalability in terms of number of connected institutions: This would allow a phased network deployment, in which institutions could progressively join the network.

Regarding the institutions to be connected, it was decided to opt for a phased approach. Out of the 70 relevant research and education institutions in the region of Madrid, nine very relevant ones (in terms of size, bandwidth demands, and research results) were selected for the first phase, defining at the same time a roadmap to gradually incorporate the others. The institutions to be connected in the first phase were Consejo Superior de Investigaciones Científicas (CSIC), Instituto Nacional de Técnica Aeroespacial (INTA), plus the public universities located in Madrid: Universidad de Alcalá (UA), Universidad Autónoma de Madrid (UAM), Universidad Carlos III de Madrid (UC3M), Universidad Complutense de Madrid (UCM), Universidad Nacional de Educación a Distancia (UNED), Universidad Politécnica de Madrid (UPM), and Universidad Rey Juan Carlos (URJC).

Network Design

After studying the different available possibilities, dense wavelength-division multiplexing (DWDM) was chosen as the core transmission technology. DWDM allows sharing of the expensive fiber optic infrastructure and provides a straightforward growth path. It also allows network self-restoration when ring fiber topologies are used.

It was decided to use DWDM equipment selected from the Metro product family in order to reduce costs, taking into account the involved distances. Using long-haul DWDM equipment would have resulted in two disadvantages: first, equipment costs surpassing the savings derived from the shared optical fiber infrastructure; and second, lack of efficient multiservice capability support. However, it would have made the physical fiber design easier because of greater distances supported.

Commercial equipment from four different vendors was analyzed, resulting in the selection of the Nortel Networks Optera™ Metro 5200 family. The reasons for this are that Optera provides carrier class reliability, is well suited to the involved distances, provides enough capacity (up to 32 protected lambdas in one ring), and is designed for scalability (10 Gb/s in one carrier are already available, which gives 320 Gb/s over the ring).

Another design decision was to use a ring fiber topology with protected carriers to satisfy the high-reliability requirement. The initial topological design, based on direct distances, was to use a single dual-fiber ring to connect all the institutions. However, this had to be discarded when measuring the fiber distance over the actual physical paths of the telecom providers and the actual attenuation of the existing fibers. After considering several topologies, a topological design jointly performed with Telefónica (the chosen telecom provider) was selected. This design was composed of three dual-fiber rings that connected the CSIC premises with all the institutions in the network. This configuration has the added advan-

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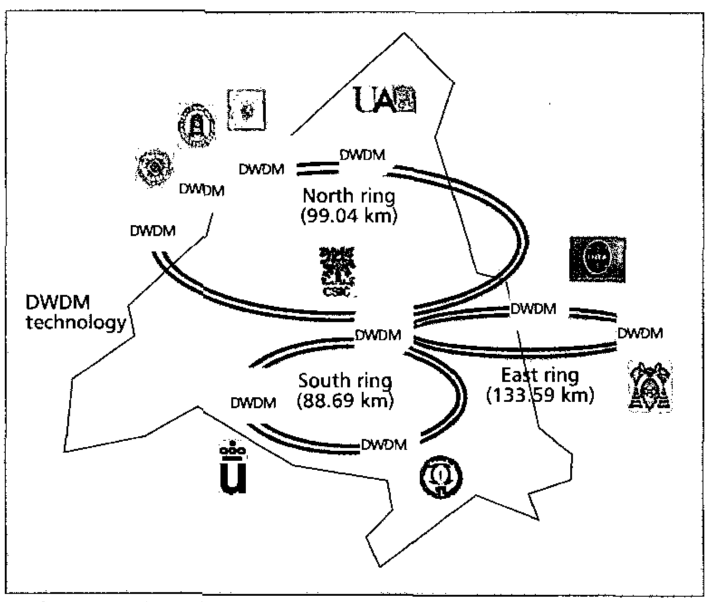

Figure 1. *Physical topology of REDI Madrid.*

tages, over the single ring one, of allowing more growth capacity in each ring, and improving reliability because a failure in one ring does not affect the remaining ones. The physical topology of the network is presented in Figure 1.

New institutions may be connected to the network by incorporating additional DWDM shelves to the rings. This is not a trivial task; the fibers of the ring need to be re-routed to reach the newly connected institution.

The target topology of carriers over the rings was a logical star that supported, for each of the connected institutions, a protected optical carrier (lambda) to the central node (CSIC-CTI). It was then necessary to design, for each ring, the optimal way to provide these carriers. The carrier design implied reaching a compromise between optical amplification and electrical regeneration on one hand, and between initial investment in optical equipment and scalability in terms of carriers on the other.

Optera Metro DWDM equipment uses an optical filter to extract sets of four lambdas from the ring. The usage of the same set of lambdas for up to four institutions in the same ring allows costs savings in equipment (fewer optical filters), but implies that the carriers are optically extracted at each DWDM shelf in the ring. This implies that equipment failures, in addition to fiber cuts, would also interrupt the ring. Additionally, extracting the carriers implies that electrical regeneration must be performed. An alternative solution would have been to use lambdas from different sets, passive passing through intermediate DWDM shelves, and optical amplifiers to overcome the attenuation (chromatic dispersion limits the fiber distance, but this is not a problem in the considered scenario). The balance is therefore between the cost of additional optical filters and amplifiers minus the cost of the electrical regeneration equipment, vs. slightly better reliability and improved scalability (cheaper than adding a new DWDM site). The solution in this case was to place all the carriers in the same carrier set.

The carriers that connect each institution with CSIC-CTI are terminated by 1 Gb/s Ethernet interface cards, over which virtual LAN and IP services are provided. A high-performance switch/router is located at CSIC-CTI where all GbE interfaces are connected. This equipment also provides a redundant connection to RedIRIS (the Spanish research network) with a 2.5 Gb/s packet over synchronous optical network (POS) interface.

Network Evolution

New institutions may be connected to the network by incorporating additional DWDM shelves to the rings. This is not a trivial task, since the fibers of the ring need to be rerouted to reach the newly connected institution, and the whole ring is affected (attenuation, equalization). An alternative approach is to deploy a point-to-point fiber pair to one of the existing institutions and include a new carrier at the existing DWDM shelf. It is also possible to provide direct links between any two institutions, even if they are not in the same ring, simply by connecting the DWDM equipment in the central node, although an optical-to-electrical-to-optical conversion would be needed.

It is also possible to increase the capacity for each institution. Cards supporting one 10 Gb/s Ethernet or 10 1-Gb/s interfaces per lambda are already available, allowing a 10× bandwidth increase. Finally, new technologies and products that are appearing (e.g., allowing increased reach) will also contribute to optimizing the optical network.

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