Project Achievements

CELTIC Telecommunication Solutions

100 Gigabit Ethernet Transport Technologies

100GET-AL investigated architectures, concepts, technologies and prototype implementations for a flexible, cost efficient, reliable and service independent transport network providing next generation transmission/physical layer technologies and carrier-grade packet transport solutions for the requirements of the future internet.

Main focus

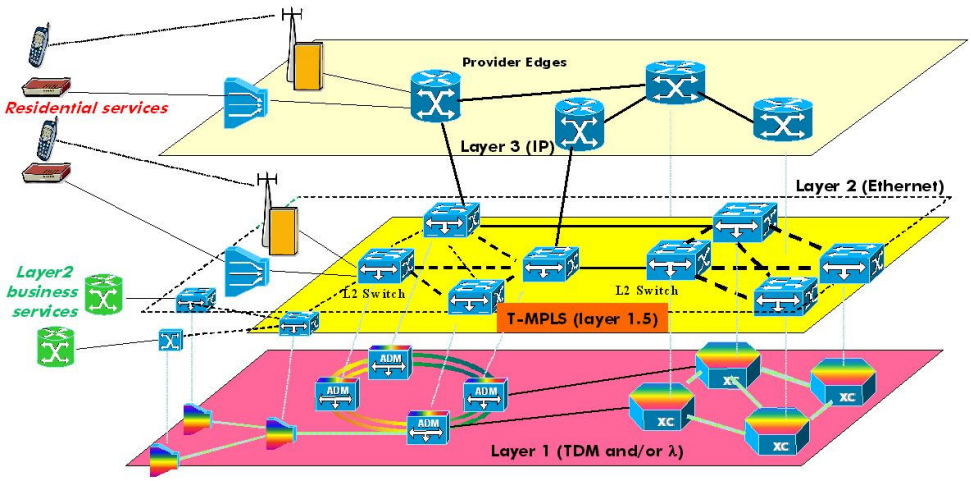
100GET-AL raised key innovations for a convergence network based on a multi-layer, multi-service architecture with new 100Gb/s transmission technologies and novel Layer 2 packet transport techniques offering carrier grade performance to fulfil availability, reliability, Quality-of-Service (QoS) and supervision requirements of future services and broadband applications. The studies included:

- Scalable network solutions with node capacities in the multi-Terabit/s range to match the rapidly growing traffic
- Flexible control plane solutions for 100G-Ethernet packet networks enabling flexible, cost-effective network operation and end-to-end QoS provisioning across multiple layers and domains.
- Physical layer technologies for next generation high capacity Ethernet based transport networks and investigation of 100Gb/s Tx and Rx subsystems.
- Technology options for low cost 100Gb/s transponders, including design, realisation and test of electronic circuits and opto-electronic components based on the most advanced electronic and opto-electronic technologies and HF packaging techniques.
- Investigation of the most powerful technology options for 100G-Ethernet transport in system demonstrator for fiber transmission and interworking with 100Gb/s packet node.

Approach

The work was structured in two major activities, one addressed new Layer 2 packet transport concepts. Key targets were scalable, carrier grade packet transport solutions to efficiently offload Layer 3 networks with IP routers by electronic as well as photonic approaches below Layer 3 supporting both packet based Ethernet services and wavelength based OTH services in a cost optimized way. An essential cornerstone for converged multi-layer, multi-domain networks was an integrated, automated control plane and related management functions to enable high quality, resilient network service provisioning at minimum total cost.

The second major activity investigated and developed physical layer technologies for next generation 100G-Ethernet based transmission. Promising options for low cost 100Gb/s transponders were investigated, including design, realisation of advanced electronic circuits and electro-optic components for 100Gb/s subsystems (Tx/Rx). Subsystems were realised on the basis of the most advanced high speed electronic and opto-electronic technologies (SiGe, InP) and HF packaging techniques, offering high integration, low power consumption and promising cost/performance tradeoffs. Different architectures and Tx/Rx subsystems were analysed and promising concepts were realised for integration into 100Gb/s Tx/Rx prototypes. Prototypes were integrated



100GET

100GET-AL

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Project Website

www.celticplus.eu/projects/celtic-projects/call4/100GET/100GET-AL/Project-default.asp

into a system demonstrator and analysed in serial 100Gb/s transmission system tests to identify the most powerful technology options. Common 100Gb/s field transmission tests were performed in collaboration with DTAG. The results of this project provided a solid basis for contributions to 100G-Ethernet standardisation (e.g. IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet Task Force, ITU-T SG 15).

Achieved results

In the **networking part** of the project several networking tools and prototypes have been investigated and realized:

- Two network cost optimization tools were developed. The first one used heuristics providing an approximation procedure whereas the second tool was based on Mixed Integer Programming (MIP) which represents a mathematical exact solution. It was demonstrated that results derived from the heuristic approach are very close to MIP solutions while having the result in a fraction of time.
- An OPEX cost model was developed and implemented into the optimization tool. This cost model consists of a large range of small cost blocks having mutual relationships with regard to network layers (optical layer, SDH layer and IP layer) and devices (ROADM, Digital Cross Connect and IP router).
- An expert system was developed supporting fast failure localization in GMPLS based networks. The system also performs sanity checks, i.e. upfront localization of configuration failures before they actually cause problems. Such sanity checks could prevent from mis-configurations that lead to degraded stability or resilience situations in a GMPLS network.
- A dynamic optical bypass demonstrator was engineered to introduce the concept of bandwidth pipes for packet transport in sub IP layers of NGNs and to emphasize its importance for QoS-assured communication services deployment. We could successfully show the automated set-up/release of optical bypasses in a small network consisting of 3 nodes depending on measured traffic figures.
- A Layer 2 gate demonstrator was developed to achieve a simple end-to-end QoS.
- A 100G Packet Processing Board was realized containing hardware for traffic management (TM), Physical Coding Sub-layer and Media Access Controller (PCS/MAC), transceiver hardware and circuitry for the connection to the central agnostic switch environment.

In the **physical laser part** of the project advanced electronic as well as o/e components were investigated and realized for the setup of 100Gb/s subsystems and demonstrators. The project addressed different modulation formats and realized various 100Gb/s system demonstrators.

Various **electronic** as well **as opto-electronic components** have been developed:

- A complete innovative cell library for design of circuits for data rates of 100Gb/s and above was developed and utilized for design and realization of 4:1 multiplexer for 112Gb/s OOK and 1:4 CDR/demultiplexer.
- InP-based MZ modulator chips with bandwidth of 53GHz were developed and prototype MZ modules for serial OOK format and IQ modulator modules were realized. Monolithic 90°-Hybrid with balanced photo detectors and dual photo diodes have been developed.
- New packaging concepts and cost effective assembly technology were developed and utilized for prototype realization. 28Gbaud Dual-Polarisation QPSK / coherent receiver module based on an monolithically integrated 90° Hybrid with Dual-PDs in InP were realized as well as 56Gbaud DQPSK receiver module based the hybrid integration of InP PDs with free-space optical Delay-Line Interferometer.
- An integrated transmitter for 100Gb/s OOK based on integrated EML and 100G microelectronics was realized. Mounting of the integrated chip and HF-lines was supported through a complete electro-magnetic modelling of the TX package.

Various **Nx100Gb/s DWDM transmission** tests were performed together with **DTAG** over their **OCTET** field fibre testbed:

- 8x107Gb/s OOK-VSB DWDM with 100GHz channel spacing over 500km field fibre applying inline dispersion management and adaptive PMD compensation.
- 16x112Gb/s DQPSK DWDM with 100GHz channel spacing over 764 km field fibre utilizing CD-compensation as well as optical PMD compensation.
- 3x256Gb/s OFDM DWDM over 764km using dual-polarization OFDM superchannels and coherent detection.
- 1 Terabit/s OFDM dual-polarization superchannel over 454km (without DCF) applying coherent detection.

The project partners have published 11 journal papers as well as 44 papers on international conferences and contributed to 100G-Standardisation: ITU-T, IEEE, OIF.

Impact

The project prepared the field for new Terabit transport networks based on cost efficient solutions below Layer 3. The derisking of new technologies for 100Gb/s transmission and processing as well as new architectures exploiting the potential of multi-layer approaches and the new functionalities of integrated network control for automated operation will enable the industrialization of novel cost efficient solutions and put network operators in the position to cope with the traffic and service requirements of future internet.

About Celtic

Celtic is a European research and development programme, designed to strengthen Europe's competitiveness in telecommunications through short and medium term collaborative R&D projects. Celtic is currently the only European R&D programme fully dedicated to end-to-end telecommunication solutions.

Timeframe: 8 years, from 2004 to 2011

Clusterbudget: in the range of 1 billion euro, shared between governments and private participants

Participants: small, medium and large companies from telecommunications industry, universities, research institutes, and local authorities from all 35 Eureka countries.

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