Project Achievements

CELTIC Telecommunication Solutions

100GbE End-to-End Carrier-Grade Ethernet (Ericsson cluster)

The project 100GET-ER investigated successfully a wide range of potentially cost-efficient solutions for next generation DWDM networks at a speed of 100 Gb/s. Focus of the innovation was the Metro area, where the strongest growth is expected for the next years. To develop comprehensive 100G interface solutions, not only system concepts were evaluated and technology demonstrations set up, but also the enabling novel components were developed within the project. In addition, packet processing and control issues were explored.

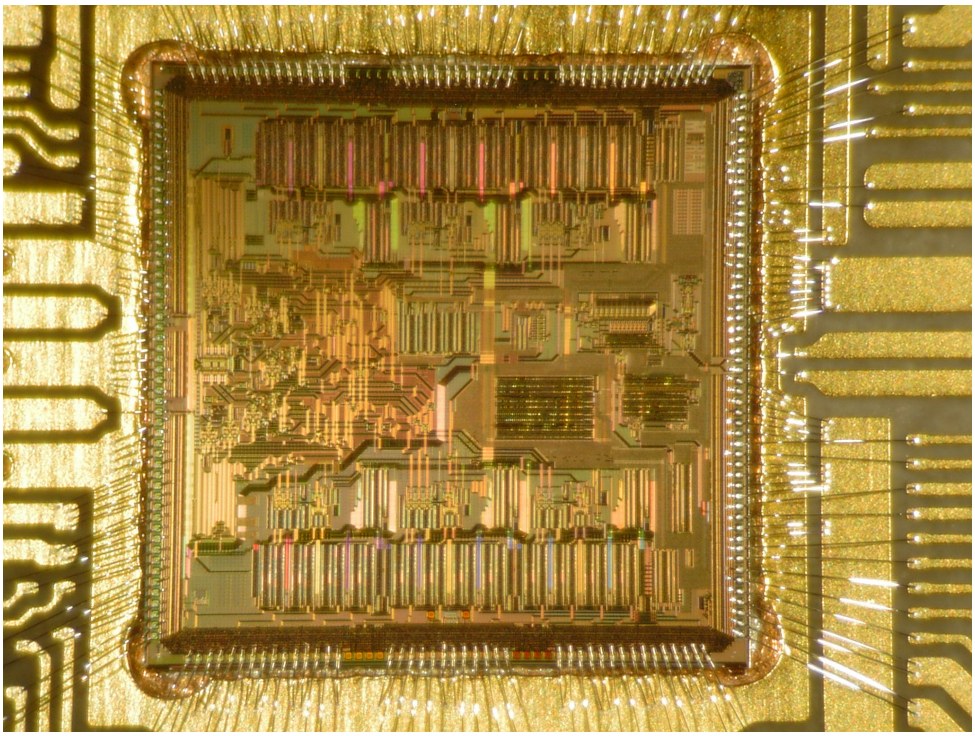
Main focus

The significant growth of IP based traffic in broadband access networks, enterprise/server networks, provider networks, core routing, and optical transport networks has resulted in a doubling of the Internet backbone bandwidth every 12 to 18 months. However, since IP traffic is dominated by video content, it is expected that the traffic in metro networks will grow much faster than in the core. In metro networks the required channel reach (<600 km) is much less than for long-haul, but the shorter reach also makes the transponders more cost-sensitive.

Therefore, the project focus was on multi-carrier formats like optical OFDM and RF-assisted sub-carrier multiplexing with higher order modulation formats. The general objective has been to move complexity from the optical into the electrical domain by employing digital signal processing, high speed ADC and DAC components, and radio frequency supported concepts that allow cost-efficient optical frontends.

Approach

The project pursued a complementary approach where system concept design was done with the development of the necessary novel components in close cooperation. Multi-carrier techniques, polarization multiplexing, and advanced modulation formats in combination with digital signal processing (DSP) allow alter-



The SiGe DAC chip that was developed within the project (chip photo courtesy of Micram)

100GET

100GET-ER

Project ID: CP4-001

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Closure date: 31 December 2010

Partners:

Acreo AB, Sweden

Chalmers University of Technology (CTH), Sweden

Christian Albrecht Universität Kiel (CAU), Germany

Ericsson AB, Sweden

Ericsson GmbH, Germany

FhG – Heinrich-Hertz Institut, Germany

MICRAM Microelectronic GmbH, Germany

Royal Institute of Technology (KTH), Sweden

SP Devices, Sweden

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Project Website

www.celticplus.eu/Projects/Celtic-projects/Call4/100GET/100GET-ER/Project-default.asp

native transmission concepts with potential for lower cost and lower power consumption.

In the project three promising technology tracks were followed:

- Radio frequency (RF) assisted multi-carrier techniques (also known as sub-carrier multiplexing) with either direct-detection (self-heterodyne) or coherent (heterodyne) receivers in combination with a DSP. The reduced signal rate will make it possible to use low-speed ADCs and low-cost FPGAs, instead of ASICs. Enabling technologies investigated for this format were the interleaving of off-the-shelf ADCs and the linearization of optical modulators to reduce nonlinear effects. Moreover the project gave input to a spin-off MEDEA+ project developing the corresponding RF components.
- Digital multi-carrier formats, i.e., optical OFDM, with low-cost direct-detection and coherent receivers. High speed DACs and ADCs in SiGe and CMOS technology were developed for this aim.
- Multilevel phase modulation formats (DPSK, DQPSK and D8PSK) with low-cost direct-detection and coherent receivers as part of the single-carrier benchmark activities.

Achieved results

Major achievements include:

- **Ericsson** and **Acreo** have shown 112 Gb/s dual-polarization 16-QAM using sub-carrier multiplexing with two sub-carriers (7-GHz and 21-GHz) and coherent receivers over field deployed fibres of more than 500 km. Extensive transmission simulations of different SCM architectures, as well as detailed simulations of the RF sub-system, has been performed by **Acreo**.
- A 14 GS/s ADC required for the 100G DP-16QAM SCM system (7 Gbaud) was developed using two interleaved 7 GS/s ADC boards. These ADC boards are now part of **SP Devices** product portfolio.
- **KTH** has developed realistic models for Mach-Zehnder modulators (MZM) and studied how the imperfections affect the system performance of a sub-carrier modulated system.
- **CAU, HHI** and **Ericsson** have demonstrated directly detected and coherent OFDM and achieved very high spectral efficiency of 7.2 bit/s/Hz as well as a record single band bandwidth of 21 GHz.
- Very high speed AD- and DA-converters are key components for future OFDM interfaces. **Micram** (SiGe) and **INT** (CMOS) developed leading edge components in two different technologies for this aim.
- **Ericsson** conducted field-trials with 112 Gb/s DP-QPSK in collaboration with **Deutsche Telekom** using a direct-detection receiver and with **Telefónica** employing a coherent receiver, both on a 50-GHz DWDM grid over 600 km and 848 km of standard SMF, respectively.
- Chalmers has shown dual-polarization D8PSK with direct-detection receivers up to 240 Gb/s over 320 km DWDM system and 10G OOK neighbouring channels. Evaluation of DQPSK and D8PSK also included simulations by Acreo.
- **IKR** has investigated means to alleviate the high packet processing requirements on network elements in 100GbE networks and developed a rate control framework for the dynamic sharing of transmission resources.

Standardization: Ericsson has actively contributed to the IEEE 802.3 100G Ethernet standardization.

Patents: Ericsson has filed three patents related to the project.

Major publications (from a list of almost 40 papers in the project):

Bengt-Erik Olsson, et al., "*RF-Assisted Optical Dual-Carrier 112 Gbit/s Polarization-Multiplexed 16-QAM Transmitter,*" OFC/NFOEC 2010, paper OMK5.

Stefan Herbst, et al., "*21-GHz Single-Band OFDM Transmitter with QPSK-Modulated Subcarriers,*" OFC/NFOEC 2011, paper OMS3.

Impact

The project has demonstrated the technical feasibility of different multi-carrier formats with potential for cost- and power-efficient implementations of 100GbE transport in the metro area. It also provided benchmark results for single-carrier formats like DP-QPSK that is seen as the de-facto standard for long-haul.

First commercial subsystem products from the project are the AD and DA converters from Micram (fastest stand-alone devices you can buy) and the ADC module employing interleaving of off-the-shelf chips from SP Devices. Additional commerzialisations of project results are probable. Whether one of the system concepts is going to be implemented as a product mainly depends on the cost structure and cost erosion of the 100G long-haul solution and on the role of the power consumption for future 100G deployments.

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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