



Enabling Practical Wireless Tb/s Communications with Next Generation Channel Coding

Newsletter / May 2019 - Issue 04

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Consortium

8 partners (7 countries)

Project Coordinator

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Project number: **760150**

Project website:

www.epic-h2020.eu

Project start: **1st September, 2017**

Duration: **36 months**

Total cost: **EUR 2,966,268.75**

EC contribution: **EUR 2,966,268.75**

Message from the Coordinator

Half time of EPIC – Highlights of the first 18 Months

The first period of the EPIC project is already over and the project reached its halfway milestone in March 2019.

Since the previous newsletter, an important milestone has been reached: **EPIC developed the architectural templates for all three code classes and has shown that**

Tb/s throughput seems to be feasible in advanced technology nodes.

The first project review meeting took place in Brussels, on 10th of April, 2019 and the project officer and project reviewers were satisfied with the advancement of the project.

New EPIC Animation Delivers the Big Idea in a Simple Explainer Video Format



Forward-Error
Correction for
wireless Tb/s
technology and
Beyond-5G systems



EU FUNDED PROJECT



[Watch on Vimeo](#)

Successful First Review Meeting in Brussels

The consortium met at the IMEC premises, in Leuven, Belgium, from the 8th-9th of April to prepare the review meeting on the 10th of April. Project results were discussed in detail and important decisions on the way forward were made.

The preparation for the review meeting was intense and fruitful – on the day of the review meeting (10th of April), all presenting partners were confident and the consortium was able to present the current project results in a unified manner.

According to the project officer and reviewers, **the project has achieved most of its objectives and milestones for the first period.** They believe that the **EPIC project**



The EPIC consortium attending the review meeting in Brussels

will provide results with significant impact.

Furthermore, the quality of the results is considered as in general good, based on the deliverables which have been submitted so far. In addition, the reviewers stated that the EPIC project has identified relevant use cases and

KPIs in order to improve FEC for wireless Tb/s technology and Beyond-5G systems. Moreover, the reviewers state that **EPIC has identified the gaps between the state-of-the-art and the future requirements** and made advances **for all three code classes towards Tb/s throughput FEC decoders.**



Organization of a special session at ISTC

The EPIC project organized and participated in a special session, dedicated to implementation of FEC for future communication systems, at the International symposium on Turbo Codes and Iterative Information Processing, which took place on the 3rd-7th of December, 2018, in Hong Kong. Erdal Arıkan (POL) and Norbert Wehn (TUKL) gave invited talks on "Polar Codes for Terabit/s Data Rates" and "When Channel Coding Hits the Implementation Wall," respectively.

Two additional regular talks were given by Stefan Weithoffer (TUKL) and Rami Klaimi (TB) on "25 Years of Turbo Codes: From Mb/s to be-

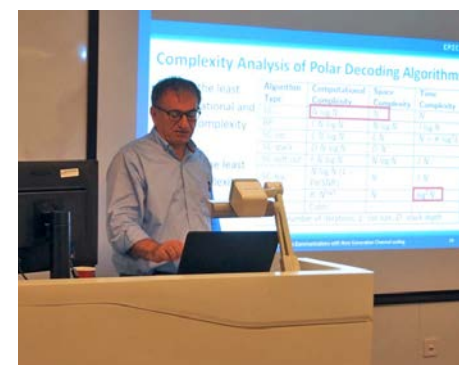
yond 100 Gb/s" and "Low-complexity Decoders for Non-binary Turbo Codes."

Moreover, two posters were presented: "Mitigating Correlation Problems in Turbo Decoders" by TB and, "A 100 Gbps LDPC Decoder for the IEEE 802.11ay Standard" by IMEC.

Open access has been provided to all publications, posters and presentations. Please take a look at the project website, for direct links to the different presentations/publications: www.epic-h2020.eu/results.



Norbert Wehn presenting at ISTC.



Erdal Arıkan presenting at ISTC.

Project Highlights: The First 18 Months

Wireless communication is a key technology of our information society and there is a continuous demand for higher throughput, higher spectral efficiency, lower latencies, lower power and large scalability on communication systems.

This imposes large challenges on the baseband signal processing. Channel coding, or forward error correction (FEC), is a crucial technology component of any digital communication system. FEC provides reliable communication in the face of noise that corrupts the transmitted signal, but does at the expense of decreased information bandwidth and increased implementation complexity.

FEC is a major source of power consumption, silicon area and largely contributes to the overall latency and throughput limitations in baseband signal processing. Beyond-5G use cases are expected to require wireless data rates in the Tb/s range in a power envelope in the order of 1-10 Watts. EPIC key performance metrics (KPI) are throughput in the order of 1 Tb/s, an energy efficiency of about 1 pJ/bit, and an area efficiency > 0.1 Tb/s/mm², while meeting the stringent communications and flexibility requirements (in terms of code rates, lengths of codes, etc.) of EPIC use-cases.

At the beginning of the project a thorough search of leading

industry standards, business platforms, and emerging applications resulted in a wide range of Tb/s use cases that were elaborated in detail: data kiosk, virtual reality, intra-device communication, wireless fronthaul/backhaul, data center, hybrid fiber-wireless network and satellite communication.

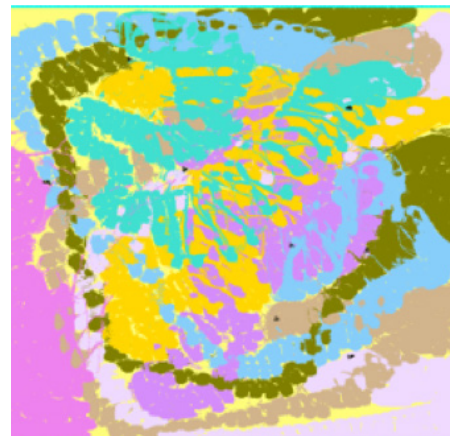
A comprehensive overview of the state-of-the-art FEC decoding in current wireless communication systems from an architecture and implementation perspective were carried out and corresponding gaps with respect to the EPIC use cases were identified, i.e. KPI performance gaps were detailed for turbo, LDPC and polar codes.

After that, the design spaces for all code classes were spread out and an in-depth exploration of this design space was carried out with regard to the EPIC use case requirements.

This design space exploration described all the design parameters related to code structure, decoding algorithms, hardware architectures, and the different constraints dictated by the target application and technology.

Then, the most promising combination of parameters and techniques from the design spaces to meet the EPIC requirements were identified with the goal to narrow the huge design space. Since there is no silver bullet that matches all code classes, each code class was treated separately.

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The layout of a 100 Gb/s turbo code decoder in 28nm technology. This decoder outperforms state-of-the-art by more than 10x in throughput and 4x in area efficiency.



Layout of an 512/427 polar code list decoder with list size 2 in 28nm technology that outperforms state-of-the-art with 17x higher throughput, 10x higher area efficiency and better energy efficiency.

The EPIC board gave very positive feedback on the project progress.



Project Highlights (cont.)

However, there are some commonalities from an architectural point of view. To achieve very high throughput towards 1Tb/s, extreme high parallelism with reasonable area overhead is mandatory.

Hence, heavily pipelined architectures for all three code classes were selected as major parallelism paradigm.

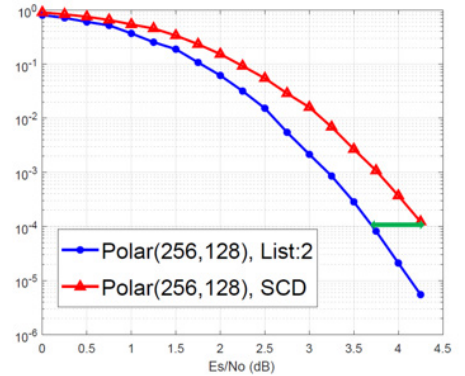
For each code class, we identified and extensively described promising codes, code construction techniques and architectural templates to achieve the EPIC goals. First results show that throughputs far beyond 100 Gb/s were achievable in 28nm technology for all three code classes.

EPIC already started many dissemination activities. These activities include involvement in standardization efforts, participation in dedicated workshops, organizing of special sessions in various conferences and scientific

publications. Two keynotes directly related to EPIC at the ISTC 2018, one of the most important conferences on channel coding worldwide, emphasized the importance of the implementation aspects and challenges for high-throughput FEC as pursued by EPIC.

As a direct result, DLR organized a workshop in February on High Throughput Coding in Munich. This workshop was very well attended with 70 participants from the scientific and industrial community. EPIC is also member of the Horizon B5G networking cluster which unites all relevant projects from the EU's Horizon program.

EPIC had an Advisory board meeting in December, 2018. This board consists of highly reputed scientists, who gave very positive feedback on the project progress.



The graph shows a trade-off between communications performance and implementation efficiency for two different 256/128 polar code decoder with list decoding (list size 2) and successive cancellation algorithm respectively. The list decoder has a gain of 1 dB at FER 10⁻⁴ compared to the successive cancellation decoder but with an additional area cost of 0.36mm² (0.23 m² versus 0.59 mm²) and 434mW power increase (200mW versus 634mW) in 28nm technology.

EPIC DECODER ACHIEVEMENTS



The first turbo code decoder that exceeds 100 Gb/s in 28nm technology with scalable interleaver and an error floor that outperforms the LTE turbo code.



The first unrolled window decoder for LDPC-CC for Tb/s throughput.

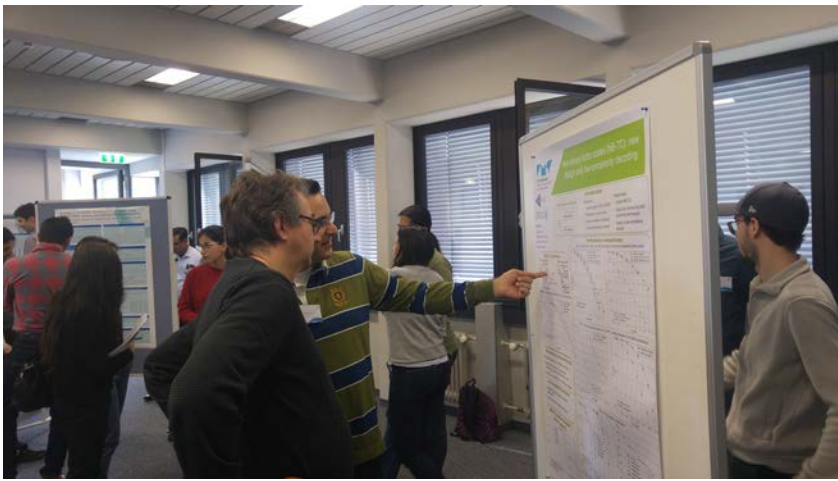


SC and SCL polar decoder with outperforming throughput and energy efficiency.



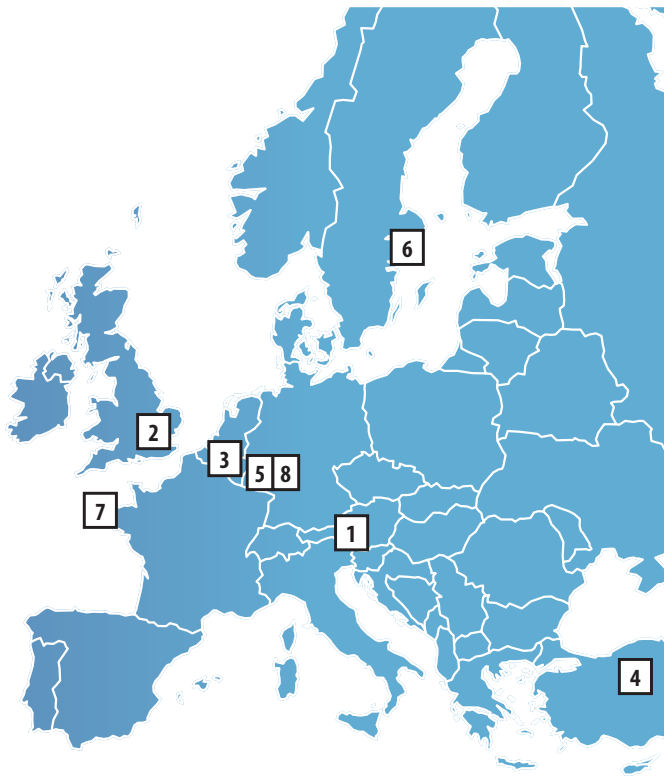
A 100 Gb/s Polar Code decoder FPGA prototype.

Oberpfaffenhofen Workshop on High Throughput Coding



Project Partners

- 1 TECHNİKON
- 2 INTERDIGITAL EUROPE
- 3 imec
- 4 POLARAN
- 5 TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
- 6 ERICSSON
- 7 IMT Atlantique
Institut Polytechnique de la Loire
École Mines-Telecom
- 8 CREONIC



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Past Events

IEEE Globecom 2018
9th-13th of December, 2018
@ Abu Dhabi, UAE

IMT Atlantique participated, with an oral presentation.

ASELSAN 4th Communication Technologies workshop.
18th of February, 2019
@ Ankara, Turkey

Polaran participated, Erdal Arıkan gave an invited talk.

2019 Oberpfaffenhofen Workshop on High Throughput Coding
27th-28th of February, 2019
@ Oberpfaffenhofen, Germany

TU Kaiserslautern and IMT Atlantique gave oral presentations

MWC 2019
25th-28th of February, 2019
@ Barcelona, Spain

IDCC attended the exhibition

EC THz Workshop
7th of March, 2019
@ Brussels, Belgium,

IDCC attended the workshop.



Upcoming Events

European Conference on Networks and Communications
18th-21st of June, 2019
@ Valencia, Spain

The EPIC consortium will participate in a special session on advanced THz technologies towards terabit/s wireless communications, on Wednesday, June 19 from 16:00 to 17:30. Find us in R1.

PIMRC 2019
8th of September, 2019
@ Istanbul, Turkey

IEEE International Symposium on Personal, Indoor and Mobile Radio Communications
Workshop on Enabling Technologies for TeraHertz Communications, co-organized by IMEC