5G CHAMPION - Rolling out 5G at 2018 Winter Olympic Games

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Abstract—The 5G CHAMPION Consortium will provide the first fully integrated and operational 5G prototype to the 2018 Olympic Games in PyeongChang, Korea – this effort is a major leap ahead compared to existing punctual technology trials, such as, e.g., Proof-of-Concept platforms focusing on mmWave communication in specific bands, etc. This paper describes the overall set-up including a synergetic combination of technologies such as beamforming based mmWave & Satellite service provisioning, virtualized infrastructure, software reconfiguration across the entire stack, accurate positioning and high-speed solutions. The key enablers are described in detail and related efforts in standards and regulation organizations are discussed.

Keywords— 5G, Beamforming, mmWave, Satellite, Software Reconfiguration, Virtualization, FBMC.

I. INTRODUCTION

5G -Next Generation Communication Networks will be a global game changer from a technological, economic, societal and environmental perspective. The so called vertical markets and industries will experience a drastic transformation thanks to 5G enabled technical capabilities available to trigger the development of cost effective new products and services. [15] presents a detailed analysis of uses cases and corresponding requirements for representative vertical markets such as Factories of The Future, Automotive, Health, Energy and Media & Entertainment.

Currently research has being carried out to design technology portfolios that will make 5G a reality. What is clear today is that 5G will meet the 5G target KPIs thanks to a set of key technological components [14]. The 5G roadmap from research to productization is clear today: 5G standardization framework will be ready by 2016, commercial 5G network infrastructure for 20XX and 5G terminal and devices for 20YY. Nevertheless, real field 5G system proof of concept (PoC) and performance benchmarking have not been done yet.

With this paper we present the 5G CHAMPION European/Korean Research project which is in the phase of preparing a fully operational 5G PoC platform to be showcased at the 2018 Olympic Games in PyeongChang, Korea – two years ahead of time of the 2020 target commercial roll-out of the technology. All 5G key technological building blocks will be developed in 5GCHAMPION and implemented into a new architectural approach providing an efficient end-to-end system performance encompassing cutting edge 5G radio-access, core-network and satellite technologies.

The proposed approach is far more advanced compared to other similar activities focusing on prototyping, due to 5G CHAMPION's tight integration of a multitude of new enabling technologies. Inherent synergy effects are expected to provide substantially improved system performance compared to other efforts, where the focus is laid only on a single specific technology, such as wide-spread prototyping in 28 GHz mmWave spectrum (see, e.g., [1]). Other still running funded research projects also touch on selected aspects of the forthcoming 5G system. E.g. European collaborative research projects MiWaveS, mmMAGIC and METIS-II with respect to channel models, new algorithms and RF blocks for mmWave communication, ADEL, SPEED-5G and FANTASTIC 5G, and finally Flex5GWare providing the first HW and key building blocks for a 5G platform, but none of them aims at proposing such a synergy of different enabling technologies..

Most challenging 5G characteristics will be addressed by the proposed set-up, including in particular:

- Latency in the ms range;
- Capability to serve very dense user environments without loss of performance;
- Capability to provide various network functions;
- Capability to support high precision/integrity ubiquitous location based services and timing;
- Capability to support various types of IoT, and interoperability between them;
- Capability to efficiently provide ubiquitous 5G services.

The reminder of the paper is organized as follows: Section II gives an overview on the 5G CHAMPION System Architecture, Use Cases and key enablers to be showcased are followed by an overview of relevant standardization and regulation activities in Section III. Section IV finally gives a Conclusion

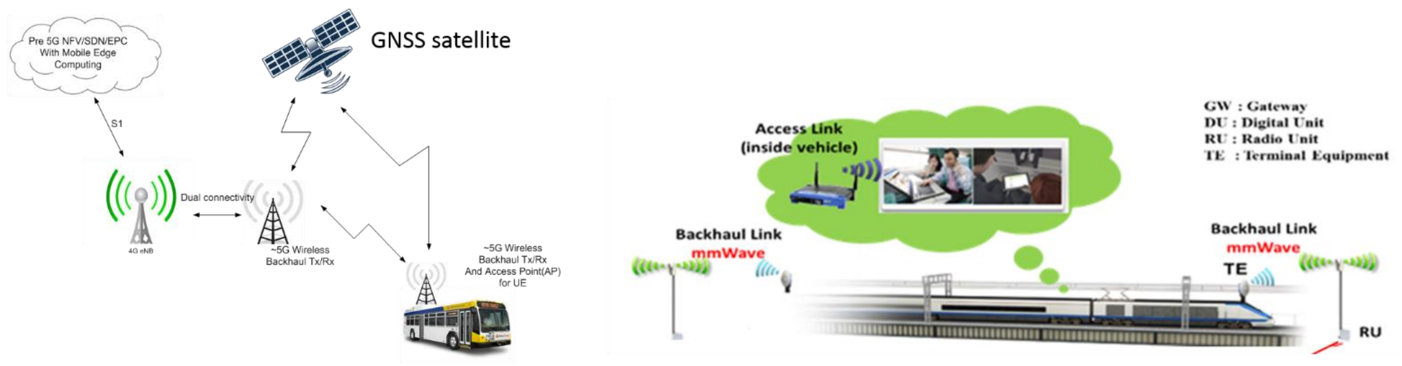


Figure 1: 5G CHAMPION System Approach.

II. 5G CHAMPION Architecture, Scenarios and 5G Key Enabling Technologies

The overall 5G CHAMPION System Approach is illustrated in Fig. 1. It will address key 5G requirements and use cases through meeting the following key technological objectives:

1) Provide a mmWave high capacity backhaul link with 2.5 Gbit/s maximum data-rate using 400 MHz ~ 1 GHz bandwidth in the 24-29.19 GHz band;
2) Provide up to 20 Gbit/s user data rate over a mmWave indoor link;
3) Provide in the high mobility scenario a user-experience of 100 Mbit/s;
4) Provide a seamless access to satellite communications for 5G devices including narrowband IoT service to 5G UE 'as is' via a satellite component.
5) Demonstrate 1-2 ms latency over the 5G wireless backhaul link;
6) Demonstrate an agile management of the core network functionality and services through an SDN/NFV evolved packet core;
7) Ubiquitous (indoor-outdoor) location accuracy < 1 m;
8) Improved multi-link connectivity supporting simultaneous or adaptively selecting wireless backhaul to several entry points into the network.

The 5G CHAMPION PoC (Figure 2) includes (i) mmWave radio access for the wireless backhaul, (ii) heterogeneous access and (iii) localised EPCs (Evolved Packet Cores). Additionally, 5G CHAMPION demonstrates the capability of interoperability with satellite systems. The objective is to analyse and determine the relevant configuration/operation of the 5G radio interface maximising service performance via satellite (e.g., 5G UE operating in frequency bands allocated to Mobile Satellite Service in the 1.5 GHz – 2.5 GHz).

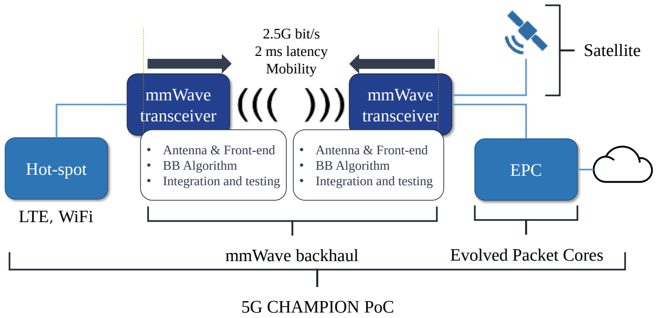


Figure 2. 5G CHAMPION PoC.

A. Satellite MTC

The 5G context offers a promising opportunity to offer an integrated satellite/cellular service to 5G User Equipment 'as is' as depicted in Figure 2. This can be made possible taking advantage of

- the flexible front ends that will be implemented in User Equipment to operate in a wide range of frequency bands sub 6 GHz;
- the flexible radio interface designed to provide narrow band and wide band communications over extended coverage while optimizing the UE power consumption.

The project will contribute to define this satellite component able to serve 5G user equipment 'as is' to address a large market of users/usage not only having regular needs (isolated areas) but also occasional needs (e.g. un-frequent mobility in areas with no cellular infrastructure) for global connectivity service. It will investigate the feasibility of enabling 5G User Equipment with a "satellite ready" capability that could be activated upon software configuration.

The objective of the project is to determine which configurations (channel bandwidth, MAC/PHY protocols settings) could allow low bandwidth direct service to 5G devices without any hardware modification, to support Machine

Type Communications and personal emergency communications that can address critical applications especially in the area of security, transportation, automotive and energy/water utilities sectors. 5G waveforms (e.g. filtered multicarrier) could be adapted to the specific requirements of low cost, low power consumption and satellite constraints (RF characteristic/performance, satellite channel characteristics). As the requirements of narrow band IoT transmission (e.g, low power, wide area, low throughput, … etc.) are close to the ones of satellite communication; only mirror adaptations are envisaged to efficiently support satellite and terrestrial communications providing seamless connectivity to end users.

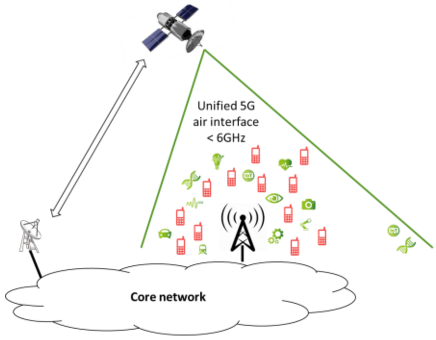
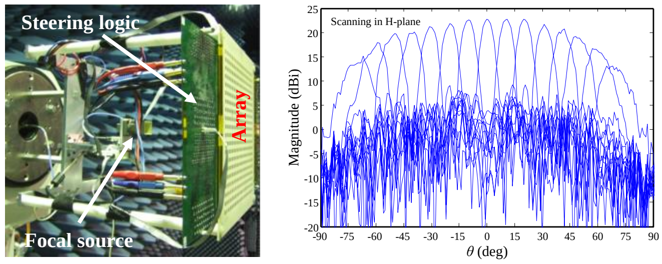


Figure 3. Satellite MTC unified air interface concept.

B. mmW for high speed mobility

In order to achieve objectives 1) and 3) as indicated above, the 5G CHAMPION project will develop mmW mobile backhaul links using analog and hybrid analog-digital beamforming supported by novel mobility management techniques.

A first transceiver architecture is based on an analog approach (Figure 4), in which beamforming is obtained by controlling a spatial feeding electronically reconfigurable array or transmit-array antenna. In this case, a single front-end is connected to a focal source illuminating a planar array of unit-cells working as an electromagnetic lens. Each unit-cell includes a first antenna working in receive mode (Rx) connected by a phase-shifter to a second antenna working in transmission mode (Tx). The radiated beam can be electronically scanned by controlling the transmission phase independently on each unit-cell. Thanks to the spatial feeding architecture and the possibility to fabricate the planar array in a standard PCB (Printed Circuit Board) technology, this approach can provide a relatively low cost, wideband (around 3 GHz at 28 GHz), and efficient high-gain antenna with excellent electrically scanning capabilities. Figure 4(a) illustrates a prototype of the transmit-array working at 10 GHz (X-band) previously demonstrated at CEA-Leti [16]. This prototype presents a maximum gain in the broadside direction of 22.7 dBi, a 3dB-bandwidth of 15.6%, and a 2D beam-steering capability of ±70°. The second approach is based on the hybrid analog-digital architecture, in which four beamforming arrays are designed for a highly directive radio link with 400 MHz bandwidth in the 26.65 – 29.19 GHz band for backhaul.



(a) (b)

Figure 4. (a) photograph and (b) measured beam-steering capability on the H-plane.

In order to support long range transmissions (from hundreds of meters to km's), good antenna gain with patch antenna elements, a large number of antennas for array gain and state-of-the-art power amplifier (PA) technology are needed. A RF transceiver will be dimensioned for specified array gain by scaling the number of parallel phase controlled RF paths and parallel digital paths can be employed to extend capacity or range.

Despite of array gain, best power delivery capability calls for careful thermal design and efficient heat conduction. To minimize wiring losses in the RF front-end antenna array width of antenna element and electronic components must match as well as possible. For capacity dual polarized antenna solution is practical approach for line-of-sight (LOS) channel. Figure 5 illustrates a concept of this antenna.

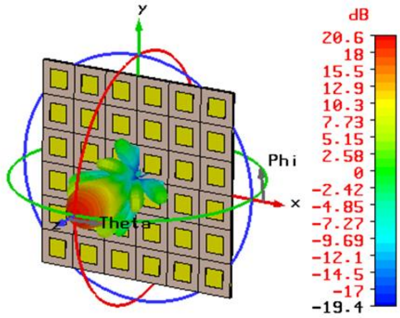


Figure 5. Patch antenna array.

In addition to high channel capacity and high link reliability requirements on the mobile wireless backhaul, 5G CHAMPION tackles high speed mobility, e.g. a moving hot-spot for a high speed train. In this case, it is of paramount importance to design efficient techniques for beamforming synchronization, tracking as well as handover management [6]. In this regard, we consider approaches tightly coupled with the RF implementation.

For the hybrid analog-digital approach we propose an initial beamforming synchronization based on sub-carrier parallelization [7]. More specifically, we utilize an Orthogonal-Frequency-Division-Modulation (OFDM) to create parallel beamforming on different subcarriers and employ a sparsity-aware estimation method, e.g., the Adaptive-LASSO algorithm

[8][9], to obtain accurate angular information of the channel paths. For instance, Figure 6 shows a realization of four parallel beams utilized during the transmission of a pilot OFDM symbol, and more specifically, the result refers to an hybrid analog-digital architecture with 4 digital paths and 64 linear polarized antennas. The analog beamformers are tuned to 4 different directions, and subcarriers are modulated such that each beam can separated in the frequency domain. The beamforming synchronization is then performed by jointly processing the received signal across multiple directions.

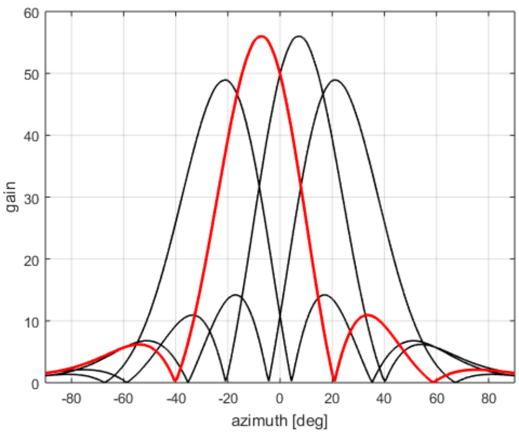


Figure 6. Example of sub-carrier based beam scanning. Red beam refers to a specific subcarrier.

C. Interconnected core networks and MANO

In the 5G era, radio IP capacity is expected to become reach 20 Gbit/s per sector (mobile speeds up to 20 Gbit/s), and ultra-large content traffic (e.g. UHD Video Streaming, Augmented Reality (AR), Virtual Reality (VR)) will travel across the faster radio access network. All mobile traffic have to travel via packet core network (i.e. PGW in case of 4G). Today, most countries have only a few sites with PGWs across their nations.

The SDN paradigm provides a new capability for fast service provisioning in the cloud with the network through standard programmable interfaces. Also with the cloud computing, datacenters promote on demand provisioning of computing resources and services [6]. If 5G core nodes are distributed closer to cell sites, content servers (or caching servers) can be placed on the rack right next to the distributed 5G core with NFV technologies. This can help significantly reducing backhaul traffic by having mobile devices downloading content immediately from the content server. To this end it is desirable to distribute their packet core functionality to a number of local sites near to the end users in the coming 5G era. 5G Core and applications will run on virtualized servers at the local network sites. Massive IoT and mission-critical IoT are the main differentiator against 4G services. Mission-critical IoT (Ultra-reliable and low latency communications) applications include remote controlled machine, autonomous driving (self-driving), etc. These types of ultra-real-time services require radio latency of less than 1ms, and end-to-end latency of less than a few ms [7].

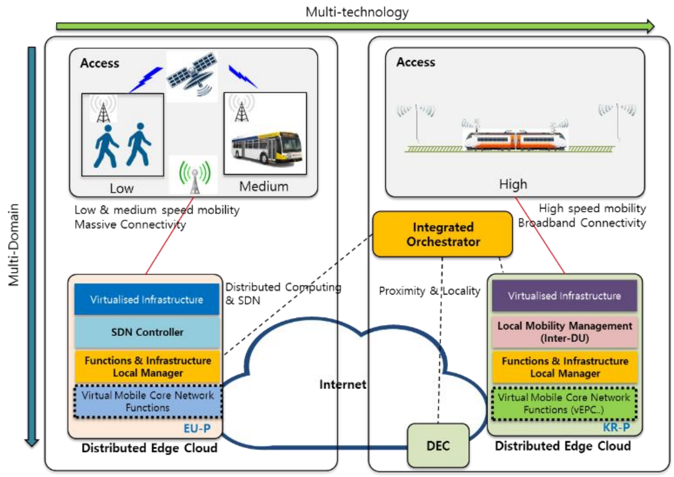


Figure 7: Conceptual architecture of 5G Distributed Mobile Core.

D. Localization

In order to achieve objective 7), 5G CHAMPION proposes a new indoor-outdoor positioning solution relying on the interoperability between GNSS and mmW 5G technology. While the former is a well-established technology, the latter is still objective of research. However, recent studies have demonstrated the potential of this approach in achieving high accuracy location information in LOS channel conditions [10]-[12]. In 5G CHAMPION, this technology will be further developed for more complex multipath environments, e.g., indoor, and compared to state-of-the-art GNSS solutions.

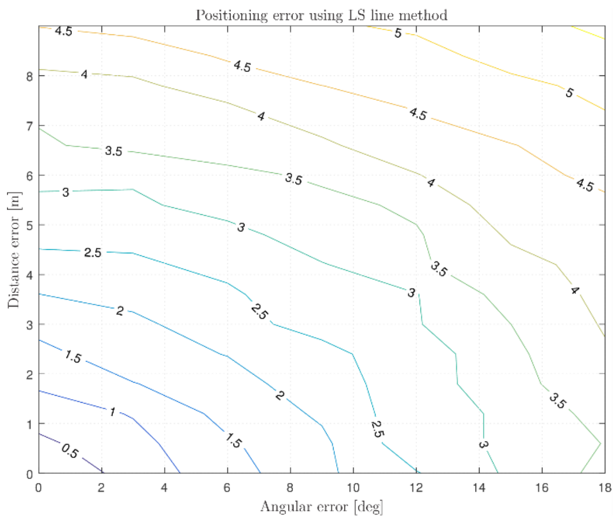


Figure 8. Positioning error with LOS and 3 NLOS links.

Figure 8 shows a preliminary result obtained with a basic least-square algorithm [12] and a synthetic measurement model emulating 3D Direction of Arrival, direction of departure and distance estimate (for instance, obtained from the channel estimation algorithm as described in [10]).

E. Software Reconfigurability

Network Functions Virtualization: The 5G network has been focused on network functions, rather than network entities which will be defined, implemented and applied where needed. Virtualization of core and radio access network functions will optimize the use of network resources, add scalability and agility.

To this end, the ETSI NFV ISG (Industry Specification Group) has defined the architecture, open APIs and reference points, leveraging open source proof of concept (PoC) projects and communities to drive open standards of NFV [18]. These open standards are intended to enable 3rd party vendors to develop framework components that can collaborate with various vendor components so that CSPs are not restricted in selecting functional and management components.

The main appeal of using NFV to deploy network elements and virtual network functions (VNFs) is that services can be launched more quickly, by installing software on a standard hardware platform. This is akin to the way software applications could be developed and launched for the PC platform when it first emerged. Another advantage is lower capital expenditures, because standardized hardware platforms tend to drive down costs.

Reconfigurable Radio Systems: The European Commission has recently revised the Radio and Telecommunications Terminal Equipment Directive (R&TTED) and adopted the new Radio Equipment Directive (RED) [2] in 2014. This Directive establishes a regulatory framework for the making products available on the market and putting into service in the Union of radio equipment. One of the key novelties introduced by the RED relates to the possibility to introduce new radio equipment features through Software.

In this context, ETSI has developed technical solutions for enabling the reconfiguration of mobile devices through so-called "RadioApps". Those are similar to existing "Smartphone Apps" with the difference that the modification of radio parameters is made possible. It is indeed proposed that an equipment manufacturer can gradually open up its platform to defined internal Application Programming Interfaces (API). Corresponding code is executed in a secure environment called "Radio Virtual Machine (RVM)".

The basic system architecture for mobile device reconfiguration is defined in [3] as illustrated in Fig. 9. Furthermore, ETSI TR 102 967 [4] analyses requirements related to the issuance of a Declaration of Conformity and its handling in the context of software reconfiguration affecting radio parameters - such a Declaration of Conformity is required by regulation administrations in Europe before the concerned equipment can be introduced into the European market [5].

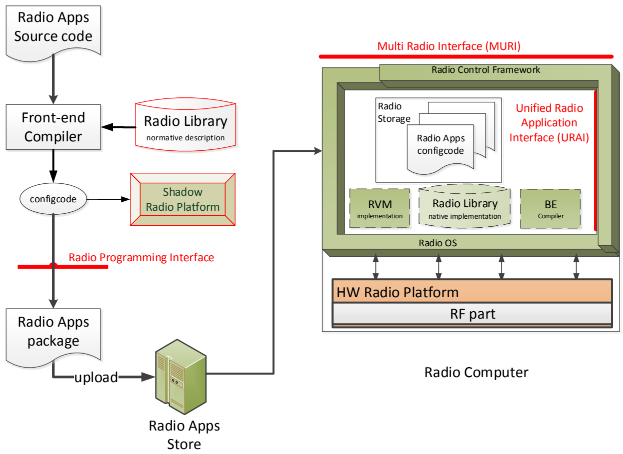


Figure 9: System architecture for Radio Computer where Radio Library and Back End (BE) compiler are included within the Radio Computer [3].

III. STANDARDIZATION TODAY, TOMORROW AND BEFORE 2020

A. ETSI

ETSI is addressing Software Reconfigurability in its Reconfigurable Radio Systems (RRS) Technical Body. In this context, an entire eco-system is set-up including solutions with a focus on software reconfiguration in Mobile Devices [3-5] which is made possible for commercial deployment through recent changes in Europe’s Radio Equipment Directive (RED) [2]. In addition, ETSI and its Technical Committee Satellite Earth Stations and Systems is well adapted to define the satellite component for 5G [24].

B. 3GPP

3GPP has started the 5G standardization effort for developing the “New Radio” access technology in TSG RAN and the “Next Generation” core network in TSG SA. The New Radio will be non-backward compatible to the legacy LTE-Advanced technology, and meet all the 5G requirements and use cases defined by the IMT-2020 [5]. The Next Generation core network will define new architecture to support diverse use cases and scenarios, and enable tight multi-RAT interworking.

Among the various 5G deployment scenarios, the high speed scenario focuses on providing continuous coverage along high speed train tracks using either 4 or 30 GHz frequency band [21]. The study item (SI) on New Radio access technology approved in Mar. 2016 will cover initial evaluation of various new physical-layer techniques such as modulation, waveform, multiple access, channel coding, and MIMO for difference deployment scenarios [22] And various options for functional user plane split between central and distributed units for embedding the New Radio (NR) in a multi-RAT architecture [24].

C. ITU

ITU-T FG IMT-2020 addresses relevant standardization issues related with 5G fixed networks. Specific tasks and areas of work include exploring demonstrations or prototyping with other groups, notably the open-source community, enhancing aspects of network softwarization and information-centric networking, developing the IMT-2020 network architecture, studying fixed-mobile convergence and network slicing for the fronthaul/backhaul network, defining new traffic models and associated aspects of QoS and operations, administration and management applicable to IMT-2020 networks. Its activity was initiated in May 2015 and will complete its tasks by the end of 2016.

IV. Conclusion

5G Networks are reaching today the maturity from research and innovation to prototyping PoC. Vertical markets and industries have strong expectation on a 5G drastic transformation thanks to 5G enabled technical capabilities available to trigger the development of cost effective new products and services. What we miss today is a real-field PoC of 5G to showcase the full potential of 5G. 5G CHAMPION will provide the real-field PoC of 5G Networks capabilities at Peyong Olymic games in 2018. The 5G CHAMPION concept is a system including key building blocks for mmWave access and backhaul network, for sub 6 GHz direct 5G satellite narrowband access, positioning and for a flexible and evolved packet core network managed by an SDN interface.

V. Acknowledgment

The research leading to these results has received funding from European Union H2020 5GPPP under grant n. 723247 and supported by the Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No.B0115-16-0001, 5GCHAMPION). We thank to Dr. Tommi Tuovinen and Jani Saloranta for providing Figure 5 and Figure 6.

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