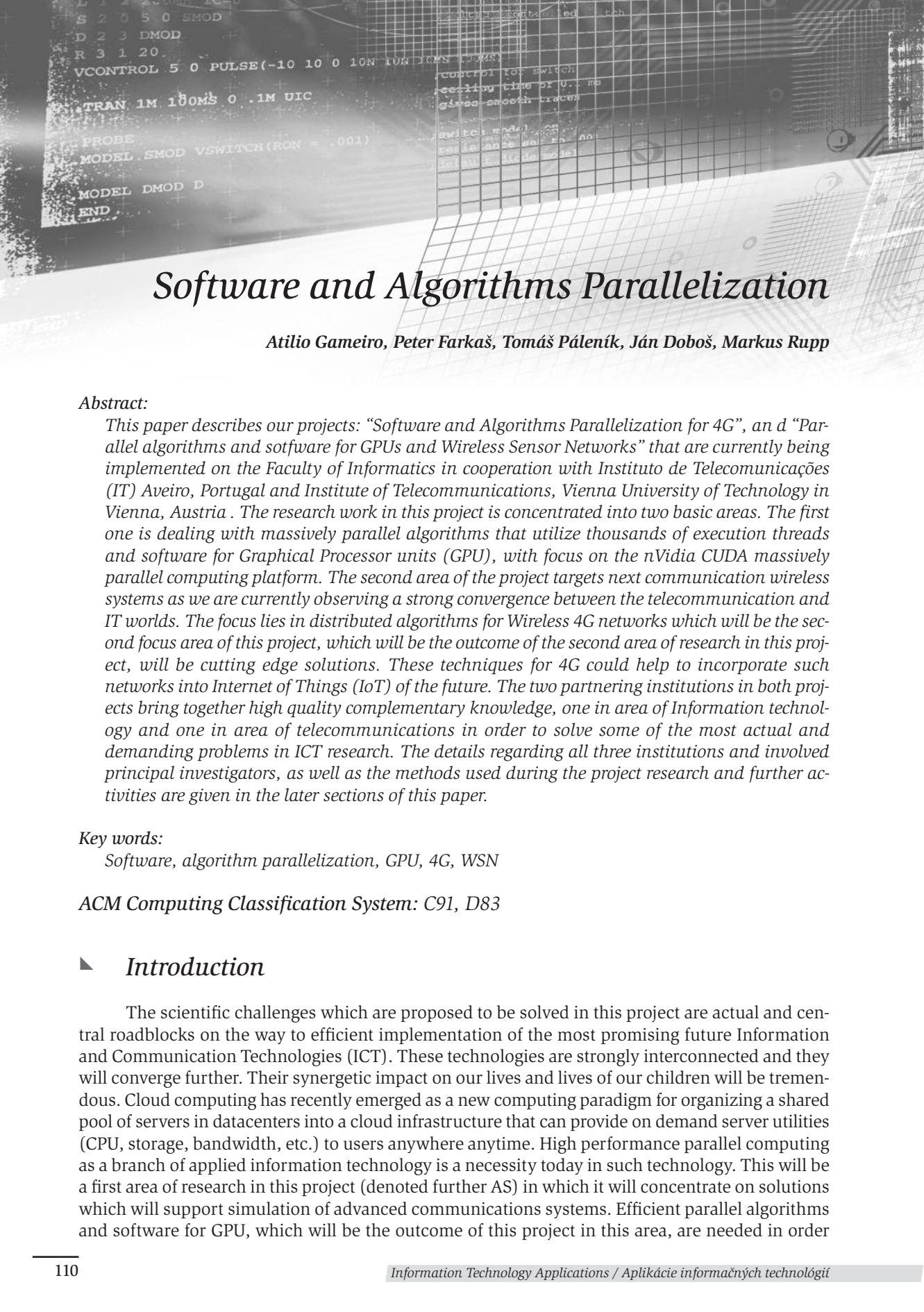




Software and Algorithms Parallelization

Atilio Gameiro, Peter Farkaš, Tomáš Páleník, Ján Doboš, Markus Rupp

Abstract:

This paper describes our projects: “Software and Algorithms Parallelization for 4G”, and “Parallel algorithms and software for GPUs and Wireless Sensor Networks” that are currently being implemented on the Faculty of Informatics in cooperation with Instituto de Telecomunicações (IT) Aveiro, Portugal and Institute of Telecommunications, Vienna University of Technology in Vienna, Austria. The research work in this project is concentrated into two basic areas. The first one is dealing with massively parallel algorithms that utilize thousands of execution threads and software for Graphical Processor units (GPU), with focus on the nVidia CUDA massively parallel computing platform. The second area of the project targets next communication wireless systems as we are currently observing a strong convergence between the telecommunication and IT worlds. The focus lies in distributed algorithms for Wireless 4G networks which will be the second focus area of this project, which will be the outcome of the second area of research in this project, will be cutting edge solutions. These techniques for 4G could help to incorporate such networks into Internet of Things (IoT) of the future. The two partnering institutions in both projects bring together high quality complementary knowledge, one in area of Information technology and one in area of telecommunications in order to solve some of the most actual and demanding problems in ICT research. The details regarding all three institutions and involved principal investigators, as well as the methods used during the project research and further activities are given in the later sections of this paper.

Key words:

Software, algorithm parallelization, GPU, 4G, WSN

ACM Computing Classification System: C91, D83

Introduction

The scientific challenges which are proposed to be solved in this project are actual and central roadblocks on the way to efficient implementation of the most promising future Information and Communication Technologies (ICT). These technologies are strongly interconnected and they will converge further. Their synergetic impact on our lives and lives of our children will be tremendous. Cloud computing has recently emerged as a new computing paradigm for organizing a shared pool of servers in datacenters into a cloud infrastructure that can provide on demand server utilities (CPU, storage, bandwidth, etc.) to users anywhere anytime. High performance parallel computing as a branch of applied information technology is a necessity today in such technology. This will be a first area of research in this project (denoted further AS) in which it will concentrate on solutions which will support simulation of advanced communications systems. Efficient parallel algorithms and software for GPU, which will be the outcome of this project in this area, are needed in order

to support huge complex tasks in simulation of today's Cloud computing era communication and storage networks.

Distributed algorithms for Wireless 4G networks described in (ETSI TSGR 2011, 2014) will be the second focus area of this project, which will be the outcome of the second area of research in this project, will be cutting edge solutions. These techniques for 4G could help to incorporate such networks into Internet of Things (IoT) of the future. The two partnering institutions bring together high quality complementary knowledge, one in area of Information technology and one in area of telecommunications in order to solve some of the most actual and demanding problems in ICT research.

1. Detailed Project Goals Description

As mentioned before, the project goals are concentrated into two fields. Both are related to the basic scheme of a generic communication system shown in fig. 1.

The acronyms in fig. 1 (Palenik, 2014) should be well known, but they are also given here: "ARQ stands for the Automatic Repeat and reQuest, ECC for Error Control Coding, CM for Constellation Mapping – the modulation in digital domain, FR for Framing, (I)DFT for (Inverse) Discrete Fourier Transform, CPI/R for Cyclic Prefix Insertion/Removal, CE for Channel Estimation, FDE for Frequency Domain Equalization, The channel model is assuming a Rayleigh-fading multipath channel described by channel matrix H_c with AWGN noise". Many activities of this project, especially those devoted to parallelisation deal with the simplified model described here.

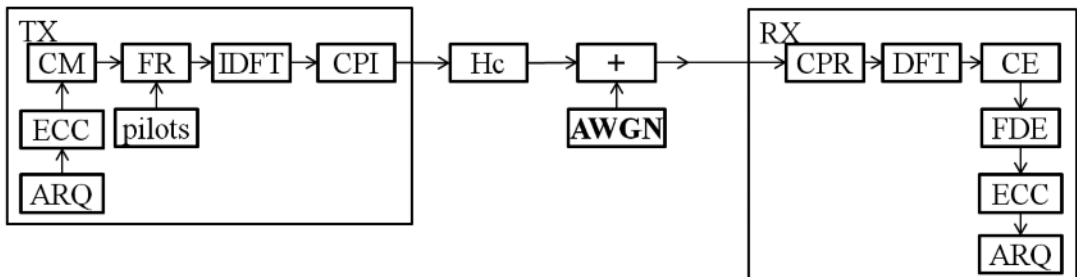


Fig. 1 A simplified LTE-system blocks overview.

1.1 In the first – AS field the following goals are targeted:

1.1.1 To create a technical report that will contain the identification the most computationally intensive modules used in simulations of modern communication systems in the era of cloud computing. The goal of this report would be to identify the most computationally complex blocks inside an LTE or LTE-A system cascade. Some research effort in this direction has already been made by the team at Paneuropean university and an early massively parallel decoder for Convolutional Codes has been designed in (Palenik 2013). This design, however proved to be unsuitable for a more-complex iterative setting, such as the turbo-decoder present in LTE and LTE-A. Therefore new potential bottlenecks have to be identified.

1.1.2 Creating a proposal of massively parallel algorithms for GPU which can be utilized in the modules identified in goal 1.1.1. While the parallelism would be evaluated in general with the number of parallel threads given as a metric, specific architecture level constrained should be taken into account even in this early stage.

1.1.3 Realization - implementation of first version of the parallel software for GPU based on algorithms proposed in 1.1.2. Implementation would have to be seamlessly integrated into the Mat-

lab environmnet, thus eliminating the need for laborous and error-prone exchange of data between Matlab and and external executable program. The nVidia CUDA platform currently supports such tight integration and will be the preffered implementation choice.

1.1.4 Testing verification and debugging of the first version of the software and technical report writing with recommendations for the second – even more optimized version of the algorithms.

1.1.5 Proposal of selected improved massively parallel algorithms which will take into accounts the results and recommendation of 1.1.4.

1.1.6 Implementation of a second version of selected, extremely optimized parallel software for GPU based on algorithms proposed in1. 1.1.5.

1.1.7 Testing verification and debugging of the second version of the software.

1.1.8 Creation of documentation that will facilitate for practical application and use of the accelerated parallel algorithms and software for GPU developed in this project.

1.1.9 Preparation of new project proposal, based on the result an experience gained during this project.

1.1.10 Publication of the project results in 4 conferences and one journal paper.

▀ *1.2 Originality and topicality of the first area (AS):*

Nowadays, the Graphical Processing Units (GPU) bring new unsolved challenges into the area of Applied informatics. In contrast to previous computing technology (focused on CPU computations), huge parallelism is necessary to utilize the substantial resources of the GPU efficiently (Carothers 2010, Karras 2012).

Despite the advances in compiler technology, shown for instance in NVIDIA's nvcc compiler, there are currently no compilers and software tools which would take the burden of parallelization of algorithms from the programmer with adequate quality. Therefore it is still very actual and topical to perform the optimization of such demanding parallel algorithms and software for GPU manually.

▀ *1.3 In the second – SAD field the following goals are targeted:*

1.3.1 Development of distributed collaborative algorithms to enhance fairness, capacity and maintaining the per user capacity in networks with increasing node density. There are many challenges specific to the topic of distributed algorithms, bringing even more difficulties than the handling of thousands of threads inside a GPU. The most prominent being the lack of simple and reliable synchronisation mechanism between threads. This algorithm could lead to unexpeted perturbations in the algorithm run with unforeseen consequences.

1.3.2 The realization of experiments with the algorithms from 1.3.1.

1.3.3 Dissemination and documentation of the results.

1.3.4 Practical deployment consideration of the Hierarchical Cellular System (HCS) system concept in real-world communication scenarios.

▀ *1.4 Originality and topicality of the second area (PAS):*

Despite the significant efforts within the research community on topics dealing with the future wireless systems, the concepts of hierarchization and cooperation are still at an infancy stage and dealt at a highly theoretical level. The area of parallelisation reamins in the focus in both academic and industrial commercial areas. In 2011 a GPU optimized implementation of a 3GPP turbo-decoder emerged. The primary drawback is that the source code is closed and so these modules can be best used only by the academic teams that developed them. The usage of such simulation soft-

ware by broad academic community is limited to the usage of existing black boxes (although with theoretically well described operation). This is simply not sufficient, especially if the research focus demands novel modifications and upgrades to existing methods, which is often true.

2. Other Information about the Project

In this section other basic data about the projects is provided.

2.1 Project partners complementarities:

The cooperation between IT Aveiro and Faculty of Informatics and Pan-European University arises from the main objectives of the project, which core aspect lies in the convergence between IT and Wireless Communications and the complementarities between the partners in these two key areas. The Pan-European University has a significant expertise in the software part, namely techniques for parallelization of algorithms and GPU, which are at one side of the project, while Instituto de Telecomunicações, namely through the Mobile Communications groups has acquired significant know-how in the definition of 4G wireless systems through its participation in national and joint European projects. This complementarily allows tapping of synergies that are essential for the development of the so-called information society. As the two countries involved are small at the European scale, it is difficult to find inside each country teams that on one hand exhibit this diversity of expertise and on the other hand are aligned in terms of research objectives. This was the key condition that was found between the Portuguese and Slovakian teams that spurred out the common proposal.

2.2 Project schedule:

The project SK-PT-0014-12 started on January 14-th, 2013 and will finish on December 31-st 2014. The project SK-AT-0020-12 started on January 14-th, 2013 and will finish on December 31-st 2014.

2.3 Project budget:

The project SK-PT-0014-12 is supported by the Slovak Research and Development Agency (APVV) by 4990,- Euro and Portugal Fundação para a Ciência e Tecnologia (FCT) will support it by 4000 Euro. The project SK-AT-0020-12 is supported by the Slovak Research and Development Agency (APVV) supports the project by 3712,- Euro.

2.4 Principal Investigators

2.4.1 SK-PT-0014-12 Principal Investigators

Prof. Ing. Peter Farkaš, DrSc. (Slovakia), Prof. Dr. Atilio Gameiro (Portugal).

Peter Farkas (Prof, Ing, DrSc), (MIEEE, MIEICE, URSI) received the Ing (MSc) degree from Slovak University of Technology (STU) in 1980, PhD degree from St. Petersburg State Polytechnic University (former Leningrad Polytechnic Institute) in 1987 and DrSc. degree from STU in 1997. He is with Department of Telecommunications at STU, since 1999 as a Professor. His research interests include Error Control Coding, Communication Theory, Mobile Communications and MC CDMA. Since 2011 he is with the Faculty of Informatics, Paneuropean University in Bratislava, Slovakia.

Atilio Gameiro received his Licenciatura and Ph.D. degrees from the University of Aveiro in 1985 and 1993, respectively. He is currently a professor in the Department of Electronics and

Telecommunications of the University of Aveiro, and a researcher at the Instituto Telecomunicações, Aveiro. His current research activities involve space-time frequency and cross-layer algorithms/techniques for wireless systems, and cognitive radio.

▀ 2.4.2 SK-AT-0020-12 *Principal Investigators*

Prof. Ing. Peter Farkaš, DrSc. (Slovakia), Univ.Prof.,Dipl.- Ing. Markus Rupp, Dr. techn. (Austria). Markus Rupp received his Dipl.-Ing. degree in 1988 at the University of Saarbruecken, Germany and his Dr.-Ing. degree in 1993 at the Technische Universitaet Darmstadt, Germany, where he worked with Eberhardt Haensler on designing new algorithms for acoustical and electrical echo compensation. From November 1993 until July 1995, he had a postdoctoral position at the University of Santa Barbara, California with Sanjit Mitra where he worked with Ali H. Sayed on a robustness description of adaptive filters with impact on neural networks and active noise control. From October 1995 until August 2001 he was a member of Technical Staff in the Wireless Technology Research Department of Bell-Labs at Crawford Hill, NJ, where he worked on various topics related to adaptive equalization and rapid implementation for IS-136, 802.11 and UMTS.

Since October 2001 he is a full professor for Digital Signal Processing in Mobile Communications at the Vienna University of Technology where he founded the Christian-Doppler Laboratory for Design Methodology of Signal Processing Algorithms in 2002 at the Institute for Communications and RF Engineering. He served as Dean from 2005-2007.

He was associate editor of IEEE Transactions on Signal Processing from 2002-2005, is currently associate editor of JASP EURASIP Journal of Advances in Signal Processing and JES EURASIP Journal on Embedded Systems. He is elected AdCom member of EURASIP since 2004 and served as president of EURASIP from 2009-2010. He authored and co-authored more than 400 scientific papers and patents on adaptive filtering, wireless communications, and rapid prototyping, as well as automatic design methods.

▀ *Conclusion*

This paper describes our projects “Software and Algorithms Parallelization for 4G” and “Parallel algorithms and software for GPUs and Wireless Sensor Networks”, that are currently being implemented in the Faculty of Informatics in cooperation with Instituto de Telecomunicações (IT) Aveiro, Portugal and Institute of Telecommunications, Vienna University of Technology in Vienna, Austria with financial support from Slovak Research and Development Agency (APVV) under contracts SK-PT-0014-12 and SK-AT-0020-12. Communities in Slovakia and Europe will be in near future confronted with many challenges. For example citizens with age over 65 will in most of them form about 30% of population and the care of them will need huge financial resources. Infrastructure, which was build in past for big cities and adapted to centralized paradigm (water supply, energy supply etc.) are no more adequate for future needs. It is hoped that ICT technologies will leverage these problems via contributing to set up of Ubiquitous sensing environments, Internet of Things and cloud computing. In communication networks and storage systems, which will be the physical basis of such cloud environments new scientific challenges arise with processing and protecting of information. Coding will play even more important role in future ICT infrastructures based on distributed cloud systems. The techniques known now are not adequate fully for the future needs. The aim of this project is to contribute to new techniques, which will be better adapted to future needs. The proposed research will take into account the development in networks especially wireless.

From the Portuguese side the added value brought by the Slovakian partner is the expertise in parallelization of software computing in order to build computationally efficient simulators for wireless communications. From the Slovakian side the added value brought by the Portuguese partner is the expertise in wireless communications that will provide the required framework for

the Slovakian partner to focus their efforts towards a well defined telecommunication application. It is to note that the members of the two partner's teams have already collaborated during a 6-th FP IST Program in the European Network of Excellence CRUISE, financially supported by European Commission and therefore have a good knowledge of each other competence; this is ensuring efficient interaction and maximizing the chances for the project's success.

▀ Acknowledgement

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Paralelizácia algoritmov a paralelný softvér

Abstrakt:

Tento článok popisuje dva medzinárodné projekty bilaterálnej spolupráce v odbore 10203-Aplikovaná informatika, v súčasnosti realizované na pôde Fakulty informatiky Paneurópskej vysokej školy v spolupráci s partnerskými inštitúciami so zahraničia. Prvým partnerom v projekte „Paralelné algoritmy a softvér pre programovateľné grafické procesory a bezdrôtové senzorové siete“ je Inštitút telekomunikácií na Viedenskej technickej univerzite v Rakúsku. Druhým pro-

jektom bilaterálnej spolupráce je projekt „Softvér a algoritmy paralelizácie pre 4G simulácie“ realizovaný v spolupráci s Inštitútom telekomunikácií na Univerzite v Aveire v Portugalsku. Vedecké ciele a výzvy, ktoré sú navrhnuté na riešenie v týchto projektoch môžu odstrániť kľúčové prekážky na ceste k realizácii najslubnejších informačných a komunikačných technológií (ICT). Tieto technológie sú vzájomne silno previazané a v budúcnosti budú konvergovať ešte vo väčšej miere. Ich synergický vplyv na naše životy a životy našich detí bude významný. Klaudové počítanie sa nedávno objavilo ako nová paradigma výpočtov pre zabezpečenie zdieľaného využívania serverových zdrojov v dátových centrách a klaudovej infraštruktúry, ktorá môže zabezpečiť serverové prostriedky podľa potreby (CPU, pamäť, pásma, atď.), pre používateľov kdekoľvek a kedykoľvek. Vysoko výkonné paralelné počítanie ako odvetvie aplikovanej informatiky je v takejto technológii nevyhnutnosťou. Distribuované algoritmy pre bezdrôtové senzorové siete (WSN) budú druhou oblasťou, na ktorú sa sústreďí výskum v projektoch. Distribuované algoritmy pre WSN, ktoré budú výstupmi projektu budú predstavovať špičkové riešenia pre fúziu dát. Efektívne narábanie s dátami pomocou nich môže pomôcť začleniť tieto siete do Internetu vecí budúcnosti. Partnerské riešiteľské inštitúcie disponujú vysoko kvalitnou a vzájomne sa dopĺňajúcou bázou znalostí. Jedna v oblasti komunikačných sietí a jedna v oblasti aplikovanej informatiky.

Kľúčové slová:

Softvér, paralelizácia algoritmov, GPU, 4G, WSN

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