Editorial
Opening of the 2022 TVLSI Editorial Year—Connecting Trends From Society to VLSI Systems

I. A Walk Through Trends From the Past Year(s)

THE past year of 2021 has consolidated several societal courses observed in recent years, marking an unprecedented acceleration in a number of trends that have now reached their tipping point. The accelerated digitalization of human activities and outcomes has made the human side of supply chains more distributed on one hand [1] while putting an unprecedented pressure on its logistics side and mandating fundamental rethinking of its resilience–efficiency balance [2].

At the organization level, digitalization and remote working as new norms have led to a definite shift from time-based to outcome-based work organization. This trend has fundamentally altered the mutual expectations of organizations and individuals while leading to a higher job market mobility and a major power rebalance in favor of employees [3]. On the other side of the talent equation, academia has experienced a major acceleration in the process of incorporating technologies for remote learning modalities, shifting from asynchronous consumption to synchronous participation, stepping up a trend that has started about a decade ago [4]. As another landmark of the past year, the translation of biotechnology and pharmaceutical discoveries into drug commercialization at scale has gained an impressive momentum.

From an economic viewpoint, increased (and increasingly uneven) liquidity has spilled over into an unprecedented range of technology-enabled intangible assets such as non-fungible tokens (NFTs) and cryptocurrencies, and technology-centric special-purpose acquisition companies (SPACs), among others. Environmentally, the beneficial effect of the slowing down of human activities and traveling on the natural world has been visually evidenced by popular satellite images of our clean(er) skies. Although such benefits have proved to be only temporary, the rapid decrease in air pollutants during lock-down periods has decisively reinvigorated the general sense of responsibility in environmentally conscious consumption and in green and clean technologies. As other major trend, fundamental lifestyle changes have taken place in our relationship with the built environment, vastly expanding the range of activities being traditionally performed in our residences.

Overall, the above trends reflect an accelerated societal restructuring to further decouple value creation from traditional geographical boundaries (at all scales, from local to global) for both talent and organizations, while further strengthening the central role of supply chains and infrastructures as aggregators and catalysts of human activities and value capture [5]. Although such overarching trends transcend specific technological developments, they are being undoubtedly fueled and enabled by relentless innovation in semiconductors and VLSI systems, as discussed in the following with explicit reference to each of the above trends.

II. How VLSI Systems Will Support On-Going and Future Trends

Beyond the obvious enablement of digitalization, VLSI systems are being a key enabler of smart logistics, and its rapid rebalancing in such a rapidly changing global scenario. As major challenges for our community, more pervasive and real-time monitoring (e.g., asset tracking from pallet to item, from warehouse to house) will require a decisive push for relentlessly lower cost and smaller form factor. Such push mandates fundamental advances in heterogeneous integration of multiple sensing modalities, processing, and wireless communication capabilities, as well as relentless power reductions.

Beyond the clues left by the notable change in the name of a well-known social network service company, remote social interactions are here to stay, although they will definitely need to become more natural. Unobtrusive and intelligent wearable technologies for a more accurate and timely representation of our physical stance will be needed for realistic and natural interaction in the virtual world, from sensing to haptic systems. Ubiquitous wearables will be complemented by on-body biosensors to keep track of our physical state, and to nurture our well-being (e.g., from thermal and visual comfort adaptation to assisted wellness programs for health prevention, establishment of targeted healthy habits). From a connectivity viewpoint, short-range dense body networks [6] and ms-scale latency in 5G and eventually 6G communications [7] will be instrumental in enhancing our sensorial experience in remote interactions (e.g., learning and training), and expanding the range of action of our physical skills (e.g., remote surgery). Sensemaking of such data and personalized monitoring will need to be supported by drastic advances in computing both at the edge and at various stages up to the cloud, assuring the necessary responsiveness in such interactions.

Although more futuristic, highly pervasive sensing and connectivity can also potentially accelerate the drug discovery pipeline, and enable continued improvements in medical treatment by closing the loop at each stage of the

Digital Object Identifier 10.1109/TVLSI.2022.3140540

drug development process (cycle). Analogously, continued advances in computational performance will be needed to handle the vastly higher model complexity required in this process (e.g., synthetic biology). Sustaining historical trends in computational performance of VLSI systems will certainly require tighter coupling of algorithm-level data flow and (heterogeneous) physical design and data orchestration, taking traditional across-level design methodologies to a new level (more than 2-D, highly heterogeneous). In the longer run, alternative computational paradigms will expectedly help advance computing in a nonstrictly linear development pathway (e.g., quantum computing).

In this decade, dense and unceasing connectivity with rapidly increasing data sensitivity will certainly require very substantial advances in architecture-level down to physical security [8], while enabling hardware patch-ability throughout the entire lifespan of silicon systems as we are currently used to in software [9]. As a representative example, hardware e-wallets will be widespread to preserve our own exclusive access to decentralized data structures such as blockchains (e.g., crypto-currencies, decentralized certification of asset ownership or authenticity). Given the inherently large value safeguarded by e-wallets, protection of their secret keys against a range of physical attacks is progressively becoming critical, and is moving from differentiating technical features to essential requirements. At the same time, decentralized management of crypto-currency public ledgers and mining already take more than 0.5% of the worldwide electric power, and their power demand is increasing at a breathtaking pace of 10X every five years [10]. The environmental impact is unclear, and its estimates range from mostly carbon-neutral load [11] to environmentally unsustainable [12]. Although there is no conclusive argument on its environmental impact, the global power requirement of blockchains certainly steers some of the renewable energy sources away from other uses, thus directly or indirectly contributing to carbon emissions [13]. The mitigation of such emissions and considerations on the net financial reward of mining all translate into the fundamental necessity of a new breed of VLSI systems with much improved energy efficiency per transaction. To further motivate such advances in VLSI energy efficiency in the area of blockchains, the power-hungrier proof-of-work (POW) consensus mechanism to preserve public ledger integrity will most likely not be replaced by alternative and more efficient mechanisms. Indeed, POW has the unique ability to prevent coordinated large-scale malicious actions aiming to subvert the blockchain structure (e.g., 51% attacks). Preserving public ledgers from such potential coordinated actions becomes increasingly more important in today's world where instant communications are easily supported (e.g., by social media and discussion websites), and algorithms tend to dominate decision making in the overall volume of financial transactions. As a representative example, instances of such coordination to affect stock pricing have been widely covered by financial news in early 2021 [14].

From an environmental viewpoint, the proliferation of connected and self-powered systems toward the trillion scale for the Internet of Things (IoT) will inevitably pose another entire set of challenges, requiring decisive VLSI system innovation. By 2030, the projected annual cumulative capacity of batteries for IoT devices will overshadow the overall capacity of batteries for electric vehicles by an order of magnitude, which is already well known to be a gigantic threat to environmental sustainability [15], [16]. Batteries for IoT devices are also expected to be economically unsustainable even in later stages of their lifecycle. For example, their replacement will amount to a global cost of several trillions of dollars per year, if each IoT device keeps requiring a battery [15]. Our community must lighten the burden of batteries and eventually completely relieve IoT devices from it, to ultimately make the IoT feasible at scale both environmentally and economically.

As further areas where VLSI systems will need to progress more decisively are in agile design methodologies, as well as in open ecosystem creation to further encourage economies of scale, relentless cost reductions, and accelerated development. The related advances will eventually contribute to creating a more efficient and resilient semiconductor supply chain, helping address some of the major challenges discussed in the previous section. More on this will come in future editorials.

III. Transactions on VLSI Systems: Current State and What's Next

This year, our journal has sustained its upward trajectory in terms of impact and quality. The acceptance rate has been progressively reduced in the past two years, and is now 28.3% after a decisive 5.1% reduction in the year 2020 and an expectedly more graceful decrease by 1.6% in 2021 [17]. The impact factor of IEEE Transactions on Very Large Scale Integration (VLSI) Systems (TVLSI) is now 2.312 and hence higher than any prior year, after a steady improvement of 17% in 2020 and 14% in 2021. To further enhance the impact, each new submission is now required to be contextualized in terms of relevance and timeliness of the challenges being addressed, which will be considered as an explicit part of the review process.

As reported in the journal cover and website, our Editorial Board has been further enriched with the presence of very energetic and dedicated Associate Editors, whose contribution has kept improving the average turnaround time down to 45 days, which is 16 days shorter than in 2020, and two days shorter than that in 2021. Overall, the turnaround time is now in line with or better than the flagship journals of the three IEEE Societies that our journal serves and belongs to.

As a tradition of our journal, we are excited to publicly acknowledge the five highest performing Associate Editors for the year: Prof. Chirn Chye Boon [Nanyang Technological University (NTU)], Prof. Yong Chen (University of Macau), Prof. Paolo Crovetti (PoliTO), Dr. Rajiv Joshi (IBM), and Prof. Mingoo Seok (Columbia University). Their dedication to our readership and community is a great example for all of us, and will undoubtedly inspire many others to bring our service and journal to new heights in the future.

As a recent initiative, TVLSI has now greater accessibility and offers a new opportunity to interact through LinkedIn (https://www.linkedin.com/company/ieeetvlsi). I encourage all authors and readers to follow the page to receive updates on particularly impactful publications within the scope of our journal. Our website has been upgraded too and is now hosted by IEEE (tvlsi.ieee.org).

As upcoming initiatives, this year, we will all work together to build up our new EDICS database to accurately map the interests of readers, authors, and reviewers to the areas and topics within the scope of TVLSI. This effort will be instrumental in enabling the next generation of services from our journal, such as personalized newsletters with content curated and tailored around personal interest. Given the exponential growth of knowledge in all related areas, we believe that personalized and targeted services will provide the readership with an optimal balance between focused insights, up-to-date knowledge, and broad coverage of the field. We are truly glad to take the lead in this exciting journey. Thank you all in advance for your help in updating your EDICS database, and for helping take TVLSI and subsequently other TRANSACTIONS to a whole new level!

To start the editorial year with the right tone, this journal issue begins with an invited keynote paper in the area of hardware and physical security. TVLSI will indeed keep being home for the hardware security community, following its robust presence in topics spanning from architectures to circuits, and down to physical protection. The keynote paper is authored by Prof. Makoto Nagata (Kobe University) and other co-authors, and focuses on protection techniques against physical attacks on silicon chips. The challenge is (literally) looked at from different points of view, and in particular from both the frontside and the backside of silicon dice. An overview of physical attacks against cryptographic circuits and their underlying vulnerabilities is provided along with a vertical and unified view of circuit-to-packaging technologies. The keynote paper includes a comprehensive coverage of multimodal side-channel attacks, relevant on-chip monitoring schemes for attack detection (e.g., electromagnetic, laser), and validation through silicon demonstrators. Among the other contributions, a secure packaging technology that monolithically unifies the backside and the frontside is shown. A longer term perspective is also presented at the intersection of materials science, device engineering, circuit design, and system implementation.

As usual, I am immensely grateful for the irreplaceable contribution of Prof. Pasquale Corsonello and Prof. Mircea Stan as Associate Editors-in-Chief, and Stacey Weber as an Editorial Assistant. My deepest thanks also go to the TVLSI Editorial Board for the year 2022 with each and every Associate Editor generously contributing with their unique expertise and energy, as well as to the Steering Committee for continued support and valuable feedback.

Wishing you an exciting and purposeful new year!

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