Guest Editorial

Security-by-Design for Electronic Systems

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In a recent Special Section published in IEEE Trans. on Consumer Electronics we introduced smart electronics [A1]. We presented a set of papers which were selected after rigorous review with a scope of artificial intelligence (AI) or machine learning (ML) approaches used for various levels of system abstractions, from device-level to system-level. In one school of thought energy-smart, security-smart, and response-smart are 3 dimensions of smart electronic systems [A2]. Security-by-Design (SbD) has been proposed as a novel paradigm for the design of smart electronics [A3], [A4].

The current Special Section has been presented with an intention to bring SbD principle to the attention of readers and new upcoming researchers. In the existing trend, the cybersecurity solution are mostly an afterthoughts. In other words, the system design is done first then cybersecurity solutions are retrofitted [A2], [A3]. SbD instead promotes cybersecurity as a design habit tightly integrated right from the first step of design flow as a proactive task. SbD has seven fundamental principles [A2], [A3], [A4]: (1) cybersecurity is proactive not reactive, (2) cybersecurity is a default, (3) cybersecurity is embedded into the design, (4) cybersecurity is full functionality - positive-sum, not zero-sum, (5) cybersecurity is end-to-end to provide lifecycle protection, (6) cybersecurity needs to be visible and transparency, and (7) cybersecurity solutions should respect have for users.

Most of the cybersecurity solutions have been heavily relying on software-based approaches [A2], [A4]. However, hardware-based solutions as well as hardware-assisted solutions are critical to meet the principle of SbD. Hardware-Assisted Security (HAS) is cybersecurity provided by the hardware for the information being processed by an electronic system, for hardware itself, and/or for the electronic system [A4]. In HAS, additional hardware components can used for cybersecurity, hardware design modification is performed and/or electronics-system design modification can be performed. Hardware-Assisted Security (HAS) is thus a subset of SbD.

Physical Unclonable Function (PUF) is a cybersecurity hardware primitive that relies on nanoelectronics manufacturing process variations for robust cybersecurity of electronic devices as well as large Cyber-Physical Systems (CPS) [A5]. In last decade tons of research has been presented in the existing literature to explore its use in various electronic devices and systems. The following 2 papers of this special section deals with the PUF.

The paper titled “Realizing Robust, Lightweight Strong PUFs for Securing Smart Grids”, focuses on the design of robust PUFs and demonstrate its use in smart grids [A6]. Specifically, strong PUFs have been explored for LFSR-based key generation and cybersecurity in smart grids.

The use of PUF in a specific application domain is the scope of the he paper titled “iGLU 3.0: A Secure Noninvasive Glucometer and Automatic Insulin Delivery System in IoMT”. It presents a low-cost, yet robust cybersecurity framework using PUFs [A7]. Specifically, arbiter PUF design and corresponding protocols have been presents for cybersecurity of Internet-of-Medical-Things (IoMT) devices in smart healthcare framework. An example of automatic noninvasive glucose reading and insulin delivery with integrated cybersecurity has been demonstrated.

Blockchain is a specific digital ledger technology (DLT) which has been getting lots of attention due to its success in the cryptocurrency domain [A8]. The research in blockchain is evolving in multiple fronts. Blockchain is being explored as a cybersecurity

solution for data as well as CPS. Research is also performed to make blockchain more secure. This Special Section presents 2 papers that explore use of blockchain to make CPS more secure, thus SbD solutions for the complex systems.

The paper titled "eChain: A Blockchain-enabled Ecosystem for Electronic Device Authenticity Verification" presents the idea of blockchain to ensure authenticity of electronics [A9]. Due to the global nature of electronics supply chains their originality is often compromised, and fake electronics are present everywhere, which has 2 types of major issues: loss of revenue of the original manufacturer and compromising of the system in which the fake electronics are deployed. This paper proposes mitigation of this key problem through use of blockchain based supply chain.

The paper titled "Designing Hardware-Smart Contracts for Remote Device Management" present custom hardware for efficient smart contract execution [A10]. Smart contract implementation in a public blockchain ensures that the contract terms cannot be changed due to its immutability. This paper proposes an on-die hardware module that can communicates with the smart contract for its functionalities.

SbD principles are further demonstrated in other accepted papers in which devices are made cyber attack proof by integrated cybersecurity features right at the device level with an intention to make systems in which these are deployed resilient to cyberattacks.

The paper titled "2-Phase Adiabatic Logic for Low-Energy and CPA-Resistant Implantable Medical Devices" demonstrates a method for robust security in IoMT devices [A11]. This paper presents design of cryptographic modules which are energy-efficient to run in the IoMT-devices at the same time not susceptible to the physical attacks on cryptographic hardware which can make good guess of cryptographic keys without defeating the cryptography itself rather than analyzing physical signal like power traces.

The paper titled "Fortified-NoC: A Robust Approach for Trojan-Resilient Network-on-Chips to Fortify Multicore based Consumer Electronics", advocates making each component of electronic system cybersecure [A12]. This paper presents methodology to design to Fortified Network-on-Chips to secure the data and resources against different kinds of hardware trojans. Hardware trojans can be built into the NoC of a consumer electronics to have a backdoor entry so that electronics which can be exploited when needed.

The guest editors sincerely believe that this Special Issue will be a good reading for researchers in the areas of cybersecurity and electronic systems around the globe. The guest editors would like to thank all the contributing authors for their excellent contributions for this Special Issue. The guest editors also sincerely thank all the reviewers for their help in reviewing the manuscripts throughout the multiple revisions to have a rigorous selection of the works.

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APPENDIX: RELATED ARTICLES

[A1] F. Pescador, and S. P. Mohanty, "Machine Learning for Smart Electronic Systems", Guest Editorial, *IEEE Transactions on Consumer Electronics*, Vol. 67, No. 4, Nov 2021, pp. 224--225.

[A2] S. P. Mohanty, Security and Energy Trade-Offs in Smart City Cyber-Physical Systems, Keynote Address, IEEE Smart Cities Conference, 2019, Casablanca, Morocco, 16 Oct 2019.

[A3] I. J. Gedeon, P. Snively, C. Frey, W. Almuhtadi, and S. P. Mohanty, "Privacy and Security by Design", Guest Editorial, *IEEE Consumer Electronics Magazine*, Vol. 9, No. 2, March 2020, pp. 76--77.

[A4] S. P. Mohanty, J. Plusquellic, G. S. Rose, W. Zhang, and M. K. Michael, "Hardware-Assisted Security for Emerging Internet of Things", Guest Editorial, *ACM Journal on Emerging Technologies in Computing Systems*, Vol. 18, No. 1, January 2022, pp. 1:1--1:3, DOI: https://doi.org/10.1145/3475952.

[A5] S. Joshi, S. P. Mohanty and E. Kougianos, "Everything You Wanted to Know About PUFs," *IEEE Potentials*, vol. 36, no. 6, pp. 38-46, Nov.-Dec. 2017, doi: 10.1109/MPOT.2015.2490261.

[A6] …, "Realizing Robust, Lightweight Strong PUFs for Securing Smart Grids", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

[A7] …, "iGLU 3.0: A Secure Noninvasive Glucometer and Automatic Insulin Delivery System in IoMT", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

[A8] S. P. Mohanty, V. P. Yanambaka, E. Kougianos and D. Puthal, "PUFchain: A Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in the Internet of Everything (IoE)," *IEEE Consumer Electronics Magazine*, vol. 9, no. 2, pp. 8-16, 1 March 2020, doi: 10.1109/MCE.2019.2953758.

[A9] …, "eChain: A Blockchain-enabled Ecosystem for Electronic Device Authenticity Verification", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

[A10] …, "Designing Hardware-Smart Contracts for Remote Device Management", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

[A11] …, "2-Phase Adiabatic Logic For Low-Energy and CPA-Resistant Implantable Medical Devices", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

[A12] …, "Fortified-NoC: An Robust Approach for Trojan-Resilient Network-on-Chips to Fortify Multicore based Consumer Electronics", *IEEE Trans. Consum. Electron*., early access, doi: xxx.

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