

IEEE Council on Radio-Frequency Identification: History, Present, and Future Vision

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Abstract—This article summarizes the history and present state of the IEEE Council on Radio-Frequency Identification (CRFID). The aim, scope, and achievement of CRFID on technical & academic activities, publications, and membership services & education are highlighted, with focus on how CRFID commits and grows resources to achieve its goals for its technical communities. This article also provides the vision and path to the council's future, and on this path, CRFID is broadening the technological frontiers of IoT, Blockchain, Cyber-Physical Systems (CPS), Cyber-Physical Social Systems (CPSS), Digital Twins, Parallel Systems, Parallel Intelligence, and many other related enabling and transformational techniques.

Index Terms—IEEE council on radio-frequency identification, Internet of Things, cyber-physical social systems (CPSS), digital twins.

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I. INTRODUCTION

THE COUNCIL of Radio Frequency Identification (CRFID) was recognized by the IEEE in 2015 and became the 46th society/council within the IEEE Technical Activities Board. CRFID's field of interest is the theory and practice of matters related to RFID and RFID related systems. The key is understanding the expanse of the related systems that include the Internet of Things (IoT), Cyber-Physical Social Systems and digital twins. Since its establishment, CRFID has grown rapidly through activities, conferences, and publications.

A. The Origin and History of CRFID

In 2007, the first IEEE RFID Conference was held in Grapevine, Texas and would later partner with the largest RFID tradeshow in North America, RFID Journal LIVE!. The IEEE Technical Committee (TC) on RFID was created in 2008 to serve the emerging community of multi-disciplinary engineers that worked in this field. In June 2015, IEEE TAB approved the transition from RFID TC to IEEE Council on RFID. CRFID became the 46th society/council within the IEEE Technical Activities Board. The field of interest for CRFID is the theory and practice of matters relating to RFID (radio frequency identification) and RFID-related systems. The purpose is to advance and coordinate work in the field of radio frequency identification (RFID) carried throughout the IEEE and as such is scientific, scholarly, and educational in character.

B. Aims and Scope

The purpose of IEEE CRFID is to advance technology and applications of RFID and RFID related systems. These systems include numerous technologies and societal elements associated with various supporting IEEE Societies. CRFID brings together the diverse elements and applications of RFID to serve the overall IEEE and global technical communities. CRFID is positioned to be the leading global, collaborative community for RFID and IoT technology, and is “bridging the physical and the digital” elements to applications in networks,



Fig. 3. CRFID contacts and activities with industries.

CRFID deliberately involves younger volunteers in its organizing committees. The RFID conferences scour emerging fields and showcase diverse, early-career researchers in “hot topics” and keynote sessions. CRFID members recruit senior design and student research teams to present at RFID conferences.

From 2020, CRFID will set up four awards the IEEE CRFID Heinrich Rudolf Hertz Award, the IEEE CRFID James Clerk Maxwell Award, the IEEE CRFID Charles A. Walton Award and the Emily Sopensky Award on the IEEE RFID Conference, the IEEE DTPI Conference and the IEEE RFID-TA Conference, respectively.

While CRFID maintains high quality across all its conference events, there are three distinctive attributes of conferences that set us apart from many other engineering conferences:

- **Functionally Multi-Disciplinary:** The Council on RFID’s conference events have shepherded a technical community that is both broad and deep for over a decade. This technical community has expertise ranging from physical layer devices (circuits, semiconductor manufacturing, microwaves, RF, antennas, digital design, signal processing, telecommunications, etc.) through applications (logistics, transportation, computing, robotics, etc.). CRFID has managed to avoid the “silo-ing” that exists in many societies, while speaking a common, unifying language of RFID and wireless systems.
- **Industry-Relevant:** The conference series in which CRFID participates have unusually high industry relevance. This is achieved by strategic trade-show partnerships and industry-friendly venues. The flagship IEEE RFID series has an average *draw* (ratio of paid attendees to accepted papers) of 4.7 and boasts a majority of nonacademic attendees. This has been achieved by a long-standing partnership with the RFID industry’s largest trade show, RFID Journal LIVE! The associated IEEE WiSEE conference is similarly successful with a draw of 4.4, smartly locating its events near aerospace hubs and government labs and partnering with topical technology workshops.
- **Original:** The multi-disciplinary nature, industry relevance, and energetic youth of the IEEE CRFID community leads to a key distinction: the CRFID conference series are uniquely suited to cultivate and explore new technologies. In this area, CRFID is not content to simply

Young Professionals, Student Engagement, and Social Media

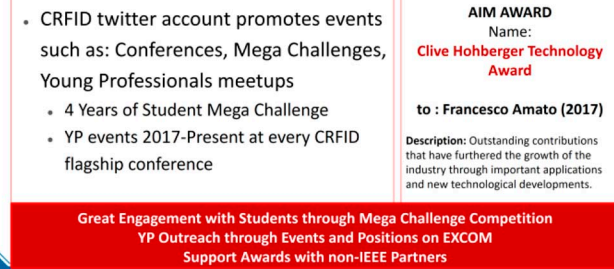


Fig. 4. Young professionals, student engagement and social media in CRFID activities.

track and follow emerging technologies, but to seed them. This can be seen with past efforts involving the Internet of Things (which was a concept developed in our technical community nearly a decade before it became pervasive in IEEE circles) and with current efforts to launch events in digital twins/parallel intelligence (IEEE DPTI 2020) and wireless motion capture (IEEE RFID 2020 Workshop on Wireless MoCap).

The flagship conference of CRFID is the IEEE International Conference on RFID, an annual conference that is held in North America every spring and co-located with an industry trade-show. The data and activities for this conference series are shown in Figures 2 and 3. Offering compelling tutorials, workshops, hot topics lectures, student competitions, panel discussions, and round table talks, this conference is known for its consistently high draw – the overwhelming majority of the attendees are *not* presenters and are coming for the quality of the technical content.

The IEEE International Conference on RFID – Technical Applications (IEEE RFID-TA) was founded to support emerging applications in RFID as well as conference venues outside of the United States. Held in early fall, the conference venues roughly alternate between Asia and Europe. IEEE RFID-TA in 2019 dedicated a session to women in RFID.

IEEE Wireless for Space and Extreme Environments (WiSEE) explores the multidisciplinary fields in electrical engineering that constitute wireless space systems. Drafting off the increased activity in space research, private space enterprise, and CubeSat missions, IEEE WiSEE draws from an IEEE community that has many of the same stakeholding societies as CRFID. IEEE CRFID became a technical co-sponsor in 2015 and a financial co-sponsor in 2018. Currently, CRFID is the only regular societal/council sponsor of this annual event.

In recent years, CRFID technically and/or financially sponsors/co-sponsors a number of IEEE conferences, workshops, and one-time events around the world, which contributes to CRFID’s healthy fiscal state.

III. ACADEMIC PUBLICATIONS

CRFID launched the IEEE Journal of Radio-Frequency Identification (J-RFID) in 2017. IEEE J-RFID is a quarterly



Fig. 5. CRFID technical committees and societies activities.

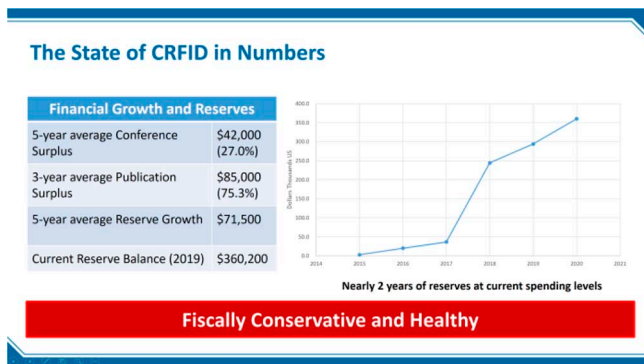


Fig. 6. Snapshot of IEEE CRFID financial state in numbers.

TABLE I
IEEE J-RFID BY NUMBERS

	2017	2018	2019	2020*
# of submitted papers	69	57	50	47
# of accepted papers	31	34	35	17
# of rejected papers	16	22	15	15
Acceptance rate	66%	60%	70%	53%
# of papers published in the current year	31	26	29	17 (up to June) 50**(by Dec.)
# of pages published	322	239	287	500**

*For 2020 the data is up to June (when the 2nd issue of the quarterly journal is published)

**Estimated number taking into account the papers that are already and/or will be submitted to the remaining two issues of the year (both are special issues).

journal which is published online, and publishes peer-reviewed manuscripts addressing various aspects of RFID systems. The articles describe advances in theory, algorithms, design techniques, implementations, and applications of RFID systems. Both emerging research and commercial trends in the rapidly evolving field of RFID are covered. Applications span a wide range of fields including healthcare, asset monitoring, security, finance, energy, and transport. In recent years, IEEE J-RFID has attracted more and more attentions from both academic and industry. The numbers by year are shown in Table I.

As of June 2020, IEEE J-RFID has been selected for inclusion in the Web of Science (“the world’s most trusted publisher-independent global citation database) and articles published since its launch (January 2017) will be included in the Emerging Sources Citation Index (ESCI).

TABLE II
IEEE RFID VJ IN NUMBERS

Year	2013	2014	2015	2016	2017	2018*
# of curated papers	22	43	59	21	18	23
# of visits to RFID VJ on Xplore		2,892	2,345	2,144	6,097	4,546

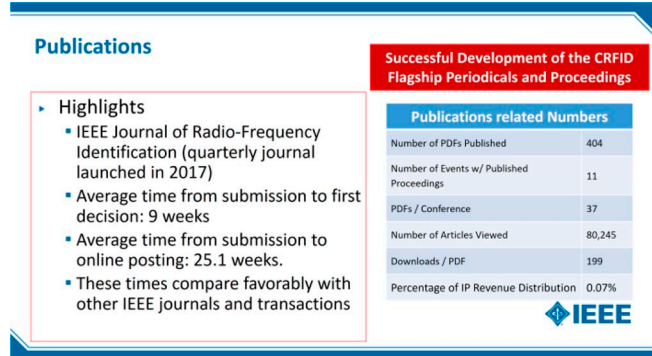


Fig. 7. Snapshot of CRFID publications highlights.

IEEE J-RFID has an average time from submission to first decision of 9 weeks, and from submission to online posting of 25.1 weeks, which compares favorably with those of other IEEE journals and transactions. In addition, IEEE J-RFID welcomes both academic research manuscripts and industry technical standards, which is quite reasonable for the fast-growing and widely-impacted RFID eco-system.

CRFID also sponsored the IEEE RFID Virtual Journal (VJ) which was one of the three IEEE Virtual Journals starting from 2013. The virtual journal was a quarterly online publication that was established to bring together in one place the best work in RFID technology, systems, and applications. For each quarterly issue, the distinguished associate editors of the Virtual Journal, representing a diverse group of IEEE Societies, highlighted the best work available in the field from across the IEEE journal and conference publications. These high impact, peer reviewed publications were curated to provide the highest quality information available about this rapidly evolving field. The editorial content focused on timely topics and draws together emerging research and commercial trends to provide a comprehensive perspective on RFID and its emerging impact on society.” The CRFID community has made significant contributions on VJ during 2013 to 2018 (seen in Table II).

Despite the fact that RFID VJ was a useful resource for the technical community, its publication was stopped, as of September 2018, due to the relatively high production cost, which was not viable for a newly-established council such as CRFID.

IV. MEMBERSHIP SERVICES AND EDUCATIONAL ACTIVITIES

CRFID has significant growth of global membership and chapters in both Academia and Industry, with increasing penetration to regions and local sections. CRFID’s model is to provide services for the minimal dues. Along with this increase



Fig. 8. Distribution of 9 Chapters since 2015.

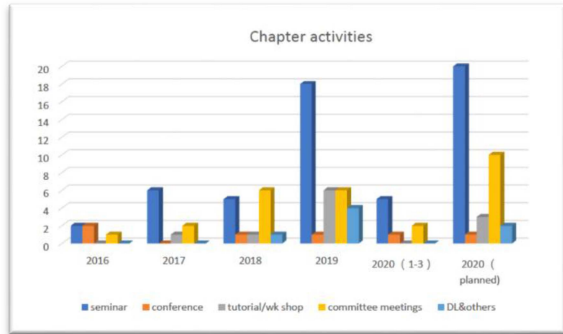


Fig. 9. CRFID Chapter activities by year.

in activities around conferences with non-member societies, CRFID seeks to engage additional IEEE societies in joining CRFID. Since 2015, 9 chapters have been established globally (seen in Figure 8). And currently, CRFID has 11 member societies under active MoUs and 4 pending MoUs. The CRFID currently has over 10.5 k affiliated members, including a 10% growth in affiliation.

Lead time to develop chapters ranges from 8 months to a year. We aim to engage at least two chapters or joint chapters each year. Ensuring that the local talent is invested and sincere is part of building a solid, long-lasting Council with local technical interest and support. Established chapters in long-standing sections deal with the ebb and flow of chapters within their own jurisdiction on an annual basis. As per regulation, we expect that the chapters will hold at least two meetings per year, and track attendance, as is required, to receive reimbursement from the hosting Section. With new technology being rolled out by IEEE Member and Geographic Activities (MGA), we hope to provide the chapters the ability to record their meetings which can then be archived on our site. The CRFID distinguished lecturer (DL) program can enhance kickoff meetings.

We take a conservative approach, deliberate and thoughtful, to building solid, active chapters. Of the 1700+ who have indicated interest in the RFID technical group, we have 20+ indicating an interest in serving further. Determining the strength of these in leadership will be a major undertaking of the council.

Over the years, we continuously organize high-quality chapter activities with support from industry by the guidance of CRFID. 36 Seminars have been delivered by IEEE fellows, invited industry speakers, university professors, and



Fig. 10. Active Chapter activities with industry impacts (Examples glance).

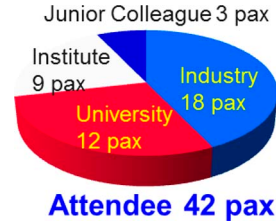


Fig. 11. Active Chapter attendee data (example glance).

researchers through the newly established chapters with supported from other IEEE societies such as Electromagnetic Compatibility (EMC), Antennas and Propagation (AP), Microwave Theory & Techniques (MTT) and so on. Multiple Workshops has been delivered with fully support from IEEE members, industry, and government representatives. Chapters are very active in organizing or co-organizing conferences, exhibitions, and symposia independently or with other IEEE societies or industry parties (seen in Figure 9 and 10).

To encourage student participation in IEEE RFID technology, student competitions have been conducted by Macao Chapter. An RFID-themed summer school for students has been organized by the Romania chapter. Due to the Covid-19 pandemic, an online forum has recently attracted more than 250 registrations from IEEE members, industry participates and university students and researchers this year. Merlion RFID Forum 2020 has been organized to deliver the 9 virtual talks via Zoom by a kick-off Distinguished Lecturers of CRFID in August and September by Singapore chapter.

An online forum was co-organized with university EMBA program by IEEE CRFID Singapore chapter. On 7th July 2020, over 250 registered participates from EMBA students and alumni and people who have interest on RFID technology. The event drew great attention from academic researchers but also industry organizations and end-users from executive levels.

V. VISION AND FUTURE

RFID is the last mile connection between the physical (living and nonliving) and the digital (data driven) world in the domain of identity management. Similar to all other domains, identity management has greatly benefited from the emergence of newer technologies in the digital world such as IoT, ML/AI, Blockchain, 5G, Big Data and so on [1]. However, its position as the undisputed last mile connection between the physical

Fig. 12. Active Chapter promotions (examples glance).

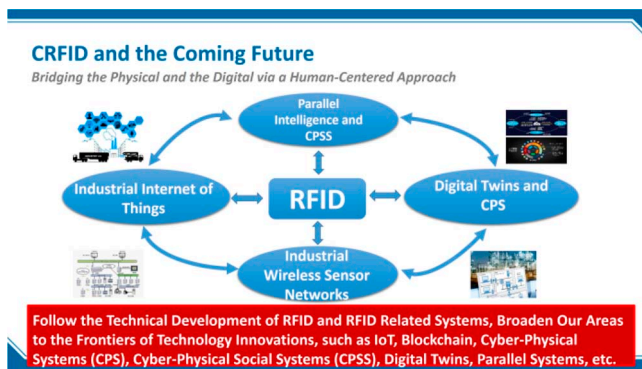


Fig. 13. CRFID and the coming future.

and the digital world has given rise to an ever-increasing scope for research, standards and development to leverage the enormous progress in the upstream digital world. All domains that need a last mile connection between the physical and digital world viz. Retail, Healthcare, Logistics and Supply Chain, Manufacturing, Security and Surveillance, and Livestock are dependent on RFID. The market for RFID technology has seen a steady rise over the past years and holds a promising future with more and more investments in hardware and software.

CRFID is well positioned to be the leading global, collaborative, community for RFID and IoT technology, and is “bridging the physical and the digital” elements to applications in networks, power harvesting, tagging, smart cities and blockchain as examples (seen in Figure 13). CRFID’s technical scope gradually move towards the concept of “Intelligent IoT (iIoT)” where RFID technologies and systems to include data analytics

are the framework for the changing applications and nomenclature in the community. After all IoT is an outgrowth from RFID.

- **Technical Achievements:** Follow the technical development of RFID and RFID Related Systems, broaden CRFID areas to the frontiers of technology innovations, such as IoT, Blockchain, Edge-Computing [2], Cyber-Physical Systems (CPS), Cyber-Physical Social Systems (CPSS), Digital Twins [3], Parallel Systems [4], and many other related enabling and transformational techniques [2], [3], [4].
- **Conferences:** Continue our good activities and investment, innovatively creating high-value conference IPs in the newly emerging areas
- **Publications:** Continue our publishing efforts with creative plans to continue attracting and publishing high-quality and impactful work.
- **Membership and Collaborations:** Create synergy among collaborative and supporting societies, create beneficial publications, conference and technical activities for the signing society members and volunteers

The CRFID is striving for the goals of its coming future, and will succeed in its mission of “Bridging the Physical and the Digital via a Human-Centered Approach”.

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REFERENCES

- [1] R. Bhattacharyya and P. NikitinGuest, “Guest editorial: Special issue on IEEE RFID 2019 conference,” *IEEE J. Radio Freq. Identif.*, vol. 4, no. 1, pp. 1–2, Mar. 2020, doi: [10.1109/JRFID.2020.2973562](https://doi.org/10.1109/JRFID.2020.2973562).
- [2] Y.-Y. Bai, Y.-H. Huang, S.-Y. Chen, J. Zhang, B.-Q. Li, and F.-Y. Wang, “Cloud edge intelligence: Status quo and future prospective of edge computing approaches and applications in power system operation and control,” *Automatica Sinica*, vol. 46, no. 3, pp. 397–410, Jul. 2020, doi: [10.16383/j.aas.2020.y000001](https://doi.org/10.16383/j.aas.2020.y000001).
- [3] J. J. Zhang, P.-D. Xu, and F.-Y. Wang, “Parallel systems and digital twins: A data-driven mathematical representation and computational framework,” *Automatica Sinica*, vol. 46, no. 7, pp. 1346–1356, Jul. 2020, doi: [10.16383/j.aas.c200347](https://doi.org/10.16383/j.aas.c200347).
- [4] F.-Y. Wang, X. Wang, L. Li, and L. Li, “Steps toward parallel intelligence,” *IEEE/CAA J. Automatica Sinica*, vol. 3, no. 4, pp. 345–348, Oct. 2016, doi: [10.1109/JAS.2016.7510067](https://doi.org/10.1109/JAS.2016.7510067).