FINAL REPORT

14TH ITU ACADEMIC CONFERENCE

ITU KALEIDOSCOPE

ACCRA 2022

Extended reality – How to boost quality of experience and interoperability

7-9 December 2022
Accra, Ghana

ITU Kaleidoscope Secretariat

15 December 2022

"*The future belongs to you, but it can only belong to you if you participate and take charge*", Dr Collins Yeboah-Afari, Director-General of the Ghana-India Kofi Annan Centre of Excellence in ICT, said in his Opening remarks, quoting the former Secretary-General of the United Nations, Kofi Annan

TABLE OF CONTENTS

1.   ITU Kaleidoscope 2022 highlights

The ITU Kaleidoscope conference (K-2022) on *Extended reality – How to boost quality of experience and interoperability* took place in Accra, Ghana, from 7 to 9 December at the National Communications Authority (NCA), with options also available for remote, online participation.
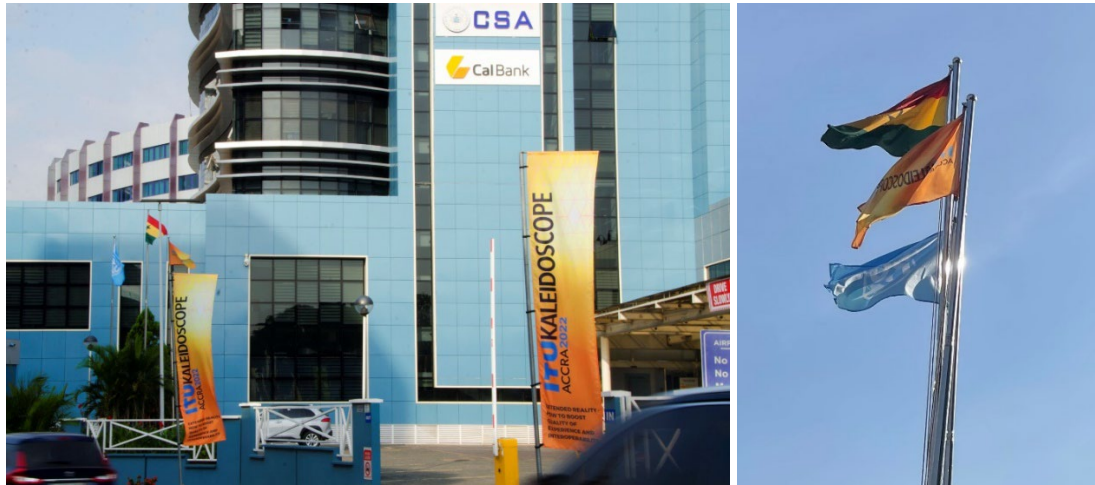
The conference was kindly hosted by NCA, the Ministry of Communications and Digitalisation, and the Ghana-India Kofi Annan Centre of Excellence in ICT (GI-KACE) which took the lead in the local coordination.

Beginning from left to right: Ezer Osei Yeboah-Boateng, Deputy Director General, NCA; Emer Windsor, ITU; Alessia Magliarditi, ITU; Collins Yeboah-Afari, Director-General, GI-KACE; Joe Anokye, Director General, NCA; Honourable Ursula Owusu-Ekuful, Minister for Communications & Digitalisation; Chaesub Lee, Director, Telecommunication Standardization Bureau, ITU; Honourable Akosua Asabea Annoh, Mayor of Abuakwa South Municipal Assembly, Kyebi, Ghana; Martin Adolph, ITU.

We wish to sincerely thank the Ministry, NCA and Kofi Annan Centre for their outstanding support and generosity and for the excellent local organization that made Kaleidoscope 2022 an amazing edition.

Nearly 250 experts and academics participated in the conference (52 connected remotely), including many students coming from the north of Ghana.

The conference was technically co-sponsored by the Institute of Electrical and Electronics Engineers (IEEE) and the IEEE Communications Society (IEEE ComSoc).

All accepted papers, including the keynote paper, keynote summaries and invited paper (details can be found at the Programme webpage) are published in the Conference Proceedings. All accepted and presented papers have been submitted for publication in the IEEE *Xplore* Digital Library. Outstanding papers may also be published in the IEEE Communications Standards Magazine.

A 10-month, substantial preparatory process was required for this 14th Kaleidoscope edition. This process involved the efforts and collaboration of TSB staff, a Steering Committee (SC) of 8 members, a Technical Programme Committee (TPC) of 30 members, all internationally recognized ICT experts from academia, research institutes and the private sector, and a Host Committee of 4 members led by Dr Collins Yeboah-Afari, Director-General of GI-KACE, and including Dr Yaw Okraku-Yirenkyi (in the picture below) who acted as the main focal point for

the ITU Secretariat and coordinated all activities and local teams in a highly professional manner; Mr Fred Yeboah from GI-KACE, and Dr Kwame Baah-Acheamfuor, from the Ministry of Communications and Digitalisation of Ghana.

Alessia Magliarditi, ITU Kaleidoscope Coordinator, chaired the meeting of the Award Committee that selected the winners of the awards for the best papers. The Award Committee was composed of six conference attendees: two SC members, Mostafa Hashem Sherif, and Eva Ibarrola; an ITU staff member, Martin Adolph; and three professors from the Host Country, Kester Quist-Aphetsi, Martin Mabeifam Ujakpa from the Ghana Communication Technology University, and Abdul-Rahman Ahmed from the Kwame Nkrumah University of Science and Technology, Ghana.

At the Closing Ceremony, the winners of the best paper awards and the recipients of the young author recognition (YAR) certificate, as well as the author of the video demonstration track were awarded with the ITU Certificate of appreciation from the ITU Kaleidoscope 2022 General Chairman, Dr Collins Yeboah-Afari, and TSB Director, Dr Chaesub Lee (all appearing in the picture below).

Beginning from left to right: Yaw Okraku-Yirenkyi; Kester Quist-Aphetsi; Isaac Boateng, NCA; Martin Adolph; Emer Windsor; Chaesub Lee; Collins Yeboah-Afari; Dhananjay Kumar, Anna University, India (1ˢᵗ prize ex-aequo); Alessia Magliarditi; Eva Ibarrola, Mostafa Hashem Sherif; Alexandra Rowland, University of Twente & Kadaster, The Netherlands (1ˢᵗ prize ex-aequo and YAR); Sophie Westfahl, University of Applied Sciences Neu-Ulm, Germany (3ʳᵈ prize and YAR); Erwin J.A. Folmer, University of Twente & Kadaster, The Netherlands (1ˢᵗ prize ex-aequo)

At the Closing, TSB Director thanked the Steering Committee members: Christoph Dosch (ITU-R Study Group 6 Vice-Chairman; ARD, Germany), Eva Ibarrola (University of the Basque Country, Spain), Kai Jakobs (RWTH Aachen University, Germany), Gyu Myoung Lee (Liverpool John Moores University, United Kingdom), Tiziana Margaria (University of Limerick, Ireland), Mitsuji Matsumoto (Professor Emeritus Waseda University, Japan), Roberto Minerva, (Télécom SudParis, France) and Mostafa Hashem Sherif, (Consultant, USA); the whole Technical Programme Committee and in particular its Chairman, Mostafa Hashem Sherif, for ensuring transparency through the double-blind peer-review process; and all the partnering organizations which supported the promotion of the conference: Waseda University, the Institute of Image Electronics Engineers of Japan (IIEEJ), the Institute of Electronics, Information and Communication Engineers of Japan (IEICE) of Japan, the Chair of Communication and Distributed Systems at RWTH Aachen University, the European Academy for Standardization (EURAS), the University of the Basque Country, Liverpool John Moores University, Korea Advanced Institute of Science and Technology (KAIST), the University of Limerick and Confirm Smart Manufacturing.

Dr Collins, in his closing remarks, encouraged Africa, and especially Ghana, to continue the conversation had at Kaleidoscope this year, also at the policy level to ensure that we fully benefit from all XR technologies i.e. AR, VR, and MR. He also noted that the Ministry of Communications and Digitalisation has developed Ghana's Digital Policy which will provide the framework for legislation on the country's digital transformation agenda and clearly define digital policy and strategy. "The Ghana Digital Policy is expected to enhance growth of the sector and also improve interoperability, standardization, security, privacy and quality of experiences", Dr Collins affirmed.

Alessia thanked the ITU Secretariat, Emer Windsor, Erica Campilongo, Martin Adolph, Gent Bajrami and Pascal Borde from ITU TSB, and all the local people that contributed to the success of the conference, including the Communication, Technical and Registration, and Ushering teams from the Kofi Annan Center coordinated by Dr Yaw Okraku-Yirenky, and the Media and Network teams from NCA, led by Michael Ansah (in the pictures below).

Communication Team: Nii Ogbamey Tetteh, Selasie Kwabla Awagah, Emmanuella Godlove Osei, Agyeman Osei Tutu, Sarata Omane, Jacqueline Lartey, Doris Tawiah Nartey, and Stephen Boakye Yiadom

Technical and Registration Team: Allwin Wellington, Anthony Marfo, Felix Antwi, Yaw Okraku-Yirenky, Nicholina Adjetey, Andrew Adjorlolo, Eugene Djan, Joshua Agyei, and Charles Acquah-Moses

Ushering team: Doris Tawiah Nartey, Beatrice Quansah, Jacqueline Lartey, Lady Martha Annorbah, Evette Bruce Nkrumah, Theresah Appiah, Tracey Budu, Doreen Fordie

Media and Network Teams from NCA: Michael Ansah, Rimaskeb Cobbson-Cobbold, Maxwell Owusu Marfo, Kwadwo Omari Agyapong, Charles Acquah-Moses, David Opoku, Michael Fiador, Daniel Edem Hedidor, Harrison Nugbalor, Eddie Appiah, *Julius Darkey*

2.   Conference programme

Dr Collins Yeboah-Afari, introduced by Nana Fosu Nyante from the Kofi Annan Centre (in the photo below, at the lectern), officially opened the 14ᵗʰ edition of the Kaleidoscope series, in his role as General Chairman of the conference, pointing out that Ghana is the first West African country to host the ITU Kaleidoscope Conference.

Dr Collins affirmed that Data on Extended Reality (XR) shows that more than half of Africa's population does not enjoy a fully digital experience, and therefore the Government of Ghana, through its various Ministries and implementing agencies, is championing the Digitalisation Agenda in Ghana.

Studies have also shown that connecting more people to Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality (VR) technologies, all under XR, could transform everything from healthcare and education to sports and tourism among other sectors of the African continent and the world. To do this, Dr Collins said that the right technologies must be deployed, and capacity building in advanced and exponential technologies must be done, and this is the reason why Kofi Annan Centre, as part of its mandate, trains people in Data Science, Artificial Intelligence (AI), Internet of Things (IoT) among others while advancing research in these areas. "Kofi Annan Centre is the capacity-building development agency of the Ministry of Communications and Digitalization and we have prioritized efforts to help create awareness in

the ecosystem also build capacity to help build critical mass of talent and help the build on the foundation of this economy that the Ministry is leading", Dr Collins concluded.

The **Opening Ceremony** included welcome remarks from the Honourable Mrs. Ursula Owusu-Ekuful, Minister for Communications & Digitalisation of Ghana, and Chaesub Lee, Director, Telecommunication Standardization Bureau (TSB), ITU. TSB Director informed the audience that ITU standardization experts are studying where ITU could deliver unique value to metaverse innovation, building on established ITU work in areas such as virtual and augmented reality and immersive live environments. These studies have identified a clear need for common interfaces, for example to enable our avatars to navigate from one metaverse world to another, carrying with us our profile, preferences, history, and virtual cash.

Another key priority to ITU is to determine how metaverse worlds could help us to achieve UN Sustainable Development Goals relevant to education, healthcare, and inclusion.

Dr Lee also remined the audience that one of the upcoming special issues of the ITU Journal on Future and Evolving Technologies will focus on the Metaverse: Communications, networking and computing. This special issue is inviting submissions until March, and he encouraged the researchers attending Kaleidoscope to make the most of this opportunity.

The Opening was followed by **Ceremony of United for Smart Sustainable Cities** (U4SSC). Dr Lee delivered the U4SSC Certificate to the Honourable Mrs. Akosua Asabea Annoh, Mayor of Abuakwa South Municipal Assembly, Kyebi, Ghana, for their efforts towards its smart and sustainable city transformation, at the presence of the Minister for Communications & Digitalisation.

TSB Director pointed out that, as a result of rapid urbanization to cater to this growing urban population around the world, the concept of Smart and Sustainable Cities has taken the centre-stage to leverage emerging technologies like Internet of Things (IoT), Artificial Intelligence (AI) and Metaverse, among others, to ensure the availability of the city resources in terms of social, economic, and environmental aspects, to improve the quality of life of the inhabitants by resolving urban challenges and optimizing urban operations.

The United for Smart Sustainable Cities (U4SSC) initiative was created to provide an open platform for knowledge sharing and promote dialogue on driving digital transformation for the creation of smart and sustainable cities. This initiative is supported by 18 United Nations agencies and programmes and is coordinated by ITU, UN-Habitat and UNECE. The United for Smart Sustainable City – Key Performance Indicators (KPIs) - based on ITU standard Y.4903 - have been developed to assess and monitor tools for the manifestation and realization of smart city goals.

Dr Lee announced that over 150 cities across the globe have successfully implemented these KPIs, and the newest city on the block is Kyebi in Ghana. Over the years, Ghana has adopted

socio-technical framework for digital transformation, keeping its citizens at the centre of this process. The efforts and investments towards this cause by the Government of Ghana is envisioned to position the country as a regional hub for digital services in the coming decades.

As Kaleidoscope 2022 Master of Ceremony, Alessia introduced all sessions and session chairs of the conference.

Keynote sessions

The first keynote session, moderated by Martin Adolph, Telecommunication Standardization Bureau, ITU featured Dr Pablo Pérez, Lead Scientist, eXtended Reality Lab, Nokia, Spain, who presented his keynote paper on *Exploring the realverse: Building, deploying, and managing QoE in XR communications* [presentation]. His paper is available on pg. xix of the Conference Proceedings. This was followed by the keynote speech of Dr Junseong Bang, ETRI, Republic of Korea, on *Metaverse interoperability with composability in hyper-connected and hyper-personalized virtual environments* [presentation]. His keynote summary is available on pg. xiii of the Conference Proceedings. This keynote session was moderated by Dr Ezer Osei Yeboah-Boateng, Deputy Director-General, NCA, Accra, Ghana.

Prof. Ian F. Akyildiz, (in the picture) Truva, USA, and Editor-in-Chief of the ITU Journal on Future and Evolving Technologies (ITU J-FET) delivered the third keynote speech which focused on *Metaverse: Challenges for Extended Reality and Holographic-Type Communication in the Next Decade* [presentation]. The keynote summary is available on pg. xiv of the Conference Proceedings.

Prof. Akyildiz's research work has been recently published in the ITU Journal: *Wireless communication research challenges for Extended Reality (XR)*, authored by Ian F. Akyildiz and Hongzhi Guo - Volume 3 (2022), Issue 2, Pages 273-287. This session was moderated by Mr Isaac Boateng, Deputy Director, Technical Regulations, NCA, Accra, Ghana.

On Day 3, the last keynote speech was delivered by Dr Darlington Akogo (in the picture), Founder, CEO, minoHealth AI Labs, karaAgro AI, Runmila AI Institute, Ghana, and focused on a clinical evaluation of deep learning systems for the diagnosis of pleural effusion and cardiomegaly in Ghana, Vietnam, and the United States. This session was moderated by Dr William Akotam Agangiba, Computer Science Department, UMAT. The keynote summary is available on pg. xvi of the Conference Proceedings.

Invited paper and invited special session

In addition to the four keynote speakers, the programme included one invited paper that presented a comprehensive survey of eXtended Reality (XR) standards, and an invited session organized by the Host Committee which featured a talk on the Metaverse and the future of education, highlighting frameworks, features, potential applications, challenges and opportunities.

The *survey of Extended Reality (XR) standards* [presentation] that can be found on pg. xxxi of the
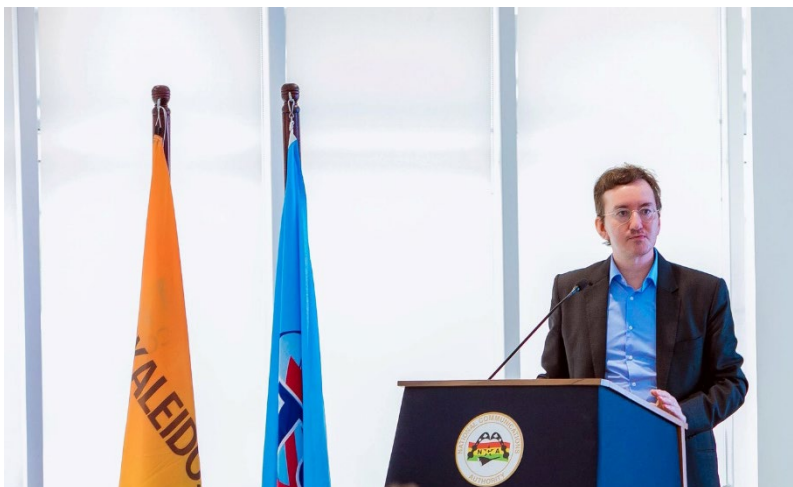
Conference Proceedings, is authored by Gillian Makamara and Martin Adolph, TSB, ITU.

Martin (in the picture), presented the survey at the conference and the session was moderated by Dr Kenneth Ashigbey, CEO, Ghana Chamber of Telecommunications.

The invited special session [presentation] was presented by Dr William Brown-Acquaye, Ghana Communication Technology University, and moderated by Dr Forgor Lempogo, Ghana Communication Technology University (both in the pictures below).

Paper sessions and winners

14 research papers from 10 countries were submitted for review, 9 of which were accepted for publication and presentation at the conference in 3 different sessions.

The academic papers submitted to this year's conference shared insight into ongoing projects and research on the development and widespread adoption of extended realities, focusing on how standards can help boost quality of experience and interoperability, and challenges for extended reality and holographic-type communication in the next decade.

The authors of the award-winning papers shared the prize fund of CHF 6 000.-.

FIRST best paper (ex aequo): "The knowledge graph as the interoperability foundation for an Augmented Reality application: The case at the Dutch Land Registry" presented by Alexandra Rowland and Erwin J.A. Folmer (University of Twente & Kadaster, The Netherlands), and co-authored with Tony Baving (Kadaster, The Netherlands) [presentation]

FIRST best paper (ex aequo): "Enhancing user experience in pedestrian navigation based on Augmented Reality and landmark recognition" presented by Dhananjay Kumar, and co-authored with Shreayaas Iyer, Easwar Raja and Ragul Kumar (Anna University, MIT Campus, Chennai, India), and Ved P. Kafle (National Institute of Information and Communications Technology, Japan) [presentation]

THIRD best paper: "A framework for the design, implementation and evaluation of a multi-variant Augmented Reality application" presented by Sophie Westfahl (University of Applied Sciences Neu-Ulm, Germany), and co-authored with Dany Meyer-Renner (University of Applied Sciences Neu-Ulm, Germany) and Antoine Bagula (University of the Western Cape, South Africa) - [presentation]

Alongside the winners of the best paper awards, 6 entrants received **Young Author Recognition Certificates** that are delivered to young authors of up to 30 years of age presenting accepted papers:

1. Zicheng Wang and Yetong Wang (Inspur Communications Technology Co., Ltd., China) – paper S1.2 *Towards computing and network convergence: QoE-oriented service anycast based on SRv6*;
2. Sophie Westfahl (University of Applied Sciences Neu-Ulm, Germany) - paper S2.1 *A framework for the design, implementation and evaluation of a multi-variant Augmented Reality application* (in the photo below)
3. Alexandra Rowland (University of Twente & Kadaster, The Netherlands) – paper S2.3 *The knowledge graph as the interoperability foundation for an Augmented Reality application: The case at the Dutch Land Registry* (in the photo below)
4. Xiangyu Qu (Zhejiang Dahua Technology Co. Ltd, China) – paper S3.2 *Research and standardization requirements for 5G network peak control technology in video transmission*

5. Mfundo A. Maneli (University of the Western Cape, South Africa) – paper S3.3 *A comparative analysis of Augmented Reality frameworks aimed at diverse computing applications*


The Conference Proceedings, which are freely available for download, contain the nine papers that were selected by the Technical Programme Committee on the basis of double-blind reviews, with the help of over 40 subject matter experts from leading academic and research institutions worldwide; the keynote paper, three keynote summaries, the invited paper and the extended abstract of the video demonstration track that were peer-reviewed by the Kaleidoscope 2022 Steering Committee. All presented papers, summaries and abstract will be also published in the IEEE *Xplore* Digital Library in January 2023.

Programme, presentations, and biographies are available online.

Relevant recommendations and conclusions from the paper sessions, as drafted and presented by the Session Chairs at the Wrap-up session, are available online in PDF format on the programme webpage. This session was chaired by Mostafa Hashem Sherif, Kaleidoscope Technical Programme Committee Chair.

The conference fostered stimulating discussions on topics of strategic importance to the ITU community and generated great interest and interaction among the audience, including many students who significantly contributed to the Q&A sessions.
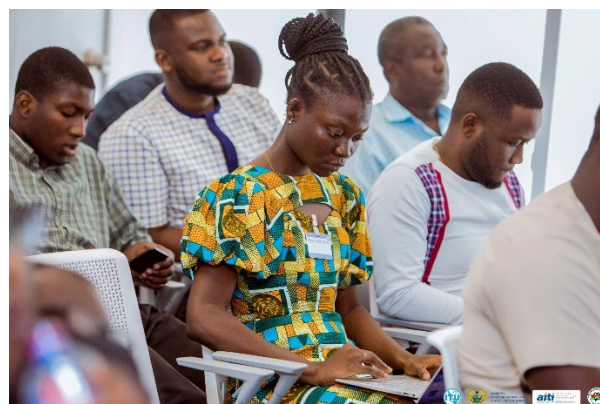
Relevance to the ITU work

The papers and keynotes accepted for presentation at the conference are related to various ITU activities, in particular to ITU-T SG9 - Broadband cable & TV, SG11 - Protocols, testing & combating counterfeiting, SG12 - Performance, QoS & QoE, SG13 - Future networks, SG16 - Multimedia & digital technologies, and SG20 - IoT, smart cities & communities; Focus Group on "Artificial Intelligence for Health" (FG-AI4H), and Correspondence Group on Metaverse.

As for every edition, Kaleidoscope papers are also related to the activities of the ITU Radiocommunication Sector. This year in particular they are related to the work of ITU-R SG4 - Satellite services, SG5 - Terrestrial services, and SG6 - Broadcasting service.

A mapping of papers and keynote summaries and ITU activities (i.e. Study Groups, Focus Groups, etc.), also highlighting relevant standardization work and ITU Recommendations, has been presented by Alessia, on behalf of TSB Director, at the meeting of the ITU Telecommunication Standardization Advisory Group (TSAG) that took place from 12 to 16 December 2022, and will be submitted also to the next ITU Radiocommunication Advisory Group (RAG) and the ITU Telecommunication Development Advisory Group (TDAG). Temporary documents providing information on selected papers will be also submitted to the various ITU Study Groups for consideration in their activities.

Video demonstration track

For the third time at Kaleidoscope, the Video demonstration track was included in the programme, and one video demonstration was selected by the Steering Committee for presentation at the conference. It provided an online demonstration on how to make extended reality safe and secure for teenagers. The author and presenter is Agasthya Gangavarapu, a young and talented student at the Eastlake High School, USA, also founder and researcher at Saefty4xr, a non-profit organization focusing on building safety layers and best practices for eXtended Reality (XR) devices and systems.

His extended abstract, peer-reviewed by the Steering Committee and published in the Proceedings, and his video are available online.
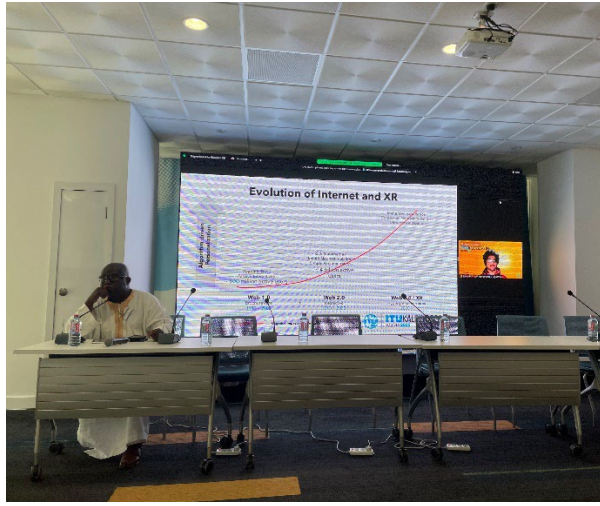
3.   Students' Exhibit

This year's programme included the Students' Exhibit that showcased studies on Cat Swarm Optimization with Lévy Flight (CSOLF) for Link Load Balancing in Software Defined Networks (SDN), Joint Vision-Position Aided Millimeter Wave Beam Prediction Using Vision Transformer (ViT), digital transformation in the African Region, the role of big data leading to a digital transformation, how giving users control in a digital era, and Ant Colony inspired approach to Decentralized Data Processing for Load Balancing in IoT.

Kwaku Akyeampong Amanin Kwarteng, Osman Mamudu, Patrick Tambol Nkpeek, Ebenezer Akutteh, Abraham Delalom Tomety, Michael Wilson, from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, and Ghana Communication Technology University, presented their research work at the conference in a three-minute pitch session to raise the audience's interest in their studies. Prof. Kester Quist-Aphetsi, Ghana Communication Technology University, moderated the pitching session and invited the participants to the exhibit that took place in an open space close to the conference room.

4.   Social activities

The Host kindly offered all coffee breaks and lunches during the three days of the conference, as well as a very nice cocktail and live music at the end of the first day.

At the end of the second day, NCA organized a tour for all participants to visit the New State-of-the-Art Broadcasting Monitoring Centre, as well as the Communications Monitoring Centre, the Common Platform and the Computer Emergency Response Centre.

5.   Next Kaleidoscope

Please stay tuned for news on the 15th edition of the ITU Kaleidoscope academic conferences here.