Standardization Steps for FAS in 6G Networks

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***Abstract*—The sixth generation (6G) of mobile communications systems has been the driving force behind many recent academic and industry-led research efforts. In this paper, it is shown that the timely evolution of technology can greatly benefit from standardization efforts that are currently lacking in the field of fluid antenna systems (FASs). It highlights the importance of standardization to promote this technology to help reach 6G targets and map the actions that we understand are paramount in this effort. Furthermore, the potential of FAS to improve the radio interface in 6G by improving the well-consolidated multiple-input multiple-output (MIMO) antenna technology and exploring synergies with emerging reconfigurable intelligent surface (RIS) technology is explored. This paper also summarizes the findings and encourages the academic community to work together to overcome the obstacles of standardization in order to achieve the successful implementation of FAS.**

***Index Terms*—FAS, MIMO, RIS, International Telecommunication Union (ITU), standards development organization (SDO).**

I. Introduction

The sixth generation (6G) of wireless communication systems aims to achieve ambitious performance indicators with the goal of meeting the growing demands of a connected society [1]. Motivated by academic and industry-led research efforts, an idea that has recently been spotted light in 6G research is the possibility of using a fluid antenna on mobile devices [2]. The rationale behind it is the notion that if an antenna can change shape, it can virtually adapt to any propagation condition that the communication system can possibly undergo. The fluid antenna has gained considerable attention after the recent works of Wong *et al.* [3], [4], who coined the concept of a fluid antenna system (FAS).[1]

In the literature, many works on FAS are shown [3]–[13]. Despite recent academic advances on FAS, international standards development organizations (SDOs) are yet to address the issue. A notable example of this is the lack of information on FAS in the *"Framework and overall objectives of the future development of IMT for 2030 and beyond"*, Recommendation ITU-R M.2160-0 [14]. It was approved in November 2023 by the International Telecommunication Union (ITU) in the 2023 Radio Assembly (RA-23), after a long period of efforts in the Working Party 5D (WP 5D) of ITU Radiocommunication Sector (ITU-R) [15]. Although FAS technology might still be considered embryonic, there is great momentum on the topic, which can motivate both academia and industry in the FAS community to collaborate with SDOs to make FAS a reality.

In this context, the aim of this paper is to show that the timely evolution of technology can greatly benefit from standardization efforts, which are currently lacking. Fragmentation in the development process of mobile communications technologies is a general concern, which is particularly uncomfortable in the case of FAS. Furthermore, achieving the goals established in the Recommendation ITU-R M.2160-0, both in terms of very challenging performance indicators and in the variety of defined use cases, can have a significant advantage from the use of standardized FAS solutions. Last but not least, an important objective of this paper is to encourage constructive dialogue on FAS standardization for 6G networks, with the ultimate goal of facilitating the adoption of this technology in a timely and efficient manner.

The remainder of the paper is organized as follows. Section II presents a brief overview of FAS works. Section III shows the importance of standardization to promote this technology to help achieve the 6G goals and maps the actions that are undoubtedly of paramount importance in this effort. Section IV concludes the discussion of the article.

II. A Brief Survey on FAS

The literature on FASs has grown rapidly in the last few years, so we briefly explain the main concepts and select some

[1]The information and views set forth in this article are those of the authors and do not necessarily reflect the official opinion of the institutions with which they are affiliated.

articles that, in the authors' vision, can provide a good grasp of the work being done on FASs and liquid materials.

The term "fluid antenna" was recently restated in [3] and the acronym FAS was coined in [4] to describe any fluid conductive structure controlled by software, a moving mechanical antenna structure, or even pixels with RF switches that can change shape and position to reconfigure gain, radiation pattern, operating frequency, and other characteristics.

The aim of FAS is to automatically switch the antenna position to one of the best N fixed locations, which are commonly referred to as "ports". For the case in which the fluid antenna is used to explore different user fading envelopes to achieve multiple access, it is called fluid antenna multiple access (FAMA) [5], [6].

Shojaeifard *et al.* [7] proposed the combination of multiple-input multiple-output (MIMO), surface-wave-aided reconfigurable intelligent surfaces (RIS), and FAMA. In this configuration, MIMO helps avoid obstacles, and RIS acts as a massive scatter and also as a surface waveguide. In the user-equipment (UE), FAMA resolves interference by exploring different fading envelopes between the desired and interfering signals. Interestingly, FAMA is entirely user-centric and requires no coordination between base station (BS), RIS, and UE.

An interesting survey on FAS was elaborated by Wong *et al.* [9] and also suggest research topics. In a series of three-part letters [10]–[12], Wong *et al.* reviewed the basic principles, discussed obstacles, and revealed research opportunities for fluid antennas. They also presented a new paradigm of RIS for massive connectivity and compiled references to recent studies on FAS.

Studies on liquid materials for fluid antennas are also on pace. The recent status of liquid antennas and a vision of its future are presented in [16]. Similarly, antennas incorporating gallium-based liquid metals are presented in [17] and liquid reconfigurable antenna arrays are presented in [18].

A complete tutorial [13] on FAS for 6G networks was recently published, which addresses virtually all previous works on FAS, going through communication theory, optimization methods, hardware design, other survey articles, and even has a section about standardization discussion.

III. Challenges for FAS Standardization

A. The Policy Maker Process

Standardization plays a crucial role in promoting and adopting any communication technology, and the same can be said for FAS. Considering the amount of work done so far on FAS, briefly presented in Section II, it is a good momentum to start discussion on FAS in international standardization organizations.

These are the main actors in the field of mobile communications systems standardization, in order of current prominence: ITU; Third Generation Partnership Project (3GPP); European Telecommunications Standards Institute (ETSI), International Organization for Standardization (ISO), and International Electrotechnical Commission (IEC); and Open Radio Access Networks (Open RAN) *fora*, such as O-RAN Alliance.

It is worth making an effort to describe the structure and main responsibilities of the ITU. Headquartered in Geneva, Switzerland, the ITU is the United Nations (UN) specialized agency for information and communication technologies (ICTs). The organization was established in 1865 and, originally, was named Telegraph Union. Its role has been changing ever since, reflecting the evolving challenges inherent in the technical and business transformations that the telecommunications sector underwent in this period. One of the characteristics that separates it from the other SDOs, which also play important roles in the standardization of mobile communications systems, is the preponderance of state actors in the work carried out, especially in the decisions taken within the ITU. In this sense, it is the most political SDO, prone to what has been dubbed techno-diplomacy [19].

The ITU structure comprises four divisions, namely:

- General Secretariat — This is the highest administrative and financial branch of the institution, led by a Secretary-General (SG), a Deputy Secretary-General (DSG), and closely assisted by the ITU Council, which is the governing body of the ITU between plenipotentiary conferences.
- ITU Radiocommunication Sector (ITU-R) — The ITU-R can be considered the most traditional branch of ITU since the very origins of the institution are attached to radiocommunication conferences. It is responsible for everything related to the use of the electromagnetic spectrum. It is led by the Director of the Radiocommunication Bureau (BR, in its acronym in French).
- ITU Telecommunication Standardization Sector (ITU-T) — This is the ITU branch responsible for the standards related to communications in a confined medium. Examples include optical communications, video coding/decoding, and, most recently, new ventures such as the metaverse and artificial intelligence (AI). It is headed by the Director of the ITU Telecommunication Standardization Bureau (TSB).
- ITU Telecommunication Development Sector (ITU-D) — The main task of the ITU-D is the promotion of cooperation among the Member States and Sector Members to ensure that everyone is on the same pace, bringing forward the ICT ecosystem as a whole worldwide. The regional presence of the ITU is also under ITU-D. It is led by the Director of the Telecommunication Development Bureau (BDT, in its acronym in French).

As of late, the ITU has been working in cycles of four years between its main conferences. The elections for the SG, the DSG, the directors of the bureau, the members of the ITU council, and the members of the Radio Regulations Board (RRB) take place in the Plenipotentiary Conference (PP), which is also responsible for amendments to the ITU constitution, besides the revision and institution of other general guidelines that are to be followed by the organism as a whole. The World Radiocommunication Conference (WRC) is conducted by ITU-R, the World Telecommunication Standardization Assembly (WTSA) by ITU-T, and the World Telecommunication Development Conference (WTDC) by ITU-D.

Standardization is a transversal undertaking in the ITU, and it is carried out in all three sectors, with different tasks assigned to each of its components. However, most of the work on International Mobile Telecommunications (IMT) in the ITU is accomplished within the ITU-R. Note that IMT is the umbrella under which mobile communications standards fall.

As we can see, roughly ITU-T plays a role in the promotion of Open RAN. At the same time, the ITU-D is tasked with the diffusion of best practices, such as the adoption of structured national spectrum management, equipment certification, and cyber-security enhancing routines, for instance.

Most of the work between conferences has been done in Study Groups (SGs). In ITU-R, IMT is mostly restricted to Study Group 5 — Terrestrial Services (SG 5), with limited issues, such as non-terrestrial networks (NTN), being conducted in Study Group 4 — Satellite Services (SG 4). Within SG 5, WP 5D is responsible for everything IMT-related, although consultations with other groups are constant.

In the context of the mobile communication systems standardization ecosystem, ITU has three core tasks, all of which fall within the responsibilities of WP 5D, namely:

- Spectrum allocation to the Mobile Service (MS), with the possibility of the identification of specific bands to the IMT application.
- Evaluation of candidate technologies to a given IMT standard.
- Definition of the expected characteristics of any given IMT generation.

The agenda for a given WRC is set at the previous conference. In the period between conferences, the SGs conduct studies in preparation for each of the agenda items. In the case of the allocation of bands to a radiocommunication service or to an application, technical studies are conducted, often employing simulations and detailed calculations, to evaluate whether incumbent services are negatively affected by the new competitor. The recent introduction of advanced antenna systems (AAS), which introduced massive MIMO and beamforming capabilities in IMT systems, has significantly affected the results of these studies.

Another impact worth mentioning has to do with the interpretation of the rules already established in the Radio Regulations (RR). It can be argued that the main job of the ITU as an institution is the maintenance and enforcement of the RR, which is a treatise and therefore legally binding to the member states. It is a detailed and thoroughly negotiated set of rules that ultimately aims to discourage conflict between neighboring countries by avoiding detrimental interference on the radio spectrum.

AAS is an example in which legacy commands from the RR may be challenged by the introduction of a novel technology. After all, a power limit designed to protect an incumbent service from the IMT might need to be reconsidered if beamforming and massive MIMO systems are employed.

It should be noted that the evaluation of candidate IMT technologies in WP 5D can also be harmed by the disregard of relevant technologies. The use cases and performance indicators defined in the Recommendation ITU-R M.2160-0 must be attested by inspection or simulation if a proposed technology is to be stamped as IMT-2030 complying Radio Interface Technology (RIT). In the hypothesis that an applicable technology, such as FAS, is neglected, the whole process can be damaged, and the proposed RIT may be rejected.

The first document prepared by the ITU (WP 5D) on 6G was a report detailing the future technology trends in International Mobile Telecommunications for 2030 and beyond (IMT-2030), which is the ITU denomination for 6G [20]. That report shows the relevance of advanced antenna technologies for IMT-2030. It includes, for example, MIMO, RIS and NOMA, but FAS was not mentioned in the report, which shows the lack of knowledge of the international standardization community about FAS technology.

B. The Academic Rally and Steps for FAS Standardization

As presented in Section II, academy has been doing a great effort to understand the behavior of FAS. Despite advances in research, SDOs have not integrated fluid antennas into their outlook [21], [22]. This presents an opportunity to highlight the importance of fluid antennas to meet the challenging requirements of 6G.

As suggested in [13], an interesting approach to introduce fluid antennas in 3GPP Release 20 is through RAN Working Groups in the study period from 2025 to 2027 focusing on UE with a FAS-equipped terminal rather than trying to implement FAS on BS. This approach will not only enhance the quality-of-experience (QoE) for users with sophisticated FAS handsets, but also improve overall network performance, especially utilizing the current BS infrastructure.

A recent report conducted by the IEEE Future Networks Technical Community [23] highlights that when a technology is considered to be "ahead of its time", it can be expedited through appropriate standardization. As FAS (or FAMA) is highly disruptive, it is not even on the radar of SDOs. In order to enhance visibility among SDOs, the concept of a fluid antenna can be explored as an individual subject or in conjunction with a more extensively researched technology such as RIS or MIMO. Therefore, it is an opportune time to rally the academic community in order to bring about the realization of FAS.

Considering the long road to take to standardize a given technology, the first step to boost FAS standardization is to include it as a study item on an SDO agenda. Countries have different processes to deal with standardization, but in the case of an international organization, such as the ITU, a member state or even sector members can consider the inclusion of new technologies during the standardization process. In the case of 6G, one of these opportunities was already lost with the publication of the Report ITU-R M.2516-0 in 2022. [20].

However, other opportunities will arise as the process advances. For example, FAS can still be presented for the evaluation of WP 5D as a constituent part of any of the IMT-2030 candidate technologies; nevertheless, that will only happen if institutions like the 3GPP, among others, take FAS into account in their own preparatory work. If that is the case, these institutions should ensure that member states and sector members start considering FAS while conducting studies for the identification of new bands for IMT in the related group within ITU's WP 5D to avoid future conflicts and delays [24].

Considering the technical aspects on FAS previously discussed, some insights are listed below to help policy makers address the FAS standardization process. First and foremost, FAS is not a spectrum demanding technology; in fact, is just the opposite, a FAS UE shares the same resource block (time slot and frequency band) with other UEs. This is a great contribution for spectrum efficiency, which is desired for any regulator.

Additionally, FAS has great synergy with other technologies, such as [13] artificial intelligence (AI), full-duplex (FD) communications, green communications, integrated sensing and communications (ISAC), next generation multiple access (NGMA), non-terrestrial networks (NTN), physical layer security (PLS), RIS, terahertz (THz) communications and extremely large-scale (XL)-MIMO or continuous aperture (CAP)-MIMO. This technology synergy is interesting because FAS standardization can take a "ride" with other technologies.

And last but not least, as mentioned previously, if FAS standardization starts from UE instead of BS, the implementation should be easier.

Of course, there may be some drawbacks; for example, the security of the liquid for the user, in the case of a fluid leakage, may be argued for the liquid-base antenna hardware implementation. However, these other issues can be properly addressed in the course of standardization processes.

IV. Conclusions

Although FAS technology is in the early stages, there is good momentum to start discussion on FAS in international standardization organizations, and it can be treated as a separate technology or in conjunction with other antenna technologies, such as MIMO, or new materials for telecommunications, such as RIS. To achieve this goal, the academic community should have an active role in standardization study groups. The primary objective of this paper has been to drive constructive and decisive conversations around the standardization of FAS for 6G networks. Our ultimate goal is to ensure the efficient and timely adoption of this technology.

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