TOWARD THE "SPACE 2.0" ERA

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The word "satellite" has historically meant global radio coverage, long-distance inter-continental telephony, global TV broadcast, precise localization available in the sky and across the oceans. This was consequential to the early studies about geo-stationary orbits carried out since the visionary paper of A.C. Clarke published in "Wireless World" in 1945 [1].

The fact that Dr. Clarke has been appreciated worldwide as science fiction writer clearly indicates that the research on satellite communications has been characterized, at least during the early decades, by a strongly visionary attitude. With the passage of time, satellites consolidated their role as "long-distance" communications enablers. However, 70 years after Clarke's article, the role of the satellite has apparently been fixed by the title of that visionary document: "extra-terrestrial relay". Indeed, the most remunerative applications of satellite communications have so far been digital TV broadcasting (standard DVB-S), where the satellite is simply a relay node, and radio localization (GPS, GNSS), where satellites work as "radio-beacons". Just coincidentally with the mass-market explosion of modern Information and Communications Technology (ICT) services during the 1990s, the role of satellites has become marginal and ancillary. The change of philosophy in wireless networking design during the 1980s privileged the local "cellular" connectivity rather than the global interconnection. For almost 25 years now, cellular networks have demonstrated their superior capabilities of supporting mobile connectivity in the presence of high user density. Satellite networks, in the old vision of "extra-terrestrial relays," are no longer competitive. Geostationary (GEO) satellites can provide global coverage, but very long propagation path and high delays and latencies severely limit the link efficiency. On the other hand, Low-Earth-Orbit (LEO) satellites are more suitable to support bidirectional networking, but their coverage area is relatively small. Considering this panorama, a question duly arises: "Apart from the well-consolidated DVB-S and GPS/GNSS market niches, is there still room for space communications in the future ICT market?"

Considering the weaknesses of the existing terrestrial networking technologies, the answer is affirmative. The distribution of cellular networks is not everywhere uniform. In a big European country like Italy, Long Term Evolution (LTE) is available over less than 30 percent of the territory. On the other hand, the recent data published by the FTTH Council Europe evidenced a great difficulty of fiber penetration in the EU countries. Only nine of the 21 nations individually analyzed should achieve "FTTH maturity" (20 percent penetration) by 2016 [2]. Another critical weakness of terrestrial networking is the vulnerability with respect to natural disasters and terrorist attacks, clearly evidenced by the dramatic connectivity disruptions encountered during the aftermath of September 11th and the Katrina floods [3].

The potential of space networking is enormous in terms of broadband, low-cost ubiquitous coverage and disaster resilience. From a merely theoretical viewpoint, satellite link capacity is clearly superior to the terrestrial capacity. From a more practical viewpoint, the monetary costs and the environmental impact of satellite connections are greatly lower than those of the corresponding terrestrial connections.

In order to fully exploit such potential, a radical change of the current vision of space networking is required. Nowadays, space networks are regarded as information broadcasters and/or coverage enhancers. In order to promote a relaunch of space technology for ICT, a complete redefinition of the role and paradigms of space communications and networking should be conceived in the perspective of Future Internet. As stated in [4], Future Internet must be globally "anywhere-anytime," must be capable of assisting society in emergencies, and must be trustworthy. Terrestrial cellular communications cannot effectively fulfil these basic requirements due to their intrinsic "local" nature. For this reason, Future Internet can be thought of as a "building" supported by two basic pillars: the "local" pillar made by terrestrial networking, and the "global" pillar made by space networking. This target is very ambitious: in such a futuristic vision, the space segment would become the main actor in the provision of the global ubiquitous connectivity, instead of a merely ancillary infrastructure broadcasting information and/or patching coverage holes. In some sense, we can highlight this expected revolution with the term "Space 2.0," which marks a clear discontinuity with the "Space 1.0" era, begun in 1945 with A.C. Clarke's article.

The potential outcomes are very attractive, but the potential risks are also very high. Indeed, space communications and networking will have to rethink themselves in terms of augmented interactivity, dynamic and context-aware reconfigurability, resilience, and disaster immunity. The Feature Topic, "Satellite Communications and Networking: Emerging Techniques and New Applications," the first part of which is

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published in the current issue of *IEEE Communications Magazine*, is intended to show the current status of satellite communications and networking technologies with a look at the change of perspective that will characterize the coming decades.

The first article, "Waveform Design Solutions for EHF Broadband Satellite Communications," by M. De Sanctis, E. Cianca, T. Rossi, C. Sacchi, L. Mucchi and R. Prasad, illustrates basic design criteria and advanced practical solutions for waveform generation in broadband satellite communications operating in the millimeter wave bandwidths, i.e. Extremely High Frequencies (EHF).

The second article, "Cognitive Spectrum Utilization in Ka-band Multibeam Satellite Communications," by S. Maleki, S. Chatzinotas, B. Evans, K. Liolis, J. Grotz, A. Vanelli-Coralli, and N. Chuberre, deals with the application of advanced cognitive concepts, already in use in terrestrial wireless communications, to multi-beam satellite systems operating in the Ka-band.

The third article, "IP Mobile Multicast over Next Generation Satellite Networks," by E. Jaff, P. Pillai, and Y.F. Hu, proposes a novel PMIPv6-based solution for global satellite-based IP multi-cast receiver mobility.

The fourth article, "Contact Graph Routing in DTN Space Networks: Overview, Enhancements and Performance," by I. Bisio, G. Araniti, N. Bezirgiannidis, E. Birrane, S. Burleigh, C. Caini, M. Feldmann, M. Marchese, J. Segui, and K. Suzuki, discusses the application of Contact Graph Routing (CGR) in different Space Delay Tolerant Networks (DTNs).

The fifth article, "Integration of Satellite and LTE for Disaster Recovery," by M. Klapez, M. Casoni, C. A. Grazia, N. Patriciello, A. Amditis, and E. Sdongos, considers a very significant topic from a societal viewpoint: the efficient and resilient integration of satellite and terrestrial 4G networking to support emergency communications in the aftermath of natural and/or man-made disasters.

The last article, "Software Defined Networking and Virtualization for Broadband Satellite Networks," by S. Medjiah, L. Bertaux, P. Berthou, S. Abdellatif, A. Hakiri, P. Gelard, F. Planchou, and M. Bruyère, analyzes the potential advantages that satellite networking could take from SDN and network virtualization in four different technically-relevant user cases.

Approaching the 70th anniversary of A. C. Clarke's article, we think the papers published in our Feature Topic can contribute to innovate concepts and methodologies of space communications and networking in a renewed perspective where "Sky" will become the true "global" infrastructure available to connect all of humanity.

REFERENCES

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[4] Integral SatCom Initiative (ISI): Future Internet Position Paper — Jan. 2009, http available at: www.isi-initiative.org.

BIOGRAPHIES

CLAUDIO SACCHI was born in Genoa (Italy) in 1965. He obtained the "Laurea" degree in electronic engineering and the Ph.D. in space science and engineering at the University of Genoa (Italy) in 1992 and 2003, respectively. Since August 2002 Dr. Sacchi has held a permanent position as assistant professor on the Faculty of Engineering at the University of Trento. He is currently affiliated with the Department of Information Engineering and Computer Science at the University of Trento. He is the author and co-author of more than 80 contributions published in international journals, edited books, international conferences, etc. Dr. Sacchi is Senior Member of the IEEE.

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