

APEX STANDARDS

Landscape Fundamental Research in Telecommunications

Fundamental research and early stage ideas are commonly documented in peer-reviewed academic journals. Following our previous analyses of technological reliance using patent data, and standardization give-and-takes using 3GPP TDoc data [1][2][3][4][5], we investigate patterns of scientific publications and relations in the telecommunications industry in this report. We focus on the most important journal series, including:

- IEEE Trans. on Information Theory
- IEEE Trans. on Wireless Communications
- IEEE Trans. on Communications
- IEEE Trans. on Microwave Theory & Tech.
- IEEE Trans. on Vehicular Technology
- IEEE Trans. on Circ. and Sys. for Video Tech.
- IEEE Trans. on Signal Processing
- IEEE Trans. on Antennas and Propagation
- IEEE Communications Letters.

The selection is based on the fact that, when a scientific paper is cited, the majority of telecom patents (81%) and 3GPP TDoc documents (76%) can be traced back to papers from these IEEE transactions. Other relevant journals, such as ACM and OSA, are not considered. Strategic, priority publication on arXiv is analyzed in [8] and also excluded.

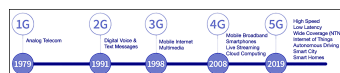


Figure 1: The evolution from 1G to 5G.

Fig 2-5 illustrate how leading corporations and nationally funded research institutes publish in these mainstream journals.

Although many factors influence how scientists publish such as language differences and profitability alignments, innovation counterfactuals from such R&D output warrant further examination from the national level [6]. Compared to the engineering advancements introduced by 3G and 4G, the New Radio fundamentally redesigned in 5G enables the transmission of ever-increasing amounts of digital data at an ever-quicker rate. In future generations, the relevance of fundamental research underlying inventions, patents, and standardization tactics will only expand [11]. Governments and business leaders should consider these publication dynamics when developing innovation policies and allocating R&D expenditures. ■

Replication Data. Email support@apexstandards.com for access of data analyzed in this report.

Data Limitation. Publication and citation strategies vary. At the firm level, a protective culture influences how works are communicated publicly, i.e., while certain firms use publication in a top journal as a key performance indicator (KPI), others prefer to keep knowledge in-house as trade secrets, or be disclosed through other means, such as patents or copyrights. Colleagues citing one another in an effort to enhance their respective citation totals is one of the elements affecting the citation accuracy. Moreover, incremental work often necessitates a greater number of earlier dependencies and, thus, citations, whereas fundamental or groundbreaking work necessitates fewer. Despite restrictions, the data provide a quantitative evaluation of the shifting impacts of governments' and industry' emphasis over telecom innovation.

References

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- [6] A/S Tech R. N4000174: "Brain Drain and Calibration of Talent Search Criteria: Tracking Patentees Career & 3GPP Deleg. Changes," classified.
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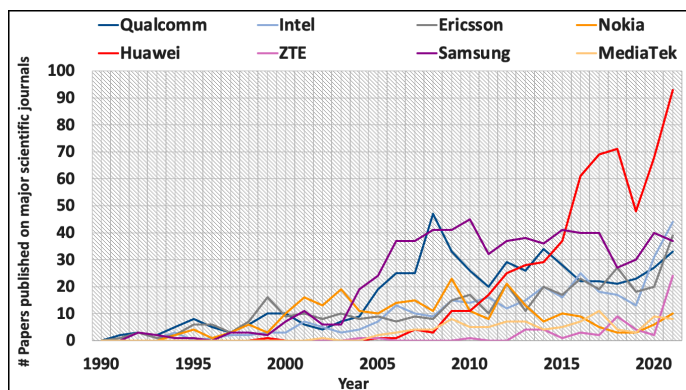


Figure 2: The leading publishing corporations by year. We notice a consistent upward trend since 1990, with Qualcomm (US), Ericsson (Sweden), and Nokia (Finland) among the leaders. Intel (US) and Samsung (South Korea) began to catch up in the late 1990s; both maintain an upward trend, with Samsung experiencing a considerable increase in paper counts after 2005. Over time, MediaTek (Taiwan) maintains a single-digit paper count. After 2010, ZTE (CN) began to regularly publish, and has published more recently. Huawei (CN) started to publish earlier than ZTE in 2005, and has since published in IEEE's critical telecom series, as soon as establishing the firm's largest R&D Center of North America in Ottawa, Canada, and luring top talents away from Nortel's headquarters [7].

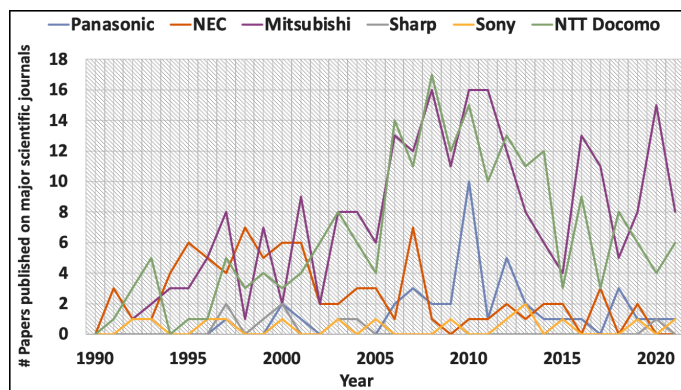


Figure 3: Japan has the most multinational conglomerates and once dominated the global electronics supply chain in terms of innovation and quality, particularly during the 1970s and 1980s. Mitsubishi has the greatest paper counts on the top IEEE communications journals, followed by NTT Docomo, the nation's largest service provider. From 1990 to 2010, NEC accumulated the most papers. Panasonic, on the other hand, published little until 2005, when it began to catch up. Sony and Sharp publish infrequently on IEEE. This can be attributed to the Japanese publishing culture, where top science enjoys the same, if not greater, prestige while published in domestic, native language journals.

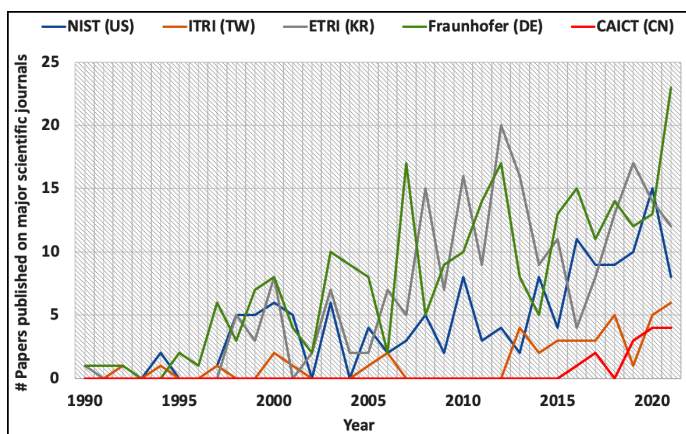


Figure 3: Top publishing government agency and nationally funded research institutes. Starting in 1990s, NIST (US) constantly publish and averages ten papers per year over the last decade. Fraunhofer (Germany) consistently tops paper counts, and in 2021 published the most (26). Taiwan's ITRI publishes regularly as a supply of human capital for the world's key ICT suppliers. ETRI publishes most aggressively in Asia since the late 1990s, when Samsung and LG became conglomerates and entered the telecom industry, followed by the nation's policy support.

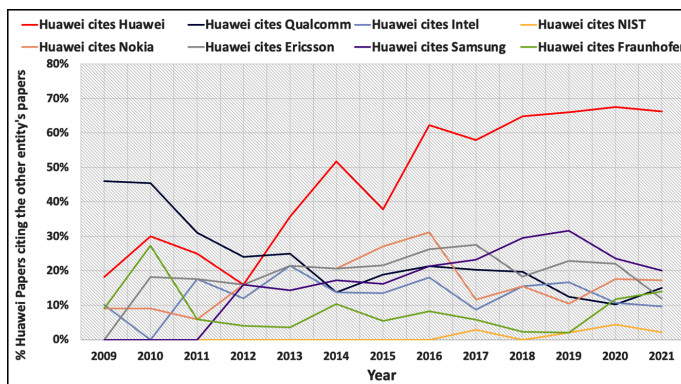


Figure 5: Huawei keeps expanding self-reliance. In 2009, 47% of top IEEE telecom papers written by Huawei scientists referenced one or more Qualcomm's publications. That number has dropped since then. Starting in 2012, Huawei-authored IEEE papers acknowledge less than 30% use of external science from any single entity; on average, Huawei publications rely less than 20% on major western telecom firms. In 2016, 30% of Huawei papers cited Nokia's work, however this proportion has reduced to 18% in 2021. In the previous decade, Samsung's papers have received the most Huawei citations, with a peak in 2019 (31%), followed by a recent decline to 20% in 2021. In contrast, Huawei's self-cites, on the other hand, continues to grow; since 2016, over 60% of Huawei papers reference its own work. Huawei, one of the most iconic firms in China, appears to be at the vanguard of achieving the nation's grasp on homegrown science from its very source, onto technological dominance, self-reliance and self-sufficiency ambitions.