Analysis of International Situation on Rateless Codes Based on Big Data

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Abstract. As one of the key technologies of the new generation of high mobile wireless communication, rateless codes have drawn attention of countries all over the world. From the patents, we investigated the development trend, the patent source and distribution, main organizations, research hotspots and core patents by using analysis tools including the PatSnap database, Innography and the Insights. The results show that the quantities of patent applications has generally increased since 2006. China, American and Korea ranked the top 3 of the number of patents. Top three organizations for patents applications were Qualcomm Incorporated, Thomson Licensing and Huawei Technologies Co., Ltd. The research hotspots mainly focus on arrangements for detecting or preventing errors in the information received (H04L1) and coding, decoding or code conversion, for error detection or error correction et al. (H03M13).

1. INTRODUCTION
Rateless codes were first proposed by Byers et al. to solve the problem of rate modulation in high mobile wireless communication in 1998. In 2002, Luby proposed LT codes, which are the first realization of a class of erasure codes that we call universal erasure codes [1]. With the help of the design of good degree distribution and low-density coefficient generator-matrix, the decoding complexity is greatly reduced. Then Shokrollahi proposed Raptor code in 2006. Based on LT codes, the linear complexity decoding was realized by precoding. In recent years, Yang et al. concatenated LT code and network code, and proposed Batched Sparse (BATS) code in 2014. Cassuto et al. proposed Online Fountain Codes (OFC) in 2015 [2]. The most suitable application scenario of rateless codes is broadcast communication. Raptor code and its improved scheme are widely used in various broadcast wireless communication protocols [3]. In addition, rateless codes have frequently been suggested as a building block for distributed storage systems [4].

In this paper, we investigated the development trend, the patent source and distribution, main organizations, research hotspots and core patents by using analysis tools including the PatSnap database, Innography and the Insights, in order to provide valuable technical information for the development of rateless codes technology in China.

2. DATA SOURCES
In this study, we select the PatSnap database as the source used to retrieve patent information. PatSnap database covers patents of 116 countries/regions, 130 million patents and 170 million chemical structures, which are updated weekly.

997 patents on rateless codes are included in the PatSnap database as of Mar 12th, 2021.
997 global patent applications for rateless codes, there are 994 invention patents and 3 utility models. There are 365 patent applications in China, accounting for 36.61%, and 632 foreign patent applications, accounting for 63.39%.

3. PATENT BIBLIOMETRICS ANALYSIS

3.1. Patent Application Trend
By analyzing the trend of patent applications for rateless codes, we can understand the development trend of the technology in this field as a whole.

As shown in Figure 1, the quantities of patent applications have generally increased since 2006. The quantities of patent applications increased rapidly after 2012, which indicates it has entered into a period of rapid development. In 2014, the number has reached its peak of 112 pieces. Then the number declined slightly in 2015, but it is still at a high level and maintains a steady growth trend. It should be noted that the quantities of patent applications began to reduce after 2017. (Due to the time lag from application to publication, the patent applications in 2020 did not represent the final trend, just for reference)

3.2. Patent Technology Life cycle
Numerous studies show that patented technology generally follows the four phases of the technological life cycle theoretically, that is, the period of germination, development, maturity and recession[5]. The number of patent applications and patent applicants changing over time is used to help analyze the stage of the life cycle of the current technology field.

As shown in the Figure 2, the technology life cycle curve of rateless codes moves along the abscissa and ordinate from early to 2014, indicating that it is in the technology germination period and technology development period. From 2015 to 2019, the curve moves slowly and negatively along the
abscissa, while the ordinate remains stable, indicating that the technology is in the Technology maturity period.

3.3. Patent Application Distribution by Country/Region

3.3.1. Ranking by Source Country/Region

The top 10 source countries/regions of rateless codes patent applications are shown in TABLE 1. Geographically, the applications for rateless codes are mainly in China and the United States. The patent applications of the two countries account for 69.41% of the global patent applications.

| Current Assignee Region | No. of Patents |
|-------------------------|----------------|
| China                   | 373            |
| United States           | 319            |
| Korea                   | 71             |
| France                  | 64             |
| Japan                   | 28             |
| Germany                 | 19             |
| Canada                  | 16             |
| Finland                 | 9              |
| Sweden                  | 9              |
| India                   | 7              |

3.3.2. Ranking by Target Country/Region

TABLE 2 shows the top 10 target countries/regions for patent applications. From the table, the target countries/regions in the field of rateless codes are mainly concentrated in China and the United States, followed by Korea, European Patent Office and Japan, with the largest number of patents accepted by China reaching 365, accounting for 40.38% (93 PCT applications are not counted). The results show that China has not only strengthened its technological research and development in this field, but also become the most important target country in technology layout in the world.

| Authority                | No. of Patents |
|--------------------------|----------------|
| China                    | 365            |
| United States            | 218            |
| Korea                    | 81             |
| EPO                      | 73             |
| Japan                    | 55             |
| China Hong Kong          | 13             |
| Germany                  | 12             |
| Canada                   | 11             |
| India                    | 10             |
| Russia                   | 10             |
3.4. Analysis of Applicants

3.4.1. Main Applicants

TABLE 3 shows the top 10 applicants with the largest patent portfolios in the technology field. They are the largest players and the competitive threats in the technology space.

Qualcomm is the organization with the largest number of patent applications in this technology field, and the number of their applications is significantly ahead of other applicants. Among the top 10 applicants, there are 7 foreign institutions, all of which are enterprises, while only one of the 3 domestic organizations is enterprise, and the others are universities. The study in China is concentrated in universities and research institutes. To some extent, it shows that Chinese universities and research institutes have strong R&D capabilities and can provide better technical support for enterprises.

TABLE 3. The top 10 applicants of rateless codes patent application

| Current Assignee                  | No. of Patents |
|----------------------------------|----------------|
| Qualcomm Inc                     | 75             |
| Thomson Licensing                | 62             |
| Intel Corp                       | 54             |
| Huawei Tech Co Ltd               | 43             |
| Samsung Electronics Co Ltd       | 30             |
| Zhejiang Univ                    | 24             |
| Beijing Inst Of Tech             | 21             |
| Digital Powerradio, LLC          | 20             |
| Aware, Inc.                      | 18             |
| Postech Academy-industry Foundation | 18         |

3.4.2. New Entrant

Applicants who have filed patent applications for the first time in the past five years are defined as new entrants in this field, which can reflect the potential new competition in this field. Alternatively, they can be considered as potential acquisition or partnership opportunities. This section analyzes the new entrants of rateless codes patent applications, and the results are shown in Figure 3.

Fig. 3. The top 10 new entrants of rateless codes patent application

Among the top 10 new entrants, 5 Chinese applicants are all universities, while the other 5 foreign applicants are all enterprises. It shows that universities and research institutions are still the main innovative entities in the field of rateless codes in China.
3.5. Patent Technology Field

3.5.1. Research Hotspots

Through the statistical analysis of IPC classification number of rateless codes patents, the proportion of main technology branches in this technology field is obtained, which helps to grasp the research hotspots in this field. TABLE 4 shows the top 5 IPC with the largest patent portfolios in the technology field.

**TABLE 4. The top 5 IPC of rateless codes patent**

| IPC Group  | Code explanation | No. of Patents |
|------------|------------------|----------------|
| H04L1      | Arrangements for detecting or preventing errors in the information received | 576 |
| H03M13     | Coding, decoding or code conversion, for error detection or error correction; Coding theory basic assumptions; Coding bounds; Error probability evaluation methods; Channel models; Simulation or testing of codes | 293 |
| H04L12     | Data switching networks | 108 |
| H04L27     | Modulated-carrier systems | 106 |
| H04L29     | Arrangements, apparatus, circuits or systems, not covered by a single one of groups H04L 1/00-H04L 27/00 | 92 |

3.5.2. Technical Direction of the Main Applicants

We can pinpoint the major players in the technology space by understanding the top assignees within different key technology areas. This helps us locate potential partners for licensing, potential threats of litigation, and targets for invalidation. This section makes a statistical analysis on the technical subject of the main applicants, and the results are shown in TABLE 5.

**TABLE 5. The technical direction of the main applicants for rateless codes**

| Assignee/IPC Group          | H04L1 | H03M13 | H04L12 | H04L27 | H04L29 |
|-----------------------------|-------|--------|--------|--------|--------|
| Qualcomm Inc.               | 57    | 49     | 0      | 8      | 4      |
| Thomson Licensing           | 37    | 15     | 3      | 3      | 1      |
| Apple Inc.                  | 13    | 0      | 11     | 12     | 13     |
| Samsung Electronics Co., Ltd.| 14    | 28     | 0      | 2      | 0      |
| Huawei Technologies Co., Ltd.| 27    | 4      | 3      | 0      | 3      |
| Intel Corporation           | 7     | 0      | 8      | 6      | 10     |
| Daphimo                     | 10    | 0      | 10     | 10     | 0      |
| Ln2 Db, LLC                 | 10    | 11     | 0      | 8      | 0      |
| Intellectual Ventures II LLC| 9     | 0      | 9      | 9      | 0      |
| Beijing Institute Of Technology| 20   | 3      | 2      | 0      | 2      |

As the applicants with the largest number of patent applications, Qualcomm’s patent applications are mainly distributed in H04L1 and H03M13. Thomson Licensing’s patent applications are mainly related to H04L1 topics, and are also involved in the top five technical topics. Apple’s patent applications are evenly distributed among all technical topics, but none of them involve H03M13, while Samsung’s patent applications focus on H03M13. The patent applications of Huawei and Beijing University of technology focus on H04L1 technology.

3.6. Core Patents

The importance of patent is determined by the date of application of patent, patents family, the legal
status, the frequency of patent being cited, the identification of important technologies by experts and technicians in the industry, and is affected by the market development and the evolution of technical standards. By analyzing the cited times of patents in the field of rateless codes, we can identify the patents that have been widely used and referenced. These patents are more influential and represent the core innovation technology in this field to a certain extent.

As shown in TABLE 6, the U.S. patent US71649B2 applied by Qualcomm in 2001 has been cited the most, up to 255 times. This patent involves adaptive rate control technology for wireless communication systems. The patent US7702986B2 is also from Qualcomm, involving the method and apparatus for generating codewords with variable length and redundancy from a single Low-Density Parity-Check (LDPC) code with variable length input words. These patents show that not only does Qualcomm have the largest number of patent applications in this field, but its patent value and influence are also at the world leading level.

| Patents            | Cited by Count | Current Assignee               |
|--------------------|----------------|--------------------------------|
| US7164649B2        | 255            | Qualcomm Inc                  |
| US6567473B1        | 174            | Intellectual Ventures II       |
| US6498808B1        | 124            | Intellectual Ventures II       |
| US7702986B2        | 109            | Qualcomm Inc                  |
| US6667991B1        | 94             | Intellectual Ventures II       |
| CN103414540A       | 45             | Nanjing Univ Of Posts & Telecomm |
| US20100094970A1    | 45             | Patentvc                       |
| US20070133691A1    | 41             | Ntt Docomo Inc                 |
| US20080232357A1    | 40             | Legend Silicon                 |
| WO2007109216A1     | 36             | Kyocera Corporation            |

4. CONCLUSION
Through patent analysis of rateless codes, several conclusions are as follows:

In the field of rateless codes, the technology mainly comes from China and the United States, and the patent applications of the two countries account for 69.41% of the global patent applications. Patents are mainly distributed in China, the United States, Korea, the European Patent Office and Japan. Top three organizations for global patents applications were Qualcomm Incorporated, Thomson Licensing and Huawei Technologies Co., Ltd. The research hotspots in this field are arrangements for detecting or preventing errors in the information received (H04L1) and coding, decoding or code conversion, for error detection or error correction et al. (H03M13). The number of patent citations of foreign applicants is generally higher. Although the number of patent applications in this field in China has increased significantly, the patent quality needs to be further improved.

The patents of rateless codes in China is mainly in the hands of universities and institutes, it is suggested to strengthen the combination of research and development to realize the industrialization. In the process of technology research and development, scientific research activities should be carried out in accordance with market demand; before patent application, the market prospect of scientific research achievements should be estimated through analysis, and the possibility of authorization and successful transformation after application is judged; after the enterprise has the intention to transfer or license, it is recommended to highlight the technical advantages through the patent technology and market analysis, which increases the opportunities for the successful license or transfer of patents.

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