Quantum Cryptography Inventive Energy

JULY 2018

QUANTUM CRYPTOGRAPHY INVENTIVE ENERGY 2018

INTERNATIONAL PATENT CLASSES (IPC): QUANTUM CRYPTOGRAPHY

IPC Domain	Description
B82Y10/00	Nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic
G06N99/002	Quantum computers, i.e. information processing by using quantum superposition, coherence, decoherence, entanglement, nonlocality, teleportation
H04B10/70	Photonic quantum communication
H04L9/0858	Details about key distillation or coding, e.g. reconciliation, error correction, privacy amplification, polarisation coding or phase coding
H04L9/0822	Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) using key encryption key
H04L9/08	Arrangements for secret or secure communication; Key distribution
H04L9/0836	Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) involving central third party, e.g. key distribution center [KDC] or trusted third party [TTP] involving conference or group key using tree structure or hierarchical structure
H04L9/0852	Quantum cryptography
H04L29/06	Arrangements, apparatus, circuits or systems, not covered by a single one of groups; characterised by a protocol
H04L63/064	Hierarchical key distribution, e.g. by multi-tier trusted parties

Quantum cryptography is a technique to ensure the confidentiality of information transmitted between two parties. The best-known example of quantum cryptography is quantum key distribution which offers an information-theoretically secure solution to the key exchange problem. The quantum key distribution guarantees long-term secrecy of confidential data transmission and the key obtained from quantum key distribution cannot be copied. Quantum cryptography recently made headlines when European Union members announced their intention to invest $13 million in the research and development of a secure communications system based on Quantum cryptography. The system, known as SECOQC (Secure Communication based on Quantum Cryptography), will serve as a strategic defense against the Echelon intelligence gathering system used by many countries.

We identified following top 10 International Patent Classification (IPC) in the Quantum cryptography domain through the study of key patents. The overall number of Applications published in the United States Patent and Trademark Office (USPTO) and Patents granted by USPTO are given in the table below (from the year 2010 till 2017. These are total numbers granted and published by the world at large at USPTO in that specific year.

S.No	IPC Domain	Year							
1	B82Y10/00	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	24	37	16	3	0	1	43
	Granted	1	1	1	6	22	392	960	1383
2	G06N99/002	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1
3	H04B10/70	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	12	14	25	28
	Granted	1	1	1	1	3	18	49	72
4	H04L9/0858	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1
5	H04L9/0822	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1
6	H04L9/08	2010	2011	2012	2013	2014	2015	2016	2017
	Application	309	182	128	250	401	610	687	1034
	Granted	1	1	1082	1	1	1556	1380	3142
7	H04L9/0836	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1
8	H04L9/0852	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1
9	H04L29/06	2010	2011	2012	2013	2014	2015	2016	2017
	Application	446	341	225	2419	5386	8850	10856	11511
	Granted	10739	11422	12934	15095	17629	24343	34965	47301
10	H04L63/064	2010	2011	2012	2013	2014	2015	2016	2017
	Application	1	1	1	1	1	1	1	1
	Granted	1	1	1	1	1	1	1	1

STATE OF ART OF ANY TECHNOLOGY USING CRAFITTI's INVENTIVE ENERGY

Inventive Energy (IE) is a yearly metric of the trend of last five years of invention activity in the specific technological domain such as the QUANTUM CRYPTOGRAPHY calculated based on a number of patent applications published and a number of patents granted in the respective technological domain. **Inventive energy is a composite metric of two indices – Patent Intensity Index and Patent Activity Index.**

CRAFITTI's **INVENTIVE ENERGY** measures the pace and intensity of **inventive activity** in a particular technological field. Inventive Energy provides a true picture of the state of the art of technology as it is a **composite metric** of Patents Granted and Patent Applications published in specific technology domains annually for a period of five years.

Inventive Energy *in specific technology domains can be utilized by existing technology players, start-ups, new players, investors, VCs, Research and Development teams and technology and Product Strategy Teams to design more informed future.*

Patent Intensity Index of a year is measured in terms of the yearly average of a number of total patents granted and patent applications published in last 5 years. *As an analogy, the Patent Intensity Index is denoted as the Mass which is reflected as a number of Patents and Applications granted and published respectively in the preceding 5 years.*

Patent Activity Index is measured in terms of the yearly average of *relative* pace of patent applications and granted patents in the IPC domain. *As an analogy, the Patent Activity Index denotes the Velocity or relative pace of Patents and Applications, granted and published respectively in the preceding 5 years, with higher weightage assigned to recent years.*

For any year, the two indices include a measure of yearly averages of last five years of a number of applications published and patents granted. For example, for 2017, these indices use data from years 2013-2017.

Patent Activity Index of top 10 QUANTUM CRYPTOGRAPHY IPC classes for years 2014-2017

A value of **Patent Activity Index** *is less than 1.0 indicates that relative average number of applications filing is reducing compared to a number of patents being granted.* **The index also gives a red, amber and green signal.** Red indicates the value of the index is less than 1.0. **Amber** indicates it is between 1.0 and 2.0 and green indicates it is above 2.0, i.e., *the number of applications being published every year on an average is more than 2 times the number of patents being granted on an average*. A higher value of patent activity index is an indication of more recent inventive activity in the domain or the specific IPC class. In turn, a higher activity index will signify a higher Inventive Energy. *Activity Index is analogous to*

the velocity of the particle. The PAI (Patent Activity Index) of top 10 Quantum cryptography IPCs for years 2014-2017 are given below.

IPC Domain	Description	BM-PAI 2014	BM-PAI 2015	BM-PAI 2016	BM-PAI 2017
B82Y10/00	Nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic	8.76	6.57	3.55	0.26
G06N99/002	Quantum computers, i.e. information processing by using quantum superposition, coherence, decoherence, entanglement, nonlocality, teleportation	1.00	1.00	1.00	1.00
H04B10/70	Photonic quantum communication	2.31	1.56	1.17	0.92
H04L9/0858	Details about key distillation or coding, e.g. reconciliation, error correction, privacy amplification, polarisation coding or phase coding	1.00	1.00	1.00	1.00
H04L9/0822	Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) using key encryption key	1.00	1.00	1.00	1.00
H04L9/08	Arrangements for secret or secure communication; Key distribution	277.37	140.43	86.23	66.11
H04L9/0836	Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) involving central third party, e.g. key distribution center [KDC] or trusted third party [TTP] involving conference or group key using tree structure or hierarchical structure	1.00	1.00	1.00	1.00
H04L9/0852	Quantum cryptography	1.00	1.00	1.00	1.00
H04L29/06	Arrangements, apparatus, circuits or systems, not covered by a single one of groups; characterised by a protocol	0.18	0.25	0.28	0.28
H04L63/064	Hierarchical key distribution, e.g. by multi-tier trusted parties	1.00	1.00	1.00	1.00

*BM-PAI – *Bhushan Mishra Patent Activity Index* – named after its creators

As can be seen in the above table, the PAI for IPC classes H04L9/08 Arrangements for secret or secure communication; Key distribution is above 2.0 for years 2014, 2015, 2016 and 2017, indicated in green.

The PAI for H04B10/70 Photonic quantum communication is above 2.0 for year 2014, indicated in green, below 2.0 for the year 2015-2016, indicated in amber and for the year 2017 red (below 1.0).

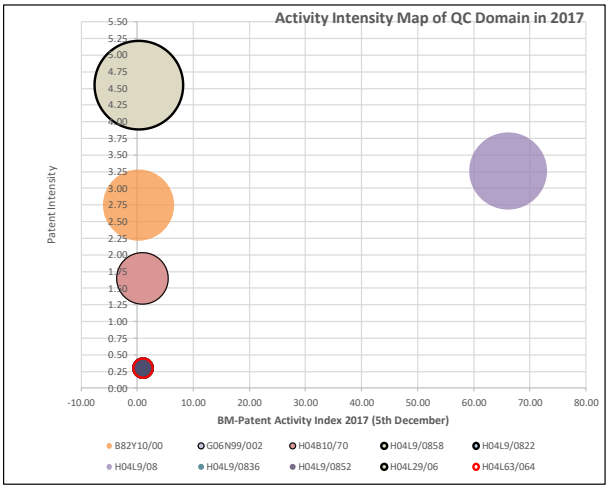
Similarly, for the IPC classes G06N99/002 Quantum computers, i.e. information processing by using quantum superposition, coherence, decoherence, entanglement, nonlocality, teleportation; H04L9/0858 Details about key distillation or coding, e.g. reconciliation, error correction, privacy amplification, polarisation coding or phase coding; H04L9/0822 Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) using key encryption key; H04L9/0836 Key transport or distribution, i.e. key establishment techniques where one party creates or otherwise obtains a secret value, and securely transfers it to the other(s) involving central third party, e.g. key distribution center [KDC] or trusted third party [TTP] involving conference or group key using tree structure or hierarchical structure; H04L9/0852 Quantum cryptography; and H04L63/064 Hierarchical key distribution, e.g. by multi-tier trusted parties, the PAI is below 1.0 for years 2014, 2015, 2016 and 2017, indicated by amber.

The PAI for B82Y10/00 Nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic is above 2.0 for years 2014-2016, indicated in green, and below 1.0 for the year 2017, indicated in red (below 1.0). The PAI for H04L29/06 Arrangements, apparatus, circuits or systems, not covered by a single one of groups; characterised by a protocol is below 1.0 for the year 2014-2017, indicated in red (below 1.0). This implies that the number of Patent

Applications being published in the preceding 5 years (inclusive of current year) *remains less* than the number of Patents being granted. This indicates a reducing Invention activity in the specific domain. Thus, it can be concluded that IPC domain H04L29/06 is seeing reducing Invention Activity and has low invention velocity from 2010 to 2017.

H04L9/08, and B82Y10/00 are the prominent IPC classifications in the quantum cryptography technology which talks about ***photonic quantum communication, and nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic*** *respectively. The inventive activity in H04L9/08 was higher in the year 2014, since then the patent activity has been reducing as the number of Patents being granted has started increasing. Further, the inventive activity in B82Y10/00 was also higher in the year 2014, since then the patent activity has been reducing. However, the inventive activity of H04L9/08 is still higher than other key IPC classes.*

Activity Intensity Maps of Top 10 Quantum Cryptography IPC classes in the year 2014 and 2017

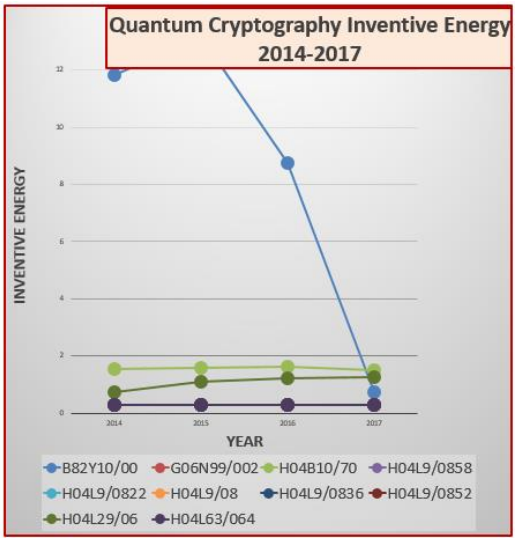


Activity Intensity Map (**AIM**) of a set of IPC classes is a Crafitti proprietary visualization of intensity in terms of a number of patents granted and patent applications published, and inventive activity in terms of relative pace of patent applications and granted patents in any IPC domain. For any year say 2014, these indices include a measure of yearly averages of last five years of a number of applications published and patents granted. For example, for 2014, these indices use data from years 2010, 2011, 2012, 2013 and 2014.

Quantum Cryptography Inventive Energy of Top 10 IPC classes

IPC Domain	Description	Patent Activity Index				Patent Intensity				INVENTIVE ENERGY			
IPC		BM-PAI 2014	BM-PAI 2015	BM-PAI 2016	BM-PAI 2017	2014	2015	2016	2017	2014	2015	2016	2017
B82Y10/00	Nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic	8.76	6.57	3.55	0.26	1.35	2.00	2.46	2.75	11.83	13.16	8.74	0.72
G06N99/002	Quantum computers, i.e. information processing by using quantum superposition, coherence, decoherence, entanglement, nonlocality, teleportation	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
H04B10/70	Photonic quantum communication	2.31	1.56	1.17	0.92	0.66	1.03	1.40	1.65	1.53	1.60	1.64	1.52
H04L9/0858	Details about key distillation or coding, e.g. reconciliation, error correction, privacy amplification, polarisation coding or phase coding	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
H04L9/0822	Key transport or distribution, i.e. key establishment techniques where one party	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
H04L9/08	Arrangements for secret or secure communication; Key distribution	277.37	140.43	86.23	66.11	2.67	2.93	3.09	3.26	741.48	410.84	266.10	215.41
H04L9/0836	Key transport or distribution, i.e. key establishment techniques where one party	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
H04L9/0852	Quantum cryptography	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
H04L29/06	Arrangements, apparatus, circuits or systems, not covered by a single one of groups; characterised by a protocol	0.18	0.25	0.28	0.28	4.19	4.30	4.42	4.55	0.75	1.09	1.24	1.25
H04L63/064	Hierarchical key distribution, e.g. by multi-tier trusted parties	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30

Inventive Energy for the year 2014 for IPC class G05B19/418 is simply a product of Patent Activity Index for the year 2014 (in this case a value of 1.66) and Patent Intensity for the year 2014 (in this case a value
of 1.97). The Inventive Energy for the year 2014 for IPC domain G05B19/418 comes out to be 1.66 x 1.97 = 3.27, as shown in the Table. In general, the Inventive Energy of IPC class H04L12/28 (Data switching networks -> characterized by path configuration, e.g. LAN (Local Area Networks) or WAN (Wide Area Networks)) is highest among these top 10 IPC classes.



Key Findings

Due to its inherent simplicity and utilization of substantial information on published and granted patents, the present study on the inventive energy provides a de facto standard for enterprises active in the Quantum Cryptography to evaluate the front edge of technology in various applications of the QUANTUM CRYPTOGRAPHY.

IPC class on the photonic quantum communication (H04L9/08) has seen the tremendous inventive energy in the 2014-2017 Index. Other two prominent IPC classes on and nanotechnology for information processing, storage or transmission, e.g. quantum computing or single electron logic (B82Y10/00), and Photonic quantum communication (H04B10/70) have also been quite active among the IoT enthusiasts and R&D teams.

One of the findings from the present inventive energy study is that the patenting in the field of Quantum computing has accelerated over the last three years. However, the development of actual quantum computers is still in its infancy, but experiments have been carried out in which quantum computational operations were executed on a very small number of quantum bits. Both practical and theoretical research continues, and many organization, national governments and military agencies are funding quantum computing research in additional effort to develop quantum computers for civilian, business, trade, environmental and national security purposes. Further, there is a decrease in the patent activity in the Photonic quantum communication which were higher in the year 2014-2016.

Further, the reduction in Inventive Energy of H04L9/08 from 2014 value of nearly 277.37 to the value of 66.11 in the year 2017, *indicates the trend of Patents grants has started in the period that typically brings down the Inventive Energy as it is a function of the ratio of applications published and a patent granted for the particular year.* Furthermore, the present inventive energy study identified that inventors are active in the implementation of the secure communication mechanisms.

IPC classes with high Inventive Energy typically will have higher business potential and growth in the Quantum Cryptography technology. The Inventive Energy can be utilized to create the quantum cryptography Inventive Strategy to find problems in high inventive energy IPC classes. This can be a leading indicator for not only any startup or disruptor but also to existing patent owners to expand and strengthen their portfolio through this guidance rather than letting serendipity and opinion about future guide their inventive effort.

As the patent examiner not only evaluate the patentability of the corresponding technology but also assess the legal aspects of the filed patent application at various levels of scrutiny before granting the patent, therefore, patent grant trends identified by the present inventive energy study in the quantum cryptography technology will enable the decision maker with the due-diligence aspects of the quantum cryptography technology.

Any organization willing to invest in the quantum cryptography technology can utilize invention energy metric in general and this study in particular, as it automatically takes care of three major inputs required

to understand the state of the art of quantum cryptography technology – Patent Applications, Granted Patents and Specific IPC classes relevant to quantum cryptography in a composite metric.

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