Pluto

Breaking down the barriers in academia

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1. Introduction

Most of the world progresses with collaborations between people. So does academia. Researchers advance the knowledge of humanity by sharing their achievement with peers and developing more researches from the shared ones. A system of such activities is called Scholarly Communication, where journals and publishers work as the major media. Scholarly communication is specifically important in that it is a circulating system: a well shared knowledge gives much more potential for yet another knowledge.

Humanity has progressed a lot. Much of the world has achieved democracy, relieving from the central power of Monarchy and Aristocracy. Religions are separated from politics. Scientists further contributed to the improvement of society with outstanding technologies. The recent advancement of IT has pulled it up by enabling almost every piece of information and knowledge to nearly everybody. It is unfortunate for the mankind, not to mention the academics, that Scholarly Communication has gone the other way.

Though the invention of internet has made the traditional exclusively-available brick-and-mortar journals now accessible to anyone in the globe, researchers are still behind the walls. Commercial publishers are earning tremendous profits on the efforts of researchers, putting significant financial burdens and paywalls on the system. Journals, for-profit or not, are adding to the limitations with their closed, centralized structures and policies. Things worsen as most of the world, academic or not, evaluates the researchers and their outputs by irrational, outdated metrics: citation counts and impact factors.

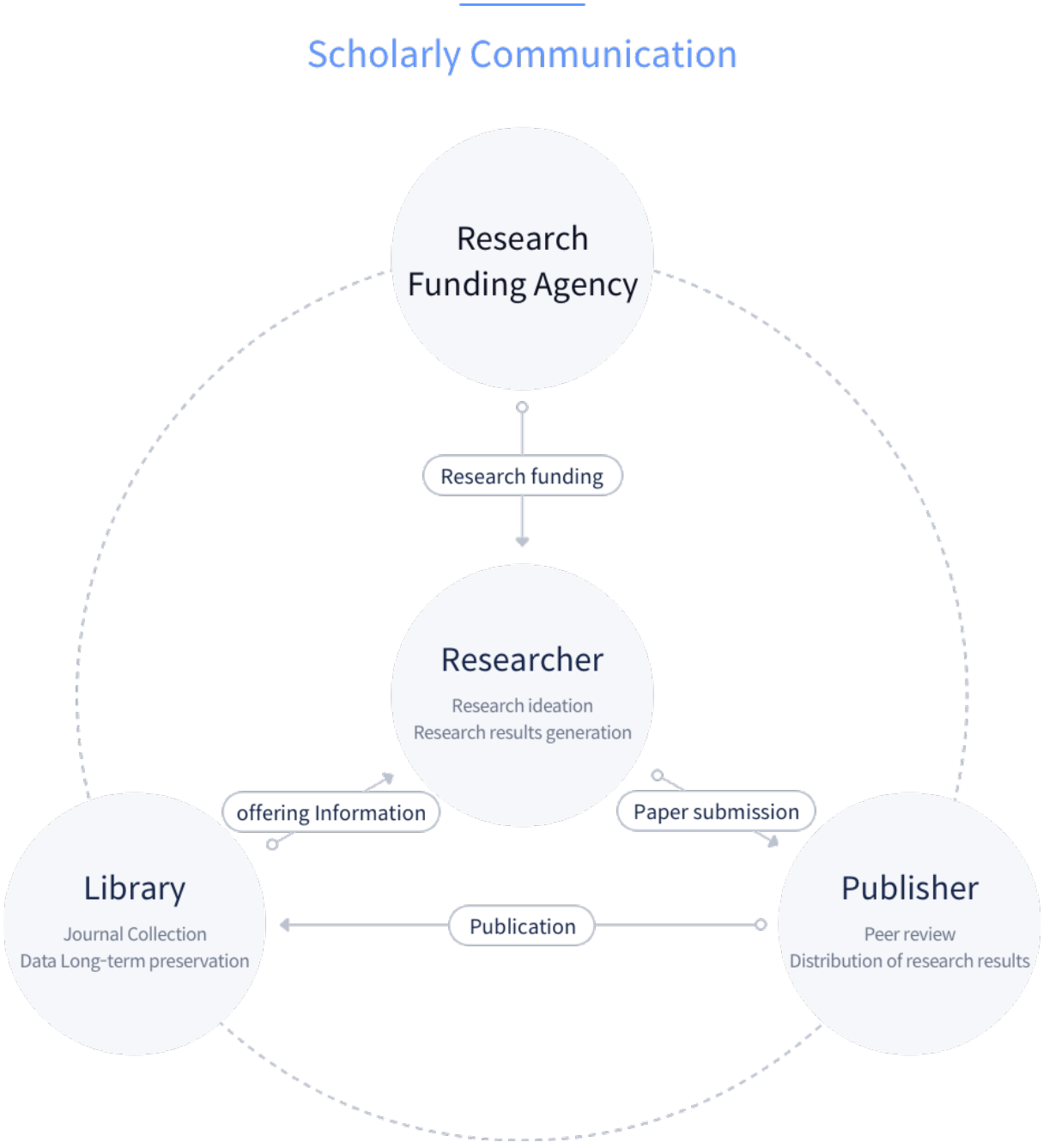
Pluto, just as all the academics around the world would do, craves to solve these absurdities, by creating a fair, transparent, reasonable, and efficient communication platform for scholars, decentralized from the present too much power of publishers. Using blockchain technology, Pluto decentralizes the way academics share, evaluate, and reuse their research outputs. The scope of these outputs is extended beyond the present narrow definition confined to published papers to a broader sense of various information occurring mid- research. The values arising in the cycle of the system, both in financial and reputational terms, are credited rightfully to the ones who contribute to them. The reputational compensations, in the long-term, will work as an alternative metric for academics.

By creating a decentralized, transparent, and reasonable system of records for academic activities, Pluto makes the global scholarly communication efficient than ever. The whole cost savings will be greater than 80 billion USD throughout entire research industry. Besides being efficient, the paradigm of scholarly communication shifts with Pluto. As all kinds of mid-research outputs are empowered and promoted to be shared, the lifetime value of researches will be fully utilized, making the current global R&D of more than 2 trillion USD an obsolete number. Along with the practice of validating researches, the alternative, objective performance indicator for researches, and a new system for allocating resources, there will be extraordinary advances in current challenges like incurable diseases or sustainable energy. Ultimately, the decentralized academia initiated by Pluto will advance the way the knowledge of humanity itself advances.

2. Backgrounds

2.1. Scholarly Communication

Academia evolves in a circulating process. A prior knowledge piece makes a basis for newer ones. Researchers conduct their studies extending from past ones by others, or oneself sometimes. Such process, or the system of it, is called Scholarly Communication. More formally, it is defined[1] as 'a system that creates and evaluates research and other scholarly documents, distributes them to academics, and preserves them for future use."



Scholarly communication consists of four major players: Researchers (Scholars), Research funders, Libraries and Publishers.

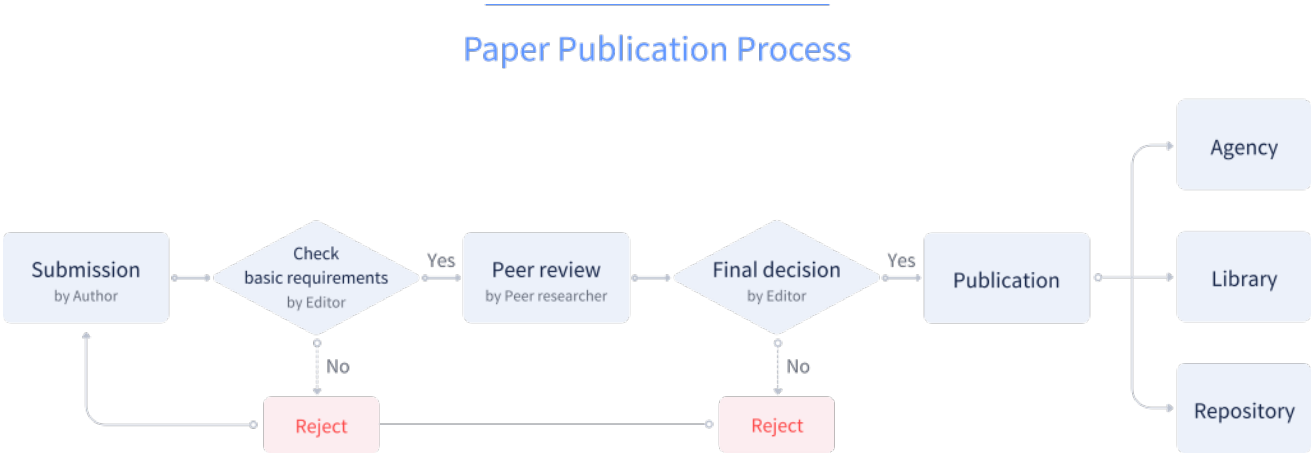
- Researchers make the greatest contribution to scholarly communication by conducting research and generating achievements. Researchers generate research achievements such as experimental data, research reports, and seminar materials using the funds received, and submit the papers to the publisher.

- Research funding agencies are mostly governments or companies, who support researchers with grants for researches.
- Publishers are responsible for evaluating, publishing, and distributing research achievements through the journals they possess. They publish journals, and generate high returns by receiving subscription fees from readers.
- Libraries collect journals from publishers and enable users to search and access them. They are responsible for the long-term preservation of such publications. They are also the main consumers of the research achievements.

Scholarly communication begins when a researcher uses research funds to generate research achievements and submit papers to the publisher. The publisher verifies academic papers submitted by the researcher, and decides the subscription fee and distribution method of papers. The library uses the budget supported by the university or institution to select and access the necessary academic information. When another researcher obtains the necessary information from the library and conducts research using it, new research achievements are generated and published again. In other words, scholarly communication is a constantly circulating system.[2]

2.2. Journals

Journals are sort of academic magazines which have the ability to register, evaluate, validate, distribute, and archive research achievements.[3] Publishing a paper through a journal is the main means of disseminating the research achievements. This is closely related to the researcher's reputation and social rewards. In particular, the number of papers published in SCI-listed journals and their citation counts are used as the indicator of the competitiveness of countries, institutions, and researchers.



When the author submits a paper to a journal, the editor, who is the manager of the journal, receives it.[4] The editor is generally an expert in the same field, and is appointed by the publisher of the journal. The editor confirms that the relevance and format of the paper meet the criteria, and then requests the peer reviewers for evaluation. After peer evaluation, the editor finally decides to accept or reject publication.[5] Most of the copyrights to the research achievements are owned and managed by the publisher. Published journals are distributed to subscribing libraries and institutions. Researchers are given originality over their researches by submitting their papers to journals and registering their research achievements.

2.3. Peer Review

The peer review procedure is the most distinct feature of journals. In general, two or three researchers in the same field will examine various aspects such as the scientific value of the paper or whether hypotheses and results are aligned properly. The peer review system based on the recognition of peer researchers is the key factor in enabling academic journals to become the major media for scholarly communication.

There are various forms of peer review. Single-blinded review is the traditional form of peer review, which the names of the reviewers are hidden from the author. Anonymity of the reviewers allows for impartial decisions because the reviewers are not influenced by the authors. The double-blinded review is a method that both the reviewer and the author are anonymous. It has the advantage that the reviewers can evaluate without any prejudice to the author. The open peer review method is a new type in which both the author and the reviewer are known to each other. The open peer review has been tried in many journals and websites due to the increasing trend of online publications. In addition, various attempts have been made to solve the problems of existing peer review process. This is covered in detail in Section 5. Impact.

2.4. Recent Trends

The advance of internet in recent decades has opened a broad potential for changes in scholarly communications. Journals are published more in digital forms than in hard-copied papers. Researchers are collecting their references in online repositories. Lots of digital tools have been developed that are used in research industry.[6]

Among those recent changes, one of the remarkable is the Open Access(OA) movement. OA was proposed as an alternative scholarly communication model, as access to academic papers became difficult due to market oligopoly and excessive pricing by large publishers. The OA movement advocates the principle that research achievements (scholarly papers) should be accessible and utilizable to everyone at no cost. OA is defined as allowing users to read, download, copy, distribute, print, or search the full text of a work without any form of financial, legal, or technical barriers other than the access to the internet itself.[7]

There is also voice from the academics on peer reviews. Some alternative systems of peer reviews have been already attempted,[8,9] and conferences and forums are being held for researchers and publishers to gather and share their thoughts on current issues on peer reviews.[10,11] Still, there is no consent between academics and separate journals on the standard traits of a sound peer review system.

3. Problem

More than half of journals in the world belong to for-profit publishers. The odds are worse in the top journals with higher impact factors and subscriptions. From the past contributions when the publishing industry was solely “brick-and-mortar”, that is, when publishers were actually important in hard-copying and disseminating research findings, they have cumulated influences around many learned societies, and now they’re exploiting those influences disrupting the whole system.

The major control of whole system by commercial publishers is significantly problematic as there is a serious misalignment of interest between the publishers and the system. While scholarly communication, or scholars worldwide collectively, aims for the advancement of knowledge of humanity, commercial publishers seek for profits, and obviously their profits increase with the number of publications globally. This has led to a bad ethos where academics are obsessed with publishing more papers rather than pursuing a great study. Collaborations are discouraged and scientific advancements are slowed down. Moreover, this misleading focus on publication had generated undesirable practices in academia, and now hinders solving many of identified problems.

Beside this huge problem from centralization of scholarly communication on few for-profit publishers, this section of paper will list several problems arising from it. These problems span from direct effects on scholarly communication itself, to broader ones in general research environments.

3.1. Lack of proper evaluation index

Currently, there is no index for research achievement evaluation which is reasonable and journal- independent. The evaluation of the paper depends mainly on the impact factor(IF) of the journal and the number of citations. IF is the index that determines the relative importance of a journal within a subject area. A paper published in a journal with higher IF is usually perceived to be better.

However, it is unreasonable that the index for the comparison of the journals is used as the evaluation index for individual papers. According to a study about bioscience in South Korea, 63% of the 323 top cited papers were published in journals with below-average IF.[12] In other words, it is not appropriate to evaluate the quality of a paper by the IF of the journal it is published in.

It is also not reasonable to simply evaluate the impact of a paper with its citation counts. Citation frequency and pattern are different for each research field, and the number of citations alone does not tell whether the response is positive or negative. Some fields such as medicine, papers are cited right after the publication, but fields such as social science are not cited until two years later. Since citations cannot be withdrawn, even canceled papers can increase the number of citations.

The bigger problem is that the evaluation of researchers also depends on journals. Most researchers are evaluated by the number of papers and the IF of the journals. In other words, the quantity of papers which have been published in academic journals with high IF becomes the researcher's achievement.

The evaluation of research achievements is very important for researchers because it is directly linked to employment, promotion, and research funding. Since researchers can appreciate the value of the research and increase their reputation only through influential journals, they are not able to make other rational choices despite

high costs. The evaluation on the quantity of papers put a burden on researchers. This leads to an unethical act called salami slicing, which deliberately divides one study into multiple submissions. This creates dangerous consequences, which in the short term will distort the career of the researcher and, in the long term, reduce the value of the paper itself.

While some of the leading scientists in the world have criticized these issues and made a declaration[13] calling for a halt, these practices are still continuing. The reliability of the entire scholarly communication is reduced due to the evaluation of the research performance which is dependent on publishers. Researchers need to be recognized for their achievements as they contribute to the scholarly community.

3.2. Market Oligopoly

3.2.1. Centralized Role

Publishers have the greatest influence within scholarly communications since they have accumulated and privatized too much information along the course in the history of scholarly communication. In particular, four large commercial publishers, namely Elsevier, Springer, Wiley-Blackwell, and Taylor&Francis, account for 25% of the world's academic journals market, and 35% of the total journals. These journals are the top 50% of the total journals. In other words, half of the most widely quoted journals in the world are published by these publishers. In fact, in 2016, Elsevier's revenue was £ 2,320,000, with a margin of over 36%. They are earning excessive profits in scholarly communications from this oligopolistic power.[14]

The copyright of the paper written by the researcher is owned by the publisher. The validation of the paper is also made by the labor force that fellow researchers provide to publishers for free. It is ironic that publishers are making profit from researchers using resources they have acquired free of charge from researchers. Honorable works by researchers with so much time and resources are contributing more to the profitability of publishers rather than for the advancement of academia.

Moreover, as centralized systems are prone to censorship and surveillance, so is current academic publishing.[15] This means, research findings of specific topics can be artificially removed from journals, or readers in certain areas can be banned. The recent removal of papers involving Chinese political issues from mainland China sites is a typical example of such censorship.[16] Put in general words, a system owned by specific individuals or groups might suffer censorship and surveillance which are aimed for the interest of the system owners, not the users.

3.2.2. Excessive Pricing

High Subscription Fee

Large journals have continued to raise subscription fees based on market oligopoly power. Journal subscription fees have risen by more than 10% each year, faster than inflation. It is difficult to keep a subscription with a limited library budget. Since one article is published only in one journal, researchers need to subscribe as many journals as possible. As a result, publishers with influential journals can use this scarcity to constantly raise subscription fees. They require subscription fees of 2 to 10 times that of non-profit publishers.[17]

Excessive subscription fees created access barriers to research achievements. This is especially a problem in developing countries where the research budget is scarce. Most African university libraries are not able to access journals except for the ones that publishers have donated.[18] Even relatively wealthy Harvard library have been forced to cancel subscriptions because of lack of budget. Due to the excessive commercialization of publishers, not only developing countries but also relatively wealthy institutions are feeling the barriers to access research achievements.

The biggest contributor to the increase in subscription fees is the publisher's Big Deal business model. The Big Deal is disadvantageous to the library because it bundles thousands of journals without sufficient information about the actual demand or level of the journals. If the library cancels the subscription for low-quality or low-demand journals in the bundle, the publisher raises the subscription fee for the remaining journals. Publishers are able to use their low-demand journals to pursue profits and gain market power by taking limited budgets.

High Submission Fee

Publishers may charge an additional fee for a variety of options (cover publication number of additional pages exceeding the allowed limit, color chart, etc.), or publication fee for reviewing the paper. For example, wiley - blackwell 's Evolution Journal charges $ 500 for each color picture in the paper and $ 55 for each page exceeding the standard.

Academic papers do not have to be a monochrome static work that is fixed in a single form as a medium for sharing research achievements. Unlike in the past, technological advances have led to diverse ways of expression, but publishers are burdening researchers by charging for additional options.

Article Processing Charge(APC)

The OA movement has emerged to solve the problems of existing publishers, but it has created a new business model called APC for large publishers. This APC not only lacks a clear basis of calculation but also makes a significant burden on researchers. In 2010, the average APC was $906, and journals of the highest APC prices around $2,000- $4,000 were mostly those with higher impact factors possessed by renowned publishers.[19] The result is an estimated 6% increase in publisher’s revenue, and the proportion of APC in total revenue is increasing.

3.3. Efficacy of Peer Review

3.3.1. Failures in Review System

In scholarly communication, publishers are responsible for not only the distribution of papers but also the evaluation. Some publishers do not offer reliable paper review services despite high commercial benefits they receive. In April 2017, Springer's journal 'Tumor Biology' caused retraction of 107 articles collectively due to review manipulation, which showed that even reviews from prominent publishers can go wrong.

There are many problems in the traditional peer review. Reviewers in a single blinded review can have a bias because they know who the author is, and they can make more negative evaluations using anonymity. Reviewers are mainly researchers in the same field, so they can deliberately delay evaluation in order to intercept and prioritize research results.

Moreover, even in a double-blinded review, reviewers can easily recognize the author since they are in the same field of research. Therefore, editors and reviewers and still influence the peer review process by having bias on the author. In addition, the process is not transparent, so it is hard to notice if there is a fraud in the process. Open review, where both parties are aware of each other, is often suggested as they would remove some problems aforementioned, but it still is doubted that having their names open might suppress reviewers from making constructive criticism. There surely is a need for transparency in review process, but still remains other things to consider.

3.3.2. No Validation on Data and Reproducibility

Reviewers may produce poor evaluations since they do not evaluate the validity of statistical data or reproducibility of experiments. As a result, the current scholarly communication is in a 'reproducibility crisis'. According to the article 'Cancer research is broken'[20] published by the American media Slate, only 11% of important studies in cancer biology were reproducible. In fact, 52% of 1,576 researchers responded in the survey that "most of the papers lack the reproducibility of the research."[21]

The lack of reproducibility can lead to the possibility of new research based on wrong conclusions, leading to a chain of false research. It can lead to massive resource losses. In fact, the article mentioned above estimates that the US government has suffered financial losses of about $ 28 billion due to irreproducible cancer research. This shows that the total amount of resources that would have been wasted due to irreproducible research in all areas of research will be even greater.

These problems also exist due to lack of transparency in peer review process. Transparent disclosure of the paper review process can prevent them. It is possible to prevent fraud through free discussion from public. Atmospheric Chemistry and Physics introduced an interactive open access publishing method that allows comments to be freely made available to the public. More than 30 comments have been posted on controversial subjects, and heated discussions have been held.[22]

3.3.3. Absence of Motivation

Peer review makes a great contribution to the development of academic society. However, since there is no reward for conducting reviews, researchers are not motivated to take time and effort. Currently, researchers are providing the labor force to the publisher at no cost. As a result, the editor is having trouble finding reviewers, which also leads to delays in the review process. In a survey of more than 5,000 reviewers in Springer and Biomed Central, 43% fully agreed that recognition for peer review will increase motivation. 72% wanted to record and view their review performance.[23] Researchers wanted to be recognized for good reviews. In particular, they wanted to get recognition based on quality rather than quantity. The peer review process should be made transparent and open and let researchers to get reasonable recognition and compensation.

3.4. Inefficient Communication

3.4.1. Discovery Services

One of the key tasks in a scientific study is collecting relevant references from past studies. In this task, academics today use digital tools called discovery services, the search engines for scholars. Discovery services aggregate information around academic contents from several contents providers including journals,

publishers, universities and other research institutes, and index them with relevant meta data, so that academics can utilize them to easily find relevant contents for their studies.

The problems in current scholarly communication, such as opaqueness, paywalls, lack of indices, and the copyright issues, make it extremely hard to provide a decent discovery service. Even when academics, or their institutes, have paid countless dollars to use a discovery service, they usually have to go through even more papers to find relevant ones. The ones they find using current discovery services might look decent at first glance, but it is occasional that they find it irrelevant after reading the full text. The problem suffers the other way around as well. As for the authors of the contents, they would want their research findings to reach the peers who would find theirs useful.

3.4.2. Repeated Work for Separate Journals

Since there is no standardized publication process and format, researchers should write articles in accordance with the requirements of the journal to be published. Generally, careful work is required to match the format of the manuscript. This reduces the likelihood of the paper being rejected by the editor who first reviews the manuscript, so researchers need to spend considerable time on it. Each journal requires a very complicated format, and the manuscript may be rejected because of other minor issues that are not very relevant to the content such as the annotation style, the third level title, and the italics.

If a paper is rejected, it will take a long time for the researcher to revise the format of the manuscript in order to submit it to other journals as well as to go through the review process. The review process through publishers takes an average of three months, and feedback is very passive. This unnecessary repetition of procedure in scholarly communication leads to waste of resources that should be utilized in research.

3.4.3. Publication Bias

Publication bias refers to a phenomenon in which publishers only publish positive results rather than negative ones. Here, 'positive results' refers to research that discovered new information and proved causality, while conversely, 'negative results' is a kind of research that did not find new facts or proved that there is no relationship between phenomena.

Since journals prefer new and exciting research, researchers do not share information about the research if they could not identify causality or discover new things. It is assumed that the drawers and hard disks of labs all over the world are accumulating unreported negative results.

Contrary to what was formerly a forum for sharing and debating, scholarly communication is now focusing only on performance. Publication oriented research performance evaluation practices, or so called “publish-or-perish”, have made researchers dedicated to their own experiments for performance and not to share experimental results even within the same laboratory. Due to lack of communication, researchers do not have access to experiments that have already been performed and failed. Therefore, duplication of the same experiment is carried out, which leads to unnecessary waste of resources.

There is a big difference between ‘replication’ and ‘duplication’ in research. Replication means repeating the experiment under the same conditions to increase confidence in the results of the experiment, and duplication

means that the researcher does not know about the experiment already performed and does the same experiment. In other words, replication is an important process to demonstrate the reproducibility of the experiment, but duplication leads to waste of resources.

3.4.4. Resource Allocation

Researchers are also having a hard time getting research funding. Reduced government funding and intensified competition have made it difficult for researchers to start new research projects. Among 11882 researchers from a survey, 44% said that their biggest challenge was to get funding, and a significant percentage (65%) were concerned about quitting the study. Since governments and funding agencies support budgets without careful consideration of the potential impact of researches, these funds are largely dominated by a small number of influential researchers.[24] The average age of recipients of NIH research fund R01 in the United States is 41, and the top 20% of researchers share 58% of the fund.[25] Young researchers with relatively low influences are in a difficult position to secure sufficient research funding.

Distributing the resources in research industry is even harder since they have no proper indicator for assessing the credibility of academics as described in Section 3.1. Using the outdated number of publications in high IF journals, those with existing careers will always have more chance to get grant opportunities and younger academics wouldn't stand a chance against them. This causes so-called Matthew Effect in research industry. To solve this problem, research crowdfunding platforms [26] have emerged. However, researchers have difficulty in promoting themselves and proving their credibility in the research field.

In short, large publishers oligopolizing the market with their past influence have generated excessive commercial profits in scholarly communications. High subscription & submission fees and APCs created access barriers to research achievements. Unreliable and ineffective peer review process is another significant drawback as well as difficulties in improving discovery services.

Moreover, publication bias and publication-focused evaluation system hindered information sharing and communication among researchers, resulting in duplicated experiments. Publication procedures without profound standard waste a lot of time and resources. Researchers are having trouble in getting research funding due to structural problems.

Since evaluation index of research achievements solely depend on the IF of journals, researchers are not able to make any other reasonable choice. Researchers should inevitably rely on high IF journals and their publishers to be recognized. These problems can be solved by decentralizing scholarly communication, providing transparency and independence to the system and giving it back to the hands of researchers.

4. Solution

4.1. Vision & Mission

Pluto breaks down the barriers in academia. We dream of a world where anyone could fully realize the potential in the academic field. With this vision, Pluto aims to achieve the following mission.

> Pluto makes scholarly communication efficient, reasonable and transparent, decentralizing the system from potential control by any single party.

4.2. Design Principles

Following guiding rules are set forth, to help make decisions in designing details in any aspect of Pluto platform.

- All actions and transactions on the platform are transparently open to the public.
- All rights associated with any work on the platform are reserved by the original author.
- All activities on the platform are compensated according to the contribution.
- All major decisions on the platform are made by the consensus of participants.

4.3. Blockchain Solution

Blockchain is a decentralized system of records grown by its peers within a consensus protocol, originally conceptualized as the basis of now well-known cryptocurrency Bitcoin in 2008 by the pseudonymous individual or group known as Satoshi Nakamoto. Blockchain by its design has several properties that would fit so well to the Pluto's core design goals, thus adopted as the backbone technology of Pluto platform.

4.3.1. Blockchain in a Nutshell

Blockchain is a distributed list(chain) of records(blocks), steadily grown by its participating peers. The network of peers adheres to a common protocol for validating new blocks to be added to the existing chain, which is usually referred to as consensus algorithm. These algorithms are designed in a way such that incentivizes participants to act honestly and makes malicious actions are less beneficial. This design principle makes the data in blocks, as well as being transparent, irreversible once recorded, and the only chance of manipulating the data is when the majority of the network colludes.

4.3.2. Smart Contract

First proposed by Nick Szabo and well known for its implementation in the Ethereum blockchain, smart contracts expand the consensus protocol to a broader sense. Now adopted by most blockchains on the space, smart contracts enable computer codes to be recorded on to blockchains and does what is set forth to be done in the codes when certain conditions are met. The smart contracts system implemented on Ethereum and other blockchains are Turing complete, meaning they can execute almost any kind of computation that an ordinary computer can, so is sometimes referred to as World Computer.

This system of storing executable codes makes blockchains programmable. Almost any implementation of

digital transactions can be made within it, which are called Decentralized Applications(DApps), and Pluto being implemented on blockchain is an example of DApp.

4.3.3. Blockchain for Pluto

There are some notable properties of blockchains that help achieve the design goals of Pluto as its backbone. As already mentioned above, data recorded on blockchains are **transparent** and **irreversible**. Powered by smart contract's **programmability**, the scope of this data expands to any kinds of information that might exist in digital forms. For Pluto, activities of users can be compensated automatically with digital assets, either of economic value that can be transferred between users or of descriptive status of users such as reputation.

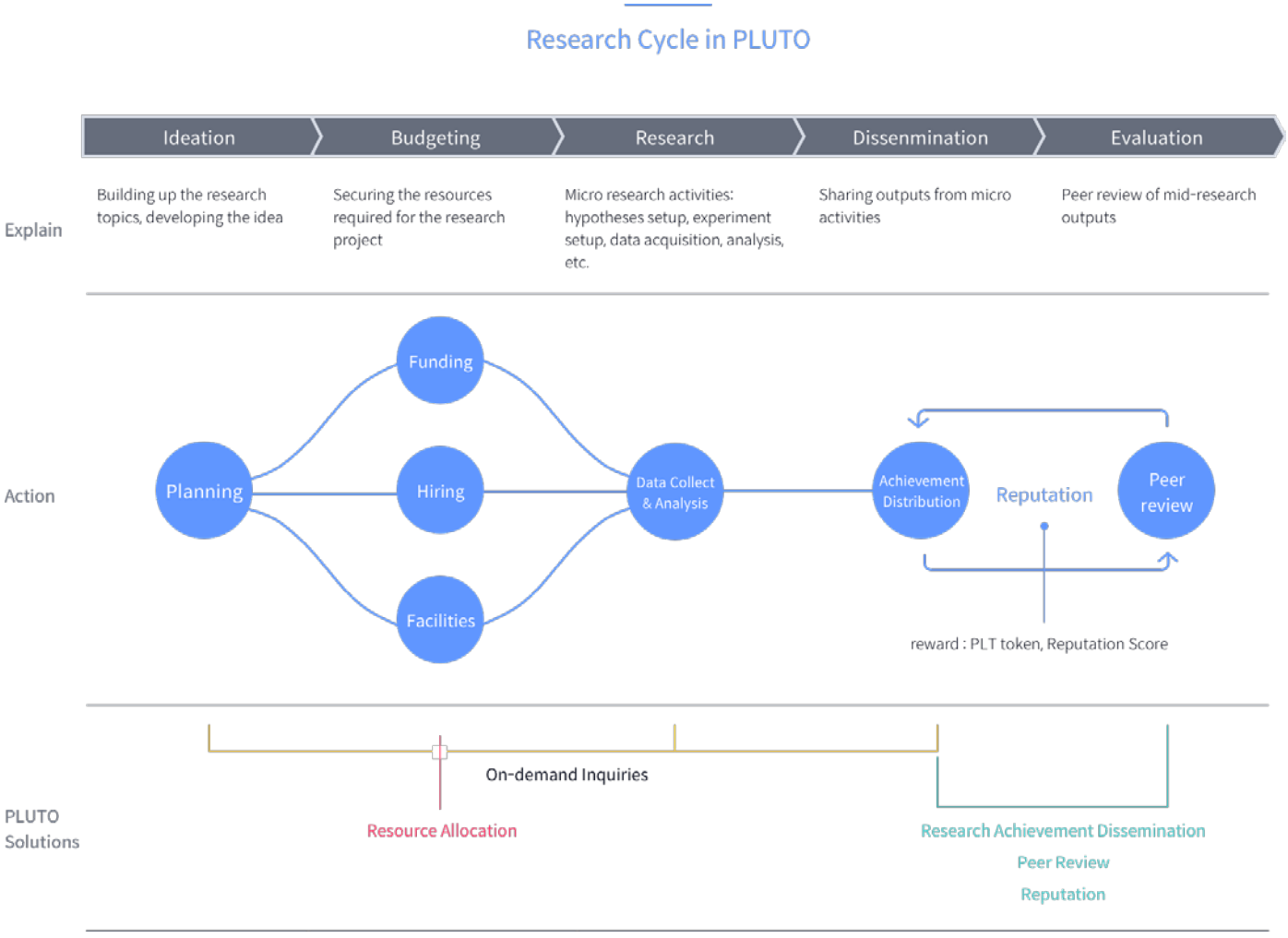
Furthermore, some blockchains provide protection of information on top of transparency by implementing the zero-knowledge proof, a method of verifying a certain condition without any third information apart from the condition itself. This enables DApps to provide **privacy when necessary**, while ensuring the participant of interest is acting honestly.

As records are managed by a peer-to-peer network, there is no single third party that intervenes in any part of the system, thus making it **decentralized**. It directly follows that any systems implemented on blockchains are **censorship resistant**, unless the network consents on specific rules.

Pluto utilizes these properties of blockchain to manage a transparent system to record research activities and facilitate fair transactions between academics. While keeping the transparency and fairness of the whole system, privacy and copyrights are ensured when necessary. Blockchain also enables a reasonable compensating mechanism for academic activities, either in economic values or in academic reputation, or both. At the same time, the system works on its own, or in other words it is operated by its participants, without any central authority, individual, or group having control over it.

4.4. Pluto Platform

The whole Pluto platform represents a research network where any sort of players involved in the academia can utilize with 100% confidence without need of trust, including but not limited to researchers, institutes, funding agencies, and so forth. Pluto ecosystem deals with all kinds of value transfers throughout a research lifecycle, i.e. any transaction of information or economic value, from ideation, planning, budgeting of a research project, to data acquisition, analysis, dissemination, evaluation, and reuse of a research achievement. On top of smart contracts system enabled with blockchain technology, a compensation mechanism with tokens and reputations enables the realization of the proposed ecosystem of scholarly communication. Following sections address key features of Pluto platform.



4.4.1. Research Achievement Dissemination

The most basic feature of Pluto is, of course, spreading the pieces of information generated in the courses of researches. Unlike the traditional practice where academic paper was the only form of research achievement that mostly determined the performance of a researcher, users can submit any type of information as long as it has the potential to add value to further scientific progression, including but not limited to proposals, research ideas, hypotheses, design of experiments, research protocols, experimental data, analyses, and interpretations. To embrace and encourage these various types of contents to be shared, multiple data formats will be supported on Pluto in both uploading and viewing, such as data sheets, images, videos, and of course, texts. To ensure a decentralized, trustworthy form of dissemination, they are stored using decentralized file storage such as IPFS, with unique identifiers such as Digital Object Identifier(DOI) assigned for each piece of information.

Users have full control of the licenses over their original works. They can set the copyright policies for different types of uses, including simple viewing/downloading, citing for other works, commercial uses, and etc. The Pluto team will dedicate to protecting users' copyrights so that researchers, especially in their early career, do not hesitate to share their knowledge in the fear of others exploiting it.

Beyond simply storing pieces of information in a decentralized database, Pluto will support several features to help researchers easily find their designated information. As a core component, an article page will show both those citing it and cited by it. Basic features like sorting, categorizing, and keyword search are also on the list, along with a curating algorithm to recommend relevant articles to users.

[Potential issues]

- As research achievements are expressed in various types and formats, detailed items of evaluation for each could differ as well.

4.4.2. Reputation

Users with verified identity are assigned reputation points based on their past activities and their contributions. The change in reputation is generally based on the activities that are recorded on Pluto, but it may include the records from external sources that can be imported with APIs, only when the community agrees to accept that source. The activities on Pluto that would increase one's reputation include but are not limited to: submitting a decent research achievement to the platform, giving a proper evaluation score for those submitted by others, and helping them improve their works with a constructive comments. The reputation diminishes over time, or in other words, more recent activities account more to the reputation.

The degree of contribution for each activity is determined by the consensus of the community. At the same time, the reputation works as a weight on the intent of individual user. That is, the consensus of the community isn't simply the aggregation of individual opinions, but is weighted by the reputation of each. In case of the activity being regarded as malicious rather than contributing, the user might lose reputation. Therefore, the reputation system on Pluto is a reinforcing cycle of consensus.

[Potential issues]

- The determination of initial reputation for newly registered users. Possible options include social proofs by existing users and external APIs for existing achievements outside Pluto.
- How to achieve IDV of researchers. This also may be solved with social proofs. Other options include IDV apps such as Civic, ORCID and uPort or projects like ID2020.
- Whether to have separate reputations for types of actions, namely author, reviewer, and others.
- Whether to have reputations for separate research fields. This seems quite challenging since clearly categorizing research into certain fields is a hard work, and interdisciplinary researches are increasing recently.
- In case of totally failing to discriminate reputations for separate fields, users might be given options of reputations when making an action, one for their major field of interest, and another for minor ones.
- Throughout the whole roadmap of developing the platform, the design for reputation should be progressively improved. Having a reasonable reputation formula is one of the key necessities of the platform. General design will be much improved with external advice, and data acquired from Proof of Concept prototype and early stage launch will be utilized to improve the formula via machine learning.

4.4.3. Peer Review

Every research achievement submitted on Pluto undergoes a peer review process. This review process has two major roles: indexing the submitted contents with a credible evaluation, and giving the submitter chance to collect ideas to improve the achievement. It is basically a public review, meaning anybody registered with verified identity can participate. The evaluation is incentivized with compensations in both platform tokens and reputations. The review proceeds in the following order.

Submission

A researcher submits a research achievement. The copyright policy and the number of reward tokens for peer reviewers are set at submission. The copyright policy of course includes full open access without any fee, and the reward tokens which apparently seems to be a substitution for what is currently known as submission fees or APCs can be an arbitrary positive number, from 0 to the amount the submitter has. Half of this reward is automatically distributed to the reviewers in the Blind Period, and the rest is given to reviewers acknowledged by the author. The article is directly in the Blind Period

Blind Period

- Blind Reviews: Reviews should mandatorily include detailed comments in text evaluating the research achievement of interest. They have an option to recommend revising the article, which will then let the author have a revision round. Specifically, those in the Blind Period also have to give a quantitative score of the article. Blind Reviews are available until 48 hours after more than N reviewers with a total of more than M reputation have submitted Blind Reviews.

- Blindness: In the Blind Period, most of information are blind except those necessary for reviewing. Both the author and the reviewers do not know the identity of one another. The quantitative scores in the reviews are also private. All the reviewers can access during the Blind Period is the contents of the research achievement of interest. The author can exceptionally look at the written comments of the reviews and whether they recommended revising.

- Revisions: When any of the reviews recommend revising the article, the author can optionally trigger a round of revision. The time for revising is also set by the author, and the revision round ends 48 hours after either the author uploaded the revised version or the time requested for revising has passed.

- End of Blind: The Blind Period ends 24 hours after both the submission of Blind Review and revision round, if any, ended.

- Blind Score: After no reviews are submittable and modifiable, the article of interest is now given a Blind Score. The Blind Score is the average of the scores given in the Blind Period, weighted by a function of each reviewer's reputation.

for an article with a set of blind reviewer R,

$$(Blind\ Score) = \frac{\sum_{i \in R} score(i) * f(rep(i))}{\sum_{i \in R} f(rep(i))}$$

where, if $rep(i) \geq rep(j)$, *then* $f\{rep(i)\} \geq f\{rep(j)\}$

  - N reviewers && M reputation are requirements to ensure enough audiences have evaluated the article. Detailed numbers are to be determined.
  - 48 hours are buffers for potential incoming reviews, modifications on already submitted reviews, and submissions of revised reviews.
  - 24 hours are buffer for the author to finish checking the submitted reviews and selecting acknowledged reviewers to take the half of the reward tokens. The specific numbers of hours are subject to change.
  - Specification of the weighting function is to be determined.

Reward Distribution

At the end of Blind Period, the rewards for the Blind Period of the article of interest are automatically given to the reviewers. Half of the tokens set by the author, if not 0, are evenly distributed to the acknowledged reviewers, as aforementioned. If the author didn't select any of the reviewers, all the reviewers are distributed the tokens.

The other half tokens are distributed according to how close a given score is to the Blind Score. Reputations are given in similar method, except that giving a too much outlying score would rather decrease the reputation of the reviewer. This is initial basic guideline, and the detailed specifications needs to be determined.

Public Period

Any articles successfully ending the Blind Period are directly in the Public Review Period. All the reviews are now publicly disclosed. The Public Period is a stage for open discussions about the article. Public Score is calculated in the same way as the Blind Score by the reviews given in this period.

[Potential issues]

- Normalization: A nominally same score might have different meanings depending on the reviewing patterns of individual reviewers. A 5 given by someone frequently giving from 2 to 6 means much more than the same score from one giving 4 to 8.

- Abuse Prevention: Malicious actions such as spamming scores over every submitted article with meaningless comments must be automatically dealt by the protocol of the platform. It is challenging that defining an abuse in peer review is subjective, and distinguishing abuses from normal reviews is a necessity. Highly unlikely cases can still be dealt with platform governance, not with the automatic protocol.

- Distribution of Reputation: The distribution of the entire users' reputations or their weight functions, on Pluto must be modeled in a way such that the one with greatest weight still cannot expect to have control over the public intent on a single article.

- Compensating Mechanism: We need a sound model to distribute the PLTs to reviewers and reinforce their reputations. Much like preventing the abuses, setting a criteria for deciding "correct" evaluation is a challenge.

4.4.4. On-Demand Inquiries

Beyond merely being a simple Social Network, Pluto provides a marketplace of research oriented inquiries. Researchers can request for a verification of reproducibility, validation of data, proxy experiment, the data itself, or any other information relevant to a certain research. Inquiries are set in advance bounty rewards in tokens, and an answer chosen by either the requester or the community receives the reward.

The requester doesn't necessarily need to be the author of the research of interest in the inquiry, so even researches outside Pluto can be actively discussed and further developed. Just as other actions on the platform, inquiries and answers reinforce to the reputation through the community response. Giving a decent answer to an inquiry benefits in terms of bounty tokens, reputation, and potential chance of being cited, making a significant incentive for actively sharing mid-research achievements. To prevent abusing by the requester, a single answer would disable retraction of inquiry. To promote more inquiries and answers, digital tools specialized for specific research fields will be integrated to the platform.

On-demand inquiries will further motivate academics to share their information arising in the middle of research progress. Moreover, they would provide some aspects that were missing in traditional peer reviews, such as validating data and reproducibility.

[Potential issues]

- It seems quite ethical to the research integrity that the author should be requesting for data validity and reproducibility of a research. Settling this as a practice for academics would be a challenge. Best practice is, of course, these procedures being included in the peer reviews.

- Whether to give requesters choice over bounty models. They might choose among i) unpaid ii) requester decides iii) community decides.

- Whether inquiries and answers can be set forth its copyright policies as well. Researchers might rather stand defensive in sharing information if they are mandatorily open and free, especially for those of significant value.

4.4.5. Resource Allocation

With the aid of reputation and transparency of the platform, resources for entire research industry can be allocated through the platform in a transparent and efficient way. Such resource allocation includes but is not limited to management of research funds and decision of their grants, crowdfunding for research, recruitment or proposal for a joint research, renting of equipment and facilities, requesting or providing language editing service related research and etc.

Credibility of individual researchers can be inferred from their reputations. Evaluation on non-person entities such as employers, laboratories, institutes, or fund agencies can be made by community consensus as well. This would generate criteria for deciding a better allocation of resources in both supply and demand side. Even decisions of these resource allocation can be left to community consensus in a long run.

Putting the records of interactions in these resource allocations transparently on the platform would enable far more applications. Managing a trace of equipment status and renting records on the platform would expand to a service for equipment management, repair, or insurances. Crowdfunding and research grant management, if recorded transparently, will enable further transparency in entire flow of funds in researches, from fundraising to actual use of funds.

[Potential issues]

- Strategies to attract organizations to use the platform for resource allocation should be prepared.

- Crowdfunding, in general, promises to reward the contributors proportional to the contribution. Research crowdfunding would require a whole new concept of incentivizing crowdfunds. Contributors might be given free copyrights over the contributed research.

- If the actual transaction, beyond the decision making, of resource allocation is to be made over the platform, a well-designed form of contract for each type of resources is required.

In conclusion, Pluto ultimately will become a comprehensive solution for entire research industry, where the major players, individual or organization, get an overview of information and value management for their research projects. Together with reasonable and transparent system that boosts the interactions between players, academic societies will witness the progression accelerated to the degree that is never seen before.

5. Impact

Pluto, decentralized scholarly communication platform enabled by blockchain and its smart contracts, will make communication between academics more transparent and reasonable than ever. Most of transactions involved in the entire research industry will be integrated into the platform, from the core features like peer evaluation and dissemination of academic works to the general features such as resource allocation. By making these transactions in the research fields transparent and efficient, the global research industry will work with greater efficiency, and academics will interact with each other in a whole different way.

Individual researchers will save lots of resources and efforts that were unnecessarily wasted in traditional communications. There would be no excessive efforts needed to keep alignment to the formatting and other requirements for separate journals. There would be less need for repetition of burdensome experiments when academics actively share their mid-research achievements with their co-researchers, while they get acknowledged for sharing those data. Time and resources are further saved as publication procedure becomes more simplified. Funds are literally saved and reinvested directly into research itself as the cost of communication strictly diminishes.

These spare resources saved with use of Pluto, will aggregate to more than 80 billion U.S. dollars.[27] Resources will then be reinvested to researches, generating much more scientific values. Economic values transferred on Pluto further generates value in academia since they are mostly exchanged directly between researchers without any third party intervention. The positive feedback of Pluto will drastically increase efficiency of scholarly communication as more academics begin to use it. As a consequence, more and more resources will be reinvested in academia, give additional opportunities to researchers, and make Pluto more effective.

On top of efficient communication among academics, Pluto shifts the paradigm of academia. As researchers are acknowledged with not only the traditional papers but also many other mid-research works, the lifetime value of researches will be fully utilized. Researchers are relieved from the pressure of publication, and truly focus directly on research activities. Unlike the current practice where every step of research is directed to writing a paper with great impact, Pluto empowers all intermediate activities of a research project where their outputs, including the final paper, play a role of delivering the ideas. This will promote lots of research ideas and information to be shared around researchers generating further more knowledge, just as Johannes Kepler had come up with his theories after analyzing Tycho Brahe's data.

Pluto changes the way researches are evaluated as well. Currently most researchers, when they search for references relevant to their studies, collect hundreds of articles with keyword search, and then skim through titles and abstracts to find suitable ones. Community-based public, quantitative evaluation score strengthened with reputation system on Pluto will give a standard for finding target papers for academics. Researchers can utilize these evaluation scores to sort their references in ascending/descending order, efficiently obtaining more proper research achievements. Furthermore, the practice of validating data and experiment reproducibility on Pluto helps filter truly valuable researches.

The objective indicators of performance given in both reputation and evaluation scores transforms how resources and opportunities are offered to researchers. Along with various mid-research outputs getting acknowledged in Pluto, peer-reviewing activities are also credited as contributions to the field. Young, emerging researchers will have chances to build up their reputation with more options of activities. These reputations of researchers then work as

a basis for allocating resources, such as grants, employments, equipment and so forth. The elimination of excessive paywall will especially enable researches in developing countries.

These changes in scope of research achievements and how academics share and evaluate them will foster the global R&D market with currently more than 2 trillion USD.[28] With the paradigm shift in how academia works, the number of digits for the global R&D industry will increase, and the scientific value those numbers account for, i.e. the knowledge, itself will be significantly greater. Humanity will witness groundbreaking advances in challenges like Millennium Prize Problems, incurable diseases, quantum computers, or sustainable energies. Efficient and reasonable allocation of resources and opportunities will further promote the global research industry. Unlike current unbalanced distribution of scholarly communication where North America and Europe accounted for roughly 70% of total market,[29] more academics from diverse areas will join the advance of knowledge with fair opportunities.

In short, transparent and reasonable scholarly communication of Pluto will save the unnecessarily wasted resources in traditional system, to be reinvested in academia and research itself. The paradigm shift in academia by Pluto will not only ensure quality improvement in researches but also expand the size of global research industry. These influences are further amplified as more academics from the world are given fair and even opportunities. The whole impacts of Pluto, or the decentralized academia of humanity, will take the knowledge of humanity to another level, thus the prosperity of mankind.

6. Roadmap

The end goal of Pluto is contributing to the academic society with a transparent system without need of trust, where the 55 million academics worldwide,[30] or the global costs of $80 billion, find their own place, prove their 100% potentials, and contribute to the academia with fair opportunities and rewards. To achieve the mission, Pluto team will establish a stable, decentralized platform using blockchain technology and create an ecosystem beneficial to both researchers and relevant institutes.

Pluto's roadmap has three development stages, and each stage will support more features. On the way, Pluto aims to steadily penetrate the industry with strategic endeavors in attracting more researchers. The first stage will be a Proof of Concept prototype to prove the potential of open, transparent discovery service with a post-publication public review feature. Second stage will be the major integration of the service with public blockchain ledgers to ensure provable transparency and incentivizing. Third stage will be supporting direct publishing of research findings to fully work as an alternative to current publishing platforms. Followings will list full features of each stage.

6.1. Phase 1 (1Q, 2018)

- Normalized database of existing academic papers
- Discovery service with full visibility on citation mappings and impact indices
- Researcher identity verification
- Post-publication evaluations

6.2. Phase 2 (2Q-3Q, 2018)

- Open APIs for normalized database
- Data migration to public blockchain
- Distributed authentication plug-in using blockchain accounts
- Value transfers / payments through rootchain cryptocurrency
- Incentivized, portable evaluations (exportable to other platforms)

6.3. Phase 3 (4Q, 2018)

- Full-functional publishing platform on public blockchain
- 3rd-party application integration (research & publication tools)
- Platform token distribution

As the team achieves the above development stages one by one, more researchers will be incentivized to participate in the system. The ultimate goal of Pluto beyond this roadmap is to build an integrated research information system, decentralized on a public blockchain, to ensure transparency on the entire global academia, and enable seamless experience in whole research industry.

7. Tokenization

7.1. General Explanation

Implementing an autonomous compensation mechanism requires the aforementioned “Smart Contract” system from a public blockchain. Regarding the current infrastructure and specifications, Pluto service will be implemented on Ethereum network, and Ether, the base cryptocurrency of the network, will be used as the medium of value transfers in the early stage.

Most features of Pluto service can be implemented without an independent currency system. To attract early stage users to actively participate in the system and align their contributions with the growth of the system, tokenizing is a necessity. Obsolete legacy systems usually are focused on compensating the initial investors with their shares and dividends, but often fail to reward the actual users who contribute to the growth of the system. It is the key differentiator in decentralized systems to well incentivize the contributors. Holding some stakes of the system will compensate the contributors when the system grows, thus motivating more contributions, and the other way around, system tokens will be given as direct rewards to contributing activities.

An independent token economy will enable the issuance of the currency in accordance with only the system it belongs to. This can be utilized to incentivize users on certain activities to accelerate the growth. Registering, inviting newcomers, submitting papers, and reviewing are such activities that will further increase the total value of the system. Tokens will be newly issued and distributed such contributors under a predetermined protocol.

7.2. Token Distribution

Tokens are planned to be issued with following distributions. Detailed numbers and proportions are subject to change.

<table>
<tr><td rowspan="5">Actual User</td><td>Registering</td><td>50,000,000</td><td rowspan="2">Research Community</td><td>Advisors & Supporters</td><td>50,000,000</td></tr>
<tr><td>Inviting</td><td>50,000,000</td><td>Partnership</td><td>100,000,000</td></tr>
<tr><td>Reviewing</td><td>100,000,000</td><td rowspan="2">Foundation</td><td>Team</td><td>100,000,000</td></tr>
<tr><td>Submitting</td><td>100,000,000</td><td>Initial contributors</td><td>200,000,000</td></tr>
<tr><td>Transition</td><td>200,000,000</td><td colspan="2">Reserve</td><td>50,000,000</td></tr>
<tr><td colspan="6">TOTAL</td></tr>
<tr><td colspan="6">1,000,000,000</td></tr>
</table>

About half of the tokens will be allocated to actual users of the platform, by rewarding their contributing activities. Regarding that majority of the research community will be also potential users of the platform, the proportion of tokens allocated for platform users will probably exceed at least 60% of total issued. Initial contributors are fundraising organizations in the early stage which will back up the operating expenses for the team. Supporters

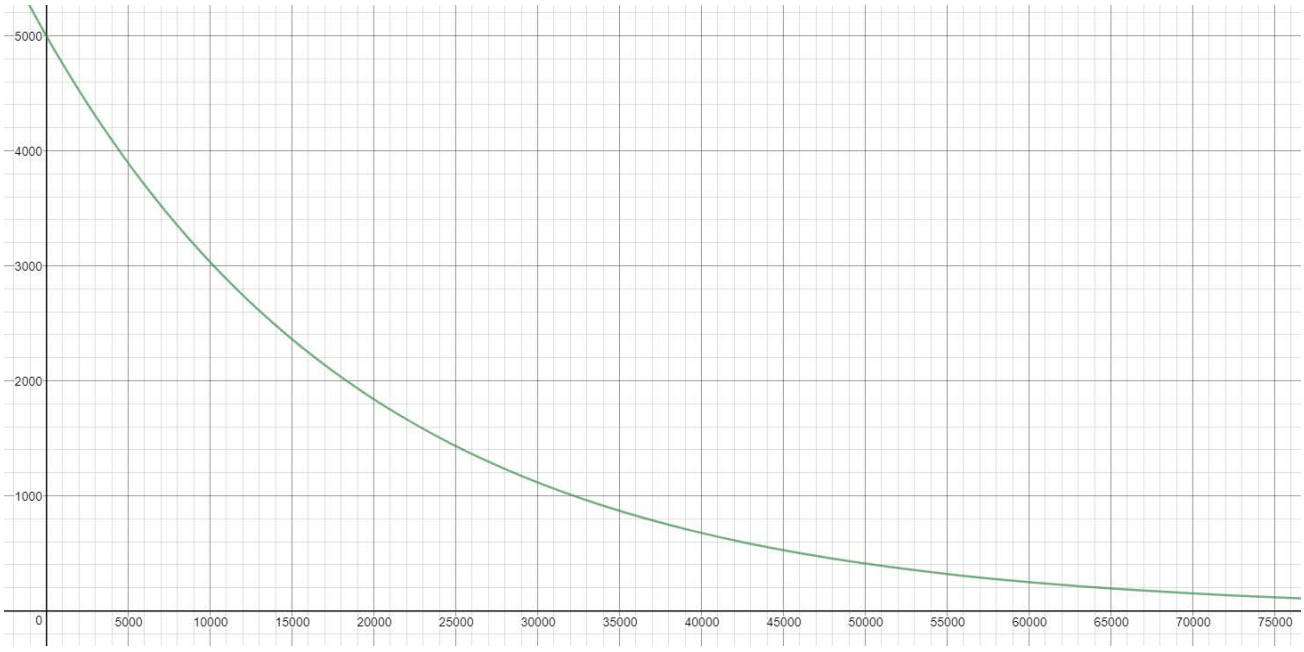
are advocates of open science who will be rewarded for promoting the project around research communities.

Tokens allocated for transition refers to those exchangeable from Ethers (one-way). After cumulating sufficient record of activities on the platform, users with contributing activities more than certain criteria will be able to change their Ethers to platform tokens with some discount rates. Note that this exchange of Ether to platform token will only be available when the tokens, thus the platform, are proven enough values from the community. This transition is purposed to be give-away for incentives rather than fundraising for the platform.

Rewards for user activities will be given in corresponding functions decreasing with the number of actions on the platform. That is, earlier contributors will receive more tokens as rewards. Following table describes each activity and the reward functions for X^{th} action of respective category. The details are subject to change.

	Description	Dist. Function	$\int_0^\infty f(x)\,dx$
Registration	Sign-up and verifying researcher ID	$f(x) = e^{(\ln 100 - \frac{x}{5\times10^5})}$	50,000,000
Invitation	Inviting a new user	$f(x) = e^{(\ln 1000 - \frac{x}{5\times10^4})}$	50,000,000
Reviewing	Evaluating papers by others	$f(x) = e^{(\ln 2000 - \frac{x}{5\times10^4})}$	100,000,000
Submitting	Submitting own paper	$f(x) = e^{(\ln 5000 - \frac{x}{2\times10^4})}$	100,000,000

All the functions have constantly increasing slopes, with decreasing rewards converging to zero. The graph of the rewards for submitting papers would look as follows:



8. Team

Junseon Yoo, Project Lead

When Junseon was young, he wanted to be a great physicist like Edward Witten. However, while studying in POSTECH he realized that he's not as smart as to solve the secrets of the nature, so he changed his major from Physics to Industrial Engineering. After changing his major, he had careers in startups in the field of Entertainment, Social Media, and Virtual Reality. In 2016, when he was fascinated by the concept of Ethereum and decentralization, he was writing a paper with one of his colleagues in the university and noticed the existing problems in academic publishing. He gathered the team and started this project.

Hyeon Lee, Technology Lead

Hyeon majored Computer Science in POSTECH. His subjects of interest in the field included: computer architecture, data mining, and artificial intelligence. His first exposure to programming was android application and web programming, and he's experienced large scale weblog processing engines, SNS back-end systems, and etc. Since he met Ethereum in 2015, building completely decentralized and autonomous system is what he has been focusing on.

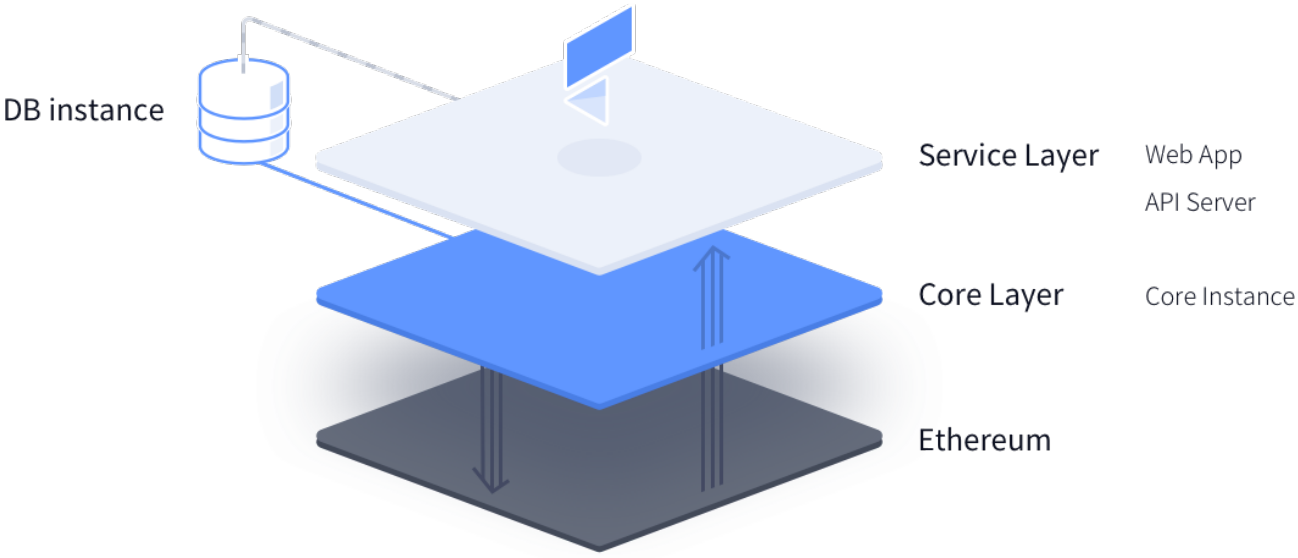
Taeheon Lee, Back-end Engineer

After graduating POSTECH Electrical Engineering, Taeheon has been working on software development including designing large-scale server monitoring system and handling big database. After he'd heard about blockchain technology, he was fascinated by the concept of 'Decentralization' and 'Autonomous System'. Authoritarianism and Centralization in academic society discomfort him, and now he believes that decentralized autonomous system can accelerate scientific progress.

Mill Shin, Front-end & Project Manager

Beginning with elementary school, Mill got interested in software development starting with QBasic. When he was a child, he engaged in computer programming with creating and distributing game trainers (memory editing programs). After receiving Bachelor of Economics from Chung-Ang University, he started his career as a developer in IT startups. He worked hard at Frontend, DevOps, and so on. Mill has also engaged in the Global Open Frontier program from KossLab, a Korean government agency which invests in open source communities. He enjoys exploring bleeding-edge technologies, and nowadays blockchain is the one that draws his mind.

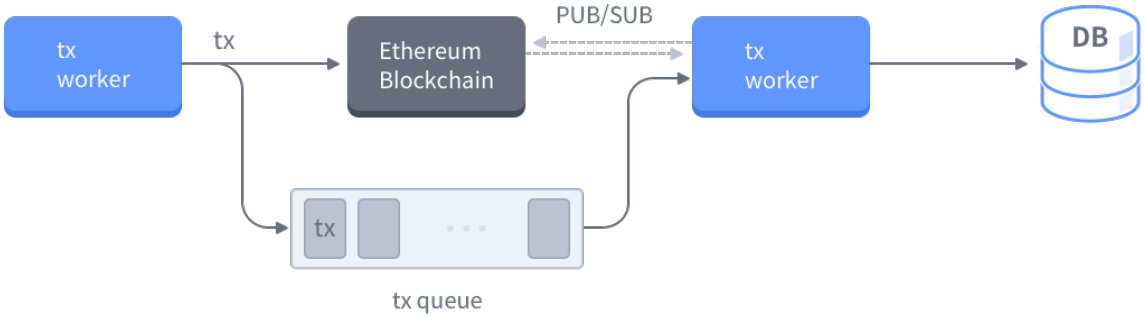
9. Platform Architecture



9.1. Architecture Description

The layer of Pluto can be divided into two parts: the core layer for communication with the blockchain and the service layer for interactions with the user. The core layer transparently manages the data existing in the service by exchanging transactions with Pluto's smart contract existing on the Ethereum blockchain, and provides the service layer with the requested data. The service layer provides data to the user using the web application, and provides immediate feedback through the DB instance.

9.1.1. Core Layer



The core layer manages blockchain related events such as Pluto wallet issuance and data recording. If a transaction request occurs within a service, the associated instance generates the transaction on the blockchain, and enqueues a series of data, including tx hash, into the queue managing transactions.

After recognizing that the event has occurred, the worker instance fetches it to observe the transaction processing status and update it. In addition, unlike other services that communicate with the blockchain using personal wallets such as Metamask, the Pluto ecosystem is made up of PLT tokens alone. Therefore, issuing a wallet is also done through the same process as other transactions through the smart contract managed by Pluto.

Moreover, if the data is affected by the order when it is written (for example, if Bob leaves a review on it as soon as Alice shares her research), concurrency issue may occur since the service layer records it in the DB

instance in advance. To solve this problem, the core layer receives dependency information and reorders it.

9.1.2. Service Layer

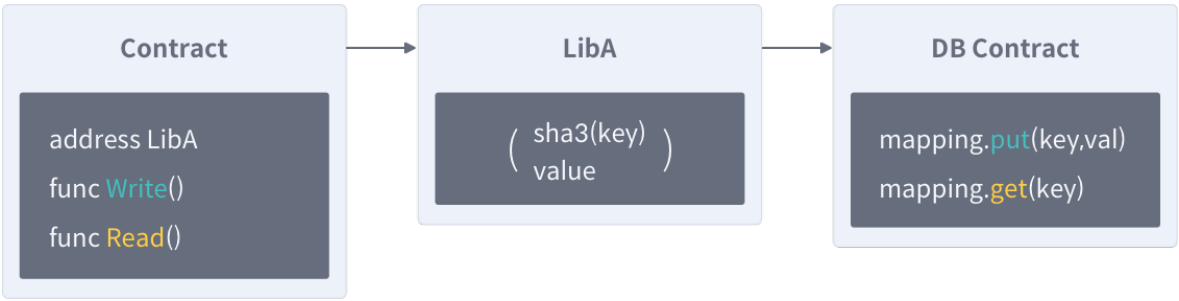
The service layer provides the Pluto web application, which provides an interface that simplifies communication through blockchain in Pluto service while providing requested data. In addition, the service layer manages the authorities related to Pluto service users and subscriptions, and caches blockchain data in DB instances. In addition, the service layer checks the transaction processing for each data record and analyzes the dependency on it to resolve the concurrency issue described in Section 9.1.1.

9.2. Smart Contract Architecture Description

Pluto's smart contract consists of the user contract that manages the user's identity and wallet, the DB contract that records events occurring in the service, and the reputation contract that manages the reputation of the researchers.

Since PLT Token is used for all economic activities in Pluto, smart contracts managed centrally are required at this stage. Currently all contracts are managed through Pluto root wallet. When data is written to the smart contract, the hashed result value through the field identifier and the primary key becomes the key. They are then stored in a hash bucket that matches the type of the field.

The user contract issues a wallet contract to be used as an identifier of users in Pluto, and records the information of users in the contract with the address of the contract as key. Here, information such as email, name, institution of users is recorded.

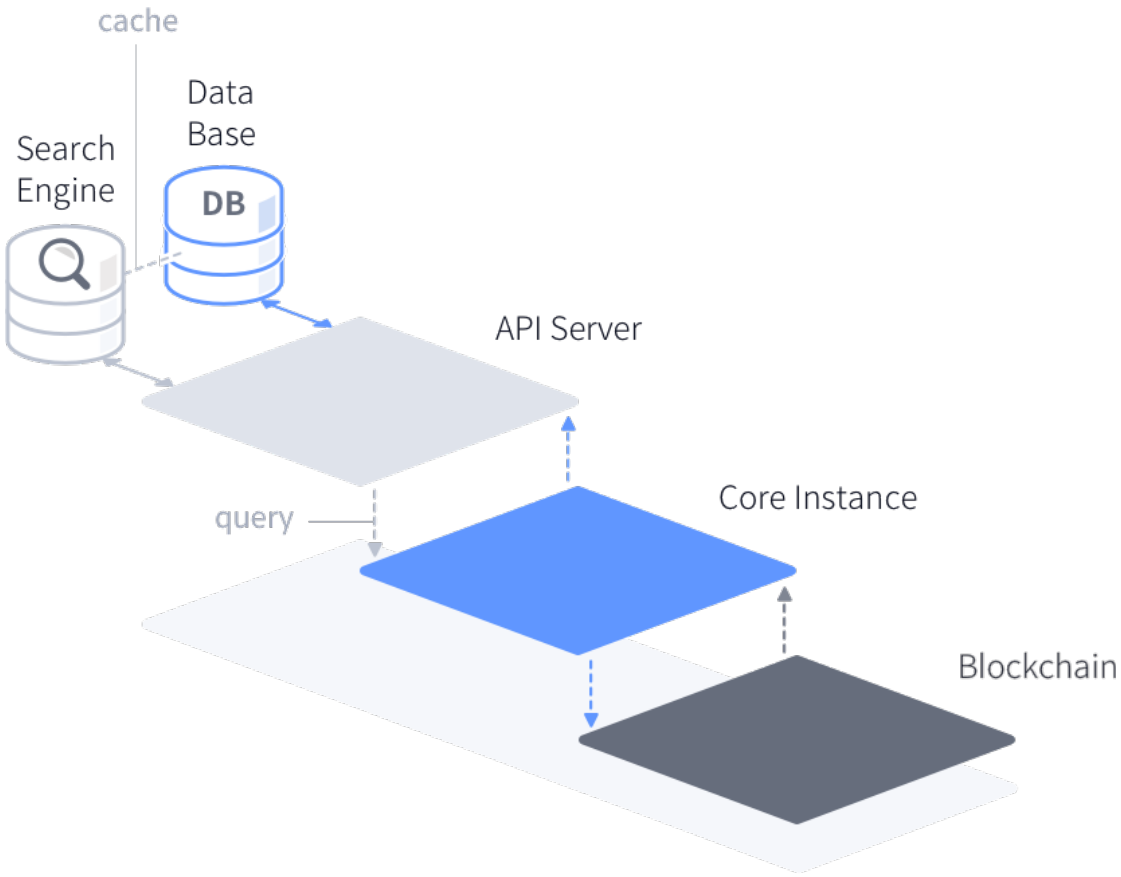


The DB contract exists to record a series of events that are performed inside the service, such as uploading an article. Since every event has a different data format, the DB interface is maintained consistently while allowing access to the data using different libraries to handle it.

Finally, the reputation contract manages the reputation score which is the evaluation index of the users in Pluto. The contract works similar to a typical ERC20 contract, but the reputation score is affected by almost all of the actions taking place inside Pluto, and a temporal damping occurs where recent actions have a greater effect than outdated ones. These features mean that frequent transactions can occur in contracts. Therefore, batch processing(described in 9.3.3) and fault tolerance of data update must be ensured by supporting WAL (Write Ahead Log) in the core layer or using side chain (described in 9.4).

9.3. Database on Pluto

Since all data of Pluto is recorded in blockchain, data transparency and consistency is ensured. However, querying data recorded in smart contract is inconvenient and takes a lot of processing time at present. Therefore, it is very difficult to provide the search function for a specific keyword. To solve this problem, Pluto uses an external DB instance that caches the data recorded in the blockchain. This instance supports query and search function. Also, it is used to record the log of user behavior, which are used to improve the service function in the future.



9.3.1. Indexing/Caching Data

In Pluto, the data recorded in the Blockchain is in a specific format according to its type, which means that the data is designed to be recorded in a relational database (RDB). These data are first stored in the RDB, which is the data source that the service layer refers first. In addition, the additional data (serial number, category, subject, keywords, abstraction) needed for the search is cached in a search engine such as Elastic Search.

9.3.2. Querying/Searching Data

As mentioned in Section 9.3.1, the data source that is referenced first in the service layer is the data cached in the RDB. The service layer executes the query on the RDB to retrieve the data. If the user needs a keyword search, the service layer executes a query on the search engine and retrieves the corresponding data.

If the DB instance becomes unavailable for some reason, the service layer sends a data querying request to the core layer. The core layer that receives this request directly accesses the blockchain and fetches the data through the method written in the smart contract and delivers it to the service layer. (In this case, only limited querying is supported.)

9.3.3. Considerations about data consistency

When caching data written in the blockchain to the RDB, if a DB instance is unavailable or transaction writing fails during data I / O, inconsistency may occur between the data written to the blockchain and the data written to the RDB. To solve this problem, Pluto introduced several solutions.

The first solution is a fallback strategy that performs task queuing by defining each transaction as a task when a data I / O transaction occurs in the core layer. As mentioned in Section 9.1.1, the core layer sends a transaction for data I / O to the blockchain, and information about the transaction is sent to the queue of the task manager instance. The task manager instance which is in the idle state fetches it, creates a filter for the transaction and subscribes it. If this transaction is processed abnormally, then the instance accesses the DB to handle the failure (transaction retry or unprocessed data deletion).

The second solution is a periodic data update. This is accomplished in two ways: by caching via LRU(Least Recently Used) update and by updating via batch. In the first method, if the specific record is not read for a certain period of time, the service layer marks the data stored in the DB as invalid. The core layer then takes the data recorded in the blockchain and performs LRU page replacement. This allows synchronization with the data stored in the blockchain.

Batch processing is characterized by having a longer update period than the first method and more data to be updated. After a certain period of time, the service layer requests data to be updated to the core layer, and the received data is updated in the RDB to perform synchronization with the blockchain.

9.4. Considerations about Developing Pluto on Ethereum Network

The first consideration to implement the Pluto service on the Ethereum network was transaction fee and data transaction duration. In the case of a transaction fee, in the current Ethereum network, it is paid as Ethereum by the account issuing the transaction. However, this model was not suitable since Pluto service users use PLT Token to act on the platform. Therefore, Pluto created the delegator smart contract to execute the transaction of users. Thus, current Pluto service is handling all transactions through the delegator account. To autonomously change this part, we need a solution that can transfer signed transactions through each user's account.

In the case of a data transaction, when a user generates a transaction to store data on a blockchain, there are problems with the duration until this transaction is confirmed, and data type storage incompatible with the blockchain. When a user writes data on the Pluto service, it is not immediately visible to other users because of the delay until confirmation.

It was determined that this would harm the user experience, such as writing simple comments on the platform. Pluto tries to solve this problem by using DB instance as write buffer.

In Pluto, research achievements are represented by various media such as text and photographs, and these data are hard to store in blockchain. To store these type of data in decentralized form, other services use decentralized file storage such as IPFS or Swarm. However, since the existing decentralized file storages do not support the permission function, it is difficult to use the subscription model supported by Pluto. Therefore, in early stage, we use general file storage and manage the permissions on the service layer.

However, the biggest difficulty in recording all the activity in Pluto on the blockchain is in frequent transaction occurrences. Examples of such transactions are voting, commenting or reputation updates. The occurrence of these micro transactions not only affects the main chain, but also causes frequent data I/O. To solve this problem, an off-chain type solution is required, so Pluto is considering the introduction of Plasma. Plasma is simply a framework for verifying child blockchains. Through the use of Plasma, it is expected that frequent transactions occurring in Pluto can be decentralized and autonomously processed.

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