Space Situational Awareness through Blockchain Technology

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ABSTRACT

Kessler Syndrome is a well-known consequence of high-density constellations in Low Earth Orbits (LEO). The rate of satellites being placed in LEO is increasing drastically, whereas the rate of decay of orbital debris is still the same. The current system that predicts collisions is time consuming and complex. At Earth level, it is difficult to maintain everything by a single system, which makes us move towards decentralized systems. This paper explores a self-organizing decentralized network of Ground Stations and Satellites.

The current system for tracking satellites and debris, takes a lot of computing power, and does not provide an accurate result. One of those systems, SOCRATES, predicted a close approach of 584 m, between Iridium 33 and Cosmos 2251 [1]. Those two satellites ended up colliding and creating debris. It is discussed how the new proposed system will aid towards the safety of the space tourism and satellite constellations.

A collision could be better sensed locally, instead of being predicted by distant systems. Just like blockchains, any information about new objects will spread from the node that detected it. A few types of nodes will exist in the network based on their task priorities. Possibility of “Consensus” utilization between Alpha nodes in the network, is discussed along with crowd sourcing. The Bitcoin or Ethereum, which are based on blockchain consensus, have a delay of about 30 seconds, which includes sharing and processing of the information by almost the whole network. Unlike this, the satellite network will take much less time, as the information is not to be processed by all nodes and it can use broadcasting features over wireless network. Also, all the nodes in the network will not require the whole blockchain in their memory, which will reduce the complexity of the electronics required on the satellites. Potentially, all the new satellites are supposed to carry this small electronic system which can be part of the network if required. Several uses for adding this block, like giving up its location if the orbital debris removal comes into picture, are also discussed. The network will prioritize the information about the current positions of the orbital debris and satellites but will also share the predicted impacts or close pass-by. This data will improve the statistical analysis for the conjunction assessment by making it more accurate and less complex than the current situation.

1 INTRODUCTION

According to this report [2] by Institute for Defense Analyses (IDA), USA’s Space Situational Awareness has more capabilities than any other SSA systems. The report points out that, the SSA systems are being upgraded, but we still have fewer observations for any Object-In-Space (OIS). High value assets like satellites are tracked continuously, but it is difficult to frequently track debris objects that are less than 10 cm wide.

The current SSA systems have limitations when it comes to “updating with spontaneous changes”. They try to anticipate everything very well in advance. Just a few collisions would make all that data absolute. This paper proposes a network, that will ease up the processes involved in Space Situational Awareness, using a decentralized network utilizing Blockchain Technology. The paper offers smooth transparent SSA operations, which makes it easier to decide, “who should bear the cost of maneuver?”. For future scenarios, where everyone could afford maneuvers, the system described in this paper could be turned into autonomous system. The report [2] from IDA, has case studies, where they have used a framework for their analyses. The same framework along with blockchain is discussed in this paper.

Section 2 provides a good reasoning the new SSA system. The design of the blockchain based SSA system is described in Section 3. This paper is an on-going project, and the requirements of the SSA system are still being collected and researched on. There are two major aspects of the research, 1 - the SSA system preferences from Spacefaring Nations and Institutes, and 2 - implementation using Decentralized Network, utilizing Blockchain Technology. Space politics and open source technologies are discussed in Sections 4. Section 5 outlines a few possible effects on the space environment.

2 NEED FOR A NEW SSA SYSTEM

The need for cooperation among operators and the inherent problems of mutual trust have been widely recognized in the literature [3][4], which was one of the reasons for creating Space Data Association [5]. For the Space Data Association's data center, there are several membership requirements and benefits such as Conjunction Assessment, RF interference, geo-location support and authoritative contact information for a given space object. It is important to note that it's a centralized solution, which means a central point of failure and ability to be controlled by single entity. Many companies are reluctant to share information about their satellites [2]. Even with official contracts, it is difficult for them to trust such a Data Center. Along with such trust issues, there's also some cost associated with it. The blockchain based solution offers more transparency and hence will aid towards building that trust. As blockchain is decentralized, the cost of building the system is proportionately divided, along with incentives or profits.

With increasing capabilities of SSA technologies, it is going to be difficult to hide space assets [2]. Certain measures could be taken in the network to maintain a level of anonymity. Once an object is detected in Space, it is important to identify it to contact the owner in case of a predicted collision. The blockchain solution offers anonymity and identification as well. It will be possible to associate the object detected to a network node, but the node may or may not declare its identity.

Currently only a few of the low earth orbits are crowded, but soon there will be more space traffic. The space around the Earth will be occupied by various types of satellites, debris, and spaceships containing humans. The ISS, in LEO, spends substantial amount of resources to avoid collision with OIS. Kessler described a scenario where a collision in densely crowded space, will start a cascading chain reaction of collisions [6]. Currently the time between two collisions is very low as number of objects in space are low, compared to the space available. As we launch new satellites and spaceships, state-of-the-art technology will be used in that. A more rigid material will be used to protect assets in space. These will protect them from space debris and meteoroids. It is possible that one of these could turn into space debris, and we won't be able to afford getting hit by such an object.

Companies like SpaceX, OneWeb, Swarm, are launching satellite constellations, that will cover the whole globe. Spectrum could be considered aa a limited resource. More companies will launch their constellations to provide service to prospective customers. With wireless communication, we have observed that certain applications have reached the saturation density, based on the availability of the spectrum or ability to transmit in the frequency ranges. Limitations could be authority induced or being not able to design specific transmitters. Somewhere down the line, we are going to hit the saturation for space as well. It may not stop the whole operation, but it will certainly add obstacles like interference, noise. One known limitation, that is currently being experienced by most of the companies is that there are different authorities/entities controlling the spectrum in sovereign states. In this paper, this issue is considered as limitations of Spectrum usage. For Radio communication, ITU-R maintains MIFR, which includes all the frequencies being used, and available. One of their goal is to maintain efficient use of the spectrum. For the future, ITU-R needs to develop more standards for the types of uses of spectrum in space. The system described in this paper, could use such standards.

Ideally, we would use Radars to detect any incoming objects, but it is difficult to detect and track smaller objects that are coming towards spaceship with a relative speed, twice the orbital speed. Avoiding such objects or countering, would have to be done in much less time. To counter this, what if satellites and spaceships broadcast such information collected from their radars. Similar technology is being considered for autonomous vehicles. The vehicle in front of you provides information about vehicles in front if it.

Let us consider one example scenario that happened in September 2019. There was a predicted collision between SpaceX's Starlink 44 and ESA's Aeolus [7]. From this scenario, two conclusions could be drawn. 1 - need for frequent updates on accurate locations, which will make it easier to assess the collision risk, and 2 - Reliable and fast communication as well as coordination between involved parties. This scenario had only two parties involved, and yet there was a problem somewhere. If multiple parties get involved, the coordination process will become time consuming, and we may not have enough time to perform safe maneuvers. The requirements of a new proposed SSA system are enlisted below. These are based on various conclusions from scenarios such as the one described above.

1. Frequent observations of objects.
2. Frequently updating catalog and sharing new objects with the whole network in minimum time.
3. Improved accuracy of observations.
4. Faster referencing with Catalog of known objects.

   a. New satellites or spaceship could carry a beacon node that will make it easy for tracking
   b. Commercial Satellites, spaceship, that know their own location, should broadcast it periodically.
5. A network protocol, that will enable optimized use of Spectrum.
   a. This protocol will co-exist with any protocol that is being used now, Software Defined Radios incorporating beam-forming capabilities.
   b. There will be additional security as and when required by the network nodes.
   c. Ability to connect satellites of different organizations and facilitating information transfer along with resource sharing.
6. Anonymity if required
7. New Architecture of Trust [3]

3 BLOCKCHAIN AND DECENTRALIZED NETOWRKS

Blockchain and decentralized networks offer unique capabilities. There are companies that are trying to utilize blockchain based decentralized network to connect the whole Earth. Companies like SpaceChain [8] are developing open-source blockchain networks that will operate in Space. It is difficult to sum up what is exactly happening in Space. A decentralized network will help us connect the dots.

Let us consider a network of satellites, ground stations, and potentially any device that has the capability of connecting to a wireless network. Let us call this network "Decentralized Horizon Network" (DHN). Some nodes in the network will perform more tasks and contribute towards creation of blocks. This will make the blockchain network a Consortium type [9]. Various aspects related to blockchain network are discussed below.

3.1 Consensus

The network, as a whole, does not require consensus. There is no proof-of-work for all the nodes. If a sensing satellite detects an object, it shares that information to the network. No other node will deny this information. On the other hand, it is possible that the same object is detected by another satellite and shared to the network. This will create duplicate entries. Here, there are two entities that would need consensus on the identity of the object. If the accuracy of the reading, from both systems is correct, then it can be mathematically proved that the two readings represent the same object and the newer reading will be used. There are different types of technologies that are used to detect objects, like optical sensors or RADARs. It will create readings with different accuracies. Combining these readings generates more accurate/high quality orbits. A tool or method as described in this paper [10] could be utilised in the DHN. The combination and utilization may require consensus. Once all the satellites, ground stations that detect OIS, submit the data to DHN, we will be able to see an overview of available observations. It would be possible to allocate specific ground stations to target certain objects that were not tracked correctly. Collectively, it would improve the readings. This could also be a special request from the network, and the ground station or satellite submitting that reading, will get (let's say) more currency to perform that task. All the sensors (satellites or ground stations) could gain consensus on tracking down objects, with more efficiency, and (potentially) covering almost everything in space.

Once readings are collected, orbits will be predicted by different entities or nodes in the network. There are number of ways to perform these predictions. Some universal constants are used for the predictions as well as for taking the orbital readings. Even if all the nodes in the network, use the same constant values, to the highest possible accuracy, we'll still end up getting an inaccurate reading, leading to an inaccurate prediction. This happens because the constants being used, are not exactly constant. For example, Gravitational constant has a relative uncertainty [11].

Once all the data is collected, regarding satellite orbits, it'll be possible to find out overlapping orbits. Here, the involved parties need a consensus on who will perform a manoeuvre to avoid collision.

3.2 Blockchain

Blockchains store information in blocks that are connected with cryptographic hash. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data. This is perfect for a ledger, where it needs to store all the transactions as they occurred and must be immutable. In case of DHN, immutability will be required to store orbital data corresponding to timeline.

Consider figure 1 that shows sectoring of space around the Earth.

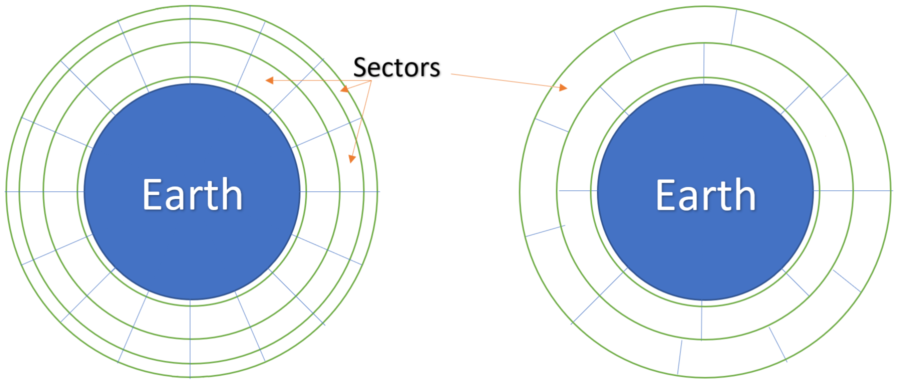

Fig. 1: Possible Sector Division

It is analogous to cellular network. Each sector will be pre-defined. Size of the sector will depend on some factors related to spacecrafts and orbits. Consider the following type of sector. A hexagonal face is selected to cover the surface of the Earth, like a soccer ball. Hexagon is the closest representation of a circle that could provide a regular tessellation. Radially outward lines are drawn through the vertices of the hexagons. Imagine concentric spheres of radii $R_{\oplus}+nL$ where n is a non-negative integer and L is length of the sector as shown in the Figure 2. Sector property *d* is adjusted such that the time *t* spent by an object in a sector, will remain approximately same. The shape of the sector is shown in figure 2.

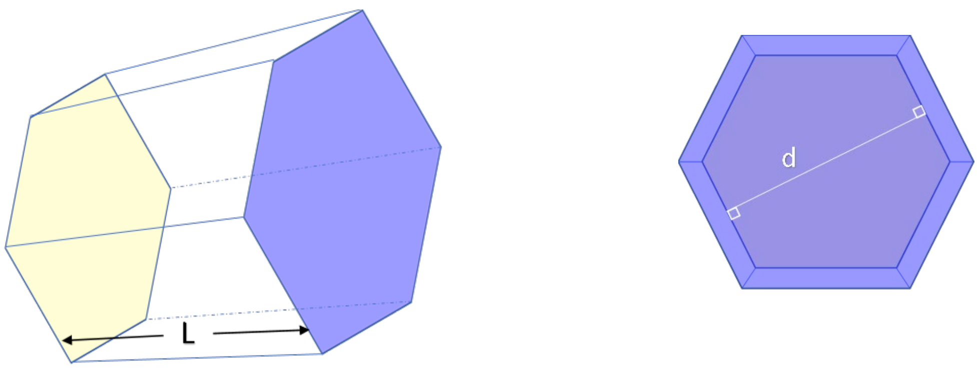

Fig. 2: Sector Design

In this case of sector shape, it becomes a complex process of determining the sector as compared to cubical sector. Each sector will be associated with a time span *t*. The time-spans will be predefined epochs. Such sectors are referred as “T-Sector”. Properties of t-sectors –

1. Position around Earth, in Geocentric Celestial Coordinate System
2. Area, Volume, and other sector specific information, that will not change over time
3. Unique Identifier, Alphanumeric
4. Caretakers, stakeholders if any
5. Timestamp, and time span.
6. Predictions if any.

More research is required to define sectors. These definitions could be applied to any celestial body. Conventional coordinate systems could also be used to define sectors. In any system, we need a sense of orientation for the reference body. For example, setting the reference for the North pole and South pole, and setting the 0 longitude somewhere on the body. It is important to create a reference system or define a convention which will automatically define a reference. One of such convention is the definition of the North pole. This paper concerns primarily about the Earth System, hence all the references are well known, which would be used to define the sectors.

Blockchain hashing and immutability property will be used in maintaining t-sectors that correspond to different epochs. For example, data for all the sectors is generated for epoch 1 and some Satellite Z decides to do a maneuver from epoch 5, it’ll broadcast that request to respective nodes, and the miner will add it to the blockchain. Based on the time of maneuver, the miner will create a new branch or update existing branch from epoch 5.

After collecting tracking data for object X, it's orbit will be predicted, along with possibility of error, which is added to consider perturbing forces. The egg shell of this predicted orbit will pass through a lot of sectors. Object X will be added to each t-sector, that is touched by its egg shell. In this way, data will be generated. Let's call the collection of this data, a catalog. This catalog has all such sectors and past-present-future time spans, with list of objects passing through at that time. Dividing the data into sectors, will make it easier to divide the computing power. The t-sectors that contain more than a certain number of objects, will be flagged. Different computing beta nodes could compute different sectors. It is possible to combine sectors of an orbit for convenience.

Multiple nodes will detect same objects. Different readings of the same object could be resolved in several ways. Initially, an accepted deviation is established for the consensus. This will resolve a lot of issues related to orbit determination. This approach is not going for precise location of the tracked object, but an approximate sector for the same. At the end of predictions, there will be a few entries in one epoch, where same object exists in multiple t-sectors. This is where miner nodes will require a consensus. For the purposes of tracking and predicting collisions, it would be a minor set-back. Unless the blocks are predicted to be congested, it will be safe to wait for the next reading of that object. If the next reading is obtained, then the predictions will be altered, and hence the previous consensus will not be valid or required.

3.3 Smart Contracts and Decentralized Autonomous Organizations

There are some processes that happen over a period of few days to few years, whereas some happen within minutes. The work of ITU, would fall under long run processes. Tracking and avoiding debris are short lived processes.

A DAO for orbital position allocation could facilitate smooth space operations between space agencies. A spaceship could book a certain path through space at certain time, which would be avoided by others. This path will be selected based on the data available in DCH. Similarly, frequencies for special operations could be booked for usage. Every year, ITU-R has to resolve a lot of reports regarding interference on allotted frequencies. There were 92 cases of harmful interference received in 2014 [12].

3.4 Gas, Currency and transmitting power

In a conventional blockchain network, a currency is created in order to facilitate different operations and transactions. From the initial judgement of the space network, it would be difficult to put incentives based on unknown factors and scenarios. Once the network usage, node performance and maintenance are thoroughly explored, transaction costs, mining rewards could be decided.

Gas and its limits are used to pay for the use of resources of the node. Time and computing power decide the cost of transactions. Conventional blockchain networks use internet as the backbone network. Hence if a node is offering power instead of transaction cost, it will not be able to pass it on through that network. It is possible to provide power along with a small transaction cost.

Satellites in Sun-synchronous orbit have access to all the power they need, from the Sun. Rest of the orbits have a phase of eclipse somewhere in their orbit. Batteries are used to power the satellite in those eclipse times. These Sun-synchronous orbit satellites can provide power to other satellites via beam forming. In short, satellites that have plenty of power, can pay by transmitting that power to the destination node. More research would have to be done for such cases. If it is possible, it opens a large set of applications where satellites may not have to carry batteries at all. Circuits that get activated by beams and perform the task required.

3.4.1 Energy Harvesting and Gas transfer

As more satellites are launched, there's more energy being transmitted by satellites. It is possible to use the RF ambient energy for low power applications [13].

3.5 Network Nodes

There have been a lot of types of implementations of blockchain networks. For the application described, a practical approach of designing a new type of network is required. If we consider the existing architectures that are already in space, they mainly consist of networks of satellites that follow their own protocols. There are constellations being launched for different consumer requirements. Each of these clusters have their own networks. In order to make use of these networks, an inter-network protocol would have to be designed. Based on the use cases, and nodes required to facilitate the network, nodes are divided into following types –

(α) Full node, miner, broadcaster – Alpha Node
(β) Special purpose nodes, routers, sensing satellites – Beta Nodes
(γ) End user nodes, Spaceships, Satellites, Space Stations – Gamma Nodes

The Gamma nodes would get served for all the purposes required. Beta and Gamma nodes do not have to carry the whole blockchain or block set. There will be special contracts between Alpha and Beta nodes (service nodes). There will be a limited number of Alpha nodes, based on the communication availability on the node and reach of Alpha Nodes. Redundancy could be introduced by adding sleeping Alpha node, which will get activated only if the Alpha node in certain area stops functioning. Alpha nodes will act like the backbone of the network. Service nodes will have to keep some digital currency in holding for the service they are providing. These are essentially getting incentives for the service, but if they fail to perform up-to the required mark, a penalty would be taken from them. This is where consensus will come into picture. In addition to this penalty, a reporting system will be implemented, where network nodes can report issues about other nodes that are either functioning incorrectly or faulty communication. This will help in terms of building a metric for reliable communication. It can be used to set the incentive values. It is easy to abuse such a system, and hence security of this system needs to be explored thoroughly.

Satellites, or ground stations that track objects in space would be beta nodes, as their primary task is not related to facilitation of the network. Similarly, the nodes that do data processing would also be beta nodes, which would be conveniently placed on Earth. If there's a node in space, with extra computing power and battery power, then it would be used for minute changes related to refining predictions. The Alpha nodes could perform beta node operations. From Fig 2, Alpha nodes can act as Beta as well as Gamma.

Storage is limited and expensive resource in space. For the network to operate smoothly, it would have to maintain a few past epochs and more future epochs. Technologies like Inter-Planetary File System (IPFS) will be useful to store old blockchain data [14].

For better tracking, a small device or tracker will be designed that could be placed on new satellites or objects. The satellite operators can turn it off at any point. This will make it easier to track down satellites and identify them. Such satellites or objects will be Gamma nodes in the network.

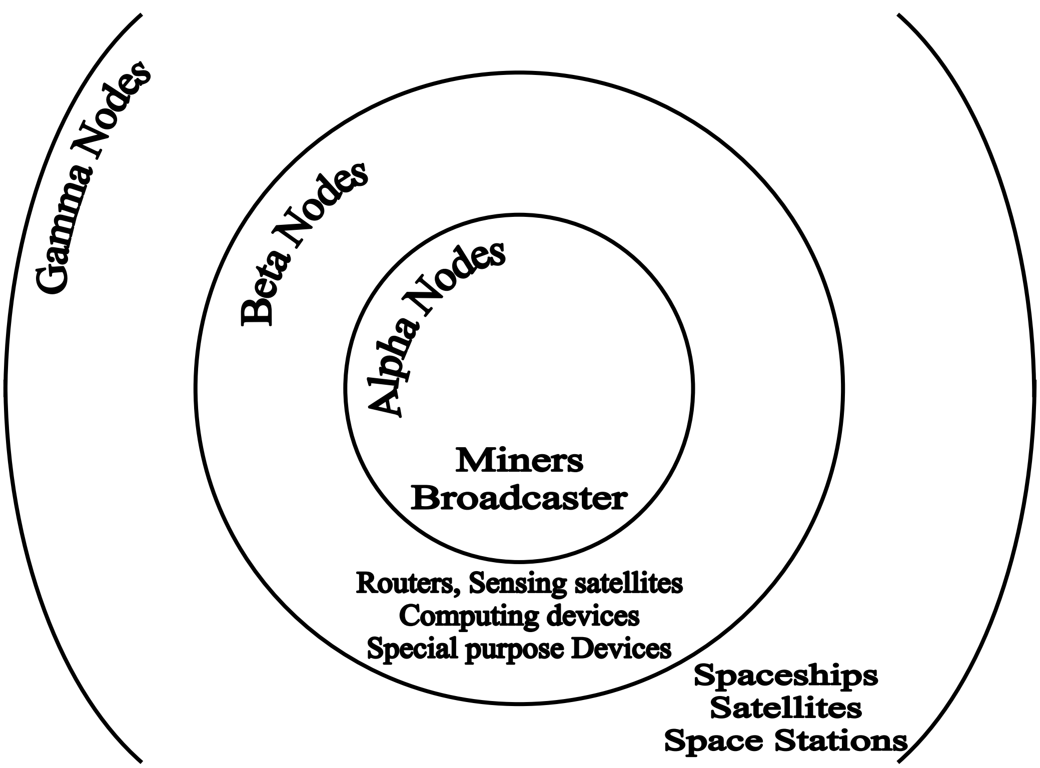

Fig. 3: Venn diagram of network nodes

3.6 Security, Trust and Anonymity

There are a lot of known issues regarding security in blockchain networks. In the case of DHN, protection of Alpha nodes gets more priority than other nodes. Attacks on conventional blockchains are mainly because of the currency or data involved with it. Those reasons won't come into picture for the Orbital Debris. However, a network could not be left susceptible to threats. Various aspects of security are required to be explored.

A mechanism of Growing trust would have to be implemented. When a new node joins the network, without human getting involved, how could the network determine if the node is "good" or "bad"? Audits could be performed by network nodes, that would create credibility metric for the node. Reporting could be used that will report issues about the nodes. These are preliminary ideas which will be tested with the network.

3.7 NETWORK ARCHITECTURE AND FRAMEWORK

The vision of the blockchain based SSA system matches with the framework described in the report [2] from the Institute for Defense Analyses. The framework is shown in figure 4. The network nodes will interact with each other on the application layer using blockchain protocols, along with some additional protocols.

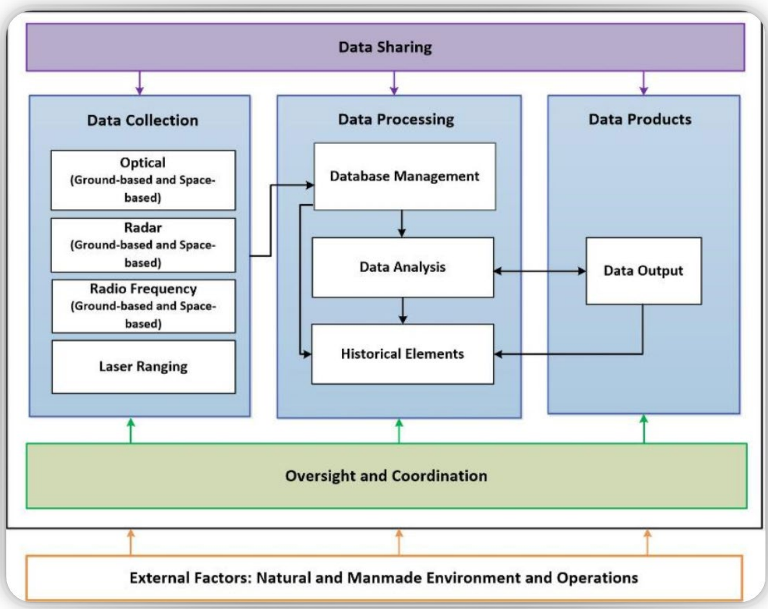

Fig. 4: Framework; credits: IDA [2]

Blockchain will be involved in Data Sharing, Data Collection, Oversight and Coordination. It will provide Data Products that will be used for "Oversight and Coordination".

DHN will have a backbone decentralized wireless mesh network of Alpha Nodes. For the initial deployment of the network over a large scale, this backbone is required to facilitate operations. Developers will design the blockchain protocol that serves the network. As blockchain is a fairly new software platform, having academics involved in the blockchain strategy system ensures that it is continually challenged and researched in varying disciplines.

Miners, industry bodies and traders are the stakeholders for networking. In a conventional blockchain, priority is given to "verifying the transaction and gaining consensus on the same", which starts a race for hashing. Gaining consensus on processed data is much more important than consensus on detected object. This is the part where a collaborative effort is required from all data processing units. Current SSA systems don't have an easy mechanism to do this. DHN would have to incorporate such networking between nodes.

In order to incentivize this process, we need the exact resource utilizations. More research would have to be done on this, to make it incentivize fairly. Until this incentive is not figured out, a yearly membership could be given to the members of the network. This ensures smooth initial operations and aids in the development of the system. This is similar to initial coin offering, where instead of tokens, unfettered access to the network is given to the nodes that will join.

3.8 NETWORK PROTOCOL

Blockchain networks mainly rely on some network architecture, that facilitates the connection between nodes. For blockchain in space, there is no such network architecture. It would have to be built from scratch. There are companies that provide backbone to such architecture, but it would be more centralized solution. If a single entity owns the backbone of the network, there exists a central failure point. A new network protocol would have to be designed, that could be run with the assumption of multiple available channels. Unlike a centralized network, there could be two simultaneous connections in a decentralized network. This is like an Ad-hoc wireless mesh network. It differs from the Ad-hoc network in a way that there are different entities that own the nodes of the network. A conventional Ad-hoc network gets a prior set-up time. For this space-based network, there should be some protocol that will automatically configure the network. With addition of nodes, and changes in environment, it must adapt. Changes in environment could be a Solar Flare, or someone else using the frequencies that the network was supposed to use. If a certain path of the network becomes unusable, it must be able to reach the node using a different path. These are computational challenges, as well as counter measures for known problems.

More research is required on the pointing out the requirements of the network protocol. One important requirement could be that it must use minimum bandwidth. With software defined radios, it is possible to transmit and receive signals at different frequencies. It would be wise to build a protocol that could utilize more frequencies, if required. As the density in DHN grows, a single node will not have to communicate to distant nodes directly. The network protocol would have to incorporate such scenarios of various densities.

3.9 Network node on each satellite

Wireless networks enable us to triangulate a signal. Based on the data from communication signal, it would be possible to take a reading of orbital location. In this case, the reading of the object is not accurate, but there are several approximate readings. It will enable the sensing satellites to look into certain directions in order to get an accurate reading of that object. Approximate readings could also be useful in the prediction of orbits, which will fill various blocks. As more readings are collected, the data would be refined, and fewer objects will exist in blocks. An acceptable accuracy of the readings would have to be established.

3.10 Secondary use cases and priorities

Spaceships, Satellites and Space Stations will make use of DHN. These will provide currency or power for operations. DHN can be a network of smaller DHNs, because of the inclusion of special purpose beta nodes. These nodes will allow the connection to external networks. For example, a spaceship needs the information about a recent solar flare and that information is not available in its DHN. It would have to search the same in some database that is connected to the Internet. Such special request will go through a node that is connected to the internet. Entrepreneurs can develop IoT or Internet applications and utilize the DHN for their consumers. It is important to note that the priorities of the DHN would have to be specified. The highest priority is given to the tracking of debris and sharing the same information. This could be analogous to the radio communication, where certain frequencies are allocated for distress signals.

There could be incentives on sharing critical observations. For example, a company wants to track down its satellite. They could set a bounty on the tracking. The node that submits the correct information, will get the bounty for that. Another incentive could be given to a specific network path. Assume a scenario, where a satellite is over Russia, and it needs to connect to its station in Los Angeles, it would need a relay network. This relay can be incentivized. This requires more research to be done on such use cases.

Space weather has a lot of on-going research which could benefit from DHN. For example, a satellite could carry a certain type of sensor along with its payload, and that sensor information could be collected by DHN and provided to the research community. DHN could contain a decentralized data marketplace. It would be easy to incentivize this process, which will generate interest in a lot of satellite companies to add that sensor. Satellite and Orbital Debris tracking is one of the applications of DHN, but it could always be expanded to very large-scale applications. In the Future, where all the debris is managed perfectly, and space traffic is perfectly controlled, the DHN priorities could be changed to what's on demand. Hence, having such a network, will always be useful for something.

3.11 Limitations

There's still a lot of research required for the scalability of the decentralized blockchain network. DHN can be constructed to the Global Scale as it does not require conventional consensus or sequential hashing. The interconnection between DHNs and other networks, and its adaptiveness depends on the design of the network protocol. It is assumed that the network is going to be designed by a team consisting of people from all the Spacefaring Nations. The people who design it, will not be able to access or control the network after it's deployment. The network and its existence depend on the network nodes that will be controlled by different Spacefaring Nations and Institutes. It is important to make sure that the majority of the Alpha nodes are not owned or controlled by a single entity.

4 SPACE POLITICS AND OPEN SOURCE TECHNOLOGIES

Space politics could be one of the issues to form a DHN. Some Space Agencies would not like their satellites to be discovered or tracked down. There are military satellites that may get discovered because of such a network, even though it is difficult to identify a detected object. NORAD keeps a track of the objects it detects, in a catalog, which is publicly shared. In the catalog, there are several entries which are not identified. A few of those entries could be the same object, a satellite that is performing maneuvers. Identification could be an issue for certain sensor types, but the use-case of this paper, it is only important to identify unique objects. The real identity of the object is only important when there's a prediction of collision, involving that object. As space is not governed by any entity, one of the parties from the prediction, would have to perform a maneuver. This is where it gets difficult, on the decision of which party should perform the maneuver. DHN's blockchain is immutable and provides transparency in its operations which will help in that decision. Having all the hysterical data about the orbit, makes it easier to determine who occupied the orbit first. From the previously described DAO of ITU, it would be possible to allocate orbits to certain satellites. It would be possible to form a contract, which will decide who should bear the expense of maneuver, or how would the cost be divided among the involved parties. This is a case of collision involving one or more cooperative parties.

If a collision between two debris objects is predicted, it will not be possible to move either of the objects. There are several methods that could change the course of the object, but who will perform such an operation? It is possible that the after effect of the collision might be harmful for certain entities, and they could take counter measures to avoid that collision between two debris objects. It must be known that any collision could potentially lead to more collisions. Hence it is a responsibility of everyone to maintain the safe space. UN's Committee COPUOS, has approved space sustainability guidelines [15]. These guidelines could be converted to a smart contract.

5 POSSIBLE EFFECTS ON THE SPACE ENVIRONMENT

The space around Earth is limited. More wireless signals in Earth's Atmosphere may damage natural cycles. Current wireless technology is operating in non-ionizing wireless spectrum. Within the past century, we started using wireless communication, and we are about to use frequencies closer to 300 GHz for 5G. There have been experiments with visible light communication. Communication through ionizing frequencies is harmful for humans as well as the environment. Hence, we must utilize the spectrum with utmost efficiency and try to reduce wireless network traffic as much as possible.

6 CONCLUSION

Once such an SSA systems comes into existence, it will make a lot of the space operations easier. It would be possible to know the exact locations of objects and make appropriate decisions. The DHN would be able to detect a collision much faster than current SSA systems, assuming a certain density in the DHN. DHN would spread out that information much faster than the current systems. This makes it easier for satellite operators to calculate if the collision would affect one of their assets or not. If a CubeSat company can not afford tracking of its satellite all the time, it can pay for on-demand tracking. It would be possible to utilize crowd sourcing in a way.

Space tourism is emerging, and it is expected to have increased demand within a decade. At that point, the SSA systems would have to be much more sensitive and faster than the current systems. Blockchain based decentralized SSA system will be able to keep up to that level. With Satellite constellations, satellite robot formations, construction in Space, the SSA systems will require more automation in their operations. The DHN in its design, will allow for it to be automated. The smart contracts which depend on human decisions, could be programmed to perform actions using consensus. Such scalability is important for SSA systems. In conclusion, it would be beneficial for everyone to maintain the SSA system with decentralized network based on Blockchain technology.

7 ABBREVIATION AND ACRONYMS

LEO: Low Earth Orbit
SOCRATES: Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space
OIS: Object-In-Space
SSA: Space Situational Awareness
IDA: Institute for Defense Analyses
ESA: European Space Agency
ITU: International Telecommunication Union
ITU: ITU Radiocommunication Sector
MIFR: Master International Frequency Register
DAO: Decentralized Autonomous Organizations
5G: 5th Generation of Telecom
NORAD: North American Aerospace Defense Command
DHN: Decentralized Horizon Network
IPFS: InterPlanetary File System

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