NUNET

A Global Decentralized Computing Framework

Whitepaper

Version 0.5, July 2019

Summary

NuNet is a computing framework that provides globally distributed and optimized computing power and storage for decentralized networks, by connecting the owners of data and computing resources with computational processes in demand of these resources. NuNet is designed to be an extremely flexible network, encompassing mobile consumer devices, edge computing and IoT devices alongside with PCs, servers and data centers, allowing seamless interoperability among its components and intelligent automation of workflow design.

The allocation of resources within NuNet follows market mechanisms -- that is, Nunet is designed to serve as an open global marketplace of decentralized platforms of services, data and computing resources. Based on concepts and architectures under development within SingularityNET since early 2018, it is especially architected to meet the needs of distributed computational processes executed on decentralized networks such as SingularityNET and other networks participating in the Decentralized AI Alliance (DAIA).

From the point of view of an *owner of computing or storage resources* (e.g. the owner of a smartphone or server farm) NuNet is extremely simple: the resource-owner announces the existence of their resources to NuNet's peer-to-peer network, and specifies the parameters of availability of their resources, and the balance of goals they want their resources to work toward (expectation or stability of profitability as measured in some particular currency; diversity of value achieved across multiple value types; positive social impact achieved).

From the point of view of an *owner of computational processes* (e.g. a business or nonprofit needing some computing done), NuNet is also extremely simple: the process-owner announces the existence of their process to NuNet's peer-to-peer network, and specifies the particulars of their needs (in terms of time, cost, preferred payment or other value transfer mechanisms, reliability, security, etc.).

To enable the network to meet the needs of participating owners of computing or storage resources and computational processes, NuNet includes *network operations agents* of multiple types, including those that leverage decentralized AI algorithms to solve the real-time optimization problem of leveraging the geographically dispersed heterogeneous resources made available by resource owners to serve the diverse requirements of process owners.

NuNet's tokenomic and governance frameworks provide self-regulation of the interactions of these three types of network participants: computing and storage resources, computational processes, and network operations agents. The net result is to lower

operating costs for the computational processes involved, and also to increase accessibility -- of resources to process owners, and of processes to resource owners.

In short, NuNet provides a unified platform that bridges between the evolving ecosystems of decentralized applications and global IT infrastructures, using decentralized smart network operations agents for

- computational process owners to express and publish their specialized computational requirements and bid for resources and know-how, as well as to spot-sell their functionalities and capacities across diverse ecosystems.
- computing and storage resource owners to express and publish their specialized capabilities and offer them to processes that need them across diverse ecosystems

Processes operating on NuNet may be simple, standalone computing processes intended to be executed in isolation; but they may also be participants in various different decentralized networks. In the latter case, NuNet realizes what may be called a *meta marketplace economy* (MME) -- a modality of operation that will become increasingly valuable over the next few years, as the "network of networks" aspect of the emerging decentralized economy transitions from concept to reality with the increased adoption and interoperability of decentralized computing networks.

The network operations agents underlying NuNet will support the MME aspect of NuNet's operations using, among other mechanisms,

1. a native token, interoperating and compliant with the tokens and other value exchange mechanisms already implemented within the ecosystems supported by the NuNet framework; and
2. a governance paradigm geared towards establishing rich collaborations among human as well as AI agents over an open-ended, heterogeneous globally connected infrastructure.

NuNet is designed to serve both commercial and social-impact ends, in a synergetic way. It will serve as a commercial ecosystem supporting a growing number of businesses in need of highly customizable and dynamically distributed computing as well as purpose-optimized workflow design for low cost distributed computing behind their decentralized applications. It will also support the global benefit of humanity by introducing initiatives and projects where NuNet participants can donate resources and know-how towards solving critical global problems.

The state of global computing

The decentralized NuNet network is designed to operate effectively within a tech ecosystem currently working according to quite different organizational principles. The current global computing ecosystem and market is largely oligopolistic and vertically integrated, and is mainly dominated by large ‘cloud’ infrastructure providers, such as Amazon WS, Google

Compute Engine, MS Azure, and software-as-a-service providers, such as IBM, Oracle, Salesforce, SAP, and others. Most of these providers offer powerful computing platforms within which they provide tightly integrated ecosystems of paid data storage, data processing, and machine learning and AI algorithms. Consumers of these cloud computing infrastructures often use more than one provider, integrating these infrastructures with their own in-house infrastructures, resulting in multi-cloud and hybrid-cloud infrastructures,[1] thus pushing providers to develop appropriate solutions towards such ends.[2] However, cloud computing providers that offer tools enabling design and efficient operation of computing workflows, must use their own proprietary solutions and components, which often duplicate those of their competitors[3].

Cloud computing ecosystems are therefore to a large extent isolated. For example, processes and computing pipelines implemented on Google Compute Engine cannot at any deeper level integrate with computing pipelines implemented on Amazon WS. Historically, this was justifiable by the fact that the physical concentration of computational resources provided better speed and efficiency, mostly due to fast communication within data centers. This state of affairs, however, is becoming obsolete and hinders the computing market potential and further development. Furthermore, huge amounts of unused computing power and data are scattered hidden in private computers, mobile phones, wearables and other private devices. The data produced by private devices, while legally owned by the device owners, is in most cases controlled and accessible by vendors and cloud providers. The raw data accumulated in IoT arrays is locked and controlled by device manufacturers and their proprietary cloud infrastructures. Again this is justifiable by the requirements of security and privacy which are currently addressed by creating sealed and centrally managed data silos within each vendor's boundaries.

This creates a situation where the already radically decentralized physical infrastructures are managed in a centralized fashion which, as recent examples show, becomes sub-optimal even with respect to security and privacy considerations that justified the closed centralized infrastructures in the first place. It becomes sensible if not critical that future computational architectures could and should be able to take advantage of such latent or siloed resources of both computing power and data.

"Cloud wars" notwithstanding, the global computing landscape is getting disrupted by new technologies of the emerging data economy. *Edge* and *fog* computing are beginning to distribute computing power across broad geographical networks of devices, and is being enabled by a variety of new technologies including ultra-fast broadband, wireless and mobile internet connections, a steadily increasing mass of mobile devices with significant

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[1] ZDNet, January 2019, Cloud customers pairing AWS and Microsoft Azure, according to Kentik (https://www.zdnet.com/article/cloud-customers-pairing-aws-microsoft-azure-more-according-to-kentik/)

[2] ZDNet, April 9, 2019, Google's app management platform aims to connect clouds -- even AWS, Microsoft Azure; TechTarget, May 30, 2019, Azure Cost Management adds AWS, reflects multi-cloud strategies.

[3] AWS Data Pipelines (https://aws.amazon.com/datapipeline/), Google Cloud Dataflow (https://cloud.google.com/dataflow/), Azure Logic Apps (https://docs.microsoft.com/en-us/azure/logic-apps/logic-apps-overview), Alibaba Machine Learning Platform for AI (https://www.alibabacloud.com/product/machine-learning), etc.

storage and processing capacity, and advanced autonomous robots. Distributed computing technologies allow for stream computing, microservice architectures and Internet of Things ecosystems that can logically manage and execute workflows across different machines and geographical locations. Advances in artificial intelligence and machine learning technologies have allowed algorithms to perform efficient data transformations autonomously, or with minimal human intervention. Lastly, distributed ledger, and related technologies featuring cryptographically secure identification, automated trustless interactions and smart contracting as well as reputation management and more, enable incredibly fast and efficient micropayment exchanges among individual processes and microservices, again with little to no human intervention.

Given these recent developments, still rapidly unfolding, all the major building blocks needed for a globally decentralized computing and data economy are already in place today. And yet, the computing platforms of centralized cloud providers are still largely constrained by closed networks, proprietary payment systems and hard-coded provisioning operations.

These seemingly highly technical points have an importance for humanity and its future that should not be underestimated. The computational universe is becoming an increasingly important part of our life in the physical universe, and has already surpassed the imagination of science-fiction writers of only a few decades ago. But despite these incredible advances, this is barely the beginning of the computational revolution. If we think in Kurzweilian terms regarding a Technological Singularity potentially occurring toward the middle of this century, we can say that the majority of the specific technologies that will underlie this Singularity have yet to be created and implemented. The principles according to which we build, operate, use and share computational resources in our physical and computational universes, will greatly influence our ability to tap into human creativity and shape the future of our world, in these critical next few decades as AI systems and other computational networks come to more and more greatly exceed human capabilities in various regards.

NuNet: A flexible, decentralized alternative

Technological advances of the last decade, in computer science and allied areas, enable numerous possibilities beyond the centralized and oligopolistic technology infrastructures that have become economically dominant. They afford a great variety of options for implementing radical innovations in the management of global computing resources for the benefit of all. What is needed is an economic and computational context in which experimentation with, exploration and interconnection of multiple innovative potentials occurs freely and rapidly and is driven by a broad variety of human and AI actors.

NuNet provides such a context, via creating a global scalable decentralized computing framework fostering a multi-marketplace community of pragmatic pioneers. It achieves this via:

1. Breaking barriers that prevent interoperation of fundamental computational components owned by the general public and different economic players;

2. Enabling interoperation of human and machine intelligence for designing, implementing and executing components, and their combinations, in the global computational framework;
3. Decoupling computational processes from physical computing infrastructure and location by enabling fluidity and mobility of the computational workflows across multi/hybrid- clouds and diverse proprietary resources.
4. Developing ontology, semantics and APIs for providing computational reflection, location and context awareness information to computational processes, enabling intelligent workflow creation, learning and meta-learning with limited human intervention;
5. Developing the framework for fair and secure exchange of value of data created by each computational process, mobile device, resource and its owner participating in the ecosystem, where the value can be negotiated in local exchanges without central authority or control.

NuNet's data exchange and computing framework will enable the integration of distributed computing technologies into a decentralized and scalable network, allowing for anybody to share, monetize and utilize the value of individually owned memory, computing capacities, algorithms, code and data, human creativity and machine intelligence.

There is a broad, deep aspiration here: Ultimately, NuNet aims at supporting the elevation of intelligence and the overall efficiency of our computational universes into the next level. There is also a nitty gritty practical aspect: Anyone can earn money (of various sorts) via simply installing a NuNet app on their phone; various sorts of compute processing needed by various businesses will be achievable at lower cost than using alternative methods; and some kinds of data/computing combinations that are now infeasible, or accessible only to tech giants, will become more broadly available (e.g. large-scale analytics of data collected via individual smartphones).

NuNet will enable computational processes (i.e. *agents*, to use a more concise term) to enact a variety of critical capabilities, leveraging the infrastructure providers and vendors that also play a key role in the network, in a manner orchestrated by the NuNet network operations agents. It will enable agents to:

1) exchange capability and action information between each other;
2) express the value of their capabilities and actions in chosen currency units or cryptographic tokens;
3) exchange this value between each other in any chosen form, giving rise to ad-hoc value and thereby creating networks of high complexity;
4) create additional value (local, global, economic, social…) by performing individual or collective actions in the network;
5) learn about actions, performance and capabilities of other agents or value creating networks;
6) encapsulate any simple or complex computational process, AI or ML engine and interact with humans for leveraging human intelligence for their actions;

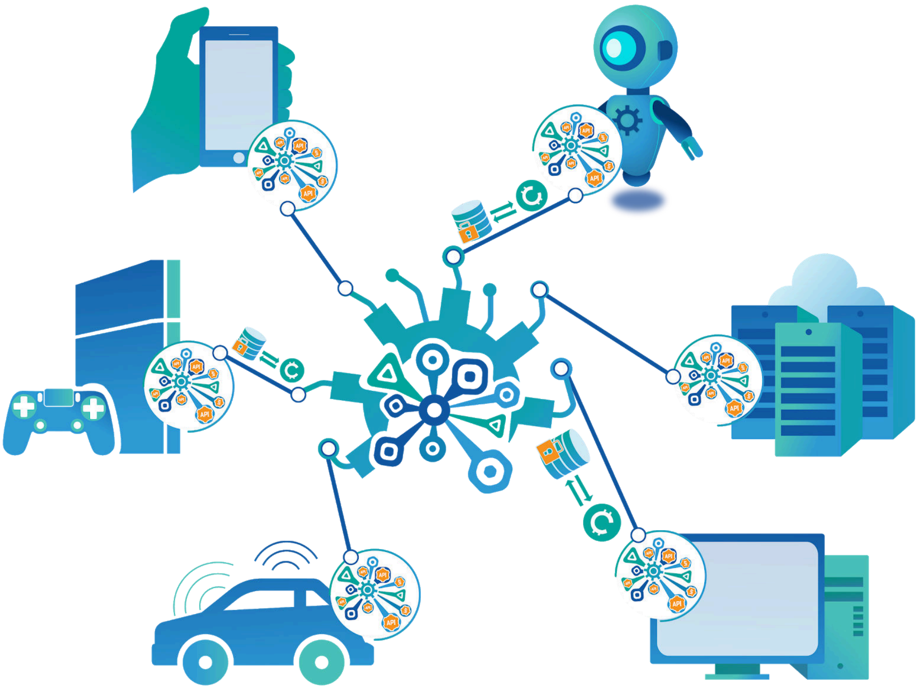

Figure 1: Computational workflows involving computing power and data of various devices are enabled by NuNet adapters installed on each device and network operating agents orchestrating them.

Breaking the barriers of data silos, concentrated hubs of computing power and centralized utilization of software and code, NuNet has the potential to play a key role in shifting the state of global computing from oligopolistic and monopolistic structures to open collaboration and resource sharing without compromising security and privacy, where network effects of disruptive technological developments are fairly shared by all constituents of the system.

Architecture: principles and overview

All computing processes, no matter how powerful or simple, are based on three fundamental aspects: *memory*, *communication* and *functional transformations* of data. Computational infrastructures at every scale are built by providing increasingly complex architectures for combinations of the components that realize these three aspects. None of them are free of charge: implementation of memory and communication require both physical resources and energy, and design of functional transformations require intelligence and time. In addition, all of these computing processes are certainly associated with specific types of legal ownership and economic value.

The architecture of NuNet is based on the principle that physically and logically decentralized networks should also be managed in a decentralized way, which, contrary to the established approaches, allows one to *increase* the security and privacy of network constituents, along with providing next level capabilities for optimized data and work flows.

We are convinced that decentralization, openness and freedom of data and resource sharing do not need to be traded for individual security and privacy; but can actually complement and enforce each other if done right using available technologies. The philosophy of design is therefore based on the core principle of decentralized systems and distributed trust, where network is considered insecure and trustworthiness of messages and identities of workflow components questionable until this is proven at the level of each individual agent of the network. NuNet adapts and expands this principle for decentralized workflow organization, where each node of the network has a power to decide, negotiate economic or social benefits and commit resources and data to the computational workflow organized in a decentralized manner by other nodes in the network.

Architecturally, this principle will be realized via lightweight NuNet agents running as portably as possible across the participating decentralized computing networks and infrastructures. NuNet agents will provide a low level API to be utilised by computational agents of enabling four main functionalities: computational reflection, context awareness, mobility and value exchange;

Computational reflection

NuNet will provide means for computational actors to exercise certain levels of computational reflection in terms of: (1) resource allocation, (2) data representation, (3) execution introspection:

> The *physical resource allocation* aspect of computational reflection will allow agents to have continuous interaction with their execution environments, and search and request for additional computational resources and infrastructures according to their own criteria. Additionally, agents will be able to download or update required libraries, i.e. evolve their own execution strategies, and this will allow for agents' free migration from one node (virtual machine, cloud vendor, private computer or a mobile phone) in a distributed computing environment to another;
>
> *Capability and data representation* aspect will allow agents to semantically represent their own computational capabilities and input and output data. This information will be made available for other agents to query when negotiating pairwise contracts and workflow designs;
>
> *Execution introspection* is the ability of each agent to monitor actual resource utilization by its algorithms, keep history of execution times and memory usage, and access its own state during execution, amongst other features. Agents may decide to share part of this information with the network in order to prove their capabilities and quality of services;

Note that the abstraction of NuNet does not define in any manner how computation or actions of agents will be performed. Using means of computational reflection, computational agents will be able to design and apply workflow design and workflow execution functionalities pertaining to their individual choice and requirements. Furthermore, a human element can be seamlessly incorporated into the same model. For instance, an agent can represent a UI through which tasks that need human intervention can be performed and integrated into the workflow. A hybrid computer-human collaborative case can be imagined where NuNet workflows formulate a computational task, which is then performed by humans through crowdsourcing or freelancing marketplaces (Amazon MTurk, Udemy), or even code hosting platforms (GitHub, Bitbucket, etc.)[4]. The tokenomy of NuNet will support and facilitate decentralized marketplaces where human and machine jobs will be demanded, offered and contracted on commercial or other basis. Computational reflection will enable owners of resources to advertise and price their capabilities and for resource users to estimate, track and manage computation costs in dynamic and transparent way.

Context awareness

Context awareness, provided by NuNet agents, will amount awareness of location and proximity to other NuNet agents in the network. Proximity in this sense means the cost of collaboration with these agents and includes a list of parameters which may be agent specific and therefore not centrally managed. Considering the wide variety of hardware devices, the network of NuNet agents will constitute a dynamic topology where physical location of resources may change over time, as well as resources can go offline and pop-up in other places. The topology of NuNet's network, however, will be defined not by geographic distribution of physical resources, but rather by the relative costs of transferring data between agents in a workflow in terms of time and price. Each NuNet agent installed in a particular device or resource will accumulate, keep and update this information upon request and provide it to computational agents via an open API. Note, that NuNet agent will be radically decentralized in the sense that no meta-agent will control or have information about the whole network. Therefore context awareness functionality will include methods of querying and learning local network topologies by individual NuNet agents, eventually supporting and enabling automatic or semi-automatic search and discovery of computational processes as required by clients or other processes in the ecosystem, independently of the network or physical location of processes.

Mobility

NuNet agents will support mobility of computational processes by enabling them to move between devices of the network and in this way enabling the dynamic optimization of computational workflows and business processes -- bringing data closer to processes or processes closer to data. All computational processes are containers, which can be spun and installed at the location of choice. Choices of moving containers across the network will be made by workflow organizers, while NuNet will provide necessary APIs providing context awareness and computational reflection information as well as support installation and destruction of containers as instructed.

Note that mobility of computational agents provides not only for the greater efficiency of computational workflows by enabling processing closer to data, but also completely new

[4] Algorithmic governance of decentralized applications (DApps) was one of the original ideas behind the [Ethereum world computer ecosystem].

business models. For example, highly sensitive data can be processed at client's site by planting containers with proprietary AI / ML algorithms within the boundaries of the clients private cloud and ensuring that no data is leaked. Containers with algorithms may be cryptographically signed and secured and NuNet will ensure that the container is destroyed when the computing job is done, in this way securing privacy and intellectual property of both data and computing intelligence providers.

Value exchange

An essential part of NuNet is the economic mechanism which will enable the network to connect computational resources, data and algorithms owned by different vendors into one network. NuNet adapters will therefore enable to exercise payments to resource owners directly from the computational agents of distributed computing frameworks or for individual users using NuNet. The goal of NuNet is to overlay the computational network with the payments network and provide interoperability and exchange adapters for tokens and payment methods used by owners of computing resources, decentralized computing platforms and marketplaces.

Supported functionalities

NuNet's APIs will support the functionalities of decentralized computing platforms and marketplaces, initially of SingularityNET and members of the Decentralized AI Alliance (DAIA). These functionalities include, but are not limited to:

Mobile computational processes

A computational agent encloses a computational process that turns input data into output data, without any restriction whatsoever on the nature of the process or the amount of computational resources that it needs. Agents isolate the process' computational logic from the physical implementation, resources and location. A computational process encapsulated into an agent can be any combination of memory and processing, which can range from complex AI and machine learning processes to simple queries for retrieving data from a database or a streaming source. The abstraction layer that isolates computational logic from physical implementation enables agents to be agnostic to the physical infrastructure and location, which can be dynamically changed as per demands of specific workflow.

Flexible workflow design

Agents are building blocks that can be combined to form arbitrarily complex domain specific computing workflows that can perform a variety of useful computations in the network. The same agent can participate in many workflows, and connect with other agents to form clusters. Agent mobility enables such workflows to operate across boundaries of cloud vendors, mobile devices, private clouds and more, while respecting and ensuring ownership, economic value of resources, and data security/privacy are maintained by the respective parties. NuNet implements a tokenomic mechanism to enable and facilitate the design of frictionless cross-vendor workflow execution.

In terms of *workflow design*, agents, using NuNet's functionality, will be able to search for other agents in the network, which could provide building blocks for their original task, calculate the costs of such workflows, and estimate time requirements of execution. This would allow for agents to make optimal decisions with or without help from humans, and enable agents to express larger computational tasks that would be difficult for one agent to achieve.

The *workflow execution* aspect of computational reflection will enable agents to time, schedule and manage the actual execution of their workflow, data transfers between agents, error propagation, crash recovery, necessary caching, etc[5].

Data and value production & exchange

Inputs and outputs of computational processes are data, whereis data has its own inherent value. The value of data, however, is not absolute, but instead relative to what other participants of the ecosystem (i.e. computational processes) can do with it and how they value it with respect to ecosystem's dynamics. Data's value, broadly speaking, is context dependent and is subject to negotiations between providers and requesters. Entities can value static data (e.g. stored in a database) or dynamic data (e.g. real-time streaming) that is time sensitive, private or public, and useful in either broad or very specific contexts. Also, it is important to keep in mind that data has associated costs -- of production, storage, analysis and transformation. As these costs become more transparent, specific solutions can be designed for various stages of the data creation/analysis life-cycle and these open and collaborative efforts could likely result in the reduction of transactional data costs and the ability to deliver improved insights. Transparent, secure and efficient matching of all data forms to the immediate requirements of societal, business, government and individual processes will tap into the enormous economic potential of the data economy[6], which for the time being is still waiting to be unlocked.

NuNet provides tools for the economic exchange and sharing of data (which may be, but is not necessarily free). Note, that in a computational workflow data can be very specific and time sensitive, i.e. produced purposefully for the next process, and by converting input data to output data agents *produce value* which they can then exchange with other agents on the basis of a tokenomic mechanism. Since the value of data is different for different agents, NuNet enables a decentralized value exchange mechanism, based on, but not limited to, pairwise negotiations and contracts between computational agents. NuNet's tokenomic mechanism will also enable solutions for tamper proof traceability of resource consumption, data provenance and vendor-consumer relations. It will provide the basis for enabling companies and customers to accurately trace and manage their spending and decentralized partnerships.

[5] E.g. using large scale data processing and stream processing engines, such as Apache Flink, Apex or others.
[6] https://en.wikipedia.org/wiki/Data_economy

Logical scalability

Computational reflection of agents, especially in their workflow design and execution aspects, will allow entities to create workflows (i.e. logical structures) in the network in a decentralized manner (see picture below). In a decentralized network, meta-agents can act as intermediaries that transform input data into output data through the curation of other agents' computational services, which ultimately can be expressed as a logical structure consisting of a variety of agents existing in a connected network workflow. So while such a meta-agent uses the same abstraction as other agents in the network, internally it holds only the computational reflection (or representation) of a workflow: the identities of agents in workflow, their inputs and outputs, their cost, location and data offered, as well as scheduling information needed for designing and executing a workflow[7].

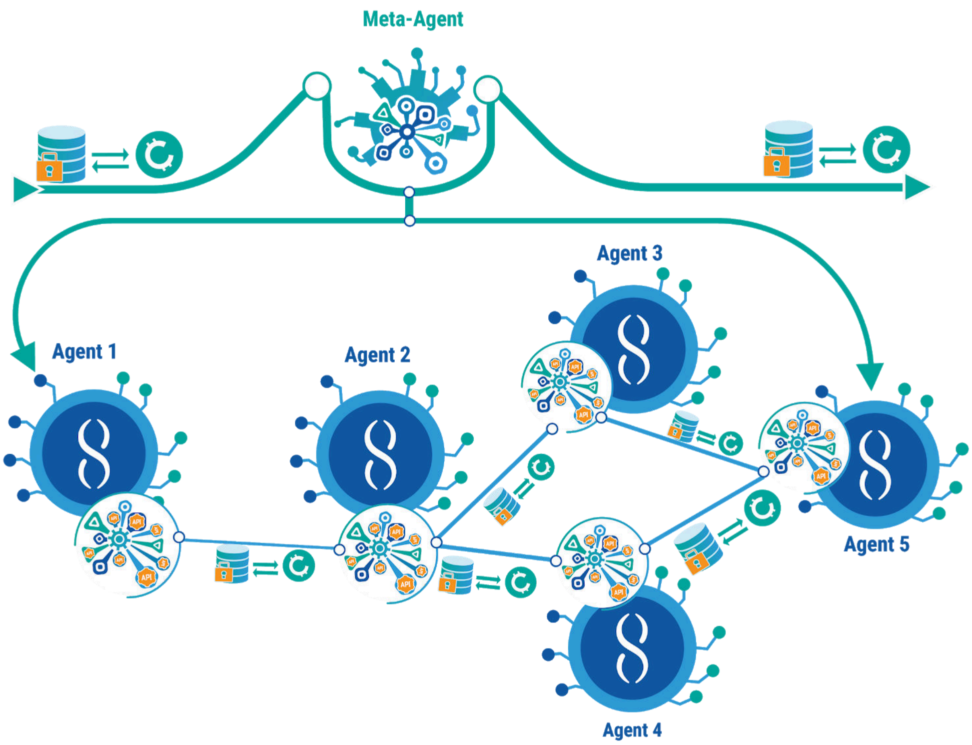

Figure 2: Meta-agents will be able to create complex computational reflections consisting of a hierarchy of sub-meta agents, all the way down to base agent services hosted on supported decentralized computing platforms, such as SingulairtyNET.

Once the computational reflection is fully mapped out by the meta-agent, the workflow can be executed entirely at their discretion, provided that the initial data and the amount of tokens covering the costs of all computational agents within the workflow are covered. Note that as meta-agents are able to design workflows involving other computational agents, similarly meta-agents themselves can be incorporated into higher order workflows giving

[7] E.g. using Apache Beam -- a unified programming model for defining data processing pipelines.

rise to the logical scalability property. Meta-agents will be able to create complex computational reflections consisting of a hierarchy of sub-meta agents, all the way down to base agent services, that are constantly and dynamically changing their costs, workflows and services offered. Furthermore, these workflows can be designed by a human operator, automatic procedure or an AI agent using the same level of abstraction.

An ecosystem of adaptive decentralized computations

NuNet will support the principle of radical decentralization of the computing platforms and marketplaces in the sense that every agent will be able to become a meta-agent if it decides to do so and has computational, cognitive, and financial resources or the support of human operators to execute such roles. Given a large enough number of agents operating in the network, their ability to form workflows on their own will lead to pluripotency and degeneracy (i.e. many-to-many relations of structures and functions), competition, cooperation and capacity of the network to self-organize into progressively more complex cognitive structures.

In the decomposition of NuNet participants into computational resource providers, computational resource users and network operations agents, meta-agents may fall into any of the categories; or a single meta-agent might span 2 or 3 of the categories.

Learning and meta-learning

Computational agents will be able to express any computational algorithm, AI or a machine learning engine, and will also be able to access information about their own and other agents' capabilities through NuNet, as well as the history and activity in the network. Therefore, agents will be able to learn from experience about the credibility, efficiency and security of other agents, and also about other dimensions and activities happening in the network. Different meta-agents may start to specialize in analyzing other agent's reputations and rating their performance, and then providing this information to other agents in exchange of tokens or information. These intricate interactions ultimately will give rise to a decentralized ecosystem of reputation systems within the network, that humans and machine agents will be able to examine and rely upon when designing computational workflows. Overall, these capabilities will allow individual agents to learn from their own, or network, experience and become better at performing their task and allow them to be adaptive to changing circumstances, new algorithms, cutting-edge AI engines and novel use cases.

Human-mediated cognitive development

Ecosystems of adaptive decentralized computations, whose individual agents are capable of learning and meta-learning in collaboration with each other, will give rise to the learning and adaptive capabilities of the decentralized marketplace of NuNet as a whole. Since some agents will represent humans participating in the network, and in the beginning human agents may contribute the largest part of intelligence of the network, the framework as a whole will be able to learn from human actions and intelligence and progressively undergo cognitive development. Governance mechanisms of NuNet will guide this evolutionary development for the benefit of all.

Business model

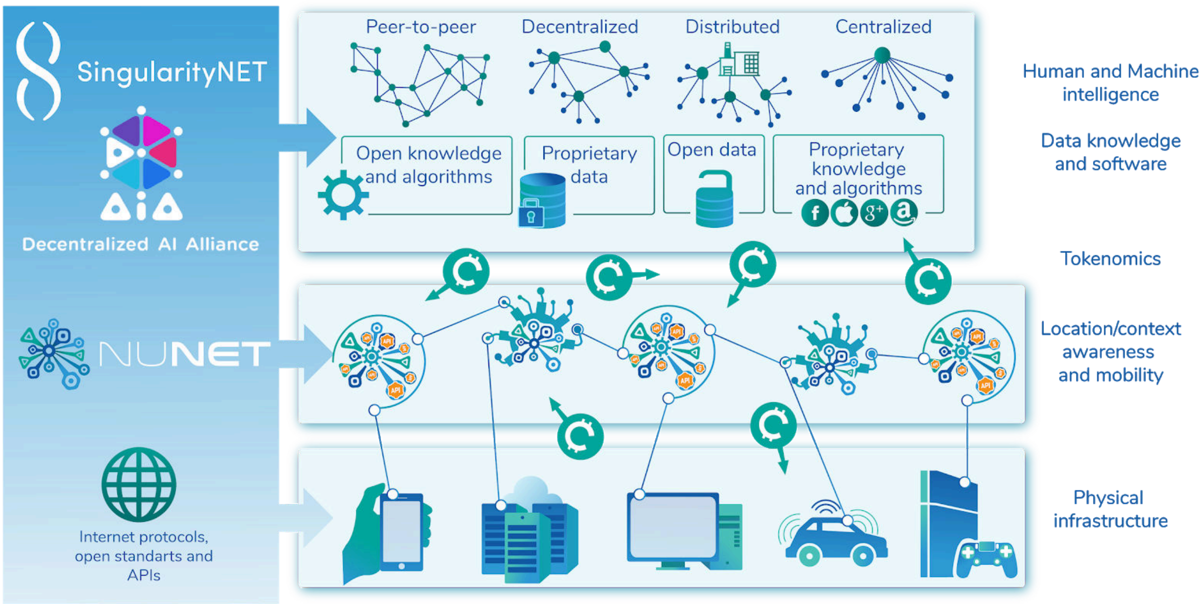

Figure 3: NuNet is a technical and business layer relating algorithms and data of different frameworks with the computing and storage resources of heterogeneous hardware devices.

NuNet comprises a technical and business layer right above the physical infrastructure and below distributed computing and data frameworks, such as SingularityNET, the networks launched by members of the Decentralized AI Alliance, and ultimately many more. The open layer of NuNet will support many existing technological solutions offered by general computing, AI, cryptography, blockchain and many other domains[8]. The core goal and function of NuNet is to provide decentralized and optimized computing power and storage resources for decentralized computing platforms. Specifically, it will support decentralized interoperation of algorithms, AI and ML engines, humans or any other deterministic, probabilistic or even non-deterministic processes. The main principle of NuNet is based on abstracting all these processes away, with the help of computational agents, and then building an infrastructure for an evolving API of APIs for interaction between an unbounded plethora of meta-agents. NuNet will also enable solutions for tamper proof traceability of resource consumption, data provenance and vendor-consumer relations. It will provide the basis for enabling companies and customers to accurately trace and manage their spending and decentralized partnerships. Initial stages of building the NuNet involve installing the

[8] E.g. members of [Decentralized AI Alliance](#) (DAIA)

fundamental components of the decentralized system, and then allowing the system to evolve by guiding its development towards the increasing intelligence and benefit of society.

The tokenomic mechanism of NuNet will be based on the natively issued token, which will provide means and mechanisms of providing micropayments directly from computational processes to the owners of distributed computing resources and subsequently between computational processes, data sources etc. The micropayment system will provide means for value exchange between processes running within different decentralized computing platforms interrelating through NuNet with physical infrastructure. Technically this will be done via enabling token exchanges on the level of NuNet adapters.

NuNet will charge a percentage of the value of micropayments exercised through NuNet adapters depending on the precise service mix that every adapter will be providing in specific context (API calls, mobility services, etc.). NuNet's adapter services will be priced per their added value for facilitating computational workflows for the constituents as well as globally using the network. The final price of services for the constituents of decentralized computing networks will be calculated and exchanged using NuNet tokens as Native tokensa basis and will consider:

(1) cost of location, context awareness, mobility and exchanges between tokens (in NuNet native tokens);
+
(2) amount of native tokens tokens of decentralized platforms and frameworks (e.g. AGI, Golem, fiat, Safecoin, Filecoin, etc.);
+
(3) cost of computing, storage resources and data paid to the owners.

Components (2) and (3) will depend on the pricing structure and strategies of respective constituents of the network. The (1) component will amount to a small percentage on top of each transaction or workflow operation that uses NuNet's adapters. This percentage will be statically determined initially, but eventually will be made dynamically negotiated in the context of individual workflows as a machine-negotiated "brokerage fee."

The fees thus collected will be distributed among network operations agents, thus providing funds for operation and ongoing development of the NuNet network. The financial viability of the network in the long term depends on the volume of activity and transactions in it. When the network will grow to accommodate network operation agents owned by partners, third party developers and businesses, the scale of operations performed by partners and users will allow to finance NuNet from small transaction fees via its adapters.

Governance and management

Network governance decisions may be categorized into: Minor, Major and Critical, where:

- Minor decisions are workaday decisions made in the course of operating the network;
- Major decisions are those with strategic importance;
- Critical decisions are those with potential large, direct existential impact to the network;

Minor decisions will be made by the Foundation, partners or the pool of owners of network operations agents, depending on the case (initially the Foundation is the only owner of network operations agents, so this distinction can be refined via consultation with counsel during the network's first years of operation). Foundation and partners will also elect a Technical council which may include representatives of owners of network operations agents.

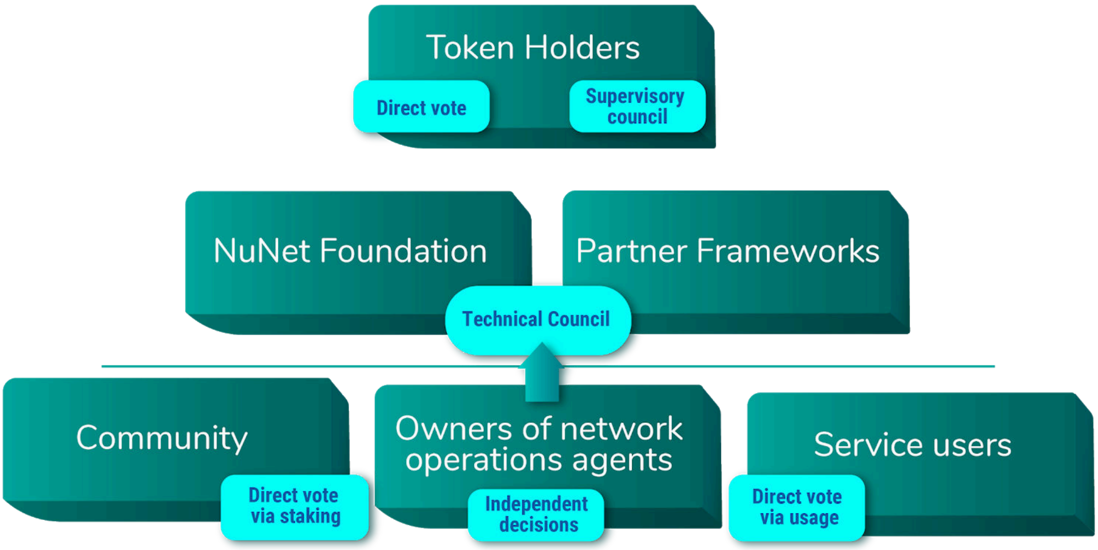

Figure 4: NuNet's governance structure

In Years 1-3 following the TGE, the NuNet Foundation will handle Major and Critical governance decisions as well, but the network will transition to democratic governance as it matures. Within the first year following the TGE, a Supervisory Council of 3 members will be elected by the token holders, to serve an oversight and communication function on behalf of the token holding population. The intention is for the community to collaboratively make decisions regarding network operation, but for full democratic decision making to properly kick in only once the community has stabilized and matured to a reasonable degree.

In Years 4-5, Major and Critical governance decisions will require both approval of the NuNet Foundation, and vote of network participants holding a majority of the tokens held by all participants in the vote.

Beyond Year 5, Major network governance decisions (excepting those regarding Foundation activities that by law must be made by the Foundation's Board) will be made via a vote in which approval is given by voters holding a supermajority (60%) of the tokens held by all participants in the vote. Critical decisions will require a vote in which approval is given by voters holding a large supermajority (70%) of the tokens held by all participants in the vote.

The approval of new agents as network operations agents is considered a Critical decision, and may be done at any point according to the processes for Critical decisions as described above. When the network matures and transitions to fully democratic governance, any party may be able to introduce new network operating agents given their compliance to legal, KYC requirements and Foundation's policy.

Milestone release designs and crowdfunding rounds are Critical decisions, involving all layers of governance and eventually voted upon by token holders and community. After each milestone release is achieved, Foundation, partner frameworks and owners of network operation agents will propose the design of the next milestone release, which will be evaluated and voted by the Technical council. For the next crowdfunding round to get launched, the proposed milestone release will have to be approved by token holders via vote of the Supervisory council or a direct vote further into the project. Eventually, the milestone release and its development roadmap will have to be approved by a larger community, service users and the majority of owners of network operations agents via independent decisions, staking mechanism and token purchase.

Initially the proportionality of fee distribution among owners of network operations agents will be simple: all fees will go to the NuNet Foundation. As new network operations agents are introduced, a scheme for dividing fees among owners of network operations agents may be approved via the processes for Critical decisions as defined above. The final goal of the NuNet framework and tokenomics development is to allow network operations agents, resource consumers and users to ask and bid for resources in a competitive meta-market, where resources, intellect and knowledge will be directed towards socially beneficial tasks via democratic voting and individual staking.

Launching team

Dr. Kabir Veitas holds a PhD in Interdisciplinary Studies (2019), masters degrees in AI (2009), international business management (2007) and a degree in business administration (1997). He has a multi-year experience in strategic business consulting, multi-stakeholder negotiations and project management, socio-economic cost-benefit analysis, policy design as well as held executive positions in the past. His later career focuses on decentralized computing system's research and development, social integration of AI, IoT and distributed ledger technologies, artificial general intelligence research and technology policy design, based on long standing interest and research of philosophy of mind, cognitive science, complex systems and future studies of human socio-technological systems.

Robin Lehmann holds an M.Sc. in Computer Science (2015) from HS Weingarten in Germany, with extensive experience in machine learning, autonomous vehicle software design, project management, R&D, embedded development, and computer engineering. Robin has been programming since the age of 12, and began to focus on machine learning after attending a massive open online course held by Sebastian Thrun, Peter Norvig and

Andrew Ng in 2012. Armed with this knowledge, he developed preemptive maintenance based on machine learning for Festo, the world's leading pneumatic machine parts producer.
In 2017, he became an active developer in the blockchain space. He soon discovered SingularityNET, and was enthralled with their vision, at which point he became an active member of the community. By May 2019, he was hired at SingularityNET to work part time as a "Developer Relations Engineer," living out his dream of utilizing technology to further humanitarian goals and joining in the quest to help bring life to Artificial General Intelligence. After developing projects for Audi, BMW and VW, Robin now serves primarily in a project management role. When he is not working with SingularityNET, he is currently leading a team of engineers who research and develop automated annotation software for multi-sensor data for sensor validation.

Dr. David Weinbaum (Weaver) holds a PhD in Philosophy and Sciences from Vrije Universiteit Brussel (2018) and M.Sc. in Electronic Engineering from Tel Aviv University (1989) with experience in computer engineering, parallel algorithms, symbolic computing, software and hardware design, and R&D management. His work and research aim at developing
models of self-organized distributed cognition, distributed thought processes and distributed social governance towards the emergence of a Global Brain. His major research interests are: cognitive science, artificial general intelligence, complex systems, consciousness, cybernetics, evolution theory, foundations of thought, philosophy of mind, Deleuzian theory of difference,
futures studies and the singularity, posthumanism and the transformative potential of human consciousness.

Dr. Ben Goertzel is the CEO of the decentralized AI network SingularityNET, and the Chief Scientist of Hanson Robotics, chairman of AGI Society, OpenCog Foundation, Decentralized AI Alliance and futurist nonprofit Humanity+. He is one of the world's foremost experts in Artificial General Intelligence aimed at creating thinking machines with general cognitive capability at the human level and beyond. Dr. Goertzel has decades of expertise applying AI to practical problems in areas ranging from natural language processing and data mining to robotics, video gaming, national security and bioinformatics. He has published 20 scientific books and 140+ scientific research papers, and is the main architect and designer of the OpenCog system and associated design for human-level general intelligence. Dr. Goertzel is the founding member of the Global Brain Group, established in 1996 for researching collective intelligence arising from the interconnection of humans, computers and AI systems.

Initial roadmap toward the vision

The scope and breadth of NuNet's long term vision, as should be clear from the envisioned functionalities reviewed above, is highly ambitious. Achieving this vision will necessarily require a large team of researchers and developers, a multi-year development roadmap and considerable financial resources as well as complex project management. Furthermore, implementing the vision implies the unprecedented amount of integration of open protocols, technological stacks, partner ecosystems and commercial providers as well as fundamental research for resolving many uncertainties along the way. Given the uncertainties involved in the technical and market context within which NuNet will be operating, it would be foolish to make a detailed long-term roadmap now and expect it to be adhered to in all its particulars as reality unfolds. But it is nevertheless valuable to formulate an initial, provisional roadmap based on our understanding at this stage and our projections of the future development of the ecosystem. The management and governance structure of the project will be key going forward, both for guiding incremental development of the platform, and for revising the roadmap as lessons are learned and situations change.

The provisional roadmap sketched here considers eight main aspects of development: 1) peer-to-peer network; 2) core APIs, description languages and data exchange mechanisms; 3) resource and process mapping; 4) meta-marketplace; 5) optimization and orchestration; 6) data sharing and provenance; 7) human/machine -- NuNet interface and 8) partnerships and technology integrations.

No.	Functionality	Priority
1	Peer-to-peer network	
1.1	Interoperability between devices / resources	1
1.2	Interoperability between computational processes	1
2	Core APIs, description languages and data exchange mechanisms	
2.1	Resource description API	1
2.2	Computational process description API	1
2.3	Workflow design & description API	1
2.4	Topology API	2
2.5	Resource discovery API	2
2.6	Multi-dimensional value description API	3
2.7	Traceability and provenance API	3
2.8	Negotiation API	4
2.9	Reputation API	5
3	Resource and process mapping	
3.1	Manual mapping of processes to hardware	1
3.2	Automatic mapping	2
3.3	Open collaboration and self-organization	3

3.4	Logical scalability	4
4	Meta - Marketplace	
4.1	Bidding / asking mechanism for resources	2
4.2	Payment mechanism via the native token	2
4.3	Peer-to-peer negotiation language and contracts	4
4.4	Token exchange mechanism	2
5	Optimization and orchestration	
5.1	Execution introspection and performance monitoring	3
5.2	Resoure usage monitoring and tracking	4
5.3	Manual resource allocation via basic mobility	1
5.4	Automatic resource allocation via advanced mobility	4
5.5	Traceability of resource consumption	3
5.6	Cross-vendor cost tracing and logging	3
5.7	Advanced automatic optimization	5
5.8	Learning and meta-learning	5
6	Data sharing and provenance	
6.1	Identity management	2
6.2	Security and privacy	3
6.3	Data provenance and traceability	3
7	Human/machine - NuNet interface	
7.1	Provider dashboard for managing resources	1
7.2	Application level user interfaces	1-5
7.3	User dashboard for managing costs and workflows	3
7.4	Interface between Nunet and human marketplaces	4
7.5	Automating and integrating all above	5
8	Partnerships and technology integrations	1-5
8.1	Software Development Kit	
8.2	Integration of computing environments/ecosystems	
	-- SingularityNET	
8.3	Integration of hardware providers	
	-- Cloud providers	

	-- Single board computers	
	-- Mobile phones (Android)	
	-- GPU mining farms	
8.4	Integration of data exchange protocols	
	-- IPFS, Ocean, etc.	
8.5	Integration of decentralized storage	
	-- Filecoin, Storj, etc.	
8.6	Integration of micropayment infrastructures	
	-- Ethereum, TODA, etc.	

Figure 5: Highlights of long-term development roadmap.

This provisional long-term roadmap of NuNet is designed for iterative development. Each milestone will cover a subset of functional requirements of the whole roadmap while providing clear and actionable deliverables, linked to concrete use cases. The iterative development strategy will enable the project to organically adjust to quickly changing technological landscape, partner technologies and ongoing innovations. The governance and management structure of Nunet is designed for empowering NuNet token holders, users and community to have a maximum say regarding network's design and operation decisions in democratic and beneficial way and during the whole implementation period.

According to the initial plan, NuNet will cover the roadmap in five milestone releases, which will be crowdfunded in separate subsequent rounds tied to each release. The planned period of each release is 12 months, with the exception of the first release, which will take 18 months from the completion of the crowdfunding round. The decision to initiate subsequent crowdfunding rounds based on detailed release roadmaps will be voted for by all layers of NuNet's governance structure including developers, partners, token holders, users and broad community of potential members.

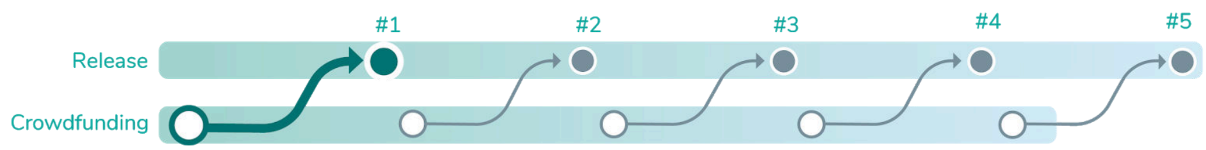

Figure 6: The scheme of iterative implementation of NuNet's long term development roadmap.

First milestone release and early use cases

NuNet will develop via iterative milestone releases covering, deepening and expanding the general roadmap of framework's development. Milestone releases will be designed around the implementation of concrete use cases following fast prototyping and design of viable products and solutions from the early stage. Milestones will be chained together by the roadmap thus iteratively building its core functionalities of peer-to-peer networking, core APIs, resource and process mapping, meta-marketplace, decentralized process orchestration, data sharing and provenance and human/machine interface. Each subsequent milestone will be planned and designed after the previous milestone is completed in open source software development style, considering lessons learned, partnerships developed and changing technological landscape. This project development and management strategy is supported by NuNet's governance structure as described above. Below is the list of use cases and viable products describing first milestone release and candidates for subsequent releases or implementation by partners.

First milestone release: Health data pre-processing and sharing

The health wearables device market is booming with double-digit annual growth rates, expected to reach 450 million shipments by 2022[9] and amount to $60B market by 2023[10]. Health wearables become parts of patients' treatment plans, insurance companies' policies and individual lifestyles. The amount of data collected globally by these devices increases even at higher rates.

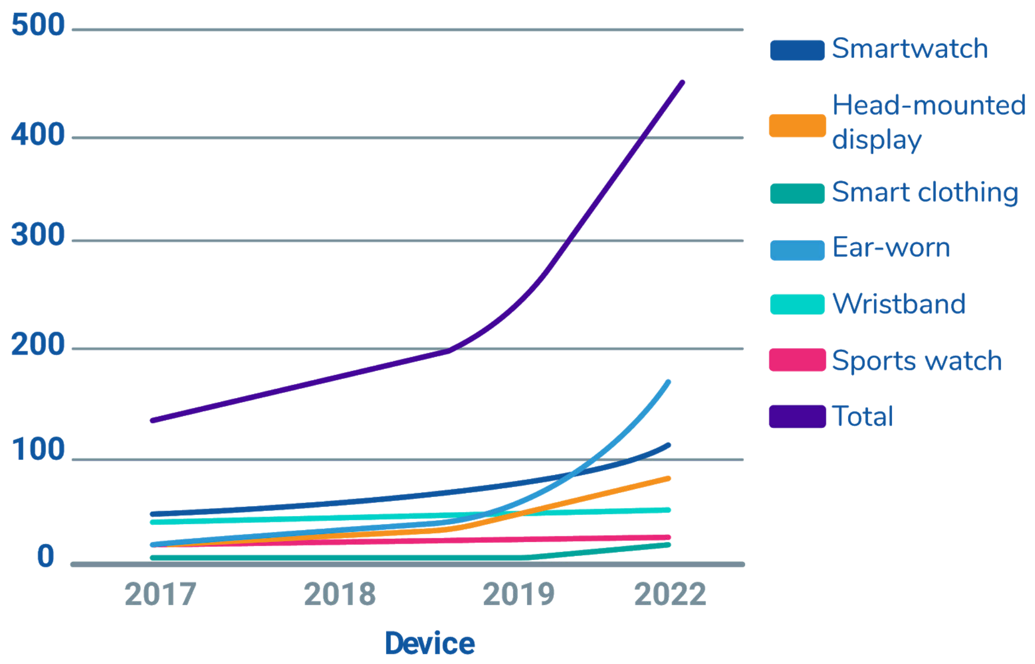

Figure 7: Worldwide shipment of health wearables (Gartner, November 2018).

[9] Gartner (November 29, 2018) Gartner Says Worldwide Wearable Device Sales to Grow 26 Percent in 2019.

[10] Business Wire (January 14, 2019) Juniper Research: Healthcare Spend in Wearables to Reach $60 Billion by 2023, as Monitoring Devices & Hearables Become 'Must Haves' in Delivering Care.

However, data privacy and consent are continuing to be pose significant barriers to the realization of the myriad opportunities offered by individuals' health related data in the domains of patient monitoring, longevity therapeutics, predictive, preventive, personalized and participatory medicine and medical research in general. Providing continuous aggregation, processing and mining for data collected via multiple devices from different vendors is an unresolved engineering and management problem. Unlocking this potential is paramount for human society and civilization on many levels, solutions towards which contain tremendous social, business and personal value.

Data sharing among individual health wearables is currently very limited -- each wearable provides only certain types of sensors and information but not other, i.e. heart rate, step count, blood pressure, sleep cycle, etc. This information is usually stored in a private cloud, which is accessible and shareable only among users of the same provider or device manufacturer. Medical research and precision medicine however is based on the integration of all these types of data which, currently is based on sharing databases on the provider level. Furthermore, predictive, preventive, personalized and participatory medicine (P4) needs integration of other types of data, including genome sequencing, electronic medical record and more.

The core architecture of NuNet provides a platform enabling effective management and enaction of decisions regarding data sharing, processing, storage and anonymization, where these decisions may happen at the level of the individual human or device. Specifically, in the NuNet approach:

1) Fitness data of each device is recorded and stored in a local database or cloud as the application of a device provider allows;
2) NuNet adapter is installed on every individual device (e.g. smartphone or tablet) where fitness data is stored. The adapter exposes NuNet APIs for resource description, traceability and provenance, resource and data discovery and others;
3) Using these APIs each device announces the availability of certain types of data to other NuNet enabled devices; Using the same APIs, healthcare service providers and data aggregators announce their services;
4) Healthcare, personalized and precision medicine providers, longevity therapeutics and medical researchers use NuNet-enabled devices to find data sources, sign contracts, provide micropayments for personal data usage and offer their services in terms of personalized advice and analysis;
5) Health wearable users can search for service providers and additional knowledge that can be retrieved from their data. Alternatively, they receive notifications about offers from service providers which they may accept or reject at any moment, retrieving their personal data;
6) NuNet enables data pre-processing and anonymization at user's device by decentralizing data processing workflow and installing parts of it to device where data is. In this way it ensures that private data never leaves a device in the first place.
7) Service providers, which use proprietary or open source algorithms for data analysis and aggregation, leverage decentralized computing framework of NuNet to bid for

free computing resources available at mobile devices which may or may not correspond to the ones that provide data.

8) Individual data and compute resource providers establish formal digital relations with data aggregators and compute resource users via the smart contract mechanism. Smart contracts can involve any type of barter (data for analysis, compute resources for data) exchange or micropayments. Canceling a smart contract ensures that the data is not accessed by third parties any more.

Decentralized genetic-algorithm framework

As a first step toward supporting a rich variety of AI processing algorithms, we will enable the early alpha versions of NuNet to coordinate decentralized and distributed optimization processes using Genetic Algorithms (GA) and Genetic Programming (GP). These algorithms are chosen because

- they are particularly well suited for a processing infrastructure consisting of a large number of processing units with widely varying capability (including some with very weak capability), loosely and erratically connected together
- they are applicable to a wide variety of AI problems and optimization problems, applicable to a variety of practical and scientific domains

This NuNet based GA/GP framework will support any genotype (solution space) and fitness function (objective function) fulfilling certain APIs, as is commonly done in OO genetic algorithm frameworks.

A specialized, simplified version of many aspects of the broader NuNet ecosystem would apply in this context:

- AI developers will contribute AI plug-ins to improve the GA/GP framework, e.g. specialized mutation and crossover operators, or EDA (Estimation of Distribution Algorithm) modeling tools or fitness estimation methods
- Applied AI developers will write code mapping specific types of practical real-world problems (e.g. predicting financial or climatological time series, designing certain types of machinery, extracting concepts from text, mining patterns in tabular or graph data, clustering data vectors, classifying genomic data, etc.) into GA/GP problems
- App developers will write NuNet apps using this AI code to solve specific problems, e.g. predicting aspects of climate change, recognizing patterns in ecommerce data, learning classification rules from genomic data about human disease, etc.)
- Users will be able to choose from among these apps, running multiple apps on their devices at various points in time, and in many cases receiving tokens as reward for their contribution of resources

This NuNet-based GA/GP toolset will support commercial services, in which apps provide value to customers who then pay for their services, with their payment ultimately resulting in tokens flowing to the NuNet resource providers. Payment may be made directly in NuNet tokens or in other tokens or (e.g. fiat) currencies via conversion gateways.

As NuNet framework will support staking resources, fiat and currency for socially beneficial services as defined and voted for by the community members, it will enable to use GA/GP to provide AI analysis for the common good, e.g. data analysis toward climatology or medicine. It will allow to run computation loads of certain socially beneficial but not necessarily commercially profitable and adequately funded projects on the framework. Additionally, NuNet Foundation may decide to provide bonus tokens to organizations using AI tools and computing resources for common good, so that they can adequately compensate resource owners; in this sense a GA/GP application would be used to experiment with tokenomic as well as algorithmic methodologies of post-monetary economy.

Federated machine learning

The concept of *Federated Learning* was first introduced by Google in 2017 as collaborative machine learning without central data. Models are trained either from a starting point or from scratch using millions of distributed computing devices and their data. This approach is radically different from traditional, centralized training where the data and computational power are owned, operated and controlled by a single entity.

In the decentralized learning approach the device downloads a model by a resource consumer, then uses its own data to train this model and just send the result of this training step back. Leveraging the data and compute of the devices to be combined to update a model in the cloud. The updates are encrypted and not identifiable - the data remains anonymous and not traceable back to its origin.

This kind of machine learning system is a perfect use case for NuNet and its goals. To realise this quickly we will leverage existing federated training frameworks and include the NuNet adapter into them. This will make it possible to leverage NuNet and all its participating devices for commercial and common training of AI models.

The models can either be single-party, multi-party or a common system. An example for a single-party system would be a music recommendation service where the model is adapted using the individual choices but after a certain number of choices and model updates the result is communicated back. Here the funding of the resources distributed to the participants would be invested by the single-party.

A multi-party system could be a fraud detection system of multiple financial partners that are sharing a resulting models but don’t want to expose their individual data sets. Another use case of this would be an autonomous driving model that is shared by multiple cars from multiple vendors but updated on the data of all of them. The funding of the compensational resources is done by the involved parties.

A common system could be a climate prediction model shared and updated by all humans interested in stopping climate change. Other common models could be a medical system to predict and prevent diseases trained and shared among all of humankind. The participants can donate their resources to achieve a greater good without having to spend money but instead leveraging their mobile phones and power but most importantly their time and data.

This kind of training adapts the model and possibly the application using it on the device to the data of the individual user - thus resulting in a hyper personalized model where the input of the individual becomes an update for the model of the whole.

Secure data exchange in decentralized systems

The complex problem of ensuring security of IoT ecosystems is the biggest obstacle to large scale IoT adoption and integration into business models. Furthermore, data privacy, provenance and high granularity access management, while being instrumental for unlocking the potential of data economy, hits new levels of complexity in decentralized IoT systems where “firewalls” have to be distributed across a large number of devices, most of which are too low powered to run full operating systems or an Internet protocol stacks. IoT security systems have to be decentralized by design, without a single trust layer or a trusted party. Ability to customize and integrate blockchain and state-of-the art trusted computing technologies in decentralized computing workflows on NuNet framework allows solution providers to address many obstacles of IoT adoption by design at case by case basis.

Flexible decentralized computations at the edge

NuNet leverages computing frameworks of its partners by allowing to build flexible and radically decentralized computation graphs spanning IoT devices of different capacities and owned by different economic players and community members -- simple or advanced sensors, robotic microcontrollers, embedded systems, virtual machines on the edge, fog and cloud. It enables to design efficient and fast data and AI workflows for dynamic IoT environments where huge amounts of streaming data can be processed as close to the edge as required by the business model and capacities of the particular system. In the future, NuNet and SingularityNET are planning to partner for implementing technologies required for the automatic adaptability for balancing computing loads in IoT networks in real-time.

Cross-vendor process integration

Decentralized by design computing architectures and data workflows of IoT networks, which span large geographical areas and involve diverse ecosystems of individually secured devices, allows solution providers to integrate devices and computational process owned and operated by different businesses into a single business process. Using blockchain based custom state-of-the art data privacy, provenance, access management solutions and an economic mechanism powered by fine-grained microtransactions, NuNet and SingularityNET enables data economy and business ecosystems with many partners that do not need to be centrally managed or rely on a single trusted party. The capability of integrating multiple vendors and businesses into one value chain has huge potential in largely untapped IoT domains such as smart city, international supply chains and management of large partnerships in general.

Mobile IoT device ecosystems

Mobile IoT device ecosystems, such as sensors and cameras equipped drones, cars, smartphones and in general more or less advanced autonomous robots provide implementation challenges simply due to the fact that their topologies constantly change. Furthermore, network connectivity speeds and patterns may change considerably when components of the network move with respect to each other. NuNet, leveraged by AI ecosystem of SingularityNET, provides the ability to balance computing loads between the edge and 'core' of such networks and subnetworks thus supporting diverse mobile or stationary IoT device ecosystems, such as semi-autonomous rescue and security drone fleets[11], car fleets, collaborative robots, truck platoons, etc. Furthermore, NuNet elables cross-vendor cooperation via its tokenomics mechanism, allowing to integrate devices and ecosystems of different vendors into a single computing workflow.

Large partnerships

Automating supply and delivery chains are special cases of business processes involving large number or independent economic entities which for technological, economic or competitive reasons cannot be coordinated in a centralized manner (e.g. competing shippers may not want to subscribe or trust a centrally managed database owned by a large competitor), yet the coordination and real-time information exchange would clearly benefit all participants of the ecosystem. Secure distributed trust technologies combining public and permissioned blockchains may be integrated to IoT and AI processes for supporting diverse business models and commercial collaborations which were not available before (e.g. in smart power grid management, connected houses, utility management, etc.). A global decentralized computing framework of NuNet provides a technological basis for building such collaborations and computing workflows, leveraged by SingularityNET and other partner's ecosystems.

Tokenomics

NuNet will be formally launched by a nonprofit foundation, the NuNet Foundation. A fixed number of NuNet tokens will be minted at an initial Token Generation Event (TGE) orchestrated by the NuNet Foundation, to be divided among:

- **Initial participant pool**: to be sold to members of the public interested in purchasing NuNet-based services going forward
- **Reward pool**: to be used to provide additional incentive to providers of compute and storage resources to the network, and those who stake their NuNet tokens on network participants
- **Benefit pool**: to be provided to computational processes intended to further the overall benefit of humanity and other sentient beings, to enable them to secure compute and storage on the NuNet network

[11] https://drive.google.com/file/d/1xdIu66CpHWG1CAuR6RN5wZs2P_gMaA7C/view

- **Network operations pool**: to be provided to the network operations agents (and their owners, initially humans) creating and maintaining the NuNet infrastructure

Tokens generated during TGE will be released in batches via iterative governance of the roadmap implementation. 20% of pre-minted tokens will be released initially for funding the implementation of the first milestone release of NuNet framework. Subsequent releases of tokens are considered Critical decisions and will be managed accordingly as defined above.

New NuNet tokens will be minted after this only based on a vote in which approval is given by voters holding a large supermajority (70%) of the tokens held by all participants in the vote.

Shortly after network launch, a simple staking mechanism will be provided, enabling network participants to stake tokens on a particular provider of compute or storage resources, achieving rewards for their staked tokens. Later on, a sophisticated staking mechanism will be developed and ongoingly refined based on feedback from the community, including both staking on storage and compute capabilities, and staking on functionalities of agents. Token holders will be able to support beneficial projects with tokens, while resource owners and algorithm developers will be able to stake their resources for specific projects and computing workflows -- enabling efficient mixes of centralized commercial, decentralized public and community's resources for specific needs of projects and initiatives, execution of which is not feasible otherwise.

Fees charged for network utilization will be distributed among the owners of network operations agents. Initially the network operations agents comprise the NuNet Foundation and its founding team, as these are the parties currently developing and maintaining the NuNet infrastructure. As the network develops, additional network operations agents may be approved via a democratic process.

As the network matures, more software operations may move from network operations agents to meta-agents operating within the network in a non-privileged way. For instance, initially, the matching of offered compute or storage with resources requested by various processes, will be carried out by network operations agents developed by the NuNet Foundation team. But later on, meta-agents carrying out this matching may be developed by other community members, so that less and less of the matching needs to be conducted by network operations agents. The maintenance and development of the core NuNet software will be the mainstay of the network operations agent pool even in a mature network, however.

Partnerships and envisioned interoperations

The operation of NuNet will be intimately related to the decentralized computing platforms and frameworks which it will support. Initially, the NuNet network will be developed with close partnership, technical and governance level coordination with SingularityNET and other members of Decentralized AI Alliance. NuNet will also seek partnerships with other decentralized computing frameworks and protocols, as rollout and community building proceed.

We now review some of the partnerships and technical interoperations that are envisioned to be valuable as NuNet matures:

SingularityNET

SingularityNET is a decentralized platform for applied AI and AGI tools and datasets, which gives developers a way to share and monetize their creations. It is a tool for software developers across many vertical markets which lets anyone create, share, and monetize AI services at scale. SingularityNET aims at becoming a democratically governed 'decentralized self-organizing cooperative' when matured. External, non-AI Agents who wish to obtain AI services from Agents in the network will be able to contract them from SingularityNET's marketplace. Anyone using SingularityNET's Software Development Kit will be able to create a node (an AI Agent), put it online (running on a server, home computer, robot, or embedded device), and enter it into the network so that it can request and/or fulfill AI tasks in interaction with other nodes and engage in economic transactions.

NuNet will provide SingularityNET agents with access to the network of decentralized computing resources, computational reflection for optimizing resource capacities for specific Agents and economic mechanism for micropayments. Furthermore, NuNet will provide the architectural and logical layer necessary for SingularityNET Agents to self-organize into complex, dynamic and intelligent workflows.

Decentralized AI Alliance (DAIA)

Through the ability to support computational processes running within different decentralized computing and data sharing platforms of DAIA members, NuNet will provide a meta marketplace ecosystem which will allow to design data processing workflows that work across different decentralized platforms, private or public infrastructure of different owners of large and small scale computing resources.

Others

Other potentially valuable targets for inter-operation and cooperation may include, but are very far from limited to:

- Golem: A decentralized marketplace for computing power;
- Ocean Protocol: An ecosystem for the data economy and associated services, with a tokenized service layer that securely exposes data, storage, compute and algorithms for consumption;
- iExec: Blockchain-based virtual cloud computing and data renting framework;
- Enigma: A peer-to-peer network, enabling different parties to jointly store and run computations on data while keeping the data completely private;
- IPFS: A peer-to-peer hypermedia protocol to make the web faster, safer, and more open.

- Filecoin: A decentralized storage marketplace that achieves staggering economies of scale by allowing anyone worldwide to participate as storage providers. It also makes storage resemble a commodity or utility by decoupling hard-drive space from additional services. On this robust global market the price of storage will be driven by supply and demand, not corporate pricing departments, and miners will compete on factors like reputation for reliability as well as price;
- Storj Labs: decentralized cloud storage;