Anoma: Undefining Money

Versatile commitments to value

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Abstract

Coordination, the transmission of information between agents about their internal states and preferences, allows involved parties to collectively plan their actions for mutual benefits beyond what they could have individually achieved and thus leads to the persistence of social groups over time. Coordination requires a mechanism, a medium, a form in which the information in question can be represented, such as oral speech, written language, or fiat currency, which must suit the context in which it is used. Money, the numerical abstraction of value, is a form which enables coordination across wide networks of economic agents who benefit from engaging in trade, but the unidimensional reduction in conjugation with the game theoretic dynamics of multiplayer zero-sum competition results in systemic divergence from the underlying collective preference set of the system's participants which scales in proportion to the depth of abstraction in play. Left uncurtailed, operating in an environment with finite carrying capacity, the externalized harms of this escalating divergence will eventually reach the level of existential threat.

In this paper, we first motivate this choice of coordination as the target of our investigation, explain why we must avoid blockchain dialectics, and note the necessity of divorcing our analysis from historically contingent ideological superstructure. We then investigate the nature of coordination as such and identify the salient properties of the mechanisms which enable it. Having bounded the abstract problem, we then narrow the analytical frame to the particular case of international economic exchange. We analyze the existing mechanisms of currency, natural language, and legal contract, attempt to roughly capture how and why they have failed, and enumerate the requirements of any mechanism which aims to rectify this abstractive deficit. Finally, we introduce a particular protocol, Anoma, designed to facilitate large-scale coordination without a unidimensional unit of account and allow participants to factor many variables in digital expressions of their values. We describe the components and structure of Anoma and then analyze whether or not Anoma satisfices these requirements. In subsequent papers, we outline the means by which this protocol can be instantiated using contemporary distributed ledger technology and cryptographic primitives.

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1 Introduction

1.1 Motivation

1.1.1 A morning of economic mismediation

Take a walk to the corner store in the morning to grab a coffee and an energy bar for breakfast. On display you find a banana salted caramel bar, a chocolate-coated blueberry bar, and a hazelnut toffee bar, the cheapest of the three. Having selected hazelnut toffee, you evaluate the coffee choices: Ethopian dark roast, Brazilian medium roast labeled fair trade, or the house special. Wanting to be conscious of the conditions of labor, you select the fair trade Brazilian medium roast, tap the chip in your card at the counter, and head back out, now equipped with your coffee and energy bar, into the hustle and bustle of a New York city morning.

As it happens, the three energy bars are produced by three different companies. The banana salted caramel and chocolate-coated blueberry bars — a bit more expensive — are produced by companies which source their ingredients directly from farmers and use recycled packaging, while the company which produces the hazelnut toffee bar instead buys from industrial nut wholesalers and obtains their packaging materials from a paper factory which clear-cuts trees — less costly production practices, hence the cheaper price. The producer of the Brazilian medium roast labeled fair trade, while their workers are kept above the poverty line, sustains its low prices only by overextracting nutrients from the soil and moving as soon as a field's arability is exhausted. In your trip to the corner store, you purchased not only the coffee and the energy bar which you intended to, but also deforestation and destruction of arable land which you didn't.

Later in the day, you browse through the Android app store and find a neat little puzzle game for only a few dollars, which you purchase and play with your friend during lunch break. The game, you discover, has a multiplayer mode in which participants connect over the internet and are matched up based on their location for low latency. When you launch it, you absentmindedly tap the confirmation box that allows the application to view your location data.

The start-up company you work for resells upscale mattresses with one-day in-city delivery free of charge. You work in the procurement division, but unbeknownst to you, a third of the company's budget is spent on subway advertising, as A/B testing found that the company could charge a few hundred dollars extra markup if their brand was ubiquitous. On the subway ride home that evening, since the walls of the train cars are filled with advertisements instead of poetry, you pay a few dollars more for solo puzzle mode in the app and play it all the way. Just as you exit the game, you see an in-app add for a Times Square comedy show tomorrow. What a coincidence!

As it happens, a third of the purchase price of the Android game went to Google, the owner of Android, and slivers of that went to fund a Street View car driving around a German neighborhood without permission, K Street lobbyists campaigning against consumer privacy regulations, and behavioral research into location-based advertising targeting, conveniently made use of by the application itself as soon as you agreed to share your location — the application developer didn't even elect to specifically target by location, but rather passed all data points in their possession to DoubleClick's automatic engine and instructed it to maximize revenue. Your employer pays your salary from the mattress sale profits which you help bring in, part of which you then use to purchase an application to distract you from the advertisement space paid for by the very same company. In your puzzle adventuring, you purchased not only the indie mobile game which you intended to, but also surveillance capitalism which you didn't.

Something is off. In your purchases, you intended to obtain a quick breakfast or a bit of fun for lunch break, not deforestation, soil nutrient extraction, or surveillance capitalism. Had you known about the net impacts of these interactions with the economic system — in part, a less habitable world for your children — you might not have elected to make them at all. Even in your contractual labor, the pay you receive, funded by the profits which you help bring in, is then used to purchase a game in order to escape from the intrusion into the world of the company which pays you. Money, which serves as the medium for your interactions, is not representing that which you value — it has diverged, and if the net impact to the purchaser is negative, even inverted itself. Are these interactions merely an assortment of concerning patterns, perhaps now merely isolated exceptions, or are they manifestations of a more deeply rooted common phenomenon, perhaps now the rule?

1.1.2 Transcending blockchain dialectics

Distributed ledgers offer a novel mechanism for mediating rule-governed interactions, such as the transfer of money, which has a high degree of programmability and a certain resistance to capture as compared to its centralized alternatives, but what precisely is the problem which these technologies are solving? What is the raison d'être of money itself? The development of new distributed ledger technologies is primarily conducted within the incentive system of the existing legal and capitalist superstructure, so these questions cannot be answered by analyzing developments internal to the industry, but rather must be investigated directly, from first principles, lest the analysis remain conceptually tethered to the dominant economic paradigm.

Operating within any concrete space of innovation, mimesis, and recombination, one can easily fall into a dialectical groove, designing a new protocol as an attempt to repair mistakes, combine features, and synthesize tradeoffs of prior work. Such cumulative progress is concrete and easily attainable,

but it runs the risk of diverging far from the context of use, doubly so in the blockchain space, where flashy tokens and shiny digital objects turn protocol designers' eyes towards the intricate clockwork of internal mechanics and away from the real world outside. As this paper will demonstrate, protocols are languages for coordination, and their usefulness is correspondingly determined by the coordination problem they aim to provide a suitable mechanism for addressing and how well they do indeed provide such a mechanism. Dialectical progression of blockchain systems is helpful as a bottom-up, evolutionary methodology for sussing out technical contours of the protocol design space, but the factors of natural selection at play are largely driven by internal elegance and short-term profit incentives inseparably entangled with the coordination problems the protocols themselves often aim to alleviate, so this progression cannot be expected to converge towards the areas of the mechanism design space which genuinely address those problems. Rather, this design space must be investigated directly, and the requirements of any proposed solution determined, against which concrete protocol proposals can then be evaluated.

1.1.3 Superstructural disentanglement

The conceptual framework employed in our everyday living and everyday economic interactions is deeply intertwined with the paradigm of Westphalian nation-states, which subtly permeates itself through the discourse. For example, the idea of "transparency" of official bodies — often taken as a terminal value by political campaigns or NGOs — is an attempt to ensure consistency between public statements and actions taken by an official body, thus predicated upon both the hierarchical structure of authority in which such bodies are responsible for implementing laws and the existence of a legal enforcement system that would make the discovery of a discrepancy between statements and actions deleterious to the official body in question. As law itself is merely a particular form of coordination, if we inadvertently import conceptual notions from the existing ideological superstructure they will confuse our analysis since these notions may not apply in a situation with a different superstructure. This paper is trying to investigate whether or not there exists a coordination mechanism capable of facilitating large-scale interaction without the disadvantages of the present systems of money and legal contract. As this mechanism may require a different superstructural basis than money or legal contract, we must construct and analyze the suitability of the requisite superstructure for this new mechanism from scratch and take care not to mistakenly import conceptual frameworks which axiomatize concrete manifestations of such particular forms.

1.2 The structure of this paper

The common cause of these dystopian recurrences, if there is one, must be identified, separated from the superstructural ideological entanglements, reflected upon, and inverted into a description of the coordination problem and an enumeration of the requirements of a proposed solution. A solution must then be articulated and checked against these requirements to determine suitability. The task of this paper is thus threefold: first, to zoom out and disentangle the conceptual model, second, to extract from the model a clear problem statement and requirements of a proposed solution, and third, to propose a concrete protocol and test it for suitability against the requirements so articulated.

Accordingly, this paper is split into three sections. The first section investigates the nature of coordination as such, the mechanisms which facilitate it, and the salient properties of said mechanisms. This analysis is conducted through the lens of present problems, properly abstracted in order to partition away contingent dependence on particular material conditions. This section concludes with an explanation of the situational dependence of mechanisms of coordination, and a description of the general sort of analytical process which must be undertaken in order to determine the suitability of a particular form to a particular scenario.

The second section narrows the scope of our conceptual frame by fixing the boundaries of the particular class of coordination problems which are of interest, clarifying what it would mean to elect not to solve these coordination problems, and deconstructing the unique nature of this class. The second section then analyzes existing proposed mechanisms, attempts to determine why and how they have failed, and enumerates a list of requirements of any coordination mechanism which aims to rectify these issues. Altogether, this section aims to provide a sort of litmus test which can be used to evaluate whether any proposed mechanism will in fact satisfy these criteria and thus ameliorate this class of coordination problems.

The third section proposes a particular protocol, Anoma, the instantiation of which aims to serve as such a mechanism. This section first describes the components, structure, and interaction points of Anoma, then uses the litmus test provided by the second section to analyze whether or not Anoma satisfies these requirements. Finally, the third section concludes with an analysis of the ways in which this protocol can only approximate abstract properties due to computational limitations. The paper concludes with a brief summary of directions for future work.

2 On coordination

2.1 What is coordination?

Two laborers coordinate to lift a large stone together and place it upon the foundations for their new shelter, a clan of hunters coordinates to encircle a wild boar together and capture it for dinner, a community coordinates to build a new school together and better educate their children. A municipality coordinates to prevent wildfires, a state coordinates to ensure new buildings are safe, a nation coordinates to send humans to the moon.

Coordination requires transmission of information between the participants and a certain requisite degree of binding to hold participants to their commitments. Mechanisms for coordination must reflect the real relations of mutual interdependence amongst their participants, and the form of coordination mechanisms must mirror the content of coordination which is desired or they will diverge and fail to function. If individuality is the preservation of information about the self through time, coordination at different levels can be understood as scales of individuality, where the choice of any sort of preferred level is an arbitrary one.

2.1.1 Examples of coordination

A pair of deep-sea divers uses hand signals to coordinate their actions underwater. They point towards interesting features on the seafloor to photograph or investigate, look at each others' air meters and signal when their counterparty should go up for air, and hold two fingers apart to indicate a dangerous current or incoming sea life.

Players of DotA, a complex real-time online multiplayer game, must agree each time tick on the results of the actions taken by each player in conjunction with the intricate rules of the game. Each player plays a character which has different skills, each with use conditions, ranges, and various effects upon the virtual battlefield. In principle, these rules could be written down and their effects computed with pen and paper — so players could play a game with the same structure of rules as DotA but via a different medium — but doing the calculations by hand would take far too long. Furthermore, the calculations must be precise: were the players to disagree on the results of a particular action, their states would diverge and they would no longer be able to play the game together. These players use the computational tool of a computer to compute the effects of a complex ruleset each time tick and display the results back to them in the game user interface. Coordination here is mediated by digital messages sent between the players' computers, which convey the actions taken by each player to all the other players. Despite being executed by a computer, however, this ruleset is transparent. Skilled players of the game can learn the rules for all of the skills and predict or estimate the results of their actions prior to taking them. DotA is team-based — two teams play against each other on this virtual battlefield — and coordination also takes place amongst the members of each team via

voice or text chat. As players internalize this ruleset, they develop compact terminology to refer to different patterns of actions and results, which they use to communicate their intentions and suggestions to each other through the course of the game. Coordination here takes place on multiple levels which reference each other.

Coordination can also take place in simple situations of binary choice. Consider the case of a tribe deciding whether to stay in a valley with dwindling agricultural yields the past few years but existing shelter and cultural heritage or to hit the road and go foraging for awhile while searching for more fertile ground on which to resettle. Members of the tribe may disagree on the best route forward, but none of them would be able to survive alone. Splitting the group would be worse than either choice, so the tribe members elect to conduct a vote, according to the results of which they all agree to proceed in unison. In this case, ballots created by each member serve as the medium for transmitting their preferences, and the commitment amongst members in advance to act in accord with the results of the vote, whichever choice is selected, allows for the continued unity of the tribe. Such votes are limited, however, in what they can convey — once a set of choices is selected for the ballot, voters can only choose between them, even if they prefer another idea which is a combination of the options — thus the deliberations prior to the creation of such a ballot, another layer of coordination involved here, are critical.

Participants in a complex supply chain coordinate with each other through the medium of money. Purchases at the end of a supply chain send funds and thus information about demand up the supply chain, which then informs producers' choices about what kind of goods to manufacture or how to prioritize their research and development efforts. Similar to a vote for one candidate or another on a ballot, the choice of whether or not to purchase a particular good or service is binary. The end consumer cannot convey through purchasing their preference for a good which does not yet exist, they can only choose between the choices on offer. Unlike in the tribal vote, there does not exist a clear prior step of mutual deliberation — the relationship between the consumer and producer is asymmetric.

2.1.2 Internal and external

Coordination implies a distinction: were there not distinct agents, there would be no need to coordinate. Divers, DotA players, and tribal members all have internal thoughts, motivations, and intentions, which to the others are opaque — yet it is these internal structures and plans about which they must communicate in order to coordinate with each other. The divers signal before they move in order to avoid running into each other; the DotA players communicate their skill readiness prior to entering into a team fight in order to use them in synergy; the tribal members convey their willingness to accord with the results of a particular ballot before voting in order to

ensure that the tribe can remain together no matter the result. Information about the internal structures is thus articulated by one participant onto the physical substrate which the participants together inhabit in order for the other participants to perceive it and interpret it as information about the internal state — the divers' signals, the DotA players' chat messages, the verbal commitments of the tribal members. The representation of this information is physical — hand signals, words in chat, audio waves of speech — but the information is helpful for coordination only insofar as it is about the internal states, so participants must interpret this information as about the internal states of other participants.

2.1.3 Transmission of information

Coordination occurs at many scales and in many fashions: perhaps the clan of hunters is not in the American high desert but rather World of Warcraft, perhaps instead of two laborers lifting a stone it is two writers authoring a book, perhaps instead of a community building a school it is a nation launching a probe into outer space. In all cases, this coordination requires transmission of information. The laborers must inform each other of their actions to lift in unison, the hunters must inform each other of their positions to encircle simultaneously, the community members must inform each other of the details and construction plans of the new school. Information transmission requires a medium: for the laborers, speech, for the hunters, hand motions, for the community members the written word. Mediums differ, and must be chosen to match the specifics of the situation at hand. Hand motions would not suffice for a community to agree upon the details of the new school, and written language would be of little use to the hunters as they attempt to encircle the boar. These suitable mediums of coordination — hand signals, speech, and the written word — allow the participants to coordinate with each other. The advancement of language is a progression of mediums: new forms of language enable more complex kinds of coordination to take place successfully.

2.1.4 Mutual benefit

By acting in unison, the divers can lift and surface with a heavy object neither could have carried alone. Playing together, a DotA team can combine their skills in a team fight and defeat their opponents, but playing alone they would be picked off one by one. Staying together, the tribe members can care for one another when they are sick, share the proceeds of a hunt amongst themselves for more balanced nutrition, and construct shared shelter, but venturing off alone they would be vulnerable when sick and likely to starve if their foraging luck turned sour. Coordination benefits the individual agents, allowing for their continued happiness, health, and existence in a way which a party could not have achieved alone.

Involved agents can choose whether or not to coordinate — the diver could always dive alone, the DotA player could play by themselves, the tribe member could strike out foraging solo — so their choice to coordinate with others implies the existence of a benefit which they could not have personally obtained. Furthermore, in physical terms, coordination mechanisms are not free — hand signals, written text, and spoken word require expenditure of energy — so the benefit to involved parties must exceed the cost of operating the mechanism itself in order for coordination to be worthwhile. Correspondingly, a coordination mechanism which persists over time — the hand signals used by the divers, the computer program used by the DotA players, or the language spoken by the tribe — indicates a stable equilibrium where all parties are better off coordinating than not, and where the costs of the mechanism itself are less than the benefits from coordination. This equilibrium, however, is local: there may be other equilibria in the configuration space of coordination mechanisms which are better for everyone, if they had some way of coordinating to switch. Complexity of the medium in question is critically relevant here, insofar as mediums which allow for more nuanced expression allow switching to points further away in the space of potential actions. Compare money or voting to spoken language: selection between a binary set of choices on a ballot or whether to purchase one good or another are too limited to allow the involved parties to switch to another mechanism of coordination, while spoken or written language can explain the rationale for and describe the potential implementation of a system quite different from the one currently in place.

2.1.5 Scales of individuality

What is it for a social group engaged in coordination — friends, divers, DotA players, tribes, guilds, nations — to persist over time? To refer to the social grouping as that which persists entails a persistent identity over and above both any particular mechanism utilized by the group at any particular point in time and any particular participant — new babies are born into tribes while elders pass away, players join and leave games while the rules and culture persist. This persistent identity is a continuous contour through time along which information is preserved. Much or even most of the information may be lost — tribal rituals may be forgotten if the last elder who remembers them fails to pass them down to their descendants, players may leave to join other games without teaching anyone their skills or passing along all aspects of the culture in which they once participated, guilds may forget tools of the craft if their membership declines and can no longer support specialized personnel — but to be able to refer to the group itself as one thing in one time and in a later time entails that some has been preserved, or at least that there exists a continuous trajectory from one point to the other.

In this sense, the collective is the individual. Individuals conserve a measure

of temporal integrity [1], preserving information about themselves over time, propagating their past information intakes into their future interactions. The contrast of the individual with the collective, as if there is some sort of necessary trade-off between the preferences of different levels, is merely misled — the individual and the collective do not exist as separable categories engaged in a sort of existential struggle but rather as particular points along a smooth continuum of individuality. There is no preferred level of individuality — cells in your retina and hippocampus coordinate to scan this line of text and remember it, countries coordination to jointly launch the Voyager probe with a golden inscription describing in brief the knowledge of humanity — coordination at more microscopic levels is necessary to enable coordination at more macroscopic levels, and coordination at more macroscopic levels feeds back into and provisions resources more beneficially for coordination at more microscopic levels. At all scales, coordination, this preservation of information through time, and the corresponding sense of individuality, requires a mechanism. It is these mechanisms which this paper shall discuss next.

2.2 Mechanisms for coordination

Coordination cannot take place without a mechanism: a physical substrate which sits between the agents who wish to coordinate, using which they can in some way represent their preferences and intentions and thereby communicate them to others. That which these agents — the participants in coordination — must agree upon is not the representations encoded on the medium but rather the internal states themselves, insofar as they pertain to future actions. These internal states cannot be agreed upon directly because the internal states of each participant are inaccessible to the others. Thus, there must be some sort of binding between the physical form upon which states are represented and the internal states concerning which coordination is desired. Whether or not a mechanism is suitable is dependent on the particular situation in which coordination is called for.

2.2.1 Facilitation of agreement

In order to coordinate, agents must communicate information about and agree on their internal states, such as plans, motivations, and intentions — the direction in which the hunters will walk to encircle the deer, the preference of each member of the tribe as to whether to stay or go, the contributions everyone will make towards the new school — so that they can act in synergy. Because these internal states are not directly accessible, in order to communicate information about their internal states, agents must represent it in an intersubjective physical form — visuals of hand gestures, sound waves of speech, written plans for a school — which the other agents must then interpret as information about the internal states of their counterparts.

In the case of money, the communication is less explicit but still present. By buying or selling a good at a particular price, an agent commits to a willingness to exchange, implicitly conveying a preference for goods relative to one another based on their prices. If Sally will sell a turkey for 10 dollars and Bob will buy a turkey for 12 dollars, while Sally will buy milk for 5 dollars and Bob will sell milk for 4 dollars, they can buy and sell turkeys and milk respectively for mutual benefit. The form of representation, currency, is limited in expressive power — agents can only make the choice of whether or not to buy, or whether or not to sell — they cannot express a more complex or nonlinear preference with a number.

2.2.2 Semantic embodiment

In order to allow for agreement, coordination mechanisms require a certain amount of embodiment in the language of the semantics of the world, of binding between the language and the world. Language is only useful as a tool for a community to coordinate if people mean what they say, if committing to a statement of future action entails that one will carry out one's commitment. Small groups can enforce this kind of commitment mechanism with strong norms of honesty, where the penalty for failing to honor one's promises is ostracism from the group, a threat to one's existence in a tribe out in the wild, or at least to one's style of life or livelihood if the small group in question is an organization within a wider society. In part through this embodiment, the language acquires meaning, and becomes useful for coordination amongst groups of participants for their mutual benefit. Of course, the threat of ostracism is not itself why members participate in the group — they may enjoy doing things together and simply care about other group members — rather, this sort of binding is a way for the group to protect itself from malicious or selfish agents who would otherwise be able to "free ride" and benefit themselves at its expense.

2.3 Situational dependence

Mechanisms for coordination, as physical forms, do not facilitate coordination in a vacuum. In order to be useful for coordination, a form must suit the background environment and particular purpose of coordination in question. As motivations, preferences, and intentions change over time, physical forms on which such states are represented must possess an appropriate degree of dynamism, allowing for preferences to be updated, else they will lag behind the underlying states. Mechanisms must also reflect the underlying mutual interdependence, the potential shared benefit from coordination amongst different sets of parties who could possibly do so, or they will not be able to satisfy this purpose. Relatedly, if a mechanism is controlled by a party outside, or distinct from, the parties who are coordinating, this distinction entails a potential divergence on the part of the mechanism from the

mutual benefit of those who are using it to coordinate, since what is in the best interests of this other party may be different.

2.3.1 Suitability of form

The form of coordination must allow for the parties in question to articulate the relevant information into or onto the form, and must allow for other parties to understand the information represented in the form as information about the intentions and preferences of the party articulating. It may also be desirable for the medium to be such that other parties not involved in the coordination cannot understand the information: when the hunters circle around the deer, they don't want the deer to be able to read their signals, lest it be able to flee before they surround it. Forms vary in their density of information transmission: hand signals which must be interpreted at a distance must be quite different from each other in order to be distinguished, while written characters read at close distance can differ only in small strokes while meaning totally different things. Forms also vary in their error tolerance. Speech transmitted in a noisy environment must encode more redundancy than writing or digital communications which need not deal with so much noise background. The precise replicability of writing, conversely, lends itself to wide transmission and broadcast without changes in content as one might experience when playing a game of "Telephone."

2.3.2 Dynamicism — a matter of time

The usage of coordination mechanisms is situated in time. These mechanisms allow participants to agree upon actions for their mutual benefit, but what constitutes beneficial actions or changes in state for each participant changes over time, as environmental conditions change and different choices are made by others. In order to coordinate, internal states must be articulated onto an external medium such as speech or writing, so that others can perceive and interpret them. When so articulated, however, the medium is immediately "dead": the participant's preferences may change, but the words they spoke or wrote will not, so those preferences represented in the physical form will diverge from the participant's actual preferences at present. Different coordination mechanisms can reflect these changes more or less quickly. Speech can easily be revised, whereas written pamphlets cannot easily be taken back once distributed. A form of coordination which fails to reflect changes in the underlying preferences quickly enough will lead to a lag in the ability of those coordinating to react to changing conditions, as the preferences reflected by their joint actions will be the preferences articulated awhile ago — and residuals of these old preferences can linger and create their own currents of events. This lag entails a certain danger in binding: if old preferences cause actions but no longer reflect the best interests of the participants, the superstructure

of coordination which once resulted in mutual benefits may now result in harms which outweigh them.

2.3.3 Reflection of mutual interdependence

Coordination mechanisms must reflect genuine mutual interdependence of value amongst their participants, for coordination mechanisms exist for their shared benefit. The hunters benefit from jointly encircling the boar, and the community members from building their own new school. Insofar as they exist in and persist through time, misalignment between mutual interdependence and present coordination mechanisms can result in the attempted re-purposing of mechanisms to operate in a context for which they are ill-suited. Westphalian state borders drawn on a map with colored crayon, perhaps once aligned with the primarily domestic economic interdependence and common cultural heritage a few centuries past, now align neither with the locally-focused mutual interdependence of their constituent communities nor with the global mutual interdependence of humankind on itself.

2.3.4 Alignment of control

Mediums vary in whether their locus of control is internal, possessed by those who utilize them, or external, located outside the context of use. Some can be controlled only by their participants, while some can be externally influenced. Using language to articulate designs for a new school requires no one's consent, while the payments for the lumber with which to build the schoolhouse, if made in a fiat currency, may be intercepted or canceled by an authority outside the community and potentially misaligned with its interests. Self-sovereignty requires the ability to coordinate without the aid of an external entity. Communities reliant on a currency issued by a fiat power are not self-sovereign, for the government can censor or otherwise limit the ability of the community members to use this mechanism.

2.4 Reputation and balance

More complex forms of coordination often possess as a component a kind of reputation, which varies across the set of participants — social status in a tribe, rating or ranking in a video game, stored currency in a monetary system — where the level of reputation a particular participant has influences how much sway they have over decisions made by the group. This sort of reputation can be accurate insofar as it reflects the past history of how well participants have done — successful deer hunts, past wins in a video game, products manufactured which other people chose to buy — and thus indicates an internal understanding on the part of the participant in question of the relevant rules of the game. However, this history is past — reputation is useful insofar as it actually corresponds to a participant's ability to contribute

to the group's collective actions in the present and continued survival in the future. Should reputation diverge from participants' present abilities, it will no longer help but rather instead hinder the ability of the group to coordinate, as influence in collective decision-making will be misallocated.

To measure the balance in a system of coordination requires the choice of a metric, which itself is arbitrary, reductive, and fixed in time. Bank account balances are easy to measure; social status, not so much — though modern financial instruments even make the former quite tricky. In complex systems of coordination, no particular metric corresponds exactly to influence within collective decision-making, but many metrics certainly correlate: as long as labor is sold, possession of money provides the ability to dictate the action of others. Accordingly, if the amount of money by a participant differs from their decision-making ability, this constitutes a misalignment no longer in the interests of the group as a whole, since they will have lots of influence but may not make the decision in the best interest of the group as a whole.

2.4.1 Centralization and inequality

When we speak of inequality — of social statuses, video game ratings, or bank account balances — we are speaking of inequality of this sort of reputation. The problem with the centralization of money, which in accordance with the ability of money to compel action constitutes the centralization of causal power, in the hands of fiat-issuing central authorities or billionaires is not merely a vague sort of unfairness. Rather, it is much more computational — individuals or hierarchies simply do not have the information and computational capacity to spend money as effectively as if it were more widely dispersed (and often the most important tasks are very limited in a per-person way, e.g. having and raising children). Production of value is not in any way so centralized, so the centralization of money is an indication of the abstractive divergence in play.

2.4.2 Privacy: restriction of action

Insofar as the interests of participants in an economic system diverge from each other, whether or not this divergence is fundamental or a coincident byproduct of wayward ideological currents, transparency of interactions within a sub-graph of the network to participants which are not themselves part of the interactions is likely to exacerbate informational inequality and constrain action. Consider private vs non-private payments for simple goods. If the payments are private, information about each payment is retained only by the users who are direct participants in it, whereas if the payment is public, information about each payment is available to everyone (or someone who has access to it). Centralization of such information can lead to metricification in an attempt to control behavior. If the information is completely public, it can still be centralized anywhere in a sense, restricted

instead by computational capacity. The more information an agent — such as Google or Cambridge Analytica — already has about a person, the more data points they can connect together to predict behavior and influence it by advertising. In this sense, leverage of information compounds, and privacy provides at least a partial defense against such compounding.

Privacy and transparency are opposites, so at first glance, it might seem that the same argument applies in favor of privacy for government officials and legislative bodies. After all, we don't want them to be manipulated by advertising either! There is a partial truth here, but also an essential distinction: such bodies are tasked with enforcing the rules of the coordination itself. It is not the content of the private actions of such officials we want to be transparent, but rather their actions in their official capacity in which they are supposed to serve as a neutral enforcer of the rules. Transparency is only an issue here because a particular few participants have been designated as part of the coordination mechanism itself (e.g. the executive branch of a government responsible for enforcing the law forms an essential part of the binding for the mechanism of law itself).

This paper remains agnostic on the question of whether privacy is necessary or relevant if there is neither centralization nor competition and thus divergence of interests. This question is fascinating but out of scope. It is not necessary to answer here because our investigation into coordination mechanisms aims to proscribe a solution specific to a particular context in which inequality and competition are both already manifest.

2.5 Metastability

Metastability is for something to vary in time with respect to something else which persists. The participants in a coordination mechanism may have some kind of collective identity — a family, a clan, a tribe, a team, or a nation — which persists even as the mediums of coordination change, perhaps from radio to television, and as the identities of the participants themselves change, perhaps when babies are born and people die within the bounds of a broader community. In this sense, the collective identity of the group persists, in that we can refer to it, and the ability of this group to coordinate persists through time even as the means change. This is a kind of information preservation of the group itself as an individual, looping back to the levels of individuality discussed earlier.

Why, one might ask, does this collective identity persist? Why does it not dissolve as each participant pursues their own separate ways? Coordination mechanisms enable the communication and joint planning of action for mutual benefit amongst their participants. As the participants' abilities are limited, more participants in a coordination network opens up more possibilities of positive-sum joint action. Thus coordination mechanisms have network effects: the more participants in any particular one, the more valuable

it is to participate. Accordingly, they may be "sticky" — participants may elect to keep using a coordination mechanism as it is individually better for them than not to use it, while a potentially better coordination mechanism remains unactualized because it would be less valuable for any participant to start using it alone. In this sense, it is the participants which render a coordination mechanism useful, and the set of participants may persist as a coordinating identity with some continuous thread of identity even if the mechanisms change.

2.5.1 Systemic transition

As coordination mechanisms have network effects, switching coordination mechanisms, even if it would result in every party being better off, requires coordination amongst the participants in question on the selection of the new mechanism itself. Unless this switch can be realized instantaneously, successfully transitioning between mechanisms which are themselves local optima in configuration space requires both that the new mechanism is a better equilibrium, i.e. that everyone is better off, and that those who initially start using it can continue to interact with the existing system at the same time as using the new one, such that the decision to start using the new system is in their interests as well and every point in between is a step upwards or at least sideways in the gradient.

Concretely, for example, this kind of mechanism transition is quite easy to enact with language, where private languages can be developed in small groups of people, between romantic partners, in academic cliques, etc. without impairing the ability of the participants to use regular language in their other everyday interactions, but more difficult with currency, where e.g. users of the US dollar who try to issue local currencies may find themselves targeted by government rules forbidding such. As this example illuminates, privacy as covered above is also relevant to the possibility of systemic transition. Insofar as particular participants in present coordination games might be unfairly advantaged, an advantage which might be lost in a new coordination system, they may attempt to target participants in a new system early on to prevent it from spreading. Thus privacy provides a kind of protection for early-stage experimenters without which systemic transition might not be possible.

3 Situational assessment

The first section of this paper articulated the general sense of coordination and gave examples in different contexts and at different scales. This section shall narrow the scope to the concrete problem in question: worldwide (Earth-wide) economic coordination. First, we disclose specific and general instances of coordination failure in the scope of this problem, which

demonstrate that present coordination mechanisms are failing in some fashion. Then, we analyze these present coordination mechanisms one-by-one and attempt to pin down why and how exactly they are failing. By inverting the characteristics of present failures, this analysis aims to illuminate the requirements of a hypothetical mechanism which would solve this coordination problem. We then attempt to enumerate these requirements as exhaustively as possible, so that they might inform concrete proposals for new mechanisms and provide a sort of litmus test with which to evaluate them.

3.1 Analytical limitations

Coordination mechanisms are embedded in a background context on which their properties depend. The modern worldwide economic system is intertwined with a complex social, conceptual, and ideological superstructure apart from which it would not function. As discussed previously, we want to separate our analysis from this superstructure, as it is historically contingent and deeply entangled with current problems. However, although the content will be different, such a superstructure will be essential for any new proposed coordination mechanism, so what we can specify here without one will be necessarily limited. We can deal with the abstract possibilities, properties, and characteristics of this coordination problem, pin down ways in which the existing mechanisms fail to solve it, describe requirements of a mechanism which would be able to, specify how this mechanism could be constructed, and gesture towards the nature of the superstructure which would be necessary to support it. As this scale of superstructure is too large to be described exactly, and the functionality of the coordination mechanism and the content of the superstructure are mutually engendering, our precision is correspondingly limited, so we aim not to construct a perfect solution but rather to at least illuminate the area of solution space clearly enough that candidates can be distinguished on an analytical basis prior to instantiating them in practice.

3.2 Scoping the problem

Coordination is context-specific. In order to analyze and potentially address a coordination problem we must pin down the particular case to which we refer. Here, we are interested in worldwide economic coordination and global supply chains, particularly the trade of physical goods such as food, water, provisions for shelter, and other essentials. As we will argue, the global supply chains which have emerged in the past century enable increased specialization and corresponding efficiency, but the present coordination mechanism of currency and Westphalian legal superstructure is ill-suited to coordination at this scale, resulting in a divergence and even reversal of the effects of action from the intentions of the participants.

3.2.1 Pertinent clues

3.2.1.1 Surveillance capitalism Pick up your iPhone in Berlin and say "Hey Siri," and your voiceprint is relayed across cross-Atlantic wires to Cupertino, California, where racks of servers await to analyze each and every wavelength, then store it in databases available for perpetual perusal by advertising companies, who use it to custom micro-target each subsequent ad you see for click-through rate just a wee bit higher. Facebook, Google, and Twitter profit by fomenting false discord to keep users glued to their products, the more opportunities to serve them advertisements.

It is not so difficult to recognize surveillance capitalism [2] as such, in one form or another, but individuals acting alone are powerless against the might and data monopolies of the internet giants, who tie their centralized orchestration systems with the twine of capital. The companies themselves are subject to a multipolar trap in the information which they choose to show, relay, and amplify: the user engagement which pays Google's engineers' salaries comes at the cost of damage to the epistemic commons. Why?

3.2.1.2 Public goods provisioning Trees planted along a boulevard provide benefit to evening strollers nearby who can appreciate their beauty, children hanging out the windows of their parents cars who can sniff their flowerbuds, and denizens citywide who can breathe in fresher air, yet incur cost only to the one who plants, waters, and cares for them. Payment is individual, but benefit diffuse. The one who pays receives only a small part of the benefit, so they may elect not to pay to plant more trees — without a mechanism to route parts of the benefit shared by all back to the one who planted the tree, without a mechanism to collateralize the costs between those who benefit, trees which might have provided benefit won't be planted — public goods are thus in such instances underfunded.

3.2.1.3 Multipolar traps A village's farmers all share parts of a common field, and choose each year between two crop varieties: a regular one which produces a solid yield and leaves the soil nutrient-rich for the subsequent planting, and a variant which produces yield a bit higher but extracts too many nutrients from the soil such that arability a few years hence will be greatly diminished. A farmer who makes a higher yield will be able to sell more crops at market, buy better seeds for the year hence, and increase his social standing within the village. If all farmers plant the regular crop, the nutrients within the soil will renew themselves and harvests can be reaped year after year, but if even just one farmer defects and plants the higher-yield variant, they will start to ruin the soil for future sowing.

In a multipolar trap, many individual actors have a choice between alternatives, where one alternative is better for the individual but worse for the commons, and another alternative is better for the commons but worse for the

individual. Even if all individuals are better-off if everyone chooses the alternative which is better for the commons, without a mechanism to bind them in agreement, individual incentives will favor defection, and a single defector ruins the commons for all.

3.2.2 Forms of coordination failure

Minutiae of individual behavior are recorded, categorized, and transferred to corporate data warehouses in California so that advertisers can tune their copy for just a wee bit more click-through. Cities lack trees to oxygenate the air, even when plenty of space is available to plant. Common fields are rendered infertile by repeated planting of extractive monocrops. Are these dystopian trends merely coincident, or are they manifestations of the same thing? In each case, there appears to be a trade-off between the individual and the collective good, but this is merely an appearance, betraying rather a lack of a mechanism to coordinate at the appropriate scale.

The modern surveillance state is not a class but rather an archetypal example, because the progression has advanced far enough to where the multipolar trap concerns information itself. The more effectively particular claims convince readers to purchase a product or spend time on a social media platform, the more profitable companies will be which author or promote such claims, regardless of their veracity, and the damage incurred to collective sensemaking itself renders collective action more difficult. In the case of public goods, where the benefit is diffuse but the cost is borne by a lone party, a better state of affairs for all is not realized because of a lack of a mechanism to split the costs or reroute some of the benefit. In the case of multipolar traps, actors making individual choices in the presence of competition will result in everyone being worse off because of a lack of a mechanism to commit to an agreement and prevent defection. Failure of public goods provisioning and defection in multipolar traps are parallel to each other: in the former case potential benefit is not realized, in the latter case potential harm not averted, in both cases because of a lack of a mechanism to allow actors within the system to coordinate with each other. Both public goods and multipolar traps can chain on top of one another and fractally recur — the successful provision of specific goods may enable more, and the damage wrought by a single multipolar trap may harm the community's ability to itself coordinate in a larger group.

In all of these cases, it is a mechanism which is lacking: a mechanism by which to route value around, to pay for public goods, to bind consenting actors in voluntarily, enforceable agreements. Coordination failures where all participants would have been better off coordinating indicate the lack of a coordination mechanism. Yet we have coordination mechanisms, of sorts, which do operate at this scale: money, law, and language. What's missing?

3.3 Deficient abstractions

Coordination at the scope in question, of international commerce and global supply chains, does take place, via currency, natural language, and legal superstructure, but these mechanisms are ill-suited to the scale and complexity in play, resulting in a divergence between the results of the actions of individuals — the effects of the system as a whole — and the underlying preferences of the participants. This constitutes a coordination failure. We now analyze each of these abstractions in turn and attempt to illuminate both how and why they fail.

3.3.1 Money

The tokenized representation of value, which we shall refer to as money, has emerged across many cultures in a variety of forms, from stone tablets to zeroes and ones on a rotating disk [3]. Money is taken for granted, embedded in the structure of modern commercial activity, legal structures, and social relations to such a degree that participants in those structures rarely step back and examine from first principles the many roles which the abstraction of money plays and whether or not such an abstraction serves their collective interest. Yet prima facie, the justification for money is not obvious. The representative units of account themselves are generally useless, often chosen precisely for their status as such. As an abstraction, money is reductive, in the translation from a multitude of goods and services to a number one merely loses information. Why do we elect to mediate our relationship to the irreducible quality and variety of value with a unidimensional numerical quantity? What is money for?

3.3.1.1 Means of coordination In virtue of what does money represent value? One may value money, but this is merely an entanglement with the form, a fetishization of the representation. Money routes as we transfer it. By purchasing an apple instead of an orange at the corner stand for breakfast one routes value to the apple farmer instead of the orange farmer, and as the apple farmer then uses it to pay this employees this money is turned into the capacity to enact material changes, as he can plant more apples for the next season, which we can then purchase and eat again.

3.3.1.1.1 Means of abstract comparison Prices enable goods, services, or arbitrary types of valuables to be compared against each other. This sort of comparison is computationally efficient precisely because it is reductive: an apple and an orange differ in innumerable ways, but by assigning both a price one can choose breakfast on the basis of whichever is cheaper. In simple cases with a lot of local information, this kind of reduction is unlikely to be necessary — two vendors at a weekly farmer's market can bargain apples for oranges on the basis of their knowledge of demand, this year's

crop conditions, and the quality of the individual fruits themselves — but at scale, where the buyer cannot factor all of the variables involved, reduction to a price enables comparison between alternatives which might not have otherwise been possible.

3.3.1.1.2 Facilitation of exchange Albert's hen just laid four fresh eggs, but Albert has no cheese with which to make an omelet. Sally's cheese just cured, but Sally lacks bread with which to eat it. Joel's made more bread than he can eat, but Joel lacks some eggs to balance his diet. Between Albert, Sally, and Joel there is no possible bipartite exchange, but introduce a representative unit of account and Albert can sell his eggs, Sally her cheese, and Joel his bread, then each buy what they need. In this fashion money facilitates mutually beneficial exchange which would not otherwise have been possible [4].

3.3.1.1.3 Pareto-efficiency Pareto-efficiency is a concept used to describe when a variable state of affairs is in an optimal configuration. A state of affairs is not Pareto-optimal if there is an alternative allocation where improvements can be made to at least one party's well-being without reducing any other party's well-being. If there is a transfer or alternative allocation of resources which satisfies this condition, the state change is called a Pareto improvement. When no further Pareto improvements are possible, the state of affairs is Pareto-optimal.

Money, as a coordination mechanism, enables the limited enactment of Pareto improvements. If the group agrees on a common currency to use as medium of exchange, each participant in the group can make offers to sell any resources which they possess at the price which they value them at and bids to buy resources which other participants possess at the prices which they value them at. If a resource is valued differently by two participants, they will trade, and the seller will be able to use the currency obtained to buy other resources which they value more. In this fashion, money clears the market repeatedly until all Pareto improvements have been made.

However, as a coordination mechanism money is limited in that each resource must be valued separately. Without a more complex contracting system, if two resources together provide a kind of synergy greater than the sum of their parts, there is no way for this to be captured in their prices. Only simple Pareto improvements where improvements to well-being are linear in each variable can be made by the clearing of a market.

3.3.1.1.4 Price information enables decentralized coordination When you choose a bag of potato chips at the supermarket, the shop owner can track which brand you selected when you scan the bar code at check-out and use this information to choose how many of this sort they will supply

next month. The potato chip supplier, having estimated aggregate demand, can then place orders with their suppliers for the raw ingredients — potatoes, oil, salt, flavoring, etc. — and the suppliers can then source natural resources and design their supply lines to satisfy this demand. In this way your purchase of potato chips conveys information all the way upstream to energy suppliers and raw goods producers, all without any intentional effort on your part. As each step along the information transmission line involves a purchasing decision being made by an entity who is themselves competing in a market, the information thereby conveyed about demand is likely to be accurate. Thus, a price system enables invisible coordination at scale without central direction or total knowledge on the part of any individual participant. [5]

3.3.1.2 Deficiencies This dimensionality reduction which is the source of money's utility is simultaneously the cause of money's failure to accurately represent the underlying value. Dependence on a fiat authority as canonical currency issuer can lead to manufactured economic crises resulting from mismanagement, speculation, or manipulation, and the hierarchical nature of structurally unipolar power lends itself to capture and the subjugation of individual rights, particularly privacy and freedom of exchange. Money fails to express the implications of economic agents' behavior (trade, production, and consumption), resulting in externalized costs, adverse selection, and eventually multipolar traps.

If the raison d'être of money is to represent value, this divergence constitutes an abstractive deficit, where money is becoming increasingly anticorrelated to the collective preference set of its users. Money has diverged so far from value that it has become inverted, the accumulation of capital now flows precisely to companies who make their stacks by monopolizing information itself, by fomenting dialectics, establishing either/or, destroying the capacity for collective sensemaking.

3.3.1.2.1 Perils of intermediation Local incentives in the design space often seem to result in increased abstraction — synthetic combinations of primary assets, tokenization of debt, derivatives on derivatives — while individual instances can in certain cases be helpful to provide more accurate predictions (by proxy of price), this tendency to stack abstractions comes at a cost, because each layer introduces the possibility of divergence from the underlying value which is meant to be tracked [6]. Divergence of a higher layer of abstraction from a lower layer can often take the form of harmless speculation, but the causal influence runs in both directions: if the accuracy of the abstraction is relied upon by individuals or firms, speculative bubbles and crashes can create manufactured financial crises even when the underlying physical capital is sufficient to suffice economic needs.

Why does this happen? Monetary supplies are finite, so the actions of par-

ticipants which are internal to the system themselves can acquire a greater influence than the changes in the outside world which the monetary system is supposed to be tracking. If a currency, stock, or financial instrument of any sort has a fixed supply, and one can predict that many others will soon purchase it, one may profit by virtue solely of anticipating internal market dynamics, even if they are unrelated to the outside world.

Explicit currency is required only to manage a scarcity of value, which should eventually be progressed beyond. In a setting where resource constraints no longer apply in most cases, explicit management of money should disappear from most activities of daily life (e.g. purchasing groceries), the accounting will still happen in the background but there is no need for it to consume computational cycles on the part of the shopper. In the absence of induced demand, resource utilization will rarely exceed the bounds of what the system can support (exceptions exist, e.g. building rockets, large collective projects, those will still require explicit accounting).

Rather than repeatedly abstracting, synthesizing new assets as combinations or derivatives of existing ones, the primary design imperative for a decentralized financial system which seeks to remedy the abstractive deficit from value should be to disintermediate; to represent as accurately as possible in a single layer of assets the value being tracked, and to allow for dependencies between those values to be managed in a way which does not require excessive financialization.

3.3.1.2.2 Computational intractability of impact Insofar as money is a mechanism for representing value and mediating causal action, a considerate individual would want to understand the impact of spending money — when they purchase a book on Amazon or a carton of bananas at the local grocery store, what are the downstream causal results? Is the author of the book duly compensated? Are the banana farmers able to utilize sustainable agriculture practices? Are warehouse workers in the delivery supply chain subject to serious workplace safety risks? Does part of the purchase price get redirected to corporate lobbyists in the halls of parliaments? Even assuming a considerate purchaser, this problem rapidly becomes computationally intractable for two reasons: the complexity of the supply chains involved in the majority of modern goods, and the informational dimensionality reduction at each step of intermediation.

Complex supply chains provide economies of scale, so they are unlikely to go away, but the informational dimensionality reduction is a representational artifact. Compare purchasing bananas from a local farmer to purchasing them at a supermarket. In the former case, the buyer can far more easily incorporate more information into their decision — they can ask about the farmer's practices, inquire in the community as to the quality of the food, ask the workers on the farm how they are treated, etc. As soon as that farmer instead sells bananas into a complex supply chain, all of that information is

lost, as the farmer's practice is reduced to a single scalar — the price of one banana. Consumers downstream in the supply chain, due both to the difficulty of accessing local information if they are far away and their lesser stake in the future of the local community, abstract over the local complexity of the farmer's practices and treat "bananas" as a fungible good exchangeable at a price. Yet these more complex causal impacts may be critical, especially in the long-term — future agricultural fertility is dependent on sustainable farming practices, future community productivity is dependent on prosocial labor relations, and future health is dependent on production quality. This lost information is crucial to what the involved stakeholders actually value.

3.3.1.2.3 Multipolar traps In multipolar traps, agents who can elect to internalize a particular cost or externalize it to the commons are subject to competitive pressure which does not incorporate that cost — those who internalize it are then at a competitive disadvantage (and generally selected out). Consider the case of several shoe manufacturers choosing whether to incorporate the externalizable cost of carbon emissions (e.g. the damage the carbon emissions will do to the environment). Since shoe manufacturers don't pay the cost of the carbon emissions, a shoe manufacturer who chooses to incorporate this cost into their choices (e.g. choose a lower-carbon-emission rubber supplier at a higher price) will produce more expensive shoes, and will end up losing in the market, since the consumers will buy cheaper shoes. This kind of situation is very common in capitalist markets (common externalities are environmental damage, human health and well-being, quality of information sources, etc.), academia (common externalities are the replication crisis, groupthink in fields, etc.), and other areas as well.

Currently, the most commonly implemented solution is for a central authority with a monopoly on the use of force (the government) to implement a regulation that will ban the behavior or force the cost to be internalized, thereby changing the incentives of the parties — this works fine in principle but often not very well in practice, and many of the most serious externalities (climate damage, human health) now arise from international competition, which the Westphalian nation-state system is ill-equipped to deal with.

3.3.2 Natural language

The ability of natural language to discuss complex systems of interaction in simple terms is dependent upon the users of the language — readers, writers, and speakers — internalizing the structure of the system of interaction themselves. Consider the case of a DotA game, where players refer to complex sequences of action by abbreviations or bespoke terminology — the players have themselves learned about the characters, their skills, and how they relate together in multiplayer fight patterns, common knowledge which they share and can thus discuss. The reasons for which they have elected to learn this structure may differ: perhaps one player simply wishes to be able

to win more games, a second learned along with their friends, and a third learned the skill-sets as a piano player learns physical technique, in order to more easily produce neat new combinations on the fly — but no matter the reason it is in virtue of this internalization of the rules and patterns of the game that these players can easily coordinate.

This internalization is not merely a requirement of coordination, it is also a requirement of skillfully playing the game itself. Just as chess players do not calculate out exponentially increasing possible sequences of moves but rather play many games, study the patterns of interaction, and cultivate a sense of the pieces on the board, DotA players do not write down their characters' movement speeds or add together on a calculator the damage of a combination of skills but rather develop a sense of their advantage or disadvantage versus a particular adversary, a sense of when they can win or would likely lose a fight, and a sense of how particular combinations of skills used in particular ways work in particular situations, then act in the moment according to this sense. Natural language then can be used to refer to particular patterns of skills or actions internalized in this sense.

In this sense, the ability of natural language to compactly refer to patterns in a complex system and allow for coordination in participants' engagement with it is dependent on their internalization of its structure. Natural language works as a mechanism of coordination for a small tribe because the members of the tribe have internalized enough of the structure of interactions between tribe members, since this structure is simple and part of their everyday lives. Most of the structure of the global economy, however, is far removed from the everyday lives of any particular one of its participants and thus not internalized in this fashion. Natural language can be used to probe into the system on a case-by-case basis, but without this common understanding doing so is piecemeal and fallible, and as it is money rather than natural language itself that mediates the system of economic interaction, natural language can only encourage participants to change their behaviors or cry foul and appeal to some external authority capable of governing the system. Consider for example social media. One could conduct an investigation, say, into the pollution emitted by a particular company, determine the potential future impacts on the environment, and write a series of social media posts to call attention to this problem. But what can they call for? This pollution is but a manifestation of the inability of participants in their everyday interactions with the system to accurately express and convey their preferences. To call for participants to change their behavior is to ask them to internalize part of the system, but since the system cannot be wholly internalized this is a piecemeal solution, like putting putty over cracks in a wall when the cracks stemmed from the foundation shifting under the house. To call for a change in the law or for an action by an existing enforcement body is to request intervention from a system external to both the system of economic interaction and the system of social media itself.

The economic system is not like a game of DotA or chess, where players learn the rules in order to improve the quality of play. As agents interacting with the economic system, excepting perhaps cases of economics-as-performance-art, our interest lies not in the internal structure but only in the effects at the boundary between the system and the world — whether or not we get a beer at the corner store, whether or not chemicals in the food lead to future health problems, whether or not carbon emissions ruin the atmosphere for one's children. These impacts at the boundary are dependent on the internal economic structure — when we interact with the system by performing a transaction such as buying a pack of cigarettes, casual ramifications radiate outwards from our action across the internal structure, determining net impacts at the boundary — so if the agents interacting with the system do not internalize this structure, either these impacts are unintelligible or the system itself must provide a means for reading its own structure and calculating them.

Alone, as it does not internalize the global economic system, the coordination mechanism of language does not suffice. The binding force cannot be maintained as meanings diverge and the penalty of ostracism lessens for a group in a wider society with many alternatives — especially as the enforcement of ostracism begins to require usage of the medium itself. This lack of binding force leads to the creation of central parties with a legal monopoly on violence who can provide the kind of enforcement necessary for written law — and they do, but this enforcement comes at the terrible cost of centralizing the mechanism for coordination in a singular entity which can be captured and diverted from fulfilling the best interests of the coordinating community as a whole. It is law which we shall discuss next.

3.3.3 Legal contracts

The present use of currency as a mechanism for economic coordination is deeply intertwined with the Westphalian nation-state system and a system of legal enforcement with systems of written regulation and contract law. Although the particulars of legal systems vary, those which comprise the majority of the modern economy all feature hierarchical, jurisdictionally geolocalized legislation where laws are written down in natural language and enforcement the responsibility of a branch of government with a monopoly on the use of coercive force.

Legal contracts, as a form of coordination, in the context of the modern legal system, are expensive enough to render the expense of contracting prohibitive in many cases where coordination is essential. Creating a legal contract requires extensive education and legal expertise — or the contracting of someone with the like, into whose contracting price the cost of this education will be incorporated. Even the ability to refer to a system of law as distinct from the system of economic interactions which it governs entails an essential separation: law must undertake explicit procedures for self-

modification — town hall voting, parliamentary bill authoring, executive decree — in order to update itself to reflect changes in the economic system which it attempts to regulate.

3.3.3.1 Separate internalization The legal system is an attempt to do that which natural language does not — namely, to internalize the structure of economic and interpersonal interactions, in a form consisting of descriptions, delineations, and corresponding norms or incentives. It is in virtue of internalizing this economic and interpersonal structure that law hopes to be able to regulate it by altering incentives for actions of interest, mediated through the mechanisms of enforcement in play.

This articulation of law, as an attempt to write down a set of norms to regulate the behavior of a system which lies outside law itself, and which must thus be enforced by human agents who interpret the law, faces an essential tension in language between generality and specificity. If the law is too general, or too vague, it will not clearly classify distinct cases meriting distinct treatments or distinct norms as such, so that interpreting agents can miscategorize a particular case as belonging to another line of reasoning in order to further their personal aims. If the law is too specific, it will not clearly classify similar cases meriting similar treatments or similar norms, so that interpreting agents can miscategorize a particular case as not meriting a certain treatment because it fails to meet the i's-dotted-t's-crossed letter of the law in order to further their personal aims.

As a coordination mechanism, law attempts to contain competition, but it itself is subject to competition. The specialization of law — the complexity of the system which it must encapsulate and the corresponding professionalization — leads to law itself being subject to competition, as those responsible for interpreting the law are in fierce competition with one another for clients or positions which they must retain in order to continue their existence as lawyers, prosecutors, judges, or other interpreters of the law. This competition for the continuance of individual existence is then a countervailing force against systemic fairness — individual success results from twisting one's interpretation of the law in order to win cases or cast judgments in alignment with a political philosophy, not from adherence to some more fundamental sort of equanimity or adherence to the "spirit of the law."

3.3.3.2 Boundaries of enforcement The ability of a legal system to facilitate coordination and pass regulation to mitigate multipolar traps depends on the activities in question happening within its jurisdiction. If the participants who desire to coordinate do not lie within the same jurisdiction or can easily move, the legal system is not binding, as the rubber manufacturer will just locate themselves in the most favorable jurisdiction with the least pollution regulation. The boundaries of political systems lag the reality of economic interchange — modern commerce relies upon global supply chains,

for which there is no effective overarching legal body — so any attempts by local jurisdictions to incorporate externality costs using the law fall victim to restructuring of supply chain locations on the basis of cost optimization and thus avoidance of such regulations.

3.3.3.3 Voting Over half the population of the United States — a hundred and fifty million people — are eligible to run for president, but when a citizen casts their vote in November, only a half dozen names are on the paper slip, and only two which stand a reasonable chance of election. Regardless of the particular nature of intermediate mechanisms — political parties, primaries, signature canvassing — the majority of the selection has occurred in the narrowing down of a hundred and fifty million to a half dozen, due to choices made along the way by whoever or whatever organizations were responsible for determining which names were on the ballot. The narrowing down of a half dozen to one is but a paltry input into this system. The ballot is the illusion of choice.

In a small tribe conducting a poll to determine whether to weather challenging agricultural conditions or pick up roots and search for another home, a complex process of deliberation can occur in which tribe members have a fair chance to participate, a sort of lateral communication to determine the contents of the ballot of choices whose impact is far more important than the voting itself.

In large-scale, decoagulated political system like that of the United States today, however, this process of determining the contents of the ballot is itself an object of specialization and competition, the land of dynastic political machines, professional lobbyists and consultants, and backroom negotiations, far removed from the voters themselves. It is not necessary to pronounce any sort of ethical judgment — it is simply the case that in this state the mechanism of voting does not allow those who are voting to express preferences outside a very narrow range predetermined elsewhere.

3.3.3.4 Computational costs As law lies outside the system which it attempts to regulate, yet must internalize the structure of that system in order to regulate it accurately, the complexity of law itself, and the corresponding complexity of interpreting how the law applies to a particular case, increases as the complexity of the system itself increases. This manifests as the creation of specialized schools, training programs, credentialing systems, etc. This increase in complexity of interpretation entails an increased cost, which in and of itself renders law unsuitable as a mechanism for cases of coordination where the benefits gleaned from coordination no longer outweigh the cost of the mechanism. Although individual cases may have a small benefit or harm, however, these cases may be replicated across many instances, adding up to substantial harms — say workers choosing not to sue a company for violating labor law in not paying extra for overtime because

the cost of the lawsuit would exceed their annual paychecks anyways, or consumers choosing not to sue a company for violating environmental protection laws because the individual benefits to the one who would pay the legal fees aren't worth the costs, even though the collective benefit from the emissions reduction would be enormous.

3.3.3.5 Conceptual suitability The concept of a nation state is a means of organization amongst the participants, which may or may not be helpful depending on whether or not the relevant coordination needs to take place amongst the citizens of the nation state. For example, the theoretical legal debates on the Paris accords take the relevant units of abstraction in play to be nation-states themselves. Theorists of the accord concern themselves with whether or not particular rules of emissions capping or pricing are fair with regards to economic status, historical pollution emissions, etc. Nation states, however, are not themselves polluters — the source of pollution is rather companies operating supply chains or individuals in their daily lives. Even if there were a way for such an accord to be fair with respect to nation-states, this would not necessarily be sufficient or even helpful in providing fairness amongst the relevant actors themselves, these companies and individuals, who may often move across the boundaries of nation-states. Occasionally this discrepancy is recognized — for example in the recognition that having less strict emissions regulations for poorer countries might simply lead to dirty industries migrating to those countries and serving global supply chains — but the contradiction is fundamental — no treaty between nation-states can adequately regulate emissions, because the relevant economic actors are neither equal with others within their respective nation states nor bound by national boundaries.

3.4 Design imperative

In order to enable coordination at scale, in a way which ameliorates this abstractive deficit, we require a coordination mechanism which allows participants to express arbitrarily complex preferences and settle trades in a Pareto-efficient fashion, which internalizes the web of complex interactions and allows participants to reason about the effects of their actions, and which allows this reasoning to be done by the system itself — to happen computationally — rather than requiring participants to internalize the system themselves. This mechanism must be able to replace the interlocking superstructure of money and law without replicating their dimensional reduction in another form. This shift is necessitated by the combination of the desired global scale of economic coordination and more accurate expression of preferences. Alternatively, humankind could retreat to tribes, giving up global scale, or continue with the current system, accumulating externalized harms until they reach the level of existential risk, which is not far off.

3.4.1 Alternatives

3.4.1.1 Tribal retreat If the degree of divergence of money from value is proportional to the depth of abstraction and representation at play, and the depth of abstraction and representation at play is proportional to the scale of the system over which money facilitates coordination, then reducing the scale of coordination would suffice to alleviate this abstractive divergence. Concretely, this would mean ditching globe-spanning economic supply chains and returning to more local commerce. While this might not literally require returning to roaming nomadic tribes — although that may not be such a bad idea [7] — it will require reducing the market size and potential for specialization substantially, however much is enough to reduce this abstractive deficit.

Save the question of whether or not this trade-off would be freely chosen, enacting such a switch is subject to a "bootstrapping problem," insofar as there is no global coordination mechanism which would enable us to agree to it in the first place. Furthermore, even shifting back to more local commerce, the shared environmental impacts remain — so if particular localities enacted different rules governing permissible pollution, for instance, ones which were stricter would suffer the effects of pollution emitted by ones which were less strict, perhaps gestating strife or conflict.

3.4.1.2 Continuance Continuance is less an explicit alternative than the default path. Absent the emergence of an alternative coordination mechanism which allows participants in the economic system to better express their preferences, and absent the retreat back into local commerce and downscaling of globe-spanning supply chains, the current system of currency-mediated economic interaction will persist, and the corresponding abstractive divergence will continue to accumulate externalized harms to the common environment. The network effects of currency itself render this system metastable, but the common environment has a limited capacity to absorb these externalized harms — greenhouse gas emission, soil nutrient extraction, deforestation, etc. — while maintaining hospitable conditions for its inhabitants — temperature, fresh water, calm weather — so this equilibrium is necessarily short-lived. Externalizing harms back into the environment upon which an organism depends to continue living is self-terminating behavior.

3.5 Mechanism design

The space of possible coordination mechanisms is too vast to exhaustively search, so we begin with an existing example as a template and enumerate the particular requirements of the situation at hand. The best example of a distributed, decentralized, and difficult to capture mechanism for coordination in existence is natural language. Natural language is high-dimensional

and not subject to the same all-or-nothing coordination costs as a fiat currency: two people can define new terms in a conversation without relinquishing the use of regular language in other communications. Language also does not require global consensus, consensus can be achieved at any scale to convey meaning. As discussed previously, language does not internalize the economic system, and thus is not sufficient to facilitate the kind of coordination we are interested in, but it provides us with a template. Natural language, a protocol for signification, allows for flexible transmission of information through many-dimensional commitments to meanings [8]. Similarly, a protocol for the abstraction of value should allow for flexible expression of value through many-dimensional commitments to preferences.

3.5.1 Desiderata

What properties must a satisfactory candidate replacement for money, aiming to remedy this abstractive deficit, fulfill?

3.5.1.1 Preference expression The mechanism must allow for arbitrarily complex expression of individual preferences which change over time.

3.5.1.2 Economic internalization The mechanism must be able to internalize the particular structure of the economy, such that participants utilizing the system can reason about the causal impacts of their interactions with it on the boundary of it.

3.5.1.3 Computational outsourcing The mechanism must allow participants to outsource the computational burden of tracking complex interactions and preferences to algorithms which they control, while remaining transparent to their alteration and inquiry.

3.5.1.3.1 The computational reductionist dilemma The computational reductionism of currency is both an essential feature which enables its usage and a fatal drawback which renders its wide-scale deployment existentially threatening. Computational reduction leads to this intractability of impact, but it is also a key component of the source of money's usefulness, insofar as it enables easy comparison of goods and services and transmits preference information which is easy to convey. The mechanism must not import an analogue sort of reductionism, and it must not require that participants perform all the computation themselves. Rather, it must outsource the computational load in a fashion which allows us to maintain transactional simplicity for the participant at the point of interaction, while preserving the ability to reflect complex preferences through the mechanism itself. This hidden computation must still be transparent, and the representations of preferences themselves should be shareable amongst participants.

3.5.1.4 Pareto-efficient settlement The mechanism must retain the Pareto-efficiency of money, such that reallocations of resources which make all participating parties better off can be effected by their combined efforts. Furthermore, this Pareto-efficiency must cover the multi-resource non-linear case which money does not, allowing complex interactions to be factored correctly into participants' preferences.

3.5.1.5 Schelling binding The mechanism must provide the proper amount of binding force to hold users to their commitments. The sort of binding in play must tie continued ability to participate in the system without a separate hierarchy to enforce the tie, but rather just in virtue of interacting with the system, playing the economic game. This can be a termed a sort of "Schelling binding." One could always switch blockchains, but then one would be playing a game with different rules. The game is defined by the rules, where playing by the rules provides access to the market which participants are creating. It is this value of market access itself which must provide the requisite binding force.

3.5.1.6 Interdependency reflection The mechanism must allow for co-ordination to occur in the groups and at the scales which reflect the real mutual interdependency of values. The form of the mechanism must be flexible enough to mirror this underlying structure.

3.5.1.7 Systemic transitionability In order to provide a feasible path from the current equilibrium to a new equilibrium, the mechanism must interface to existing systems so that subcomponents of the network of participants can start to adopt the new coordination mechanism without forfeiture of connections and commercial interaction with the remainder of the as yet untransitioned network. The mechanism must be able to slowly intake data and commerce, providing privacy to its participants to protect them from targeting, until a threshold point is reached when the network effects of the new mechanism exceed those of the old.

3.5.2 Semantic embodiment

Taken in isolation, a coordination mechanism or language is meaningless, merely a set of symbols. Only by interaction and bidirectional causal links can a language acquire meaning, insofar as it correlates with the world. This process must be bidirectional, as communication across a medium entails the articulation of the structure of the world into the form of the medium and the conceptual apprehension of the structure of the world through the structure of the language.

3.5.2.1 Oracle problem

The oracle problem captures the first direction: influence of the world on the internal structure of the language, in this case the state of the ledger. The state of the ledger must be able to reflect, or correspond to, measures of interest in the world, such as supply chain impacts, working conditions in a factory, or other kinds of economic boundary conditions.

3.5.2.2 Actuation problem

The actuation problem captures the second direction: influence of the structure of the language, the state of the ledger, on the world. The state of the ledger must able to affect the state of the world, so that resources tracked on the ledger and reallocated by the ledger suitably impact the state of the world.

3.5.3 Enumeration of requirements

As heretofore described, according to our analysis, a better coordination mechanism must satisfy the following requirements:

1. Preference expression
2. Economic internalization
3. Computational outsourcing
4. Pareto-efficient settlement
5. Schelling binding
6. Interdependency reflection
7. Systemic transitionability
8. Semantic embodiment

4 Anoma

The Anoma protocol instantiates such a candidate: arbitrarily expressive, time-limited, binding commitments to value, communicated through an intent gossip system, settled atomically on a distributed ledger by a trade system which preserves Pareto-efficiency, and capable of scaling fractally in both security and throughput to reflect real interdependencies.

Such a set of protocols is like a new language: alone, it is isolated, with no necessary relation to the world nor ability to effect change in it. Users must elect to interact with the Anoma network in order to exchange data to and from this commitment system — it is only through oracle access to the outside world that the state of the ledger can begin to reflect external states of affairs, and only through users electing to treat data on the ledger as significant that causal action can be taken back upon the world. Why might users use such a system? Language, as such, has no systemic binding force, yet it perseveres, should the new language of the Anoma protocol prove useful we expect similarly.

4.1 Abstract protocol

Anoma consists of a decentralized ledger, with a particular state at any point in logical time, on which the state of interest to the participants can be represented and using which they can negotiate changes in resource allocation compatible with their combined preferences. On this ledger, participants can create "validity predicates": programs which describe their preferences, and allow for state changes in accordance with their preferences to be enacted.

4.1.1 Ordering in time

The protocol uses a BFT consensus mechanism to agree on the state and on changes to the state over time. The history of events is segmented into logical units of blocks and transactions, where a block consists of many transactions, executed in sequence by the state machine, which effect changes to the state of the ledger. Each participants operates the same state machine and thus comes to the same conclusion about the new state after executing a block of transactions.

4.1.2 Digital preference expression

Each participant in the protocol can author a validity predicate which expresses their preferences – the conditions under which they would take particular actions, subject to the state of the economic system as reflected in the state of the ledger. For preferences which may change quickly, users can author and sign off-chain intents – arbitrary signed data – which are then authenticated and interpreted by the validity predicates when a transaction is attempted. Intents must be broadcast over the intent gossip network, but they can expire after a short duration of time has passed so that old commitments aren't persisted, and users can then author and sign new intents which reflect their current preferences.

4.1.3 Counterparty discovery

The protocol provides an intent gossip system, whereby participants can author "intents": short bits of data which include details about their preferences, such as what kind of barter they might wish to execute. These intents are then broadcast across the intent gossip layer, where particular gossip nodes called matchmakers can aggregate compatible intents together to create transactions which can then be settled against the ledger.

4.1.4 Pareto-optimal settlement

The ledger provides Pareto-optimal atomic settlement, where intents from any number of participants can be combined together to create a

single transaction which executes all relevant state changes, which is then accepted if and only if all involved participants consent.

4.1.5 Privacy for content, transparency for ruleset

The protocol provides privacy for the content of transactions, while the protocol can verify that they accord to particular rulesets using zero-knowledge proofs.

4.2 Instantiation of properties

Earlier in section 3.5.3, we enumerated a series of desiderata which proposed protocols must satisfy. Let us now check if Anoma satisfies these requirements.

4.2.1 Preference expression

Users of the Anoma protocol express their preferences by authoring validity predicates which allow for the execution of state transitions, possibly reallocating resources under a user's control, which result in a state that the user prefers. For parts of their preferences which are expected to change rapidly in time, users can instead author validity predicates which validate signatures on intents and utilize data or code in the intents to determine what preference function to enforce. Validity predicates can be crafted to only accept recently signed intents, so that old preferences will not linger on longer than desired. Users then sign these intents off-chain, continuously updating their preferences in light of the real-world situation, and intents need only be relayed to the ledger when a state transition actually takes place.

4.2.2 Economic internalization

In order to allow users of the protocol to incorporate impacts of the economic system upon the world into their preferences, the instantiation of the protocol must internalize the particular structure of the economic system. If this structure is internalized, the effects of actions at the boundary, such as purchases of goods, can be calculated and rendered transparent to users, and users can incorporate impacts at the boundary of particular practices of production upon the environment into their digitally expressed preferences and collective negotiation with other participants (particularly producers).

4.2.3 Computational outsourcing

Users of the Anoma protocol can outsource the computational load involved in determining whether or not particular actions constitute benefits, in accordance with their preferences, to nodes operating within the Anoma intent

gossip and matchmaking network, whose responsibility it is to try out possible state transitions and find ones which satisfy the preferences of involved users (and thus can be executed against the ledger).

4.2.4 Pareto-efficient settlement

The Anoma ledger allows for any state changes to be made which are preferred by all of the participants in question (who may be providing resources which are then shifted around as part of executing the transaction). This settlement is atomic, so any number of parties can participate in an exchange which either happens completely or not at all.

4.2.5 Schelling binding

To submit transactions to the blockchain, where the rules are agreed upon by this consensus mechanism, is to play a particular game. The blockchain is a virtual abstraction, a software program – nothing compels anyone to use it or to use any particular version. Once participants start using the protocol, other participants gain access to the economic system by joining — it becomes a Schelling point — so there is a sense in which the protocol has a sort of "Schelling binding."

4.2.6 Interdependency reflection

The Anoma protocol is designed to be instantiated fractally in a topology which can adjust to reflect the underlying economic interdependencies. Local instances can be launched in geographically or commercially local communities and then interoperate with each other when necessary for cross-community commerce.

4.2.7 Systemic transitionability

Monetary and legal systems are deeply interwoven into the mechanisms of modern commerce and the ideological superstructure of modern society, and they will take time to dislodge. At first, Anoma will primarily interface with the existing systems of coordination by allowing early adopters to make use of money as a component in their coordination – facilitating complex kinds of bartering which transactions costs of the legal system would have rendered infeasible, making payments privately to avoid tracking by governments and surveillance capitalists, and redirecting monetary flows for their collective benefit to fund public goods in their community. If used carefully and comprehensively, Anoma's privacy features, where adherence to the ruleset is verified publicly but the contents of interactions remain private to their participants, will provide protection for early adopters of the system against participants in the existing system whose advantageous positions

might be threatened and who might try to target them. As the system gains wider adoption, more and more interactions can happen within the protocol without any sort of monetary intermediation. Eventually, should fractal instances of Anoma gain wide adoption, money or at least dominant fiat currencies should no longer be necessary, or at least greatly curtailed in their influence. Should Anoma succeed in internalizing the economic system, participants in it will be able to use the protocol as a lens to understand and guide their interactions, and thus make choices which better reflect their values.

4.2.8 Semantic embodiment

4.2.8.1 Oracle problem The Anoma ledger itself has no way to differentiate between true and false data about the world, no way to even obtain such data (these are equivalent). In order to get data about the world onto the ledger, we require an oracle. Trusted parties with some kind of external reputation may be able to serve as such an oracle, and commit-reveal Schelling-point games can be created to encourage truthful reporting under the assumption that in the shared intersubjective world there will be one true answer but many false ones.

4.2.8.2 Actuation problem The actuation problem is the reverse of the oracle problem: how does the state on the Anoma ledger affect the state of the world? Insofar as participants consider particular state on the ledger to be valuable, actuation can take place through their willingness to perform actions in exchange for state changes on the ledger, such as handing over a cup of coffee in exchange for the transfer of tokens. Direct actuation could be achieved by physical infrastructure which validates the state of the ledger and takes action accordingly, such as gates at a border crossing enforcing taxation rules. Participants may also elect to create a sort of legal proxy intended to serve as an interface between the new mechanism and the old.

4.3 User interfaces

Users will be able to interface with the protocol using mobile applications, web frontends, and programmatic APIs. Mobile applications and frontends will likely specialize in a particular use-case, such as private cash or non-fungible asset auctions, and construct their user interfaces accordingly. Mobile applications in particular should be able to automatically connect to the peer-to-peer intent gossip network to pull appropriate intent data, such as currency exchange pairs when paying at a point-of-sale in a different currency than the merchant accepts, source the best rate (in this example), and select the appropriate local or global ledger for settlement purposes.

Interfaces to the protocol should provide an overlay for economic interactions which allows users to see the impacts of their actions on the bound-

ary of the system while hiding the details of the interior, which should be transparent but computable over so that users need not reason through the complex supply chain links themselves.

4.4 Approximation factors

Concrete hardware is computationally limited, so the concrete instantiation of the protocol can only fulfill abstract properties modulo a sort of computational limitation approximation factor. For example, the complexity of intents, validity predicates, and the kinds of atomic settlements which can be executed by the ledger are limited by the amount of computation that can happen within a particular block, and more broadly within a period of time. Fractal scaling means that this computation can be parallelized insofar as the underlying economic relations themselves are concurrent, but the complexity of atomic settlements is still bounded by the throughput of a single instance of the ledger. Over time, improvements in database speed, virtual machine execution efficiency, validity predicate optimization, etc. can raise the limits, and cryptographic techniques such as zero-knowledge proofs can be used to compress the computation so that the ledger only needs to verify the proof.

The consensus mechanism is limited by the information-theoretic bounds of Byzantine-fault-tolerant systems — consensus safety and progress are only guaranteed under conditions of more than two-thirds of participants behaving honestly (less than one-third behaving in a Byzantine fashion). This particular approximation factor is quite specific to the technical context; there is no direct analogue in coordination between members of a tribe or players of a game. For this reason, it is particularly important that the set of participants in the consensus mechanism has a high degree of overlap with the set of stakeholders in the local economic system, to reduce the chance of divergence.

5 Future work

This paper approaches coordination, coordination mechanisms, and protocol design in regular English, practicing a strategy of semantic descent by providing relatable examples, in an attempt to apprehend the underlying structural relations in play and articulate a dialectical path whose reasoning can be followed. Many of the discussions could be formalized in the language of game theory, which would provide additional assurance that no mistakes have been made or parts overlooked. Future work could also investigate the means of binding in more detail, perhaps with a concrete focus on specific parts of the economic system currently responsible for particularly deleterious impacts.

The Anoma whitepaper [9] provides an abbreviated summary of the motivations covered in depth in this paper along with a technical overview, and the Anoma technical specification [10] provides a complete technical description of the protocol.

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