The Case of Intent Network for Collective Intelligence

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Making two cites[1, 2] in the abstraction to make it compiles.

1 Motivation

Blockchains are *monolithic* solutions for the three essentials: *ordering*, *execution* and *finality*. sgd: More well-known name for finality is *consensus*, but the meaning of consensus goes blurry as it goes popular. This fact itself is not a bad thing, even a good thing: these are all critical for building usable and trustable applications, while an all-in-one is always superior modular (at least in the sense of audience perception).

It is bad for the other fact that, in blockchains, these three functionalities are in *lockstep*. It orders one, it executes one, and it finalizes one. And only after what it can order the following ones. Yes there is batching, but the utilization of batching 1. exactly implies the demand of avoiding lockstep 2. is not a scalable solution and comes with inherent latency penalty. HETU aims *real time* usages. So we don't consider the cases that can tolerate long latencies and can be simply solved by batching.

There are always active research and solutions on relieving execution from this lockstep i.e. *offchain computation*. We believe that those solutions are generalized/generalizable so that as long as blockchains can make use of them HETU can do so as well. This working document mostly focus on the ordering part.

Theoretical limit on improving finality. Finality inherently comes with *shared mutable states*, i.e. the *decisions* that reach *consensus*. The mutations on the states must be propagated to the *whole* network *sequentially*, otherwise the states may go diverged. So we are/will be eventually trapped by the propagation speed on the finality performance.

The alternative workaround is to build *elite networks*. Under Ethereum context it is the network of stakers (or even just a subset of all stakers that (are allowed to) participant a specific round of proposal). By shrinking the scope of propagation to just the elites, finality gains more efficiency. sgd: Ethereum probably claims the sole purpose of PoS is to be more power efficient than PoW, but I believe this reasoning on the performance of finality must also come into the play.

This solution implies *homogeneity*. Only in a homogeneous system we can reach consensus *a priori* on who are elites. Again under Ethereum context all stakers must stake the same kind of token i.e. Ether. HETU aims *heterogeneous* scenarios. We believe that in HETU, the mechanism of finality should be everyone *equally*, without any *qualification*, because it's impossible to define the qualification policy reasonably in a heterogeneous system i.e. everyone is qualified for different tasks and commitments. The finality must be propagated to everyone in the same way.

The globally-unique proposer is subjective, and that results in bad quality ordering service. sgd: The argument here needs further streamlining, probably refers the presence of MEV as an evidence, and draw conclusion that ordering must be performed in an intersubjective way.

sgd: Eigenlayer's intersubjectivity whitepaper i.e. EIGEN token can be a supporting evidence of the necessity of introducing intersubjectivity in ordering mechanism. It may be worth to consider their "forkable" solution as an alternation to HETU and discuss their drawbacks, but hopefully their drawbacks are obvious to many.

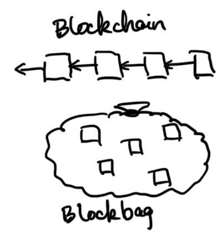
The vision. HETU proposes a modular approach for achieving all three of ordering, execution and finality. Especially, while finality inherently provides ordering i.e. based on the order of finalization, we deliberately *deprecate* that order and roll out our own ordering mechanism that is *in real time*, *compatible with heterogeneity* and *intersubjective*. HETU will eventually be general purpose, but we start small, package it as solutions for certain vertical cases. sgd: Somehow we first propose a Bitcoin that later extend it into (or reveal that it is actually) Ethereum. This working document focus on the case of financial markets. We should definitely look at some other cases simultaneously e.g. machine learning stuff.

2 L1 Sequencer: a Motivated Example of Dedicated Ordering Mechanism

sgd: The material here will be a mind experiment. The details need further polish, and not sure whether it helps in the narrative. But anyway, it is supposed to be an intermediate step to help understand the ordering/finality separation without involving unfamiliar concepts like partial ordering, brokers, etc.

3 Approach

The only-for-finality mechanism. The *chain* structure in blockchains corresponds to its inherent ordering functionality. To clearly draw the difference between them and the finality mechanism in Hetu, we explicitly change the representation from "a chain of blocks" to "a (unordered) set of blocks". sgd: Or "a bag of blocks" if that is more vivid. sgd: Blockbag? :)



The *append-only* property of blockchains is expected to be preserved, though. Anything (or any block) that has been finalized is expected to not get "de-finalized" indefinitely. This property directly enables blockchains to execute the blocks in the finalization order, and Hetu also relies on it. The "append" here seems to imply the ordered direction. Since our finality is unordered, maybe should call it *insert-only*, while the logical clocks are the ones that append-only, to draw a clear distinction.

Since the finality mechanism in Hetu requires a subset of blockchains functionalities, blockchains can certainly serve as the finality mechanism. If necessary we may conduct research on alternative finality mechanisms, but blockchains, especially Ethereum, are probably good enough for now.

What is getting ordered? In blockchains it's "blocks" that are getting ordered, and inside the blocks it's "transactions" that are ordered (subjectively) by the blocks' proposers. The two-layer design is purely for performance optimization (i.e. batching) and has no practical meaning, to we can ignore the outer layer and simply say it's transactions that are getting ordered.

The meaning of *transaction*, though heavily overloaded, probably implies finality. In Hetu what get ordered has no finality (yet). It is only finalized when it has been submitted to the finality mechanism, not upon ordered. In another word, they are not transactions "yet" upon ordered, and they may or may not "turn into" transactions depending on whether they will eventually be finalized.

In the logical clock related introductions we usually put it as it's "events" that get ordered. Since we are describing a financial market solution here I would realize the concept as *quotes*, *preorders* or *letters of intent*, and *intents* to refer them as a whole. It's probably fine to reuse *transaction* to refer what has been submitted for finality.

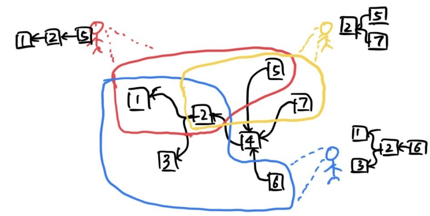
sgd: After adding the AI case the above financial terms may not appliable universally. Nevertheless, quotes, preorders and (the most focused) intents still sounds appropriate.

The properties of ordering. sgd: If necessary (which probably is), discuss the rationale behind these properties. What bad things can happen if we don't have them?

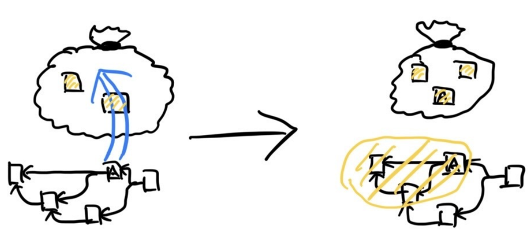
- Share-nothing distributed. The ordering mechanism itself does not require propagation i.e. communication across the whole system. In another word, Hetu does not forcefully *push* the ordered intents, like how blockchains push the ordered blocks, to the nodes. Nodes certainly need to actively *pull* the intents that are involved in the orders they would propose, and that is on demand. The system shares nothing more than the minimum. sgd: In previous discussions this has been referred as “laziness” or “lazy consensus”. Those words are also not bad in precision, and we can use them if they are better marketing terms.

- Optimal parallelization, this is closely related to the previous. More than one node can contribute to the ordering concurrently/simultaneously, and if necessary every node can contribute at the same time. This is completely on the opposite to the blockchains, where *at most one* node can contribute to the ordering at any time i.e. the qualified proposer of the round.
  No matter when, no matter where, no matter whom in the HETU system wants to order no matter what, they can do it *immediately*, without waiting for anything e.g. becoming the proposers.
- Verifiable and append-only. These are the revisiting properties of blockchains. They are necessary to *preserve* the finality through all ordered intents. The following explains this more in action.

The cooperation. The ordering mechanism forms a *partial ordering* among the intents. Notice that although we represent the partial ordering as a single graph in the illustration, the graph is not shared in reality. In another word, (probably) no one in HETU actually get to know the whole graph. Everyone can only learn it partially, according to their point of view.



However, everyone’s partial view is guaranteed to be *compatible* to the other’s one. Every partial view is a subgraph of the whole graph. And if you merge all subgraphs together, you just get the whole graph back, without any risk of confliction. sgd: Well, these material may be a bit too technical, try rephrase it more comprehensively.



If anyone wants to finalize an intent i.e. “make a deal” according to it, they submit the intent to finality. As we stated above, finality mechanism in HETU is an insert-only bag of intents. Effectively, the finality mechanism *endorses* the intents by inserting them into the consensus bag. The transitivity of HETU’s partial ordering extends the *endorsement* to a larger set of intents. sgd: This happens to match the *transitivity closure* concept in mathematic. (Well, not completely accidentally, I have designed it in this way.) Make use of this fact if having a proper formalization helps in some way.

What important is that the extended endorsement is *finalized.* Although finality mechanism does not explicitly finalize every endorsed intents, it is safe to consider all of them finalized, thanks to the verifiable and append-only properties of the ordering mechanism. As the result, HETU’s ordering mechanism becomes an *amplifier* for finality. HETU not only enables real time ordering, but also *more* finality. We believe that nodes can only be incentivized to propose ordered intents that will be finalized (probabilistically), just like they can only be incentivized to propose blocks if the blocks will be chained. With our ordering mechanism design, the fact that the ordering is not happening inside finality mechanism doesn't change the fact that the ordering still can be finalized, so Hetu does not expose challenges in economics.

sgd: Weird material above, probably fits somewhere else.

Intents do conflict. That's why finality does not endorse every submitted intent, but only the *compatible* ones. What intents are compatible is application specific, which is a topic elaborated in the following section. In the worst case, intents that do not reside on the same chain all conflict to each other. Those are the applications that essentially make use of shared mutable states, and they would better directly deploy on blockchains. We expect our targeted applications to have few contentions on the finality, but every finality involves a lot of collaboration efforts, and the willingness of the collaborations all come with *preconditions*, or assumptions. This sounds a lot abstract, but as shown below, finance can be one such case.

sgd: Personally I'm already satisfied by describing "what we are good for" in one sentence, regardless of the abstractness.

4 Case Study: Decentralized Finance

System overview. The imagined financial market is a lot like what crypto exchanges can do today. Users mostly trade tokens and their derivatives in the market. Trading offchain merchandises are possible, and the security mechanism is nothing particular to today's offchain solutions e.g. producers submit a proof of finished the work to the chain and get rewarded from smart contracts, or challengers submit a proof of producers not finishing the work to the chain to get slashing rewards from smart contracts.

The users are categorized into *dealers* and *customers*, based on whether they are providing offers or accepting ones. Dealers may not be (long) sellers; they can on short position and provide offers to buy merchandises from the others. We will use the standard terms of Hetu in the following discussion. The dealers are further categorized as *producers* who produce the (chains of) quotes (either for sale or purchase), and *broker* who produce derivatives. The customers are called consumers.

For simplicity, we only discuss trading onchain merchandises here, and we only consider deploying to Ethereum, so the tokens would be ERC-20s and NFTs. Those are directly transact-able on Ethereum through interacting with smart contracts, and the advantages of Hetu mirrors the ones stated in our vision:

- Real time. It's not as simple as "the transaction can be made faster". Because the transaction eventually still happen on the chain, and we are not doing things like preconfirmation to assure anything. The "real time" here means real time reaction. Hetu allows user to action much more frequently than the finality frequency, and those are additive actions that eventually contribute to the *same* finality. More details later.
- Heterogeneous. In plain Ethereum system brokers are homogeneous i.e. they are just smart contracts. In Hetu how brokers work is completely unspecified. It's all hidden to the blockchain.
- Intersubjective. sgd: This one I haven't got it clear. Skip for now.

Advantage over current L1 exchanges. They are centralized.

Design overview. Most of the communication/"brokerage"/potential negotiation happens offchain. The intermediate "intents" are accumulated with logical clocks. As soon as the intents are turning into a "deal", the payers submit the final logical clocks and their payments to the smart contract for finality. After the finality, the payee(s) also consult the smart contract with their logical clocks as proof to receive their rewards. These consultations can be made asynchronously and periodically batched, to reduce the overhead of interacting with the chain.

Example: a deal. The producer sells an NFT A for 1ETH. It (offchain) publishes a quote intent (A = 1ETH). The consumer buys the NFT, by submitting to HETU smart contract with the (logical clock of) quote intent and 1ETH. The producer later submits to HETU smart contract with the same logical clock (and the smart contract is able to verify that the producer is the owner of the clock) and receive 1ETH from the contract. The contract also transfer the ownership of NFT A to the consumer.

In this minimal case there's no benefit of making use of HETU. A simple smart contract that transfers both NFT and ETH will conclude the interaction in single transaction.

Example: a match. Producer 1 sells 1ETH for 3500USDT. sgd: Current market price from Google. Producer 2 buys 1ETH with 3501USDT. The consumer generates a match intent with a logical clock merging both quotes, and sends it to producer 2. Producer 2 submits to HETU smart contract with 3501USDT payment. Later producer 1 and consumer individually consult the contract and get 1USDT and 3500USDT respectively. Consumer also transfers 1ETH to producer 1 during the consultation.

sgd: Why producer 2 should submit the transaction, not producer 1 or consumer? sgd: Why pays 3501USDT not 1ETH? sgd: Is this a consumer or broker? Are these producers or consumers? sgd: I'm not good at designing a market…

In comparison, with plain Ethereum the matching engine will be a smart contract e.g. uniswap. The matching logic is public and (what's worse) it must be expressible with smart contract. You cannot perform a subjective matching, not even an intersubjective one. And further, producer 1 and producer 2 need to both interact with the matching contract. That probably cannot take place in the same block (without any speculation). However in HETU they may have adjusted their quotes for arbitrary many times before the matching is accomplished, and all those communications can happen right within 12 seconds.

Example: a derivative. sgd: Work in progress. Not sure whether it's necessary to have one more example. A single-layer derivative should be much similar to the match, and a more deeply nested one would be too complicated to illustrate.

What is ordered? (again). There are different concepts of *ordering* in a financial system. Although we can generalize all of them into "A only if B" form, but it's worth to perform a case study.

The first kind is temporal ordering. Consider the price of certain merchandise. It changes, and the current price is certainly *after* its price from previous timestamp. In HETU we represent the quote intents as "conditional quotes with expiration". The interpretation is "the price of the merchandise is $X, and the price is only valid 1. before the current block (hashed Y) reaches depth Z in the chain and 2. all previous quotes of the merchandise were not finalized". Finality mechanism checks for the requirements before endorsement, to prevent a merchandise to be sold more than once. The producers may repeatedly propose quotes for their merchandises until they are sold.

The second kind is derivative ordering. An index intent can be "the price of the index is $X, and the price is only valid while all indexed quotes are valid". sgd: Intents for options can be a bit more tricky, since it involves quote intents that will be proposed in the future. We can design for them later. Notice that all of these are not actually transactions, but instead somehow "I would like to transact with X if Y would like to transact with me". The "letters of intent" in this form are perfectly composable and can be arbitrary nested. When a highly-nested intent is finalized, a lot of intermediate transactions are finalized at once. In a blockchain system all these intermediate steps have to happen on chain, incurring high latency and lots of gas overhead. While in HETU, only one intent is submitted for finality regardless of the number of intermediate steps. This means perfect scalability.

The last kind is transaction ordering. This is the ordering of mutating states. If two consumers buy the same merchandise, the transaction ordered first will success and the other one must be aborted. In the baby step described in this working document, the market states are remained on chain (though a lot of intermediate states are skipped), so such ordering corresponds to the ordering of finalization. HETU is not responsible for it and simply leaves it on the chain.

There will be parallelization opportunities to explore in the transaction ordering. As a patch we may design certain derivative to ad-hoc bundle transactions into "mega-transactions", which make profit by reducing gas fee during finality. Don't know for sure whether that works.

Current limitations. There's no offchain computation in current design. Actually, all offchain states are intermediate, ephemeral and fine to be unreliable. sgd: probably Since financial is neither computational heavy (in the sense of *processing transactions themselves*, not *making decisions of transacting or not*) nor data heavy (ideally just one balance number per account), going offchain may not benefit much.

However, not persisting states outside the chain also means we will not have our own economics. The settlements will be in ERC-20 and there's no necessity to roll out our own token. I think we probably still can make money in some way without our own token, but others (probably) may not.

And after all, this is contrary to the vision states previously i.e. blockchains as unordered finality, nothing more. It's more like an incremental contribution to current blockchain systems i.e. yet another offloading/rollup solution (while substantially differs from current rollups). This is good for bootstrapping, but we probably should move on later.

Sketch of smart contract design. The contract's main task is to verify logical clocks. The verification results come with the determined ordering, and specific verification semantics should be integrated case by case. Finally, the contract is the temporal token holder for outstanding transactions, to enable asynchronous interaction with the chain. sgd: Also enable us to make money from the system.

Take calls for an example. The consumer interacts with blockchain first, submits an intent of either a quote or a derivative of some intents, indicating that the consumer is willing to call with certain amount of tokens. The contract performs several checks, including whether the intent is equipped with a valid logical clock, whether the call conflicts with previous calls, and the other ordinary checks e.g. whether consumer account has sufficient balance. If all checks pass, the contract transfer the tokens from consumer account to the contract account, and finalize the intent.

sgd: Work in progress.

5 Case Study: Collaborative AI

Motivation and system overview. The end users of AI market consumes AI services/products e.g. conversation sessions, content generation, etc. Currently, the services are *scheduled* / *orchestrated* / *assembled* mostly by single party. sgd: Having difficulty choose the best word... In another word, there's a centralized participant that contacts all the other participants in the systems, namely GPU owners, model creators, and end users. This one-stop architecture does not enable the full competition market and the optimal configuration of resources.

The root cause of today's centralized architectures is the difficulties of efficiently collaborate in real time. Suppose A users own GPUs and B users owns models. Without further assistance, it is hard for the individuals of either A users or B users to *ad hoc* find each other in real time that *matches* i.e. the GPUs must be capable to inference the models. Both of them cannot fulfill user demands alone. As the result, the cooperation must be negotiated ahead of time and be longstanding, which in turn requires heavier trust mechanism e.g. staking.

In HETU none of the participants need to take care of the whole workflow. The consumers, brokers and producers concept from §4 are also applied in this case. The producers provide GPUs and other AI hardware. The consumers purchase AI services by contacting one of the brokers who announce to provide the services. Those brokers, however, provide end user services based on the model inference services provided by other brokers. And those brokers that support inference rent the hardware from producers. The logical clocks, which order the intents all over, enable such collaboration despite every participant only works locally.

Example: oneshot query. Producer A announces intent of 10s GPU time for 1USDT. Broker B announces a conditional intent of "as long as A fulfills its intent to me, I provide a llama model inference of any input for 1.01USDT". Broker C announces a conditional intent of "as long as B fulfills its intent to me, I can answer a professional question for 1.02USDT". (C achieves this by sending special prompts to the model during inference.) Consumer D thinks "ok I have a computer science professional question to ask and I'm willing to pay 1.02USDT". Then D submit the intent announced by C and 1.02USDT to the HETU smart contract on the chain.

After C's intent has reached finality on the chain, C takes D's question, combined with its special prompts that can make llama model act as a computer science professor, together send to B. B then perform inference with its llama model on A's GPU. After the task is done and the proof of work is generated (or after a while no one challenges that the work is not done correctly), A, B and C interact with HETU contract on the chain with their original intent logical clocks. The contract verifies their logical clocks are based by the one submitted by D (or is the same one, for C's case). And transfer corresponded tokens according to the intents. Thus, A, B and C receives 1USDT, 0.01USDT and 0.01USDT each.

What are the clocks used for? Logical clocks are crucial in the workflow above for multiple purposes.

- B, C and D verifies the *single* logical clock from its immediate predecessors, and conclude that *all* previous intents are verified.
- Smart contract verifies A, B and C's clocks, and the relation between their clocks and the D's one, conclude that they should be paid.
- A, B and C can interact with the smart contract in arbitrary order, arbitrarily after the transaction was finalized (i.e. D submitted). HETU removes the necessities of *synchronously* interact with the chain for all the intermediate steps.

Other than constructing conditional intents, the clocks can also be used for local ordering. For example, A may announce intents of every 10s of its GPU times, and each intent is ordered after the previous one. So that if another broker E has its intent based on a latter intent of A (based on A's ordering), then E can only utilize A's GPU after B is done.

Discussions. There's no security model here. In reality we need to specify one, even if it's "yes we don't have security" that still need to be decided.

The division of GPU providers and model providers are impractical. If models must be sent to GPUs owners in clear text, models will not be confidential, and that's a lot of network overhead.

References

[1] V. Buterin. A Next-Generation Smart Contract and Decentralized Application Platform. https://ethereum.org/en/whitepaper/, 2014.

[2] S. Nakamoto. Bitcoin: A peer-to-peer electronic cash system. https://bitcoin.org/bitcoin.pdf, 2009.