Experiences Building and Operating a Blockchain-Based Tasking Market for IoT Devices

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***Abstract*—It is possible to provide tasking information to remote devices over a computer network in such a way as to minimize technical details as to how tasks are to be accomplished. By allowing autonomous or semi-autonomous remote devices to respond directly to such tasking requests, a tasking market may be created in which devices cooperate to complete human-provided tasks without requiring them to use strong AI to coordinate their actions. An enterprise blockchain forms the technical basis for a solutions architecture that implements this concept. Early evaluation of the architecture in several environments has been conducted. Results are summarized for tasking market prototypes operating across maritime autonomous robotic boats, control of a payload on a suborbital rocket, and the tasking of a computer onboard the International Space Station.**

Keywords—blockchain, enterprise, IoT, tasking, resource sharing

I. Introduction

Current Internet-of-Things (IoT) devices provide not only a wide range of capabilities but also a utilise a wide range of control mechanisms. Such control mechanisms exist on a spectrum of human involvement from direct manual control of local devices to fully autonomous remote systems. Perhaps strangely, the degree of human involvement is often inversely proportional to both the technical capability and the economic value of the device. That is, more valuable (and thus capable) devices are often commanded to perform actions under either direct manual control or via direct manual override (e.g. for administrative functions), whereas less valuable and capable devices (such as remotely deployed sensors) are left unattended to operate fully autonomously.

Further, the high-value end of the IoT spectrum is populated by devices that most often use bespoke protocols, controllers, and procedures, and are operated by the organisations that built them. That is, operational control, ownership, and economic benefit are typically tightly coupled.

The tight coupling of operational control, ownership, and economic benefit can have negative consequences, especially for expensive devices. For example, robots used in mines are often either manually controlled or semi-autonomous. The need for a robot to execute a given task at a given time in a given location must be made known to the human operator. It is left to people to coordinate the actions of many such expensive assets.

Similarly, consider the recent increase in the number of artificial satellites in Earth orbit. From the beginning of the space age in 1957 to 2010, the number of active artificial satellites never exceeded 1,000. However, the number ballooned to 7,389 individual satellites by April 2021, of roughly half are still active. This huge increase has resulted primarily from a combination of reduced costs to reach orbit, and the commoditisation of previously expensive electronic components. In other words, many satellites are currently in Earth orbit carrying the same basic components, including their suite of sensors. This is important because satellites in low Earth orbit are at a relatively low altitude. Their sensors can (intentionally) "see" only a small portion of the Earth's surface. That is good for sensor resolution, but creates delays in communication and in control due to the satellite being in an inconvenient portion of its orbit most of the time for those activities to occur.

There is thus much redundant capability in orbit, but the organisation and control of those assets means that any given organisation cannot tap into that capability; they can only control their own, much smaller, set of assets. If you require an overhead photograph of your current location from orbit, you may need to wait hours to days to get results. Weeks may pass before conditions are optimal for your needs. However, some other organisation may have a very similar capability directly overhead *right now*.

If only there was a way to task such systems across their organisational controls. A system implementing such a thing would ideally operate at a sufficiently abstract level to leave details of domain awareness and business logic to the system's edges (that is, the system being tasked and those providing tasking inputs). End users need not care about ownership, economic benefit, operational control, or technical implementation. In our examples, they only desire a photo of a location at a given time or a portion of rock wall drilled. Everything else is detail.

Mandl [1] first conceived of a high-level method to implement a semi-autonomous command and control system for satellites using a blockchain. The team at BITSCore has since extended and implemented a generalised tasking market for IoT devices based on that idea. Patent protection was filed in 2021 [5].

II. Solutions Architecture

Goals for our solution were:

- Operational control of assets remains with their owners while tasking of assets become available across authorised domains.
- Autonomous agents (at network edge) choose to participate based on constraints.
- Assets share tasking across multiple domains (ownership & control) facilitating system-wide efficiencies.
- Drive utilisation and efficient coordination of scarce assets across a wider user base to reduce underutilised capacities.

A. An Enterprise Blockchain

A generic tasking market requires several properties that are readily available in blockchain implementations, such as Ethereum. Those properties include an immutable record of sequenced events, a business domain-specific extension capability such as smart contracts, and intrinsic protections against double-spending (in this case, double completion of single tasks as well as an optional currency-driven marketplace).

BITSCore chose to implement our tasking market using our own proprietary and patented enterprise blockchain [4] that also implements a sequenced directed graph of metadata. However, implementation on public blockchains or other enterprise blockchains with the above properties is certainly possible.

B. *A Tasking Market in Smart Contracts*

A generic tasking market may be implemented in smart contracts (or equivalent code) with the assumption that message schemas, message validation, and domain-specific implementations for task execution are provided as configuration options.

In our implementation, a generic tasking market hub is created as a smart contract equivalent on our enterprise blockchain. A Web user interface allows creation of message schemas, and provides message validation.

C. *Tasking Protocol*

The protocol used in our implementation was developed in-house to provide generic market capabilities such as to get a list of available tasks (optionally of one or more named types), ask for a task to be assigned to an edge device, report on the status of task fulfillment in business domain-specific messages, and report task completion.

The protocol passes messages in JavaScript Object Notation (JSON) format over raw TCP, HTTP or other such protocols. Use of TLS for transmission security is highly encouraged.

D. *Edge Device Implementations*

Edge devices participating in the tasking market are provided with domain-specific message schemas as configuration and are expected to implement domain-specific task execution requirements (e.g., connecting to a camera, returning a photo, and using such data to populate tasking messages).

III. Evaluation

We have scheduled several experiments to evaluate the performance of our tasking market in various communications and protocol environments. We anticipate having at least some of these evaluations completed prior to SDLT 2021.

TABLE I. Evaluation Opportunities

Experiment	**Protocol**	**Status**
Experiment onboard ISS	TCP/SSL	Scheduled Oct 2021
Suborbital rocket launch	TCP	Scheduled Nov 2021
Robotic boat tasking	GRPC/SSL	Scheduled Nov 2021
Satellite on orbit	DTN	TBD 2022

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