The Convergence Ecosystem in Mobility

How IoT, DLTs and AI are disrupting the transportation and logistics industries

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Outlier Ventures

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About Outlier Ventures

Outlier Ventures is a venture platform focused on building the infrastructure for the next phase of the Web. As the first European venture firm dedicated to distributed ledger technology, we've developed an industry-leading investment thesis, based on the convergence of decentralised technologies such as blockchains and distributed ledgers, with 'deep tech' such as artificial intelligence, robotics, the Internet of Things, and 3D printing.

We are an LLP partnership, we invest our own money as long-term investors who intend to hold investments for several years. We focus on early stage, seed and pre-seed projects where direct support to founders and creating value post-investment is integral to our business model.

We have consistently proved our ability to identify exceptional projects, allowing us to constantly expand. Our team is 30 people strong, with a new office in the US, and with specialists in crypto-economics, research, legal, marketing, and tech, we bring a powerhouse of support to founders.

Mobility is a big focus area for us as an investor thus we have invested in both equity and crypto-tokens and partnered with some of the most impressive projects in the decentralised space including, IOTA, Ocean Protocol, Fetch.AI, SEED, Sovrin and most recently Haja Networks.

About the authors

Lead Author: Vangelis Andrikopoulos

Vangelis is a research analyst at Outlier Ventures focusing on how emerging technologies such as distributed ledger technologies, artificial intelligence, robotics, the Internet of Things, AR/VR, and 3D printing affect mobility, smart cities, energy, manufacturing, healthcare, telecommunications, and financial services industries. Apart from game theory he is also exploring and applying mental models such as Feynman technique, reasoning from first principles, reasoning by analogy, Socratic questioning to understand how emerging technologies are impacting the economy and society more broadly.

Author & Head of Research: Lawrence Lundy-Bryan

Lawrence is exploring the intersections of artificial intelligence, blockchains and the internet of things. He is Partner and Head of Research at Outlier Ventures and pioneered the funds' investment thesis leading to investments in Ocean, Fetch, SEED, Haja Networks, IOTA, and Sovrin. He helps inform the UK and EU on technology policy as an expert advisor to the UK All Party Parliamentary Group (APPG) on Blockchain; steering committee member for the AI Global Governance Commission; community member of the UK All Party Parliamentary Group (APPG) on AI; and member of the European Commission Observatory on Blockchain. He is a regular speaker and commentator on a range of emerging technologies having been quoted on the BBC, Bloomberg, The Economist, and The Wall Street Journal.

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Executive Summary

Executive Summary

Mobility is being shaped by the convergence of DLTs, crypto-assets, decentralized networks, data marketplaces, and AI.
Data created and captured by software and IoT becomes the most important resource as it enables automation and connectivity. More data equals a more asymmetric advantage for the beholder. Should incumbents then, with vast amounts of data be expected to hold on to them?

1. **Removal of silos.**
   DLTs by their very nature facilitate value interoperability which points to a shared and integrated mobility ecosystem characterized by widespread collaboration. Resources, value, and data can be exchanged seamlessly & invisibly. Data marketplaces. Through a combination of IoT, AI, and tokenization we will see end-users, OEMs, auto manufacturers and fleet operators incentivized to open up, share and exchange data as digitized assets through data marketplaces. DLTs allow us to align incentives by enabling transparency and monetization of data and crypto-assets.
2. **Sharing data becomes the dominant strategy.**
   Participants in the future mobility ecosystem will benefit more by sharing their data rather than hoarding them. Waymo and other incumbents who hold vast amounts of data will initially be hesitant to share, while smaller and new participants will have no choice but cooperate in order to compete. Eventually, those participants will get a competitive advantage against the data hoarders which will, in turn, be forced to follow suit. A second-order effect then will be a level playing field where best value for money and personalized services win.
3. **Self-sovereign ID and sign-in.**
   Users and vehicles individually and in concert, own and manage self-sovereign identity to unlock a global user account ("single sign-in") that is not centrally controlled by any one corporation allowing them to access a distributed ecosystem of mobility assets and services. Users can now choose who can access their data and to what extent.
4. **New economic value unlocked.**
   Smart contracts, distributed computation facilitate machine-to-machine economy via automation, security and unlocks new business models. Vehicles increasingly become computers on wheels, powered by software, with their own autonomous economic agency and new in-transit user interfaces and experiences.

Part 1:
The Convergence Ecosystem

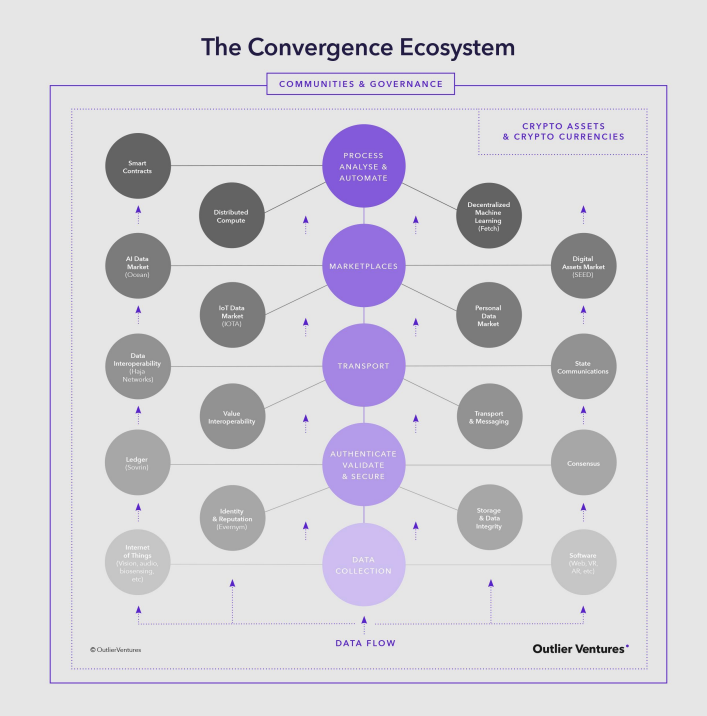
The Convergence Ecosystem

From Blockchain-enabled Convergence

In late 2016, we published a paper titled: 'Blockchain-enabled Convergence' outlining our investment strategy. The paper was the result of over three years' experience researching, investing and building blockchain-based businesses. Our insight was that blockchains are not just a secure ledger for cryptocurrencies and other digital assets, but that they represented something more transformative: a decentralised data infrastructure. Infrastructure that could solve technical and market problems across a variety of emerging technologies like artificial intelligence, autonomous robotics, the Internet of Things, 3D printing and augmented and virtual reality.

From IOTA, SEED, and Sovrin, to Fetch, Ocean Protocol and Haja Networks

Over the two years we have partnered with and invested in IOTA, a foundation building Internet of Things infrastructure with a new type of decentralised data structure. Botanic and the SEED Vault foundation it founded, creating a platform for developers to publish trusted software bots. Evernym, a company using the Sovrin Network and Protocol to establish self-sovereign identity. Fetch, a startup building an emergent intelligence protocol combining distributed ledgers with machine learning. Ocean Protocol, who are developing a decentralised data exchange protocol to unlock data for AI. Finally, Haja Networks who are looking to build protocols enabling data and database interoperability. Each of these investments has been strategically chosen because they are a complimentary piece of decentralised infrastructure required to create the Convergence Ecosystem.



The Convergence Ecosystem (cont..)

The Outlier Ventures thesis: The Convergence Ecosystem

In the Convergence Ecosystem, **data is the core asset.** Collected by the Internet of Things and software, data is authenticated, validated and secured using distributed ledgers, consensus and other decentralised technologies. When needed, data is transported and shared before ending up in marketplaces to be packaged up and sold. Finally, it is processed, analysed and automated using a range of technologies including distributed computation, decentralised machine learning and smart contracts. This entire data flow is coordinated and incentivised using crypto-assets, crypto-currencies and nascent crypto-commodities designed to incentivise behaviours for people, machines, devices and agents to the benefit of the overall ecosystem. New emergent governance models will have differing levels of decentralisation and automation depending on the values of the community. Some will value censorship-resistance above all else. Others will value self-sovereign identity or equalitarian wealth distribution. Communities can use traditional governance structures like corporations or newer structures like decentralised organisations or decentralised autonomous organisations (DAOs).

Convergence across industries

It is clear that this convergence framework is not limited to a specific market such as financial services or manufacturing. This framework and its impact and implementation will vary depending on the dynamics of particular markets. For example, the healthcare industry has very different economic, social, cultural and technological dynamics and drivers that will shape how the Convergence ecosystem will manifest. The particulars of the value chain will influence more than the technologies themselves how best to adapt to the transformation. For example, if data becomes publicly accessible on blockchains and sold in marketplaces, how will that impact businesses predicate on the capture and hoarding of proprietary data to train machine learning algorithms? The transformation brought by these converging technologies will lead to new revenue opportunities, cost savings, but most importantly new business models across all industries.

The Convergence Ecosystem in industry roadmap

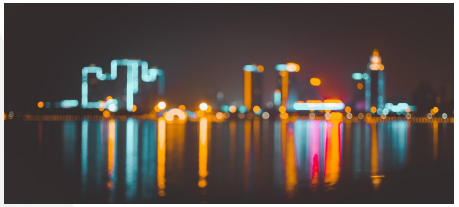
THE CONVERGENCE ECOSYSTEM

MOBILITY (Q3 2018)

This report will focus on how the mobility sector is being reshaped by the Convergence ecosystem.

Access of ownership trends, electric vehicles, and autonomy are already impacting the mobility value chain upending previous distinctions between transporting goods or people. We believe all of these changes are interconnected, and the Convergence ecosystem provides a valuable framework to understand value chain changes.

SMART CITY (Q4 2018)



Our next report coming later in the year will focus on how the Convergence ecosystem is at the heart of a Smart City.

Today, Smart City development is vendor-led and fragmented failing to put the citizen at the heart of the design. We believe putting open-source, blockchain-based data infrastructure at the heart of Smart City design is vital for long-term sustainable success.

ENERGY (H1 2019)

In early 2019 we will explore how the Convergence ecosystem is being adapted to the energy market.

Trends in energy such as renewables, storage technologies, and distributed energy resources are all forcing infrastructure to adapt. Without a holistic vision for a future energy system, we run the risk of building fragmented and incompatible systems limiting the potential zero margin cost society.

Further industries in consideration for 2019 include: **manufacturing, healthcare, telecommunications, and financial services.**

Part 2:
The Mobility Market

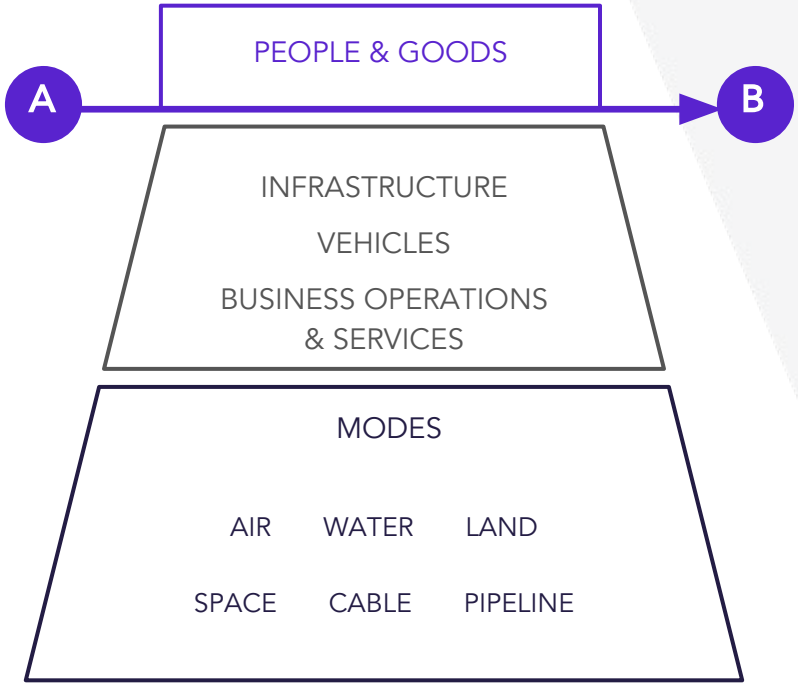
What do we mean by mobility?

Mobility is the ability to move people and goods freely and easily.

Before assessing any market it is important to understand exactly what we consider to be the mobility industry.
We decided to avoid the existing transportation or logistics markets because they are ill-suited to the changing use of different modes of transport. For example, a drone can be used for commercial or leisure purposes, the same is true for cars. These same vehicles may carry both people and goods, so the traditional transportation and logistics markets are blurring.

In our assessment of the changing mobility market, we went back to find principles. First principles of mobility apply both to the physical and digital world. Mobility serves humanity's need to move people and goods from point A to point B in a convenient, cost-effective, secure, timely and sustainable way.

Air, water, land, space, cable, and pipeline are the main media or modes used for mobility. To fulfill the aforementioned needs, humans innovate in infrastructure, vehicles and business operations & services that are different for each mode.



The mobility market is forecast to grow at a CAGR of 91.32% from $0.5 billion USD today to $2.3 trillion USD in 2030.

Estimates for the size of the mobility market vary widely depending on the methodology used. The challenge in forecasting growth is that mobility infrastructure is heavily dependant on macroeconomic factors and political motivations. A slowdown in the global economy will lead to less infrastructure spending from the public sector which in turn impacts vehicle spending or a change in government in a particular country can dramatically impact the prioritization of mobility infrastructure.

- That said, it has been forecast that globally there is a need for **infrastructure** spending to increase to $94 trillion by 2040.
- The global commercial **vehicle** market size is estimated to expand at a CAGR of 7.1% in the next 7 years.
- Most venture capital will be poured into operations, services and vehicles.

INFRASTRUCTURE

- Roads
- Railways, Railway stations
- Airways, Airports
- Waterways, Seaports
- Canals
- Pipelines
- Bus stations
- Warehouses
- Trucking terminals
- Refueling depots
- Charging stations

VEHICLES

- Automotives
- Trains
- Buses
- Trucks
- Bicycles
- Helicopters
- Watercrafts
- Aircrafts
- Spacecrafts

OPERATIONS & SERVICES

- Financing
- Legalities
- Policies
- Logistics
- Connectivity
- Fleet operations
- Asset sharing platforms
- Software platform providers

Source: PwC

What customers want from mobility providers is changing

PERSONALIZATION

- Customers prefer **customised mobility options** based on their individual and lifestyle preferences.
- Customers expect to have the same or better experience even if they do not own the vehicle.
- Vehicle is expected to behave like their other personalised devices such as their smartphone, tapping into their favorite media, settings, data for in-vehicle experience.

SECURITY

- People expect to have the ability to **carry their ID** including their personal data & preferences to allow seamless access to any mobility service.
- Security along with auditability and transparency are paramount.

AUTOMATION

- Users expect payments and transactions for access to vehicles, parking, tolls, in-vehicle services usage, charging to be automated and streamlined.

DIVERSITY

- **Car-sharing —** Customers rent unattended vehicles usually for a short period.
- **Ride-sharing —** Sharing private vehicles for usually short rides with others going towards the same direction.
- **Ride-hailing —** On demand access to drivers with their private vehicles.

Key market trends

OWNERSHIP MAKES WAY FOR MOBILITY AS A SERVICE

- In the US, the share of people (16 to 24 years) that hold a driver's license dropped from 76% in 2000 to 71% in 2013.

ELECTRIC MOTORS ARE REPLACING INTERNAL COMBUSTION ENGINES

- Exponential improvement in converting, storing, managing & sharing clean energy.
- EV battery costs could drop to ~USD 200/kWh by 2020 & ~USD 160/kWh by 2025.
- EVs become luxury status symbols (Tesla). Lower operation and maintenance costs.

VEHICLES BECOME COMPUTERS ON WHEELS AND AUTOMATED

- Vehicles become ever more digital which accelerates growth.
- IoT sensors.
- Edge computing.
- Artificial Intelligence — LiDAR, radar, cameras, ultrasonic.

VEHICLES CONNECT TO VEHICLES AND INFRASTRUCTURE NODES

- Human-machine interface (HMI).
- Vehicle to Infrastructure(V2I).
- Vehicle to Vehicle (V2V).
- 28% of new car buyers prefer car connectivity features over engine power or fuel efficiency.

MULTI-MODAL INTEGRATED MOBILITY FACILITATES END-TO-END SERVICE

- Platforms provide journey planning, booking, payment and multiplexing car & bike sharing, Parking, Ridesharing, micro-mobility.

CITIES ARE TURNING INTO MEGACITIES

- By 2030, 60% of the world's population will live in urban cities.
- Urban mobility demand will increase 36% between 2010–2030 and 38% 2030–2050.

Key market drivers

BATTERY IMPROVEMENTS ARE DRIVING VEHICLE ELECTRIFICATION

- Li-ion batteries increase in capacity by 6–7% annually.
- Battery costs fell from ~$1,000/kWh in 2010 to ~$227/kWh in 2016 and currently ~$190/kWh(Tesla).

REGULATORS INCENTIVISE SUSTAINABLE MOBILITY PRACTICES

- Emission/efficiency regulation (EU 95g CO2/km, 2021; US 54.5 mpg, 2025, CA 15% ZEV 2025).
- In some markets solar has pushed wholesale electricity prices down by up to 40%.
- Solar photovoltaic (PV) costs decreased costs by a factor of 154.

ELECTRIC VEHICLES ARE HEADED FOR COST PARITY WITH INTERNAL COMBUSTION

- EVs have fewer parts and are easier to maintain compared to ICEs.
- By 2020 total cost of ownership of BEVs will be 3.2% lower than comparable ICE vehicles.

VEHICLE AS AUTONOMOUS ECONOMIC AGENT

- Vehicle can become an autonomous economic agent driving value for its owner, i.e. TESLA drives during night while user is asleep and then pays off its lease agreement.

SOFTWARE IS EATING THE WORLD AND VEHICLES

- Algorithms powered by Artificial Intelligence enable cars to become autonomous and pushes computing to the edge.
- New operating systems are being created for Electric Vehicles that facilitate over-the-air upgrades.

CONSUMERS' PREFERENCES LEAN TOWARDS SUSTAINABILITY, SAFETY, CONVENIENCE AND COST-EFFECTIVENESS

- Increased awareness of climate change leads more people towards clean and sustainable mobility.

Source: DEKRA, TESLA, TRANSPORT & ENVIRONMENT

Key market constraints

REGULATORS STRUGGLE TO KEEP UP WITH RAPID TECHNOLOGICAL CHANGES

- Regulation often lags behind technology which is advancing rapidly.
- How do algorithms make choices in case of unavoidable accidents and who should take responsibility?

CYBERSECURITY BECOMES EVER MORE IMPORTANT

- As vehicles become more and more digital, cyber attacks pose a major threat to human lives.
- In 2015 hackers proved they could remotely hijack a moving jeep.

IT IS NOT YET CLEAR WHO OWNS THE DATA BEING PRODUCED AND CAPTURED

- Regulators have not clearly defined who should own all that generated data.
- Auto manufacturers, software companies, fleet operators and people are all incentivized to own those data streams.

CULTURAL DIFFERENCES AND COGNITIVE BIASES HINDER AUTONOMOUS AND ELECTRIC VEHICLES

- People tend to react more negatively to accidents caused by autonomous vehicles than by humans.
- Some governments do not prioritize sustainable mobility.

PARTICIPANTS ARE INCENTIVISED TO HOLD ON TO THEIR SILOED DATA AND CLOSED SYSTEMS

- Companies might prefer to keep their equipment and platforms incompatible i.e. charging stations, mobility as a service platforms which could also hinder vehicle to vehicle connectivity.

ENERGY INFRASTRUCTURE IS COSTLY

- Batteries are still to match conventional vehicles' 5min refueling time and range.
- A wide range of easily accessible charging stations is needed.

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The closed mobility value chain today

ENERGY INFRASTRUCTURE	CONNECTED VEHICLES	MOBILITY SERVICES
• Fuel — Fossil fuels, Coal, Petroleum, Natural gas • Logistics — fuel distribution • Sales channel — Gas stations	• OEMs — Original equipment manufacturing for vehicles • Vehicles production — Auto manufacturers • Distribution and sales — Dealerships • Standard ownership model	• Nascent Sharing economy — Car sharing, ride hailing, ride sharing, car pooling • Public transit — fragmented mobility services • Platforms — fleet operators including last mile mobility(scooters, ebikes) • MaaS — early stage multimodal mobility as a service platforms

- **Current value chain.**
  Currently oil and gas companies extract, refine and distribute fuel to gas stations.
- **Current state of manufacturing.**
  Original equipment manufacturers produce parts; auto manufacturers use to produce vehicles that are in turn distributed to dealerships and eventually purchased by consumers.
- **Sharing economy** is in its early stage and fragmented.

The open mobility value ecosystem of tomorrow

ENERGY INFRASTRUCTURE

- Fuel — Renewable energy sources. PV prosumers — bilateral energy exchange with smart grids.
- Logistics — energy storage and distribution is decentralized and distributed occuring in local prosumers' facilities and smart grids.

CONNECTED VEHICLES

- OEMs become more software oriented.
- Auto manufacturers also become software companies. Tech companies enter and build proprietary software and Avs (i.e. Waymo). V2V2I value exchange. Vehicles as autonomous agents.
- Distribution and sales - Decline of ownership and thus dealerships.
- Data-driven business models.

MOBILITY SERVICES

- Advanced sharing economy — Car sharing, ride hailing, ride sharing, car pooling.
- Drivers decline. Fleet operators increase.
- Integrated, multimodal mobility as a service including last mile services.
- In-transit interface for personalized experience.
- Data captured become primary source of value. Data-driven business models.

- **New energy sources.**
  Oil and gas companies are shifting their focus to growing renewable energy sources enabling companies that capture and store solar energy.
- **Consumers become prosumers.**
  People can produce, store and exchange their own energy on decentralized and distributed smart grids powered by blockchains. Consequently, energy becomes a commodity and utility providers embrace data-driven business models. Charging stations are being deployed for electric vehicles.
- **Software companies enter the value chain.**
  Proprietary software and hardware are developed for autonomous vehicles monetizing their fleets as an on-demand service instead of the traditional ownership model. Shared mobility prevails and consumers prefer to use integrated multimodal Mobility-as-a-service platforms.

Part 3: The Convergence Ecosystem in Mobility

The mobility sector has a burning platform

The transportation and logistics industries are having an existential crisis. Electric vehicles and lithium battery costs are falling quickly; autonomy software is improving at a rapid pace and ride-sharing platforms are leading customers to question the need to own cars. These three trends: electrification, autonomy, and access-over-ownership are reshaping every part of the industry and moving the industry into a new era of integrated mobility. This is the concept of a seamless transit experience incorporating multimodal, public and private transport. As the transport value chain expands to become the mobility value ecosystem, the old way of doing business won't continue to work.

The Convergence ecosystem promises a new era in transportation and logistics. It is widely accepted that transport is changing and the industry must adapt. The Internet and mobile technologies are changing the way consumers and businesses access and buy transportation services while on-demand services and autonomy will challenge the fundamentals of ownership. It's clear that we are moving towards an increasingly complex economy where software is eating the world. Previously airlines only competed with airlines; car makers with car makers; and Apple just made mobile phones and laptops. However a new era of what we are calling 'Open Mobility' is upon us: movement is decentralised, multimodal, automated, it aspires to be increasingly sustainable.

Electric vehicles, automation technologies, and alternative mobility solutions like ride-hailing are forcing automotive manufacturers (OEMs) and transportation providers to rethink their business models. After being in stasis for decades, the market is now in flux as players jockey for position as a new and integrated mobility value ecosystem emerges, bringing all modes of public, private and commercial transport together. This flux is forcing collaboration and partnerships that would have been unimaginable five years ago.

The era of open integrated mobility is upon us

An integrated open mobility ecosystem goes beyond the traditional automotive industry and brings together bikes, trains, planes, ships and newer transport types like drones and innovations like Hyperloop. As the personal transportation market moves toward access rather than ownership, the same assets can be used for commercial and consumer purposes, blurring the lines between logistics, public transit, and private transport. Uber has already experimented with grocery deliveries; Mobike and Ofo dominate bike-sharing in China; Citymapper, a UK mapping startup, is running a bus service in London. Traditional market boundaries have blurred. There are no separate consumer, public or logistics markets. There is a single integrated mobility market; yet no single company can deliver transport services without widespread collaboration and interoperability between and across them all.

Without fundamentally rethinking our approach to infrastructure for this emergent integrated mobility landscape, we will face a tragedy of the commons. Without shared infrastructure and a collaborative approach, siloed operating systems and data will limit the transformational impact of multimodal mobility. The consumer will have to navigate a range of different systems as they move from a car to a bike to a plane. Businesses will not be able to fully utilise their assets. Smart cities will remain only a dream. However for all parties to rely upon any one entity to control this system would be to submit to a monopoly that would gain from increasing data and intelligence advantages, becoming almost impossible to remove.

We need a mobility ecosystem based on shared infrastructure in which resources, data, and value can be exchanged seamlessly. The Convergence ecosystem is a valuable framework for understanding how this decentralised, multimodal, automated, and sustainable infrastructure can be designed and built.

The future open integrated mobility ecosystem

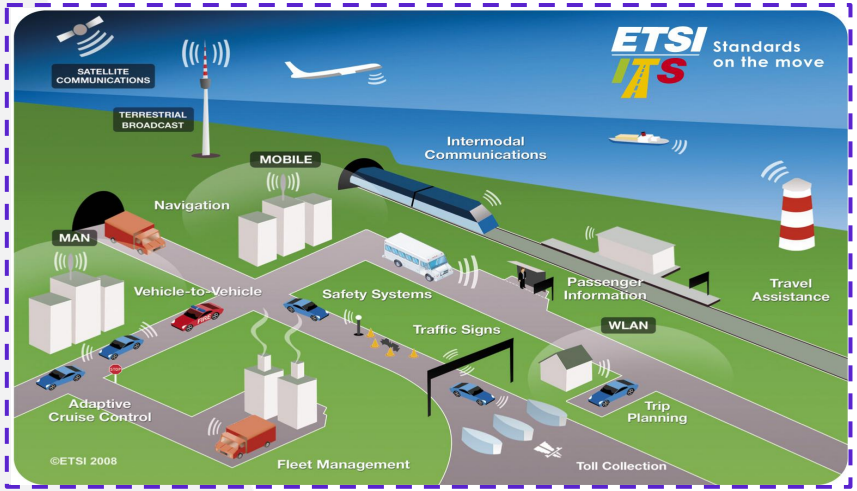
Physical Infrastructure
- Highway Tolls
- Flow Management
- Parking Management
- Multimodal Docks & Ports

Energy Infrastructure
- Supply Chain Management
- Smart Consumption
- Battery & Lifecycle Management
- Charging Infrastructure

Digital Infrastructure
- Congestion Pricing
- Data Storage
- Data Sharing & Exchange
- Operating System
- Security & Risk

Connectivity Infrastructure
- Vehicle-to-vehicle (V2V)
- Vehicle-to-infrastructure (V2I)
- Infrastructure-to-infrastructure (I2I)

Connected Vehicles
- OEMs
- Parts & Sensors
- Autonomy Hardware/ Software
- Identity & Wallet



In-transit Experiences
- Content Creation
- In-transit Services
- Predictive Content Analysis
- User Interface (VUI, etc)

Integrated Mobility
- Asset Sharing Platforms
- Car Rental Companies
- Travel Management Companies
- Software Platform Providers
- Fleet Management Providers
- Public Transport Operators
- Integrated Solution Providers
- Ticketing & Dynamic Pricing

Fleet Operations
- Asset Tracking & Analytics
- Asset Finance
- Asset Insurance
- Authentication, Scheduling & Allocation
- Fleet Procurement
- Logistics & Freight

Mobility Advisor
- Relationship Management
- Predictive Analytics
- Mobility Data Collection & Analysis

Source: ETSI

Data Collection

Sensors measuring the external environment are often bundled together under the umbrella term the ‘Internet of Things’; and they include all sensors in smartphones and wearables such as gyroscopes, accelerometers, and proximity sensors as well as hundreds of others sensors across the smart city environment. It is estimated that the amount of data created annually will reach 180 zettabytes (one zettabyte is equal to one trillion gigabytes) by 2025 up from 4.4 zettabytes in 2013 and an average person anywhere will interact with connected devices every 18 seconds (nearly 4,800 times a day).

The Internet of Things

We define the Internet of Things or "IoT" as the interconnection of identifiable connected devices into mobility's Internet infrastructure. The concept includes any ‘thing’ that has a sensor and transmits data over a network, including a vehicle or a part of it, such as its engine, users' devices, charging stations, parking lots. This allows for distributed intelligence, automation, and streamlined processes.

Vehicles become autonomous economic agents. The value will be derived from the broader aggregation of data.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Standardization of vehicle-to-vehicle & vehicle-to-infrastructure wireless communications via low power wide area e.g. Narrowband-IoT

Machine-to-machine value exchange network enabling automated allocation of resources

Improvements in energy sources and power management in IoT sensors and edge devices — zero-power electronics

MOBILITY APPLICATIONS

1. People, goods, and vehicles are equipped with sensors turning them into IoT nodes that produce and capture data. This allows for vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-anything communication making vehicles economic independent machines.
2. Data captured from IoT enables real-time traffic maps more efficient routing and reducing congestion.
3. Vehicles can be remotely monitored and maintained by uploading software upgrades.

Case Study: FOAM

The FOAM Proof of Location protocol empowers a permissionless and autonomous network of radio beacons that can offer secure location services independent of external centralized sources such as GPS through time synchronization.

Crypto-spatial coordinate standard	Proof of location protocol	Spatial Index Webapp
• Vehicle identity, history and data tracking. • Autonomous machine and vehicles payments • Supply chain tracking, transparency and efficiency.	• Supporting the growth of mobility services and autonomous vehicles through location tracking and fraud prevention. • Secure location verification and localization for networks of IoT devices sensor data.	• Vehicle identity, history and data tracking. • Autonomous machine and vehicles payments • Insurance — Automated conflict resolution and contract enforcement through trusted reporting of spatial variables.

> “We are excited to contribute to the development of a decentralized internet of mobility. FOAM will support the Mobility Open Blockchain Initiative (MOBI) through the development of geospatial blockchain protocols and standards for location encoding, map UI, and proof of location. We are eager to play a part in the next step of mobility.”

Ryan King, CEO, FOAM

Software, operating systems and applications

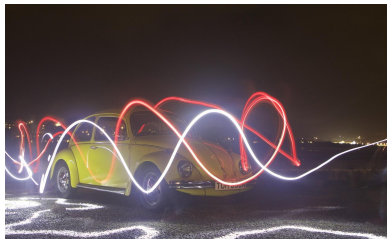
We use the term ‘software’ as a producer of data broadly to capture all personal, vehicle and infrastructure data produced through the interaction with databases, operating systems, applications, and APIs.

While sensors embedded in hardware will capture the external environment, software, operating systems and applications capture a constant feed of data from internal processes such as in-transit interfaces and mobility-as-a-service platforms.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of mobility-specific operating systems and APIs (see CarPlay, Android Auto, OpenCar)

Improvement of mobility-specific App stores and in-car infotainment (See SmartDeviceLink, Opencar)



Development and maturation of more appropriate in-car user interfaces such as voice control and gestures and HMI safety regulations

MOBILITY APPLICATIONS

1. Proprietary operating systems built for vehicles equipped with artificial intelligence algorithms act as the vehicles’ brain. This enables autonomy, connectivity, and automation.
2. Multimodal mobility as a service allows users to seamlessly find the most suitable route depending on their needs.
3. User Interface provides consumers with in-transit entertainment and applications (Web browsing, messaging, social media, AR/VR). Value is captured from the collection and production of consumers' data.

Projects to watch

- Real-time zero fee payments, secure data transfer and immutable data storage unlock the potential of connected, and autonomous vehicles, e-Mobility, Urban Mobility & new Mobility Services.
- Cars turn into digital platforms and therefore digital services and digital content in and around the car become more important than the car itself.
- Frictionless transfer of value and assets.
- IOTA is working with BOSCH and VW Group.

Disclaimer: Sovrin is a portfolio company.

- Connected machines and devices can transact and exchange value against a blockchain.
- Device-to-blockchain transactions(encrypted sign in of device data, provenance, chain of custody).
- Data sharing — Authorize and sign transactions between machines in real-time, without access to connectivity or a cloud. On-premise interoperability between systems run by different manufacturers or operating systems.

- The future of mobility requires secure and accurate location data we can trust.
- XYO is a trustless, cryptographic location network using a novel formulation reliant on a chain of zero-knowledge proofs to establish a high degree of data certainty on location information.
- Leveraging blockchain and real-world data collection into a system that enables the decentralization of self-driving vehicles, shared mobility, deliveries and mobility-as-a-service platforms.

Authenticate, Validate & Secure

Blockchains and distributed ledgers fit into the Convergence framework here at the distribution layer. Without these decentralised technologies, authentication, validation, and security would be provided by a third party without the characteristics provided by blockchains such as increased external transparency, provenance, tamper-evidence and censorship-resistance.

Distributed ledgers and blockchains

Often the terms "distributed ledger" and "blockchain" are used interchangeably, but a blockchain is a particular type of a distributed ledger which is simply an asset database that can be shared across a network, structured like a chain of blocks. When we talk of blockchains, we are referring to a specific type of data structure that is cryptographically linked together in a linear sequence of blocks, each of which contains a record of transactions.

Distributed ledgers and blockchains provide a mechanism for the transaction, verification, and storage of digital assets such as digital twins of vehicles, OEM parts and user credit for Mobility-as-a-service platforms on distributed ledgers.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Shared mobility market infrastructure delivered via consortia models (see MOBI)

Higher transaction throughput for m2m payment use cases (see, Xain)

Enhanced privacy controls such as luminosity in Ethereum Swarm or zero-knowledge implementations

MOBILITY APPLICATIONS

1. Individuals and organizations can participate without permission to share their resources and monetize their assets such as their idle vehicles.
2. Vehicle verification information can be time-stamped and accessed via a blockchain solution.
3. Original equipment manufacturers can streamline their supply chain and monitor the provenance of their products. IBM & Maersk are already rolling this out with TradeLens in the supply chain industry.

Identity and reputation

Blockchains introduced a system where transactions from individuals could be validated publicly in a decentralized manner. Identity on a blockchain is an area of increasing focus due to a surge in fraud, identity theft, and increasingly sensitive data becoming digitized.

Through self-sovereign identity, an individual will be able to authenticate or verify themselves without having to pass on their documents. Users can access their or third-party-owned vehicles and mobility services while keeping their anonymity.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Development of blockchains ability to adhere to regulations eg GDPR

Maturation of self-sovereign identity to shift control of personally identifiable information to individuals or agents

Standardization of anti-money laundering and know-your-client processes on blockchains

MOBILITY APPLICATIONS

1. In an integrated mobility environment, users have a portable identity enabling a seamless experience across different modes of transport.
2. Users and vehicles own and manage their own identity to benefit by having a global user account(“single sign in”) that is not centrally controlled and allows them to access mobility assets and services.
3. Vehicles and users can use their self-sovereign identity to get identified and verified while remaining anonymous or pseudonymous.
4. Identity can be linked to customers’ data facilitating their digital footprint that helps identification(see Sovrin).

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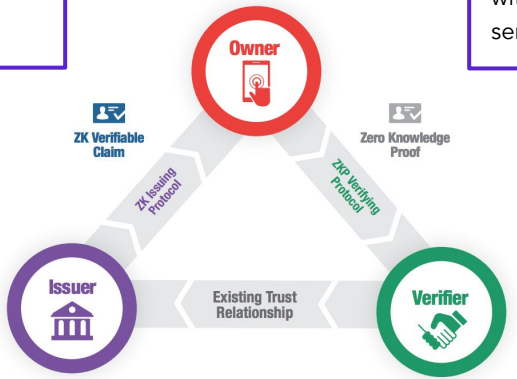
Case Study: Sovrin

Disclaimer: Sovrin is a portfolio company.

Sovrin is a decentralized, global public utility for self-sovereign identity. Self-sovereign means a lifetime portable identity for any person, organization, or thing. Having a self-sovereign identity allows the holder to present verifiable credentials in a privacy-safe way. These credentials can represent things as diverse as an airline ticket or a driver's license.

Pairwise pseudonymous identifiers	Peer-to-peer private agents	Zero-knowledge proof cryptography
Users can open a new account with a MaaS provider and be protected from ID theft as their DID can be changed without affecting any other relationship.	To prevent correlation, no private data is stored on the ledger, even in encrypted form.	Selective disclosure of personal data so users can be identified and have access to mobility services with their self-sovereign ID without revealing sensitive information.



Storage and data integrity

Blockchains will be used as on-chain pointers to off-chain data and implement an access control list to control and monitor data access. Today's implementations are utilising decentralised databases and distributed file storage to store data "off-chain" in a way that ensures data integrity. Infrastructure nodes could be used for "off-chain" storage to allow vehicles to have more space.

Transactions between vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-user can take place "off-chain" and settle in specific intervals to avoid overloading the "on-chain" ledgers. The link between the blockchains (on-chain) and decentralised storage (off-chain) is still to be defined.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Symmetric distribution of different vehicles' storage capabilities

Development of infrastructure nodes by governments and corporations to facilitate off-chain storage

Standardization of recording mobility-related data adhering to universal jurisdictions

MOBILITY APPLICATIONS

1. Participants and vehicles share their extra storage resources in exchange for value and exclusive deals.
2. Local copies of the global blockchain permit near-immediate access to information recorded on the blockchain.
3. Vehicles and platforms store data for optimisation and betterment of services.
4. Events and transactions are time-stamped and stored securely for more accurate insurance offerings and secondary market sales.

Decentralized consensus

Consensus can be defined as the process through which every system within the connected network agrees upon an event within the network. The “event” can be a simple transaction, or a relatively sophisticated smart contract function being triggered such as transfer of vehicle ownership or the record of a mobility service purchase.

Blockchains provide a reliable solution for solving the Byzantine Generals problem in an open, anonymous network. They allow the majority of the distributed entities within a network to come to an agreement on what information is accurate and enforce algorithms that replicate the data across every entity.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Development of appropriate consensus mechanisms to balance security & expenditure of computational resources eg PoW, PoL, PoS

Development of legally enforceable smart contracts that plug into legal systems for dispute resolution

Standardization of time between transactions' initiation and confirmation for different use cases eg charging, monitoring

MOBILITY APPLICATIONS

1. Certain consensus mechanisms (PoW, PoS) facilitate trust and allow unknown vehicles, users, and other nodes to participate in the network.
2. Vehicles get added to the network, turn into nodes that run and maintain it while increase security and reduce operating costs.
3. All vehicles are instantaneously and automatically up-to-date with all the latest information, updates and statuses of all other vehicles.

Projects to watch

- Consumers can positively contribute to the future of mobility and earn MOV tokens by sharing their mobility data to help with urban planning or to build the next autonomous vehicle.
- Moveco Data Hub & Insights Platform will package car generated data parameters into various data packages. Corporate customers can subscribe to the data packages to receive anonymized car generated data based on the criteria they are interested in.

- VeChain creates a digital passport of a vehicle recording all data including repair history, insurance, registration and even driver behaviour throughout its lifecycle.
- It puts data into the hands of owners, making data management comprehensive, accessible and transparent.
- Car owners have complete control over their data and can authorize third parties such as insurers.

- IPFS is a peer-to-peer distributed file system that seeks to connect all computing devices with the same system of files.
- In some ways, IPFS is similar to the Web, but IPFS could be seen as a single BitTorrent swarm, exchanging objects within one Git repository. In other words, IPFS provides a high throughput content-addressed block storage model, with content-addressed hyperlinks.

Data & Routing

Transport

After data has been authenticated, validated, secured and stored it will need to be transported. The technologies of this layer are less mature than the layers below but will become ever more critical as blockchains and DLTs proliferate if we are to avoid the same data silos that exist today in the Web 2.0 era. It is at this layer where interoperability protocols are developing for messaging, value, data and state.

Data transport and routing

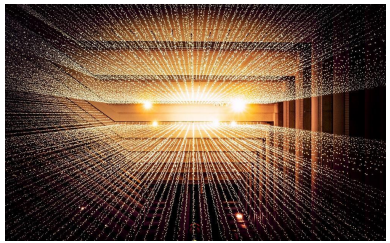
Data transport and routing refers to the development of a suite of new protocols for Web 3.0 that provide services such as connection-oriented communication, reliability, flow control, and multiplexing. With the Internet Protocol Suite this includes protocols such as TCP, UDP, and DCCP.

We expect to see a variety of new protocols such as mix network packet routing, secure tunnel switching, and other cryptographic tools to provide increased privacy controls for network participants.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Widespread deployment of full anonymity tools like stealth addresses and IP-obfuscating tools

Standardization of peer-to-peer authentication and validation



Improvement of economical micro-transactions

MOBILITY APPLICATIONS

1. Traffic control is being performed by vehicles by peer-to-peer real-time communication.
2. Users access autonomous vehicles interface to send messages securely over the networks.
3. Vehicles can purchase charging services, parking, energy(from other vehicles) and get paid by users via Mobility-as-a-service platforms.

Value interoperability

Value interoperability refers to the ability for value to move across blockchains. The most straightforward example for an interoperable transaction would be one in which an individual transfers a cryptocurrency on one blockchain in exchange for cryptocurrency on another, for example, Bitcoin exchanged for Litecoin or XRP. The interledger Protocol (ILP), Polkadot, AION, and Cosmos are all working on making this a reality.

Fleet operators could enable their vehicles to communicate with vehicles running on different blockchains and exchange value. Users can access different multimodal mobility-as-a-service platforms that might be operating on different blockchains and leveraging different tokens.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation and widespread adoption of atomic cross-chain swaps to facilitate cross platform token compatibility

Value routing protocol development enabling liquidity to be shared across exchanges seamlessly

Development and usage of decentralized exchanges

MOBILITY APPLICATIONS

1. Users have access to Mobility-as-a-Service platforms by using the same token to access a wide range of services(multimodal services).
2. Users and vehicles verification can be facilitated without sharing sensitive information.
3. Vehicles can pay for access to a charging station in the native token of one type of station and receive the resource in another type of charging station.

Data interoperability

Data interoperability allows data to move across databases. Today, incredible amounts of data are stored on the private servers of a relatively small amount of organisations. The internet's client-server architecture makes data-sharing inconvenient, while privacy and data protection laws limit the cases where it can be done legally. Even if this were not to be the case, there is no rational economic incentive for individuals to do anything other than giving away their data. Drivers and fleet operators are incentivized to share and monetize their data via mobility data marketplaces.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Development of data sharing standards adhering to all data protection and privacy legal frameworks

Cultural shift within the industry that data is better shared and big than private and small

Sharing data must bring a higher return on investment than holding data

MOBILITY APPLICATIONS

1. Vehicle-to-vehicle data sharing across different blockchains and platforms becomes seamless, fast and secure.
2. Users can find the best route by accessing multimodal mobility services.
3. Vehicles can share data across networks that allow them to coordinate efficiently.
4. Participants such as OEMs, users, insurance companies, charging nodes enjoy lower costs, increased transparency and collaboration.
5. Insurance companies can benefit from new models such as dynamic mile, behavior and route based charging.

Case Study: Haja Networks

Disclaimer: Haja Networks is a portfolio company.

A scalable and trustless peer-to-peer database, and database protocols for a global data layer to re-decentralize the web.

Decentralised Database Protocol

- Open-source protocol to build decentralized databases that enable users to own and control their data and that can be integrated with existing database systems
- Allows users to own and control their data through a cryptographic access control and can be used with any blockchain or storage system
- Allows interoperability between databases, eg. CouchDB ⇔ MongoDB

Decentralised Database Network

- Haja is currently developing OrbitDB, a scalable and trustless peer-to-peer database and database protocols for a global data layer to re-decentralize the web.
- Crypto-currency based marketplace for decentralized cloud-database services
- Enables database providers to monetize their software as a service

State channels and communication

State communication protocols provide a mechanism to limit the number of settlements a blockchain must perform by enabling off-blockchain communication channels. State channels are a scaling solution to the inherent performance limitations of blockchains. Layer 2 solutions are occurring across networks including the lightning network on Bitcoin and Plasma and Raiden and Celer for Ethereum.

In a mobility scenario, these 'state channels' are basically a two-way discussion channel between users transacting on mobility services platforms, or between a user and a service (an autonomous vehicle).

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of balance proofs to reduce settlement load.

Development of appropriate state channels to cater for different use cases eg monitoring, charging, mobility-as-a-service

Solutions to latency challenges as assets are stored across blockchains and state channels

MOBILITY APPLICATIONS

1. Mobility-as-a-service network transactions happen off-chain reducing costs and increasing speed.
2. Transactions between vehicles, users, and infrastructure are streamlined.
3. Vehicle-to-vehicle-to-infrastructure microtransactions take place off-chain, reducing the load on the main blockchain.

Projects to watch

- Chronicled leverages IoT, AI, and Blockchain technologies to power end-to-end smart supply chain solutions.
- On the Chronicled platform the authenticity, chain of custody, and data log history of each Trusted IoT Device becomes 100% provable.
- Participants can register any physical object, IoT device, or sensor on the blockchain linking the physical and digital worlds.

- The Mercury Protocol provides users with rewards for participation whilst service providers can bootstrap a network out of the box.
- It caters for multiple use cases such as 1-to-1 conversations enabling Cross platform messaging, message encryption and Large file size.
- 1-to-many: Announcements increase reach by boosting distribution, Send content to a targeted demographic.
- Many-to-many discussions which decreases queue time to send a message.

- Polkadot enables an internet where independent blockchains can exchange information and trust-free transactions via the Polkadot relay chain, with the key tenets of scalability, governance and interoperability.
- Relay chain coordinates consensus and transaction delivery between chains.
- Parachains are constituent blockchains which gather and process transactions.
- Bridges link to blockchains with their own consensus such as Ethereum.

Data Marketplaces

Data has been collected, validated and transported; now it needs to be used. Before it is processed, analysed and automated, marketplaces are emerging to allow the trading, buying and selling of data and digital assets. These marketplaces are made possible because of the distributed ledgers, consensus mechanisms and interoperability protocols at the lower levels. It is only because data has been unlocked lower down that it can be traded further up the stack. We will see the emergence of a whole host of new types of marketplaces beyond just today's cryptocurrency exchanges. New marketplaces will enable the sharing of IoT data, AI data, personal data as well as other digital assets like non-fungible tokens (NFTs) and even a new class of automated software agents.

Artificial intelligence data marketplace

With the emergence of deep learning as the most useful machine learning technique for a range of AI applications like computer vision that enables navigation of autonomous vehicles and natural language processing that facilitates in-transit user interfaces, data has become like digital oil. Just like IoT data, or any data for that matter, data for AI algorithms tend to be accumulated by the largest companies. Decentralised AI data marketplaces will reduce, and eventually remove, the competitive advantage of hoarding private data by enabling anybody to monetize data. It allows all participants and fleet operators to train their autonomous vehicles increasing the overall value of the ecosystem and set higher standards.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of secure off-chain computation methods to allow model training without revealing the data itself (e.g. TrueBit)

Sharing and transacting data on marketplaces must bring a higher return on investment than holding data

Development of checking mechanisms to ensure accuracy, integrity and validity of data

MOBILITY APPLICATIONS

1. Access to AI data especially labelled training data opens up the dataset for autonomous driving enabling a more competitive marketplace.
2. Users and vehicles own, manage and have the ability to monetize their driving data by selling on the marketplace. This has implications for participants in the value chain that currently benefit most from selling driver data.
3. Insurance companies can get access to far more data in order to improve their own modelling which should enable far more efficient pricing of risk.

Case Study: Ocean Protocol

Disclaimer: Ocean is a portfolio company.

Ocean Protocol is an ecosystem for sharing data and associated services. It provides a tokenized service layer that exposes data, storage, computes and algorithms for consumption with a set of deterministic proofs on availability and integrity that serve as verifiable service agreements. There is staking on services to signal quality, reputation and prevent Sybil Attacks.

AI Marketplace	Ecosystem	Data Ownership
Ocean helps to unlock data, particularly for AI. It is designed for scale and uses blockchain technology that allows data to be shared and sold in a safe, secure and transparent manner.	An ecosystem composed of data assets and services, where assets are represented by data and algorithms, and services are represented by integration, processing and persistence mechanisms.	A multitude of data marketplaces can hook into Ocean to provide "last mile" services to connect data providers and consumers. It's designed so that data owners cannot be locked-in to any single marketplace. The data owner controls each dataset.

Personal data markets

After peer-to-peer payments, control of personal data has been one of the most talked about applications for blockchains. This is related to but separate from self-sovereign identity, in the sense that once an individual controls their own identity, they can choose who can have access to it. This choice puts the individual in the position of the seller and the party who wants access to the data as the buyer.

Consequently, mobility services and fleet operators are incentivized to provide the best service, while taking into consideration data privacy. Users can choose the most suitable and secure mobility providers as they control their own data.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of data anonymization tools allowing usage without revealing sensitive data e.g. secret contracts and zero-knowledge proofs

Development of decentralized person data marketplaces in order to adhere to legal frameworks eg GRDP - right to be forgotten

Development of checking mechanisms to ensure accuracy, integrity and validity of data

MOBILITY APPLICATIONS

1. As people interact with vehicles, Mobility-as-a-service and other services they leave traces of physical data that are being captured to a greater than ever extent. Once captured and digitised, people have access to their self-sovereign ID and personal data wallets.
2. Users can trade data on the marketplace with insurance providers, OEMs, fleet operators, Mobility-as-a-service providers and other participants.
3. Mobility-as-a-service providers, OEMs, and insurance companies can provide personalised experience to the user by accessing their personal data in a secure and anonymous manner.

Internet of Things data markets

IoT data is already being captured and collected in vast quantities by sensors on vehicles, infrastructure and users' devices, but the sprawl of devices has created a fragmented ecosystem. On the consumer side, operating system providers like Apple, Google, and Amazon are attempting to leverage their dominant positions in smartphones and retail to sell more devices to collect more data.

IoT data marketplaces incentivize fleet operators, OEMs, and users to share and exchange their data on those marketplaces. This ultimately increases the overall value of the ecosystem.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of data anonymization methods to allow transaction and usage without revealing sensitive data eg personal identity

Development of decentralized person data marketplaces in order to adhere to legal frameworks eg GDPR

Development of checking mechanisms to ensure accuracy, integrity and validity of data

MOBILITY APPLICATIONS

1. Autonomous electric connected (ACE) vehicles produce and capture vast amounts of data through LiDARs, cameras, GPS, radars and other sensors that can be packaged up and sold in marketplaces.
2. Insurance companies, fleet operators, Mobility-as-a-service providers can purchase that data and provide personalised services.
3. Normalisation, anonymisation, and processing of car generated data protects privacy and maintains consent.
4. OEMs and fleet operators can perform condition monitoring, fix and upgrade their vehicles remotely and in real-time.

Digital asset markets

Unlike traditional physical assets or money, distributed ledger-based crypto-tokens can be programmable. This gives them more flexibility and variety than their physical counterparts.

Cryptocurrencies, or tokens designed to be a medium of exchange, are already reasonably well-defined.
Crypto-assets are tokens intended to be a store of value: digital assets which are created, bought, licensed, rented and sold in decentralised mobility peer-to-peer marketplaces.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of smart contracts to facilitate automated transactions on peer-to-peer decentralized digital asset marketplaces

Standardization of IP rights and content creators (see Kord by JAAK)

Maturation of tooling and development of cross-blockchain standards for non-fungible tokens (NFTs)

MOBILITY APPLICATIONS

1. Vehicles and their parts have unique identical digital twins (see Spherity) providing more transparent provenance and improving supply chains. This facilitates seamless online purchases streamlining ownership transfer.
2. The used-vehicle market can become much more efficient as digital twins capture ongoing sensor data and combine with machine learning tools to value vehicles in real-time.
3. OEMs, insurance, energy and mobility-as-a-service providers can own manage and transact digital assets such as insurance packages, energy for electric vehicles, maintenance kits and mobility services on the marketplace.

Projects to watch

CarBlock

- CarBlock is the world's first blockchain-based transportation solution built on data generated by smart devices. This circulation of car data on the blockchain is set to disrupt the entire connected car industry.
- Data is encrypted and put onto the blockchain so that car owners can have 100% ownership over the data they generated.
- Customised products & services.

XAIN.

- XAIN enables secure and trusted human to machine interactions.
- XAIN offers a universal, user-centric access control protocol, which leverages blockchain technology to increase trust & transparency between users and enterprises. It grants users full access control over their machine and device permissions and allows for seamless and secure 3rd party service integrations into machine networks.

DOVU

- A unified token, wallet and marketplace for earning and spending mobility related rewards.
- Users can earn and spend DOV tokens for sharing their mobility data or making small but important changes to their travel behaviour.
- Users maintain control over the data they choose to share (and get rewarded for) with realtime access controls. Disable or remove access at any time.

Process, Analyze & Automate

Now we get to the top of the ecosystem: the process, analyse and automate layer. This is where data is transformed into actions and insight using traditional and distributed computing techniques, as well as newer types of computing such as quantum computing. It is at this layer where blockchains and artificial intelligence blur and it becomes clear they are intertwined and interconnected. Both smart contracts and machine learning offer differing levels of automation and decentralisation depending on the type of input data and level of trust the use case demands.

Smart contracts

Smart contracts are programmable "if this, then that" conditions attached to transactions on the blockchain. If situation 'A' occurs, the contract is coded to have an automated response 'B'. By adding this simple concept to blockchains, contracts cannot be forged, changed, or destroyed without an audit trail. This is because the ledger distributes identical copies of that contract across a vast network of nodes, for verification by anyone at any time.

Contracts and agreements between fleet operators, automotive and original equipment manufacturers, service providers and users can be coded into the blockchain streamlining processes, increasing security and transparency.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Maturation of smart contracts offering dispute frameworks specifying arbitration procedures

Development and standardization of formal verification and authentication tools (see Tezos)

Smart contracts need to adhere to an international commercial arbitration court (see Mattereum)

MOBILITY APPLICATIONS

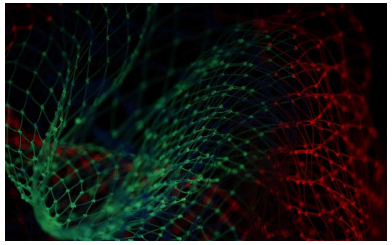
1. Autonomous vehicles manage micropayments with other vehicles and infrastructure nodes such as charging stations, parking lots, toll stations and mobility services users.
2. Smart contracts enable us to know which participant was using a vehicle or service at any given point. Consequently, new business models arise such as Mobility-as-a-service and pay-per-mile insurance.
3. Vehicles and services are interoperable with other vehicles and platforms and can seamlessly interact in an automated manner.
4. Facilitation of real-time transfer of value settlement, rebates and licensing without the need for human enforcement.

Distributed computation

Computation can be described as “the action of mathematical calculation”. Distributed computing refers to computing whereby a complex problem is broken down into more simple tasks. These simple problems are distributed out to a network of trusted computers that could be on vehicles, the infrastructure or users' devices to be solved in parallel. Then the solutions to these simple problems are combined in such a way to solve the main problem at hand.

In mobility distributed and edge computing is more suitable than centralized cloud computing as it increases security and safety.

REQUIREMENTS FOR ADOPTION IN MOBILITY



Development of 5G services to minimize latency of distributed computation results

Widespread deployment of infrastructure nodes that will provide computation resources

Standardization of limits in provision of distributed computational resources to avoid interruption of processes eg AV navigation

MOBILITY APPLICATIONS

1. Vehicles, users, and infrastructure nodes are incentivised to provide computational resources by being rewarded with a token that can be used to have access to other services in the network.
2. Mobility-as-a-service providers can leverage participants’ computational resources to provide effective and optimised service.
3. Infrastructure nodes and users can provide computational resources to free up vehicles’ resources for Artificial Intelligence algorithms that facilitate navigation for autonomous vehicles.

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Decentralized machine learning

Machine learning is a field within computer science and more specifically artificial intelligence that focuses on enabling computers to learn rather than be explicitly programmed by humans.

Machine and deep learning techniques can transform raw data into actionable knowledge; converting voice input into text output in voice-to-text programs that can be used in in-transit user interfaces or turning LIDAR input into a driving decision for autonomous vehicles.

Some projects are considering to use ternary computation in IoT devices rather than binary.

REQUIREMENTS FOR ADOPTION IN MOBILITY

Development of algorithms that require minimum computational resources

Development and maturation of application specific integrated circuits suitable for mobility

Development of 5G services to minimize latency of distributed computation results

MOBILITY APPLICATIONS

1. Vehicles gather raw data from all the IoT sensors such as LIDAR, camera, radar, GPS, wheel encoder, ultrasonic sensors and leverages decentralised machine learning to process and uses it as guidelines to optimise for best traffic management, safety, utilisation and navigation.
2. Mobility-as-a-service platforms process data gathered from users to optimise the recommendations and provide personalised services.
3. Predictive algorithms facilitate fraud detection, congestion and collision avoidance of autonomous vehicles.

Case Study: Fetch AI

Disclaimer: Fetch AI is a portfolio company.

Fetch is the world's first adaptive, self-organising 'smart ledger'. Fetch is a next-generation protocol built with a ready-to-go Useful Proof of Work system invented by world-leading AI minds.

Autonomous Economic Agents	Open Economic Framework	Smart Ledger
Useful economic activity is performed by Autonomous Economic Agents (AEAs). These are digital entities that can transact independently of human intervention and can represent themselves, devices, services or individuals. Agents can work alone or together to construct solutions to today's complex problems.	The Open Economic Framework (OEF) is a digital world that acts as the ultimate value exchange dating agency: each agent sees a space optimised in real-time just for them, where important things are clear and visible and less important things are simply removed. The OEF provides the senses for agents: their sight, touch and hearing.	A new generation of learning ledger that provides a collective super-intelligence to support agents' individual intelligences. It provides market intelligence, previously locked up in centralised silos, to everyone so that any agent that wants something is assured of the shortest possible route to find another that has it.

"Transport and mobility are a remarkable example of a complex system with too many moving parts. Managing such a system in a centralised fashion is both figuratively and literally a journey to nowhere. Fetch converges digital autonomy, decentralised ledgers and AI bring those moving parts to life and allow them to make their own decisions, free of human and centralised control."

Toby Simpson, CTO, Fetch AI

Projects to watch

- Velocia is an open network for mobility using loyalty & user acquisition rewards to incentivize specific mobility choices and data sharing.
- Introduces user-owned Smart Mobility Channels along with Smart Mobility Bounties i.e. automated rewards that can be set up by any participants.
- Automates and boosts collaboration between mobility services, and ultimately delivers Integrated Mobility.

- Enabling the Vehicle Economy Using a Blockchain-Based Value Transaction Layer Protocol for Vehicular Ad-Hoc Networks.
- Enables vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-human (V2H), or in general vehicle-to-everything (V2X) communication and interaction.
- Streamlines and automates value exchange between vehicles, users and infrastructure nodes.

- The underlying network in Blockcloud which combines Service-centric Networking (SCN) and Blockchain, has excellent connectivity and mobility, and can provide decentralized trust, fair economic incentive, and all that can be very well adapted to the internet of vehicles.
- Blockcloud can help solve the problem of frequent offline and unstable nodes in edge computing. This ensures all nodes are given suitable service resources and can gain corresponding income streams.

Conclusions

Conclusions

1. **Removal of silos.** DLTs by their very nature facilitate value interoperability which points to a shared and integrated mobility ecosystem characterized by widespread collaboration where resources, value, and data can be exchanged seamlessly & invisibly.
2. **Data marketplaces.** Through a combination of IoT, AI, and tokenization we will see: end-users, OEMs, auto manufacturers and fleet operators incentivized to open up, share and exchange data as digitized assets through data marketplaces.
3. **Self-sovereign sign-in.** Users and vehicles individually and in concert, own and manage self-sovereign identity to unlock a global user account ("single sign in") that is not centrally controlled by any one corporation allowing them to access a distributed ecosystem of mobility assets and services.
4. **New economic value unlocked.** Smart contracts, distributed computation facilitate: automation, security and unlocks new business models. Vehicles increasingly become computers on wheels, powered by software, with their own autonomous economic agency and new in-transit user interfaces and experiences.

Mobility is being shaped by the convergence of DLTs, crypto-assets, decentralized networks, data marketplaces and AI.

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