

The Planar Network

Blockchain Transport

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Abstract

Privatised public transport networks are common across Europe and Northern America but they are often created in an isolated manner so that neighbouring transport operators work independently from each other. Typically, each operator is given control over a specific mode of transport and a specific geographical region. They have their own ticket formats with their own rules and restrictions meaning that passengers travelling across operators have to navigate multiple retailers and purchase separate tickets.

This paper outlines a platform for public transport tickets that integrates operators from different geographical regions and different modes of transport onto a single network. Making use of blockchain technology and smart contracts, the platform provides a single source of truth for all ticket created, offers real time financial settlement between retailers and operators, and allows customers to purchase tickets for travel across multiple operators in a single transaction.

We examine the relationship between transport authorities, transport operators, ticket retailers and ticket distributors and how trust between each party is earned in order to evaluate the impact of a “trustless network”.

Privatised Transport Networks

Privatisation of transport networks is common across many parts of the world but the implementation of the privatisation varies. The UK rail network was privatised in 1993 under the condition that it continued to offer passengers a single ticket that is valid across multiple operators. Other countries, like Spain, Germany and Poland do not offer interoperable tickets and a ticket must be purchased for travel on each operator's network.

Both methods of privatisation result in problems for operators and passengers that can be solved using a blockchain.

Interoperable Networks

In order to offer interoperable tickets there must be a common ticket format that all operators adopt. This means there must be a governing body to enforce the standards, usually by an expensive and bureaucratic accreditation process.

Tickets sold that use multiple operators must go through a settlement process to divide the money and allocate it to each operator appropriately. This adds a significant amount of time to an already slow financial process and is a potential source of discrepancies. Typically there is no single source of truth for tickets sold, tickets created, tickets used and money settled. Ticket retailers need to integrate with an issuer which then needs to report tickets issued to the settlement system. Ticket use is not typically factored into the settlement process and it is therefore inherently inaccurate.

Retailers must have an in depth knowledge of all the industry system and standards. There is a high level of trust required to retail in this environment and it can be expensive to earn.

Isolated Networks

Where there are no interoperable tickets, travel across multiple operators must be arranged separately and results in many transactions that must be managed independently by the passenger.

It is often not possible to offer the passenger a ticket permitting travel across a choice of operators, forcing the passenger to make decisions at the time of purchase rather than the time of travel.

Each operator will typically use their own format of ticket, maintaining its own notion of what the types of ticket are and what restrictions apply. This forces the passenger to become an expert of multiple systems to gain the best value from each.

Blockchain Technology

Satoshi Nakamoto's seminal paper on Bitcoin introduced the concept of a blockchains as an immutable, distributed sequence of transactions that move digital assets between two parties¹. The blockchain itself is shared by all members of the network and each transaction is verified by members of the network using a proof of work system.

The proof of work system presented in the paper describes a means of solving the double spend problem² in a distributed system, allowing network participants to perform transactions without the need for a trusted central authority.

Smart Contracts

Blockchains have continued to evolve and more recent versions moved beyond financial transactions by introducing programmable smart contracts. Any business can transaction can be modelled using a smart contract and executed as a transaction in a peer-to-peer network.

Adoption of blockchain technology is has been rapidly accelerating in recent years with large companies like Microsoft³, Intel⁴ and IBM⁵ all investing heavily. The peer-to-peer nature of the technology makes it a natural fit for scenarios where collaboration between a number of parties is required. Sweden are doing a trial application for their land registry⁶, a Russian airline is using it to settle tickets⁷ and there are many uses for chain of custody⁸.

Using a blockchain to store ticket transactions we can tie together the retailing, creation, use and settlement of tickets from multiple operators in a single place to ensures a faster, more accurate financial settlement process.

¹ "Bitcoin: A Peer-to-Peer Electronic Cash System - Bitcoin.org." <https://bitcoin.org/bitcoin.pdf>. Accessed 14 Aug. 2017.

² "Double-spending - Wikipedia." <https://en.wikipedia.org/wiki/Double-spending>. Accessed 14 Aug. 2017.

³ "Blockchain as a Service (BaaS) | Microsoft Azure." <https://azure.microsoft.com/en-gb/solutions/blockchain/>. Accessed 6 Oct. 2017.

⁴ "Silicon Blockchain: Intel's Distributed Ledger Strategy Is All About" 23 Aug. 2017, <https://www.coindesk.com/silicon-blockchain-intels-distributed-ledger-strategy-hardware/>. Accessed 6 Oct. 2017.

⁵ "IBM Blockchain." <https://www.ibm.com/blockchain/>. Accessed 6 Oct. 2017.

⁶ "Sweden is turning a blockchain-powered land registry into a reality" 3 Apr. 2017, <https://qz.com/947064/sweden-is-turning-a-blockchain-powered-land-registry-into-a-reality/>. Accessed 6 Oct. 2017.

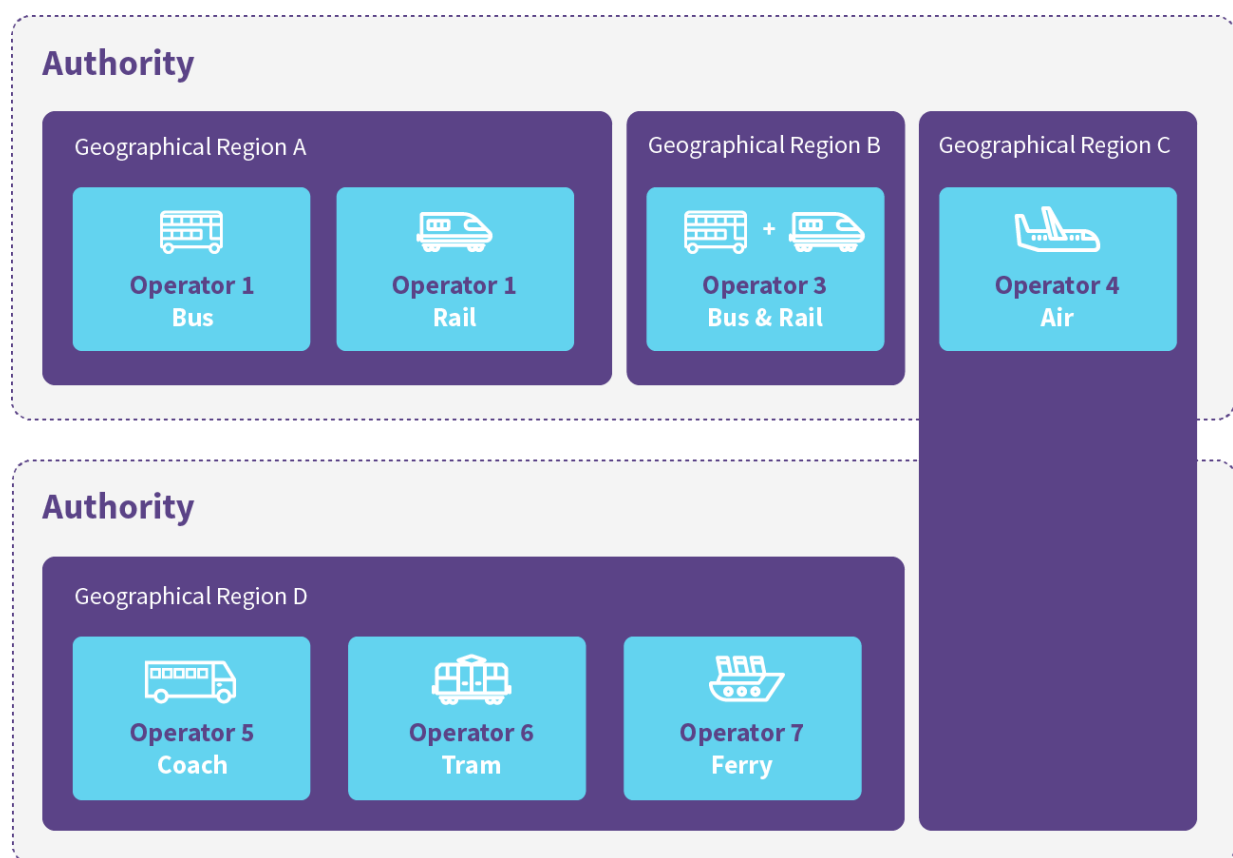
⁷ "An Airline Just Started Using an Ethereum Blockchain to Issue Tickets." 26 Jul. 2017, <https://futurism.com/an-airline-just-started-using-ethereum-blockchain-to-issue-tickets/>. Accessed 6 Oct. 2017.

⁸ "Can Blockchain become the solution for anti-counterfeiting and chain" 10 Mar. 2017, <https://scm.ncsu.edu/blog/2017/03/10/can-blockchain-become-the-solution-for-anti-counterfeiting-and-chain-of-custody/>. Accessed 6 Oct. 2017.

The Planar Network

The Planar Network is a platform that provides retailers, operators and transport authorities the necessary infrastructure to create and retail interoperable tickets regardless of mode of transport or geography.

By storing the network topology on the blockchain we can establish a number of trusted transport operators (Operators) that are permitted to offer contracts for transport between a subsection of the overall transportation network. Each Operator can be assigned its geographical region by a transport authority (Authority). There may be many Authorities on the platform covering a wide range of modes and geographical regions.

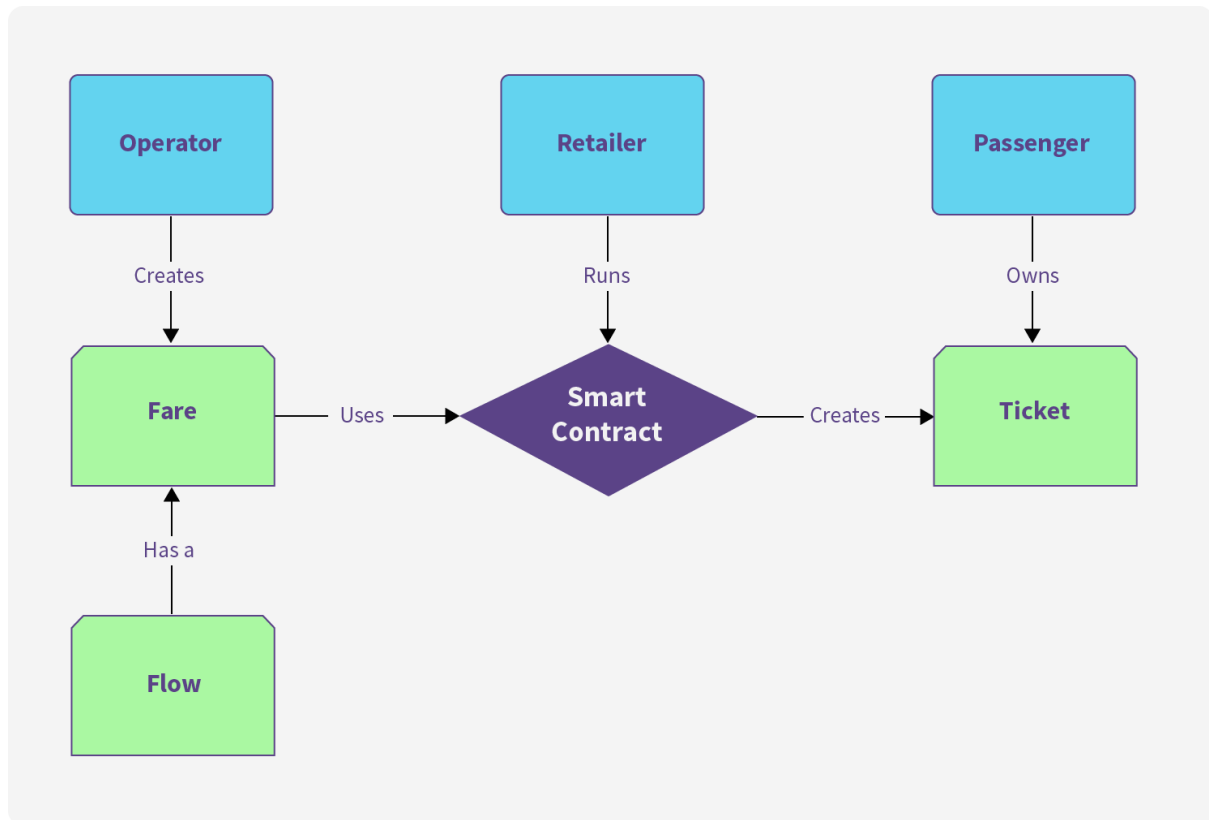


Authorities can set up Operators in in different regions with different modes of transport

Each Authority assigns Operators their geographical region by giving them permission to create Fares on a set of Flows. Flows are predefined subsections of the network consisting of an origin, destination and route code to determine the intermediate stops.

A Fare is an asset created by Operators in order for Retailers to offer travel tickets to the public. Each fare has a minimum set of properties - a Flow, validity duration and price. The ticket creation contract takes a Fare and money as an input and produces a Ticket on the blockchain when it is executed.

A Ticket has the same properties as the Fare used to create it but it also has an owner (the Passenger) and concrete validity dates (as opposed to a proposed validity duration).



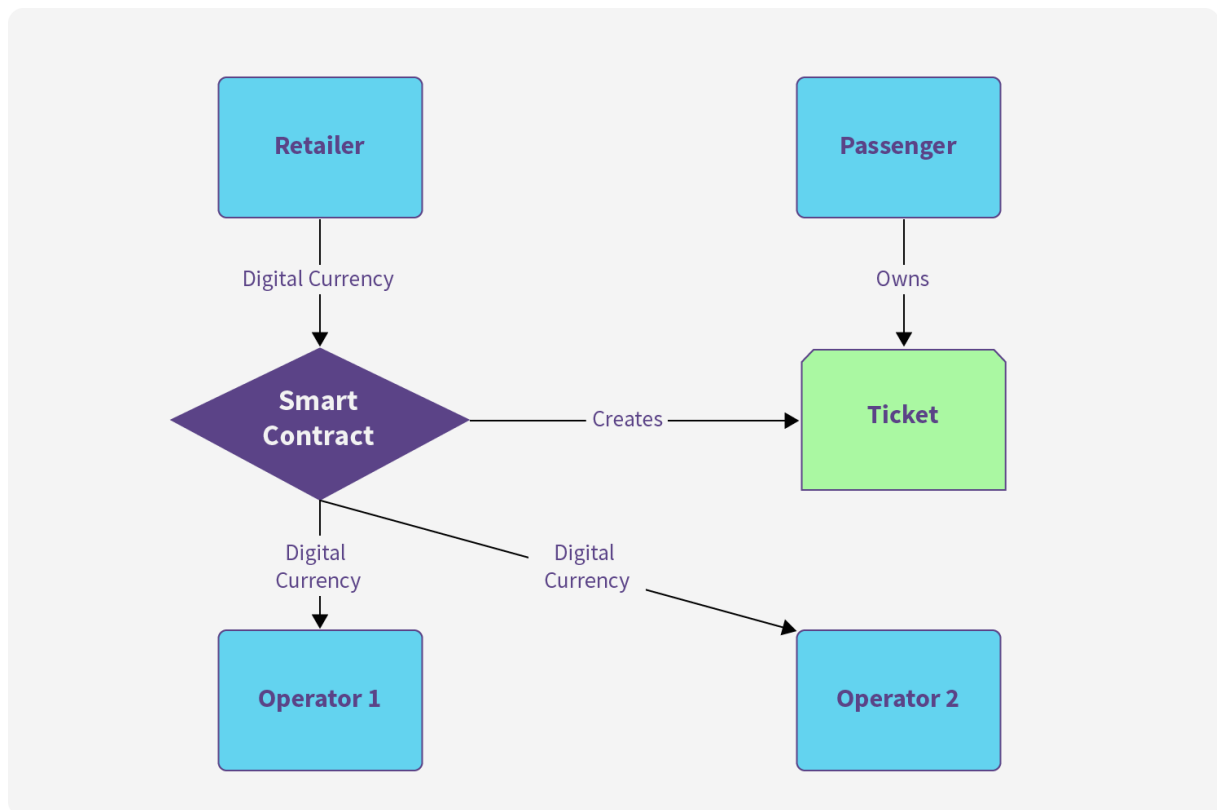
The Ticket Creation smart contract

In a blockchain ledger a wallet is a public/private key pair. Ownership of assets is assigned to a wallet using its private key to sign messages that can be verified using its public key. This means that only the owner of a wallet can sign off transactions involving that wallet.

Interoperable Tickets

Where the passenger requires transport across several Operators a Retailer can negotiate contracts with each Operator and present them all as a single contract to the passenger. Given there are multiple ways to traverse most transport networks the Passenger may be presented with multiple options at varying cost.

This gives us a means to integrate Fares from Operators across any mode of transport or geographical region.

*Ticket Creation contract with multiple operators*

Travel Across Any Operator

Some tickets allow the Passenger a choice of multiple operators. In this situation the money from the ticket sale could be put in escrow until the Passenger travels and their actual choice of Operator is recorded. It is not always possible to report accurate Passenger movements, in the event no information is received the money in escrow could be apportioned using a fallback algorithm to split the money between likely Operators.

Financial Settlement

Although many blockchains come with an in-built currency it's not necessary to use that as the basis for transactions. In order to eliminate the risk of fluctuating exchange rates the Planar Network models fiat currencies, allowing Operators to work in their native currency.

Using a digital representation of fiat currency allows the allocation of money to be tied to the creation of Tickets. As the ticket creation contract is executed it generates a transaction on the blockchain in which digital currency from the Retailer is exchanged with the Operator(s) for the right to travel on their services. The transaction generates a Ticket which represents the passenger's right to travel on the Operator's services.

This moves the system from one that tries to reconcile money taken from ticket sales with recorded ticket creation after the event has occurred to a real-time system where money is settled as tickets are created.

Operator Trust

Retailing an Operator's tickets requires a high level of trust because retailing tickets is intrinsically linked to creating tickets. Creating a ticket creates a liability for the operator to transport a passenger so Operators are very careful with who they trust to retail tickets.

Typically, this trust is earned through an accreditation process and a financial bond. The accreditation process is there to ensure that tickets are created correctly and ticket sales are reported accurately. The bond is there to ensure the Retailer can give the Operator the money they're owed for any ticket sales.

The accreditation process and financial bond both add a significant cost to any Retailer looking to enter the market.

Using a blockchain and smart contracts we can remove the need for this trust, allowing new Retailers to enter the market at a lower cost.

Retailers can only create tickets by executing the smart contract provided by the network with fares created by the Operators. This smart contract cannot be incorrectly executed so the Retailer is not at risk of incorrectly creating tickets or misrepresenting sales.

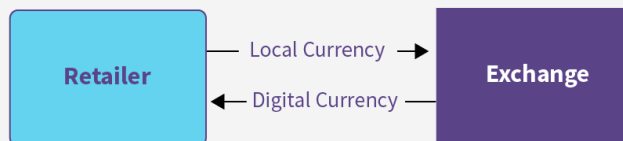
Before a Retailer can sell a Ticket to a Passenger they must possess the digital currency required to create the Ticket. Using inbuilt Planar Network Exchange Retailers can purchase the digital currency ahead of time. Instead of a predefined bond set by the Authority the Retailer can make a judgement on how much digital currency to purchase to support their expected Ticket sales.

In effect this system acts like a bond but without the costs associated with a third party financial institute.

As the Passenger acts through the Retailer their retail experience is unchanged. They would only be aware of the traditional card transaction with the Retailer and would not need to own any digital currency.

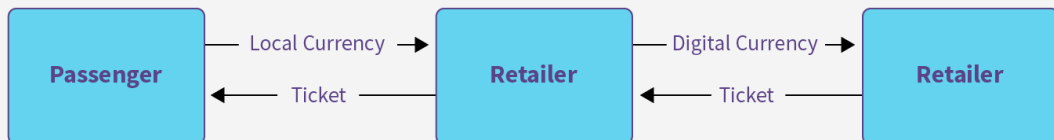
1

Retailer exchanges local currency with digital currency to support ticket sales



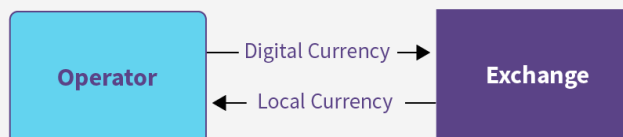
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The passenger exchanges local currency with the Retailer and the Retailer uses the equivalent amount of digital currency to create the Ticket



3

Operator exchanges digital currency into local currency with the Exchange



Digital currency exchange

Refunds

Refund transactions are the reverse of a Ticket sale. The Operator gives digital currency back to the Retailer in exchange for cancellation of the Passenger's Ticket. The Retailer is then responsible for exchanging the digital currency into local currency for the Passenger.

Typically each transport network has its own rules to define when and how much of a Ticket may be refunded. These rules can be established by the Authority and built into the refund contract that is executed on the network.

The refund itself might be a full or partial refund of the Ticket or might even be part of an exchange transaction that also contains a Ticket sale.

Passenger Travel

After the Ticket sale process has occurred the Passenger's wallet is the owner of a Ticket on the blockchain. This Ticket is not a physical coupon but a digital asset that gives them the right to travel on one or more Operators' services.

Passenger Wallets

The Passenger does not have to be aware that they have a digital wallet on the blockchain network and as there is no practical upper limit to the number of wallets available, a new wallet can be created for one-off transactions.

Where the Passenger has an account with a Retailer their wallet could be reused between transactions and would therefore hold multiple Tickets, as well as a history of expired Tickets.

The Retailer would be responsible for creating and providing access to their Passengers' wallet. As the wallet is just a private key it can be exported in a portable format to be used with other Retailers or supporting applications (e.g. smartphone wallet applications).

Ticket Distribution

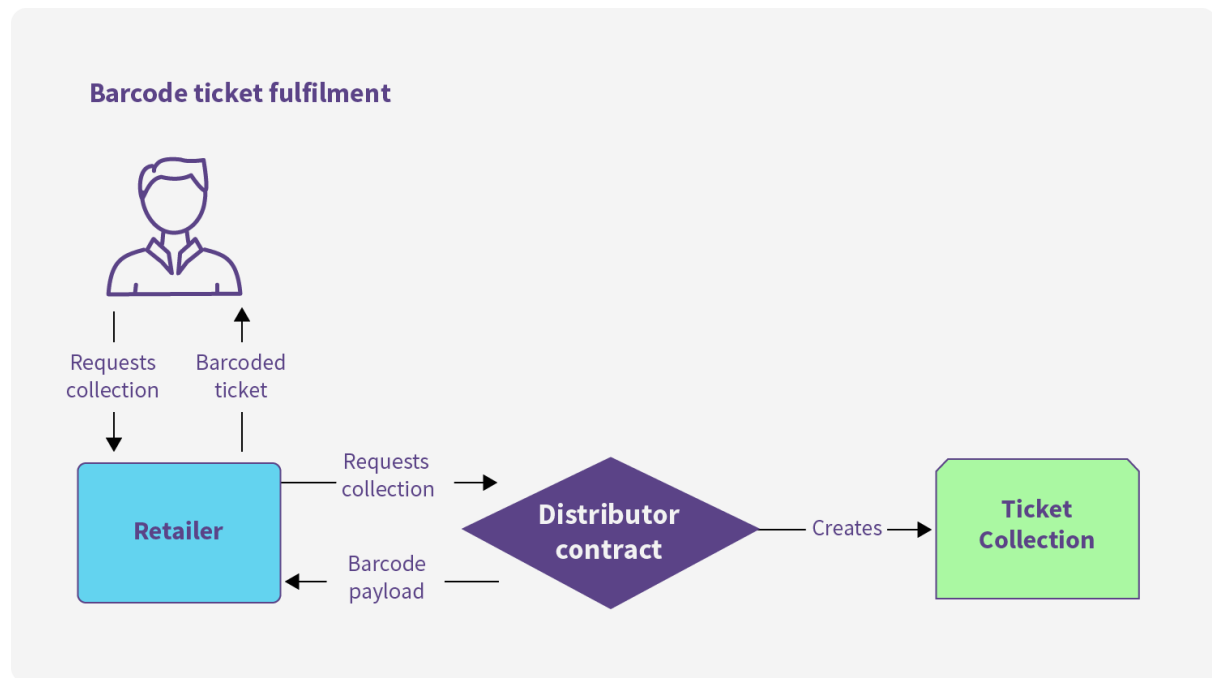
All transport networks have a well entrenched infrastructure of gates, ticket scanning and validation mechanisms. It's not feasible to immediately upgrade the existing infrastructure to directly query the blockchain for ticket validation. Instead, an integration layer must be provided to create ticket coupons in each network's existing formats to ensure that existing infrastructure will continue to work.

Some networks may offer the passenger multiple ticket formats depending on the geographical region and operators involved. These can range from physical coupons to digital barcodes or smartcards.

Physical coupons are typically self-verifying in that their validity can be checked without a connection to a central database. In order to prevent fraud, physical coupons rely on there only ever being one version of that ticket in existence at any time.

Digital tickets are validated either using a connection to a central database that is checked in real-time or a hotlisting mechanism where tickets that have already been scanned are stored locally.

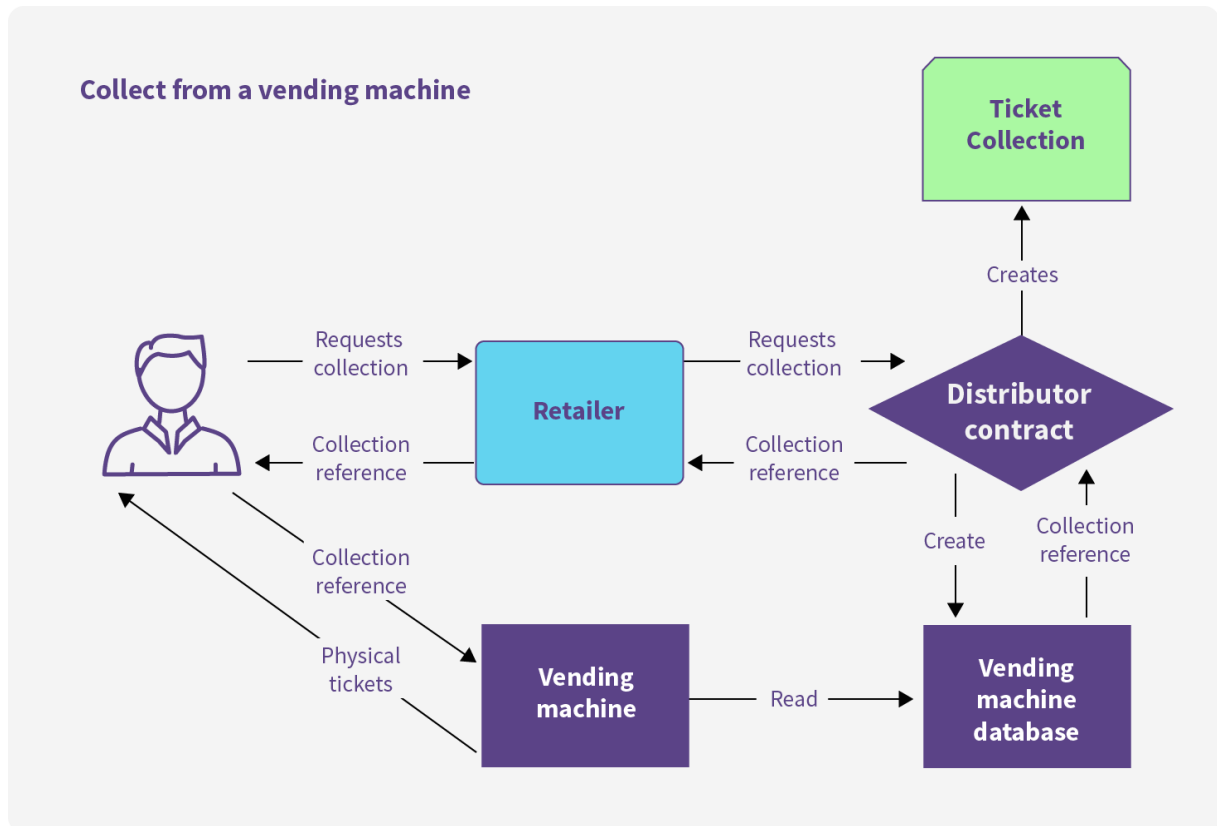
By adding a number of Ticket Distributors to the network we can implement a collection process where the Distributors act as an intermediary to create ticket coupons in the networks native formats.

*Example of barcode fulfilment*

If one of these formats relies on their only being one copy of the coupon the Ticket can be marked as collected so that Distributors could not create additional coupons.

This would allow the Passenger to defer the decision about which ticket format they would like to use until the time of travel, as opposed to being forced to choose before purchase.

The Ticket Distributors could be physical printing machines at the station connected to the blockchain network or they could be a web service for existing systems to integrate with. When the Passenger decides on their preferred coupon format they would inform the Retailer (or third party application) who would create a collection contract with a Ticket Distributor. The Distributor could offer to deliver the coupons by post, place them in a vending machine for collection or return a barcode.



Example of collection from a ticket vending machine

Where the passenger is travelling across multiple operators with different formats the Ticket can be part collected by multiple Distributors. Each Distributor providing travel coupons (native tickets) for the parts of the journey it understands.

A network fully integrated with the blockchain would not require physical coupons or tokens and by extension would not require Distributors. It would operate on a proof of identity model where each validation point would run a node on the network and access the blockchain to check whether the identity presented owns a valid Ticket for travel.

Tracking Ticket Use

All tickets have a unique identifier that can be reported back to the network upon use. Using this identifier we can approximate (exact use is often impossible) what Tickets have been used on what services. This ensures tickets are used the correct number of times and also provides accurate settlement information where multiple use of multiple Operators is possible.

Benefits

Implementing a self-verifying, decentralised ticket database aligns the underlying technology with the design of the transport network. The decentralised nature of a blockchain ledger draws a parallel with the operation of privatised transport networks where multiple participants work on the same network in a collaborative way.

Rather than relying on a heavy central authority to enforce policies, operators and retailers can take a more autonomous role in the operation of the network but still be governed by the rules established by the authority.

Building trust into the network rather than bestowing trust through an expensive bureaucratic process and financial bond reduces the margin for error and increases the efficiency of the network, encouraging more retailers to the market.

By offering a platform for integrated transport tickets, rather than just another retailing website, the Planar Network provides the backbone retailers, operators and authorities need to build a seamlessly connected transport network.

Retailers

In a blockchain based network the retailer's responsibility is to manage the retail process and provide access to ticket wallets on behalf of the passenger. In effect they would operate as an exchange between local currency and digital currency for the passenger in order to create tickets for the passenger.

As tickets are validated when they are added to the network there would be no need to go through an expensive accreditation process to earn the trust to create tickets. The retailer would not be liable for any incorrect tickets created as it is the responsibility of the operators to ensure the fares they offer are correct and the responsibility of the ticket distributors to ensure the appropriate coupons are created.

Delegating coupon creation to the distributors relieves the retailer of the need to be heavily involved with multiple ticket standards, lowering the barrier for entry to market for new retailers and lowering the cost operation for existing retailers.

Retailers can offer a wider range of products across more geographical regions and modes of transport giving them access to markets that they wouldn't otherwise be aware of.

Authorities

It is often the case that network authorities do not want to take an active role in the operation of a transport network but are required to do so in order to enforce the rules of the network.

Using a decentralised network allows the network participants to operate autonomously freeing up the authority to focus on defining the correct rules rather than enforcing them.

The central authority would maintain a role in running the network infrastructure but not be solely responsible. The blockchain ledger and application would be run by all participants of the network spreading the operational cost between them. Overall there are fewer moving parts and integration points between systems as the financial settlement is built into the network as opposed to being a disparate systems.

Operators

Binding the creation of tickets to a financial transaction between the retailer and the operator gives the operator instant access to revenue from ticket sales. The operator may choose to convert the digital currency of the network to a local currency via the authority or they could choose to use the digital currency to support further ticket sales in a dual role of operator and retailer. Either way, real-time settlement improves the operator's cash flow and operational agility.

Having a single source of information for ticket sales, ticket creation and ticket use removes a whole class of errors currently associated with retailers operating on isolated networks. There could be no discrepancies between the number or type of tickets sold and those created by the retailer.

Operators would not suffer the penalty for retailers being slow to report sales or reporting them inaccurately.

Passengers

Using the Planar Network platform passengers can purchase tickets for travel across multiple transport operators in a single transaction from a single retailer.

There is nothing to prevent a single integrated ticket being created for a trip involving air, bus, ferry and rail travel. If the authorities in each of those sectors can reach an agreement for an integrated fare it could be sold by any retailer connected to the network. Even without a cross-authority agreement in place multiple tickets could be packaged into a single transaction giving passengers access to a global transport network.

Having a portable ticket wallet that can store tickets for travel across multiple operators greatly simplifies the practicalities of traveling across a multi-operator network. All tickets can be accessed via a single app or collected using the networks existing infrastructure.

The passenger doesn't have to choose what format the tickets coupons are in before they purchase, the ticket can live in their digital wallet until they collect them as a native format.

By providing a globally integrated market place for transport tickets we make easier for other retailers to enter the market, increasing competition and improving the quality of service offered to the passenger.