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 isolation 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. The operators 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 tickets created
- real time financial settlement between retailers and operators
- a method for customers to purchase tickets 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 earnt 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 customers must purchase a separate ticket for travel on each operator's network.

Both methods of privatisation result in problems for operators and passengers that can be addressed 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 create and enforce the standards, usually through an expensive and bureaucratic accreditation process which adds a significant overhead to the cost of the network.

When a ticket involving multiple operators is sold, a settlement process is required to divide up the money and allocate funds to the appropriate operators. This adds a large amount of time to a financial process that is already slow 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 reports tickets issued to the settlement system. The actual ticket use is not factored into the settlement process making it inherently inaccurate when offering tickets that give the passenger a choice of operator..

In order to sell tickets, retailers must have and in-depth knowledge of all the industry systems and standards as they need to understand how to issue each ticket format. In addition, a high level of trust is required to retail in this environment and it can be expensive to earn. Business will often have to spend large amounts of time and money in order to become an approved retailer.

Isolated Networks

Where there are no interoperable tickets, travel across multiple operators must be arranged separately by purchasing tickets from multiple vendors. As a result, the purchaser faces the burden of performing many transactions in order to confirm their booking.

Users are often unable to a purchase ticket that permits travel across a choice of operators. This means that the user is required to make decisions about which operators they will use at the time of purchase rather than at the time of travel.

Each operator will often use its own format of ticket, deciding which ticket types are available and the restrictions that 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 parties[1]. The blockchain itself is shared with all members of the network and each transaction is verified by the members using a proof of work system.

The proof of work system presented in the paper describes a means of solving the double spend problem[2] in a distributed system, allowing network participants to perform transactions without the need for a trusted central authority to verify that the sending party has the necessary funds to complete the transaction.

Smart Contracts

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

The adoption of blockchain technology is rapidly accelerating. Large companies like Microsoft[3], Intel[4] and IBM[5] have all been investing heavily in research and development of distributed ledgers.

The peer-to-peer nature of the blockchain 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 registry [6], a Russian airline is using it to settle tickets[7] and there are many uses for chain of custody[8].

By using a blockchain to store ticket transactions, it is possible to tie together the retailing, creation, use and settlement of tickets from multiple operators in a single place to ensure a faster, more accurate financial settlement process.

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[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 with the necessary infrastructure to create and retail interoperable tickets regardless of mode of transport or geography.

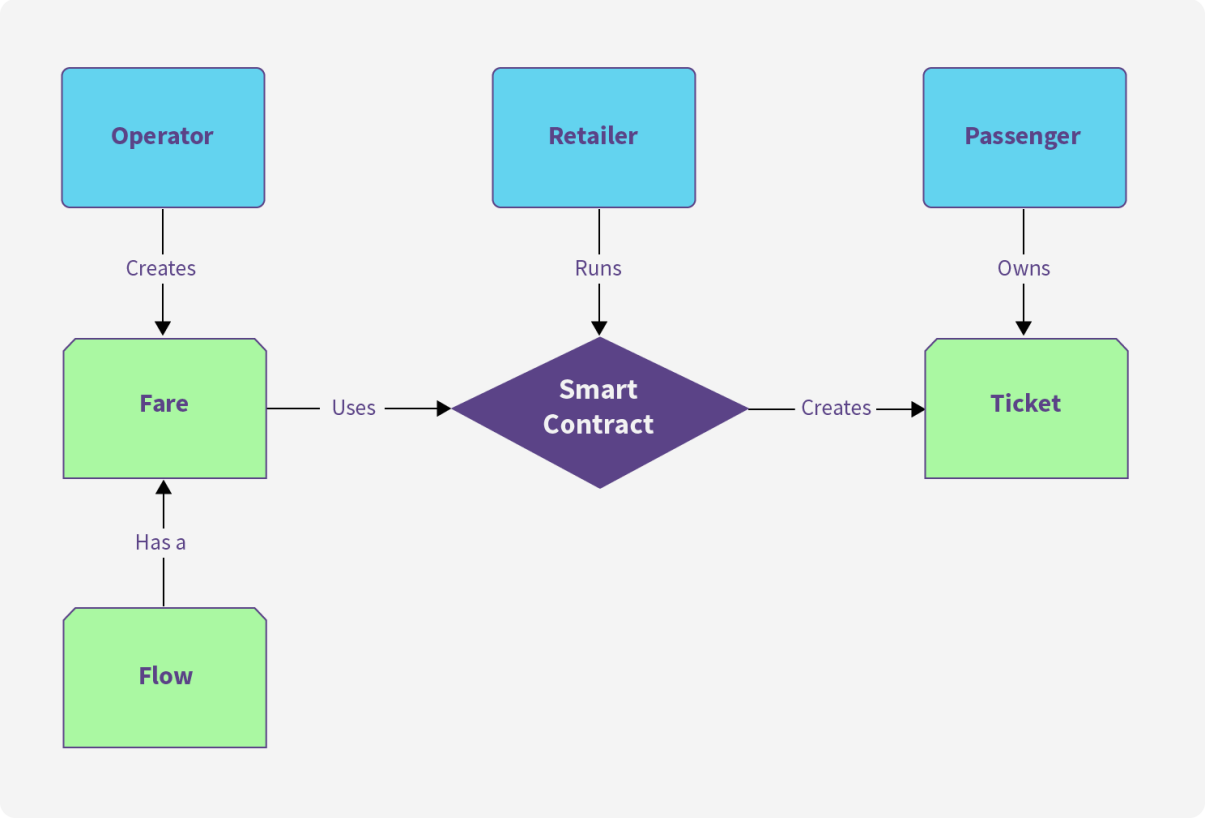
By storing the network topology on the blockchain, we can establish a number of trusted transport operators (**Operators**) that are permitted to offer contracts for transport between specific geographical regions of the overall transportation network.

Operators are set up in specific geographical regions

Each **Operator** is given permission to create to create **Fares** on a set of **Flows** that defines the region in which the operate. **Flows** are predefined subsections of the network consisting of an origin station, destination station and route code that determines 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).



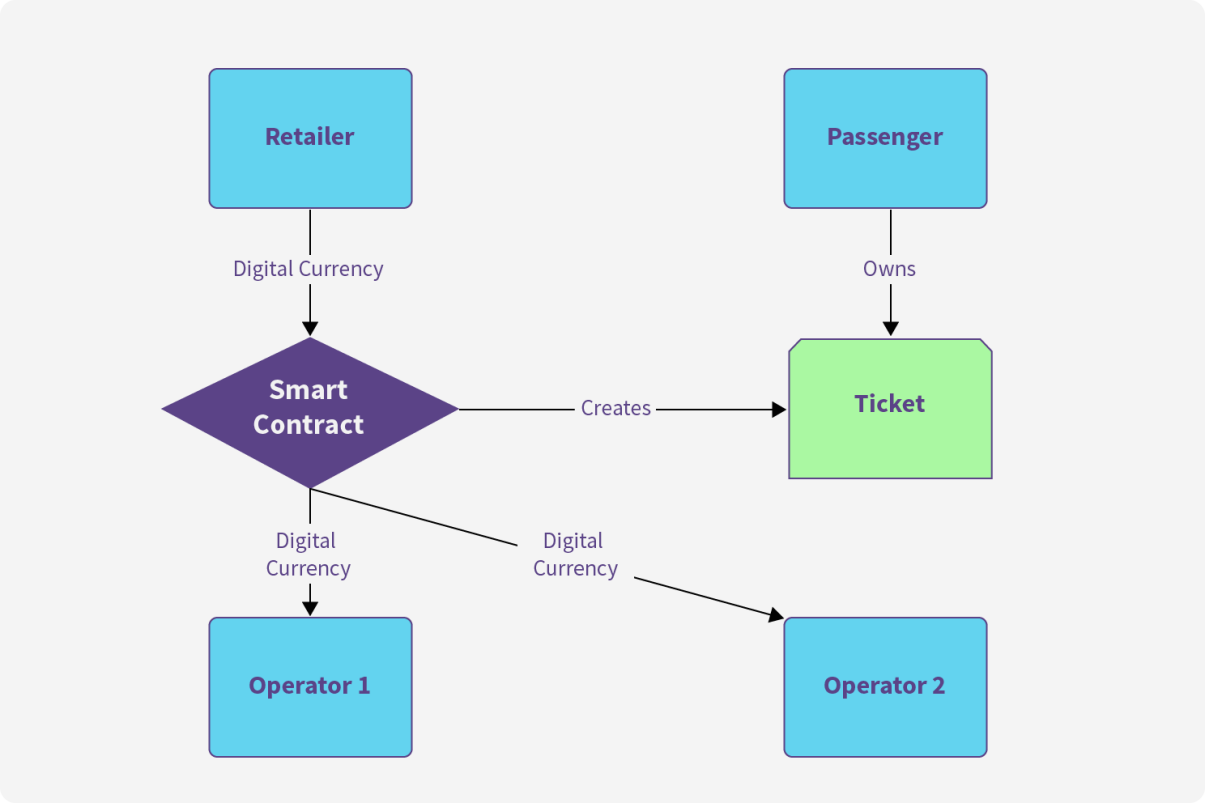
The Ticket Creation smart contract

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 provides a method to integrate **Fares** from **Operators** across any mode of transport or geographical region. That means that a user travelling from Plymouth, England to Monaco could purchase tickets that cover the journey from the nearest bus stop to the train station, the train from Plymouth to London, the tube travel to Heathrow Airport, the flight from London to Nice Côte d'Azur and the train to Monaco. The ticket options they see will vary in cost according to factors such as the time of day and availability of seats.



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. But it is not always possible to report accurate **Passenger** movements. In the event no information is received, the money in escrow would 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

At present, retailing tickets requires a high level of trust between retailers and operators 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 careful about which companies they allow to retail tickets.

In many industries, 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.

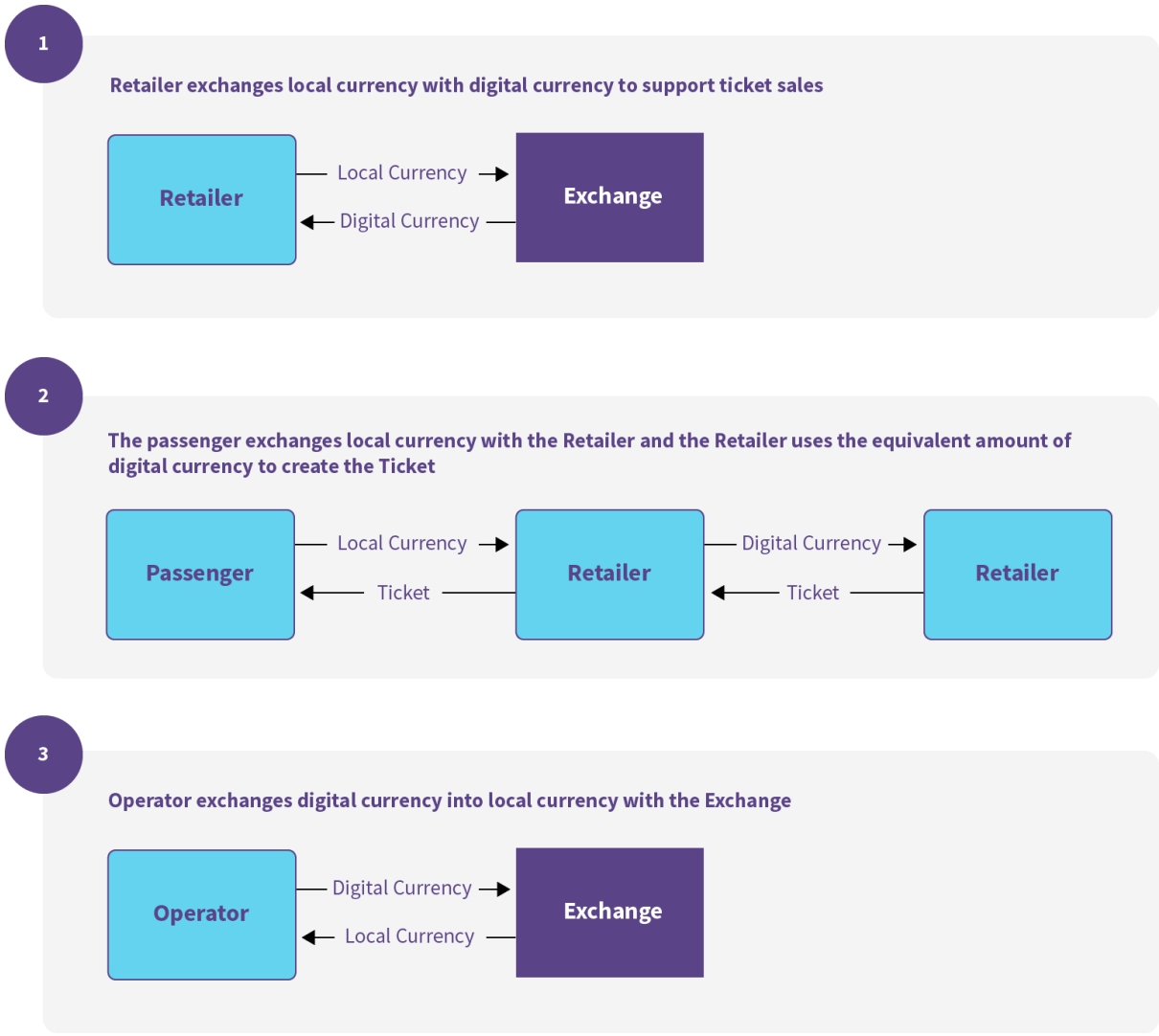
Using a blockchain and smart contracts lowers the requirement of trust as retailers can only create tickets by executing the smart contract that has provided for them, with fares that have been created by the operators. As the contract cannot be incorrectly executed the retailer is not at risk of incorrectly creating tickets or misrepresenting sales.

Before a **Retailer** can sell a **Ticket** to a **Passenger,** they must possess the funds required to create the **Ticket**. Using the in-built Planar Network Exchange, **Retailers** can purchase the digital representation of each fiat currency before they start trading. Instead of a predefined bond, the **Retailer** can make a judgement on how much of each currency is required 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.

The accreditation process and financial bond both add a significant cost to any retailer looking to enter the market. By lowering the amount of trust required for new retailers to sell tickets, they enter the market at a lower cost, giving the consumer more choice.

As the **Passenger** transacts with 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.



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 a **Ticket**. The **Retailer** is then responsible for exchanging the digital currency into local currency for the **Passenger**.

At present 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 **Operator** 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** is the owner of a **Ticket** stored 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. A **Ticket Distributor** can then convert the **Ticket** into a native token that the **Operator** understands, such as a physical ticket or barcoded digital ticket.

Passenger Wallets

Each passengers' tickets are stored inside a digital wallet provided by the network. The passenger does not have to be aware that they have a digital wallet and as there is no 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 is responsible for creating and providing access to their passengers' wallet. As the wallet is modelled on standard public/private key cryptography it can be exported in a portable format. This means it is fully interoperable and can be used with other retailers or supporting applications (e.g. smartphone wallet applications).

Ticket Distribution

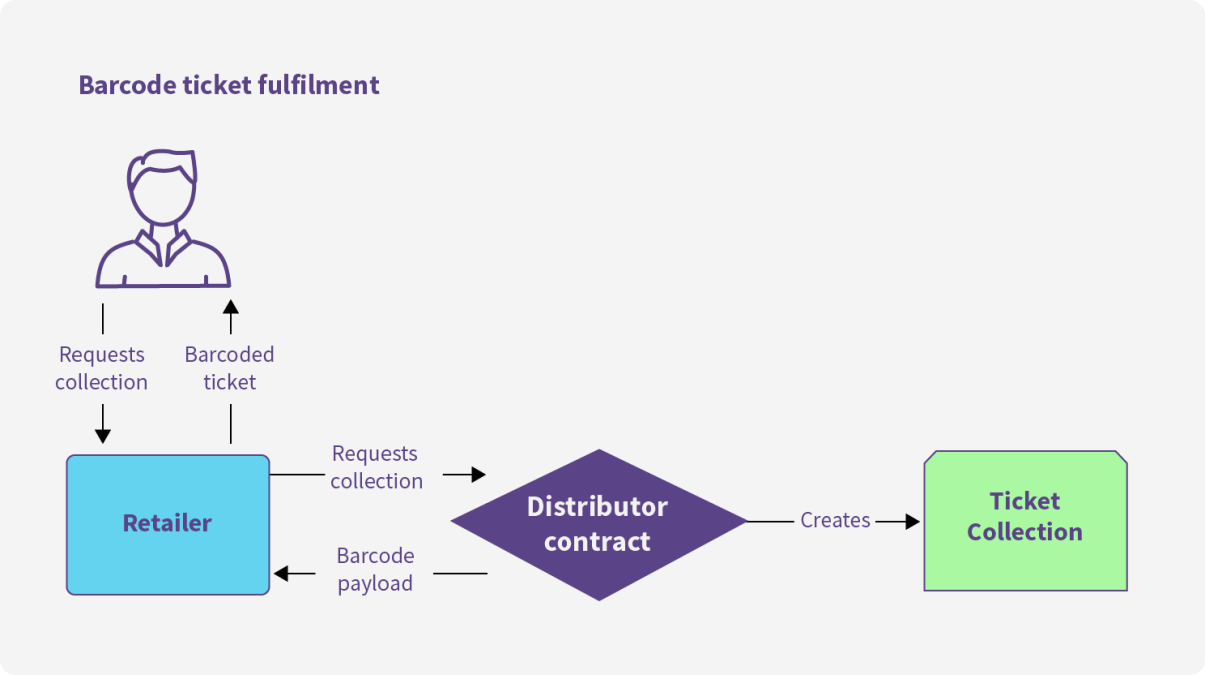
All transport networks have a well entrenched infrastructure of gates, ticket scanning and validation mechanisms. It's not feasible to immediately upgrade the existing infrastructure to directly query the blockchain for ticket validation. Instead, an integration layer must be provided to create ticket 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 and contactless cards.

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

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

By adding a number of **Distributors** to the network, it's possible to implement a collection process where the **Distributors** act as an intermediary to create ticket coupons in the network's native formats.

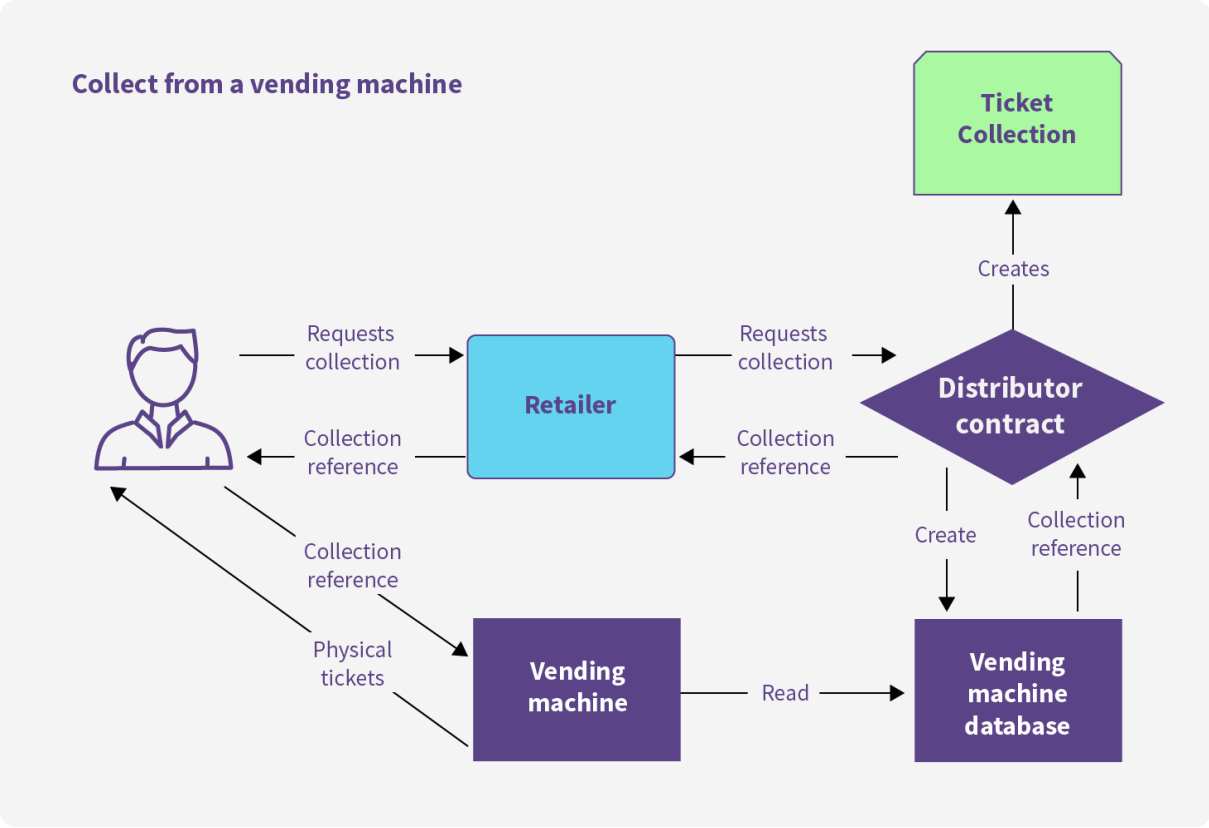


Example of barcode fulfilment

If one of these formats relies on there only being one copy of the coupon, the **Ticket** will be marked as collected so that **Distributors** cannot create additional coupons.

This allows the passenger to defer their decision about which ticket format they use until they travel, rather than choosing an option at the time of purchase.

The ticket distributors can be physical printing machines at the station connected to the blockchain network or a web service for existing systems to integrate with. When the **Passenger** decides on their preferred coupon format they inform the **Retailer** (or third party application) who would execute a collection contract with a **Ticket Distributor**. The **Distributor** can 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 sometimes impossible) which tickets have been used on different 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.