Blockchain for Wholesale Roaming Initiative

Minimal Viable Product Report

October 2021

About the GSMA

The GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. Our vision is to unlock the full power of connectivity so that people, industry, and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

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About the GSMA DLT Group

The GSMA Distributed Ledger Technology Group (DLT) develops and maintains common framework and standards; promotes dialogue, collaboration and thought leadership through its events; and drives DLT education in the telecom industry. Telco blockchain activities include use-cases in areas such as Payments, Identity, Wholesale settlement, Supply Chain, Fraud and Security and Blockchain as a Service. The group is ledger and technology platform agnostic and intends to work with varying technologies suitable for a given use case.
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1. Introduction

1.1 Overview

On the direction of the GSMA board, the Blockchain for Wholesale Roaming (BWR) initiative was created to develop a reference industry implementation and common standardised building blocks for future industry blockchain implementations. The remit of BWR is to understand operator business requirements and evaluate how blockchain technology can meet these and to assess the benefits of using blockchain technology in the context of end-to-end wholesale roaming clearing and settlement business. The first Minimal Viable Product (MVP) focused on creating common modular architectural components and developing an application for discounting settlement process. This document sets out the outcome of the first MVP and the benefits of using blockchain technology. The purpose is to inform future MVPs and commercial wholesale roaming solutions.

1.2 Scope

The following matters are in the scope of this document:

- Providing the current wholesale roaming industry overview including known pain points along with problem and opportunity statement.
- Providing an overview of the blockchain technology and its applicability to roaming business
- Describing the BWR solution, its key features, and articulate future technical challenges.
- Illustrating the value preposition to use blockchain technology for wholesale roaming business including industry business case.
- Identify collaborative work opportunities to improve operator business case through a common solution and shared economy model.
- Articulating the blockchain eco-system evolution roadmap and related wholesale roaming operational roadmap.
- Articulating the conclusion of the BWR initiative work and related recommendations.
- Highlighting potential expandability of DLT implementations for wider telco use cases such as Identity Management, Interworking, etc.

The following matters are out of scope and shall not be considered in this document:

- Describing the technical solution, source code, specifications, APIs etc.
- Writing a business case for an operator willing to explore the blockchain technology for wholesale roaming.

1.3 Definitions

Term	Description
BBFT	Blockchain Byzantine Fault Tolerance consensus algorithm replicated state machine, in which each state-update is by itself a Turing machine with bounded resources.
Blockchain	means a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems on the blockchain. Each block in the

Term	Description
	chain contains a number of transactions, and every time a new transaction occurs on the blockchain, a record of that transaction is added to every participant's ledger.
Chaincode	Chaincode initialises and manages ledger state through transactions submitted by applications in order to handle business logic agreed to by members of the network.
Closed Blockchain	A blockchain network that works in a restrictive environment like a closed network, or that is under the control of a single entity.
Commit	means permission to commit transactions in the ledger
Corda	Corda is a permissioned blockchain platform that powers DLT applications that enable businesses to transact directly and in strict privacy with one another.
Core Web App	means a cross-platform, high-performance, open-source framework for building modern, cloud-enabled, Internet-connected applications.
Cosmos	Cosmos is a platform for streamlining transactions between different blockchains, such as Bitcoin and Ethereum. Dubbed the "Internet of blockchains" by its founders, Cosmos uses a proof of stake blockchain with Byzantine Fault Tolerance.
Distributed	means that information is shared among multiple IT systems which may also be in different locations.
Distributed ledger	means a database that is consensually shared and synchronised across multiple sites, institutions, or geographies, accessible by multiple people.
Distributed Ledger Technology (DLT)	refers to the technological infrastructure and protocols that allows simultaneous access, validation, and record updating in an immutable manner across a network that's spread across multiple entities or locations. Some examples of DLT are, Ethereum, Hyperledger Fabric, and Corda.
Docker	Docker is a set of platforms as a service product that use OS-level virtualisation to deliver software in packages called containers. Containers are isolated from one another and bundle their own software, libraries, and configuration files; they can communicate with each other through well-defined channels.
Ethereum Enterprise Alliance	The Enterprise Ethereum Alliance (EEA) is a member-led industry organisation whose objective is to drive the use of Ethereum blockchain technology as an open-standard to empower enterprises.
Flash-cut scenario	means a scenario where all operators must have a coordinated event at a given interval during which transactions would be suspended pending the last operator's migration to the new ledger. If any operator fails in the upgrade for a strict single channel, all members will have to revert to previous version.
Hash function	means a one-way function that takes arbitrary data as input and creates a fixed size hash string as output. It's not possible to derive the input data from the hash, but you can verify the hash string output if the input data is known.
Hoovers	Hoovers is a database providing insights and actionable information about the U.S. and global companies.

Term	Description
Hyperledger Fabric	Hyperledger Fabric is a modular blockchain framework that acts as a foundation for developing blockchain-based products, solutions, and applications using plug-and-play components that are aimed for use within private enterprises.
IFrame	IFrame or Inline Frame means an HTML document embedded inside another HTML document on a website. The IFrame HTML element is often used to insert content from another source, such as an advertisement, into a Web page
Immutable	in context of blockchain means that once a valid transaction is included into a block, and the network has reached consensus about the new state of blockchain, neither the transaction nor the block can be altered.
Kubernetes	Kubernetes is an open-source container-orchestration system for automating computer application deployment, scaling, and management.
MVP1	Minimum Viable Product Phase 1 (MVP1) First basic functional product of BWR implementation based on Hyperledger protocol in alignment with the agreed BWR architecture considering only one ledger technology.
Off-chain	means a process or transaction computation and execution that's external to the distributed ledger network.
On-chain	means a process or transaction computation and execution that's internal to the distributed ledger network
Open Blockchain	A ledger of digital events shared among participants with a stake in the system
Open Source	Open Source is a software whose source code is freely available for anyone interested. Typically, this is done through a software licence in which the copyright holder grants users the rights to use, study, change, and distribute the software and its source code to anyone and for any purpose.
Orderer	The Orderer is responsible for packaging transactions into blocks and distribute them to anchor peers across the network.
Permissioned	means only selected parties can make changes to the distributed ledger
Permissionless	means anyone can in theory, participate in the consensus process (in practice, however, often limited by resource requirements such as owning suitable hardware or cryptocurrency).
Pods	A pod is the smallest execution unit in Kubernetes. A pod encapsulates one or more applications. Pods are ephemeral by nature, if a pod (or the node it executes on) fails, Kubernetes can automatically create a new replica of that pod to continue operations.
Polkadot	Polkadot is a sharded heterogeneous multi-chain architecture which enables external networks as well as customised layer one "parachains" to communicate, creating an interconnected internet of blockchains.
Quorum	Quorum (derived from Ethereum) is an Open Source blockchain protocol specially designed for use in a private blockchain network, where there is only a single member owning all the nodes, or a consortium blockchain network, where multiple members each own a portion of the network.
Read	means permission to view or read information in the ledger.

Term	Description
SAMENA Telecommunications Council	SAMENA Telecommunications Council is a tri-regional, non-profit telecommunications association that embodies a community of South Asian, Middle Eastern, and North African telecoms operators, manufacturers, regulatory authorities, and academia.
Smart Contracts	means a shared execution logic on a dedicated shared state that automates execution of pre-agreed conditions such as contractual terms without requiring physical intermediaries or third parties to do so.
Write	means permission to write into or update the ledger

1.4 Abbreviations

Term	Description
5G SA	5G Standalone
ACMA	The Australian Communications and Media Authority
API	Application Programming Interface
BaaS	Blockchain as a Service
BCE	Billing and Charging Evolution
BFT	Byzantine Fault Tolerance
BSR	Billing Statement Report
BSS	Business Support System
CAMEL	Customised Applications for Mobile networks Enhanced Logic
CDR	Call Detail Record
DCH	Data Clearing House
DLT	Distributed Ledger Technology
EPL	Ethernet Private Line
eSDR	Electronic Special Drawing Rights
FCH	Financial Clearing House
FTE	Full-time Employees
GPRS	General Packet Radio Service
GUI	Graphical User Interface
HLF	Hyperledger Fabric
HPMN	Home Public Mobile Network
HTML	Hypertext Markup Language
IMR	IT and Telecom Market Research
IoT	Internet of Things
IOT	Inter Operator Tariff
LTE	Long Term Evolution

LTE-M	LTE for Machines
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
MVP	Minimal Viable Product
MVP1	Minimum Viable Product (first version)
NB-IoT	Narrow Band - Internet of Things
NRTRDE	Near Real Time Roaming Data Exchange
OSS	Operating Support System
PoC	Proof of Concept
RAEX	Roaming Agreement Exchange
RTDR	Roaming Traffic Data Report
SAMENA	South Asian, Middle Eastern, and North African
SDR	Special Drawing Rights
SFTP	Secure File Transfer Protocol
TADIG	Transferred Account Data Interchange Group
TAP	Transferred Account Procedure
TRAI	Telecom Regulatory Authority of India
ViLTE	Video over LTE
VoLTE	Voice over LTE
VPMN	Visited Public Mobile Network

1.5 References

Ref	Doc Number	Title
[1]	GSMA PRD IG.03	Blockchain - Operator Opportunities
[2]	GSMA PRD IG.09	Distributed Ledger Technologies (DLT) capabilities mapping with operator use cases
[3]	GSMA DLT Shared Industry Vision	HTTPS://INFOCENTRE2.GSMA.COM/GP/WG/WWG/DLT/LISTS/NEWS/DISPFORM.ASPX?ID=1
[4]	Telco DLT	Research & Market Telco DLT
[5]	Global DLT	Research & Market Global DLT
[6]	Identity	Allied Market Research Identity
[7]	Supply Chain	Markets & Markets Supply Chain
[8]	Blockchain as a Service	Markets and Markets BaaS
[9]	Fraud Control Association	Communications Fraud Control Association

Ref	Doc Number	Title
[10]	Key Concepts Notaries	https://docs.corda.net/key-concepts-notaries.html

2. Blockchain Overview

2.1 What is blockchain

Blockchain is a type of distributed ledger technology that provides a way to record and share information and value between members of a community. Within this community, each member receives a copy of the ledger, and members must validate any updates and arrive at a consensus before these are recorded in the ledger. The information could represent contracts, identities, transactions, and any assets that can be represented digitally. Blockchain entries are typically permanent, transparent, and searchable, which makes it possible for community members to view transaction historical data with an expectation that the entries are valid and have not been modified. The distributed ledger takes the form of a series of linked blocks of data, hence the name blockchain.

Blockchain's underlying protocol manages how new entries are initiated, validated, recorded, and shared. Blockchain enforces policies and procedures on handling the information. Blockchain allows data (or transactions) to be securely stored and verified without any centralised authority. Instead, the data is validated by the network. Although it was originally designed for virtual currency transactions, it provides a mechanism to apply decentralised consensus to a variety of applications. Any service which requires a method to systematically record an event (such as ownership) in shared ledger could potentially benefit from blockchain.

Blockchain is considered a disruptive technology because it has the potential to transform business processes across all industries: it removes the need for "middlemen" and manual processes because it can ensure the validity of stored data (such as transactions). When created, this data is recognised as valid by all parties, and cannot be modified afterwards without making the change visible to all parties. Bitcoin is an example of first generation blockchain. At the time of this writing, the distinction is made between three functional generations that have emerged since 2008 (Refer PRD IG.03 [1] and PRD IG.09[2] for more details):

1. Money – cryptocurrency.
2. Assets – registered ownership.
3. Contracts – autonomous decisions.

Additionally, blockchain types differ from various permission models (refer Table1):

		Read	Write	Commit	Example
Open	***Public permissionless***	Open to anyone	Anyone	Anyone	Bitcoin, Ethereum
	Public permissioned	Open to anyone	Authorised participants	All or subset of authorised participants	Ripple, Sovrin
Closed	***Consortium***	Restricted to an authorised set of participants	Authorised participants	All or subset of authorised participants	Multiple banks operating a shared ledger, BWR
	Private permissioned ('enterprise')	Fully private or restricted to a limited set of authorised nodes	Network operator only	Network operator only	Internal bank ledger shared between parent company and subsidiaries

Table 1: Blockchain Permission/ Implementation Models

The BWR initiative has been designed as a closed consortium blockchain with the GSMA being responsible for managing the overall governance of the initiative and all GSMA members are encouraged to join the initiative. It is to be noted that unlike some public blockchains like Bitcoin and Ethereum, BWR solution does not use mining for consensus building therefore is energy efficient. Besides any GSMA non-members willing to contribute only to this GSMA activity can join the discussions under single activity GSMA membership category.

2.2 Blockchain Industry Vision

GSMA Internet Group has agreed a shared industry vision for the telecommunications industry and the vision is based on the following tenets (refer shared DLT industry vision [3]):

- DLT cannot be taken as a siloed business but involves other business technology enablers.
- The DLT work needs to be 80% business and 20% technology focused.
- The ecosystem is multi-stakeholder and includes Mobile Players/ Enterprise and Policy makers.
- Any use case implementation must show demonstrable proof points to the evolving opportunities.

Although not all use cases require operators to work together, there are some use cases which require collaborative development, and such use cases will be the focus of the GSMA effort. GSMA has identified such use cases in below key focus areas (refer Figure1):-

- Wholesale settlement to cover inter-operator settlement processes
- Fraud management to cover fraud mitigation and fraud litigation use cases
- Payments to cover inter-operator and operator-customer payment scenarios, and customer to customer international remittances
- Identity to cover device and people identity tracking and management

The GSMA also recognises that once blockchain solutions are deployed there are cross-technology intergration possibilities where multiple technology stacks may contribute to solve a business problem.

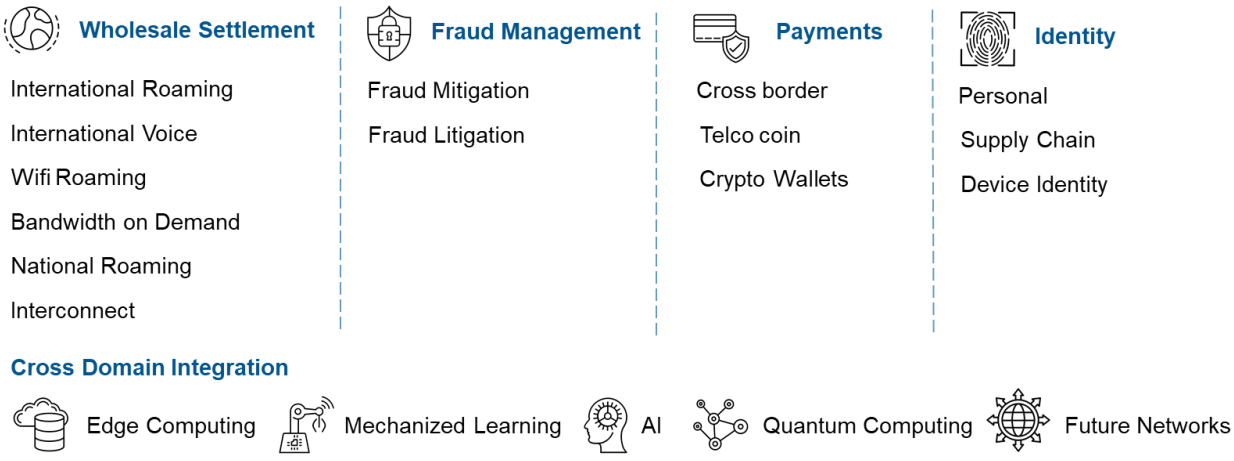

Figure 1 GSMA Focus Areas and cross technology integration

To support the evolution of these use cases the participants in the BWR initiative propose creation of reference industry implementations with an Open-Source approach for fast adoption, transparency and avoiding a vendor lock-in (refer Section 5.3 Open Sourcing).

As per some conservative estimates (refer Figure2) Telco blockchain revenue is estimated to reach around $1.8b[4] of $19.9b[5] by 2024. Of these, payments, and settlement-based OSS/ BSS implementations itself account for multi billion dollars. Global identity and access Management revenue is estimated to be around $11.46b by 2026[6] , supply chain solutions revenues are estimated to be around $3.3b by 2023[7] and Blockchain as a Service use cases revenue are around $15.4b by 2023[8]. There is huge scope for fraud management use cases where $28.3b was lost to fraud in 2019[9].

Wholesale roaming clearing and settlement is the first such collaborative use case where the industry has come together under the BWR initiative for a collaborative assessment and development of a reference industry implementation.

Figure 2 Blockchain Use Cases and Revenue Potential for Telecom Industry

3. Wholesale Roaming Overview

3.1 Wholesale Roaming Industry Today

Roaming operations ensure business continuity and ubiquitous service access to the end customer across various technology stacks including the new 5G and IoT technologies. The GSMA and its members have been at the heart of enabling international roaming through common specifications and standard implementations which have evolved over the last 3 decades. Roaming services are an essential component of an operator's cost model with critical opex and capex impacts. An essential part of enabling this business is managing the inter-operator charges through the wholesale roaming clearing and settlement process. The standard clearing and settlement process defined by the GSMA working groups aims to enable faster time to market for roaming services and healthy cash flow for the operators involved in a bilateral roaming relation.

The majority of the current billing and charging implementations are based on Transferred Account Procedures ("**TAP**") standards and the industry has started to implement the new Billing and Charging Evolution ("**BCE**") process. The BCE process was built in the backdrop of decoupling of wholesale and retail processes, explosion of data usage and inability of TAP to cater to future market needs.

Roaming for long was considered a premium service, however, over the last decade or so there has been a gradual commoditization of the roaming services whilst new innovative and more commercially savvy services have found their way in the larger opco products portfolio. Besides, operators today face contracting margins, new regulations, and increasing complexity of managing rollout of their 5G and IoT roaming services.

3.2 Process Pain Points

The following diagram (refer Figure 3) sets out some "pain points" that arise in relation to wholesale roaming clearing and settlement process.

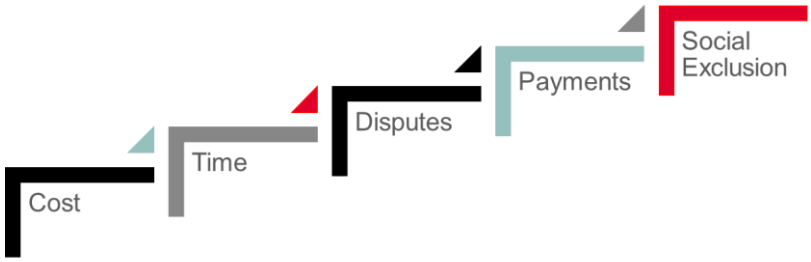

Figure 3 Wholesale Roaming Pain Points

Cost: On an average telecom operator spend nearly 20% of their operating expenses on interconnection and roaming services annually. The other key cost components are network, marketing & sales, IT support and customer management. The annual cost of wholesale roaming for the industry is $20bn (14.1% of Opex). The key cost centres for operators include managing

Operating Support System (OSS), Business Support System (BSS) and wholesale roaming agreements.

Time: The current billing and charging process for wholesale roaming takes on an average a minimum of 45 days for monthly settlement and longer than 3 months for annual or bi-annual discount settlement.

Disputes: In absence of a single source of truth operators and their agents spend a lot of time in resolving and managing disputes often leading to write-offs and revenue leakages.

Payments: Non-payment of dues along with ability to close positions in a timely fashion has been a known industry issue.

Social Exclusion: The bigger operators often have found it easier to move to new ways of working and adopting new technologies however smaller operators with limited operational bandwidth struggle to keep up to fast paced industry evolution.

3.3 Problem Statement

As per an internal GSMA study (refer Section 6.2.4 for more details) international wholesale roaming industry $57bn in 2021 and projected to be $75bn by 2025. The industry is growing at 5.6 % CAGR whereas the costs of running the process are growing at 8% CAGR which makes it an economically untenable model for the future. The technical solutions used today are semi-automated, labour intensive and sub-optimal with high costs and relative financial risk for all operators. Although TAP process is in maintenance mode and the new BCE process will continue to evolve (BCE to include Voice, SMS and 5G services), there hasn't been much innovation with regards to the underlying exchange technology in either processes. Therefore, there is a strong case for modernization and transformation of the underlying exchange technology for increased efficiencies, substantial cost reduction and opening of new revenue opportunities from innovative roaming services. The end-to-end process must be analysed to identify greater technological efficiencies, and the specific steps to consider are contract management, tariff management, data clearing, financial clearing, payments, reconciliation, dispute resolution and fraud management. Fragmentation and complexity, due to multiple entities coming up with non-standardised technical exchange solutions is a challenge that needs to be addressed as well.

3.4 Opportunity Statement

Operators have been experimenting with DLT or Blockchain and initial trial results have been promising. Blockchain creates a "single source of truth" of wholesale charge information between roaming partners, while removing the current process intensive interchange mechanism, typically delivered through clearing houses. The technology potentially enables efficiency gains in tariff management, reconciliation, and settlement, reducing costs of vendors, disputes, and fraud. The current annual cost of wholesale roaming is $20bn (14.1% of Opex) and as per GSMA industry business case a Blockchain based implementation can save up to $5bn of this cost by 2025 (refer section 6.2.4). The increased complexity due to future services (IoT and 5G services) can be managed better along with current process overheads with greater automation which Blockchain based implementation can potentially enable. GSMA BCE (Billing and Charging Evolution) specifications (processes) for future services (IoT and 5G services) can be implemented via DLT from the beginning. The BWR initiative was set up for operators to evaluate Blockchain for its

potential to enable greater automation, reduced disputes, faster settlement, lesser fraud and enable some cumulative cost savings in the process (refer Figure4).

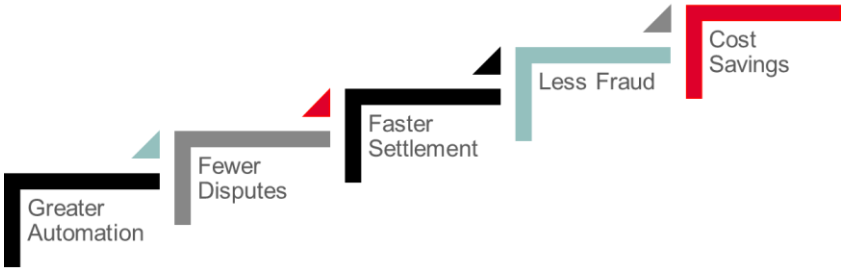

Figure 4 BWR Objectives for Wholesale Roaming

4. BWR Activities

4.1 Background

The Blockchain for Wholesale Roaming (BWR) group was set up in September 2019, in response to a GSMA Board action for the GSMA to get together all companies that conducted a successful DLT trial for roaming. Initially a group of 8 operators began working with GSMA on a Minimum Viable Product (MVP) blockchain shared network for wholesale roaming. The project aims to modernise and transform the existing end-to-end process for wholesale roaming data clearing and settlement for increasing efficiencies, substantially reducing costs, and opening new revenue opportunities from innovative roaming services. GSMA Distributed Ledger Technology group was formed in May 2021 and is responsible for blockchain standardisation activities across different use cases. BWR is incorporated as a use case workstream in the group and all GSMA members can participate in these groups.

4.2 MVP Scope and Success Criteria

The discounting settlement part of the process of the end-to-end clearing and settlement process was selected for the MVP. The idea of the project was to start small, build necessary infrastructure, demonstrate success, and gradually increase the scope to cover the end-to-end process from future MVPs.

The BWR group agreed on both functional and non-functional requirements for the MVP. Some of the key functional requirements for the solution are set out below. The solution:

- must be fully digital, enable greater automation and cater to both current and future roaming services.
- must create a single source of truth ensuring no pricing disputes take place and reduced volume disputes.
- must be agnostic to the standardised file format in use and must be able to handle both TAP & BCE and any other standardised GSMA format in future.
- should use aggregated data only.
- must ensure the exchange of information and related processing is in (Near) real time.
- should enable discrepancy management and dispute resolution; and
- be in a format agnostic standardised layout.

Some of the key non-functional requirements for the solution are as below:

- The participants work within the framework of GSMA Anti –trust policies and Articles of Association.

- The solution must be interoperable, integratable, scalable, sustainable, efficient, feasible, secure, future proof and address operator privacy concerns.
- The solution must be made available as Open-Source solution for the industry.

4.3 MVP Success Criteria

Besides meeting the functional and non-functional scope (set out above), the below success criteria were agreed by BWR group and the group aims to meet these fully in one or more MVP efforts to cover the end-to-end scope as per the agreed requirements.

4.3.1. Commercial Viability

- Reduced Time to Market – spend less time from signing an agreement to service roll out.
- Improved financials - clear return on investment, cash flow savings and reduced opex costs.
- Managing complexity of future and current roaming agreements.
- Enable dynamic roaming services of future.
- Efficient support for non-traditional partnerships.

4.3.2. Blockchain Specific

- Address operator security and privacy requirements.
- Suggest operational model for key management, upgrade management and network maintenance.
- Ensure MVP architecture is aligned with the target DLT reference industry architecture and is scalable, interoperable and meets MVP scope.
- Agree governance model for an industry wide commercial grade blockchain network and reference industry implementation network.
- Technical and operational support for MVP | Aligns with governance vision in project charter.

4.3.3. Wholesale Roaming Specific

- Greater automation of current manual and semi-automatic processes.
- No price/ charge computation disputes and reduced volume disputes by creation of single source of truth.

- Faster settlement timelines compared with current process timelines.
- Ability to integrate new commercial models to support 5G, IoT and future technologies.
- Enabling a secure and business confidential environment whilst abiding to local privacy laws
- Blockchain based governance, process definition, and clear path towards integration into legacy systems.
- Enabling a global open connectivity model for future and enriching inter-operator wholesale agreements.
- Ability to replicate the solution for other similar use cases and use of infrastructure to support other telecom industry use cases.

4.4 MVP outcome

The MVP successfully developed a solution for the roaming discounting settlement process, delivering the agreed functional and non-functional requirements. However, there were gaps identified in moving the solution to a commercial grade environment which will be covered in the next phase. In terms of commercial viability, a dedicated commercial workstream will assess how the solution can be commercially rolled out.

4.5 BWR Roadmap

The below diagram (refer Figure 5 GSMA BWR Roadmap) explains the future roadmap for the BWR initiative. The focus post completing MVP1 work will be to socialise the work with industry colleagues, onboard new participants into the work and create workstreams for operationalisation of current work and further experimentation through new MVPs. Please note timelines are subject to change and are purely for representational purposes.

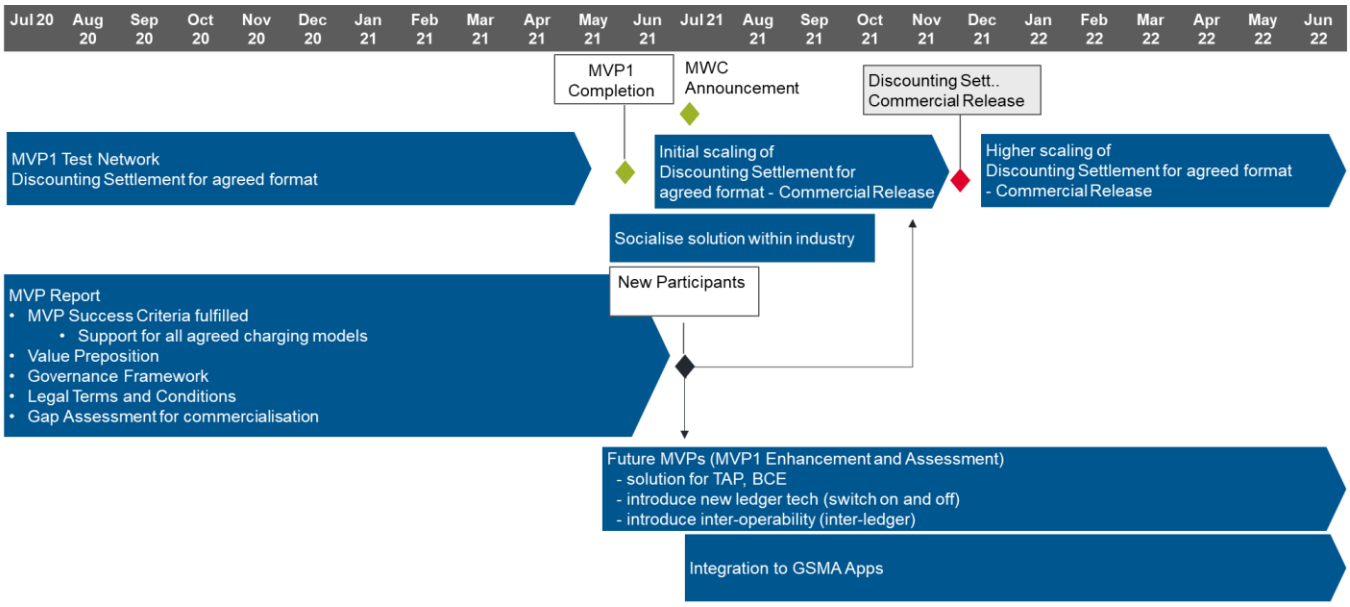

Figure 5 GSMA BWR Roadmap

The BWR MVP1 development effort was officially closed in June 2021 and the output of the effort is the open-sourced solution source code, a functional GUI, key technical specifications, agreed architectural building blocks and, an operational governance model framework and procedures. In the next phase BWR activities have been rolled into the newly formed GSMA DLT ISIG. The GSMA DLT ISIG will focus on technical, business, governance, regulatory and legal aspects for a DLT network operating in the industry. As part of the group, new MVPs are expected to be scoped out covering other parts of the end-to-end clearing and settlement process, along with operationalisation discussions and integration to standard GSMA roaming applications. The MVP1 solution developed is completely Open Source and requires further work for operationalisation. Once an operationalised operators will have a choice to either work in-house or engage with a Blockchain as a Service provider for building their part of the solution on the network. The implementations are expected to be based on the DLT ISIG open-source solution.

5. BWR Solution

5.1 Solution overview

The MVP1 of the BWR project leverages the Hyperledger Fabric blockchain solution, which uses Docker and Kubernetes to orchestrate application and system level components. The BWR network consists of a core network which includes the Orderer and the administrative organisation of the network. There can be multiple other organisations, which connect to the core network and between each other.

Every participating organisation (equals a participating legal entity / MNO in our case) consists of the following components: peer, frontend, database, and certificate authority (CA). The components are packaged as docker components and grouped as Pods in Kubernetes and can be installed on the premises of each client organisation which joins the BWR network.
There are several reasons for choosing this approach:

- **Control:** Each participant in the BWR network can have control over its data (contracts) as well as administrative rights to the technical components. Sensitive data can therefore be stored on premise or on private cloud or even on dedicated hardware, managed by the organisation.
- **Decentralised:** Using the distributed blockchain architecture, a copy of the ledger is located on multiple organisations at the same time. Transaction's flow is implemented by the orderer in the core network, where the consensus algorithm is implemented. This allows for much higher security, as there is no single point of failure and each organisation participates in the networks at the same level as all other organisations.
- **Security:** Private certificate authority (CA), allows each organisation to participate in the network by issuing cryptographic materials used to connect to the network, sign contracts and manage transactions. This allows for higher security and flexibility compared to a single centralized CA.
- **Modular:** To make the solution flexible both in terms of use case (north-bound) as well as in terms of being ledger agnostic (south-bound) a modular approach was taken. The idea is that other use cases and applications can be run easily on top of the network (such as voice use case, data on demand, identity, etc).
- **Open:** Also, the dependency on Hyperledger Fabric has been limited to core features, keeping in mind that later another DLT might be used.

MVP1 of the BWR project comprises of the following components:

- **Business Applications**: Front-end application platforms with the use case specific business functionality. Apps are loaded via IFrame into Core Web App.
- **Core Web App:** Handling communication to and between apps, session management, administration (e.g., Chaincode management through GUI), user management, system stability and monitoring
- **Blockchain Adapter and Common Adapter:** Common interface, abstraction, converting the stateless blockchain requests to ledger specific transactions. Back-end microservices functionality that can be shared for various business applications, such as business logic

processing, data access and storage, communication infrastructure to non-business services. Contains certificate authority

- **Off chain Data Services:** Ensure off chain data flow and storage handling, controlled by Chaincode
- **Blockchain Framework:** Hyperledger Fabric framework, responsible for managing the consensus and processing the transactions.

5.2 Technology choice

Various DLT technologies were evaluated before deciding to use Hyperledger Fabric as the underlying technology for MVP1. After an initial assessment of a wide range of options, Corda, Ethereum Enterprise Alliance (Quorum) and Hyperledger Fabric were more closely looked at.

BWR participant, Korea Telecom (KT), had experimented with Quorum and since Quorum generally propagates all transactions and blocks to near peers (even if it digests a private message), it seemed burdensome to generate multiple peers or large transactions on a global scale.

Quorum's BFT consensus algorithm seemed to have a lot of overhead in block verification as more peers participated. Moreover, Quorum developer community appeared to have over reliance on an organisation in the banking sector which was deemed to be a risky approach for supporting business critical infrastructure.

Although, Corda has multiple similar features and benefits to Hyperledger Fabric and other blockchains, one critical difference is that it does not use blocks, therefore lacks some of the benefits like security other blockchains offer. Furthermore, Corda has dependency on notaries where while validating a transaction the content of the transaction is reviewed and an assigned notary validated for the purpose. This requirement may compromise privacy and leaves the ecosystem open to risks of using non-legitimate transactions where they are non-validating notaries[10].

For the above reasons Hyperledger Fabric was deemed to be more suitable choice for the MVP exercise at the time. The BWR group recognises that blockchain ecosystem is ever evolving and is committed to continue evaluating current and new ledger technologies to build a ledger agnostic ecosystem.

In the end, Hyperledger Fabric was chosen as a solution for MVP1 for the following reasons:

- It offers built in identity management. This is essential as for the legally binding transactions that we wanted to conduct on our system it is necessary that those transactions are conducted by authorized parties.
- It offers enough flexibility when it comes to confidentiality of data, including dedicated channels between parties, or separate data collections that are being kept outside of the ledger (i.e., to which only authorized parties have access, but not every participant on the network).

- It is stable and scalable, as has already been shown in existing industry applications and has also had been proved by GSMA members who had been working with Hyperledger Fabric before.
- It offers a high transaction throughput without making security compromises.
- It offers the security of a Blockchain, which is an advantage over some other technologies which do not use Blockchain and build the necessary trust on the network with other means.
- It is backed by a huge developer community which is governed by the Linux foundation.
- It is available as Open Source.
- Also, most of the MVP1 participants already had sufficient experience with this DLT as most of the early PoCs used it.

It is to be noted that the above arguments were factored into deciding to use Hyperledger Fabric at the time. However, DLTs continue to evolve and the BWR is committed to explore the possibility of a multi-ledger environment.

5.3 Benefits of an Open Source Solution

The main reasons for going with an Open Source approach are:

- **Use it as you like**: Organisations or developers can change and adjust the code in accordance with the obligations set out in the applicable licensing terms and without having to pay someone for it.
- **Know what is running on your premises**: Organisations or developers can review the full code and make sure it fulfils internal requirements for efficiency, security, etc.
- **Better quality**: It is not just one vendor, but the combined knowledge of a group is flowing into the software - leading to higher quality.
- **No vendor lock-in**: Organisations are free to work with the code themselves or include different partners or vendors.
- **Faster adoption**: An open-source system makes it easier for other parties to join, as they do not have to commit to one partner or vendor. In combination with the reasons stated earlier we strongly believe that this openness, flexibility, and security will allow the software to be used in many different organisations around the globe.

The BWR source code is open sourced with:

- all DLT components of the software open sourced through Apache 2.0 license
- all wholesale roaming application components open sourced through GSMA software open-source license.

The Apache 2.0 License is a permissive free software license written by the Apache Software Foundation. It allows users to use the software for any purpose, to distribute the software, to modify the software, and to distribute modified versions of the software under the terms of the license, without concern for royalties. The user is granted a license to any patent that covers the software. However, this license shall be terminated if the user sues anyone over patent infringement related to this software. This condition is added to prevent patent litigation.

As wholesale roaming billing and charging standards are maintained by the GSMA through its working groups, it was agreed to Open Source (refer Figure6) the roaming application parts via the GSMA Contributor and User License (available as part of GSMA DLT Governance Principles PRD DLT 1.0).

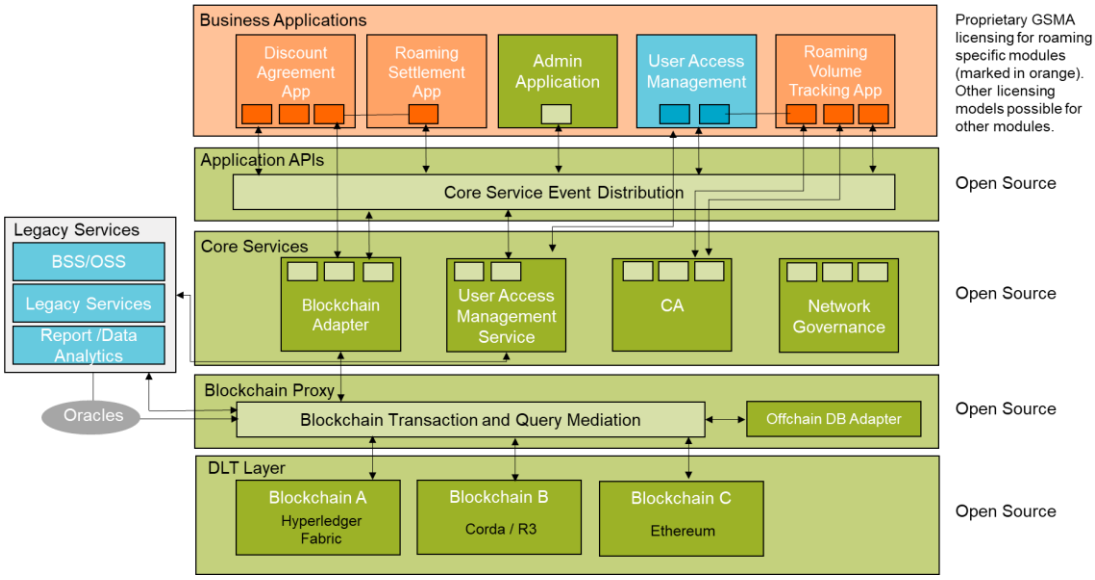

Figure 6 DLT Reference Architecture and Open Source Components

5.4 Solution challenges

5.4.1 Interoperability

Blockchain discussions have often invited a huge interoperability debate. Interoperability could be at various levels and the project has taken these different interoperability requirements into consideration. Additionally, the BWR target architecture is designed in modular fashion keeping desired levels of interoperability in mind. It is to be noted that given the evolutionary nature of the Blockchain technology, interoperability at all levels may not be feasible at this stage. However, a given use case may or may not require such level of interoperability to unlock business value. For example, a standardised telco blockchain network built on a single protocol could serve multiple use cases to unlock business value. Furthermore, at this point complex interoperability requirements haven't been identified as a business need. The project suggests a pragmatic approach where interoperability solutions are sought on best effort and need basis for each use case being considered.

Below interoperability considerations were made in the project:

- **Application-Level Interoperability:** This refers to interoperability of application instances running on two or more different network participant nodes (refer Figure 7). If all nodes in the network are hosting the same application web client instance or application stack for example the BWR web client instance is hosted on all the nodes in the network

interoperability is much easier. However, where different application web clients for similar business purposes are used in a common network (also termed as east-west interfaces) common APIs and public interface specifications are required to ensure interoperation between such comparative applications. The current BWR API specifications developed cover the north-south interfaces vertically between different architecture layers. However, in the next phase such horizontal east-west interfacing should be considered as well.

- **Inter-ledger (DLT) interoperability:** This refers to interoperability between different ledger protocols or technologies such as between Ethereum (Quorum), Corda and Hyperledger (refer Figure 7). Although most ledger technologies enable a DLT eco-system, their approaches are often heterogeneous in nature which makes interoperability amongst these protocols quite challenging. The BWR project is architecturally positioned to attain complete inter-ledger interoperability and plans to both study and run specific experiments to explore sustainable inter-ledger interoperability solutions. This is an ongoing discussion area in the DLT world with efforts such as Polkadot, Cosmos (etc), and the GSMA continues to monitor this space for further development.

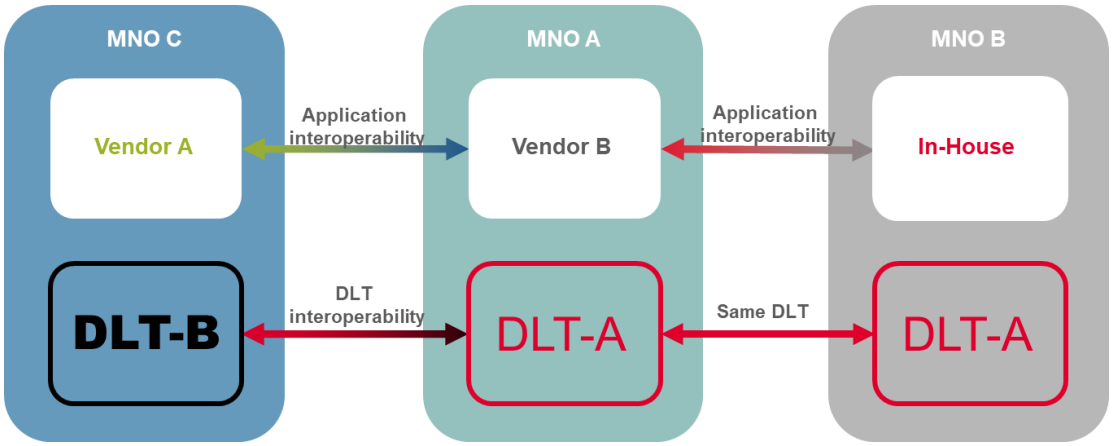

Figure 7 Application and inter-ledger interoperability

- **Intra-network interoperability:** This refers to the interoperability between participants of the same network (refer Figure 8). Within the same network it is assumed that as long as all network participants use the same architectural set-up as has been provided for example modular BWR architecture, there should be little room for intra-network interoperability issues. The Blockchain level connectivity is provided through a hybrid model of private implicit collections and private channels between two or more participant nodes in a bilateral relation. This may require initial work in ensuring that the common set-up scripts and tools are made accessible to all participants along with education on how a network participant is integrated into the network set-up. A concerted effort to maintain the intra-network connectivity through network health monitoring and coordination between the network administrator and participants is also recognised as an important connectivity requirement.

- **Inter-network interoperability:** This refers to interoperability between different Blockchain networks also called a network of network scenario (refer Figure 8). It is believed, just like the internet, the future of DLT is to evolve into a network of network kind of a model. There are various experiments and studies taking place in this area as well. The GSMA is open to explore inter-network interoperability with other similar networks to identify a solution. However, as with inter-ledger interoperability the approach here must be driven by business need and should not hinder unlocking business value within a network running on one or more ledger technologies. This is marked as an inevitable evolution path for the future of DLT networks which currently are being created as single dedicated networks.

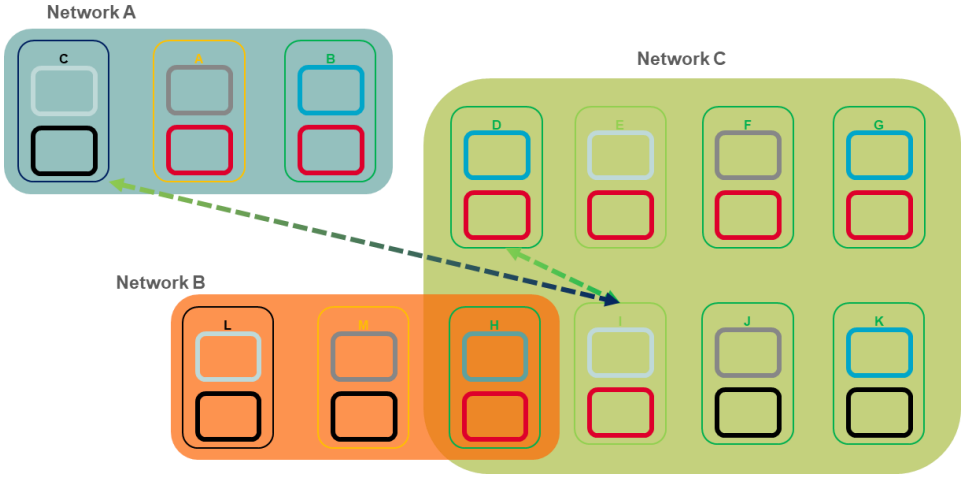

Figure 8 Intra-network and inter-network interoperability

5.4.2 Regulatory and Compliance Review

Blockchain, as a technology, has the potential to become an integral part of the operation of many enterprises, offering scalability, security, and computing power at a lower cost. However, there are several issues that need to be carefully considered to realise the potential benefits. Some of the expected issues are discussed below.

Regulation

Depending on the uses of Blockchain, and as Blockchain is utilised or considered as appropriate for enabling specific service offerings, it is likely to receive more regulatory attention. For example, in Q4 2017/ Q1 2018, the level of interest from governments and financial regulators increased in Bitcoin and other cryptocurrencies underpinned by Blockchain technology. Also, another use case is where Blockchain technology is used as a, or in a similar manner to, a distributed database system. Adherence to applicable data privacy and financial regulations is important. It is possible that issues ranging from (but not limited to) quality of service, cross border data transfers, illegal content, lawful access, electronic signatures, and identifying applicable law and jurisdictions will need to be examined on a case-by-case basis.

Compliance/ Legal

Blockchain technology provides an opportunity to conduct real time compliance checks, and ensure operations are transparent and bound by the contractual legal terms. Any exceptions may be identified allowing for corrective courses of action. However, this will also depend on technical requirements and implementation, and the types of operational and support systems utilised. Different countries may operate under different regulatory and legal frameworks, and this, in-turn, will require the review of each use case.

Privacy and Data Protection

If any personal data is to be processed in the blockchain, relevant privacy experts from the stakeholders will need to be engaged to conduct a privacy impact assessment. Identification of whether any personal data will be processed must be conducted by the participants at the very beginning. If any personal data is to be processed in the programme, roles and responsibilities will need to be defined, and the solution designed to ensure privacy compliance.

Jurisdiction for Smart Contracts

Smart contracts are self-executing programs that will execute itself upon specified criteria and which may eliminate the need for intermediary partners to confirm a transaction. These smart contracts lead to various new opportunities but may also raise legal questions in relation to applicable law and jurisdiction.

Blockchain could cross jurisdictional boundaries as the nodes on a (public) Blockchain may potentially be located anywhere in the world. This can pose several complex jurisdictional issues which will require careful consideration in relation to the relevant contractual relationships that underpin the use of the blockchain. Also, depending on the applicable law and the jurisdiction, there may be legal constraints and/or considerations with respect to using electronic signatures for closing binding agreements.

Blockchain auditability

Auditing services may benefit from the immutable aspects of Blockchain data to simplify their processes.

5.4.3 Tackling of confidentiality and privacy requirements in MVP1

A key business requirement is to ensure the confidentiality of the business data and ensure that the solution is in line with data privacy regulations i.e., business relations between partners on the network are not revealed. Documents containing confidential information should be shared off-chain between partner organisations and to reflect this transaction over the network a hash of the original data is stored on the ledger to ensure data integrity. To this effect only information relevant for achieving immutability and proving transaction event should be exchanged between competitors over the blockchain. In particular, competitors must not exchange any competitively sensitive information, including but not limited to information that relates to their individual forward-looking commercial plans. As Hyperledger Fabric's (HLF) private data collections could potentially reveal bilateral business relationships through endorsements or collection definitions, another solution was explored. Instead of initiating a transaction that is logged on the ledger, documents are sent by initiating a Chaincode query on the receiving party's HLF peer that retrieves and stores the document. Query functions are not distributed among other peers in the network. As a result,

the document transfer remains private between the involved parties. The Chaincode function that retrieves, and stores documents is to be kept simple. The Chaincode function is used for storing documents locally as well as for sharing it with partner organisations. The Blockchain adapter is notified about new documents and subscribes to any related updates written to the ledger such as document hash and signatures.

Challenges with Private Channel formation in Fabric

One of the primary considerations for confidentiality and privacy is the Channel formation and membership. To understand the Channel formation challenge, it's necessary to first define what channels are in Fabric.

A Channel is a private communication layer associated with a given ledger, composed of an ordering service and member peer nodes. To compare with traditional network services, HLF Channels are similar in concept to Ethernet Private Line (EPL) service, given that they are a logical partition structure to restrict communications to a defined set of endpoints. Each channel is formed around a separate shared ledger and separate genesis block, effectively constructing an isolated blockchain between the channel members. The only nodes that can *read from* or *write to* that channel's ledger are those organisations explicitly defined in the channel configuration.

If an operator wishes to transact with another operator, they must both be members of the same channel. On a given channel, each organisation must operate at least one peer node. All collective nodes must run the same version of Fabric code.

Given the expected end-state for BWR to include hundreds of operators, a practical implementation will require support for version upgrades as members select to migrate to the new version while still maintaining a presence on the original channel to transact with those operators that have not yet migrated.

This multi-channel approach to version control avoids a Flash-cut scenario. Using separate channels for current version and new version allows for a longer window to conduct upgrades and testing between operators.

A peer node can join multiple channels, but each channel's data is strictly confined to that channel, preventing the leaking of data between different channels while allowing the node count for an operator to be governed by transaction rate and not number of subnetworks.

Given those characteristics for channels, there are several different descriptors used in association with channels such as 'shared', 'dedicated', 'application', 'system', and 'hybrid'. Defining private data collection is also useful to understand in defining these Channel descriptors. Dedicated channels are those defined by a single application usage or a defined trust boundary that may be a subset of overall membership. Due to the nature of the channel as the message boundary, any amount of information in the shared ledger must be within the same trust domain as the channel members. This trust domain can be extended by minimizing the information stored in the channel's ledger to primarily the hash of the data while using private data collection as a secure method to exchange the underlying private data and any associated metadata between the peers. HLF supports *get* and p*ut* function API calls for private data within Chaincode simplifying this data exchange.

One of the business intelligence confidentiality concerns voiced by BWR group members is knowing which operators have agreements with which other operators. Implicit private data collection allows for any member to exchange private data without explicit Chaincode reference to the organisations. Returning to our Channels analogy to EPL, private data collection is analogous to a layer three Virtual Private Network (VPN), providing a communication path between the endpoints over the top of the underlying physical network.

For simplicity, we can refer to the channels used to conduct business as “Application Channels” and a Channel to share between all members of the consortium as a “System Channel”.

“Hybrid” channel descriptor does not have a strict definition for the formation of application channels. They can be regionally defined, time zone bounded, formed around other notions of trust boundaries, or consist of bilateral membership. A hybrid network permits each of these formations, leaving the channel formation parameters up to the channel membership whether to admit additional peer nodes to an existing channel.

Factors being considered, include efficiency of transactions received at member nodes, peak reconciliation times, the amount of non-relevant data each peer stores in the shared channel ledger, any overhead associated with each channel including a peer node joined to multiple channels, and the impact of having data in the ledger operated on directly with Chaincode as opposed to private data collection held in a database leveraging additional middleware operating on the data.

MVP1 evaluated each of these channel formations and recommended a hybrid approach. Future MVPs will define the boundaries of channel parameters to meet the confidentiality and privacy requirements whilst maintaining the flexibility articulated in this section.

5.4.4 Reducing disputes through common calculation logic

Settlements are calculated by a dedicated calculation engine module that provides an API to request calculation of a discount agreement for given usage data. The result is the deal value that may be used for settlements. Calculations are performed locally, with the option to add the calculator version to the settlement document to ensure that the same calculator engine is being used by the participating parties. It is important to keep in mind that even if calculations would be performed using the chain later, building the calculator library into wasm and only keeping around the wasm blob a general execution platform to execute the wasm and calculate the hash of this blob could be one way of ensuring that the correct engine is being used. This also opens the possibility for a kind of calculator registry (e.g., docker.io) for calculation engines (certified) at some point. It must be evaluated if this is necessary because as the usage data has been exchanged and possible discrepancies are transparent to the contracting parties, and the contract and the commercial conditions are available on the blockchain, the probability for deviations in settlement calculations are low if organisations ensure that the same calculation engine is being used.

Where, the calculation logic does not exist in the standardised implementation framework, the parties willing to use this may request to the GSMA for standardisation, and in the interim may have to use a localised solution. The standardised methodology for such a solution will need to be recommended by the relevant GSMA committee.

6. BWR Value Proposition

6.1. Blockchain with Roaming Benefits

There are several potential benefits for running roaming settlement over Blockchain network, some of them may improve the operational time response, others may simplify the operational workflows, and others may bring cost savings.

Some potential benefits are.

- **Settlement/reconciliation:** at the end of the contract duration, when the reconciliation starts, the solution triggers the settlement process, it compares the own results with the results of the roaming partner and points out the differences. BWR will potentially significantly reduce the time required for settlement/reconciliation and opens the possibility to shorten settlement/reconciliation periods from 1 year to for example quarterly or monthly settlements.
- **Reduction of Disputes:** by creating, signing, and exchanging roaming contracts digitally followed by adding a copy of the contract terms and conditions on the ledger a single source of truth is created which drastically reduces the possibility of a price dispute. New technologies where both networks know in real time the volumes exchanged may reduce even more the cases of usage related disputes.
- **Auto Disputes Resolution:** parties may set in the contract calculation logic a tolerance threshold (absolute or relative), where both parties agree on how to solve dispute cases below a limit. This configuration may radically the time invested by operators in solving small disputes.
- **Multi business architecture:** a Blockchain settlement platform could be reused for other similar use cases. In the carrier's world there are already multiple examples of settlement and non-settlement use cases which are progressing as parallel discussions to wholesale roaming settlement discussions.
- **FTE reduction or do more with the same amount of people:** due to the automation potential for settlements, reconciliation, dispute handling (etc.) the number of full-time employees (FTEs) performing these tasks today can potentially be reduced – or an organisation may look to handle increasing complexity due to new services (such as NB-IoT, LTE-M, VoLTE, ViLTE and 5G SA slices) with the same amount of people.
- **Cost Transformation:** Traditionally in the TAP world, operators have relied heavily on clearing houses for supporting their clearing and settlement operations. TAP specifications are in maintenance mode and GSMA is working with the industry to migrate operators to the BCE specifications. Therefore, it's not expected that blockchain will be implemented to support the TAP process. Blockchain can be potentially used for supporting both discount settlement and the BCE processes. This opens opportunities for more players including traditional DCHs to support this new ecosystem. DCHs can evolve into a Blockchain as a Service provider besides continuing to support the new ecosystem in below areas:

- **Evolving DCH:** some operators may decide to retain their current DCH and ask for Blockchain services as well.
- **Hybrid environment:** some operators may create a hybrid environment to continue to manage their current TAP process via a DCH and using a BaaS provider or an inhouse solution for blockchain based exchange with their roaming partner.
- **Standalone:** an operator may decide to run all clearing and settlement operations inhouse and becomes a connected operator. This includes complete integration of OSS/BSS, business intelligence systems and the Blockchain environment.

- **Development flexibility**: Blockchain may enable operators to develop their own solutions for coming challenges in the industry. This technology may create a new ecosystem where multiple businesses are allowed, and new monetisation alternatives may be realised. It is feasible to extend use of blockchain platform to other future use cases. Therefore, Blockchain platform costs may be considered as a low investment into potential monetisation opportunities of future.

6.2. Business Case

BWR group members believe that each operator needs to make their own independent business case assessment. However, in terms of defining a value preposition for use of blockchain technology, a business case may typically consist of several different elements including the below:

6.2.1. Efficiency gains through automation & simplification

A large mobile operator usually has around 600 roaming relations with single operators and operator groups resulting in 400-500 individual roaming discount agreements which need to be negotiated, implemented, managed throughout the year, and finally settled. An average settlement takes approximately 1 day including the own settlement calculation, aligning it with the partner and issuing a credit- or debit note. Very simple settlements need a bit less time but more complex settlements, or settlements where large discrepancies between the own and the partner's calculation occur can easily take up two days, three days or even more. With the assumptions above, the effort for settlements would be around 400–500-working days annually - roughly 1.5-working years - or around 2.3-working calendar years based on 220 working days per year. Today operators only support Voice, SMS, and Data services, however, with NB-IoT roaming, LTE-M, VoLTE, ViLTE and other QoS services along with 5G SA, the discount agreements and related settlements will potentially become more complex. If the current roaming operations were not improved upon the overall time required for wholesale settlements will further increase. Therefore, there is a strong case to automate and simplify wholesale roaming settlement process and at the same time ensure that roaming settlements are processed without having to recruit additional staff for dealing with this added complexity.

With the proposed Blockchain based approach, both parties create a single source of truth for the discount agreement reducing the source of potential errors & discrepancies significantly. In the case of discrepancies, it will be possible to compare own volumes and services with the roaming partners' figures to easily detect the root cause of the discrepancies. If discrepancies are within

certain absolute or relative thresholds, the whole settlement process can be automated up to the credit- and/or debit-note. BWR group estimates that the solution can reduce the time required for a settlement from 1 day on average to probably 30 minutes in the beginning and 10-15 minutes when fully operational with all roaming partners which is 1/30th of the initial time required. This obviously depends on how many partners join the network over time - but this showcases the potential of using the blockchain technology.

Some organisations may already be using semi-automated calculation engines, where some of the proposed efficiency gains may already be realised. However, the comparison, alignment and agreement of partner and own calculations is still a cumbersome process which may be fully automated using the blockchain approach. Additionally, due to creation of a single source of truth the potential to have disputes may be largely reduced.

Group operators particularly require alignment with their affiliates for having greater visibility of monthly and annual settlement, so this can be considered for the discounting settlement execution. Once the execution has been completed, the net position needs to be reflected to affiliates. This is a key requirement for a fully automated solution.

6.2.2. Shared Infrastructure across multiple Use Cases

Roaming settlement is only one use case out of many in the wholesale area. The more use cases that are added on top of the same blockchain infrastructure, the more synergies and savings that may be generated. Related use cases may be, for example, settlement of interconnection/voice and/or reduction of voice interconnection fraud. Again, this is not part of the MVP and should therefore be considered as a potential future upside to the efficiency gains.

6.2.3. Industry business case

GSMA commissioned Grand View Research in 2019 (refer Figure 9) to conduct an analysis of the roaming business. As per the report, wholesale roaming revenue was estimated to grow to $75bn by 2025. Projected growth considered the rising number of smartphone users, emergence of 5G and increase in international tourism. Although projections may not be accurate due to unproven effect of “all you can eat” models and recent COVID19 impacts, they are indicative of the future of roaming business. Below are some of the key considerations/ assumptions into the findings of the report:

- Mix of multiple primary and secondary sources for 2018 base year estimate and projections to 2025
- Combination of top-down and bottom-up approaches for market sizing
- Secondary sources include ACMA, GSMA, Hoovers, IMR, SAMENA Telecommunications Council, TRAI, US Telecom, Company Annual Reports & Investor presentations
- Global market estimated by integrating regional markets
- Estimates and projections validated through exhaustive primary research with key industry participants

- Growth rates estimated using correlation, regression, and time-series analysis
- Estimates do not consider inflation
- All estimates are for mobile operators only and exclude revenues/estimates from other players (for example MVNOs)

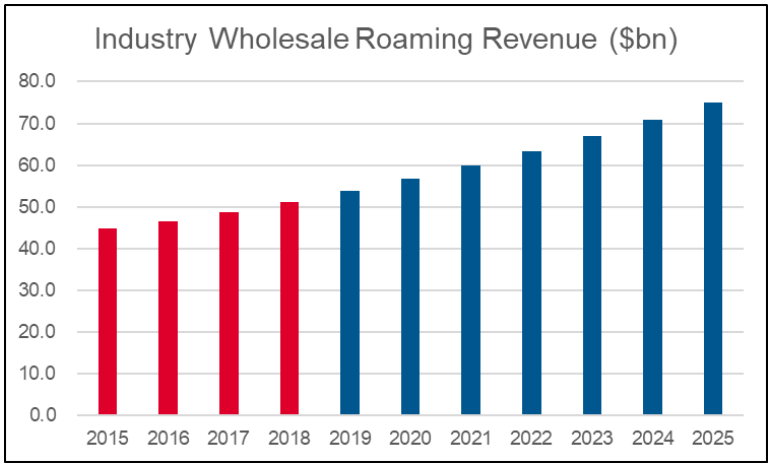

Figure 9 Industry Wholesale Roaming Revenue Projections

Based on the analysis carried out, the total mobile operator opex spend (refer Figure10) is 139.4bn USD out of which 14.15% or 19.7bn USD is spent on Wholesale Roaming. The key costs are Network (25%), IT Support (11%), Wholesale Roaming (14%), Interconnect & National Roaming (6%), Customer Management (7%), and Marketing & Sales (16%) and Other Costs (21%).

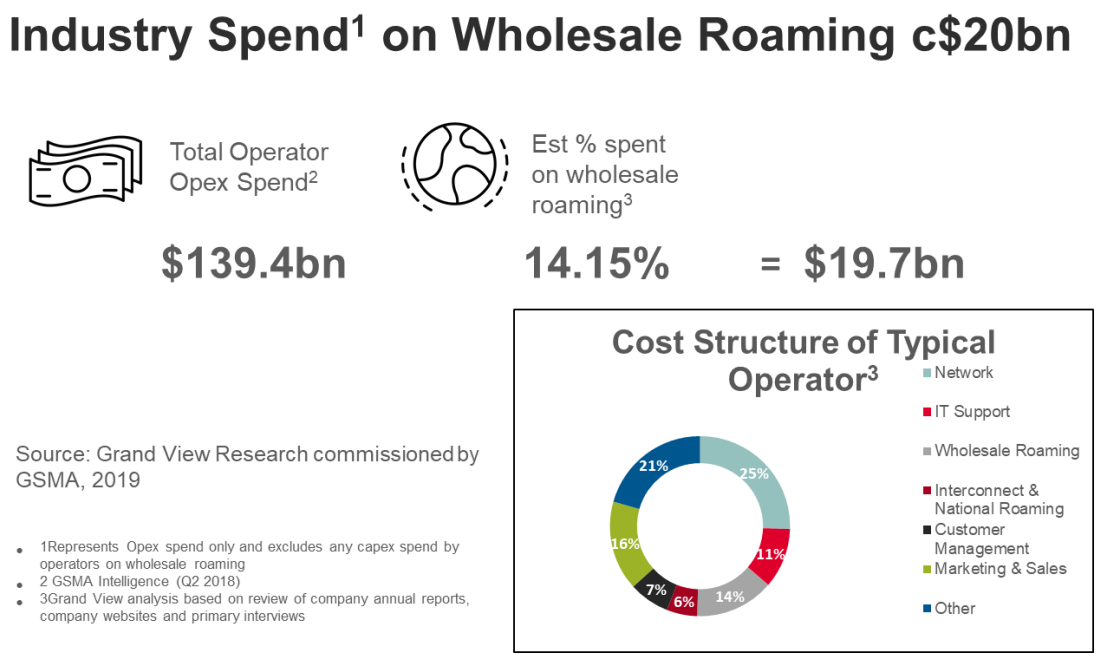

Figure 10 Roaming Industry Spend– Grand View Research Data

Breakdown of Industry Wholesale Roaming Costs

$19.7 bn wholesale roaming costs are distributed amongst Network Infrastructure ($2.5bn), IT Infrastructure ($1.8bn), Staff ($1.3bn), Vendors ($5.5bn), Roaming Fraud ($4.1bn), Dispute Time ($2.7bn) and Other Costs ($1.9bn) (refer Figure11). Grand View Research data used for the analysis took percentage spends from primary interviews with Operators, midpoint of these ranges was used to estimate global spend and sense check were made from bottom-up estimates from some categories (vendors, staff costs).

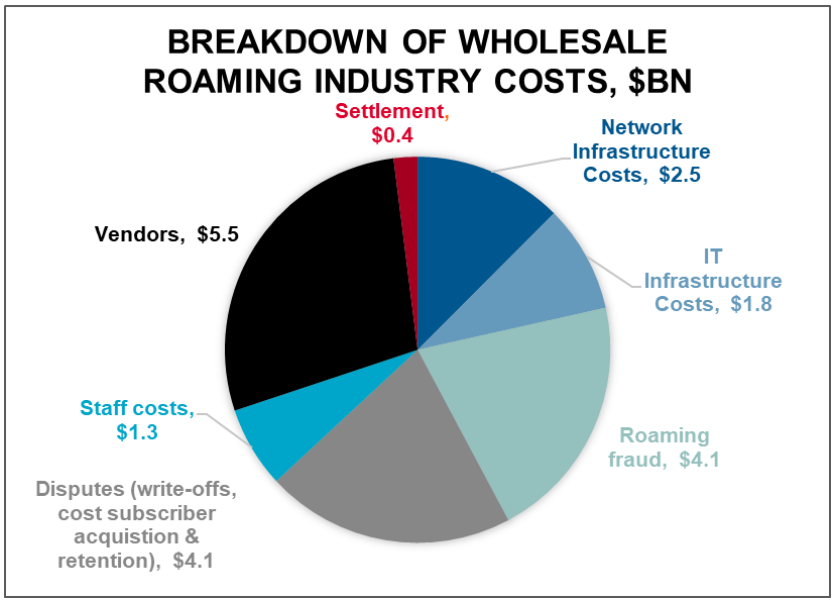

Figure 11 Wholesale Roaming Industry Costs

Using Occam's Razor (fewest possible assumptions), the GSMA conservatively assumed, 10-20% savings from disputes, roaming fraud and vendors costs which together amounts to multi-billion industry opex savings between $1.4-2.7bn in first few years of operations considering low up-take initially. Below areas were marked as key contributors to these efficiency gains:

- **Dispute resolution –** 80% of disputes are caused by different understanding of contract terms. Blockchain based implementation will substantially reduce both dispute write-offs & other costs of resolving disputes
- **Lower vendor payments –** greater automation of activity will reduce vendor costs
- **Roaming fraud –** real-time detection of roaming fraud activity could reduce both size & market for roaming fraud. It is to be noted that other mechanisms like NRTRDE and CAMEL exist today for detecting roaming fraud. Also, operators have more visibility of CDR activity in visited with GPRS, 4G and 5G technologies.

Industry P&L for Wholesale Roaming, Without Blockchain

Grandview research projects wholesale roaming revenue as CAGR growth of 5.6%, however, there is a potential risk to revenue from regional/country roaming regulation and COVID19 impacts. The GSMA estimates that costs will increase by 8.0% CAGR, particularly accounting for regulations and new services rollout (5G & IoT). Costs are also likely to increase in line with increased usage of roaming services. It is also projected that these will contribute to deteriorating margins approximately of 60%+ likely to mid-50% (refer Figure12). Overall, the industry is projected to grow at a slower pace compared to the rate at which costs are rising which implies that at some point in future the roaming cost model is untenable. It is to be noted, however, that on an average the current model works for many years to come. But as roaming is a collaborative space, if the costs are not checked some operators may face operational issues sooner compared to others thus impacting everyone such operators have roaming deals with.

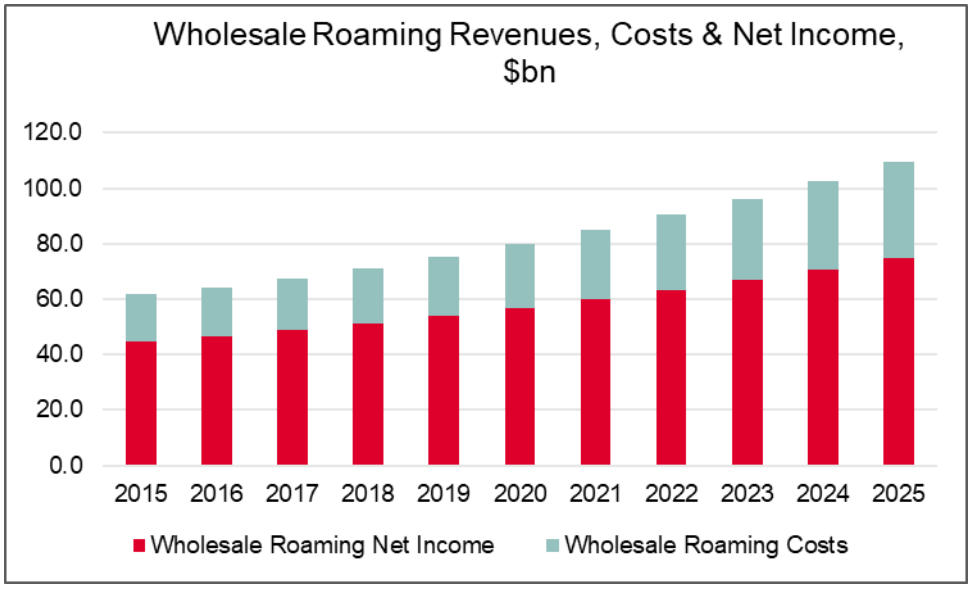

Figure 12 Wholesale Roaming Revenue vs Cost Projections

Potential Industry Savings from Blockchain Solution

Based on the GSMA analysis it is projected that a blockchain based implementation will impact most cost buckets. Blockchain impacts kick-in best on a network effect and if it were to be assumed by 2025 70% of the industry uses the technology it will imply 7.6 billion USD savings for wholesale roaming industry in that year alone (refer Figure13). It is assumed that Blockchain solution take-up to be 30% by year 4 and 70% by year 7 of operations. The projections again assume substantial savings in dispute resolution with reduction in both write offs and most time spent on disputes, greater automation impacts on vendor costs and early detection of roaming fraud activity impacts on roaming fraud related costs. These projections do not consider the upside of using the same blockchain infrastructure for other use cases with some of them having potential monetisation opportunities.

$billions	w/o Blockchain		with Blockchain	
	2018 Costs	Est 2025 costs	2025 Savings	Cum. Savings
Network Infrastructure Costs	2.5	4.2	0.0	0.0
IT Infrastructure Costs	1.8	2.6	0.0	0.0
Roaming Fraud	4.1	8.0	1.1	3.1
Disputes	4.1	7.1	4.0	11.4
Staff Savings	1.3	2.6	0.5	1.3
Vendors	5.5	9.5	1.7	4.8
Real-time settlement	0.4	0.6	0.0	0.1
Total	**19.7**	**34.5**	**7.2**	**20.8**

Figure 13 Industry Savings

6.2.4. Blockchain as an Enabler

Operators put in a considerable amount of effort and resources to perform the discount settlements today with multiple time-consuming re-iterations in the end-to-end cycle. Through Blockchain technology this effort is potentially reduced making processes automated, transparent and with increased trust in the network due to immutability of agreed transactions. In the process, there are variables to consider, to name a few:

- The different types of wholesale deals (for example: flat rate model, revenue commitment model, etc.)
- Differentiation of call destination and traffic types
- Late usage data
- Data correction due to fraud

The BWR solution unifies under a single application all the above variables and has the potential to make significant impacts on how business is conducted today. For instance, with NBIoT roll out, operators are experiencing an increase of complexity in their current discount models agreements and related operational processing, and by using the BWR solution such challenges may be handled more efficiently. The BWR work in discounting settlement use case is a steppingstone to other potential wholesale roaming settlement use cases, such as BCE or payments. All potential new use cases may potentially be easily integrated as a new business application on top of the shared common architectural components. This modular approach in the architecture may serve as a quick enabler in our toolset to incorporate any new B2B, B2C revenue generating verticals at any point. Additionally, the use of Open Source approach may further enable cost savings in research and development and reduce initial investments for operators and vendors involved.

6.2.5. Global end to end connectivity with minimised intermediation

One use case that Blockchain may facilitate is enabling global inter-operator connectivity. Currently, the interoperability between roaming partners is based on the trust that is covered by a contract and executed via trust intermediaries. For example, the connectivity to all

the roaming partners is ensured by the DCH/ FCH that are central entities required to run end-to-end the wholesale processes (TAP exchanges, charges computation from RAEX IOT.

The level of trust between roaming partners with years of collaborative operations is in many cases high today and may not require an enforcement through additional governance mechanisms. However, in the future with the 5G, local 5G network operators will join the ecosystem (small scale mobile network such as hospitals, university campuses, airports,) with a greater number of partners to be connected and with less time in establishing similar trust.

The BWR proposed governance framework may enable the connectivity authentication through the GSMA certification process (refer Figure14). An introduction of a new entity into the Blockchain network ecosystem could be legitimatised by the GSMA or a subset of the network participants. All partners may be connected to the established DLT network through a framework agreement, and sign-up bilateral agreements over the network to sustain the wholesale settlement process. A central entity such as a DCH/FCH would not be mandatory anymore but for partners not having DLT expertise or preference to outsource some or all DLT based operations, the connectivity may be ensured by a BaaS (Blockchain as a Service) provider.

DCH/FCH in this scenario could evolve into a Blockchain agent that is responsible for connectivity. Partners will have the choice to rely on an agent or not. This hybrid model will most likely be the model of choice for most operators as operators will move to Blockchain over time – and some may choose never to use Blockchain.

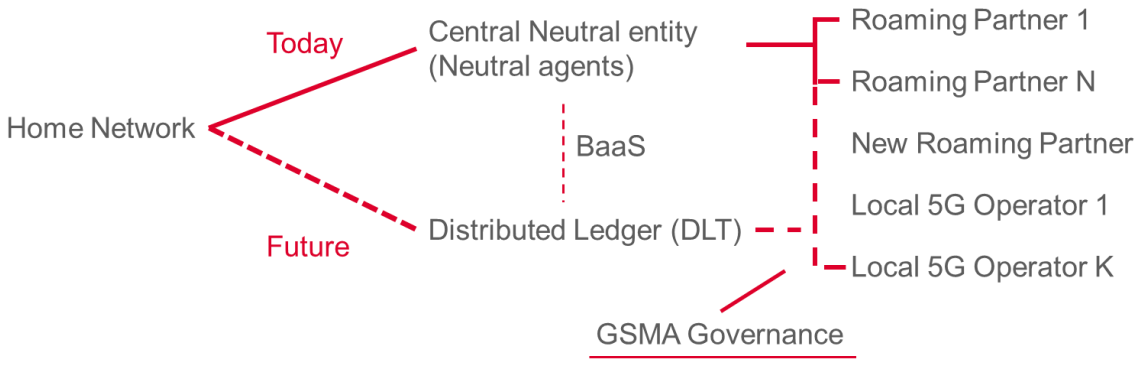

Figure 14 Global Connectivity

7. Eco-system Roadmap

7.1. Eco-system creation and DLT Evolution

In connection with the GSMA DLT industry vision, the BWR project is a first step in creating a DLT network which will hopefully provide a backbone for the years to come. To enable long-term success of the project it is important that a robust ecosystem of services and providers is created, and for the ecosystem to be future-ready for evolution in underlying technologies which power it.

As DLT technology is early and constantly evolving, it is important to allow the ecosystem to experiment and adopt different DLT technologies and methods to use them. The project has chosen to work in a method and architecture that will enable different implementations to exist and for the DLTs and the way they are used to evolve as the project evolves. This is done through open sourcing the code, as has been described in previous sections. It is also done by adopting an architecture that supports abstraction and adoptions of additional DLT technologies such as Ethereum (Quorum) and Corda which were previously evaluated by the project.

Concretely, the next versions of BWR MVPs intend to include exploration in using HLF in a different way (with private channels) and support for Ethereum as an additional DLT with interoperability with other solutions in the market - beginning the path towards an inter-ledger and an inter-network ecosystem.

7.2. Governance, Procedures & Network Operations

The BWR group recognises blockchain implementations as an eco-system play requiring strong governance fundamentals for seamless operations and has documented a governance framework for a reference industry implementation which the GSMA expects will become an approved GSMA PRD. The governance framework will provide a standardised framework for operations of the BWR activities under the new DLT group including elements such as decision-making procedures, process for introducing proposals, researching network policies and intellectual property rights policy on the Open Source code.

8. Wholesale Roaming Operational Roadmap

8.1. Roaming Services Evolution

Currently, BWR group members focus on the minimum components to be developed to show the benefits of using the Blockchain. Steps could be segmented as follows:

8.1.1. Alpha Version

The MVP1 focused on the discounting settlement in its minimal setup. It is referred as the alpha-version, intending to successfully run the discounting settlement with the minimum components that consists in:

- Agreeing and signing the discounting agreement
- Exchanging the usage report for the rating period
- Generating the Settlement report

MVP1 demo can be watched here.

8.1.2. Adding New Features

The BWR group activities have been merged into the GSMA Distributed Ledger Technology group which is open to new participants to join. This will allow the community to consolidate a roaming services roadmap that will be phased until the readiness for commercial adoption.
MVP2 will follow up on the work in MVP1 and may consider developing the following features:

- Any type of discounting agreement will potentially be covered (ref.: PRD BA.27), including complex conditional deals.
- The UI will validate the consistency of the data.
- In case of a settlement report rejected due to a significant usage deviation from the home data records, or in case of fraud volume, the usage data report will have to be re-uploaded until agreed by both Parties.
- Discounting agreements could be automatically renewed for a given period.
- The TAP charges could be provisioned to compute the net position between partners
- At the end of the settlement, the breakdown matrix from and to each TADIG code could be generated.

8.1.3. Commercial Integration

It is expected that by the end of the MVP2, two parties could run end-to-end any type of settlement from the User Interface (refer Figure15). To automate the processes, and targeting a production launch, APIs will have to be developed to open the legacy solutions to the Blockchain network. In addition, APIs providing and east-west interface amongst BWR and other settlement solutions running on the same architecture will need to be developed. Current signature processes will have to be integrated smoothly in the solution.

The roaming IOT discounting process may run for early adopters at this stage. All the conditions to launch it in production must be completed.

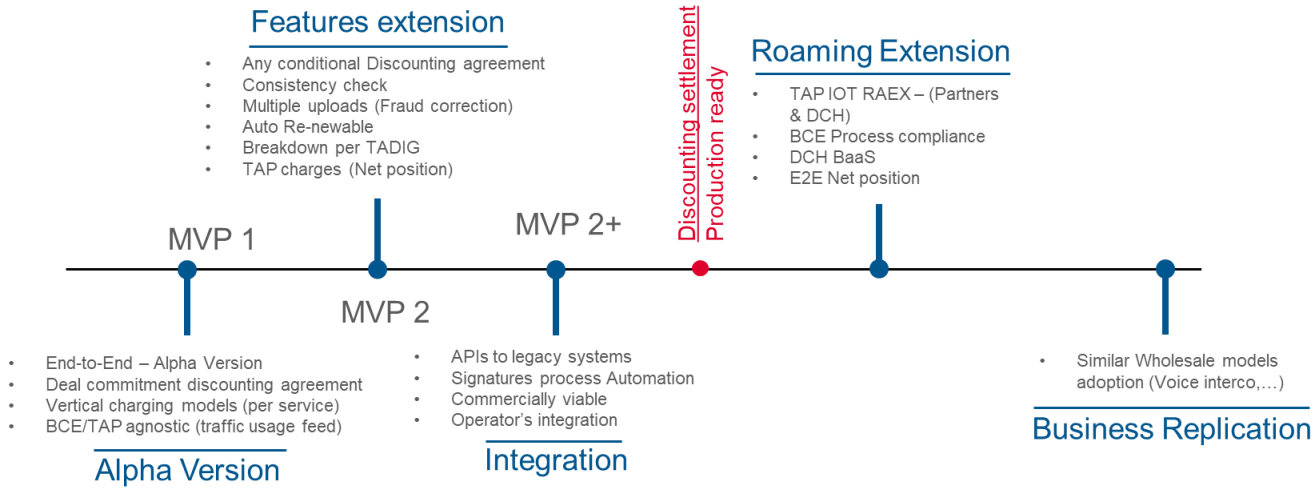

Figure 15 Roaming Services Roadmap

After completing the discounting process, BWR workstream could assess the extension to the global wholesale roaming agreement process. For example: RAEX IOT and Op Data integration. In this scenario, the IOT reference used for the TAP process will have a unique source of truth and will reduce the rejects & disputes. It means that DCHs could use this agreement to compute the charges as well. Therefore, the net position could be computed without having to provision the TAP charges. Roaming agents (DCHs, FCHs) could provide the Blockchain as a service (BaaS) to integrate any roaming partner to the solution. BCE reports could also be carried over the Blockchain network. Note that the dispute process will be handled separately between the two partners.

8.2. Migration from legacy to future

When considering a move from current settlement processes to a Blockchain based settlement, operators will need to consider many different potential impacts. As it happens, these considerations may not be too different from what an operator would consider when implementing BCE. There is an obvious opportunity here to make BCE blockchain native and streamline this investment upfront. The main processes such as contract management, data clearing and settlement itself will be discussed later, but it's important for operators to look at other processes such as booking (and other accounting activities), various reporting, forecasting, or other ad hoc analytical processes. For example, operators may use TAP or related settlement data in forecasting future agreements, accounting may book journal entries, and operations team may use the detail data for investigation purposes or validations. These are all important activities that often rely on TAP and other data generated for, or from the settlement data. Operators need to take special care to ensure the needs of these other processes are included in migration planning. Additionally, care should be taken to ensure no data is duplicated between a legacy settlement process and a blockchain process. Therefore, a careful, gradual, stepwise approach is recommended. Future MVPs will be enhanced with more robust reporting capabilities to help mitigate operators' impacts.

8.3. Current to new processes

In the following sections a current high-level state of roaming settlement will be covered and approaches that may be taken as part of a move to MVP1 and beyond.

8.3.1. Contract Management

Contract terms, and the associated commercial model, are at the heart of today's settlement process and that will be true for any blockchain based settlement process. Operators today will have a multitude of different processes related to contract creation, signing and storage. Much of which can remain if desired in the initial steps into the MVP. The MVP does allow for signing of a contract by an authorized party and will allow for the export of the terms in a JSON format. The process of contract creation in the MVP could be an extra process or can be integrated to an operator existing workflow. In today's world the data from the contract would be communicated to a person or team responsible for updating various reference tables to ensure rating of TAP usage is per the contract. Since both operators must do this there are effectively two sets of rates, entered by different teams in different systems, which is a source for error in today's process. The additional source of error is due to reliance on an agent (the DCH) to replicate a rate that is different from the one defined in the RAEX IOT. Having all the parties connected to same source of truth will minimise such errors. What is unique with respect to the blockchain process is that there is only one copy or version of the contract, whose hashed value is stored on the blockchain ledger. After one party loads the contract details, the MVP will require the roaming partner (or an agent acting on its behalf) to also validate and sign the details of what was loaded by their roaming partner. The hash value stored on the blockchain ensures the information the partner receives is identical to what was loaded. Once the contract has been signed by both parties it is considered final and the blockchain is updated and serves a single source of truth. With the storage of the hash on the blockchain, the terms are immutable and there is no room for disagreement on the terms or rates.

The contract inside the MVP contains relevant operator information and can be for one or more TADIG codes. Also, the MVP supports several discount models including flat, linear, threshold back to first, threshold tiered, and balance/unbalanced. Additional models would be part of a future effort.

Sample flow:

1. MNO A creates a contract proposal
2. MNO A signs contract & sends it to partner
3. Contract is stored in local off chain database and hash value is stored on the blockchain
4. MNO B can receive contract from MNO A and hash value stored on the blockchain enforces the details of the contract must match what MNO created since the hash values must match
5. If MNO B accepts the contract, MNO B signs it
6. Contract with MNO A and MNO B signatures is hashed, and result is stored on the blockchain
7. Smart contract terms are final and can now be used in a future settlement

As a pragmatic approach towards moving from current contracts to Blockchain based contracts project team suggests a parallel approach. In the first year of operations blockchain process can run in parallel to existing process as a confidence building measure. In parallel parties can agree on new framework agreement for Year 2 of blockchain operations where they can use a blockchain based discount letter. In Year 2 of operations existing process can be replaced by blockchain for the participating partners.

8.3.2. Data Clearing

In today's TAP based processes, usage records are sent daily to a data clearinghouse where they are forwarded and ultimately arrive at the HPMN for processing. For the MVP this process was leveraged and aggregated information from TAP was pulled for input. Just as TAP is the input for what is settled today, the same happened for the MVP. Certainly, in the future support would be added to use data from a BCE report, thus allowing a Blockchain solution that is compatible with BCE replacing TAP. In the case of the MVP the loading of this data was a manual process but could be automated in future MVPs. An example of the aggregated usage data can be seen in Table 2 below.

Year/Month	HPMN	VPMN	Direction	Services Categorised	Usage	Units	Charges	Taxes
202001	OP1XX	OP2yy	Outbound	MOC Local	3000.05	MIN		
202001	OP1XX	OP2yy	Outbound	MOC Back Home	5800.92	MIN		
202001	OP1XX	OP2yy	Outbound	MOC International	205.67	MIN		
202001	OP1XX	OP2yy	Outbound	GPRS	1399141.90	MB		
202001	OP1XX	OP2yy	Outbound	SMSMO	6705.00	SMS		
202001	OP1XX	OP2yy	Outbound	MTC	4562.67	MIN		
202002	OP1XX	OP2yy	Outbound	MOC Local	4000.05	MIN		
202002	OP1XX	OP2yy	Outbound	MOC Back Home	3800.92	MIN		
202002	OP1XX	OP2yy	Outbound	MOC International	105.67	MIN		

Year/Month	HPMN	VPMN	Direction	Services Categorised	Usage	Units	Charges	Taxes
202002	OP1XX	OP2yy	Outbound	GPRS	2300045.90	MB		
202002	OP1XX	OP2yy	Outbound	SMSMO	4505.00	SMS		
202002	OP1XX	OP2YY	Outbound	MTC	3462.67	MIN		

Table 2 Aggregated Usage

For the MVP, once the aggregated data is loaded, it undergoes some general validations, and the details of the contract are used to create a usage report that contains the usage volumes by service for each TADIG by month and that was loaded for both inbound as well as outbound traffic. This usage report uses the same layout and aggregation as the figure above.

This data is not stored directly on the blockchain but rather in a separate local database. However, hash values representing the data are stored on the blockchain thus making them tamper resistant. Additionally, this allows the roaming partner to be able to access the usage report via an internal SFTP transfer. In future MVPs, more of the summarised usage data could be stored on the blockchain itself.

8.3.3. Settlement

At the end of each settlement period, reports of the TAP files exchanged, RTDRs are used as backing for invoices. Each receiver of an invoice can reconcile what was received in TAP versus what was on the invoice. This is repeated monthly with a true up being done periodically, usually annually, where past invoices and usage are reconciled, and any necessary credit or debit notes are created. This would also consider any special arrangements of the contract, such as commitments, tiers, etc. This work can be manual and quite time consuming, thus introducing risk for error. In a Blockchain solution much for this work could be highly automated.

In the MVP, the aggregated usage for the period is retrieved and reconciled between the VPMN and HPMN roaming usage data. The terms of the contract are used as needed in related calculations. Any reconciliation discrepancies can then be viewed in a report (refer Table 3 below).

Bearer	Unit	Own Usage	Partner Usage	Delta (abs)	Delta (%)	Own Calculation (post commitment)	Partner Calculation (post commitment)	Delta (%)
MOC	min	239 348 365	238 738 452	609 913	0.25	8 352 503	8 333 897	0.22

MTC	min	106 728 666	106 708 776	19 890	0.02	0	0	0
SMS	SMS	26 129 164	26 142 111	12 948	-0.05	159 517	159 568	-0.03
Data	MB	4 565 953 059	4 566 025 417	72 358	0	16 848 930	16 849 038	0

Table 3 Discrepancy Reconciliation

The net position is also calculated and can be viewed as well (refer Figure 16 below).

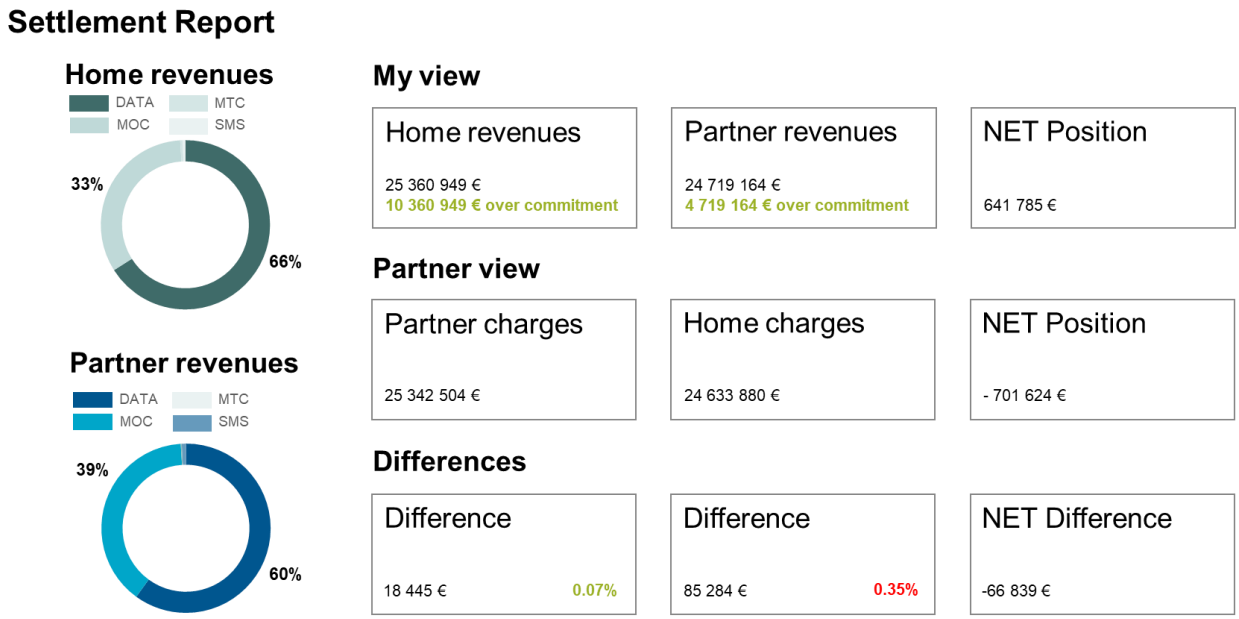

Figure 16 Net Position

If both the operators agree with the resulting position and any discrepancies are explained or are considered immaterial, the operators can now complete the settlement. Additionally, they can agree on how to handle any discrepancy amount (perhaps with a 50/50 split).

These last two reports used the power of the smart contract to calculate the positions of each operator per the terms of the contract without the need for any manual intervention.

8.3.4. Payments

In a typical settlement process once the operator positions have been finalised, funding and payment transfer can be done. The above calculation does not consider what has been paid already (TAP charges). To calculate the actual payments due, one would have to calculate the following: TAP charges (undiscounted) – discounted charges (discounted) = net position. This would have to be compared to the net position of the roaming partner using their own data and one would have to settle & agree somewhere in between. This settlement dispute management workflow is not (yet) implemented in the MVP. Depending on the setup of the roaming partners,

further breakdowns of the settlements (e.g., by TADIG) may be required. Only then credit/debit notes can be generated – either on a group level or even on a TADIG level, and only then a payment would be released. How the payment and money transfer might happen was not part of MVP1, however, doing so is a longer-term goal. It may be possible for a Blockchain settlement solution to incorporate a payment based upon some e-currency, perhaps an eSDR, since SDR is already familiar with operators today. Operators would need to obtain the chosen e-currency and then could have payments recorded on the blockchain. In this scenario operators may only need to exchange to/from an e-currency and may not require a bank for payments. With this last component a truly automated settlement that simply needs approvals at a few key steps could become reality.

9. Conclusions & Recommendations

In conclusion, through multiple proofs of concept (PoCs) & MVPs blockchain technology has shown potential in automating the time-consuming discount settlement process. While MVP1 provides only basic functionality, it proves that pricing dispute situations in the industry may be largely avoided and likewise blockchain can enable faster settlement through automation.

The BWR group will continue experimenting with new release candidates which may be rolled out in MVP2 post an industry wide prioritisation exercise. Whilst the scope of MVP2 has not been set, MVP2 potentially intends to enhance the blockchain architecture, if possible, integrate solution with other DLTs, design solution for BCE process, provide further breakdowns of volume & settlement discrepancies for example by TADIG codes and identify means to integrate with legacy IT environments. A key aim here is to close the gap between a commercial grade solution and the MVP solution to make a commercial transition easier. Initially a commercial roll out may look more like a parallel run which could be operationalised once enough confidence is built in the system. Furthermore, it is evident that the technology may have further upsides in other areas such as fraud and instant digital payments which can be explored.

The BWR group has the following recommendations as a path forward:

- Based on the gap assessment completed, plan future MVPs with a clear path towards a commercial rollout.
- Open group activities to involve larger membership for further socialisation of the MVP outcomes and greater participation in future work.
- Encourage GSMA members to participate in MVP2 and future development.
- Explore how the BWR test network can be expanded to new operators for a holistic and wider assessment of benefits.
    - Enable more GSMA members to both set up and test with MVP1 test set-up.
    - Educate GSMA members on setting up BWR blockchain node.
- Potentially explore new use cases such as use of blockchain technology in other wholesale settlement use cases, identity management and payments.

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