When Borders Blur - Overcoming Political Limits with Computing in Truly Global Societies

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ABSTRACT

The Internet and standardization of communication mechanisms worldwide has made it possible for a truly interoperable world, blurring the physical borders between countries. With the effective liberalization of borders, and increased human movement across geographies, has come rapid economic growth. However, this growth due to the free flow of ideas, people, and goods is foundationally limited due to the inefficiencies in human processing capabilities due to gatekeeping by governments exerting control over its borders (eg. through visa processing, permit controls, regulation etc..,). While a completely borderless world of governments analogous to the design of the Internet might sound naïve, the European Union stands as a testament. Furthermore, advances in transportation have increased the efficiency and reduced cost and time of travel, and will continue to improve allowing for and building economic structures involving a greater and frequent geographical movement of people. In such a world, the processing time for visas and other similar gatekeeping mechanisms present as the main obstacle to seamless human movement. Recent advances in cryptographic techniques, and decentralized architectures are starting to point towards a world where identity management and verification can become more secure, private and automated, thereby reducing "passport privilege" and slow human processing times. In this paper, we envision and sketch an interoperable digital government identity and automatic verification systems aimed to allow governance structures while overcoming the limits of human processing. Through this case, we aim to draw more attention to the limits of human processing that exist even in the most developed countries, thereby freeing valuable human resources towards more productive activities.

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1 INTRODUCTION

As the countries of the world have been brought closer than ever before through technological progress in travel, we are still separated by political borders in the visa processing system. The International Air Transport Association (IATA) forecasts 8.2 Billion air travelers by 2037 anticipating a 3.5% compounded annual growth rate and identifies an eastward shift in air traffic with Asia-Pacific region driving the biggest growth [8]. As air traffic becomes safer and more affordable, we are seeing trends towards reusable orbital rocket transportation such as Starship which proposes to drastically reduce the time needed for human movement across geographies (e.g. a travel time of 29 minutes to travel between London and New York compared to the 7.5 hours today) [46]. At the same time, it is a difficult challenge to have a non fossil fuel energy source for air travel due to the extremely inefficient energy storage methods available [35]. These issues suggest a rethinking of the future of cross country travel, using computing to improve transparency, equity and sustainability. As global transportation connectivity improves moving people between continents in the same time it takes to watch a TV episode, we continue to live in times where it takes about three weeks on an average of waiting and a week of processing in addition to hundreds of dollars to process a visa, typically in a non-transparent decision process [41]. Given the direction of global collaboration and the missed economic and innovation opportunities due to visa processing, it is high time we started addressing the limits politics pose in global human dynamics and preparing ourselves for the future while operating within the known limits of computing.

With the issuance of national identities by 175 countries of which 161 countries issue digital identities for their citizens as shown in Figure 1 [9], and adoption of new open source identity systems like MOSIP [34], governments are constantly exploring the development of foundational identity systems amidst technological and policy choices. The recent explosion of digital identity efforts, which governments identify as ways to bring efficiency to government service delivery, have been criticized for potential threats to privacy, exclusion, and transparency [29]. Despite such criticisms, as the usage of these national identity systems become mandated by governments and result in the an ecosystem of providers depending on these identities to trade goods and services, it becomes extremely important to bring attention to the *interoperability* of said identities and define the notion of trust between governments. In fact, we argue many benefits including the tamper-proof storage of the digital identities on blockchain allowing individuals to protect their

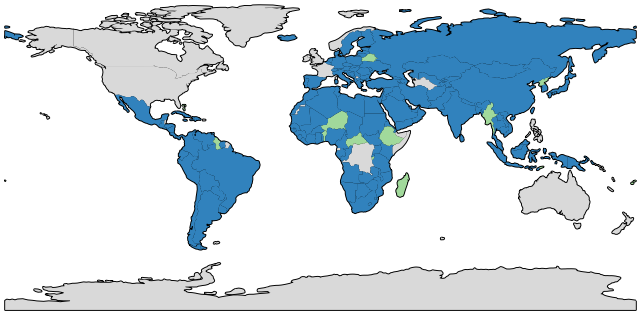

Figure 1: Countries issuing Digital National Identities. The countries in blue are those which issue digital national identities, the ones in green including the blue ones are those which issue national identities for their citizens, and the countries colored gray are those which do not have a national identity system.

information and make people aware of who accesses their data. In this paper, we aim to address the limits in seamless human mobility due to visa processing inefficiencies by leveraging digital identities, cryptographic techniques, and designing with privacy in mind.

For the rest of the paper, we describe the current format of the visa processing system, discussing the stakeholders and highlighting the bottlenecks caused by the limits of human processing. We then propose a a blueprint for an automated visa processing system. Finally, we discuss the implications of our systems as well as its limits as viewed through a computational and political lens.

2 BACKGROUND

Over the past few centuries, humans have drastically changed the landscape of travel from taking months to go around the world to a matter of hours. By the late 1400s, it took about 2 months for Columbus to Over the past few centuries, humans have drastically changed the landscape of travel from taking months to go around the world to a matter of hours. Columbus took about 2 months to cross the Atlantic by the late 1400s [13], a time that dropped to 4 days in the mid 20th century [1] and currently a record of 3.5 hours [15]. In 2008, the International Space University published a paper [6] about point-to-point long distance suborbital transportation that could cut the time to travel from New York to London to about 1.25 hours. This proposal has been reviewed by the Federal Aviation Administration [26] on feasibility and further being actively explored by SpaceX whose Starship project promises to cut down the time to 29 minutes [3, 46]. In addition, there are other proposed modes of travel such as Hyperloop, Maglev and High Speed Rail [60] that promise to improve speeds on the state of the art of transportation. These innovations point towards a future that brings countries around the globe even closer together than we already see today in the era of commercial air travel.

Advances in cryptography and their practical usage have resulted in various sectors ranging from healthcare [25] to banking [24] and indeed travel [44] adopting the technology to securely transfer information. Countries have also been increasingly adopting hardware security modules (HSMs) in digital national identity systems for authenticating and verifying electronic records through formal policy and regulatory changes [17, 58]. The current implementation and issuance of digital national identities however do not harmonize across countries with the different types of cards being issued, carrying different personal data in both protected and unprotected manners, in addition to variable ability to store additional documents on the card [50]. The number of government authorities running Public Key Infrastructure (PKI) and included in the root trusted certificates of the world is heavily skewed with a disproportionate number of CA authorities in the United States. This skew indicates a global challenge and the need to create an ecosystem of audited PKIs in an effort to establish trust between governments [55]. With the recent adoption of blockchain technologies in e-governance, governments have been actively engaging in discussions around organizational readiness, risk management, acceptability and usability of these systems and establishing auditing mechanisms [10]. These discussions and promising regulatory changes foreshadow a future where such technologies are widely and successfully adopted to decentralize trust within various countries. Governments are therefore expected to begin putting in place the necessary infrastructure to address the challenge of rapid global human movement and the limits of current political gatekeeping structures like visa processing [40].

Existing credit scoring systems can also provide insight into methods to not only automate the visa verification process but also extend access to underprivileged persons who don't have access to conventional financial credit scores. For example, to get a mortgage for a house, take a loan, or purchase insurance in the United States, one would need a credit score [54] that indicates ability to pay back debt. This credit usually comprises factors such as payment history on credit cards, amount of debt owed, length of credit history, etc. that are used as a proxy to estimate a person's financial risk. In fact, such scoring systems can tell more about individuals including inferred relations between credit score and health outcomes [30]. Yet these systems have been criticized for historical and racial biases, with many low-income neighborhoods having higher credit invisibility (no credit history with nationwide credit reporting agencies) and little information on how to understand and improve credit scores [14]. This brings forward the need for governments to address the challenges due to the non-transparent nature of these systems and use digital national identities as mechanisms for citizens to establish these scores, their consented usage by credit agencies, and private maintenance of the information. More inclusive methods for low income citizens have been experimented with using mobile credit history from Mobile Network Operators (MNOs) [4] in developing countries as well as using agricultural property and outcomes [2] and can be extended into a more holistic score to be used across country borders.

A major bottleneck that threatens to reduce the ability to fully realize the promised speed in movement around the world for global trade and business, tourism and diplomacy, is the gatekeeping functions like the visa processing and trade permit processing systems. These systems regulate whether a person, or entity is allowed to travel between countries and as such individuals from countries that do not have a prior visa waiver program cannot travel without the visa. However, visa processing experiences significant delays caused by a myriad of factors. Many of these factors though are as a direct result of human resources in the visa processing pipeline. The

Finnish consulate in Russia for instance allows only Finnish citizens, typically a fixed number of employees, who take holidays and other leaves, to make visa decisions for a demand that is seasonal [36]. Again, embassies and consulates contract local service providers, typically providers serving multiple countries, to perform an initial screening of applicants before forwarding the information for further screening by the officials [22].

3 UNDERSTANDING CURRENT VISA PROCESSING & VERIFICATION SYSTEMS

3.1 Stakeholders in the Ecosystem

While the stakeholders in the visa application process could differ between countries, using some of the current processes and data required in various visa applications, we infer the stakeholders of the ecosystem at a high level which would be necessary to implement the design as proposed in section 4.

(1) *National Identification Systems* are digital or physically issued identities potentially backed by biometric information containing the personal information of the individual for example the name, date of birth etc.,
(2) *Individuals* who are citizens of a country using a government issued identity and performing the application for a visa.
(3) *Registrars* who provide the information and verification for births, marital status.
(4) *Immigration, citizenship, and travel systems* maintain the travel history of the individuals, intention for travel, information about family etc..,
(5) *Education, Vocational & Work registry* containing the information and proof about the educational qualifications, current work experiences, and training.
(6) *Banking and Financial institutions* are responsible for both processing application and administrative fee while additionally providing necessary proof of income, or active balance in the account by attesting bank statements, investments or income tax filings.
(7) *Medical and Healthcare instutions* are required to furnish proofs of an individual's health status, disability, and vaccination records especially during travel to specific countries as seen during the COVID-19 pandemic.
(8) *Government authorities, embassies, and consulates* form the core of the process and are responsible for collecting the necessary personal information, intent, and performing necessary background and security checks to determine the authenticity of the individual before issuing a visa.
(9) Lastly, Authorities which maintain the *security, and judicial* records of the individuals, their civil and criminal histories if any are used by organizations like embassies during visa processing, employers in the process of hiring employees and are termed as *background checks* which are a critical part of the process.

In this paper we focus on the the visa processing ecosystem but our proposal can easily be extended to international trading systems for importing and exporting goods, though with the possibility of including new stakeholders.

3.2 Current Workflows & Role of Computing

An individual with the intent to travel for business, or pleasure goes through an application process starting from an online or a paper based system provided by the embassy, consulate or a contracted visa processing agency. Through the application process, the individual fills in the information regarding themselves, the identity (passport) they would like to use, self attest questions regarding marital status, income, education, medical and any criminal proceedings against the individual. Once complete, the individual applicant attaches attested copies of all necessary financial, medical, travel and legal proofs obtained from the various authorities in their country. This process could be time consuming, and error prone due to the limitations of manually filling in the information into the form if done online within a fixed time duration before the online session times out. The process of visa applications is extremely dreaded by individuals and has given rise to various consultancies offering visa assistance services. There is however, no guarantee of how these organizations maintain and process sensitive information regarding the individual applicant, leading to possible identity theft and fraud. To counteract these possibilities, visa application websites belonging to various countries publish disclaimers indicating that there are no special connections with such consultancies and urge individuals to never sign blank forms or applications [18]. The individual submits an attested version of the documents for processing and consideration by the respective country embassy. Some countries also require individuals to schedule an in person interview with the officer issuing the visa as a means of validation of the information in the application and establishing a proof of *personhood* by the consented record of biometric information like fingerprints or iris scans.

For example, the Visa *Wahala* is a popularized term West Africans use to refer to the troubles that the understandably dreaded visa application process comes with. One of the main reasons for the rejection of a US visa application is "Incomplete Application or Missing Supporting Documentations" [5]. If the consular determines they need more financial evidence, it might take twice as long for an applicant to get their visa - a process that already takes a month or more from the start of the visa application process.

Additionally, there is very little public information about the workflow between the receipt of the visa application of the individual and the issuance of their visa with average time for the United States visa application process between 3-5 weeks from the date of application. We optimistically estimate that it'd take an additional week of preparation of all necessary documents with their attestations before the application can even be submitted resulting in total average time of 4-6 weeks for the entire process. The lack of transparency in the workings of the visa application process results in individuals resubmitting their applications and potentially trusting third party individuals or organizations with false claims guaranteeing the visa. Governments across the world have been under immense pressure lately due to the "cryptic" decision making and usage of algorithms in visa processing highlighting the risk of bias and poor practice forcing governments to publish more information publicly about any verification and application prioritization or "streamling" tools to assess risks associated with visa applications [56].

3.3 Challenges with Current Practices

The current visa processing practices by various governments across the world face tremendous transparency challenges. Additionally governments also maintain detailed personal and sensitive information about the applicants sometimes including their biometrics posing significant risk to privacy and identity if the systems were subject to a cyberattack or data leakage. Such attacks are not a distant reality and have been successfully carried out in the past [47]. Embassies and consulates processing visa applications today collect as much information (if not more) about the individual as the individual's own country keeps without any public information about data retention practices. This information is also scattered and available with third party organizations providing services like the background screening, biometric storage, or paper based filing mechanisms posing a significant privacy risk.

In addition to the privacy risks and the lack of transparency, the visa application process is itself expensive costing at least 160 USD for the most common non immigrant visa to the United States for example, despite improvements to visa processing to spur economic growth [42, 53]. This is higher than the average monthly income of citizens in 10 countries (Democratic Republic of Congo, Afghanistan, Sudan, Ethiopia, Haiti, Burma, Pakistan, Cameroon, Cambodia and Kenya) and is greater than 50% of the average monthly income for 10 others (Bangladesh, Timor-Leste, Nigeria, India, Vietnam, Egypt, Morocco, Ukraine, Bolivia, and Philippines) [19]. The visa waiver program in addition allows citizens from select countries to freely move between home and another country making travel a privilege which only a few can afford. Millions of people and refugees around the world are economically restricted from easy movement and improving their livelihoods by seeking work, or providing services.

The documentation required is also challenging to obtain for many individuals in various countries due to lack of public infrastructure, type of government, and corruption. As a proof of income, many visa applications require an attested version of the current value of investments and holdings from banks and income tax filings. Some countries do not have tax structures in place and in some countries the banking structure might differ with mobile or neo-banking (online-only banking) being more heavily used than conventional physical banks offering digital services. To adapt to this, the visa application process differs heavily based on the country where the individual is requesting the visa. For instance, an immigrant residing in a country where they are not a citizen is typically requested to travel back home to the country of citizenship or provide similar documents as those in the country of citizenship during visa processing.

In poorer countries, individuals might not have access to a bank account or a credit card to establish a credit score. However, this is constantly changing with the introduction of innovative ways to estimate the risk of a borrower to establish credit scores. For instance, in Kenya, a large percentage of the population uses mobile phones and load data to have airtime. A proposed alternative credit score for these users is to use top up history for data credit to define a credit score based on which to make financial decisions regarding a borrower. Rural citizens who do not have a bank account (the majority) and therefore no credit history might have a difficult time providing the necessary documentation as a part of their visa application.

In addition to the challenges of cost, the visa application process is fraught with many inconsistencies and is time consuming due to the nature of security needed. For instance, for some consulates, making a payment with a credit card other than one issued in the country of application can result in a locking of the application which unlocks about two weeks after the application attempt and requires a restarting of the application process [7]. If the applicant were a student starting school, they could miss the beginning of their school year. One of the authors of this paper had to skip a conference he was to present at in Graz because he couldn't renew his US visa in time during his last year of study on that US visa. During a more difficult period such as the COVID 19 pandemic, 5-8 months of processing time was added to the visa application process [12].

The current practices for visa processing favor those who are economically advantaged and as more countries tighten up their borders, it resulted in the development of a new industry aimed at trying to bypass those restrictions by creating an investment based citizenship [11]. However, with the improvements in global travel making it safer, quicker and affordable along with improved connectivity and opportunity, computing could play an important role in establishing equity for individuals.

4 PROPOSED SOLUTION

With the understanding of the ecosystem and the challenges in current practices, we propose a solution which aims to achieve various design goals we describe in section 4.1 by making the necessary security assumptions. In the proposal, we detail the various components and public infrastructure which are necessary to make a system like this possible.

4.1 Design Goals

4.1.1 Security Assumptions. In the design described in this paper, we make the assumptions of a trusted relationship established between the country's citizens (individuals) and the public infrastructure which is operated by the country. Each government operates a network consisting of the ecosystem of stakeholders with secure networking protocols being used for any data exchange and communication. The stakeholders are vetted through an offline one-time process as a part of enabling the user to connect and participate in the secure network. As a part of the one-time process, the public key ownership of the stakeholder is identified, bound to a set of identities from a digital national identity system and attested by an organization within the respective country's government with the appropriate root of trust indicating the current hierarchies in government structures. For example, all educational institutions are issued cryptographic certificates binding their institution public keys signed by the respective authority (eg. University education body) attesting the institution who is further signed by the country wide authority (eg. Ministry of Education). Each country operates as a node on the global government network and *peers* with other countries on the network. We assume that individual systems like the public key infrastructure, national identity system, immigration

Stakeholder	Challenge	Design Goals
Individual	Lengthy processing time for visa application	Realtime / Near Realtime
Individual	Expensive application fee and attested proof collection	Realtime, Security
Individual	Reveal and share only the exact amount of information necessary	Security, Privacy
National Identification Systems	Establish proof of personhood and issuance of attested digital identity	Security, Privacy
National Identification Systems	Establish interoperable communication and query mechanisms	Security, Privacy
Registrars	Bind identity and issue proofs for birth, marital status etc.„	Security, Privacy
Immigration Systems	Minimize risk due to entry of the individual and understanding intent	Security
Immigration Systems	Maintain the records of proof of entry and departure	Security
Travel Systems	Identify and maintain travel history of an individual and issue proofs	Security
Educational Organizations	Establish individual's proof of education status	Realtime, Security
Educational Organizations	Indicate proofs of invitation, sponsorship or request issuance of visa	Security, Privacy
Employment Organizations	Establish individual's proof of employment status	Realtime, Security
Employment Organizations	Indicate proofs of invitation, sponsorship or request issuance of visa	Security, Privacy
Banking and Finance Institutions	Establish proof of funds, tax payments, credit scores, debts	Security, Privacy, Realtime
Medical Institutions / Healthcare	Establish proof of health status, disability or vaccination records	Security, Privacy, Realtime
Govt. authorities, Embassies	Time taken to process and screen the visa applicant	Realtime / Near Realtime
Govt. authorities, Embassies	Establish risk due to admission, intent for travel	Realtime / Near Realtime
Crime, Defense and Judicial	Establish proof of criminal activity, military ties or pending legal cases	Realtime
Govt. authorities, Embassies	Mitigate and risk due to attacks compromising the visa/immigration data	Security, Privacy
Govt. authorities, Embassies	Transparency in visa decision making process	Transparency
Govt. authorities, Embassies	Request more information on demand reducing any wait times	Realtime
Individual	Audit trace of all information requested, processed and stored	Transparency

Table 1: Challenges faced by various stakeholders in the visa processing ecosystem

and travel systems, banking etc.., are secure individually with access to various communication endpoints being tightly controlled.

4.1.2 Guarantees. With the goal to improve efficiency and overcome human and political limits in the visa application process, the proposed system also aims to provide the various stakeholders with guarantees of security, privacy and transparency.

While the citizens trust their respective governments to issue and maintain the identity information, the proposed system should only allow the consented usage of the individual's information with a transparent trace of all entities who have requested the information. Cross border interactions between government systems need to be secure and the information shared have a verifiable cryptographic binding to prove recency and integrity of the data and proper functioning of government bodies.

Any failures resulting in denial of information either selectively or due to infrastructure unavailability (downtime) can be publicly recognized with peering countries notified. Additionally, any attempts at tampering with the integrity of the individual's information can be identified with proofs of tampering being publicly published for other governments to take any necessary actions.

4.2 Components of the Proposed System

In this section, we detail the different components of e-governance and visa issuance infrastructure which form the building blocks of the of our proposed system.

4.2.1 National Public Key & Signing Infrastructure (NPKI). Each government maintaining the digital identity of their citizens provides the ability for its citizens to perform digital signatures on any document [37]. The citizens are issued identities through the NPKI infrastructure backed by biometrics for exclusively identifying individuals. The infrastructure also validates and establishes the certificates for educational, financial and healthcare institutions.

4.2.2 Digital Documents Storage Service. Various stakeholders certified by the public key infrastructure provide signed attestations for an individual attached to their national identity. The documents attested are made available to each individual using a digital documents service. Such public infrastructure is actively being implemented by various governments (DigiLocker in India [39]) storing important identity and documentation such as educational / professional qualifications, healthcare information, drivers license etc.., The service holds both signed metadata and issued documents which could be made selective available during interactive automated visa processing applications.

4.2.3 Global Government Blockchain Network. As an effort to digitally replicate the political situation, we propose each hierarchical structure within the country to interact with various systems internationally using a blockchain network. A blockchain allows a set of participants to create a shared and tamper resistant ledger of transactions that are validated by a consensus mechanism among them. Such a network decentralizes trust among mutually untrusting participants by creating transparency and accountability through collective verifiablity [45]. Connecting governments across the world and their stakeholders within the country using a consortium blockchain network allows policy adherence by ensuring strong accountability with interactions and data requests being maintained in a tamperproof ledger for transparency. Democratic governments

can use this level of transparency - a statement that even the government would not tamper with the citizens' data - to establish higher levels of trust with their citizens.

4.2.4 Local and Global Auditors. While the blockchain network connecting different governments across the world maintains privacy and transparency of interactions, it becomes important to have an ecosystem of auditors who probe various governments for proofs regarding tamper resistance. These *global auditors* are responsible for scanning the ledger and identifying instances of forgery or attempts to perform (selective) denial of service attacks. The *local auditors* are public auditors (individuals, altruistic citizens) who probe the public identity infrastructure for correct maintenance of keys and maintain an append-only log of digital signatures which are issued - similar to the certificate transparency ecosystem of today's Internet. Prior research has established the role of auditors in bringing transparency to systems where the public keys are maintained in a key directory repository [16, 32].

4.3 Proposed Workflows with New Systems

With the proposal of the components of the ecosystem, in this section, we present our proposed workflow to address the challenges described in the current visa processing ecosystem and detail the experience of an individual intending to travel across international borders.

4.3.1 Public Key Infrastructure. Each country maintains a national certificate authority (CA) and an ecosystem of sub certificate authorities (Sub-CA) responsible for auditing, validating and issuing the necessary credentials for necessary stakeholders like healthcare institutions, identity systems, educational institutions, registrars and more. The CA authority publishes their self signed root certificate $C_{\mathrm{CA}_{\mathrm{root}}}$. The certificate authority and the sub certificate authorities as designated by the respective countries form the public key infrastructure which is publicly shared with other countries over a government blockchain network. The transactions to the blockchain network include the issuances, updates and removals of certified stakeholders. The issued certificates allow stakeholders with valid certificates to participate in the blockchain network.

4.3.2 Verifiable Credentials. Verifiable credentials defined by W3C [57] operate like physical credentials (eg. passport, driver's license, etc) in that they hold similar information regarding the individual's identity, the issuing authority, information regarding the type of credential, constraints (such as expiry date), along with a host of other need based information such as nationality and date of birth. Verifiable credentials however have the added advantages of not only being machine readable but also tamper evident and privacy preserving. In our system, we are most interested in properties such as zero-knowledge proof and selective disclosure.

4.3.3 Individual & System Interactions. A citizen of a country A intending to travel to another country B uses their government issued digital identity indicating the intent. The identification could be provided as a digitally signed record from the national digital identity system. The visa processing systems of country B can verify the authenticity of the data presented and verify the root of trust established by the CA of country A. The individual's consent to share the identity information is recorded over the blockchain network along with the validation status as seen by the visa processing systems at country B. To complete the visa processing, the system requests for financial proofs, education and work information, health (vaccination) records, invitations from sponsors in country B. The individual completing the visa application process, uses their national digital documents storage service to retrieve signed documentation of education, work, or information like a sponsors letter. Using the verifiable credentials scheme, it becomes possible to selectively only reveal the information corresponding to attributes such as *current account balance*, *monthly average balance*, or *age of credit history* without revealing the information of all the transactions made by the individual. The banking institutions for example, receive the request from the visa processing system of country B and validate the public key, web of trust, corresponding to the requesting authority along with the consented list of attributes to share. This attribute policy is encoded and encrypted to be received by the requesting authority. The encrypted information is further attested by a cryptographic signature from the banking authority and further attested by the individual using a similar cryptographic signature. The signature from the banking authorities legally binds the requested results and their correctness, while the signature of the individual visa applicant binds their acknowledgement of the correctness. Using a zero knowledge proof [23], it is further possible for the visa processing system of country B to challenge the delegated stakeholders in country A (banking, identity etc..,) to prove the correctness of the data and its history. On successful completion of the application and the result of the various data verification protocols, the visa issuance process generates a cryptographically signed and encrypted response for the individual indicating the approval of the visa. With identities such as e-passports having the ability to store secure information, the issued visa token could be stored during check-in in the country of departure, printed as a QR code or made available through a secure mobile application to the individual.

Ongoing efforts by the department of homeland security (DHS) in the United States indicate the desire for governments to explore the opportunities enabled by blockchain technologies [38]. Combined with the correct implementation of the various components described in this paper, the visa processing system could be automated to be efficient, overcoming the limits of human processing and improving the ability to move between countries.

4.4 Challenges Addressed

With the proposed system, we address various challenges in the visa processing ecosystem and improve the security, privacy, and transparency of the process while reducing the lengthy processing and application time drastically. In this section, we detail how the design goals are achieved by different stakeholders.

Citizens of countries are now able to automatically and securely use their digitally issued national identification schemes and identity bound services within the country like banking, education, registrar services for completing the request for information needed for an application process on demand. With the ability to selectively request only the necessary information to be revealed it becomes possible to improve the privacy and control which information is

shared across countries. Governments receive attested and verifiable information necessary to make required decisions. All the interactions with user data is logged in append only verifiable data stores providing individuals a detailed trace of the types of data requested by the visa application from various entities allowing a correctly authenticated individual to view the details of the information shared enabling transparency in a traditionally non-transparent process. The system due to its near realtime nature of processing allows many more individuals to be processed in the same time and reduces the exorbitant costs for visa applications making them more affordable. Streamlining the process by involving a digital identity system reduces the number of third party consultants and probabilities of fraud resulting in identity theft or careless maintenance of personal data of individuals.

The national identity infrastructure can transform service delivery by the government to its citizens by bringing together cost effectiveness and increased efficiency while maintaining the security and privacy guarantees [59]. The public infrastructure necessary to make the proposed system a reality becomes democratic and performs at scale involving citizens in voluntarily performing audits [31, 51]. The blockchain network and append only logs make it possible for building transparent, interoperable and secure infrastructure with which stakeholders such as educational organizations and employers can verifiably and privately provide requesting organizations the necessary proofs securely and in realtime.

Regarding speed of processing, we estimate in the best of scenarios that visa requests will take a matter of minutes to be approved. This is with the expectation that relevant letters of invitation and/or support are already available, requests to authoritative agencies receive timely responses to verify the status of the applicants and AI systems such as improvements on that proposed in [28] are employed to assess the content of the supporting documents. In the more medium term when human receive the collated documents to process, it could take a few days for the reviewers to clear the backlog of applications for approval (instead of weeks).

5 DISCUSSION

In this section, we discuss the limits of our system as situated within the limits of the visa processing system.

5.1 Security & Privacy - Consented Data Usage

Given the security assumptions presented in Section 4.1.1, our proposed system improves over existing visa processing system in terms of security and privacy. Not only is the transfer of information from one government or verification agency to another government properly protected against interception, the proposed system could also ensure that only the necessary information is transferred. For instance, if the destination country doesn't need the *"place of birth"* field of a passport in order to issue a visa, our system will omit that information. In other words, only the minimum required information as requested and consented by the individual to the visa application process is shared, properly protecting a user's privacy.

5.1.1 Trust in Governments. The current proposal places the citizens trust in their government and considers non-colluding governments who focus on protecting the privacy and security of their citizens. However, Collusion between governments and auditors can result in data being shared without any notification or trace to the citizens. Our argument of security hinged on the fact that governments are trustworthy, for example in the sense that if government A requested information about the military status of a visa applicant from government B, government B would respond and with the true military history of the applicant. However, if government B decides to censor such information, government A would either reject the applicant's visa or accept proxy ways of verifying the applicant's information. Our current system doesn't address such proxy ways. Some possible workarounds would be for government A to accept a self declared status along with any proof available from the applicant such as endorsed letter of admission into the military, potential accolades won, duty assignment notes, etc that ideally have authoritative signatures or watermarks. This line of reasoning will have to be expanded on to make the system more robust to delayed or lack of response between governments (which could happen due to factors such as system down times).

5.1.2 Usability and Security Tradeoff. Current implementations of digital national identity systems providing cryptographic signature based attestations result in the national identity system creating, managing and destroying the keys with the help of trusted hardware execution modules [37]. However, an adversary compromising the services maintaining the temporary keys could perform multiple unconsented actions (signing multiple unrelated documents) with the keys. One way to avoid the issue is to provide individuals the ability to generate their own key pair and physically visit a government authority to verify and bind the public key to a national identity. While the keys are now secure with the individual preventing malicious or compromised government authorities from forging signatures, novice users might face usability challenges in key maintenance and its usage with possible loss of keys.

5.1.3 Biometric based authentication. The usage of biometrics in identity systems raises various privacy challenges regarding the storage and retention of the biometric data and the implications if the data is compromised. Given the sensitive nature of these systems, they are prime targets for attackers intending to commit identity theft and fraud. Without biometric authentication (face recognition, fingeprint, iris scans), it becomes possible for an adversary to compel unsuspecting individuals into renting out their identity or collude to perform the same.

5.1.4 Data protection laws. The increasing focus on privacy has resulted in many countries adopting a data protection regulation like GDPR [61], CCPA [43], and PDP Bill [27, 49] to protect the privacy of their citizens. However, there is no consensus between countries about the definition of personal information or private data which could make the implementation of our proposed solution quite difficult. These can however be very easily overcome with completely private channel based communication [20] but would reduce the performance of the blockchain architecture and result in increased computational work.

5.2 Accessibility, Equality and Inclusion

Existing visa processing systems are expensive and affordable only by people above a specific income bracket due to high processing fee.

We estimate that the significantly reduced human intervention in the application process will lead to a drastic drop in processing fees, thereby affording more people the mobility to seek opportunities around the globe. However, biometric systems for authentication that use fingerprints and iris scans to identify individuals inherently might not inclusive towards people with physical disabilities or people who have lost vision or undergone amputations. Biometric information such as fingerprints fade over time for individuals doing hard manual labor and change as children grow into adults requiring the biometric information to be periodically updated for correct functionality. Biometric authentication is also subject to errors with false positives requiring hardware vendors to carefully tune the sensitivity of the biometric devices [21]. Our system ends up allowing governments from different cultures to also decide the proper accessory information to share depending on their socially accepted norms (e.g. whether to present only age instead of date of birth) which eventually become encoded into the policies for requesting data. The transparent nature of the data being requested by the respective country to make a visa decision can be contested by privacy activists resulting in a possible democratic debate and changes to the policies.

While we believe that the proposed system could generalize, the practical implementations and deployment depend heavily on the regulations, policy and the desire of the government bodies in adopting the solution. Each country will have their own interpretations of what the implementation should be and what it means to consider the credibility of other governments based on an audited public key infrastructure. However, with initiatives like MOSIP [34], we may be in the direction of standardized biometric backed foundational IDs underlying inter-government provision of proof of identity. In automating the visa application process, discussions around how consulars determine the applicant's fit for the destination country arises. We propose to use systems such as the credit card system and social credit system to inform the definition of an immigration fit score that automatically determines if an applicant is granted a visa based on estimations of financial responsibility, law abiding qualities, etc. This automated algorithm could have biases that can have serious consequences regarding intended/unintended discrimination against certain groups of individuals [62]. However, there is active and promising ongoing research into algorithmic fairness in automated efforts.

The improvement in the transparency of the process is a step forward towards equality where each individual in the visa application process is treated equally with the same set of decision making criteria. A longer term goal of such a global network would be to achieve equity where policies are changed to allow free movement of economically disadvantaged individuals.

5.3 Expectations on Infrastructure

A potential downside of our proposition is that it expects many infrastructural changes which may take a long while to become a reality. For instance, governments and credit agencies need to actively collect, store and process biometric information about their citizens, build and maintain security practices for the infrastructure to provide a digital identity system followed by mapping individual's credentials, health, and financial records in a privacy preserving manner.

With the improvement in the global communications network, and availability of reliable and fast Internet connectivity, our proposed system could be a reality. However, with increasing reliance on digitization, it becomes important to maintain the services and minimize operational impacts to critical services. In a global network, any failures in operations could result in significant failures and delays affecting the credibility and trustworthiness of the governments putting them under increased pressure and potentially stalling regular operations for millions of people actively traveling.

5.4 Political Limits

Academic and liberal political circles have strongly supported the movement and settlement of people while the opposite argue strongly about the interest of citizens in protecting their accomplishments as a country [33]. Open borders supporters argue that the free movement of people is an essential component of human right to freedom and to build flourishing societies. Those opposing open borders argue that the United Nations' universal declaration of human rights acknowledges that individuals have the right to freedom of movement and residence within the borders of each state and not across countries. With our proposed system, governments who decide to trust each other and who are able to rely on the automated immigration scoring function will be able to truly open their borders to the right people. By governments agreeing to standards on increasing transparency in the visa decision process, individuals can be better informed to prepare themselves as great candidates to live in the destination country. Governments who choose not to be completely transparent can augment the automated system, allowing them a chance to be transparent about certain parts of the decision process. In so doing, worldwide collaboration in academics, trade, etc. will only increase exponentially. Again, since the automated system can make it easier for governments to target activists, immigrants and refugees, it becomes crucial to put counter measures in place. Allowing applicants to legally omit certain information from the application is a first step. The system can keep track of country level statistics on the public ledger on information such as anonymously collating which individuals applied for visas in which category (e.g. refugee seeker, activist, etc) and their acceptance/rejection rates. As more countries buy into this level of transparency, democratic countries that refuse to allow such metrics to be published make an open statement to the world about where they truly stand.

5.5 Sustainability

The usage of blockchain in our proposal despite being a private consortium blockchain results in high consumption of energy consuming up to 10x more energy than centralized architectures [52]. However, we hope that advances in technology will eventually decrease the energy requirement while enabling participation at scale and cause a shift towards a more sustainable outcome [51].

Our proposal's success would also mean a great rise in travel, which could worsen the effects of climate change. This is especially so since solar power is too diffuse to enable air travel as we know it and batteries to power planes by clean electricity sources have far less fuel density than fossil fuels [35]. We therefore need to

consider the ecological side effects of speeding up the travel process. A proposal towards ecological sustainability would be to track each traveler's carbon footprint with a cap placed on leisurely travels. This quota is updated and stored as part of the blockchain. Remote work will be encouraged as much as possible and those whose work truly requires travel can use the full potential of fast travel to improve efficiency. Furthermore, even though this system appears to increase complexity of society as described in [48], we believe that it doesn't do so to the point of causing regression because it merely extends existing and relatively well understood technology (most notably blockchain infrastructure) as well as proposing to use a standardize approach to visa decision making. We believe such considerations will allow participating countries to advance in their collaborations with each other for progress.

6 CONCLUSION

As technological progress marches on with the passage of time, humans naturally begin to optimize for bottlenecks in an effort to increase efficiency, sustainability and further progress. In this paper, we observe that the trend of increased interconnectedness of countries around the globe will eventually hit a bottleneck at human processing speed as is evident in the visa processing system. We leverage state of the art technology in cryptography along with the potential for governments to collaborate in a deeply global world to propose a blueprint for an automated visa processing system. With our proposed system, we see a potential to significantly cut down on the visa processing time, and therefore bringing humans from around the globe closer together for trade, collaboration and leisure more than ever before. Human processing speed is a limit that pervades every area where computation can thrive and with our blueprint, we hope to hammer down on the importance to address the human limits while liberating the workforce towards more cognitive intensive work.

REFERENCES

[1] 2015. Time to cross the Atlantic – 500 year history. https://outrunchange.com/2015/11/27/time-to-cross-the-atlantic-500-year-history/ Accessed: 2021-03-31.

[2] 2018. DIGITAL FARMER PROFILES: Re-imagining Smallholder Agriculture. https://www.usaid.gov/sites/default/files/documents/15396/Data_Driven_Agriculture_Farmer_Profile.pdf Accessed: 2021-03-31.

[3] 2020. Preparing for "Earth to Earth" space travel and a competition with supersonic airliners. https://www.nasaspaceflight.com/2020/12/earth-to-earth-supersonic-airliners/ Accessed: 2021-03-31.

[4] 2021. Data Analytics and Digital Financial Services. https://www.ifc.org/wps/wcm/connect/369c10de-1703-4497-876f-9cdf0367a4d4/IFC+Data+Analytics+and+Digital+Financial+Services+Handbook.pdf?MOD=AJPERES&CVID=lRrkzEd Accessed: 2021-03-31.

[5] 2021. U.S. Department of State Visa Denial. https://travel.state.gov/content/travel/en/us-visas/visa-information-resources/visa-denials.html Accessed: 2021-03-29.

[6] Simon Adebola, J Antifaev, C Curran, C Desportes, OG Rovira, C Kelly, et al. 2008. Great expectations: An assessment of the potential for suborbital transportation. *Masters, International Space University (ISU), Illkirch-Graffenstaden, France* (2008).

[7] A Aheni. 2016. Spain Via London...Let me tell you something!!! Visa Wahala...British/ UK Visa on a Ghanaian Passport. https://aheniblog.wordpress.com/2016/09/07/spain-via-london-ukvisa-schengenvisa/#more-33

[8] International Air Transport Association. 2018. IATA - IATA Forecast Predicts 8.2 billion Air Travelers in 2037. https://www.iata.org/en/pressroom/pr/2018-10-24-02/. (Accessed on 04/01/2021).

[9] The World Bank. 2018. Identification for Development (ID4D) Global Dataset (Global ID4D Database) | Data Catalog. https://datacatalog.worldbank.org/dataset/identification-development-global-dataset. (Accessed on 04/01/2021).

[10] F Rizal Batubara, Jolien Ubacht, and Marijn Janssen. 2018. Challenges of blockchain technology adoption for e-government: a systematic literature review. In *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*. 1–9.

[11] Katie Beck. 2017. Why citizenship is now a commodity. https://www.bbc.com/worklife/article/20170530-why-citizenship-is-now-a-commodity. (Accessed on 04/03/2021).

[12] Boundless. 2020. Coronavirus Immigration FAQ: Information for U.S. Immigrants. https://www.boundless.com/immigration-resources/coronavirus-immigration-faq/. (Accessed on 04/03/2021).

[13] Robert Bryce. 2014. *Smaller Faster Lighter Denser Cheaper: How Innovation Keeps Proving the Catastrophists Wrong*. Public Affairs.

[14] Natalie Campisi. 2021. From Inherent Racial Bias to Incorrect Data—The Problems With Current Credit Scoring Models. https://www.forbes.com/advisor/credit-cards/from-inherent-racial-bias-to-incorrect-data-the-problems-with-current-credit-scoring-models/. (Accessed on 04/02/2021).

[15] Sebastien Candel. 2004. Concorde and the future of supersonic transport. *Journal of propulsion and power* 20, 1 (2004), 59–68.

[16] Melissa Chase, Apoorvaa Deshpande, Esha Ghosh, and Harjasleen Malvai. 2019. Seemless: Secure end-to-end encrypted messaging with less trust. In *Proceedings of the 2019 ACM SIGSAC conference on computer and communications security*. 1639–1656.

[17] John Chong. 1998. A primer on digital signatures and Malaysia's digital signatures act 1997. *Computer Law & Security Review* 14, 5 (1998), 322–333.

[18] United States Citizenship and Immigration Services. 2019. Consultants From California And Texas Charged With Visa Fraud And Conspiracy. https://www.uscis.gov/news/news-releases/consultants-from-california-and-texas-charged-with-visa-fraud-and-conspiracy. (Accessed on 04/03/2021).

[19] Wold Data. 2018. Average income around the world. https://www.worlddata.info/average-income.php. (Accessed on 04/03/2021).

[20] Hyperledger Fabric. 2020. Private data — Hyperledger Fabric. https://hyperledger-fabric.readthedocs.io/en/release-2.2/private-data/private-data.html. (Accessed on 04/07/2021).

[21] Bryan Ford. 2020. Identity and Personhood in Digital Democracy: Evaluating Inclusion, Equality, Security, and Privacy in Pseudonym Parties and Other Proofs of Personhood. *arXiv preprint arXiv:2011.02412* (2020).

[22] VFS Global. [n.d.]. For Individuals | Home. https://www.vfsglobal.com/en/individuals/index.html. (Accessed on 04/03/2021).

[23] Oded Goldreich and Yair Oren. 1994. Definitions and properties of zero-knowledge proof systems. *Journal of Cryptology* 7, 1 (1994), 1–32.

[24] Hossein Hassani, Xu Huang, and Emmanuel Silva. 2018. Banking with blockchain-ed big data. *Journal of Management Analytics* 5, 4 (2018), 256–275.

[25] Marko Hölbl, Marko Kompara, Aida Kamišalić, and Lili Nemec Zlatolas. 2018. A systematic review of the use of blockchain in healthcare. *Symmetry* 10, 10 (2018), 470.

[26] Ruth A McFarlane Hunter, Richard Wright, et al. 2010. Point-to-point Commercial Space Transportation in the National Aviation System Final Report. (2010).

[27] IndiaStack. 2019. About Data Empowerment and Protection Architecture (DEPA) – IndiaStack. https://www.indiastack.org/depa/. (Accessed on 04/07/2021).

[28] Syed I Jami and Zubair A Shaikh. 2018. Semantic Web based E-Government System. *Indian Journal of Science and Technology* 11 (2018), 44.

[29] Amba Kak, Smriti Parsheera, and Vinod Kotwal. 2017. Open data and digital identity: Lessons for Aadhaar.

[30] Emily A Knapp and Lorraine T Dean. 2018. Consumer credit scores as a novel tool for identifying health in urban US neighborhoods. *Annals of epidemiology* 28, 10 (2018), 724–729.

[31] Apurv Mehra, Ankush Jain, Sudheesh Singanamalla, Satya Lokam, Muthian Sivathanu, and Jacki O'Neill. 2018. Vishrambh: Trusted philanthropy with end-to-end transparency.

[32] Marcela S Melara, Aaron Blankstein, Joseph Bonneau, Edward W Felten, and Michael J Freedman. 2015. {CONIKS}: Bringing Key Transparency to End Users. In *24th {USENIX} Security Symposium ({USENIX} Security 15)*. 383–398.

[33] David Miller. 1995. *On nationality*. Clarendon Press.

[34] MOSIP. 2019. An open source platform on which national foundational IDs are built. https://www.mosip.io/about.php. (Accessed on 04/01/2021).

[35] Thomas W Murphy Jr. 2021. Energy and Human Ambitions on a Finite Planet. (2021).

[36] Kimmo Nevalainen. 2018. Human Resource Demand Planning–tools and processes for visa processing of Ministry for Foreign Affairs of Finland. (2018).

[37] NSDL. [n.d.]. NSDL e-Governance Infrastructure Limited. https://www.egov-nsdl.co.in/e-sign.html. (Accessed on 04/06/2021).

[38] United States Department of Homeland Security. 2020. Feature Article: S&T SVIP Leverages Blockchain Interoperability to Support DHS | Homeland Security. https://www.dhs.gov/science-and-technology/news/2020/10/08/feature-article-st-svip-leverages-blockchain-interoperability-support-dhs. (Accessed on 04/06/2021).

[39] Govt. of India. [n.d.]. DigiLocker | Free, Secure, Flexible and easy-to-use application. https://digilocker.gov.in/. (Accessed on 04/06/2021).

[40] Telecom Regulatory Authority of India. 2018. The Telecom Commercial Communications Customer Preference Regulations. https://www.trai.gov.in/sites/

default/files/RegulationUcc19072018.pdf. (Accessed on 04/02/2021).
[41] U.S. Department of State. 2021. Visa Appointment Wait Times. https://travel.state.gov/content/travel/en/us-visas/visa-information-resources/wait-times.html. (Accessed on 04/01/2021).
[42] United States Department of State. 2012. Capitalizing on Visa Demand to Spur Economic Growth in the United States. https://travel.state.gov/content/travel/en/us-visas/visa-information-resources/capitalize-on-visa-demand.html. (Accessed on 04/03/2021).
[43] Office of the Attorney General. 2018. California Consumer Privacy Act (CCPA) | State of California - Department of Justice. https://oag.ca.gov/privacy/ccpa. (Accessed on 04/07/2021).
[44] Ali Ihsan Ozdemir, Ilker Murat Ar, and Ismail Erol. 2019. Assessment of blockchain applications in travel and tourism industry. *Quality & Quantity* (2019), 1–15.
[45] Morgen E Peck. 2017. Blockchains: How they work and why they'll change the world. *IEEE spectrum* 54, 10 (2017), 26–35.
[46] Harry Pettit. 2019. Elon Musk's SpaceX could cut London to New York flight to just 29 minutes with 'high-speed spacecraft'. https://www.thesun.co.uk/tech/8689029/elon-musk-spacex-space-travel-london-new-york/. (Accessed on 04/01/2021).
[47] Bahamas Press. 2021. Public data compromised by hackers in the government's visa site. Government said not a word to the public. https://bahamaspress.com/public-data-compromised-by-hackers-in-the-governments-visa-site-government-said-not-a-word-to-the-public/. (Accessed on 04/03/2021).
[48] Barath Raghavan and Daniel Pargman. 2016. Refactoring society: systems complexity in an age of limits. In *Proceedings of the Second Workshop on Computing within Limits*. 1–7.
[49] National Law Review. 2021. India Privacy and Data Protection 2020 Wrap. https://www.natlawreview.com/article/privacy-and-data-protection-india-wrap-2020. (Accessed on 04/07/2021).
[50] Reinhard Riedl. 2004. Rethinking trust and confidence in European e-government. In *Building the E-Service Society*. Springer, 89–108.
[51] Sambhav Satija, Apurv Mehra, Sudheesh Singanamalla, Karan Grover, Muthian Sivathanu, Nishanth Chandran, Divya Gupta, and Satya Lokam. 2020. Blockene: A High-throughput Blockchain Over Mobile Devices. In *14th USENIX Symposium on Operating Systems Design and Implementation (OSDI 20)*. USENIX Association, 567–582. https://www.usenix.org/conference/osdi20/presentation/satija
[52] Johannes Sedlmeir, Hans Ulrich Buhl, Gilbert Fridgen, and Robert Keller. 2021. Recent Developments in Blockchain Technology and their Impact on Energy Consumption. *arXiv preprint arXiv:2102.07886* (2021).
[53] United States Visa Information Service. 2018. Visa Fees (English). https://www.ustraveldocs.com/no/no-niv-visafeeinfo.asp. (Accessed on 04/03/2021).
[54] Alan Sica. 2017. Debt to Society: Accounting for Life under Capitalism.
[55] Sudheesh Singanamalla, Esther Han Beol Jang, Richard Anderson, Tadayoshi Kohno, and Kurtis Heimerl. 2020. Accept the Risk and Continue: Measuring the Long Tail of Government https Adoption. In *Proceedings of the ACM Internet Measurement Conference*. 577–597.
[56] Beckie Smith. 2020. Watchdog calls for transparency on government's 'cryptic' visa algorithm. https://www.publictechnology.net/articles/news/watchdog-calls-transparency-government%E2%80%99s-%E2%80%98cryptic%E2%80%99-visa-algorithm. (Accessed on 04/03/2021).
[57] Manu Sporny, DC Burnett, D Longley, and G Kellogg. 2018. Verifiable credentials data model 1.0: Expressing verifiable information on the Web. *s Draft* 7 (2018).
[58] Jonathan E Stern. 2001. The electronic signatures in global and national commerce act. *Berkeley Technology Law Journal* (2001), 391–414.
[59] Clare Sullivan. 2018. Digital identity–From emergent legal concept to new reality. *Computer Law & Security Review* 34, 4 (2018), 723–731.
[60] Catherine L Taylor, David J Hyde, Lawrence C Barr, et al. 2016. *Hyperloop commercial feasibility analysis: high level overview*. Technical Report. John A. Volpe National Transportation Systems Center (US).
[61] Paul Voigt and Axel Von dem Bussche. 2017. The eu general data protection regulation (gdpr). *A Practical Guide, 1st Ed., Cham: Springer International Publishing* 10 (2017), 3152676.
[62] Indrė Žliobaitė. 2017. Measuring discrimination in algorithmic decision making. *Data Mining and Knowledge Discovery* 31, 4 (2017), 1060–1089.