Locality of Reference- The Basis for Modifying Aadhaar Architecture

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ABSTRACT

The biometric based large scale civilian identification system in India i.e. Aadhaar is based on the centralized database architecture. An identification system that uses centralized database architecture lacks locality of reference. Aadhaar has been implemented to provide unique digital identity to the individuals of the country, to enable them to access various welfare and non- welfare services extended by the government and non- government organizations. In a biometric based identification system, the major processes that take place are: **(i)** de-duplication, carried out to facilitate the process of identification, **(ii)** authentication, carried out to establish unique identity of an individual, and **(iii)** the processes of update/ correction of the biometric/ demographic data. In all the three types of the processes, the biometric/ demographic data about the residents is captured by the respective organizations and it is communicated to the centralized identity data repository for the purpose of processing. Majority of the welfare and non- welfare services extended by the government and non- government organizations are accessed by the residents locally i.e. near the place of their living. In any of the processes, if it is identification, authentication or update/ correction, the need for a particular process starts near the place of living of the residents and the request is processed by the centralized identity database. In general, the distance between the source of data and the processing unit plays a major role in determining the performance of the system in terms of response time, throughput and accuracy. The current architecture of Aadhaar, in which the resident centric data is kept in the centralized identity database has affected the performance of Aadhaar in terms of various implementation challenges, such as poor coverage of the population for the purpose of enrolment, poor recording of births (i.e. enrolment of children at the time of birth), non- cancellation of Aadhaar numbers of those who have ceased to exist, delays in update/ correction, accuracy in terms of false rejection and false acceptance and the problem of single point of failure etc. With the introduction of internet and eventually the evolution of the distributed computing, the principle of locality of reference has proved to be the basis to determine the performance of the systems that fit in the paradigm of distributed computing. The present paper has discussed various resident centric services that uses Aadhaar to ensure unique identification of the residents and proposed a modified distributed database architecture to re- implement Aadhaar in India, based on the principle of locality of reference, in order to address various implementation challenges.

Keywords: *Aadhaar, Authentication, Database, De- Duplication, Distributed Database, Locality of Reference.*

1. INTRODUCTION

Aadhaar is inevitably employed by most of the government and non- government organizations in order to establish unique identity of the residents, in the process of extending various resident centric services such as the welfare and non-welfare services [1]. The welfare services extended by the government to the residents of the country can be categorized as **(i)** cash based welfare services, such as scholarships and welfare pensions, **(ii)** subsidy based welfare services, such as Public Distribution System (PDS), LPG subsidy, subsidy to farmers on seeds and equipment, and **(iii)** the social welfare services, such as to provide land to the landless poor, homes to the homeless people and work to the unemployed individuals [2]. The non-welfare services include the services related to income tax, to issue a SIM card, to open a bank account etc. In either of the services, if it is a welfare service or a non-welfare service, the primary job of the concerned organization is to uniquely identify the legitimate beneficiaries so that the benefits/ services should reach the intended individuals [3]. In most of the cases people access services near the place of living and therefore the

process to establish his/ her unique identity also starts locally. This unveils the fact that the resident centric data, already stored in the centralized identity database, is referenced from the locality of the residents i.e. villages and towns. In the existing identity system of India i.e. Aadhaar, the credentials (biometric and demographic data) of the residents are kept in the centralized data depository, known as Central Identity Data Repository (CIDR). The central identity data repository is responsible to carry out the operations of: **(i)** authentication of identity of the individuals, as requested by various government and non-government organizations in an electronic mode, while extending services to the individuals, and **(ii)** to carry out the operations of de-duplication, when a new person has to be enrolled in to the identification system, in order to provide him/ her, the unique digital identity. The centralized identity database i.e. CIDR is also responsible to execute the operations of update and correction [4]. The term 'de-duplication' is concerned with the process of enrolment of an individual into the identification system. 'De-duplication' ensures that no duplicate identity be issued to the already enrolled individuals by comparing the credentials of an individual as read by the scanner at

any terminal across the country with the already stored credentials of the individuals, who are already enrolled into the identification system. In order to enrol a new person into the identification system, the answer to the question '*Who Am I*' is sought with high degree of certainty to be '*You Are Not Known*' using 'de-duplication'. Once such an answer is given by the identification system, the credentials of the individual are added to the identity database. The present paper explores various services, where Aadhaar is used to establish unique identity of the individuals in section 2. Section 3 discuss various implementation challenges that are related to the performance of the identification system i.e. Aadhaar that arise due to the underlying centralized architecture. The solution to various implementation challenges are discussed in section 4 and section 5 is about the conclusion and the future scope.

2. USE OF AADHAAR IN THE SERVICE DELIVERY SYSTEM

As soon as, an individual is enrolled into the identification system and is provided identity in the form of 12 digit unique identity number, the enrollee and the identification system set up a long term, legal relationship with one another. It is the service provider agencies that come in to picture and start utilising Aadhaar number of the individuals in order to uniquely identify them, so that services should reach the legitimate beneficiaries. Presently, almost every government/ non- government organizations have made it mandatory for the applicants/ beneficiaries to have Aadhaar number at the time of requesting a particular service. The launch of Digital India has widened the scope of the use of Aadhaar, as a unique digital identity. Some of the resident centric services that uses Aadhaar as a proof of unique identification of the individuals are studied and are discussed. Against every service discussed, the tables have been given (where applicable) that contains the relevant fields (demographic data and Aadhaar number about the residents) that are required to be filled up by the applicants, to request for a particular service.

2.1 BETI HAI ANMOL YOJNA

Table 1 and Table 2 corresponds to the "Beti Hai Anmol Yojna" [5], which was launched by the Government of Himachal Pradesh to provide financial assistance to the girl child of BPL families in Himachal Pradesh and mainly to combat the female foeticide [6].

The fields along with their descriptions are enlisted as follows:

Table 1: The Application Form to fill up the Details of the Mother of the Girl Child

Field Name	Description
Aadhaar Number	Enter Aadhaar number of the mother
First name	Enter first name of mother

Middle Name	Enter middle name of mother
Last Name	Enter last name of mother
Number of Daughters	Enter the number of daughters
Mobile Number	Enter the mobile number of mother
E-Mail	Enter the e-mail ID of mother
BPL Number	Enter BPL number of family
Image of Mother	Upload the image of the mother

In order to enter the BPL Number, one has to search and fetch the family details either by opting Aadhaar Number or family number or by the name of the family member. Table 2 corresponds to the details about the Girl Child.

Table 2: Details of the Girl Child that are to be Filled Up in the Application Form

Field Name	Description
Aadhaar Number	Enter the Aadhaar number of the girl child
Date of Birth	Enter the date of birth of the girl child
First Name	First name of the girl child
Middle Name	Middle name of the girl child
Last Name	Last name of the girl child

2.2 RATION CARD (CONSUMER CARD) UNDER PUBLIC DISTRIBUTION SYSTEM

In this section the application form for Ration Card has been explored [7], which is used to access the services under Public Distribution System (PDS), which is the oldest welfare scheme of the Government of India.

Table 3: Particulars of Family Members for which Ration is required

Field Name	Description
Name of Family Members	Enter the names of the family members in the space provided
Relationship with Head of Family	Specify the relation of each family member with the head of family
DoB	Enter the date of birth of every member of the family
Aadhaar No.	Enter the 12 digit Aadhaar number of every member of the family
Mobile No.	Enter the mobile number of every member of the family

It has been specifically mentioned in the application form to give consent to use Aadhaar number and biometric details for getting ration under. As a practical scenario, the ration is delivered to a particular family after getting the biometric details verified in the real time of any family member.

2.3 DIGITAL LOCKER

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Digital Locker commonly known as DigiLocker is an Aadhaar enabled initiative under the Digital India Program to empower the residents of the country to store the documents such as documents of academic qualifications, driving license, vehicle registration certificate etc. in digital form in the cloud database, provided by the government. The stored digital documents can be used as and when required by the requesting authority in an online mode thereby enabling the residents not to hold the physical documents all the times. In order to register in DigiLocker, it requires authenticating the mobile number of the intended individual. The next step is to submit the Aadhaar number in order to be linked with the DigiLocker account and this completes the process of the registration [8]. It has proved to be the digital empowering tool to the residents of the country. The process followed for registering in the DigiLocker is shown as follows:
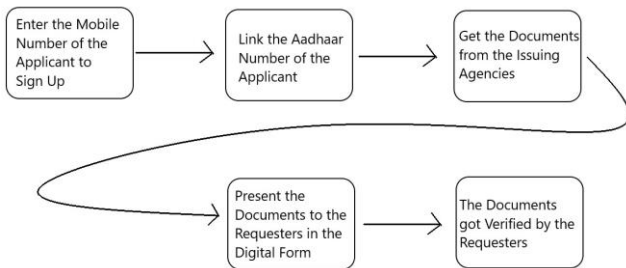

Figure 1: Use of Aadhaar as the Unique Identity, for using services of DigiLocker [8]

2.4 PRADHAN MANTRI JAN DHAN YOJNA (PMJDY)

PMJDY is an initiative of the Government of India to provide bank accounts to the financially excluded segment of the population, those who were not having bank account. The proof of identity was the major reason, people could not have procured the bank account to meet the financial needs. Prior to the launch of Aadhaar, only a few number of the identity documents were in practice to open the bank account such as PAN card, Passport, voter card and driving license etc. More importantly the Know Your Customer (KYC) was one of the major barriers behind getting a bank account by the poor and marginalized people in the country [9]. Government of India has launched PMJDY as a welfare scheme, for the financial inclusion of the residents of the country. Aadhaar has enabled the residents of the country to prove their unique identity. Table- 4 represents the application form that has to be filled up by the applicant under the scheme.

Table 4. Application Form to be filled- Up for the Registration into Pradhan Mantri Jan Dhan Yojna (PMJDY) [10].

Field Name	Description
Full Name	Enter full name of the applicant, who wish to open a bank account for the financial inclusion
Marital Status	Enter the marital status of the applicant
Name of Father/ Spouse	Enter either the name of the father or the spouse
Address	Enter the complete address of the applicant
Pin Code	Enter the Pin Code
Telephone and Mobile Number	Enter the contact number of the applicant
Aadhaar/ EID Number	Enter either the Aadhaar number of the applicant or the Enrolment ID Number
MNREGA Job Card Number	Enter the job card number of the applicant.
Occupation/ Profession	Enter the occupation of the applicant
Annual Income	Enter the annual income of the applicant
Number of Dependents	Enter the number of dependents on the applicant
Detail of Assets	Enter the detail of assets the applicant owns
Existing Bank Account of Family Members/ Household	Enter the details of the bank account numbers of the family members of the applicant
Kisan Credit Card	Enter the detail of the Kisan credit card, if the applicant holds

Most of the times, the services discussed above are availed by the common residents near the place of their living, as the common people are not much mobile. As a result thereof, the need to establish unique identity of the residents also arises locally. As a corollary to this, in the process of establishing unique identity of the residents, it requires references to the already stored data in CIDR, from the locality of the residents i.e. villages and towns.

The next section discuss various implementation challenges that arise due to the centralized architecture of the large scale civilian identification system of India i.e. Aadhaar.

3. IMPLEMENTATION CHALLENGES WITH AADHAAR

Implementation challenges, as the name implies are the difficulties that are faced by the residents, the government and the service provider agencies, with the operation of a large scale civilian identification system. Over the passage of time, with the operation of Aadhaar, various implementation challenges have come into picture, that are: **(i)** Poor coverage of the population of the country for the purpose of enrolment into Aadhaar, **(ii)** Poor recording of births (i.e. enrolment of newly born children) into Aadhaar, **(iii)** Distantly located enrolment centres from the place of living, **(iv)** Non- cancellation of Aadhaar of the individuals, who are not alive, **(v)** Aadhaar saturation more than 100%, **(vi)** Delay in update and correction in the credentials of the residents in the already issued Aadhaar, and **(vii)** Poor Reliability due to the errors

of false acceptance & false rejection and the single point of failure that persists in Aadhaar, because of the centralized architecture.

The present paper discuss the issues of Poor coverage of the population of the country for the purpose of enrolment into Aadhaar, abnormality in Aadhaar saturation, delayed process of update/ correction and poor reliability in the following sections.

3.1 POOR COVERAGE FOR ENROLMENT

Enrolment is very first step which is carried out by the enrolment agencies that are set up or accredited by the foundational identification system. It is by virtue of the enrolment of the residents into the identification system, that the residents get unique identity. The successful implementation of an identification system can be assessed in terms of the capabilities of an identification system to cover the entire population of the country for the purpose of enrolment. The statistics about the enrolment of the residents into Aadhaar is released by UIDAI as 'Aadhaar Saturation Report'. The statistics reveal that many of the states/ union territories of India are having very poor performance in terms of the enrolment. Some of the states/ union territories show good performance in terms of the enrolment of the residents into the identification system and the numbers of enrolments comes out to be close to 100%. In case of an identification system, in which the enrolments approaches 100%, seems to be showing good performance in terms of the statistics. However, for an identification system to be truly inclusive, the enrolment must be exactly 100% and every individual of the country must have been enrolled and have got unique identity. The poor rate of enrolment is also attributed to the fact of difficulties faced by the residents in order to approach the distantly located enrolment centres, among others.

3.2 ABNORMALITY IN AADHAAR SATURATION

The percentage of enrolment of the residents can either be 100% or less than 100%. In no case, it must cross 100%. It is revealed by the Aadhaar saturation report that some of the states/ union territories show very abnormal behaviour towards enrolment, as the enrolment of the residents has crossed the limit of 100% [Figure 1]. The enrolment of the residents into identification system more than 100% i.e. more people are enrolled into the identification system in a region than the actual population of the respective region, raises serious concerns over the actual enrolment. The abnormality in Aadhaar saturation is primarily due the fact that there is no provision in Aadhaar for the automatic recording of deaths of the residents and without having such mechanism, it is not possible to figure out the Aadhaar numbers of those, who are not alive, in the centralized database of Aadhaar. It is certain that in the existing Aadhaar, the percentage of enrolments also includes the residents who are not alive. In order to count the exact enrolment of the residents into the identification system, it needs to revisit the enrolment data and to suggest and devise mechanisms for the automatic
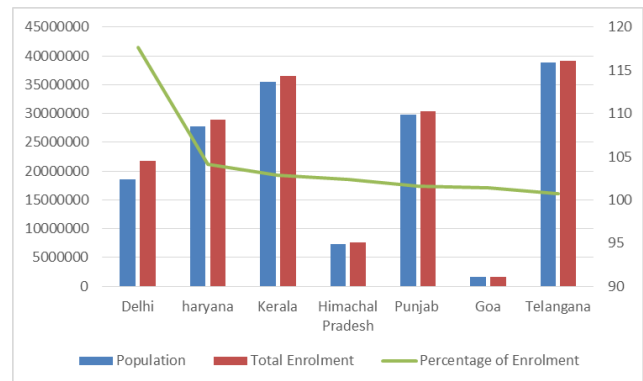
recording of deaths.

Figure 2. More Enrolments than the Actual Population of a Region [15].

3.3 DELAYS IN THE PROCESS OF UPDATE AND CORRECTION

As with the software systems, maintenance plays a major role in the successfulness of the software and its longevity to provide services for which it is developed. This holds true for an identification system as well. When an individual is enrolled into the identification system, he/ she is provided with a unique identity. With the passage of time, the need may arise to update and/ or correct the biometric and demographic details about an individual. The change in the living place of an individual and the requirement to update the biometric details of an individual leads to the process of update to be followed. Errors in name or in other such details leads to the process of correction to be followed. However, in order to realize the update/ correction in the credentials of the individuals, it takes a long period and as specified by UIDAI, it may take up to 90 days [16]. For instance, if the fingerprints of an individual fail to establish his/ her unique identity in the process of authentication and he/ she follows the process of update of the fingerprints, the Aadhaar authentication suspends till the update is materialized. In practicality, it has been identified that most of the people have experienced repeated efforts to ensure update/ correction.

3.4 POOR RELIABILITY

A number of cases of false rejection and false acceptance have been reported from the study. If the identification system fails to establish the unique identity of a legitimate individual, it deprives him/ her from accessing the services, for which he/ she was otherwise legally eligible. The error is known as false rejection and if during the process of de- duplication, the identification system incorrectly responds 'you are known', it will deny an individual from getting enrolled into the identification system and in turn it will deprive him/ her from getting unique identity. In a biometric based identification system, the rate of false acceptance increases with the increase in the size of the identity database i.e. with increase in enrolments. The errors of false acceptance can be mitigated by way of filtering based on the demographic

data; however, it increases the rate of errors of false rejection [11]. The denial of services to the residents by the service provider agencies, due to the problem of authentication failure i.e. false rejection is quite common in the welfare and non- welfare service delivery system. Shailesh Gandhi, former Central Information Commissioner, faced the issue of false rejection. While completing his know-your-customer (KYC) procedure at HDFC bank, the system refused to validate his Aadhaar through fingerprints. After the incident, he wrote, "I could do my KYC with other documents, but the horror of this hit me. If the system cannot recognize people from its database with the fingerprint impression, what would happen to those whose food grains, pensions or employment guarantee scheme, wages depend on it?" [12].

The study reveals that the people who were able to enrol with all their biometrics, many have troubled with the fingerprint authentication issues. The government has admitted high authentication failures and the UIDAI's statistics show that the Aadhaar-based biometric authentication for government services has a 12% failure rate [13]. In another statement issued by UIDAI, it has been stated that 100% authentication rate is not possible. Under Aadhaar authentication, the performance of the identification system depends upon various variables such as network connectivity and the machine failures etc. [14].

4. LOCALITY OF REFERENCE AS THE BASIS TO MODIFY AADHAAR ARCHITECTURE

Locality of Reference commonly known as Data Locality is a fundamental principal of computing [17]. The principal of locality of reference refers to the fact of predictability that exists in the sequence of accessing the memory addresses during the execution of a program. It is mainly of two types: temporal locality of reference and spatial locality of reference. During execution of a program, when the same memory locations are accessed multiple times over a small interval of time, the program is said to exhibit temporal locality of reference, such as the execution of a loop. The spatial locality of reference refers to the fact that during the execution of a program, when the data from a particular memory location is accessed, there is a probability that the nearby memory locations will be accessed over a small period of time. The systems/ programs that exhibit this type of the behaviour are referred to as exploiting the spatial locality of reference [18].

The principle of locality of reference finds its applications in various fields of computer science, to name a few, such as cache memory in processors to hold the most referenced data, in web browsers to hold the recent web pages and in search engines to find the most relevant responses to the queries [16]. In essence, the principle of locality of reference states that the data should be kept near the place, where it is most likely to be used. Inherently, the resident centric data is generated near the place of living of the individuals. Most of the times, an individual avails various types of the services offered by the government and non- government organizations, near the place of living. Eventually, the need to establish unique identity arises locally i.e. villages and towns, in order to avail the services, which is also evident from the discussion in section–2. In the existing Aadhaar architecture, every time one has to authenticate his/ her identity, the service provider entities communicates with the centralized identity data repository (CIDR), which is prone to failure due to various variables such as network failure, low internet bandwidth and/ or machine failure, software failure, virus attack, militant attack and the size of the centralized database etc. Therefore, it requires to have changes on the architectural level in the existing Aadhaar architecture.

In order to address various implementation challenges effectively, as are observed in the foundational identification system of India i.e. Aadhaar, the principle of locality of reference has been proposed as the base model to modify the architecture of Aadhaar from centralized database architecture to distributed database architecture. It has been envisaged that the credentials of the residents should be kept and managed near the place of the living of the residents i.e. the place where residents live and avail services, which are offered by various government and non-government organizations, so that the identity of the individuals can be authenticated by using the locally available data about the residents. This can be accomplished using distributed database technology, allowing the local bodies (Panchayats/ Municipal Corporations etc.) to maintain data about the residents of their jurisdiction. Keeping data about the residents locally, it will address various implementation challenges effectively.

In the modified architecture of Aadhaar, the database systems at the local body level will: **(i)** execute the operations of authentication, **(ii)** capture the resident centric data for the purpose of enrolment, **(iii)** issue Aadhaar number, **(iv)** execute the operations of update and correction, and **(v)** recording of births/deaths into Aadhaar.

In addition to the identity database systems at the local body level, identity database systems at the district body level will also be set up. The database systems maintained at the district body level will: **(i)** execute the operations of de- duplication to facilitate enrolment, **(ii)** generate Aadhaar number for the newly born child, and **(iii)** segment out the biometric and demographic data about the deceased individuals from the active identity database tables. The identity database tables that are actively involved in the process of identification and authentication have been referred to as the active identity database tables.

4.1 ENROLMENT IN THE MODIFIED AADHAAR

The data generation about the residents is a continuous process. It is the local bodies that keep the data about its residents, such as the data about births, data about deaths and the data about the parentage. Whenever,

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a birth/ death takes place, along with updating data in to the official documents of the local bodies, the data will be updated in the identity database systems maintained at the local body level. Every time a birth is registered with the Panchayat/ Municipal Corporation, a unique ID, to be called as *Birth Id* will be generated, with the issuance of the birth certificate and the details of the child will be communicated to the district level database to issue unique identity to the child. It will help and will ensure identity to every child. In case of enrolment of the residents (except newly born children), their credentials will be captured at the local body level and will be synchronized to the respective identity database system at the district body level for the purpose of de- duplication. Designating the local bodies as the enrolment centers will help people to approach to the office of a local body easily and conveniently, as the local bodies are always located in the periphery of the living place of the residents and therefore will ensure the universal coverage of the residents for the purpose of enrolment.

4.2 IDEAL AADHAAR SATURATION

In case of a deceased individual, at the time of issuance of death certificate at the local body level, a unique id to be called as *Deceased Id* will be generated, which will be synchronized to the respective identity database system at the district body level, to segment out the credentials of the deceased individual from the active identity database tables to the inactive identity database tables. It will help to achieve the ideal state of the Aadhaar saturation and in turn, will help to identify the individuals who don't have unique identity.

4.3 REAL TIME UPDATE AND CORRECTION IN BIOMETRIC/ DEMOGRPHIC DATA

In modified Aadhaar, the update and correction in the biometric and demographic data of an individual could be materialized at the local body level in real time, because of the availability of the already stored credentials with the local bodies. If the fingerprints of an individual do not work for the purpose of authentication, he/ she could approach the Panchayat/ Municipal Corporation as the case may be, and could request for the update and/ or correction in the biometric and demographic data. Allowing the local bodies to facilitate update and correction will help the common people of the society to avail uninterrupted access to welfare and non- welfare services, delivered by various government and non-government organizations.

4.4 IMPROVED RELIABILITY IN THE MODIFIED AADHAAR

The principle of locality of reference will ensure the availability of data about the residents near the place, where it is to be used to establish unique identity of the residents through the process of authentication, in order to avail various welfare and non- welfare services. Since, authentication is a multi- time process, allowing the local bodies to execute the operations of authentication, will overcome the adverse impacts of the variables, such as network failure, low internet bandwidth, machine failure, software failure, virus attack, militant attack and heavy size of the identity database system. The modified distributed architecture will handle the processes of authentication and identification at separate database systems. It will reduce the size of the identity database systems, equal to the population of a local body/ district body, and therefore it will directly benefit to mitigate the high rate of false acceptance and false rejection.

5. CONCLUSION AND FUTURE SCOPE

A foundational large scale civilian identification system has the responsibility to provide unique digital identity to every resident of the country and mechanisms to authenticate identity thereof, in order to enable them to access various welfare and non- welfare services, extended by the government and non- government organizations. The existing identification system of India i.e. Aadhaar is based on the centralized database approach that has raised various implementation challenges. The principle of locality of reference has been proposed to modify the existing centralized architecture of Aadhaar to the distributed database architecture. As a future scope of the present research work, research could be extended in the direction to provide security to the distributed setup of Aadhaar that will include the communication security and the security of the resident centric data spread over various identity database systems, at the local bodies and district bodies.

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