

# Architecture of Multi Channel Multi Database Voting System

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**Abstract:** Voting technology has seen various changes over the time, starting from traditional ballot voting system to the latest e-voting system. But technology couldn't affect the popularity of ballot voting system though it doesn't provide desirable blend of accessibility and efficiency. We believe that an architecture that combines the efficiency of current day technology and the ease of ballot voting system will revolutionize voting. We propose a novel architecture for voting system that uses multiple channels (ATM, Internet, cellular phone, telephone and ballot) and multiple databases to show that it is ideal in achieving accessibility, efficiency, feasibility and flexibility. We show through simulations that the proposed multi channel voting system is suitable for several countries. We compare the cost of this voting system with the traditional one in different scenarios with the help of a new metric.

**Key words:** Traditional voting, Online voting, Offline voting, Database synchronization, Voter anonymity, Voter authentication, Vote uniqueness.

## 1. INTRODUCTION

Advances in technologies have changed nearly every facet of our lives. One of the exceptions to this trend has been in the area of the voting system. In the past, several attempts have been made for replacing traditional voting system with modern equipments. But none of them could see successful implementation all over. At present, traditional, mechanical and electronic voting systems are being used. But these systems are not efficient with respect to the overall voting time and cost. Hand-marked and hand-counted traditional voting process increases the time required for elections. In March

2000 the Arizona Democratic Party allowed for the first time remote Internet voting in its presidential preference primary [1]. In the 2001 general elections in Washington State, 69% of the votes were cast by mail [2]. Internet voting may offer a cloak for vote theft, voter coercion, and lost public confidence in the outcome. Remote Internet voting assumes a secure infrastructure of voter terminals that does not exist. Trustworthy elections are essential to democracy and achieving them requires a balance among security, convenience and cost. Due to the digital divide and current technological limitations, e-voting cannot be proposed as a universal means of voting but rather as an alternative option, supplemental to traditional voting [3]. In order to reduce voting time we need to adopt modern technologies such as Automated Teller Machine (ATM), Internet, telephone and cellular phones. In this work, we propose the Multi Channel Multi Database (MCMD) voting architecture which combines all the available modern technologies. It supports the use of existing voting systems and adds on new features with a few modifications in traditional voting process. Users of all classes benefit from this architecture as it has provision for multiple channels. The complexity of a system can be understood by the challenges that we discuss later in this paper for designing architecture. Presence of multiple channels should not give scope for voter to transfer their right to vote. Strong voter authentication is needed. A voter should be able to cast only single vote. Synchronization in multiple databases is needed.

The remainder of this paper is organized as follows. In Section 2, we describe design issues of MCMD voting system. The MCMD voting system architecture and voting process explained in Section 3 and Section 4 respectively. Simulation results are presented in Section 5. Section 6 concludes the paper and provides links to some future work.

## **2. MULTI CHANNEL MULTI DATABASE VOTING SYSTEM**

Every voting system must possess an easily accessible and friendly interface so that all eligible voters either educated or uneducated can easily cast their vote. Current offline voting systems take more time for casting vote and creates bottleneck at authentication, counting stages of voting process due to its rigidity. To eradicate this, some modern online voting technologies have been adopted in several places like Canada and Europe. But poor and uneducated peoples cannot use these modern technologies. So for reducing voting time and increasing accessibility, the MCMD architecture will adopt offline voting technologies and online technologies such as ATM, Internet, cellular phone and telephone. We assume that all

servers, databases and communication lines in MCMD voting architecture work properly.

## 2.1 Design Issues of MCMD Voting System

### 2.1.1 Voter Authentication

Voter identification card is sufficient for perfect voter authentication in offline voting system. But in online voting system, voters cast their votes from remote places without any identification authority checking them in person. Though some authentications based on Personal Identification Number (PIN) and Transaction Number (TAN) are implemented in *Vote here gold* and *election.com* systems respectively, but anonymity cannot be guaranteed [7]. In public key and visual cryptography authentication methods, others have a chance to modify or break the information [8]. Partial authentication can be achieved in online voting system with the help of biometrics [6]. Face or voice recognition in Internet, face or fingerprint recognition in ATM and voice recognition in telephone or cellular phones can be used as biometrics. The above mentioned set of single metrics for authentication is not entirely reliable because, they can be stolen or twins may have same face characteristics and voice can be mimicked. Better authentication can be achieved by combining one or more biometrics with password or PIN. The authentication metrics for MCMD system have been tabulated in *Table 1*.

*Table 1. Authentication metrics in MCMD voting system*

S.No	Technology	Authentication Metric
1	ATM	Face + PIN
2	Internet	Face + Voice + Password
3	Cellular phone	Voice + Password
4	Land-line phone	Voice + Password
5	Offline voting	Identification card

### 2.1.2 Maintaining Uniqueness

Due to availability of multiple channels and databases in MCMD voting system, single user has the possibility to use different channels at a time and vote more than once. This violates the *uniqueness* principle of voting system [14, 15] and further, synchronization cannot be achieved in multiple databases. These drawbacks can be curbed with the help of database synchronization. For building synchronization any one of the methods can be considered:

- *Serialization*: It means serial usage of multiple channels by a single voter. Time between successive usage of channels by a single voter is greater than or equal to consistent time (time required to modify all the databases). Maintaining serialization practically is difficult because with multiple technologies, a single voter can cast multiple votes within consistent time.
- *Restriction on channel registration*: A single voter has eligibility to register for only one channel, others are discarded. Every voter has a chance to use one registered channel from which he can cast his vote. This restriction changes multi channel voting system to single channel voting system and sometimes, voter is unable to cast his vote because of unavailability of that channel.
- *Dependency and read-only channel databases*: If we conduct voting through multiple channels in independent way database synchronization and uniqueness cannot be achieved properly. Hence it must be made in a dependent way and also maintain the read-only property of all channel databases that are connected to a read-write global database. This MCMD system accepts single vote from a voter in first-come-first-serve priority basis even though multiple channels are used by him at the same time.

### 2.1.3 Maintaining Anonymity

Voter anonymity in MCMD system can be gained by maintaining anonymity in offline and online voting system. In offline voting system, voter is checked by proper authority and valid voter can cast his vote without revealing his identity. In online voting system, voter sends his information and vote through either wired or wireless channels. One special server (i.e. *Data Server*) separates the vote casted by the voter from his identity and records the vote. This simple voting protocol [10] is scalable, flexible, mobile and convenient but no way to ensure anonymity and correctness because of absence of crypto techniques. In simple cryptographic protocol [10], if servers team up then anonymity and correctness will not ensure and voters can prove how they voted. The problems in MIX net approach are, at least one of the MIX servers has to be honest and if number of servers is increased then protocol becomes slower [11]. FOO voting protocol uses the concept of blind signature and problems concerning voter anonymity and fake votes for non-voters can be introduced by the administration [12]. The combination of MIX net and FOO voting protocol are given in [13], it will ensure anonymity, scales well and also disallow fake votes, so we will use this in MCMD voting system.

## 2.2 Design of MCMD Voting System

### 2.2.1 Voting System

The entire MCMD voting system is classified into offline voting system and online voting system as shown in *Figure 1*.

- *Offline voting system:* In this, physical presence of voter must be needed along with his identification at voting station. Offline voting system is broadly divided into paper based offline voting system and paperless offline voting system. Traditional ballot voting system, machine readable ballot system and optical scan voting system are examples of paper based offline voting system [4]. Lever pull machine system and Direct Recording Electronic (DRE) voting system are examples of paperless offline voting system [5].
- *Online voting system:* In this, voter can vote from anywhere without going to voting station. Previously Internet voting was classified as poll-site Internet voting, kiosk voting and remote Internet voting [9]. Here we classify online voting system into stationary online voting system and mobile online voting system. Stationary communication devices such as Telephone, personal computer with Internet and ATM are examples of stationary online voting system. Mobile devices such as laptop with Internet and cellular phones are examples of mobile online voting system.

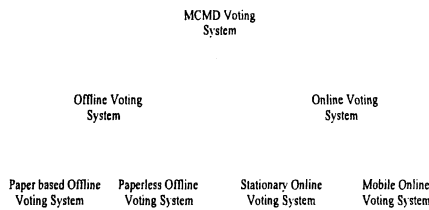


Figure 1. Classification of MCMD voting system

### 2.2.2 Voter Identification Card Design

Voter identification card should have complete and consistent voter information to authenticate voter across the multiple channels in MCMD voting system without any ambiguity. Single information of a voter may not be sufficient for authentication over different channels. This requirement calls for a sensitive design of voter identification card. So, it should contain information about the voter such as name, sex, date of birth, address, a unique voter identification number (*Vid*), photo and bar-code. Photo and bar-code with *Vid* is sufficient information for voter authentication in offline

voting system. Password or PIN are provided for each voter along with his biometrics at registration phase of voting process, which are asked and checked for authentication in online voting system. This does not guarantee against proxy voting but eliminates bogus voting.

### 2.2.3 Databases Design

In MCMD voting system, each constituency has separate global database and set of channel databases one for each online channel. Global database contains complete voter information about the constituency voters and channel database contains the information of all voters who registered for that channel. Global database is a union of all station databases in a constituency. Station database contains complete voter information about the station voters or part of constituency voters. The set of rules to be satisfied while designing databases are: (1) Global database is union of all station databases that belong to a constituency. (2) No two station databases that belong to a constituency have the common data. (3) Union of all channel databases that belong to a station is subset of that station database. (4) Any two channel databases that belong to a station may or may not have the common data.

## 3. MCMD VOTING SYSTEM ARCHITECTURE

MCMD voting architecture is designed to support multiple channels and distributed voter information databases seamlessly. The architecture of MCMD voting system for a constituency is shown in *Figure 2*. To describe the distributed architecture we introduce different kinds of servers and databases.

### 3.1 Functions of Different Servers

Each constituency has separate Offline Server (*OS*), Election commissioner Server (*EcS*), set of Data Servers (*DS*) and set of Portal Servers (*PS*). The communication between the servers is done through Acknowledgment (*Ack*) signal, which is either Positive Acknowledgment (*PAck*) signal or Negative Acknowledgment (*NAck*) signal depending on success or failure of operation. The functions of each server are given below:

- *Offline Server*: *OS* scans bar-code and *Vid* on the voter identification card and send *Vid* to the *EcS* for further validations and also receives *Ack* signal from *EcS*. If it is *PAck* signal then, ballot paper is issued to the

voter or allow voter for further process in paperless offline voting system by the proper authority, else, it rejects the voter.

- **Portal Server:** *PS* is interface between voter and *DS* and it does two functions. Firstly, it forwards authentication information from voter to *DS* and also accepts *Ack* signal from *DS*. If it is *PAck* then, send electronic ballot paper to the voter else send “*incorrect\_voter\_authentication*” message to voter. Secondly, it forwards filled electronic ballot paper to *DS* and also receive *Ack* signal from *DS*. If it is *PAck* signal then, send “*successful\_vote\_acceptance*” message to voter, else, send “*duplicate\_vote*” message to voter.
- **Data Server:** *DS* does two functions. Firstly, voter authentication is done after acceptance of authentication information from *PS* and send either *PAck* or *NAck* signal to *PS* depending on successful or unsuccessful voter authentication respectively. Secondly, it sends *Vid* to *EcS* after acceptance of filled electronic ballot from *PS* and receive *Ack* signal from *EcS*. If it is *PAck* signal then place voter’s vote in electronic ballot box and send “*successful\_vote\_acceptance*” message to *PS*, else send “*duplicate\_vote*” message to *PS*.
- **Election commissioner Server:** *EcS* is an important sever in MCMD voting system which has whole responsibility for checking status of voter (whether voter already voted or not) and also modify global database. It accepts *Vid* from *DS* or *OS* and check status flag of *Vid* record in global database for validity, if flag is set then, send *NAck* signal to either *DS* or *OS* to indicate duplicate vote else, set the flag and send *PAck* signal to either *DS* or *OS* to indicate valid vote.

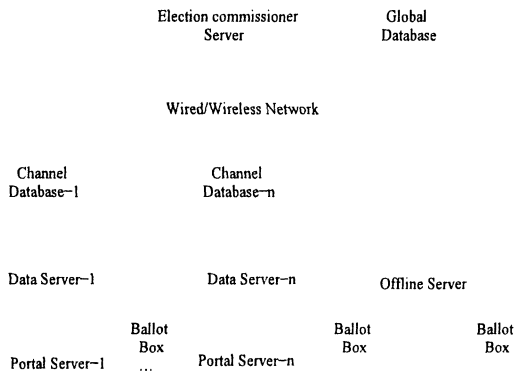


Figure 2. Architecture for MCMD voting system

### 3.2 Purpose of Different Databases

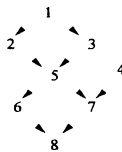
Databases store complete information about each eligible voter and also status information. In the proposed architecture, databases are distributed across the network. Each constituency has separate global database, set of channel databases and set of ballot boxes one for each online channel. The purpose of each database is given below:

- *Global database*: This read-write database contains a record for each eligible voter of a constituency. Each record has voter details and status flag which represents whether the voter has casted the vote or not. Initially all status flags are reset.
- *Channel database*: It is read only, projection of global database and constructed by taking subset of global database based on voter's online channel registration. This is used for checking voter authentication.
- *Ballot box*: Ballot box store votes, its abstraction can be realized as different kind of database based on specific channel and the technology used to realize that channel. For paper-based offline voting system ballot box is the database but, for paperless offline voting and online voting system electronic devices can be used as ballot box.

## 4. MCMD VOTING PROCESS

Entire voting process in MCMD system contains set of steps which are represented as a precedence graph as shown in *Figure 3*. It contains set of nodes and set of arrows. Each node represents a step in voting process and each arrow shows the order of execution among those steps.

1. *Creation of Voter Information Database*: Election authority should maintain uniform, centralized and interactive voter information. The first step for conducting any election is to update voter information database that will add new voter information, update existing voter information and delete passed away voter information.
2. *Issuing Voter Identification Card*: Election authority distributes voter identification card to the voter before election process starts. It contains voter details and photo as per the latest voter database.



*Figure 3.* Precedence graph for MCMD voting process



3. *Registration for Online Channels*: This is an additional process to the current voting system. In this phase, voter can register for any number of online channels and at the same time he can store required authentication information for those registered channels based on technology available to him. The authentication information for ATM is combination of face, fingerprint and PIN; for Internet is combination of face, voice and password; for telephone and cellular phone combination of voice and password are used.
4. *Agreement with Service Providers*: The election authority has to take permission from service providers such as Internet Service Providers (ISP) for Internet service, banks for ATM service and telecommunication service providers for telephone and cellular phone service and has to pay money to them for providing services.
5. *Infrastructure Setup*: Election authority has to setup offline and online voting infrastructure based on the voters registration. These registration values are directly proportional to technology development in that voting place. If technology development is high then lesser number of offline voting stations are required or else more number of offline voting stations are required.
6. *Offline Voting Steps*:
  - Voter authentication is done manually by proper authority member.
  - If authentication is successful then *OS* sends *Vid* to *EcS* for checking the global database or else voter is trying to cast others' vote. So it doesn't allow him for further process.
  - *EcS* checks status of *Vid* record in global database, if flag is set then *EcS* sends *NAck* signal to *OS* else *EcS* sets the flag and sends *PAck* signal to *OS*.
  - If *OS* receives *PAck* signal from *EcS* then authority issues ballot paper to the voter to vote in paper-based offline voting system or allow voter to vote in paperless offline voting system or else voter's trying for duplicate vote and so reject that vote.
  - Store votes in ballot box. In paper based offline voting system voter stores vote in ballot box otherwise voter stores vote in electronic ballot box.
7. *Online Voting Steps*:
  - Voter connects to *PS* by using Uniform Resource Locator (URL) for Internet channel, phone number for cellular phone or telephone channels and bar-code on voter identification card for ATM channel.
  - Voter sends authentication information to the *DS* through corresponding *PS*.
  - *DS* sends either *PAck* or *NAck* signal to the corresponding *PS* depending on successful or unsuccessful voter authentication.

- If *PS* receives *PAck* signal from *DS* then it sends electronic ballot to the requested voter depending on constituency and language chosen by the voter or else rejects the voter because of incorrect voter authentication.
  - Voter sends filled electronic ballot (contain *Vid* and vote) to *DS* through corresponding *PS*.
  - *DS* sends *Vid* to *EcS* for global database verification for duplicate vote.
  - *EcS* checks status of *Vid* record in global database, if flag is set then *EcS* sends *NAck* signal to *DS* else *EcS* sets the flag and sends *PAck* signal to *DS*.
  - *DS* stores votes in electronic ballot box and sends *PAck* signal to corresponding *PS* if it receives *PAck* signal from *EcS*, else sends *NAck* signal to corresponding *PS* and rejects vote for voter trying for duplicate vote.
  - *PS* receives either *PAck* or *NAck* signal from *DS* depending on successful acceptance or rejection of vote and sends that result to voter.
8. *Counting Process*: After completing entire voting process, election authority should collect online and offline ballot boxes for each constituency, count offline votes of each participant, count online votes of each participant, add the offline and online votes and declare the result.

## 5. SIMULATION

### 5.1 Simulation Data and Environment

Usages of online channels among various world regions, metropolitan cities of India and overall India in different years have been tabulated in *Table 2*. Internet usage data collected from International Telecommunication Union [16], telephone usage data collected from Bharat Sanchar Nigam Limited [17], cellular phone usage data collected from Videsh Sanchar Nigam Limited [18] and ATM usage data collected from Reserve Bank of India [19]. We have used these data for simulation.

The performance of MCMD voting system is simulated using Standard Template Library (STL) in C++. STL has a set of predefined classes which are used for simulation. In MCMD voting system each step such as voters arrival rate, authentication, ballot issue, database modification and vote acceptance acts as an event with separate function module. Voters arrival is denoted as random discrete event as they arrive at irregular time intervals and servers processing is denoted as deterministic discrete event as they are deterministic. The simulation is conducted with 1000 traditional voting stations and 1 million voters. The simulation is repeated by increasing

number of channels ( $N$ ) at different world regions, metropolitan cities of India and overall India. The MCMD voting system supports traditional voting model if  $N=1$ ; if  $N=2$  this becomes traditional and Internet; if  $N=3$  this changes to traditional, Internet and cellular phone; if  $N=4$  it becomes traditional, Internet, cellular phone and telephone; if  $N=5$  system accepts traditional, Internet, cellular phone, telephone and ATM.

Table 2. Usage of online technologies

S.No	Area/Year	Internet Usage	Cellphone Usage	Telephone Usage	ATM Usage
1	Africa	1.5%	6.2%	3%	-
2	Americas	25.9%	34.1%	33.8%	-
3	Asia	6.7%	15%	13.6%	-
4	Europe	23.7%	55.4%	41%	-
5	Chennai	10%	10.4%	17.1%	44%
6	Delhi	11%	26.5%	21.8%	49%
7	Kolkata	8%	7.2%	13.9%	33%
8	Mumbai	18%	19.4%	20.1%	56%
9	2005	1.9%	7.3%	5.7%	26.4%
10	2010	3.4%	17%	8.6%	35.6%
11	2015	7%	30.4%	11.7%	42.2%

## 5.2 Simulation Results

The online utilization in overall India are given in *Figure 4* and voting time for world regions, metropolitan cities of India and overall India for different years are given in *Figure 5*, *Figure 6* and *Figure 7* respectively.

### 5.2.1 Voting Time

We define *Online utilization* ( $U_{online}$ ) as the ratio of the number of voters using online channels to the number of voters using offline and online channels. The *voting time* in MCMD is defined as the time required using this system to vote for a group of people. It is inversely proportional to  $U_{online}$ . From *Figure 5* we observe that, there is a reduction of voting time in different continents like Europe, Americas, Asia and Africa with increase in number of channels in MCMD voting system. The voting time in Europe and Americas are reduced by  $1/6$ ,  $1/2$  and  $3/4$  with two, three and four channels respectively. However we find negligible reduction in Asia and Africa. From *Figure 6* we observe that, there is a reduction of voting time in different Indian metropolitan cities with increase in number of channels in MCMD voting system. The voting time in Delhi and Mumbai are reduced by  $1/4$ ,  $1/2$  and  $3/4$  with three, four and five channels respectively. For Chennai and

Kolkata it is  $1/7$ ,  $1/4$  and  $1/2$ . From *Figure 7* we observe that, there are improvements in India with usage of different channels in different years. In 2005, 2010 and 2015 the voting time is reduced by  $1/9$ ,  $1/5$  and  $1/3$  with four channels and by  $1/3$ ,  $1/2$  and  $3/5$  with five channels. There is negligible improvement with usage of two and three channels.

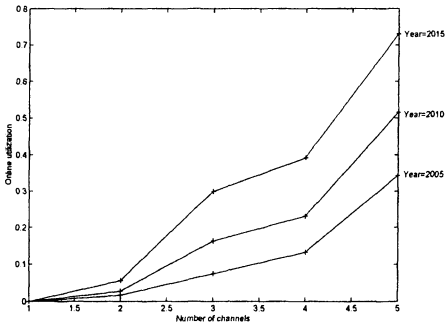


Figure 4. Online utilization in India

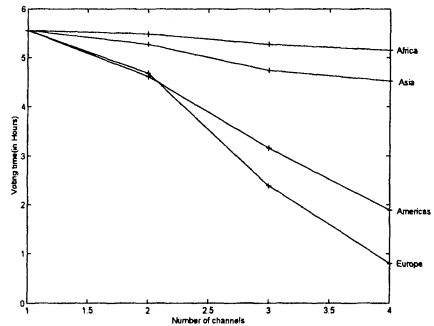


Figure 5. Voting time in World regions

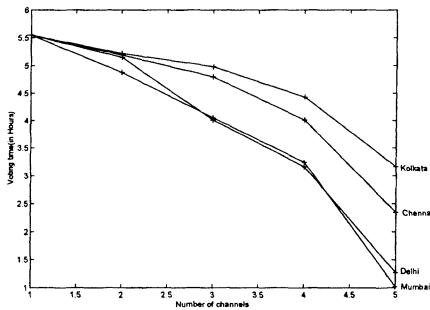


Figure 6. Voting time in metropolitan cities of India

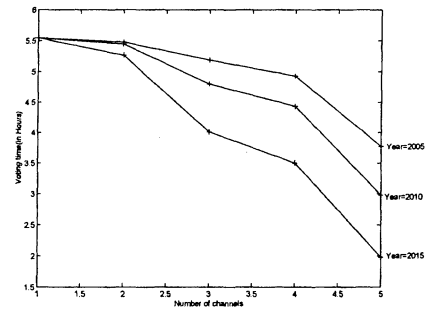


Figure 7. Voting time in India in different years

### 5.2.2 Speed-Up Factor

The speed-up factor of MCMD system at a particular  $N$  value is defined as the ratio of voting time of MCMD system with one channel to that with  $N$  channels. Speed-up factor of MCMD voting system with multiple channels compared to traditional voting system are give in *Table 2*. We calculated the average speed for two, three, four and five channels as 1.5, 2, 2.5 and 3 respectively. The MCMD voting system with one online channel gives below average speed in places like America, Europe and poor speed in all other places. The system with two online channels gives above average

speed in Europe, below average speed in America and poor speed in all other places. The system with three online channels gives good speed in Europe, above average speed in America, below average speed in Delhi and Mumbai, poor speed in all other places. The system with four online channels gives good speed in Delhi and Mumbai, average speed in Chennai and below average speed in Kolkata. The system in India with four online channels gives above average speed in year 2015, below average speed in year 2010 and poor speed in year 2005.

Table3. Speed-Up factor of MCMD voting system

S.No	Area/Year	N=2	N=3	N=4	N=5
1	Africa	1.01	1.05	1.07	-
2	America	1.2	1.75	2.93	-
3	Asia	1.05	1.17	1.22	-
4	Europe	1.18	2.32	6.9	-
5	Chennai	1.07	1.15	1.38	2.37
6	Delhi	1.07	1.38	1.75	4.36
7	Kolkata	1.06	1.11	1.25	1.75
8	Mumbai	1.13	1.36	1.71	5.4
9	2005	1.01	1.07	1.12	1.47
10	2010	1.02	1.15	1.25	1.86
11	2015	1.05	1.38	1.58	2.8

### 5.2.3 Cost Estimation

The cost of MCMD process ( $C_{mcmd}$ ) includes cost of offline ( $C_{offline}$ ) and cost of online voting process ( $C_{online}$ ).  $C_{offline}$  is product of traditional voting process cost ( $C_{trad}$ ) and Offline utilization ( $U_{offline}=1- U_{online}$ ).  $C_{online}$  is sum of  $i^{th}$  ( $1 \leq i \leq n$ ) channel cost ( $C_i$ ), where  $n$  is number of online channels.  $C_i$  is sum of service charge ( $S_i$ ) and cost of technology ( $T_i$ ) for  $i^{th}$  channel.  $S_i$  is product of number of votes casted ( $N_i$ ) and cost per vote ( $Cost_i$ ) for  $i^{th}$  channel. Number of votes casted through all online channels ( $N_{tot}$ ) is sum of  $N_i$  ( $1 \leq i \leq n$ ). For simplicity we assume that the cost per vote in all online channels is same and technology enable cost for all online channels is same.

$$\begin{aligned}
 C_{offline} &= C_{trad} * U_{offline} \\
 &= C_{trad} * (1 - U_{online}) \\
 C_{online} &= \sum_{i=1}^n C_i \\
 &= \sum_{i=1}^n (S_i + T_i) \\
 &= \sum_{i=1}^n (N_i * Cost_i + T_i) \\
 &= C * \sum_{i=1}^n N_i + n * T \\
 &\quad \text{(Our assumption is for all } i, Cost_i = C \text{ and } T_i = T) \\
 &= C * U_{online} * N_{tot} + n * T \\
 C_{mcmd} &= C_{offline} + C_{online} \\
 &= C_{trad} * (1 - U_{online}) + C * U_{online} * N_{tot} + n * T
 \end{aligned}$$

According to Election Commission of India reports about 2004 elections, only 380 million (35% of total population) votes are casted and cost of election is 1300 Crores (Cr.) [20]. The estimated Indian population in 2005, 2010 and 2015 are 1094, 1170 and 1230 millions respectively. The assumptions made for cost calculation in MCMD are: value of  $T$  is 125 Crores, casted votes are 35% of total population and cost of elections in 2005, 2010 and 2015 are 1300, 1600 and 1900 Crores respectively. The value of  $U_{\text{online}}$  is taken from *Figure 4* and values of Cost per vote ( $C$ ),  $C_{\text{mcmd}}$  are calculated by using above assumptions and formulas, and given in *Table 4*. In year 2005, cost of MCMD voting system with one or two or three or four online channels is more than traditional voting system even  $C$  is nil. In year 2010, MCMD system with one or two or three online channels is expensive than traditional voting system even if  $C$  is nil and cost of system with four online channels is less than traditional voting system if  $C$  is less than or equal to 15 INR. In year 2015, MCMD voting system with two, three and four online channels is less expensive than traditional voting system if  $C$  is less than or equal to 24 INR, 23 INR and 27 INR respectively and cost of system with one online channel is more than traditional voting system even  $C$  is nil.

*Table 4. Cost estimation for MCMD voting process*

S.No	Year	$n=1$		$n=2$		$n=3$		$n=4$		
		$C_{\text{trad}}$ (Cr.)	$C$ (INR)	$C_{\text{mcmd}}$ (Cr.)	$C$ (INR)	$C_{\text{mcmd}}$ (Cr.)	$C$ (INR)	$C_{\text{mcmd}}$ (Cr.)	$C$ (INR)	$C_{\text{mcmd}}$ (Cr.)
1	2005	1300	0	1412	0	1459	0	1506	0	1358
2	2010	1600	0	1693	0	1594	0	1607	15	1597
3	2015	1900	0	1930	24	1890	23	1893	27	1882

## 6. CONCLUSION AND FUTURE WORK

Offline voting system offers reasonable balance of security and reliability but it is not a scalable and feasible model for the modern world. Online voting systems promise benefits in terms of remote accessibility and ease of use. Our proposed MCMD voting system combines the advantages of both technologies, so that it enables traditional, Internet, ATM, cellular phone and telephone based voting depending on the requirement in a consistent manner. The MCMD voting system with two or three channels gives a marginal improvement in places like Europe and America and no improvement in other places due to lack of awareness of technology. The system with four channels gives a notable improvement in places like Europe and America, marginal improvement in Indian metropolitan cities and no improvement in other countries or places. The system with five channels gives a notable improvement in Indian metropolitan cities, marginal improvement in overall

India in year 2015 and no improvement in overall India in years 2010 and 2005. As long as cost per vote is within the bound given in *Table 4*, MCMD voting is cheaper compared to traditional voting. As a future work, performance of MCMD voting system on parallel servers can be studied. Fault tolerance and cost implication are to be studied when duplicate databases and redundant channels are employed. Reliability of the system can be improved with new cryptography techniques.

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