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ABSTRACT

There are several ways the telephone system may be used for opinion polling and public participation in discussions. The easiest method is individual call-ins to a series of different telephone numbers that each represent a different choice or vote. The only extra equipment needed here is a device that tabulates the total number of calls reaching each number. However any sharp increase in demand for connections to a given telephone exchange can severely overload the telephone system. An alternative is to use an automatic interrogation device that sequentially calls all the participants in a discussion and either asks for their votes or collects votes stored in small attachments on each participant's telephone. Using this technique, some 50,000 participants distributed among 50 central telephone offices could have their votes tabulated and relayed to a central location in about 70 seconds. This technique will be the basis for experiments with citizen feedback in the MINERVA Project being run by The Center for Policy Research. (MG)

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INCASTING AND THE TELEPHONE NETWORK

Working Paper III

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This is a preliminary report on the basic conception which guides a National Science Foundation study, "Minerva--Participatory Technology," (GI-29940) conducted under the auspices of the Center for Policy Research. Principal investigators are Amitai Etzioni and Stephen Unger. The author is especially indebted to Stephen Unger.

ABSTRACT

Incasting is a term defining that function normally associated with polling. It is the inward flow of information from many participants to a central destination. This paper describes the nature of incasting and to what extent it may be executed by using the telephone system. A new incasting network is proposed which is superimposed over the existing telephone network and it is shown how the two network augment each other.

TABLE OF CONTENTS

1. INTRODUCTION

In today's technologically advanced society, there does not exist any facility that can set up meaningful dialogues between members of the society and their leaders on a wide spread basis. A necessary facility for such interchanges is a comprehensive, wide-spread real-time polling, or vote gathering system. Such a polling system is proposed as part of the MINERVA system. [1,2]* This paper outlines the inherent problems in polling and how it may be achieved by utilizing the telephone network.

* The idea for this system originated with Amitai Etzioni and Eugene Leonard.

2. INCASTING

Polling as defined by the dictionary is the canvassing or collecting of votes or expessions of individuals in order to discover public opinion on some question. In the strict technical sense polling describes the method by which individual events are sampled or collected sequencially by a common facility. In the MINERVA system we define polling as the means by which the votes or attitudes of the participants are collected and summarized. By using our definition a poll is not limited to a sequential interrogation of participants. A "parallel" interrogation is allowed. For example, a chairman may poll the participants by a comparison of the audio level produced by the sum of all the "ayes" versus that produced by the "nays". Such a poll does not fit the strict technical definition of polling, but it is a type of polling that will be investigated as part of the MINERVA system. As stated previously polling provides the feedback required by any participatory system. It performs that function that is opposite to that performed by broadcasting. To emphasize this difference, a new term, incasting, will be introduced. Polling is to incasting as transmitting is to bradcasting. It is the means by which the function is executed.

MINERVA is a system that provides both broadcasting and incasting. Information flows from the broadcaster

(MINERVA central site) to the participants, who in turn are incasters and information is incasted back to the central site. By completing this information feedback path a dialogue is set up as in a "town hall meeting". By applying transmission techniques similar to those used for broadcasting (TV, radio, cable TV), incasting can supplement broadcasting to effectively provide the means to conduct productive dialogues among as many as 50,000 citizens. Both broadcasting and incasting are necessary; one without the other will not suffice for a meaningful dialogue to be established.

2.1 PARAMETERS OF INCASTING

When describing a broadcasting system, certain parameters are extremely useful such as, capacity (or bandwidth), rate, and coverage. Capacity is a measurement of the amount of information that can be broadcasted in a timed interval. Rate or speed of transmission is normally that of light, and therefore rarely is considered in the description of broadcasting systems. However, when considering the long transmission distance and the use of satellite circuits today, the transmission speed may be a factor. Coverage afforded by a broadcasting system is affected by the transmission power, network, and the signal to noise ratio as well as the quality of receivers. Another aspect of coverage is security or controlled coverage. It may be desirable to broadcast to a predetermined audience. Special techniques are usually employed to effect this type of coverage. Closed circuits or private lines may be used as the transmission media if a high degree of security is desired. A lesser degree of security is achieved by scrambling the transmission signal under the assumption that only authorized receivers have the ability to unscramble the signal. Finally limited control of the coverage can be achieved by not transmitting in certain geographically areas. All three methods are commonly used to achieve the desired degree of security.

The same parameters used to describe broadcasting systems are also pertainent to incasting systems. These parameters affect the configuration and type of network required. Each parameter will be discussed below. Associated problems will also be described.

2.1.1 CAPACITY

The capacity of an incasting system is the amount of information each participant is able to incast. In general this capacity C is considerably less than the capacity of a broadcasting system C (the amount of information each participant is able to receive). The minimum capacity for incasting is 1 bit of information. This allows a dichotomous decision to be incasted. It is equivalent to the "aye" or "nay" response in participatory gatherings. If further information is required, separate polls could be taken and the total information could be coded into a sequence of "ayes" or "nayes". But since polling is usually sequential, it would be time consuming to incast a single non-dichotomous response by a series of polls of dichotomous responses. The overhead of accessing each participant for his response during a poll is usually constant whether the response has a capacity of one bit or 100 bits. Therefore, the efficiency of the poll decreases as the capacity decreases.

2.1.2 RATE

The rate of incasting is a measurement of the time required to poll all participants, assemble the results, and transmit it to the destination (the MINERVA central site). The polling speed requirements affects the capacity, the type of polling, and the polling network. As pointed out previously the rate and capacity are related. As the capacity increases, the time required for a single poll increases, thereby decreasing the rate. Assuming t seconds to poll each participant, then nt seconds are required to poll n participants. Since the total time required per poll is a linear function of the number of participants and MINERVA requires that it be independent, the polling network must be capable of conducting multiple polls.

2.1.3 COVERAGE

Coverage in an incasting system consists of factors similar to those characterizing a broadcasting system. In addition to the total number of participants, coverage also includes; distribution of the participants, selection (or controlled incasting), accuracy, and security.

A typical incast may include participants located in small groups, each group separated from the others by hundreds of miles. It would be economically unfeasible to poll each participant from a central point. The logical solution is to poll each local group of participants from a local center and then to poll these local centers. Such a scheme not only allows wide spread polls to be taken economically, but also allows polls to be taken simultaneously among the different small groups, hence permitting polls to be taken in a fixed length of time independent of the number of participants.

For transmiting it is desirable at times to transmit to a pre-selected audience. The same concept exists for incasting. At times it may be necessary to poll a particular cross-section of the participants. This requires that the polling facilities have the ability to selectively poll participants previously or randomly selected.

Accuracy is quite unique to incasting. Broadcasting requires accuracy but it is measured as signal to noise ratio and capacity. For incasting, accuracy is a requirement that the results of a poll is a true indication of all the individual responses.

Security in incasting can be more restrictive than for broadcasting. If the incast is a formal vote on a particular issue, steps must be taken to insure that only elegible voters participate and only vote once. Opinion or straw polls are less restrictive and security is less important. Fraud, collusion, etc., are formidable problems of the implementation of a reliable and secure incasting system.

2.2 COMMUNICATION SYSTEMS ASPECTS

In a general broadcasting - incasting communication system, total system control is located at some central site. At this control site information is both broadcasted to and incasted from all participants.

Figure 2-1 shows the broadcasting aspect of the system. The control site broadcasts the same information to each participants (P_1, P_2, ... P_n). The arrows indicate the direction in which the information flows. Over each path is shown its bandwidth (B_i) a measure of the amount of information each participant receives. In general each path has a different bandwidth but each less than the bandwidth of the source Bmax. However in most broadcasting networks $B_1 = B_2 = \ldots = B_n = $ Bmax. The broadcasting network is characterized by its unidirectional information flow and its "fan-out". This is shown by a single source S and n separate receivers P_1 through P_n. The information flow is from 1 to n, denoted as $1 \rightarrow n$.

Similarly an incasting network is shown in figure 2.2. Each participant P_i has an incasting capacity of C_i. The poller merges the output of all participants to a single information path. This merged output is a summary of the responses of all the participants and in general its capacity C_s is greater than any C_i. The destination terminal in the incasting network is denoted as the terminal D. Characterizing an incasting system is the unidirectional flow of information from many to one, shown as $n \rightarrow 1$.

By combining both a broadcasting and an incasting system, we form a participatory system. This is shown in figure 2-3. Here each participant P has an input (measured as bandwidth, B) and an output (measured as capacity, C). The summarized output of the poller is returned to the broadcasting source as feedback. The destination of the incast is also the source of the broadcast, thereby closing information loop, forming a participatory system. A participatory system is therefore characterized by a single broadcasting source which also serves as an incasting destination. This center of information acts as filter. Bi-directional information flow is achieved but only a filtered flow is actually fed back to the participants.

2.3 SYSTEM REQUIREMENTS

A general theory and problems of incasting have been introduced so that the MINERVA system requirements can be viewed in proper prospective. The incasting system to be designed for MINERVA is to be used for votes, attitudes, and consensus taking. Conferencing, although a function of broadcasting and incasting, will not be included as incasting requirements. It will be treated as a separate function of MINERVA. For economical reasons, the MINERVA incasting system will be designed to utilize existing communications facilities as much as is practical. The system must be capable of polling the attitudes, consensus, and/or votes of individual participants. The following constraints must be considered and incorporated into the system.

a) The coverage afforded by the poll must be capable of nationwide growth.

b) The system must not overload any communications facilities used; in particular the telephone network is very susceptible to high concentrated traffic.

c) The rate for the incast must be reasonable. For the MINERVA system the rate may range between less than a minute to hours depending upon the purpose of the incast. Two different response times are envisioned:

1 - immediate - a sampled or straw poll capable of being collected within minutes, or seconds. This type of poll is useful to help continue or terminate the discussion.

2 - precise - a complete accurate poll of all votes made by participants. This poll can take up to approximately 12 hours but greater speed would be desirable.

d) The facility designed must be capable of summarizing the results and transmitting it to a central location.

3. IMPLEMENTATION

The telephone system is the only system that provides each subscriber with the ability to transmit inforamtion to any other subscriber. It has been designed to provide this function. Extensions to this basic service have been added such as conferencing, data communications, and even PICTUREPHONE (although limited). To minimize cost and still provide basic one-to-one type communication service, telephone equipment, especially in central offices, are designed to be kept as busy as possible handling calls.. These central offices are engineered on a probability basis. It is assumed, and rightfully so, that calls are originated independently and probability theory can be used to determine the equipment needed in a central office. Calling characterisitcs of subscribers such as the average time of a call, the number of calls made per subscriber per hour, etc, are used to engineer a central office.. For example, in a typical rural area, the telephone traffic consists of long holding times, but relatively few originations per hour. On the other hand the traffic in a typical commercial area consists of many short holding time calls.

If the telephone system were used in a manner different from what it has been designed for, causing the underlying assumptions of traffic rates and distributions to be no longer valid, then a serious degradation of telephone service would result.. If every subscriber served by the same central office were to initiate a call at the same time, the office would not be capable of serving all the subscribers properly.. Some would experience excessive dial tone delay, reorder tone (due to network blockage), or even no service at all. The telephone system is a delicately balanced network designed and engineered on a statistically sound basis to handle and control the flow of telephone traffic.

3.1 EFFECT OF BROADCASTING ON THE TELEPHONE NETWORK

Calling traffic patterns are greatly influenced by external factors. Natural disasters in one area of the nation will cause excessive traffic into and out of the affected area. Special circuits equipment and operators are usually required to handle such emergencies. Likewise if a prominent person travels to some location and is covered by the news media, or an important event occurs, the telephone traffic is affected accordingly. In the latter cases the telephone network can be modified prior to the event thereby alleviating any adverse affect on normal telephone service. Similarly, television telethons, and radio call-in shows tend to increase telephone traffic which can affect normal service if special precautions are not taken. Broadcasting to all subscribers, these shows encourage them to call in at the same time, thereby overloading the central office serving the broadcasting studios and perhaps causing traffic to back up to other central offices as well. Telephone operating companies usually provide special lines and telephone numbers for this call-in function. For example considerable effort was spent to provide telephone service for the Democratic and Republican presidential candidates telethons on November 3, 1968. Since the telethon was nation wide all trunks to Los Angeles (side of the telethons) would be busy if no precautions were taken. To prevent the toll offices at Los Angeles from being overloaded, blocking (or limiting network access) was done at the originating toll offices. This technique distributed the load evenly over the entire nation, hence normal traffic to Los Angeles would not be blocked due to the telethon.

To handle such telephone usage in the future, special area codes and/or office codes may be reserved. Detection could easily be done at the originating office and excessive calls could be blocked there before they could tie up the network affecting regular telephone service.

3.2 POLLING VIA THE TELEPHONE SYSTEM

From the previous section it is apparent that the telephone system has not been designed to provide incasting. It is also clear that broadcasting via the telephone system is a function not easily implemented. Disregarding for the moment the effect of polling on regular telephone service, there are a number of different methods that can be employed to achieve polling by using the telephone network. Each method will be described below together with any inherent advantages or disadvantages. The disadvantages will include any adverse affect the polling method would have on regular telephone service.

3.2.1 INDIVIDUAL CALL-IN

This method is the most obvious and easiest to implement. Each participant is required to call a particular number to register his vote. A series of different numbers can be provided each representing a different choice or vote. The only equipment needed would be an automatic answering device that could tabulate the total number of calls reaching each different number. The time that this device must hold the line should be long enough to register the vote and return some characteristic "vote tabulated" signal back to the participant so that he knows his vote has been processed. Figure 3-1 shows the arrangement required to implement this method.

The advantages of this method are entirely economic. All that are required are the vote tabulators at the broadcasting site. To initiate a poll the telephone numbers corresponding to the possible choices are broadcasted to all participants and the vote tabulators initialized to zero. After a predetermined length of time (depending upon the number of participants) or when the rate of call-ins decrease to a particular threshold, the tabulators are read and the results of the incast are available.

The disadvantages are many. The telephone network is unprotected. This method of polling creates the very same network overload conditions caused by an unchecked telethon or natural disaster. The severity of the overload depends upon the number and distribution of the participants. This method places a severe burden on the telephone system and for this reason alone should not be considered. In addition to the abuse of the telephone network, the other requirements for incasting in the MINERVA system are not met. Due to the inherent telephone blockage set up by massive call-ins, participants are required to dial over and over until they reach the vote tabulator. Many would give up after a few attempts in disgust; others may be lucker and vcte many times. It would be impossible to execute a precise poll, and even a straw poll may not be truly representative of the whole. The rate at which the incast can be completed depends upon the number of participants. Although numerous lines can serve the same telephone number, and parallel tabulators can be set up, the excessive load on the central office would be the limiting factor. In essence, the limitations of the volume of call-ins by the network causes any incast to be not indicative of the consensus of the total participating population. The incast would most likely be the consensus of those lucky or perserverent enough to complete their call to the vote tabulator.

3.2.2 CENTRALIZED CALL-OUTS

The problem with call-ins is a consequence of calls originating simultaneously. The telephone system has not been designed to handle such a surge of calls. Therefore the call-in approach is not feasible and the reverse approach termed "call-outs" should be considered.

3.2.2.1 OPERATOR INTERROGATION

The simplest case of centralized call-outs is the operator initiated call-out. In this method the operator (or operators) calls all the participants and questions them on their vote. This vote gathering technique is done quite often for political straw polls, Nielson television ratings, consumer product surveys, etc. It is very effective but extremely expensive and time consuming. This type of polling requires a priori knowledge of the identity of the participants; it would be wasteful to query each telephone subscriber to determine if he is a participant in a particular incast. Confusion may result if more than one incast were in progress at the same time. Furthermore it would be annoying to the participant to be phoned some time after request for the incast has been made (especially if it is 3 o'clock in the morning). Sample or straw polls using operator interrogation are easily implemented,but precise polls are impossible to attain due to the time requried to complete the poll. Because of the excessive time required this method is compatible with normal telephone services. It causes no serious overloading on the telephone network. However, if many operators were used to speed up the incast there may be some blockage but only at the central office serving the operator.

This method of polling may be rejected for a number of reasons; expensive, not automated, not capable of nation wide coverage, and it does not take advantage of modern technology. Its only advantages are that it does not require any additions to individual participant's telephones or to central offices, and it can be implemented immediately.

3.2.2.2 AUTOMATED INTERROGATION

The next logical step is to consider centralized call-outs without the operator. The operator can be replaced by an automatic interrogator which sequentially calls each participant. The calling may be done in one of two ways; with ringing, or without. With ringing no modification to central office equipment is required. Upon answering the interrogation call the incast participant recognizes a special "vote now" signal or a recorded announcement. At which time he reigsters his vote either by TOUCHTONE keys or by generating dial pulses. The automatic interrogator registers the vote and then calls the next participant. Since each vote requires real time intervention of the participant, this method is no faster than the operator interrogation method. Its primary advantage lies in the fact that it does not seriously overload the network and no additional equipment is required either in the central office or at the participant's premise.

The other automatic interrogation method proposed (that with no ringing) does not require direct intervention by the participant. It does however require special equipment both in the central office and at the participant's premise. When an incast is initiated the participant registers his vote in a small inactive device attached to his phone. This device is then activated by a special non-ringing signal from the central office and the vote is then transmitted to the automatic interrogator via the regular telephone network. This method of automatic call-out is being developed for meter reading applications. Its disadvantage is the excessive traffic that it generates. Since an electronic device is interrogated, the interrogation time is minimal, hence many extremely short holding time calls are established. Although the calls are not concurrent they do have considerably effect on the traffic load handling ability of the central office. For example, a No. 5 Crossbar office with three markers would have to essentially dedicate one marker to handle the meter reading (markers are control equipment used to establish and release network connections), effectively reducing the office capacity to 2/3 its previous capacity.

For this reason the operating companies will allow meter reading only during slow traffic periods (usually between 10 pm and 6 am). Use of this technique for incasting during typical broadcasting hours would put excessive traffic loads on the telephone network. Hence automatic interrogation without ringing should not be implemented.

3.2.2.3 AUTOMATED INTERROGATION WITH TRAFFIC CONTROL

A final method utilizing the centralized call-out concept consists of automatically limiting any excessive traffic created by the incast. This can be accomplished by a program modification to an electronic switching system (ESS)[4]. Normally the processing of calls is executed at the highest priority; all other work is postponed until call processing is completed. The lowest priority usually consists of routine exercises that test the hardware. It is possible to introduce another low priority job that would be dedicated to conducting polls. Such a job would be executed only if regular call processing has been completed. Furthermore, since these ESS's do have memory that can hold temporary information (call store), a list of incast participants to be polled can be stored before the actual poll. Hence during the incast only those participants need to be interrogated.

The disadvantage of this method is the unpredicability of incast rate. If the incast is initiated during a low traffic period, then the rate would be high, but if initiated during a high traffic period, the rate would be low. Another more serious problem is that of growth of the incasting network. ESS's are currently being installed at a high rate but it is still unknown when all existing central offices will be converted to ESS. Number 5 Crossbar and even Step-by-Step offices are still being installed and no estimate can be given when these will be replaced by electronic systems. If the coverage afforded by the MINERVA system were limited by location of electronics offices, then the incasting function of MINERVA would be severely limited. (However, further study may indicate how to achieve traffic controlled call-out with older type central offices.)

3.2.3. SUMMARY OF POLLING METHODS

At this point it can be seen that normal telephone service is not affected as long as the incasting rate is low. When the rate increases, whether due to paralleling techniques or to a minimization of the interrogation time (or combination of both), the adverse affect on normal telephone service becomes more and more a factor. However this factor can be controlled by assigning a low priority to the incasting function. This would then put the incasting rate at the mercy of normal telephone traffic. And it can only be implemented in ESS type offices.

The conclusion that can be drawn is that the telephone system as designed (or even modified) cannot be used to effectively provide the incasting function specified by the MINERVA system. Nevertheless limited polling is possible as described under automated interrogation. This technique can be used to augment any incasting network developed specifically for MINERVA. By expanding this concept of automated interrogation it will be shown in the next section that certain parts and functions of the telephone system can be used to meet the MINERVA incasting requirements.

3.3 PROPOSED INCASTING NETWORK

Instead of proposing an entirely new network designed for incasting it should first be determined what such a network has in common with the telephone network. Most obvious is the individual subscriber's loop; that is, the pair of wires enjoining the subscriber's phone to the central office. Since every subscriber (or participant) must have such access to a central location it is the most singly expensive item in the network. By designing an incasting network that shares this expensive item, a significant part of the total cost of the incasting network would be saved. The only other feature of the telephone network that can be effectively used for incasting would be the nationwide direct distance dialing (DDD) capability. This feature can be used to send incast control information and summaries to any place, thereby facilitating nationwide coverage.

The proposed incasting network is to be integrated into the existing telephone network. To meet the MINERVA incasting requirements of rate and non-interference, the concept of centralized call-outs using automated interrogation without ringing will be used as a basis for the proposed network. Therefore, each participant requires a special device attached to his regular telephone line. This device will be defined as the voter. To prevent the incast from overloading the subscriber's central office, the subscriber's loop must be intercepted at the central office before the network. The device that intercepts the subscriber's line and interrogates his voter is called the poller. The poller gains access to any subscriber's line through a special access network. Once connected to a subscriber's line the poller has the ability to interrogate the voter to determine whether it has been activated, that is, whether it registers a vote. Once the poller interrogates an active voter, the voter transmits the vote to the poller and deactivates itself. After the poller registers the vote, it then proceeds to the next subscriber's line to test for an activated voter. Once all the votes have been tabulated by the poller, it forwards the results via a standard data phone connection to the central location that initiated the incast. If the incast is wide-spread then intermediate pollers can be provided in a hierarchal structure, By establishing such an incasting network, parallel polling is achieved and a minimum traffic load is placed on the telephone network. Effectively the incasting network is superimposed over the existing telephone network as shown in Figure 3-2.

3.3.1 VOTER

This section describes the characteristics of the voter and how it is used for incasting. The size of the voter need not be larger than a standard telephone set. In fact it can be integrated into the telephone set itself. The participant wishing to vote may select one of n choices by depressing a key or keys corresponding to his choice. Use of LED's (light emitting diodes) will enable the number of the choice to be displayed on the voter. At this point the vote is registered in the voter and the voter is said to be activated. If the participant wishes to change his vote before the poll is taken, he may do so by resetting the voter and voting again. When the poller in the central office interrogates this voter, the vote is automatically transmitted to the poller using either TOUCH-TONE signals or a standard frequency shift signaling method. Once the voter transmits the vote, it is automatically placed into a "vote tabulated" state which indicates to the participant that his vote has been properly received.

3.3.2 POLLER AND INTERCONNECTING CIRCUITS

The poller and its associated equipment is the heart of the incasting network. Assuming a simple incasting network configuration as shown in Figure 3-3, a signal is sent via the DDD network to all pollers participating in the incast. Once activated the poller autonomously interrogates each voter for any registered votes. It then records the vote and the voter is deactivated; the poller then interrogates the next voter. Once all voters have been interrogated and their votes tabulated, the poller returns the results to the incast controller (the initiater of the poll). Note that more than one poller can be initiated at the same time, hence parallel polling is provided. With parallel polling it is possible through various configurations to meet the incasting rate specified by the MINERVA system.

It is possible for the pollers to poll other pollers, hence a polling hierarchy can be established as shown in Figure 3-4. In such a hierarchy a poller does not transmit its results until a poller at a higher level interrogates it. The regular DDD network is utilized for inter-level polling for economical reasons. This network usage does not cause any severe overloading problems since the number of pollers is small. Furthermore higher levels could be provided if any single second level poller is required to interrogate an excessive number of first level pollers.

3.3.2.1 LINE CONNECTION

The poller is required to gain access to each subscriber's line. The proposed method of access is to bridge across the subscriber's line before it appears on the network (see Figure 3-5). The line is split away from its normal connection to the telephone network by a relay R_{S_i} (each subscriber's line requires such a relay). If the subscriber's line is off-hook (busy), the relay is inoperable. Regular telephone service will always override any polling whether in progress or not. Once the incasting network has access to the line, an on-hook condition (telephone idle) is placed on that line's network appearance so that the polling does not interfere with the normal processing of calls by the central office. If the customer goes off-hook (originates a call) while the R_{S_i} relay is operated, the relay is automatically released and the line is restored to its normal network appearance. The aborted interrogation of the voter will result in an invalid ballot and the vote (if any was registered) will not be counted. The R_{S_i} relay is controlled directly by the poller through a distribution circuit, but is always released whenever the subscriber's phone is off-hook.

(It may be both desirable and feasible to arrange matters so as to give priority to the transmission of the signals between voters and pollers. This would simplify the polling process considerably while causing only a slight and very infrequent effect on the subscriber's normal phone service.)

3.3.2.2 ACCESS NETWORK

The access network (Figure 3-5) is simply a common bus that is connected to every subscriber's line through its R_{S_i} relay. Also connected to the bus are various access circuits. For simplicity each functional step in polling is separated into a different circuit. It is possible to combine these functions into a single circuit, but by separating them it can be seen how additional functions can easily be implemented. Once the R_{S_i} relay is operated, power is supplied to the loop via the R_{S_i} relay so that an off-hook condition can be detected. The existence of a voter on the subscriber's line can be detected by connecting the line tester to the bus via the R_{S_i} relay. Once the voter has been detected, an interrogation signal is sent to the voter via R_{S_i} and finally the digit receiver is connected via R_{S_i} to accept the information transmitted by the voter.

4.3.2.3 POLLER

The poller controls the access network, distribution network and the R_{S_i} relays. Using inforamtion from the access circuits, the poller decides which lines to interrogate. It then records the vote and tabulates the final results after interrogating all the voters. To accomplish such a task a small computer is required. Prices of minicomputers today make this a reasonable proposition. In addition a minicomputer would provide the flexibility needed for special polling.

The poller interfaces with each access circuit for controlling voter interrogation. It also activates the distribution network for controlling the R_{S_k} relays and interfaces with the DDD network via a data set for input control and an automatic dialer (using multi-frequency outpulsing for rapid dialing) for interrogation of other pollers. Due to the flexibility of a programmable poller, the poller can be designed as a universal poller which can function at any level. It can be programmed to execute various types of polls; straw, precise, etc, on command. Furthermore various techniques can be easily implemented to speed up the incast rate. Other features to aid in automatically establishing conferencing among its participants can also be implemented.

3.3.3 POLLING HIERARCHY

The polling hierarchy serves two functions: first it distributes the traffic load generated by the incast over the telephone network. Second, the hierarchy establishes a parallel executed poll since each poller can autonomously execute a poll over all the participants served by its central office. Since each poller can function at any level, the polling hierarchy can be adaptable. It can be changed or modified for each incast by the incast controller which resides at the destination of the incast. The incast controller can contact any poller in the network and give it all the information it needs to successfully execute its role in the incast. Based on the number and distribution of the participants for a MINERVA dialogue, a polling hierarchy can be established that would maximize the incast rate and minimize traffic burden placed on the telephone network. The polling hierarchy is established by transmitting the appropriate information to every poller before the incast is executed.

3.3.4 POLLING STRATEGIES

With an understanding of the hierarchal incast network structure, various polling strategies can be discussed which achieve the various rates required for the MINERVA system. To illustrate, it is assumed that there are 50,000 participants evenly distributed among 50 central offices (1000 participants per office). It is also assumed that there are 10,000 lines per office. Figure 3-7 shows the 2-level polling hierarchy used in this example. To determine the incasting times for a straw poll and precise poll, it will be assumed that 100 milliseconds are required for accessing, interrogating, and registering the vote from one participant.* Inter-poller communications is considerably longer since the polling is done via the regular telephone network. Five seconds will be used to estimate the total time required to outpulse, establish a network connection, transmit or receive, and release the network connection.

*If access to the voters could be achieved entirely by electronic means. (That is, if the need for operating electro mechanical relays could be eliminated, then the time to register one vote could be cut to about numeral 10 milliseconds. This possibility is being studied. See also subsector 3.3.4.3.1.

3.3.4.1 PRECISE POLL

From Figure 3-7 it can be seen that 9 inter-poller access time constants (T_c) are required to initiate all 9 second level pollers and 5 time constants to reach all first level pollers. The total time T_I required for initiation of a poll is therefore,

$$T_I = 9T_c + 5T_c = 14T_c$$

If T_c =5 seconds as assumed, then incast initiation requires 70 seconds to complete. However it should be noted that the first poller to be activated (poller #1) starts polling within the first 5 seconds. Similarly, poller #1, 1 starts within the first 10 seconds, pollers #1, 2 and #2 starts within the first 15 seconds, etc.

The time required for each poller to register all the votes of its participants is much greater than the initiation time. If we assume that every poller must interrogate every line in its central office at 100 ms per line, then 1000 seconds (approximately 17 minutes) is required for each poller to complete its poll.

Each poller reports its tabulated results when interrogated by a higher level poller (or incast controller). The same procedure used in initiation is followed, hence the total time for reporting is the same

(70 seconds). But since the initiation was staggered, polling the pollers could begin 65 seconds before the last poller (poller #9, 5) finishes, provided of course, the order of polling is the same as the order for initiation. Therefore only 5 additional seconds are required to complete the poll. The total incasting time for a precise poll is 1075 seconds for this example (approximately 18 minutes).

Since the most time is spent in polling the participants of a single central office, any strategy to reduce this time will be extremely beneficial. It can be reduced by a preliminary poll executed automatically by the poller prior to the actual incast to determine which of its 10,000 lines will participate in the incast. Assuming only 1000 participate then during the actual incast, the poller need interrogate only 1000 lines, hence reducing the polling time to 100 seconds. And the total incast time would be reduced to 175 seconds or approximately 3 minutes. These figures compare very favorably with those derived under the assumption that the telephone system would be used in a more straightforward way [3].

3.3.4.2 STRAW POLL

Execution of a straw poll can be done precisely as illustrated above. However, if it is assumed that only every third participant will be sampled, then the 100 seconds reduces to 33 seconds. But the inter-poller communication time remains at 75 seconds. Instead of reducing the total time required for a straw poll to one-third that required for a precise poll, only a reduction to two-thirds is realized. The total time can still be reduced by establishing a different polling hierarchy. Instead of using 9 second level pollers, 6 will be used with 44 first level pollers grouped as shown in Figure 4-8. It can then be shown that the initiation time is reduced to 60 seconds. A further reduction can be realized by using a three level polling hierarchy.

3.3.4.3 OTHER POLLS

The various polls described above illustrate the flexibility of the incasting network and how the time requirements of the MINERVA system can be met. Some of the techniques used include preliminary polls to determine participants, reconfiguration of the polling hierarchy to realize faster inter-poller times, and overlapping of the initiation and reporting times. Some other techniques will be presented below.

3.3.4.3.1 ANALOG POLL

In the incasting network it is possible to gain access to more than one line at any one time, by operating more than one R_{S_i} relay. It is conceivable to connect all the participants in a central office together on the access network as shown in Figure 3-9. The impedance presented to the poller is the parallel equivalence of all the voters, telephones, and line impedances. If each voter were capable of changing its impedance (such as doubling its capacitance by depressing a special button), then any measured change in total impedance would be a measure of the number of participants that depress the special button.

3.3.4.3.2 GROUPED POLL

It was assumed that 100 milliseconds was required to poll one voter. This figure is based on approximately 50 milliseconds for relay operations (25 ms for operating and 25 ms for releasing) and 50 milliseconds for activation and vote reception. The actual subscriber's line is easily capable of transmitting information at 2000 bits per second. Megahertz bandwidth is common but not guaranteed since the subscriber's loop may be up to 5 miles long. At 2000 bits per second 16 bits of information can be transmitted in less than 10 milliseconds. By multipling 256 lines together as shown in Figure 3-10, forming a polling group, each line in the group can be assigned a unique 8 bit address. By conventional polling techniques for stations sharing a single transmission facility, each voter in the group can be sequentially polled without operating or releasing any relays. Allowing two milliseconds for channel turnaround time each voter can be addressed and polled in 16 milliseconds. Hence 4096 ms are required to poll the 256 lines. Relay operations would add only 50 more milliseconds making it 4146 milliseconds or a little more than 4 seconds. By sequentially polling each polling group in this manner 10,000 voters could be polled in less than three minutes and 1000 in approximately 16 seconds. There are special problems associated with this technique of polling such as the determination of busy lines, the effect of one line going off-hook during a poll. Of particular concern is the requirement that every voter be capable of being addressable. If the poller constructs a polling group incorrectly, the addresses within the group are not unique. The parameters of 8 bit addresses and 16 bit responses were chosen to illustrate this technique. A more detailed study is required to determine the optimum sizes.

3.3.5 OTHER APPLICATIONS

When discussing the various types of polling strategies possible with the incast network, it becomes apparent that this network can be used for functions other than incasting. This section will briefly describe some other possible uses of the network.

3.3.5.1 METER READING

Since the incast network is basically an outgrowth of the telephone technique used for meter reading presently under development, meter reading is the most obvious application. A meter reading circuit could be connected to the meter and interrogated by the poller in exactly the same manner as the voter. However instead of tabulating the readings, each reading is then either saved temporarily or transmitted back to the utility over the DDD network. If saved, all the readings taken could be transmitted to the utility in a single transmission. Since the incasting network does not interfere with regular telephone service, meter reading could be executed at any time. Individual inqueries could be easily executed on demand at any time by the utility; billing discrepancies could be checked out in real time.

3.3.5.2 LINE MAINTENANCE

A major source of telephone problems are concerned with line testing. With the incasting network a line can be disconnected from the central office to distinguish between network trouble or line trouble. Automatic line testing can easily be done and the identity of faulty lines could be transmitted to the appropriate maintenance personnel.

3.3.5.3 ALERTING

Since the incasting network can gain simultaneous access to many subscriber lines, simultaneous alerting can easily be accomplished. Two ways are immediately apparent; first, ringing current can be applied to all the phones. But this method requires excessive power. This requirement could be aleviated by grouping the lines and applying ringing power to one group at a time, staggering the ringing sequence. The second method would be to activate, simultaneoulsy, special self powered alerters that are attached to subscriber's line.

3.3.5.4 SURVEILLANCE

Special surveillance units could be attached to the subscriber's line that detect predetermined conditions or states. Once such a condition is detected, the surveillance unit is activated. The poller then polls all units at regular intervals. Any unit found activated would be interrogated for more detailed information and the results would be automatically reported to the appropriate destination. This type of surveillance is most applicable for burglar alarms and fire detection systems.

4. SUMMARY

This entire section has dealt with the utilzation of the telephone system for incasting. As shown, the system cannot be used effectively without extensive modification to it. Certain limited incasting capabilities do exist but fall short of the requirements set by the MINERVA system. Additions or modifications to the system have been proposed whereby an incasting network is established which utilizes a considerable portion of the existing telephone network. Additional uses of the combined network have been presented which can be used to help justify its establishment.

References

(A later version of this report will include a more complete list of references.)

1 Eugene Leonard, Amitai Etzioni, Harvey A. Hornstein, Peter Abrams, Thomas Stephens, Noel Tichy, "Minerva -- A Participatory Technology System," Bull. Atomic Scientists, Nov. 1971, pp. 4-12.

2 Unger, Stephen H., "Technology to Facilitate Citizen Participation in Government," Jan. 5, 1972, Center for Policy Research, unpublished report.

3 Sloan Commission, On the Cable, McGraw-Hill, 1971.

4 "No. 1 Electronic Switching System," (complete issue) Bell System Technical Journal, V. 43, Sept. 1964.

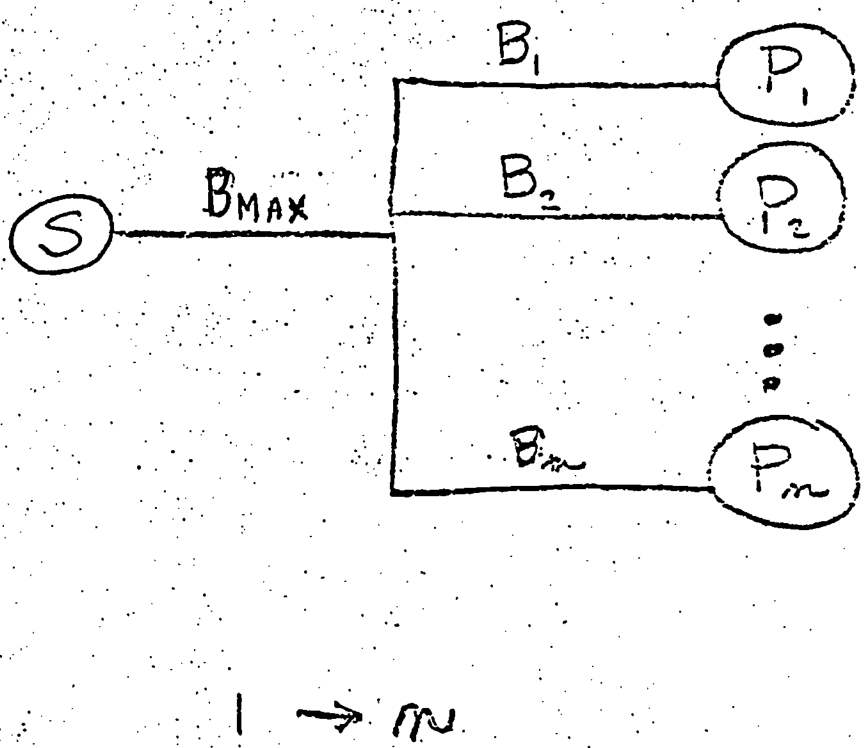

FIGURE 2-1 BROADCASTING

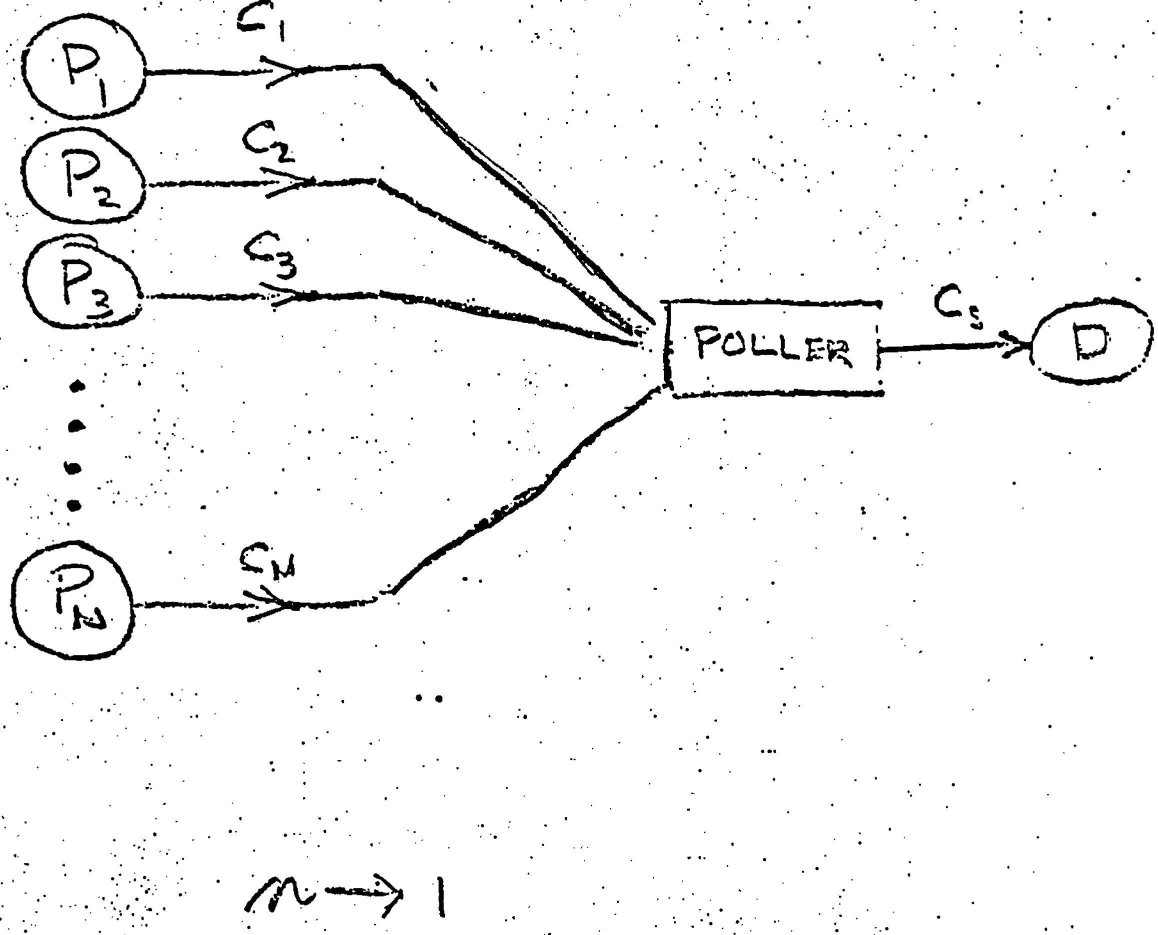

FIGURE 2-2 INCASTING

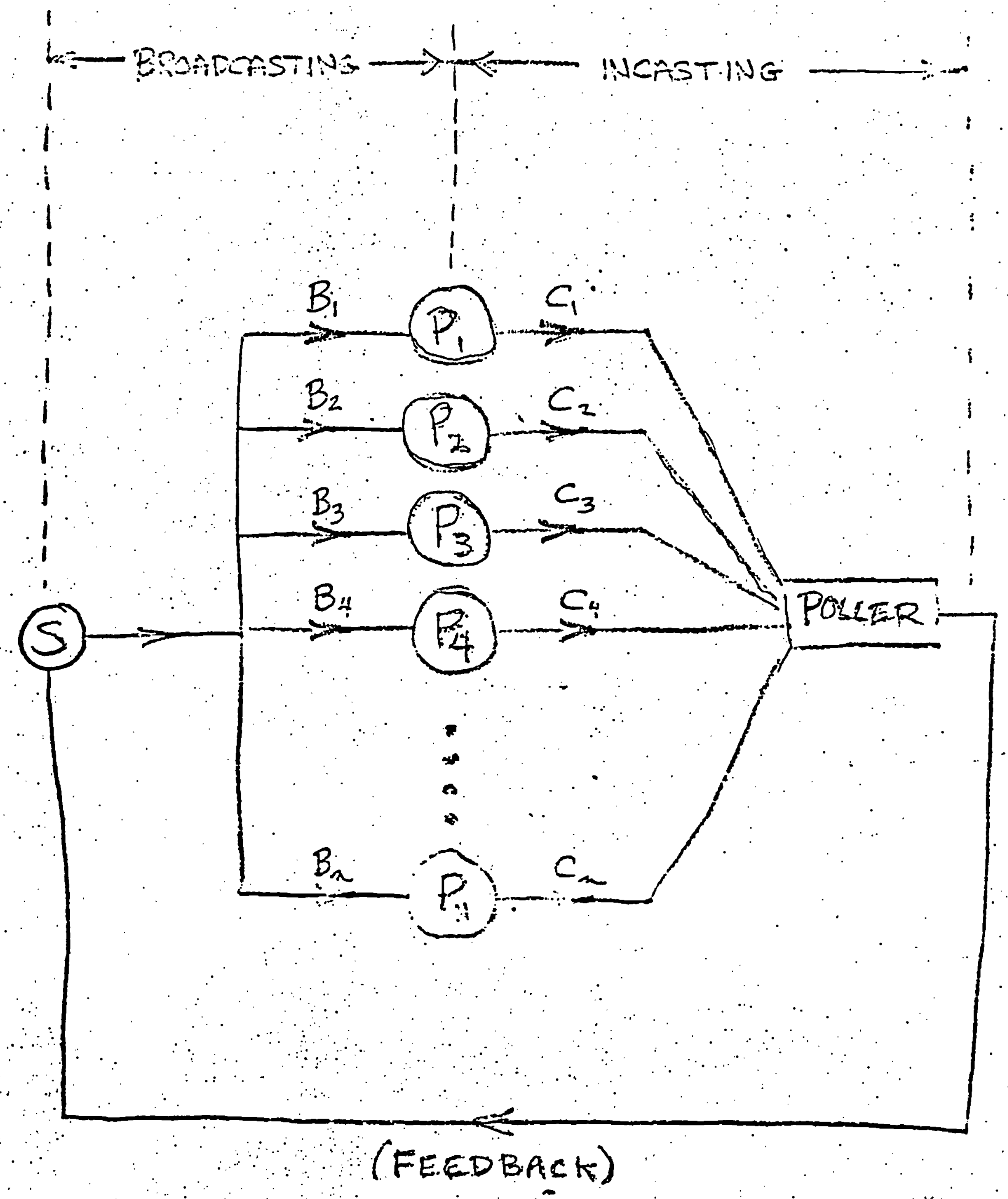

FIGURE 2-3 A PARTICIPATORY SYSTEM

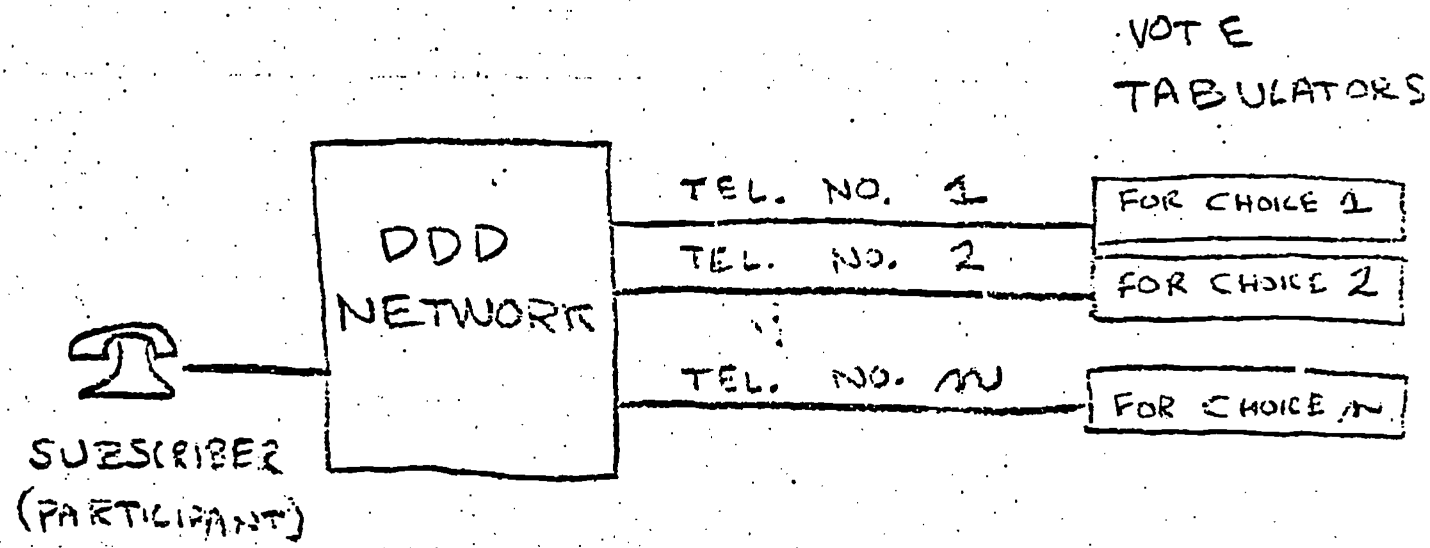

FIGURE 3-1 INDIVIDUAL CALL-IN

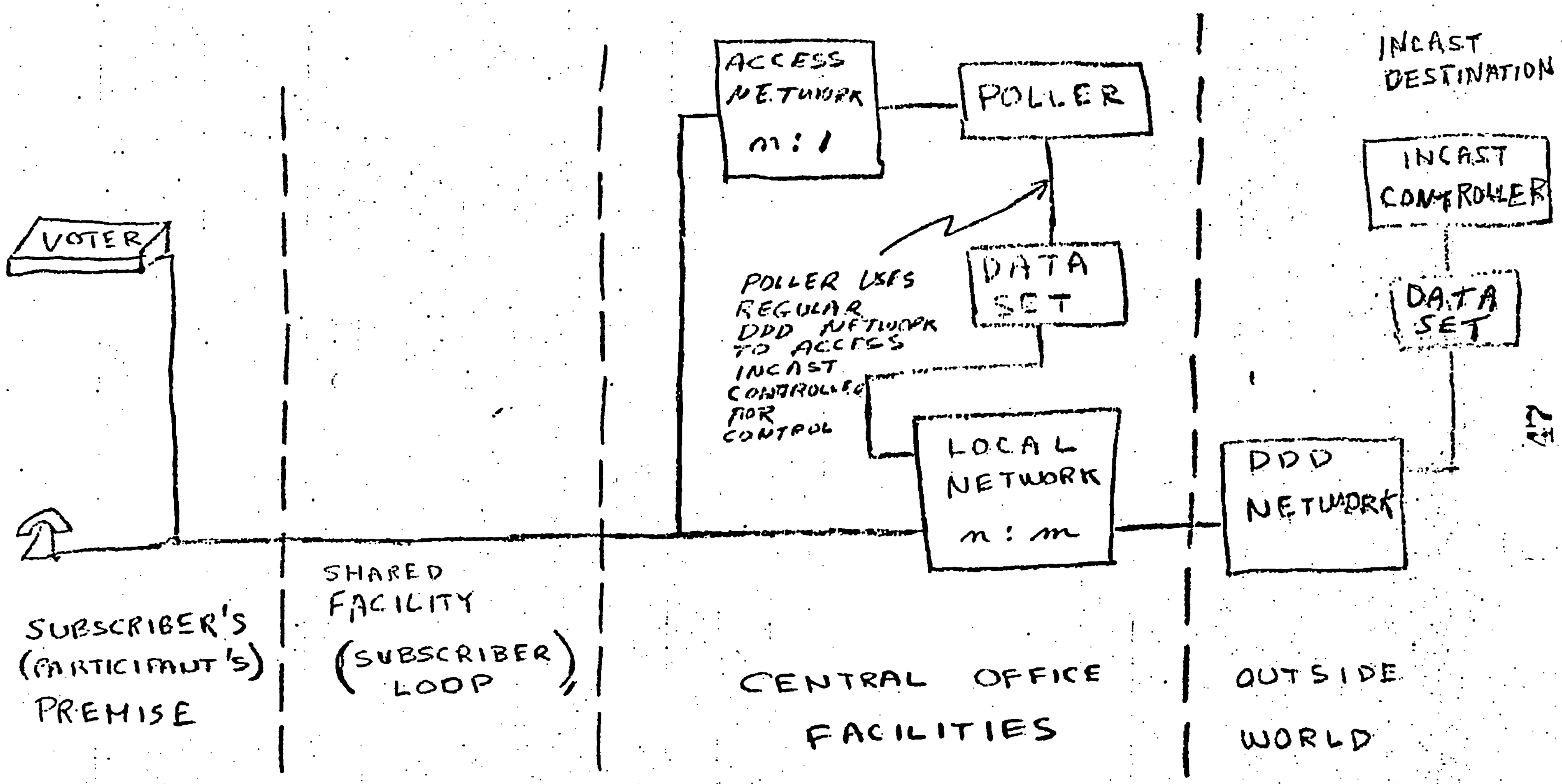

FIGURE 3-2 PROPOSED SHARED INCASTING NETWORK

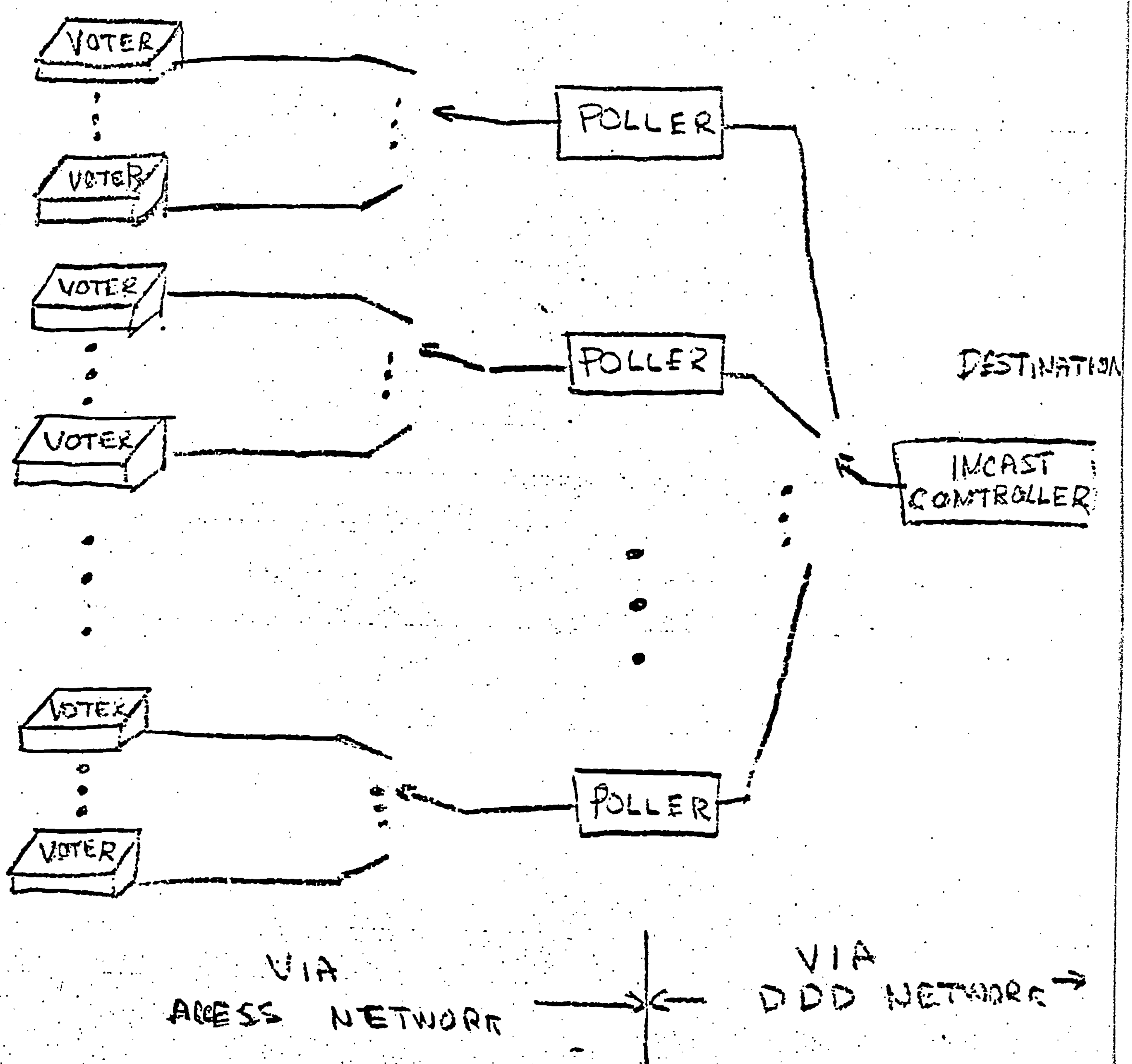

FIGURE 3-3 SIMPLY INCASTING NETWORK

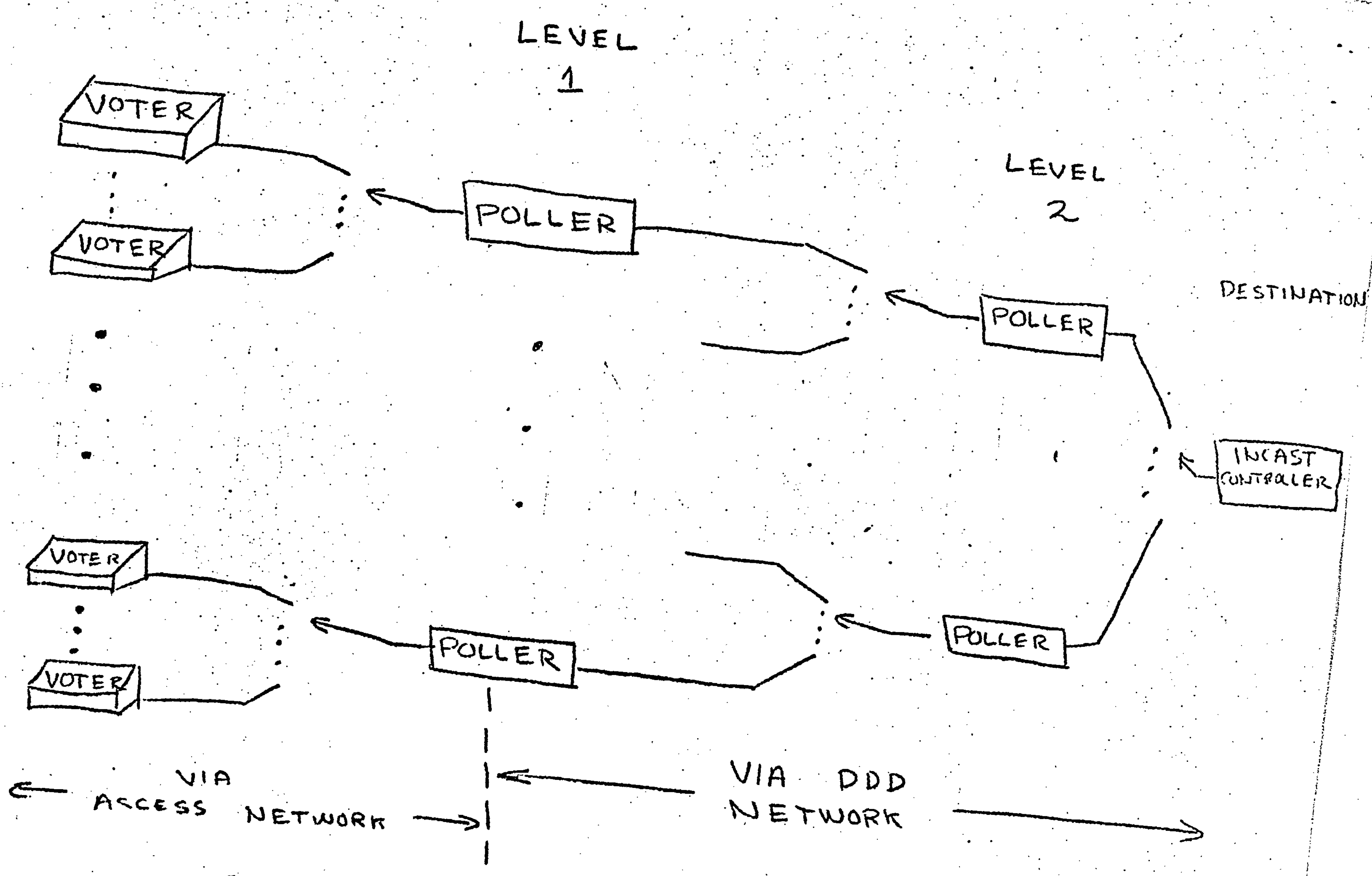

FIGURE 3-4 INCASTING HIERARCHY

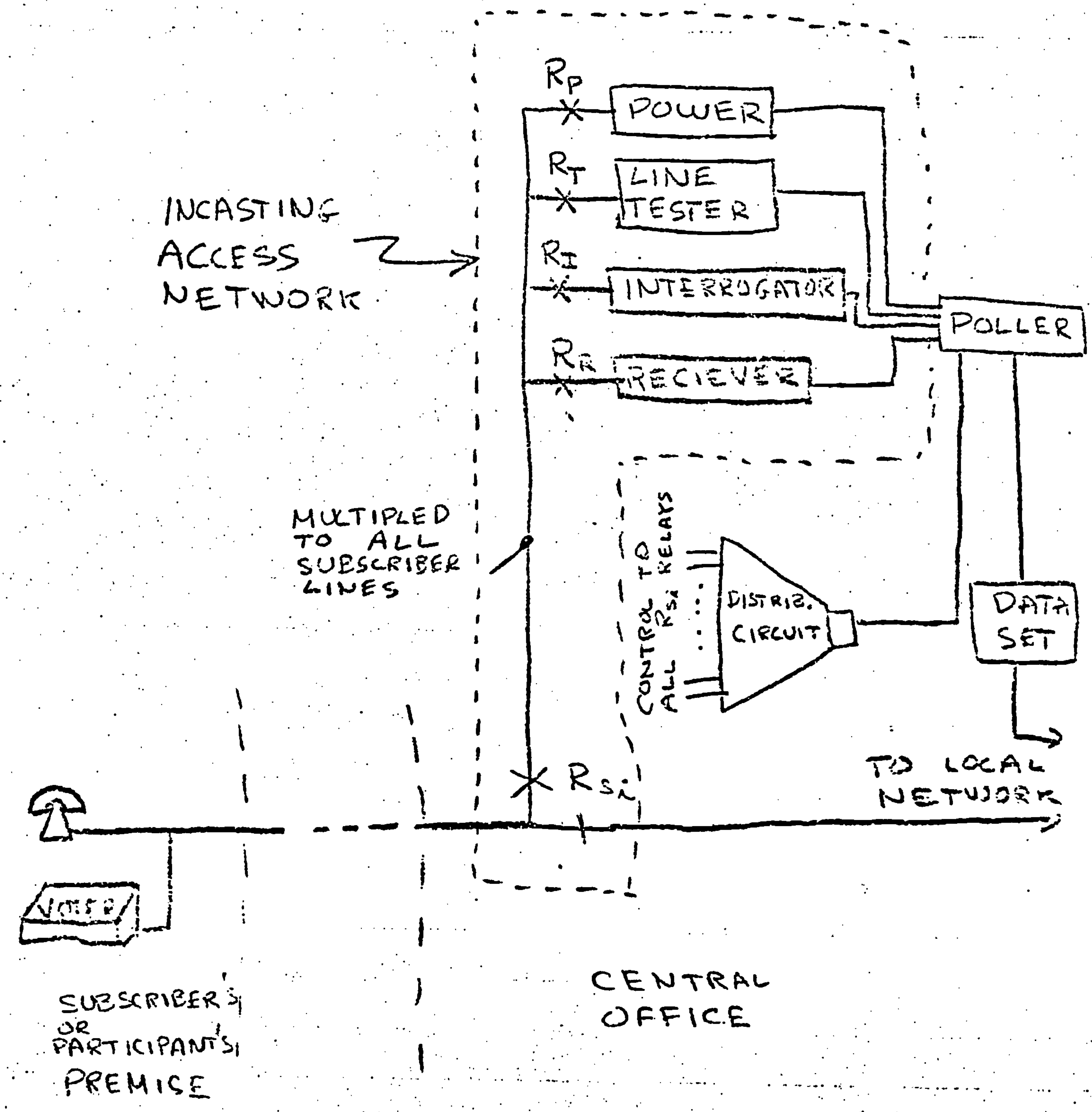

FIGURE 3-5 POLLER ACCESS TO SUBSCRIBER'S LINE

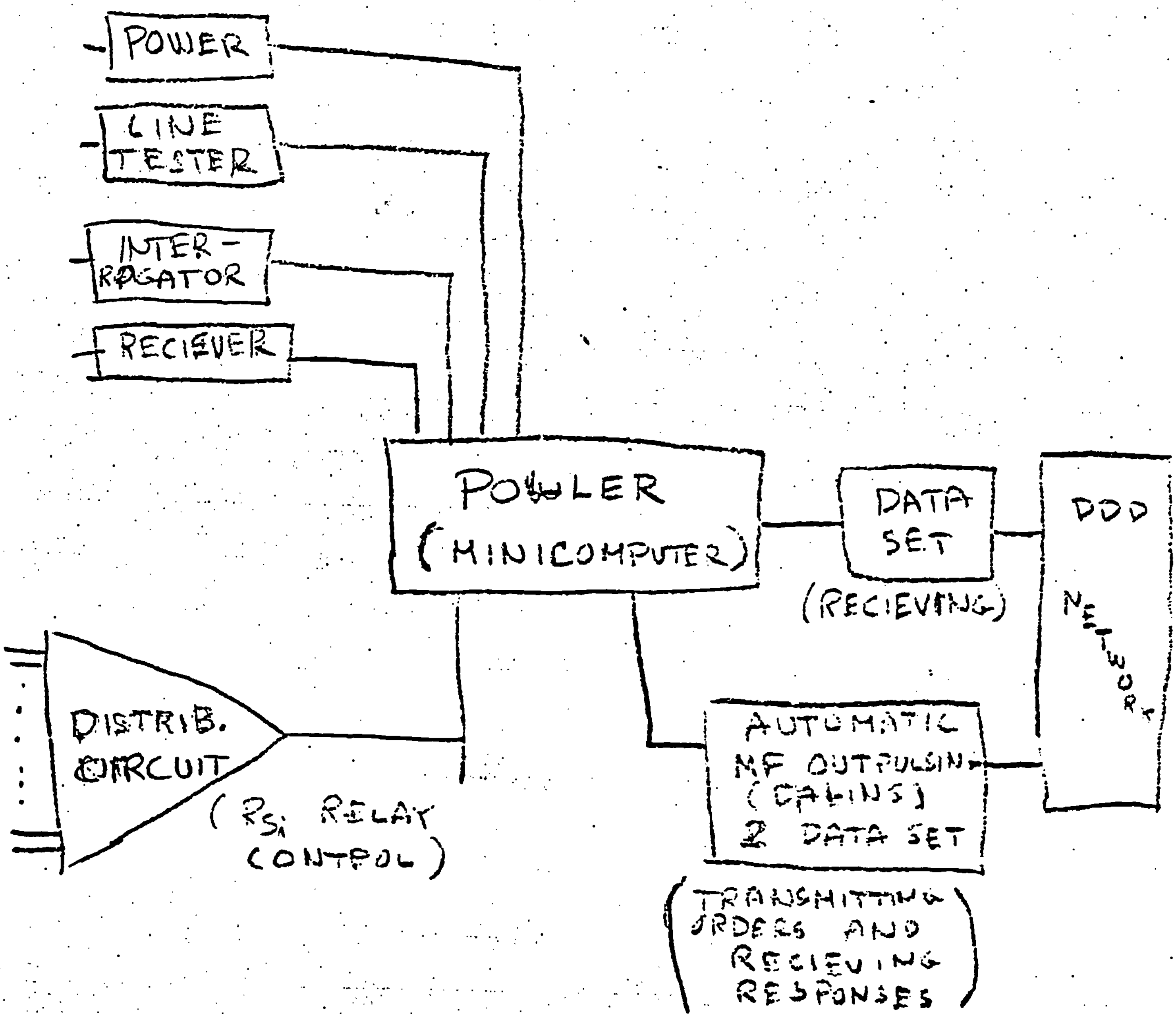

FIGURE 3-6 POLLER

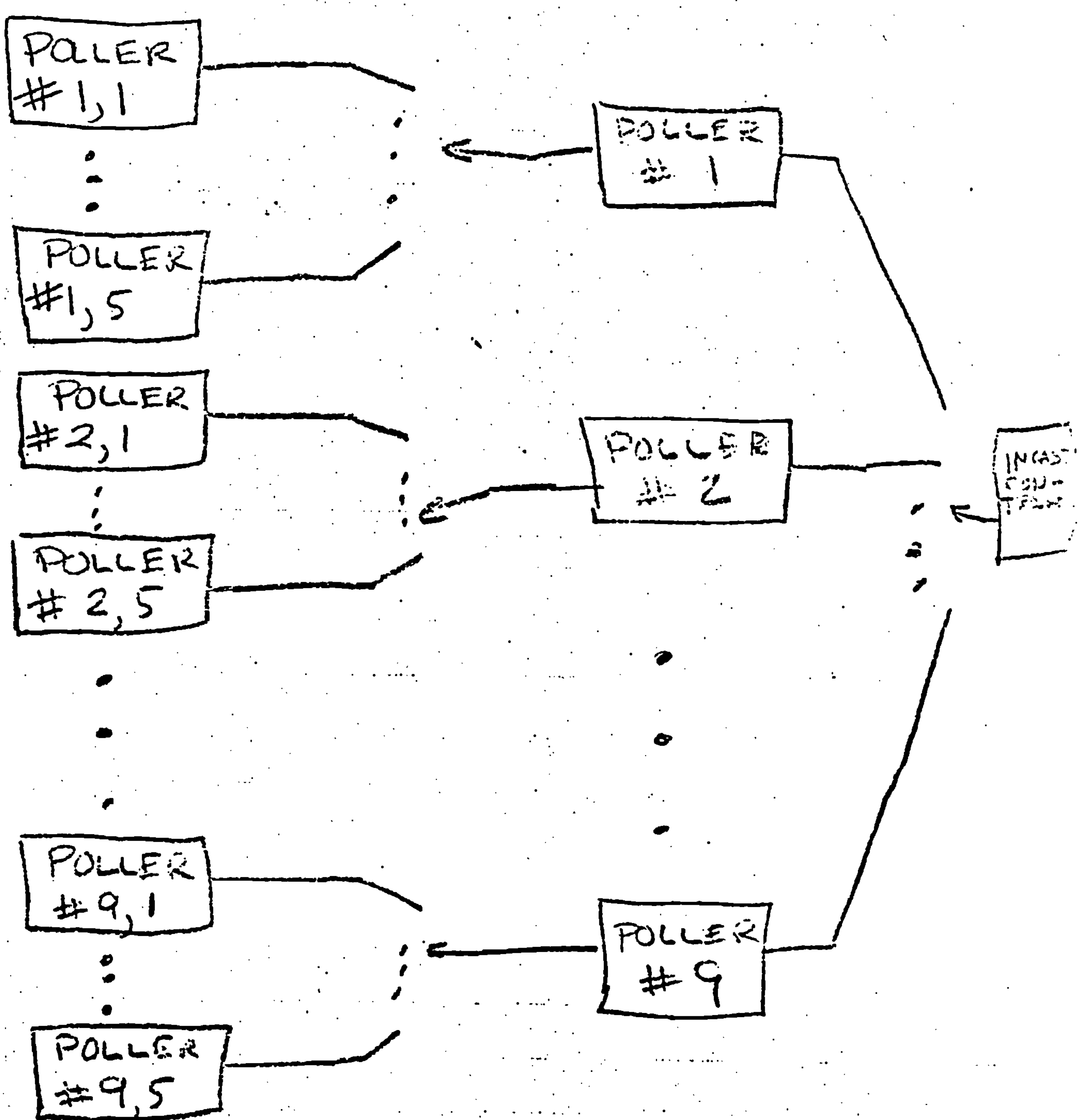

FIGURE 3-7 POLLING HIERARCHY EXAMPLE

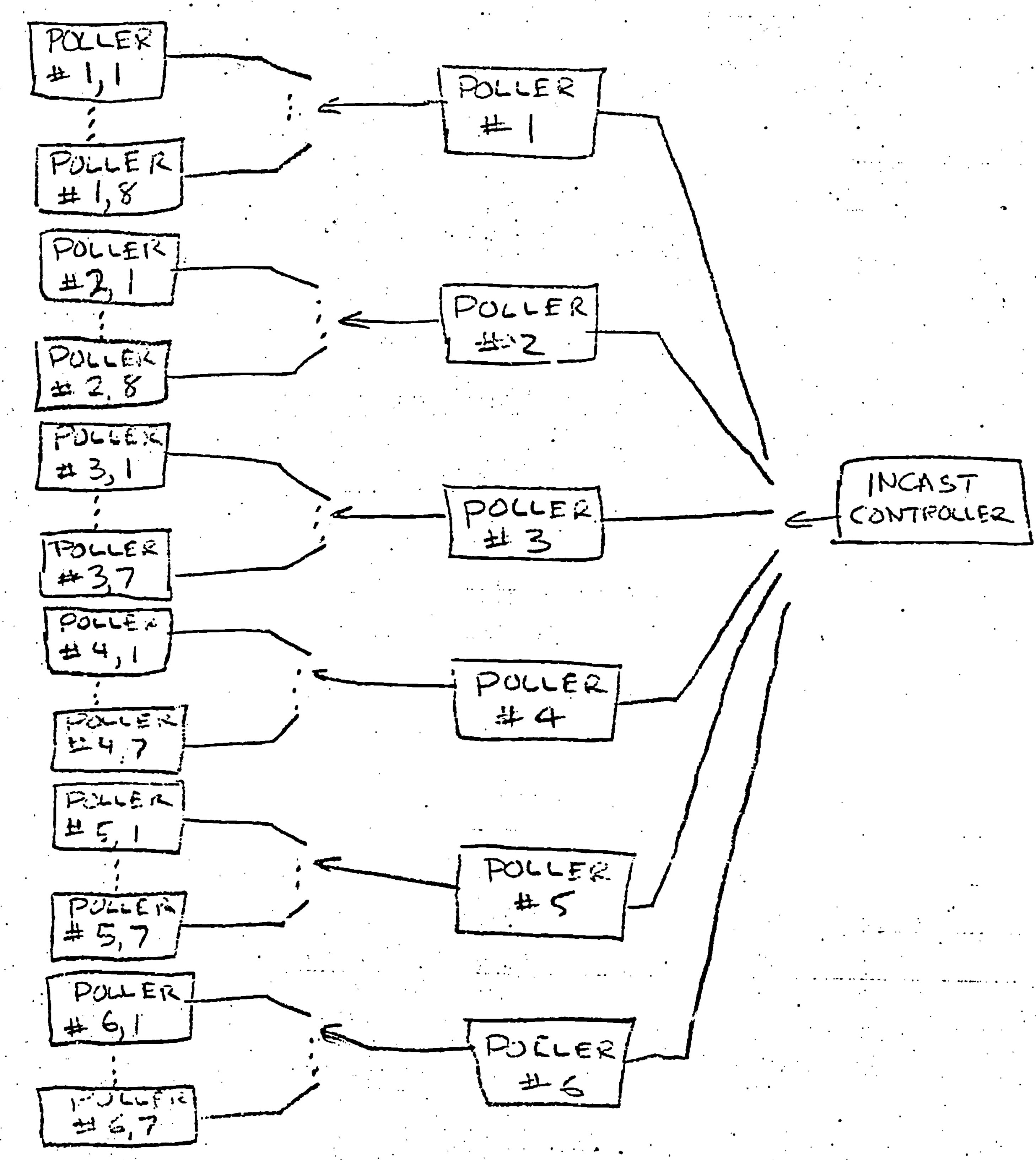

FIGURE 3-8 A MORE EFFICIENT POLLING HIERARCHY

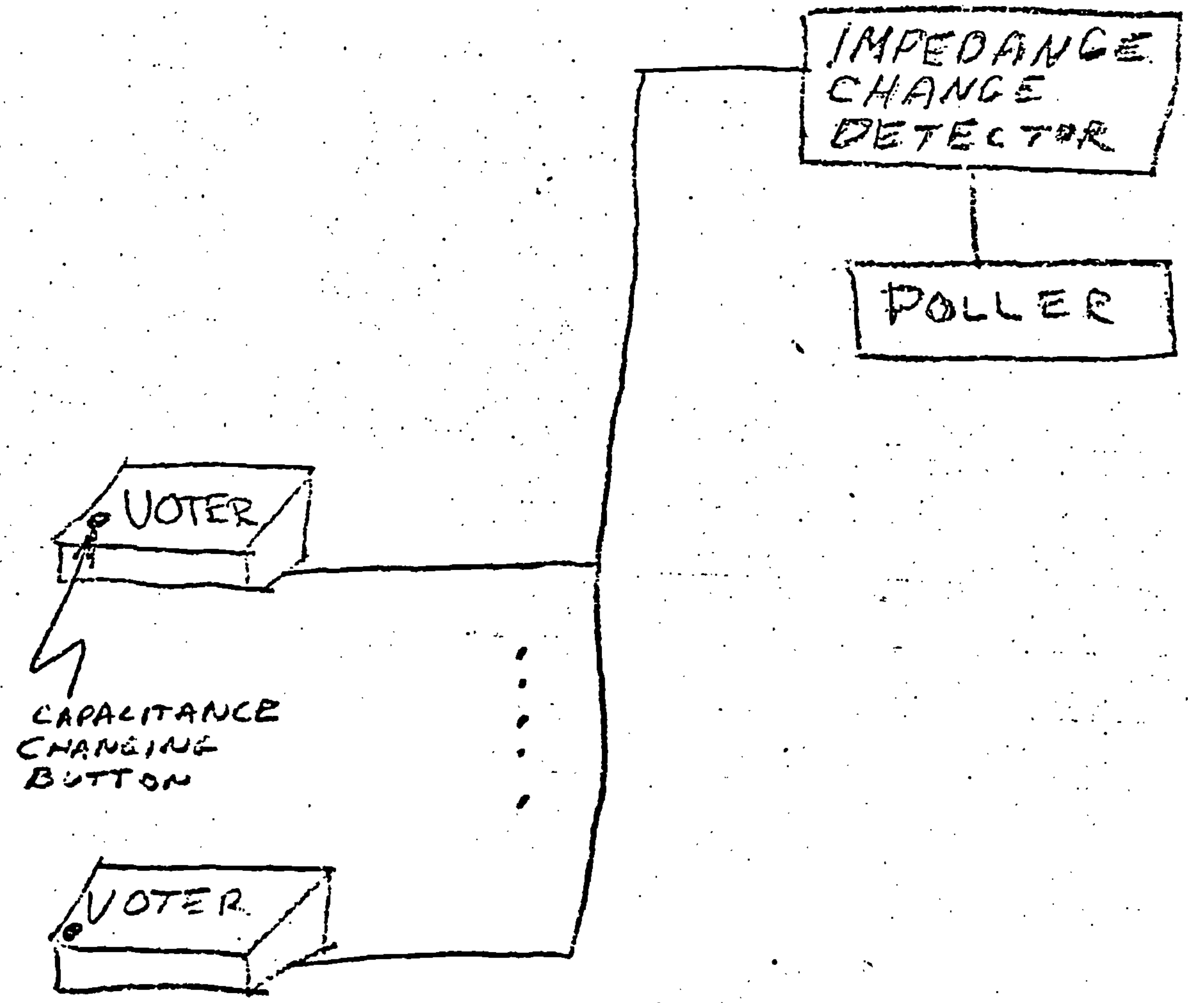

FIGURE 3-9 ANALOG POLL

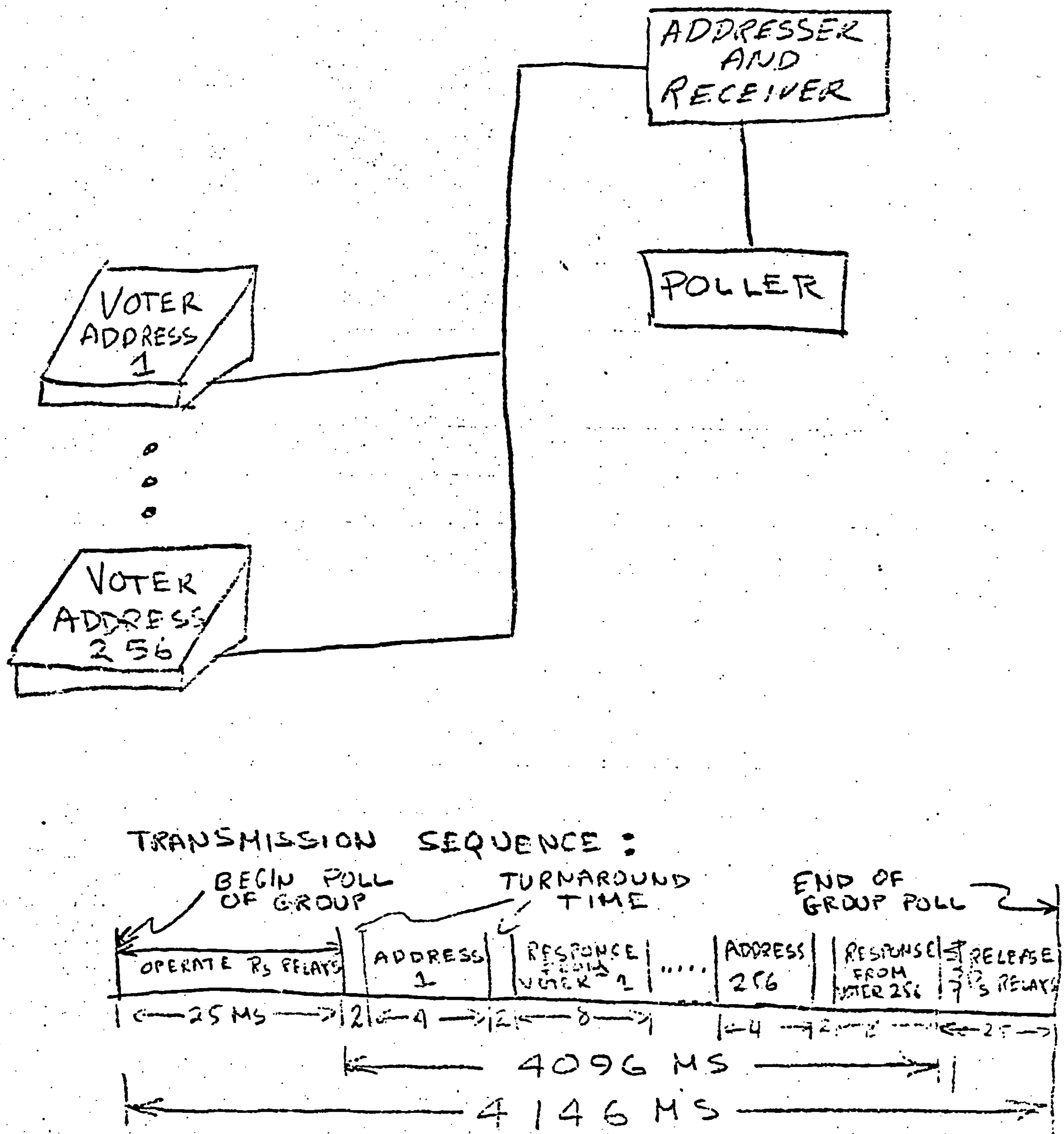

FIGURE 3-10 GROUPED POLL