1. EXECUTIVE SUMMARY

In 1967 a Presidential Commission recommended that a nationally uniform three digit telephone number be used to reach emergency response agencies. The use of 9-1-1 as the unique code to provide general access to public safety emergency response agencies was adopted by the North American telephone industry in 1968. In the 25 years following the standardization of 9-1-1, the availability of some form of this service has become nearly universal in the United States and much of Canada. It is no exaggeration to say that the American public depends on 9-1-1 service in its emergencies.

1.1 Study Method

In 1991 the Federal Communications Commission formed the Network Reliability Council (NRC) to assess the reliability of the North America Telecommunications network and to recommend measures to improve its reliability. Given the critical connection between network reliability and emergency service access represented by 9-1-1 systems, the NRC selected 9-1-1 systems as one of its seven initial focus areas.

The E911 focus group has conducted a comprehensive review of 9-1-1 service delivery and studied the connections between its reliability, telecommunications industry practices and network architecture. We compiled and analyzed data on past recent outages of 9-1-1 systems across the United States. We interviewed experts from the local exchange industry and more importantly, operators and manager of 9-1-1 systems. We also reviewed performance of selected 9-1-1 systems in heavy load conditions far beyond the design specifications.

The performance data used in this study was collected from 18 Local Exchange Companies (LECs) ranging in size from Southern New England Telephone Company to the GTE system. We gathered data on network architecture for 9,491 Central Offices serving almost 110 million access lines. In addition to the LEC input, we also surveyed 9-1-1 system administrators in 19 states serving 1,394 Public Service Answering Points (PSAPs).

The selected results contained in this report include a census of the types of 9-1-1 service provided by the LECs and a breakdown of the reported service disruptions by location of failure and cause of failure for 123 9-1-1 service disruptions that occurred in 1991 and 1992. The location of failure is categorized by the following five categories:

- LEC End Office
- LEC Tandem Switch Office
- Interoffice Facility
- PSAP 9-1-1 Equipment
- Other

The report uses seven classifications for the cause of failure:

- Hardware
- Software
- Traffic congestion/overload
- Cable dig-ups
- Craft Error (other than cable dig-ups)
- Other
- Unknown

Multiple-location categories during the same service disruption were also reported. We analyzed this data to identify likely failure points and common causes that were the high risk elements in the reported 9-1-1 outages. In order to measure the impact of the individual disruptions, we also examined restoration time by both location and cause categories.

1.2 E911 Focus Group Findings

Based on an analysis of the data collected by the focus group and on interviews with subject-matter experts we make the following findings:

1. Network design and architecture providing 9-1-1 service is increasingly concentrated with identifiable potential single points of failure. The result is an increasing risk for large 9-1-1 disruptions if outages occur in the network generally or in 9-1-1 facilities particularly. At the same time, some new and existing network features provide opportunities to increase reliability if employed in the provision of 9-1-1 service.

2. There is a need for improved communication among the local exchange carriers providing 9-1-1 service and emergency service providers.

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Divestiture has eliminated some channels for exchange of technical information concerning best practices in 9-1-1 service provision.

3. A review of 123 9-1-1 outages that occurred in 1991-1992 revealed that over half of the 9-1-1 service disruptions were caused by a failure of the interoffice facility transporting the 9-1-1 call.

4. A survey of 9-1-1 system administrators revealed that they were generally pleased with the level of 9-1-1 service delivery they are experiencing. They gave some recommendations that are included in Section 4 of this paper.

5. There are other important 9-1-1 related reliability issues which are outside the scope of this study. They include handling cellular-based and PBX-based 9-1-1 calls, PSAP equipment maintenance and ALI database accuracy. These issues are not directly related to the reliability of carriers' networks, but should be addressed jointly by carriers and 9-1-1 service providers.

1.3 E911 Focus Group Recommendations

Based on the findings of our study, the E911 Focus Group makes the following recommendations to improve the reliability of 9-1-1 service delivery:

1. Local Exchange Carriers should move to eliminate single points of failure in the interoffice facilities, serving tandem switches and ALI database portions of the 9-1-1 network, beginning with the least costly measures. These measures include exploiting existing opportunities for physical route diversity and special handling of 9-1-1 serving arrangements. This recommendation does not extend to the local loop between any subscriber and their LEC dial tone office.

2. Local Exchange Carriers should carefully evaluate and consider reversing a trend toward concentration in 9-1-1 service delivery. Examples of such concentration include large numbers of PSAPs in single tandem switch offices and the use of single high capacity network concentrators such as digital cross connect systems without the appropriate diverse routing architectures.

3. Local Exchange Carriers should defer plans to use the SS7 network for 9-1-1 services until the unique characteristics and feature requirements of 9-1-1 service are addressed in the SS7 protocol by the appropriate standard bodies. In addition to the standard work required, we recommend that 9-1-1 service deployment on SS7 not start until the conversion activity required on Docket 86-10, Provision of Access for 800 service is completed. This recommendation should be periodically reviewed.

4. Local Exchange Carriers, 9-1-1 administrators and public safety agencies should improve communications among themselves. A formal communications mechanism should be established to develop, review and update disaster recovery plans for 9-1-1 service disruptions, to share information about hardware reliability and to solicit user preferences on such issues as overflow routing.

5. A national 9-1-1 technical forum should be established to improve communications and share best practices among LECs providing 9-1-1 service. The forum should be open to all stakeholders of 9-1-1 service delivery. Emerging issues, such as cellular-based 9-1-1 calls and PBX/9-1-1 call handling would be appropriate agenda items.

6. The 9-1-1 Focus Team recommends the use of FCC outage reports per Docket 91-273 as the standard metric by which national 9-1-1 reliability improvements be tracked.

1.4 E911 Focus Group Conclusion

In conclusion, the 9-1-1 Working Group found that existing 9-1-1 service reliability was very high and that public safety evaluations of the service were similarly very positive. However, given the extremely critical nature of the service represented by the dialing code "9-1-1", we recommend certain measures to improve the reliability of the service. The combination of general network reliability measures recommended in this report

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combined with the network reliability measures recommended by other NRC focus groups will ensure that a very reliable service is made even better.

2. BACKGROUND

The processing and delivery of 9-1-1 calls is one of the most high profile services provided by the Local Exchange Carrier (LEC) companies. Very few individual service offerings are as consistently high risk situations as 9-1-1. There is no way to predetermine that any 9-1-1 call is not a life or death situation. There may not be a second chance to deliver the critical service if the first attempt is unsuccessful.

The primary goal in providing 9-1-1 service is to assure delivery of the call to the proper public safety/emergency response agency. The LEC is expected to deliver the call every time, without fail. No reason, no matter how logical, is acceptable when the critical 9-1-1 call doesn't go through.

By today's standards, 9-1-1 service delivery is almost universally outstanding. When a failure occurs, it makes national, not just local news. It is deemed news worthy not only because of the specific situation or personal tragedy involved, but because the expectation of perfect handling, makes any failure an unusual event in its own right.

2.1 Systems Overview

Today, 9-1-1 service is widely available in the United States and Canada. Though there are many variations and serving arrangements available, there are two primary system designs that provide this service: Basic 9-1-1 (B9-1-1) and Enhanced 9-1-1 (E9-1-1). Basic B9-1-1 routes emergency calls to a Public Safety Answering Point (PSAP) based on the geographic location of the LEC central office that serves the calling customer. Figure 2-1 shows a B9-1-1 configuration.

Enhanced E9-1-1 provides selected routing capabilities that allows the LEC central office to route the 9-1-1 call to a PSAP based on the geographic location of the calling party. Two other features of E9-1-1, Automatic Number Identification (ANI) and Automatic Location Identification (ALI) will supply the PSAP attendant with the calling subscribers telephone number and recorded address of the telephone from which the 9-1-1 call is being made. Figure 2-2 shows a E9-1-1 configuration.

Even though this Focus Team was named E911, we examined the delivery of both B9-1-1 and E9-1-1 calls.

2.2 9-1-1 as a National Reliability Focus Area

The initial charge given to this Focus Group by the NRC was to examine the entire 9-1-1 call process flow, segment by segment, to identify potential points of failure. Our charge involved the need to ensure that 9-1-1 calls never terminate in an announcement or overflow tone. We were also to evaluate the access to 9-1-1 during high volume calling periods. The NRC Issue Statement is contained in Section 12, Appendix 1.

To meet this charge, our team adopted the following theme statement:

The E911 System Focus Group would:

- quantify 9-1-1 system vulnerability
- identify major 9-1-1 system reliability issues
- recommend appropriate solutions for any problem area identified
- establish a measurement process and tracking plan to monitor progress

In order to successfully complete this goal, we would examine all aspects of the 9-1-1 service offering. This included but was not limited to:

- technology/architect issues
- hardware/equipment issues
- software/data base issues
- people/work process issues

Our methodology looked at each of the following segments of the overall 9-1-1 service offering:

- Local Loop
- LEC End Office
- LEC Tandem Switch Office
- Interoffice Facilities
- PSAP/CPE Equipment
- ALI Data Base Issues

We limited the scope of this focus team to only wire and

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C.O. based 9-1-1 services. We recognize that there are major unresolved issues in providing 9-1-1 service for wireless and cellular customers. While not diminishing their importance, we did not include them in this effort.

3. TEAM MEMBERSHIP

The E911 Focus Team was put together to ensure that there was experienced representation from both the 9-1-1 service provider community and the 9-1-1 public safety user community. The team composition is as follows:

Cas Skrzypczak - Team Champion
President - NYNEX Science and Technology

L. Robert Powers - Team Leader
AVP - Network Operations
Southwestern Bell Telephone Company

David Schmid - Technical Assistant
District Manager - Network Reliability
Southwestern Bell Telephone Company

Dennis Adams - Staff Director - NOF Regulatory, Provisioning Operations and Engineering Support
NYNEX

Ron Binz - Director - Office of Consumer Counsel
State of Colorado

Mary Boyd - Executive Director - Advisory Commission on Emergency Communications
State of Texas

Peter Reed - Principal Member of Technical Staff
Pacific Bell

Gary Robert - Staff Manager - 9-1-1 Planning
Bell South

Figure 3-1 lists the team members including their work location telephone and facsimile numbers.

3.1 Focus Team Structure

The Focus Group formed two working committees to direct the data compilation and analysis effort. Each working committee expanded its membership by adding subject matter experts on various aspects of the overall 9-1-1 service offering. The two working committees that were formed were the Architecture and Technology committee and the Data Base and User Administration committee.

Focus Group members were able to select the committee committees they wanted to work on. The architecture technology committee concentrated on the network topology issues, primarily from the LEC provider view point. This committee was chaired by Peter Reed from Pacific Bell. Team members were:

Dennis Adams - NYNEX
Gary Robert - Bell South
David Schmid - Southwestern Bell

The Data Base and User Administration committee was chaired by Mary Boyd - Texas Emergency Communications. Team members were:

Ron Binz - Colorado Office of Consumer Counsel
David Schmid - Southwestern Bell

This committee focused on data base accuracy issues as well as the day-to-day receiving of 9-1-1 calls at the PSAP locations. This included coordination efforts with their LEC and PSAP equipment providers.

The work of this committee, along with the entire Focus Group effort, only dealt with the delivery of the 9-1-1 call to the PSAP. The focus group did not look beyond call delivery. There was no evaluation done of the procedures that the public safety/emergency response agencies used to dispatch a response person/team to the 9-1-1 request.

3.2 Focus Team Subcommittees

After raw data was collected from both the LEC providers and PSAP users, each committee held an expanded subcommittee meeting to further explore their area of concentration. The expanded Architecture/Technology subcommittee had at least one representative from every Local Exchange Company who is a member of the Network Reliability Council. The representation was primarily at the Regional Company level, not at the individual operating division level. These representatives brought both 9-1-1 experience and perspective to the evaluation. This proved to be more valuable in identifying best practices in use in the LEC community than the formal request for data. A complete list of the Architecture/Technology working

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subcommittee is contained in Figure 3-2.

The expanded Data Base and User Administration subcommittee was composed of representatives from 19 states and Washington D.C. that reflected expertise in 9-1-1 from perspectives of State, Local and Regional Administration. Their experience level and backgrounds provided the Data Base and User Administration Committee the opportunity to seek additional insight into the answers that were provided in the PSAP User Survey. The following reflects important information that the Administrators felt pertinent to the 9-1-1 Focus Group research:

- The 9-1-1 Customer Premise Equipment in most cases is equipped with Alarms that notify the customer of potential trouble. The Administrators went on to point out that not all the 9-1-1 hardware is equipped with alarms and the circuit cards do not set off any alarms, therefore providing situations that the 9-1-1 systems could be failing without any warning.

- The survey results regarding 9-1-1 repair identified excellent service; however, the Administrators went on to point out that there are distinct differences between Urban and Rural repair response. The pure fact that remote rural locations and the distance associated with repair personnel having a timely response, often times impacts a rural PSAP more so than an Urban PSAP. An important issue in dealing with rural sites is to insure that the LEC has spare parts readily available.

- The Administrators provided insight into the 9-1-1 Data Base accuracy rate in that while the survey reported that 96% was an adequate accuracy rate, the desirable was 100%.

- The Data Base discussion also revealed that the Administrators would like to see all LECs moving toward total automation of the 9-1-1 Data Base development and maintenance process and allow real time updates. Another very important desire is to achieve nationwide standardization of the Data Base format for all companies.

- The planning of Disaster Recovery for 9-1-1 Systems is not something that is always considered in building 9-1-1 Systems. The Administrators would like to see a comprehensive evaluation of the 9-1-1 Networks, with the goal of achieving back-up systems and disaster recovery plans to ensure 9-1-1 reliability. This effort should include not only the LECs, but also 9-1-1 Users and Emergency Management Administrators so that the comprehensive plans can be included in the local Disaster Recovery Plans.

- Finally, the Administrators would also like to see more national attention given to Cellular and PBX telecommunications services. Currently these services do not provide accurate calling telephone numbers and addresses to the 9-1-1 system; therefore, requiring the PSAP to rely on the caller to know where they are.

4. DATA COLLECTION AND ANALYSIS METHODOLOGY

The E911 focus group initially determined that there were two main categories of information that were required to be successful in an evaluation of the current status of 9-1-1 service reliability. First, was to obtain an accurate listing of the existing 9-1-1 systems that are currently in service. Second, was an accurate, factual trouble history of service disruptions that had occurred in the 9-1-1 service delivery process.

The NRC sent the E911 questionnaires to the Local Exchange Carriers (LECs) who were participating in the NRC work. The E911 questionnaires were sent to the following companies:

- U.S. West
- Southern New England Telephone (SNET)
- NYNEX
- Bell Atlantic
- Pacific Bell
- GTE
- Ameritech
- BellSouth
- Sprint-Ltd.
- Southwestern Bell Telephone (SWBT)

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In some cases the regional company provided separate responses for individual (state) operating divisions.

4.1 E911 Data Questionnaires

In order to obtain the desired information, three questionnaires were designed. Each questionnaire provided a different piece of the total answer required. The three questionnaires were:

Questionnaire #1 - Summary Sheet
Questionnaire #2 - Current 9-1-1 Data
Questionnaire #3 - Service Disruption Data

Section 12, Appendix 2 contains the E911 Questionnaires.

4.1.1 Questionnaire #1 Description

Questionnaire #1 - This questionnaire was designed to obtain information on the general availability of 9-1-1 service in the responding LEC companies. Each LEC provided only one Questionnaire #1. This provided a break down by the number of central offices that provided the service and the approximate number of access lines that were served in four possible ways to reach a public safety/emergency response agency:

- E9-1-1 (Enhanced 9-1-1)
- B9-1-1 (Basic 9-1-1)
- 7 Digit/10 Digit Telephone Number - (No 9-1-1)
- Dial Operator (No 9-1-1 or public safety TN)

4.1.2 Questionnaire #2 Description

The second questionnaire - Current 9-1-1 Data was designed to provide detailed census data on the type of central office equipment used to provide 9-1-1 service, the type of equipment in use at the PSAP, the trunking/routing pattern in place to deliver the 9-1-1 call from the LEC central office to the PSAP and some information about the PSAP and ALI data base. Each LEC provided a completed Questionnaire #2 for every central office that served as either a 9-1-1 tandem switch office (Figure 4-1) or a central office that connected directly to a PSAP without trunking through a 9-1-1 tandem switch office (Figure 4-2). An end office that did not route 9-1-1 calls directly to a PSAP did not require a completed Questionnaire #2.

This questionnaire had four sections:

Section 1 - Office Identification
Section 2 - Trunking/Routing Information End Office to Tandem switch Office
Section 3 - Trunking/Routing Information Tandem switch Office End Office to PSAP
Section 4 - PSAP Information

4.1.3 Questionnaire #3 Description

The last questionnaire, Questionnaire #3, was designed to capture as much objective data as possible about 9-1-1 service disruptions that occurred in 1991 and 1992. A common definition of service disruption was required to establish a base line to compare future results against. The definition chosen was the one that had been put in place to establish FCC reportable service disruptions. This required input on any total or partial outage that resulted in significant loss of 9-1-1 call processing for 30 or more minutes duration. It is important to note that the loss of ALI information only, would not be a reportable event. The responding LECs provided a separate Questionnaire #3 for any outage that occurred on or after January 1, 1991.

This questionnaire was designed to provide the following information:

Section 1 - Time and Impact of Service
Section 2 - Location of Service Disruption
Section 3 - Probable Cause of Service Disruption
Section 4 - New Practices

4.1.4 Questionnaire Objectives

1. Identify the highest risk locations for 9-1-1 service disruptions in existing network configurations.

2. Quantify the probable cause history of 1991 and 1992 9-1-1 service disruptions.

3. Identify the network element or work process that led to the most service disruptions.

4.1.5 Additional Data Requests

The fourth section of Questionnaire #3 was designed to allow the responding companies to tell the Focus Group

about any practices or procedures that were developed and implemented as a result of the 9-1-1 service disruption. We found that the format and process used to compile the data request responses was not "user-friendly" for a narrative response. A separate request was sent to the LECs who had responded to set up a separate working committee to specifically identify any special practices, procedures and/or processes that were being used to improve the reliability of 9-1-1 service delivery. These findings are an essential part of Section 6, Countermeasures and Recommended Best Practices of this paper.

Initial analysis of LEC data from early responses revealed the need to obtain input from the day-to-day PSAP users and administrators of the 9-1-1 service. Since this input would have to come from agencies that were not part of the Network Reliability Council, the experience and contacts that our focus group members had, were used to develop and distribute this questionnaire. A copy of the User Questionnaire is contained in Section 12, Appendix 3.

This questionnaire was designed to obtain the 9-1-1 users' perspective of total 9-1-1 service delivery and outages. This questionnaire was mailed to state supported programs, as well as rural and urban areas with non-state supported programs. The list of states that received this questionnaire is contained in Figure 4-3. This questionnaire asked for information in five main areas:

- Network Outages/Failures
- Customer Premise Equipment (CPE) Outages/Failures
- Repair/Response
- 9-1-1 Data Base
- Summary - Wish list to improve 9-1-1 reliability

A summary of the answers from this questionnaire are found in Section 12, Appendix 4.

4.2 Data Collection Process

After the 9-1-1 questionnaire had been finalized, the next step was to distribute it to the Local Exchange Companies for answers. The Network Reliability Council had designated a single organization to handle the distribution, collection and raw data aggregation. This organization was not responsible for final data analysis but did all the managing of the raw data and provided many useful summaries. The grouping and output requests were given to this single point of contact by the various focus teams.

The single point of contact selected was an organization in Bellcore headed by John Healy. John and his team sent the questionnaires to the LEC companies for their response, received the individual company responses and aggregated the data as directed by the focus teams. A large number of data summaries and charts were provided to the focus team. We worked on data that was supplied to us through the Bellcore data collection organization.

4.3 Total Quality Management Approach

Our focus group elected to take a modified Total Quality Management approach to use as the basis for the analytic process used to derive conclusions. The intent was to stay as close to the quality process/procedures as possible under the structure put in place by the National Network Reliability Council.

Our focus group intends to follow a seven step quality process in its activities. As with all quality processes, this is a long range activity. You can use some quality based tools and techniques for short time improvement efforts but a complete commitment to a quality process is an ongoing long range activity.

The seven step process used was:

Step One - Reason for Improvement
Step Two - Current Situation
Step Three - Analysis
Step Four - Countermeasures
Step Five - Results
Step Six - Standardization
Step Seven - Future Plans

Each step of the quality process used a Plan-Do-Check-Act (P-D-C-A) concept. This concept is based on the belief that improvement in a product or service can be obtained if you follow a systematic approach that incorporates the following efforts:

- Plan For It - develop a process
- Do It - implement that process
- Check It - analyze your process results

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- Act - Revise your process as required

This process is a continuous cycle, where you never complete the project, but work for continuous improvement.

4.3.1 Work Completed or in Progress

The majority of our focus group and committee work activity has been in Steps Two, Three and Four. Step One-Reason for Improvement, was presented to us by the NRC. Our focus group took the NRC Theme Area for 9-1-1 service reliability and further developed it to provide a structured approach.

Step Two-Current Situation, included the Focus Team work to develop and design the questionnaires that were distributed. Bellcore provided help on the design of the questionnaires. The next step was to get the questionnaires to the right organizations. The goal was to ask the right questions to the company/person who could give factual/objective answers. Step Three, Analysis, started to involve more people in the work effort. The work team was expanded to include Subject Matter Experts (SMEs) on all aspects of 9-1-1 service delivery. The goal was to identify the root cause for most 9-1-1 service disruptions. This effort centered on examination of the data questionnaires to determine two elements. The first element was to determine and quantify the network point-of-failure location in 9-1-1 service disruptions. The second goal was to establish and quantify the probable cause of 9-1-1 service failures.

Work in Steps Two and Three was used as the basis for Step Four-Development of Countermeasures. The expanded work team developed plans to attack the most likely failure causes identified. This includes specific recommendations that are included in Section 6.

4.3.2 Work to be Done

Step Five, Results and Step Six, Standardization can only be done after there is an opportunity to evaluate the results of our recommendations. We have recommended an ongoing process that will be responsible for these follow up activities.

Step Seven, Future Plans will deal with establishing the ongoing effort to ensure that the work of both the E911 focus Group and the NRC are handed off to identifiable organizations that will complete the initial work and then enter the Plan-Do-Check-Act (P-D-C-A) continuous improvement cycle.

5. TYPES AND CAUSES OF FAILURES

This section will lay out the results obtained from the 9-1-1 data requests. Also provided is a statistical view of the data received. It identifies the location point and cause of 9-1-1 service disruptions and focuses on root causes of service failures.

5.1 National Availability of 9-1-1 Service

Questionnaire #1 provided base line data on the availability of 9-1-1 service. We received responses from 18 Local Exchange Companies with data on the method their customers used to reach a public safety agency. We asked for this information in two broad categories, central office and access lines. Our national findings showed that 71% of the central offices and 89% of the access lines have some form of 9-1-1 service. Figure 5-1 shows the national distribution of 9-1-1 service availability. There are several companies which provide 9-1-1 service to virtually all of their customers.

5.2 9-1-1 Network Architecture and Topology

Questionnaire #2 - Current 9-1-1 Data was designed to provide a census of existing 9-1-1 equipment and look at trunking, alarm monitoring, trunk engineering criteria, alternate route availability and diverse route availability.

There were 235 LEC central offices identified as a 9-1-1 tandem switch office and 422 LEC offices identified as a 9-1-1 end office.

We will look at the information concerning trunking/routing architecture first.

- Almost all (303 of 305) of 9-1-1 trunk groups were dedicated use
- Nearly 100% of the 9-1-1 trunk groups are monitored for alarm conditions
- 31% of the End Office to 9-1-1 tandem switch office trunk groups have alternate route capability

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- For the offices that do have an alternate route available, approximately 97% of the offices have route diversity between the primary route and the alternate route.

- 27% of the end offices had an alternate route that could bypass the tandem switch office if the tandem switch office was unavailable.

- 16% of the end office to PSAP or 9-1-1 tandem switch office to PSAP trunk groups have alternate route capability. For the offices that do have alternate route capability, approximately 88% of the offices have route diversity.

Figures 5-2 thru 5-12 shows the data for Sections 2 and 3 of Questionnaire #2.

The fourth section of Questionnaire #2 asked for information about the PSAP equipment. We obtained the following information:

- A known back up power source was available in about 80% of the PSAPs

- Almost 65% of the PSAPs have a backup PSAP

- Almost 87% of the PSAP ALI links are on diverse routes

Figures 5-13 thru 5-16 show the data for Section 4 of Questionnaire #2.

5.3 9-1-1 Service Disruption History

Questionnaire #3 - Service Disruption Data, provided the data for the main analysis work done by this focus group. The LECs provided a trouble history on any 9-1-1 service disruption that lasted longer than 30 minutes during 1991 and the first three quarters of 1992. A total of 123 service disruption reports were received.

There were 35 reports for 1991 and 88 for 1992. The factors examined initially were location of failure and cause of failure.

5.4 Location of Failure

The location of failure should identify the most vulnerable elements of the 9-1-1 network architecture. Multiple failure locations were possible for a single disruption. The break down of location of failure is shown in Figure 5-17.

Where you add in the multiple location failures, you find that over half (68 of 123) of the 9-1-1 service disruptions occurred because of an Interoffice Facility problem. Figure 5-18 shows a Pareto chart of the location of failure for 9-1-1 service disruptions.

5.5 Cause of Failure

The next factor examined was the probable cause of 9-1-1 service disruptions. Although the questionnaire was designed to allow for more than one cause for a reportable event, no LEC reported a multiple cause failure. Therefore, there were a total of 141 locations for the 123 reportable outages. The frequency distribution for service disruption causes is shown in Figure 5-19.

Figure 5-20 is a Pareto chart displaying the causes of 9-1-1 service disruptions.

5.6 Location by Cause of Failure

The next step was to examine the relationship between the location of failure and cause of failure. This comparison is shown in Figure 5-21.

The 141 failure locations were ranked by cause to look for areas that offered the possibility for greatest improvement. This comparison is shown in Figure 5-22.

The three highest results in this comparison all had the Interoffice Facility as the location of failure. These top three represented 42% of all failures (50 of 141).

Analysis showed that 46% (31 of 68) of Interoffice Facility failures were caused by cable dig ups. Hardware problems on facility failures accounted for another 22% (15 of 68) of the Facility failure reports.

5.7 Impact of Failure

The initial analysis only measured the number of failures. Another element, the impact caused by the 9-1-1 service disruption needed to be determined. The length of service outages was examined to find if any particular failure location or failure cause was more likely to cause long outages. Figure 5-23 shows the relationship of duration to

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location of failure.

This analysis revealed that 75% of all 9-1-1 service disruptions caused by an Interoffice Facility failure took at least 2.5 hours to restore. The restoral time by quartile break down is shown in Figure 5-24. It is important to remember that only outages of 30 minutes or longer were included in this study.

Of the three network elements under the direct control of the LEC: the end office, tandem switch office and interoffice facility, any interoffice facility failure was more likely to cause a longer duration outage than the most severe end office or tandem switch failure.

5.8 Conclusion

The Focus Group analysis looked at the following factors that contributed to 9-1-1 service disruptions:

- location of the failure
- cause of the failure
- failure location by failure cause relationship
- restoral time by failure location relationship

All factors lead to the conclusion that the most vulnerable part of the 9-1-1 service delivery process is the interoffice facility. Not only is the IO facility the most likely location for a failure to occur, but most IO failures are going to take longer to restore than any failure in another location of the 9-1-1 network.

6. COUNTERMEASURES AND RECOMMENDED BEST PRACTICES

Described below are countermeasures and "best practices" that are recommended for the significant causes of 9-1-1 service outages identified in the survey described in Section 5 of this paper. The definition of "best practices" as used in the network reliability focus area Technical Papers is as follows: "Best practices" are those countermeasures (but not the only countermeasures) which go furthest in eliminating the root cause(s) of outages. None of the practices are construed to be mandatory; however, a very small number of countermeasures that are deemed by the Focus Team and concurred by the Network Reliability Steering Team (NO REST) to be especially effective countermeasures will be designated as *"recommended."*

Service providers and suppliers are strongly encouraged to study and assess the applicability of all countermeasures for implementation in their companies and products, respectively. It is understood that all countermeasures, including those designated as "recommended", may not be applied universally.

Also discussed is the conclusion of 9-1-1 experts concerning the use of common channel signaling with 9-1-1 service.

Loss of interoffice facilities was identified as the major source of 9-1-1 service interruption. The majority of the best practices used around the country are aimed at either reducing or mitigating the affect interoffice facility failures have on 9-1-1 service. Fault tolerant network architectures, network management strategies and alternate routing are employed as countermeasures to interoffice facility failures. These strategies are detailed in the following sections of this document.

Loss of or loss of access to the 9-1-1 Tandem switch is a major concern to the emergency services community. Loss of a single 9-1-1 Tandem switch office can affect more than one million access lines. Fault tolerant architectures, network loading strategies and alternate routing strategies are employed as countermeasures to 9-1-1 Tandem switch failures. Details on these countermeasures will also be described in the following sections of this document.

Failure to receive automatic location information (ALI) makes up sixty percent of customer's (PSAP agency) complaints. Although the loss of ALI only does not constitute a FCC reportable outage, automatic location information (ALI) quality of handling a 9-1-1 call is very important to the PSAP agent.

The key element in most of the best practices cataloged in this report is diversity. The following is a set of working criteria used to define diversity:

1. A diverse network element (e.g. transport facility) is immediately available and there is nearly instantaneous restoration of services (either full or partial).

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2. The diverse network element is not debilitated by the same incident that caused the primary network element to fail.

Fault tolerant architectures are being deployed around the nation to increase the reliability of ALI delivery. Detailed descriptions of these best practice architectures are provided in the following sections of this document.

6.1 Defensive Measures for Interoffice Facilities

The following interoffice facility best practices are offered as countermeasures to the loss of or loss of access to. transport facilities from the customer serving wire center to the 9-1-1 Tandem switch or from the 9-1-1 Tandem switch to the PSAP serving wire center. This catalog of best practices may not be all inclusive. nor are these countermeasures offered as a guarantee against all possible interoffice facility failures. However. we do feel that defensive measures protecting the interoffice facility network supporting 9-1-1 service must be put in place. The best practices provided below should be looked upon as very good ideas that have been implemented around the nation and could be appropriate for many 9-1-1 Networks.

6.1.1 Diverse Routing of Interoffice Facilities

In this section, diverse routing of 9-1-1 interoffice transport facilities will be described. But first the point needs to be made that changes in the current operations, administration, maintenance and provisioning procedures will be required to support all of the best practices described below. Provisioning and administration of diverse circuits can be particular problems because of circuit rearrangement. When circuits are rearranged, unless special indications within the provisioning system (e.g. TIRKS) are made to keep circuits diverse. chances are high that circuits that were originally designed to be diverse will be collapsed into non-diverse facilities. Thus. the provisioning and administration process for 9-1-1 circuits must be vastly different than the procedures used for plain old telephone service (POTS) circuits.

The standard architecture for interoffice facilities supporting 9-1-1 service is shown in Figure 6-1. This figure depicts the typical interoffice facility architecture as deployed in today's 9-1-1 network. In this architecture. multiple circuits are carried over a common dedicated transport facility making total 9-1-1 service outage possible with a single fault (e.g. cable dig-up). Cable dig-ups are single points of failure that were indicated in our focus group survey (refer to Section 5) as contributing to 24% of all 9-1-1 service failures.

Figure 6-2 depicts a straight forward practice for mitigating cable dig-ups. Diverse interoffice facilities are designed with one-half of the 9-1-1 circuits provisioned for one interoffice facility and the other half of the 9-1-1 circuits provisioned over a diverse facility (indicated by the dotted line). Many telephone companies employ this diverse interoffice facility strategy when diverse facilities are already available. A variation of this diversity architecture is 1-by-1 facility transport systems with diverse path protection. In this 1-by-1 architecture 9-1-1 service is protected by a standby protection facility that is diversely routed from the working facility. Switching to the protection system is done automatically by the network equipment. Therefore. this 1-by-1 architecture is called a self-healing architecture.

The NRC's Fiber Cable Systems focus group has also investigated cable dig-ups. The recommendations of that team should be adopted to help prevent cable dig-up failures. Another approach in diversifying interoffice facilities used by some telephone companies is shown in Figure 6-3. In this architecture. diverse interoffice facilities from the customer serving end office home onto two diverse digital cross-connect systems (DCS) for concentration. This architecture provides diversity as in the previous architecture. (Figure 6.2) but due to the concentration by the DCS network elements. this architecture will be less costly under certain network conditions. Also. since these diverse facilities are homing onto diverse DCS network elements. circuit rearrangment (i.e. churn) will tend not to cause these diverse circuits to be placed into non-diverse facilities.

6.1.1.1 Fiber Rings

Fiber optic network elements are providing the telephone companies with the opportunity to aggregate large amounts of traffic into one transport facility. This traffic aggregation is in opposition to the transport diversity best practices described above. An important network topology available with the newer fiber optic terminals is fiber rings. A fiber ring is a collection of nodes forming a closed loop whereby each node is connected to two

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adjacent nodes via a duplex communications facility. A ring provides redundancy so services can be automatically restored following a failure or degradation in the network. Rings are usually described as being self-healing architectures.

9-1-1 service is being placed on fiber rings in some metropolitan areas around the nation. 9-1-1 experts are already reporting success stories with their fiber ring topologies, where cable dig-ups have had no affect upon the 9-1-1 service riding on that ring.

Figure 6-4 shows a simple example of a fiber ring network for use in providing 9-1-1 service. Ring features and functionality are part of the SONET technical requirements. The E911 focus group believes that, when available, 9-1-1 service should be placed on SONET rings due to the high reliability afforded by its self-healing architecture.

6.1.2 Multiple Homing of Inter-Office Facilities

Multiple 9-1-1 Tandem switch architectures will be described in more detail in a later section when protection of the 9-1-1 Tandem switch is discussed. The following two sections will describe the inter-office facility protection afforded by multiple 9-1-1 Tandem switch architectures.

6.1.2.1 Two Active 9-1-1 Tandem Switches

Figure 6-5 shows an architecture where two 9-1-1 Tandem switches are able to serve a single customer and the PSAP. From the figure it can be seen that diverse inter-office facilities, are an integral part of the two tandem switch architecture. Circuits from the end office serving the 9-1-1 customer are split between two destinations, the two 9-1-1 Tandem switches. There is also a diversity in the interoffice facilities going from the two 9-1-1 Tandem switches to the central office servicing the PSAP. If one of the interoffice facilities between the 9-1-1 Tandem switch and the PSAP's serving central office fails, that traffic can be routed through the other 9-1-1 Tandem switch and transported down this diverse interoffice facility. This dual active 9-1-1 Tandem switch architecture assumes certain features within the 9-1-1 Tandem switch that may not be available in all technologies.

6.1.2.2 Re-Homing to Back-up 9-1-1 Tandem Switch

Figure 6-6 shows an architecture where three 9-1-1 Tandem switches are ready to serve a single customer and the PSAP. In this architecture a primary 9-1-1 Tandem switch handles all 9-1-1 calls until a fault occurs. The interoffice facility diversity is achieved by splitting facility trunks between digital cross-connect systems, trunk frames and carrier systems. All of the central office trunks and PSAP circuits are split between similar pieces of equipment, minimizing the number of single points of failure. The dotted facilities indicated in Figure 6-6 show the diverse interoffice facilities in this network.

Further details on these multiple 9-1-1 Tandem switch architectures is provided in later sections of this report.

6.1.3 Alternate Interoffice Paths, when the primary 9-1-1 Inter-office Facility Fails

Alternate path architectures are employed to route a 9-1-1 call when the primary route is unavailable. There are many methods for generating an alternate circuit path. The following sections will catalog alternate path techniques used around the nation. Some of the techniques below can be with correct designing, used together. Some of the techniques will have conflicting interactions. Care must be taken when deploying the networks described below. Also, the assumption is made in all of the techniques described below that diversity is available at all of the central offices.

6.1.3.1 Alternate PSAPs

A standard method employed around the nation in increasing the survivability of 9-1-1 service is the assignment of alternative PSAPs. These alternate PSAPs as depicted in Figure 6-7 will be served off the 9-1-1 Tandem switch and possibly a second alternate PSAP served off of the end office serving the 9-1-1 customer.

When a 9-1-1 call can not be completed to the PSAP due to a failure in the facility between the 9-1-1 Tandem switch and the PSAP, the 9-1-1 Tandem switch switches can have pre-programmed alternate directory numbers and trunk groups to reroute the 9-1-1 call to an alternate destination (i.e., First Alternate PSAP). When a call cannot be completed to the PSAP due to a failure in the interoffice facility between the 9-1-1 caller's end office

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and the 9-1-1 Tandem. changes in the switch translation tables can be designed so that 9-1-1 calls are routed to the Second Alternate PSAP indicated in Figure 6-7. It is possible in either of the two schemes described above that the alternate PSAP is actually administrative telephone lines within the primary PSAP.

6.1.3.2 Operator Services Tandem switches and Access Tandem switches

Operator services tandem switches (TOPS) are well suited as backup and overflow network elements for 9-1-1 because of their low incremental cost and ubiquitous connectivity throughout the telephone network. In most cases existing trunking and translations can be used when adding TOPS to the 9-1-1 network.

Figure 6-8 shows how one telephone company makes use of the operator services tandem switch for overflow and backup. Upon receipt of a 9-1-1 call. the customer's end office will translate and seize a direct trunk to the 9-1-1 Tandem switch. If there are no trunks available or there is a failure on the interoffice facility. the backup/overflow route is to the Operator Services Tandem switch. The Operator Services Tandem switch will recognize the call as an emergency type by translating the 9-1-1 dialed digits and automatically route the call to the appropriate subtending 9-1-1 Tandem switch. If the trunks between the Operator Services Tandem switch and the 9-1-1 tandem switch are not available for any reason. the call can be looped around so the operator can manually answer the call and perform emergency call functions.

6.1.3.3 Public Switch Telephone Network (PSTN) Diversity

Normal delivery of 9-1-1 calls is via dedicated trunks. When these trunks are not available. the public switch telephone network (PSTN) may be available for delivering the call. In this best practice a device between the customer's serving central office and the 9-1-1 Tandem switch. shown in Figure 6-9. passively monitors the dedicated 9-1-1 trunks. Should a problem be detected. the device will seize the trunk and the call. The device will then automatically dial a pre-programmed directory number(s). The advantage to this scheme over having a switching control center (SCC) change the switch translation is that the process is automatic and if there is a special device at the PSAP to receive the call. ANI can be passed over the public switch network.

6.1.3.4 Cellular Network Diversity

Just as in the use of the public switch telephone network for an alternate path for the delivery of 9-1-1 calls. a cellular network can be used for an alternate call path (refer to Figure 6-10). The cellular network is more likely (although not guaranteed) to be diverse from the normal 9-1-1 interoffice facilities than the public switch telephone network.

6.1.3.5 Intraoffice Call Termination

All of the alternate path schemes described above assumed that a diverse path out of the central office was available. This assumption is not true for a large number of central offices in the nation. What is true is. given that a 9-1-1 call has been received at a central office. it is also most likely that the call can be terminated at that same central office.

Figure 6-11 shows a configuration where a call can be redirected to terminate within the central office itself. When this central office is isolated. a mobile PSAP connected to the phone jack mounted on the central office wall can then be used to receive 9-1-1 calls. The phone jack is typically installed in the most accessible location within the central office for ease in locating it during emergencies. The phone jack is usually installed within the central office for security purposes.

When a central office is isolated. an emergency vehicle (e.g. a police car) with radio capability can drive to the central office with a "crash kit." This crash kit may simply be a standard telephone set with an RJ-11 jack and a key to enter the central office. Another receptacle may also be installed within the central office to accept a jack from a mobile PSAP.

A variation of this theme of terminating a 9-1-1 call within a central office is to have a PSAP permanently located within the central office. This strategy is employed. or planned in some of the nation's largest 9-1-1 Tandem switch wire centers.

6.1.4 Red Tagged. Diverse Equipment

The alternate path schemes described above all assume diversity of equipment and circuits. Within the central

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office equipment hardware can represent single points of failure. A best practice that is utilized around the nation is to split circuits between similar pieces of equipment and mark that equipment at the plug-in level with red tags. The red tags alert the central office personnel that the equipment is used for essential services and is to be treated with care.

6.2 9-1-1 Tandem Switches

The 9-1-1 Tandem switch is critical to the normal operations in delivering 9-1-1 service. The larger 9-1-1 Tandem switches around the nation have over one million phones depending upon its proper operation, to handle a 9-1-1 call. With "all of the eggs in one basket" some telephone companies have begun to reduce the number of lines going to one 9-1-1 Tandem switch. In section 6.1.2 multiple 9-1-1 Tandem switches were described for increasing the survivability of the inter-office work. Those multiple 9-1-1 Tandem switch architectures also increase the survivability of the 9-1-1 Tandem switch. The following two sections will re-introduce the multiple 9-1-1 Tandem switch architecture and describe their ability to increase the survivability of the 9-1-1 Tandem switch functionally.

6.2.1 Redundant Paired 9-1-1 Tandem Switches

Figure 6-5 introduced the concept of multiple 9-1-1 Tandem switches, switch architecture. In this architecture one-half of the circuits home onto each of the 9-1-1 Tandem switches in the network. If one of the 9-1-1 Tandem switches is lost or access to it is lost from the end office serving the 9-1-1 customer, standard hunt group capabilities in the end office switch will ensure that the 9-1-1 calls are routed to the other 9-1-1 Tandem switch.

The paired 9-1-1 Tandem switches will be mirrored images of each other. This enables correct routing of 9-1-1 calls from the customer's end office through either 9-1-1 Tandem switch. This arrangement has shortcomings due to the added complexity of administering mirrored translation tables and the added complexity of keeping two switch databases (where before there was just one) up to date with the Data Management System (DMS). The Data Management System is a system that administers the switch translations and downloads that data into all of the 9-1-1 Tandem switches.

6.2.2 Multiple 9-1-1 Tandem Switches

Figure 6-6 presented an architecture that utilizes multiple 9-1-1 Tandem switches in an integrated fashion. Each 9-1-1 Tandem switch has a database that includes not only its primary customers' switch translations but the translations for the other two 9-1-1 Tandem switches as well. The digital cross-connect (DCS) network elements are used to steer traffic during a failure condition from the primary 9-1-1 Tandem switch. This steering of circuits is done upon command from a centralized network management center (NMC) and can be accomplished within seconds.

6.3 Local Loop Diversity

The portion of the call delivery 9-1-1 network that has not been addressed so far is that of the local loop access. The local loop access is that portion of the network which connects the telephone consumer (9-1-1 caller or PSAP) to the telephone network. Figure 6-12 shows where the local loop appears in the 9-1-1 serving arrangement. This local loop is potentially a single point of failure.

We cannot expect the 9-1-1 consumer to order diverse phone lines, however, for some larger PSAPs, engineering diverse local loop access is employed. One State Government contracted from the local telephone company for diverse local loop arrangements for all of the PSAPs in their State.

The best practice described in Section 6.1.3.4, cellular network diversity, can provide a diverse path from the telephone company's network to the PSAP.

6.4 Network Management Center (NMC)

Another area of best practices that had documented evidence of success around the nation was the use of centralized network management centers (NMC). These centers contain equipment and personnel that can monitor and manage the 9-1-1 network as a unique and separate entity from the rest of the network. In some instances this network management center (NMC) was part of a larger network management center that was monitoring other services as well, and in some cases it was specialized to 9-1-1. The strength of the network management center was that it had a procedure to manage and prioritize 9-1-1 service failure repair.

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6.5 Diverse ALI

The standard architecture for the retrieval of automatic location information (ALI) is presented in Figure 6-13. The important feature to note in this architecture is that there is one ALI database and one set of data circuits used to retrieve the automatic location information (ALI). The best practices cataloged by the focus group were aimed at eliminating these single points of failure in providing 9-1-1 service.

The best practice cataloged (see Figure 6-14) is the creation of two identical ALI database systems with mirrored databases in geographically diverse locations. In addition to these physically diverse databases, the data circuits to these paired ALI data bases are designed to be diverse. This architecture eliminates single points of failure all the way back to the PSAP. Telephone companies are also putting their ALI databases on fault tolerant computer platforms to increase even further the reliability of the system shown in Figure 6-14. Finally, "hot spare" computers are held in reserve for catastrophic events: earthquakes, floods, fires, etc.

6.6 Media-Stimulated Calling

Mass calling incidents can and do cause widespread 9-1-1 service interruptions. Service disruptions caused by media-stimulated calling has prompted the telephone industry to reassess and improve the design handling of these mass calling events. The following summarizes some best practices used in the industry to eliminate or mitigate the effect media stimulated calling has upon 9-1-1 service.

The most critical network element in providing 9-1-1 service that could be directly effected by a media-stimulated calling event is the 9-1-1 Tandem switch. If the media-stimulator is served off a 9-1-1 Tandem switch, the PSAPs being served off that 9-1-1 Tandem switch may experience delayed dial tone when call transfer is attempted by the PSAP agent, the 9-1-1 customer may observe a slow down in call processing (a long time to get ring back from the PSAP) and in the worst case the 9-1-1 customer will receive a reorder tone (i.e. busy signal). One step in mitigating this problem is to move the high volume calling stimulator to a foreign exchange (FX), see Figure 6-15, so they are not served off the 9-1-1 Tandem switch.

A specific example of a best practice used to minimize the affect a media stimulated mass calling event had on the local network, including 9-1-1 call delivery processing, is the way Southwestern Bell handled the promotion and selling of tickets for a concert in Austin, Texas.

Local network operations personnel, working with their External Affairs and Marketing coordinates, met with the ticket sales organization in advance of the ticket sales day. SWBT presented call volume information from the local Austin central offices and into the 911 bureau for a normal Saturday. Using the typical Saturday call volumes as a base line, SWBT showed the ticket sales group the potential impact on the network if pre-planning wasn't done and special arrangements made to handle the expected high volume generated by the ticket sales.

With this information SWBT was able to get the ticket sales organization to start their ticket sales at 6:00 a.m. rather than 8:00 am. SWBT also placed call gaps on all the ticket sales numbers prior to the sales date.

On the morning of the ticket sales, SWBT established a conference circuit to monitor the progress of ticket sales. Most of the local radio stations that were involved in promoting the concert dialed into the circuit. The Network Management Center was also on the circuit and SWBT had a representative at the 9-1-1 bureau to monitor their service levels. Tickets went on sale at 6:00 a.m. and were sold out by 6:47 a.m. Upon selling out the ticket sales organization announced it on the conference circuit and the local radio stations immediately broadcast that all the tickets were sold. This led to an immediate drop in call attempts. The 9-1-1 bureau handled their normal call volume without losing any calls.

This example of pre-planning and cooperation between all parties shows what can be accomplished, if communications are established before an emergency occurs.

6.7 Common Channel Signaling 7 (SS7)

Common Channel Signaling 7 will be the signaling method used for nearly one hundred percent of ordinary telephone calls by 1996. 9-1-1 calls are unique in some of their characteristics and features that they require. Some of these features are: call priority during network

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congestion, calling party number (CPN) delivery, call transfer with original CPN delivered. It is the opinion of the focus group that work in the standards bodies (e.g. ANSI T1S1 committee) needs to be done with the SS7 protocol before 9-1-1 calls should be handled by SS7.

6.7.1 E911 Service during the Civil Unrest in Los Angeles

Civil unrest in Los Angeles between April 29, 1992 through May 2, 1992 greatly stressed Pacific Bell's and GTE's Enhanced 911 networks. The previous call load record for the City of Los Angeles's PSAP was 20,810 calls on New Year's Eve, December 31, 1991. Each of the four days during the civil unrest exceeded this call load with April 30, 1992 recording the highest at 62,749 calls. Figure 6-16 provides the breakdown by day of calls dialed into the Los Angeles Police Department PSAP.

The Los Angeles Police Department PSAP has sixty positions to handle the 9-1-1 call volume for Los Angeles. This size makes it the largest enhanced 911 PSAP location in the nation. Manhattan has a PSAP with over ninety positions, but has not yet changed over from Basic B911 to E911. Two telephone companies, Pacific Bell and GTE, serve the greater Los Angeles area. Having two telephone companies serve one area requires a sharing of automatic location identification (ALI) information, which complicates the design of the E911 network architecture. Figure 6-17 gives an overview of the city of Los Angeles E911 network.

The Pacific Bell E911 network during the civil unrest experienced a call volume that the system was not designed to handle. The system experienced call overflow (i.e., busy tones), slow dial tone for transferring 9-1-1 calls to secondary PSAPs and slow ALI database response times. The GTE E911 system experienced the same ills.

To mitigate these problems in the future some changes have to be made. Both companies had in place programs to replace their ALI data base systems. These upgrades will alleviate future high volume demands upon the ALI systems. The Los Angeles E911 PSAP has adequate trunking for normal E911 volumes (even New Year's Eve), but below the necessary number of trunks for an unprecedented emergency like the Civil unrest experienced. Also, slow dial tone can be attributed to the call processing treatment at the 911 Tandem switch (i.e., 9-1-1 calls receive the same priority as POTS calls for dial tone resources). This last issue is one that should be addressed in a user's group forum since to change call processing would require switch manufacturers to modify the way they design their software.

The E911 system worked fairly well considering the stress placed upon it, but was truly kept alive by human intervention. For example, an ALI test system was put into service by fast thinking operations managers. Based upon this experience, contingency planning has been deemed the most important component for providing emergency service during times of crisis. NYNEX provides a model for best practice. On an annual basis NYNEX shuts down its large PSAPs within New York City and tests their contingency plans to ensure that the plans are complete and PSAP personnel are comfortable with emergency action.

A final understanding about the operation of 9-1-1 service as a result of recent emergency events around the nation indicates that the public needs to be educated on the proper use of E911 service. During hurricane Andrew a large number of 9-1-1 calls were made by citizens testing the E911 service to ensure that it was working properly. During the civil unrest in Los Angeles a large number of secondary and abandoned calls were made. If these non-emergency calls could be reduced, the load upon the 9-1-1 network and PSAP agents would be greatly alleviated. Figure 6-16 indicated that forty percent of the calls into the Los Angeles PSAP were abandoned or secondary calls. Figure 6-18 provides a summary of key findings from the Los Angeles experience. These recommendations have been verified from analysis of recent emergency situations.

7. METRICS

The E911 Focus Team recommends the use of FCC outage reports per Docket 91-273 as the standard metric by which national 9-1-1 improvement will be tracked. The goal that the E911 Focus Team recommends to the NRC is NO 9-1-1 FCC Reportable Outages.

8. PATH FORWARD FOR SUSTAINING E911 FOCUS GROUP WORK

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The E911 Focus Team supports the proposal that the Exchange Carriers Standards Association (ECSA) assume the responsibility to conduct ongoing macro-analysis of FCC outage reports.

In addition, the E911 Focus Team recommends that the NRC accept an offer from the National Emergency Number Association (NENA) that NENA would serve as a 9-1-1 industry forum for information exchange between all 9-1-1 stakeholders. This offer is shown as Figure 8.1

NENA can provide both a technical information and user administration issues forum. NENA can also provide representation for 9-1-1 for standards bodies work. If required, NENA may also request that the E911 Focus Team or its equivalent be reconstituted.

Also, Bellcore and ECSA have compiled an "Industry Network Reliability Initiatives Matrix" for the E911 focus area. Section 12, Appendix 5 lists the findings of this effort. The only areas where existing initiatives were found are:

- Operations, Administration & Maintenance
- Regulations

Part of the ongoing NENA work on 911 will encompass initiative development for the areas where no initiatives were found.

9. CONCLUSION

In Section 5 of this report, the statistical data relating to the causes of 9-1-1 failures was provided. Interoffice facility failures were shown to be responsible for 55% of 9-1-1 service failures. All of the best practices cataloged in Section 6.1 are designed to eliminate or mitigate cable dig-up faults. Another 25% of the faults were attributed to hardware failure. The focus group identified the best practices listed in Section 6.1.4 that if implemented, will reduce the instances of these faults; Reducing hardware single points of failure also addresses some of the faults listed under the category of "Other" (e.g. power) and software. Likewise the best practices cataloged in Section 6.2 provides diversity and redundancy in the 9-1-1 network. These practices will directly address about 94% of the causes of failures identified in the Section 5 survey.

The conclusion is that the 9-1-1 community is aware of the vulnerabilities in the 9-1-1 network and best practices which address these vulnerabilities are being implemented. It is believed that by sharing ideas (i.e. best practices) used around the nation that we will ensure that very reliable service is made even better.

10. ACKNOWLEDGEMENTS

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Figures

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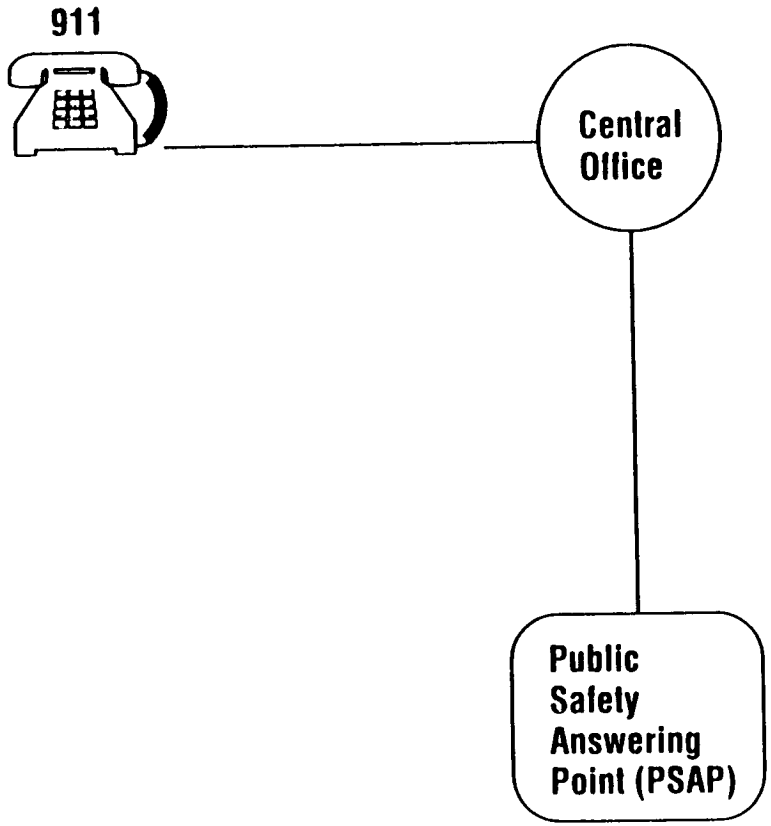

Figure 2-1: Basic 911, B911

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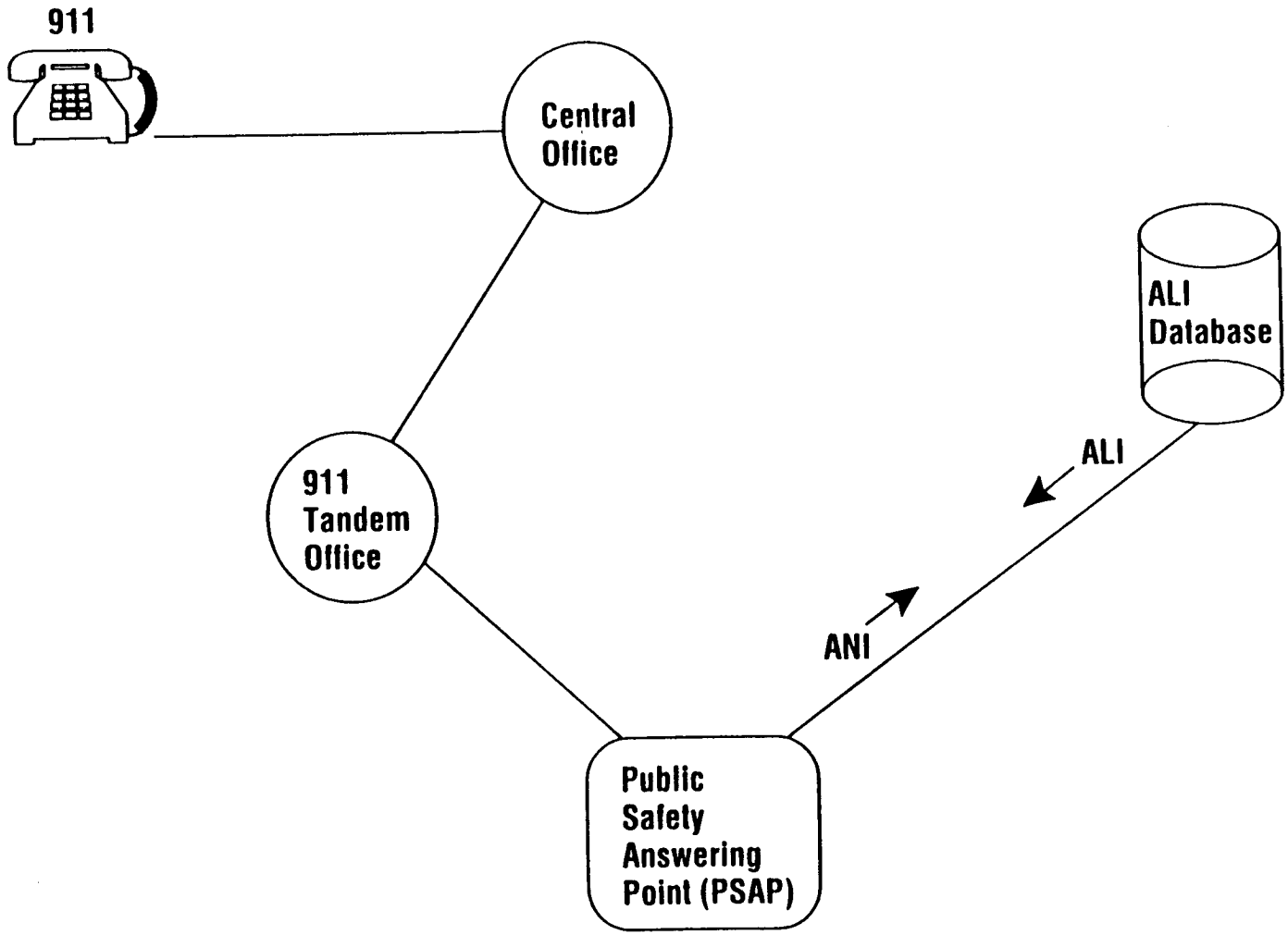

Figure 2-2: Enhanced 911, E911

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FIGURE 3-1: E911 FOCUS GROUP TEAM MEMBERS

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Bob Powers AVP-Network Operations (Retired)	211 Belvidere Dr. San Antonio, TX	210-824-8852 314-235-1978

FIGURE 3-2: ARCHITECTURE/TECHNOLOGY SUBCOMMITTEE MEMBERS

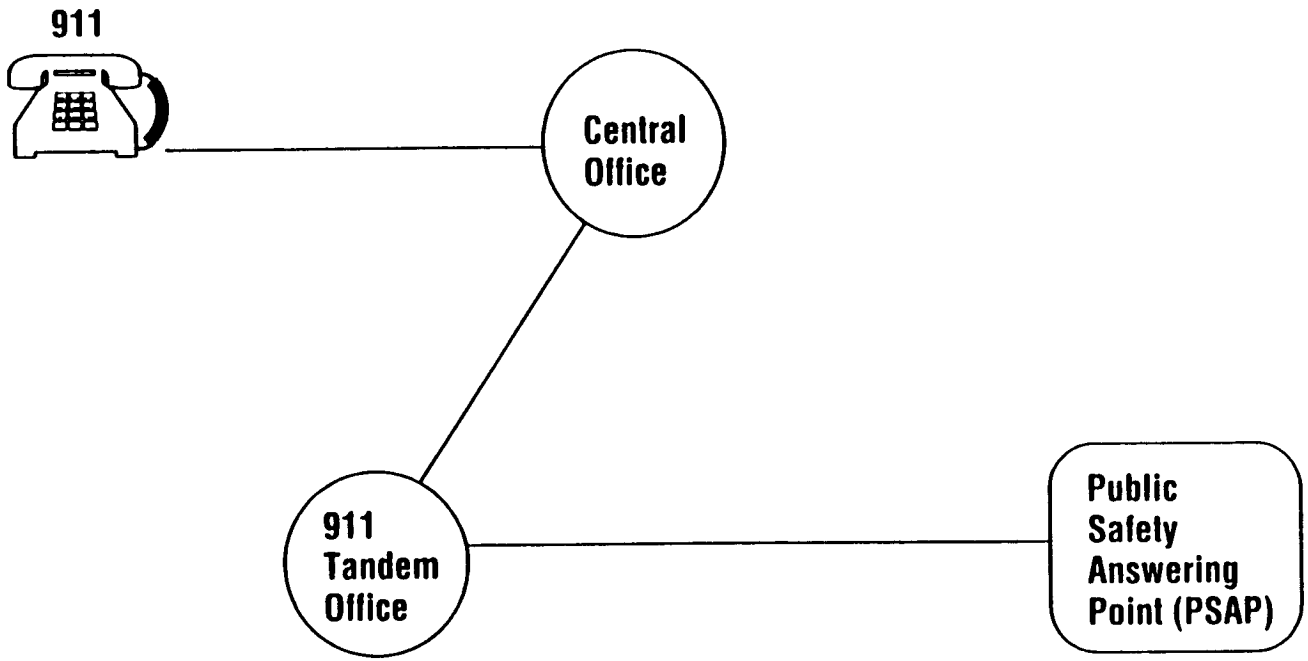

Figure 4-1: 911 Tandem Office

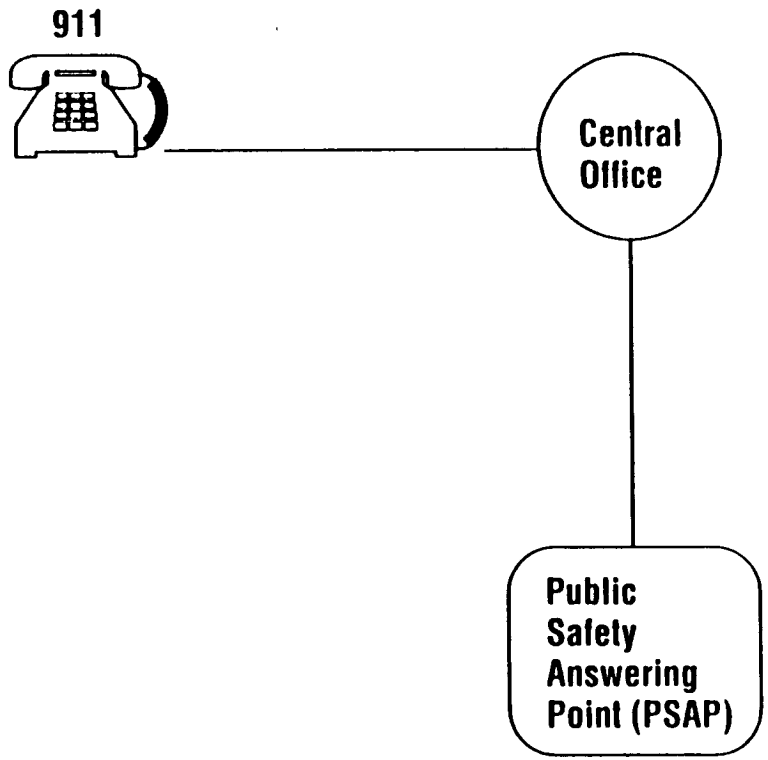

Figure 4-2: End Office (No Tandem)

STATE

Alabama

California

Delaware

Florida

Illinois (City of Chicago)

Maryland

Massachusetts

Missouri

Nevada (City of Las Vegas)

New Jersey

New York

North Dakota

Oklahoma

Ohio

Rhode Island

South Carolina

Tennesse

Texas

Washington, D. C.

West Virginia

FIGURE 4-3: STATES THAT RECEIVED THE USER QUER QUESTIONNAIRE

F

	#C.O.	% C.O.	(000) #C.O.	(000) % C.O.
Enhanced 9-1-1	5103	54	83,009	76
Basic 9-1-1	1595	17	14,322	13
No 9-1-1 Dial 7D/10D TN	2782	29	12,295	11
No 9-1-1 Dial "0"	11	0	10	0
Total	9491	100	109,636	100

Figure 5-1: National Availability of 9-1-1 Service

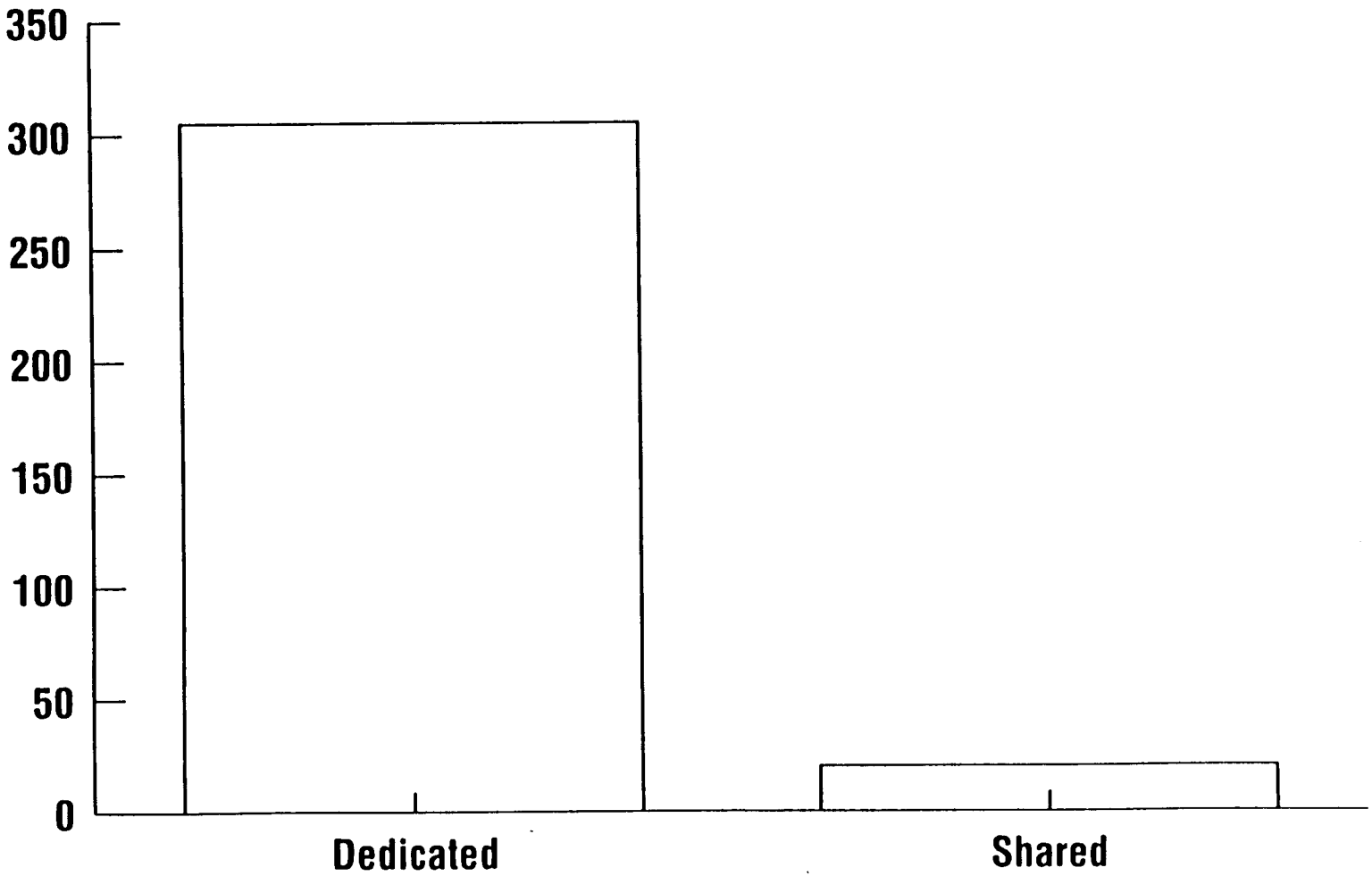

Figure 5-2: Dedicated Trunking EO to Tandem

Figure 5-3: Type Signalling EO to Tandem

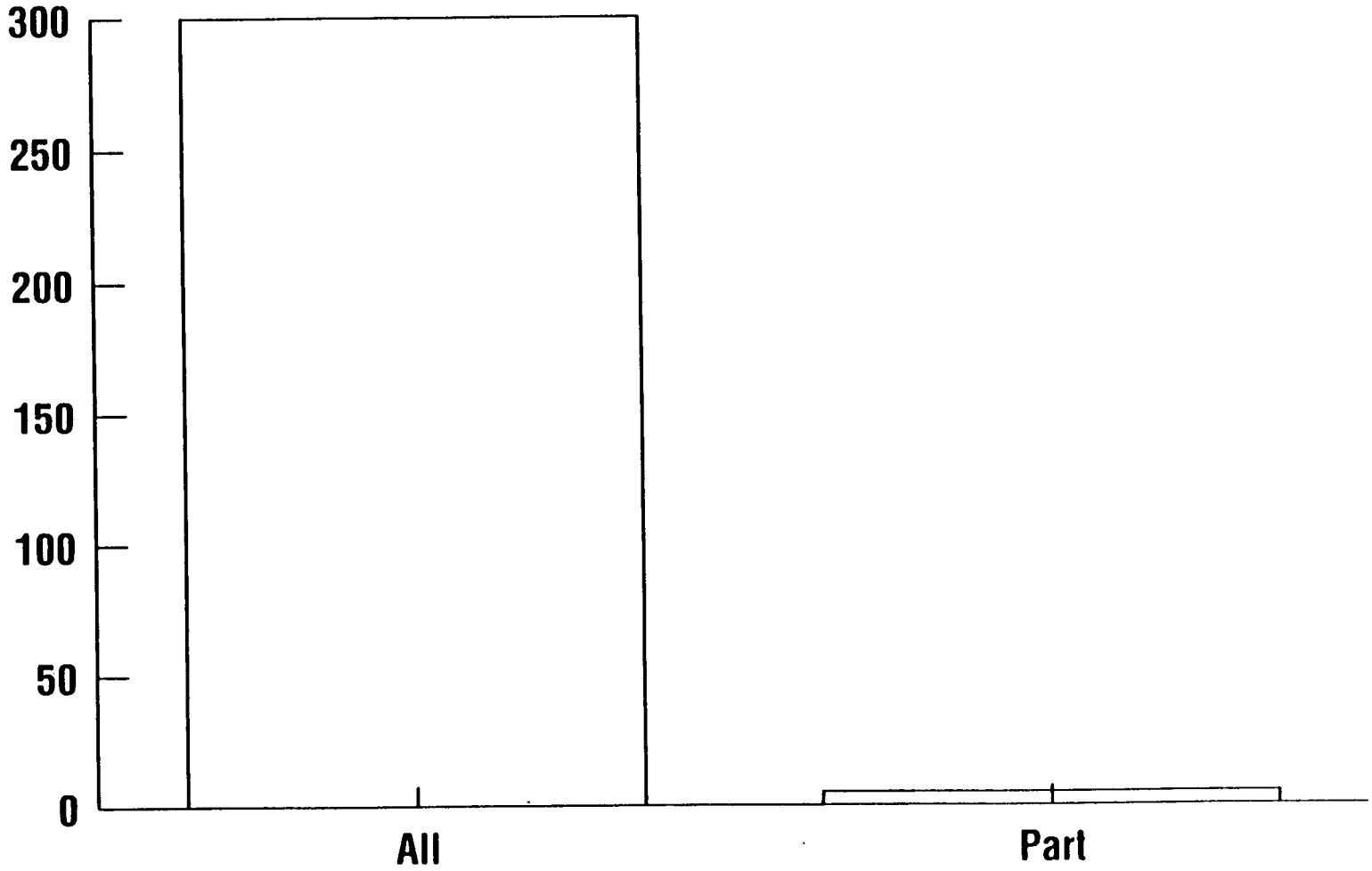

Figure 5-4: Alarm Monitoring EO to Tandem

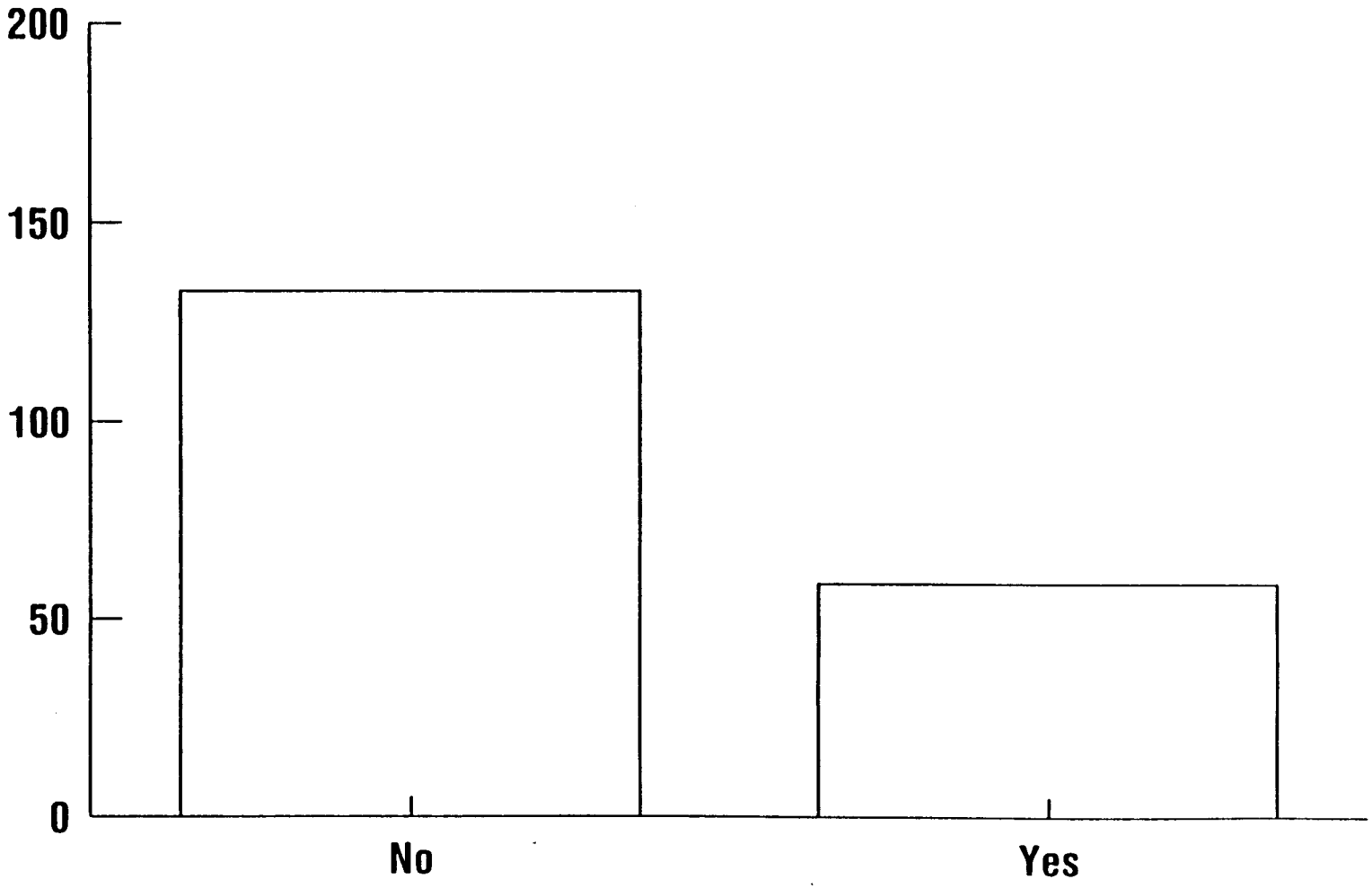

Figure 5-5: Alternate Route EO to Tandem

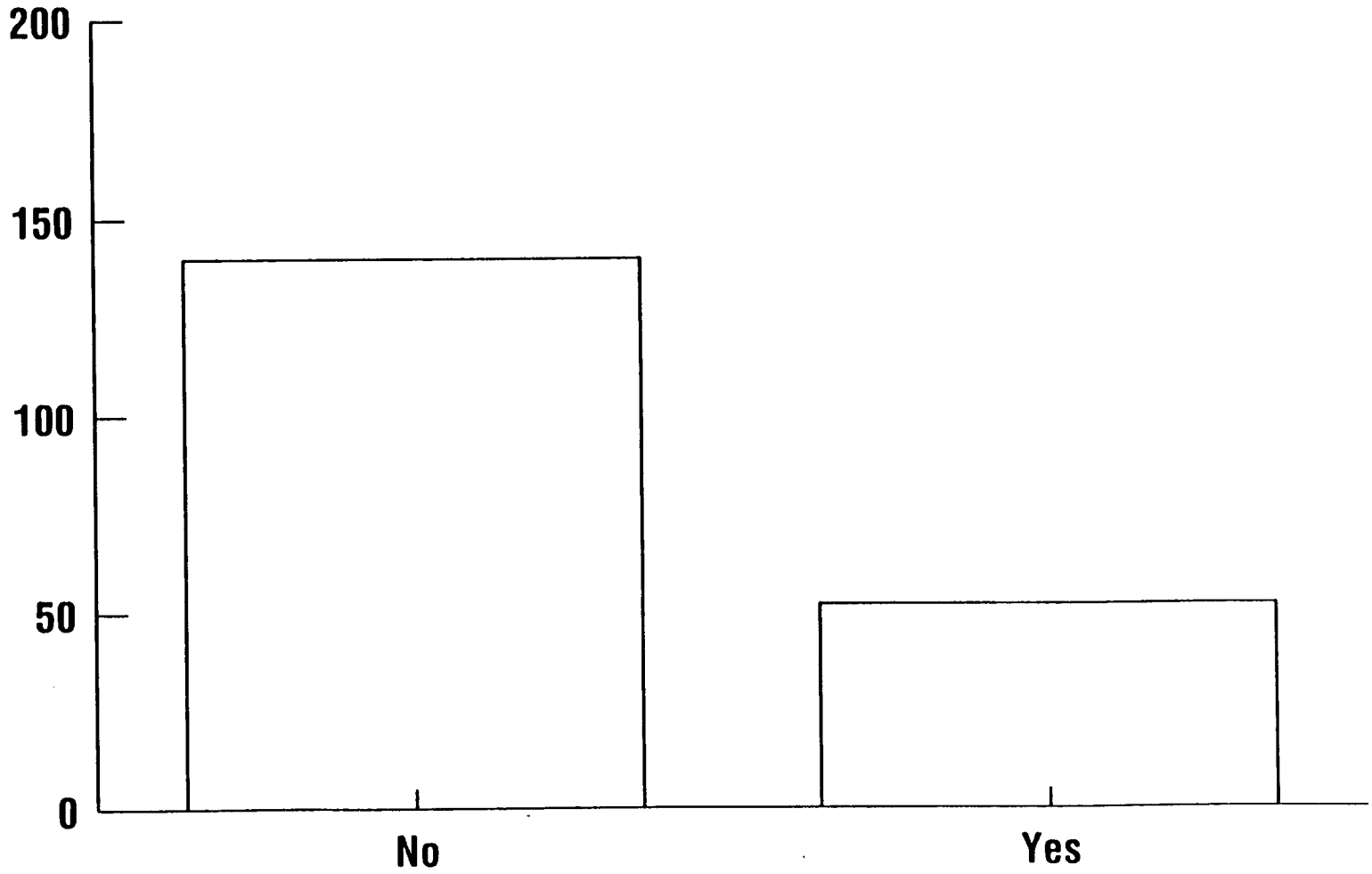

Figure 5-6: Alternate Route EO Around Tandem

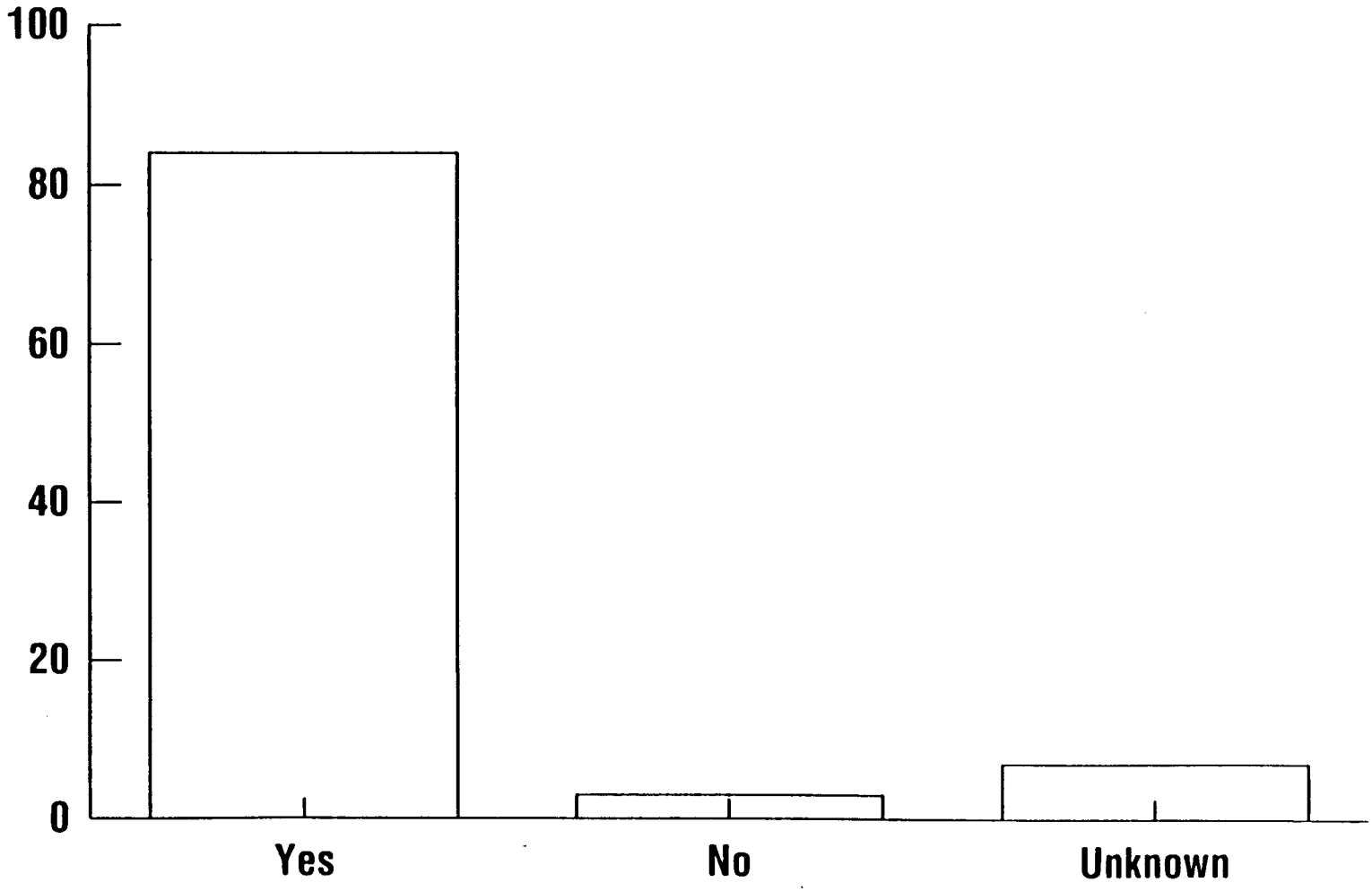

Figure 5-7: Diverse Route EO to Tandem

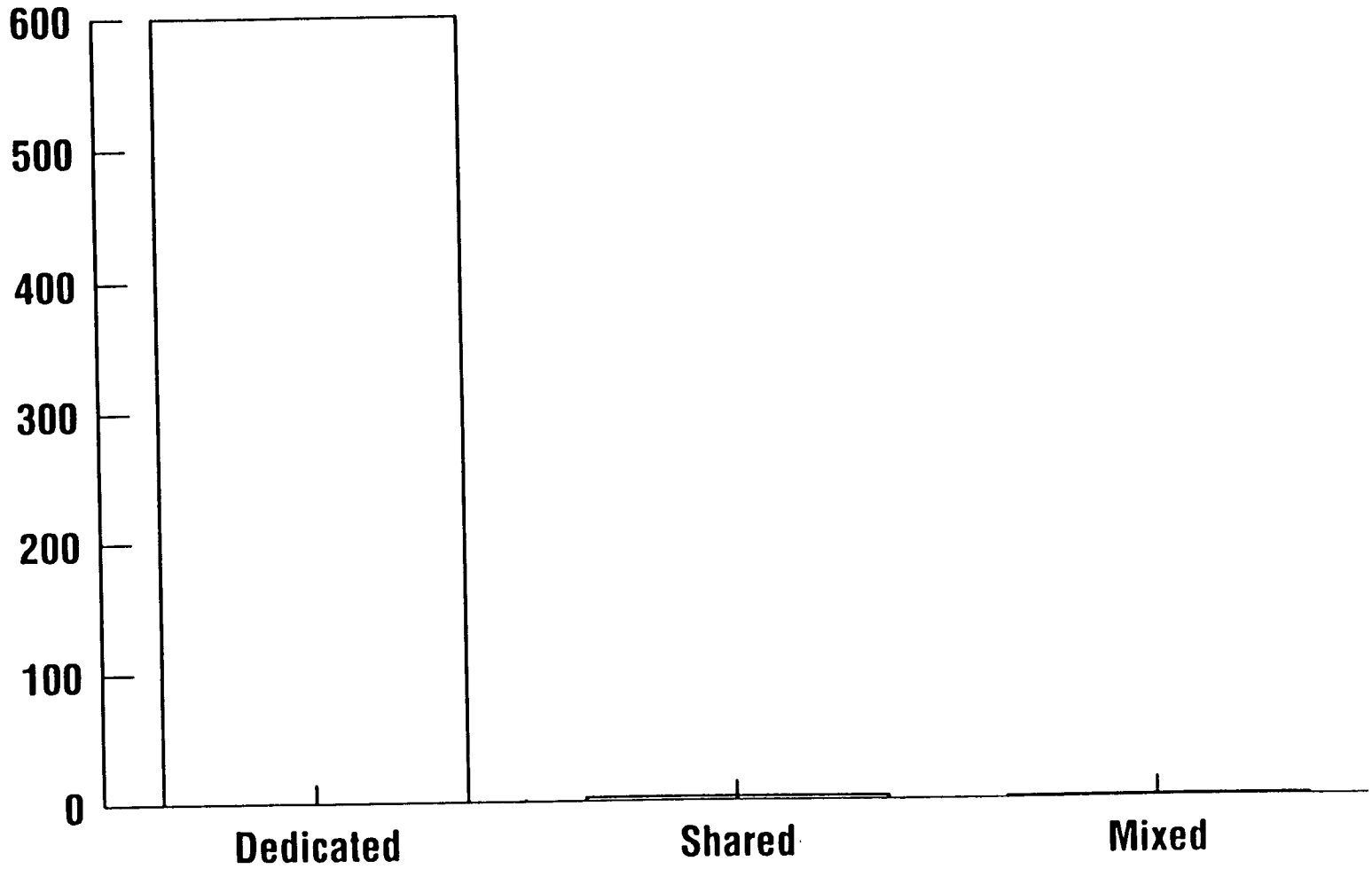

Figure 5-8: Dedicated Trunking to PSAP

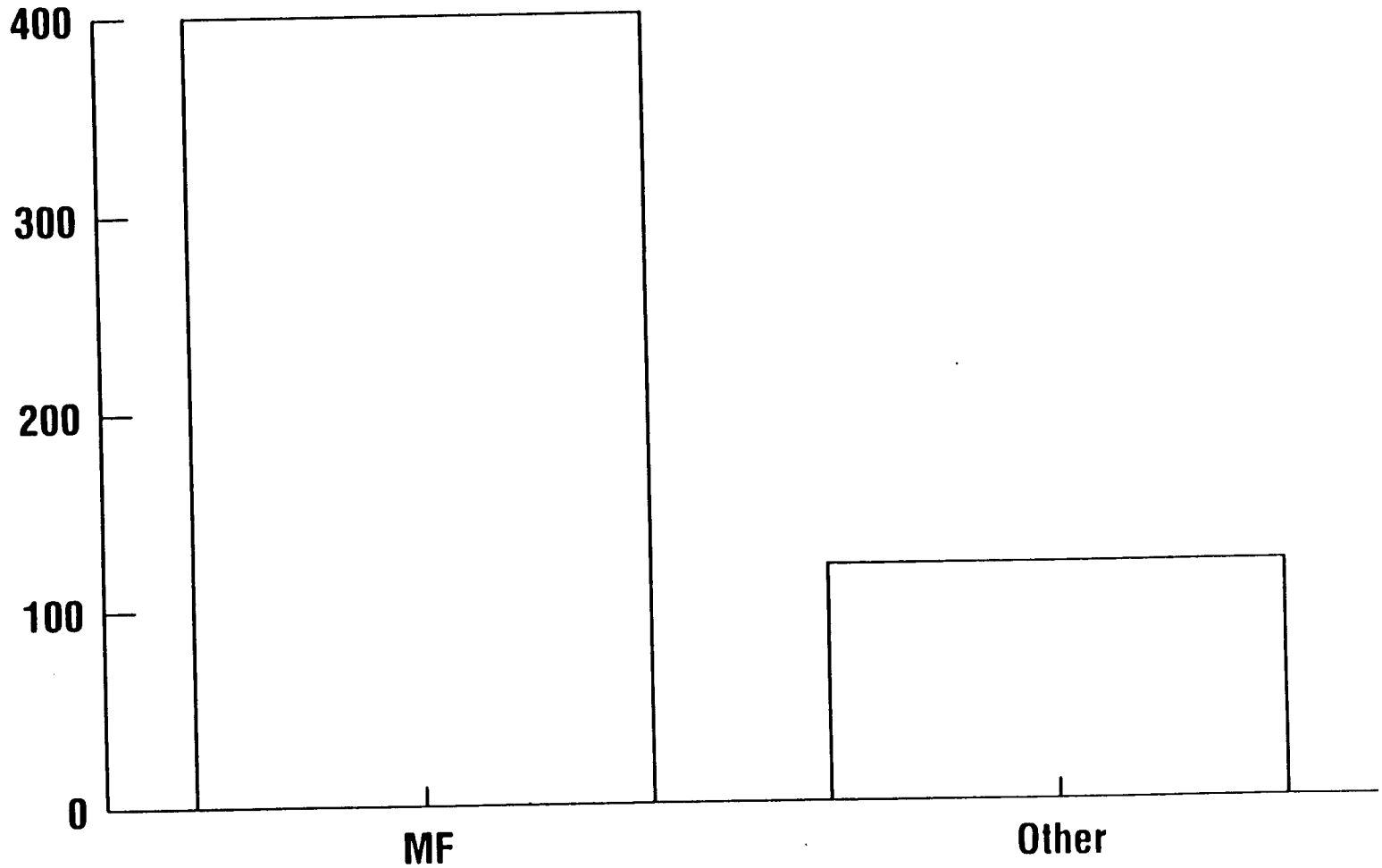

Figure 5-9: Type Signalling to PSAP

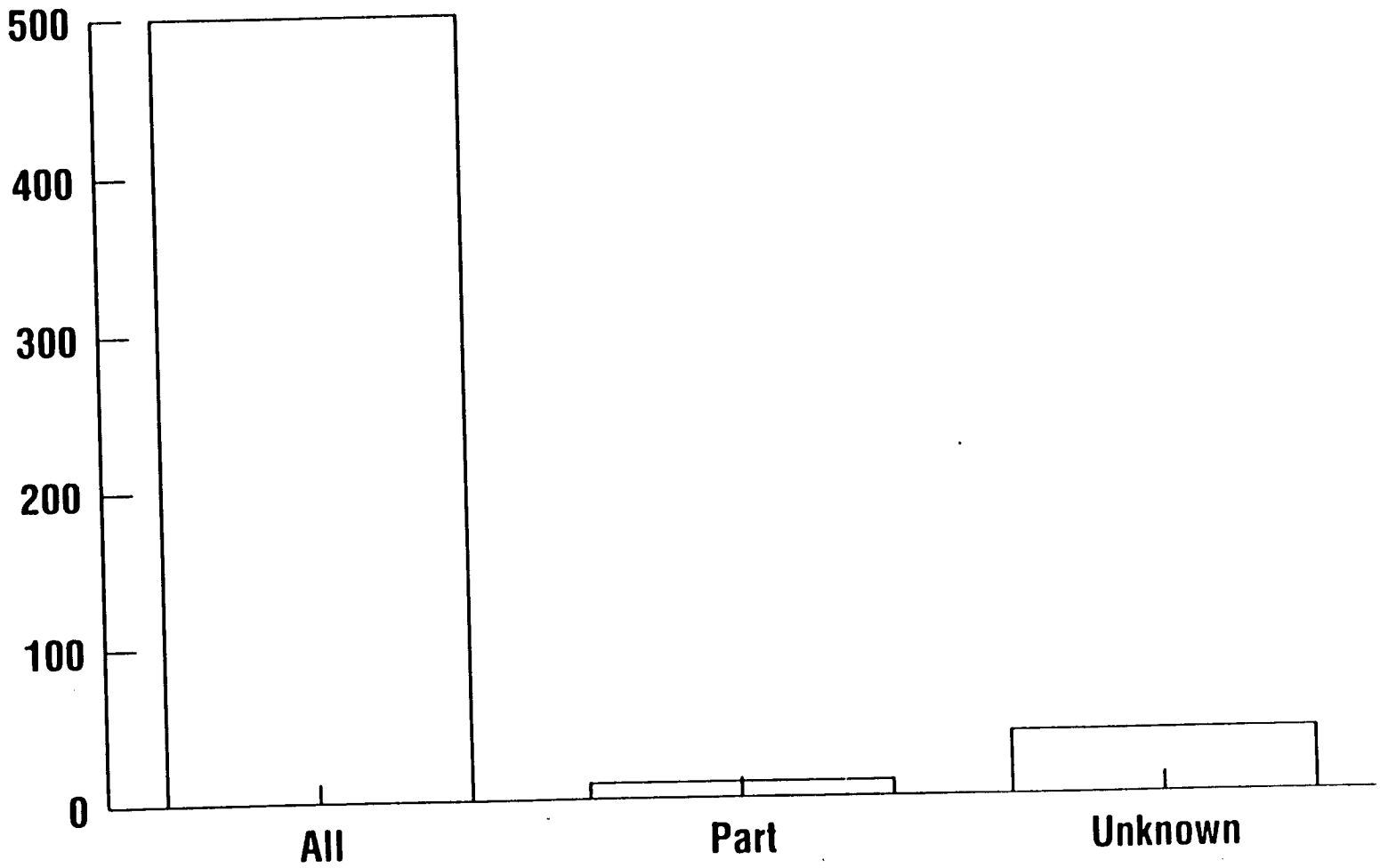

Figure 5-10: Alarm Monitoring to PSAP

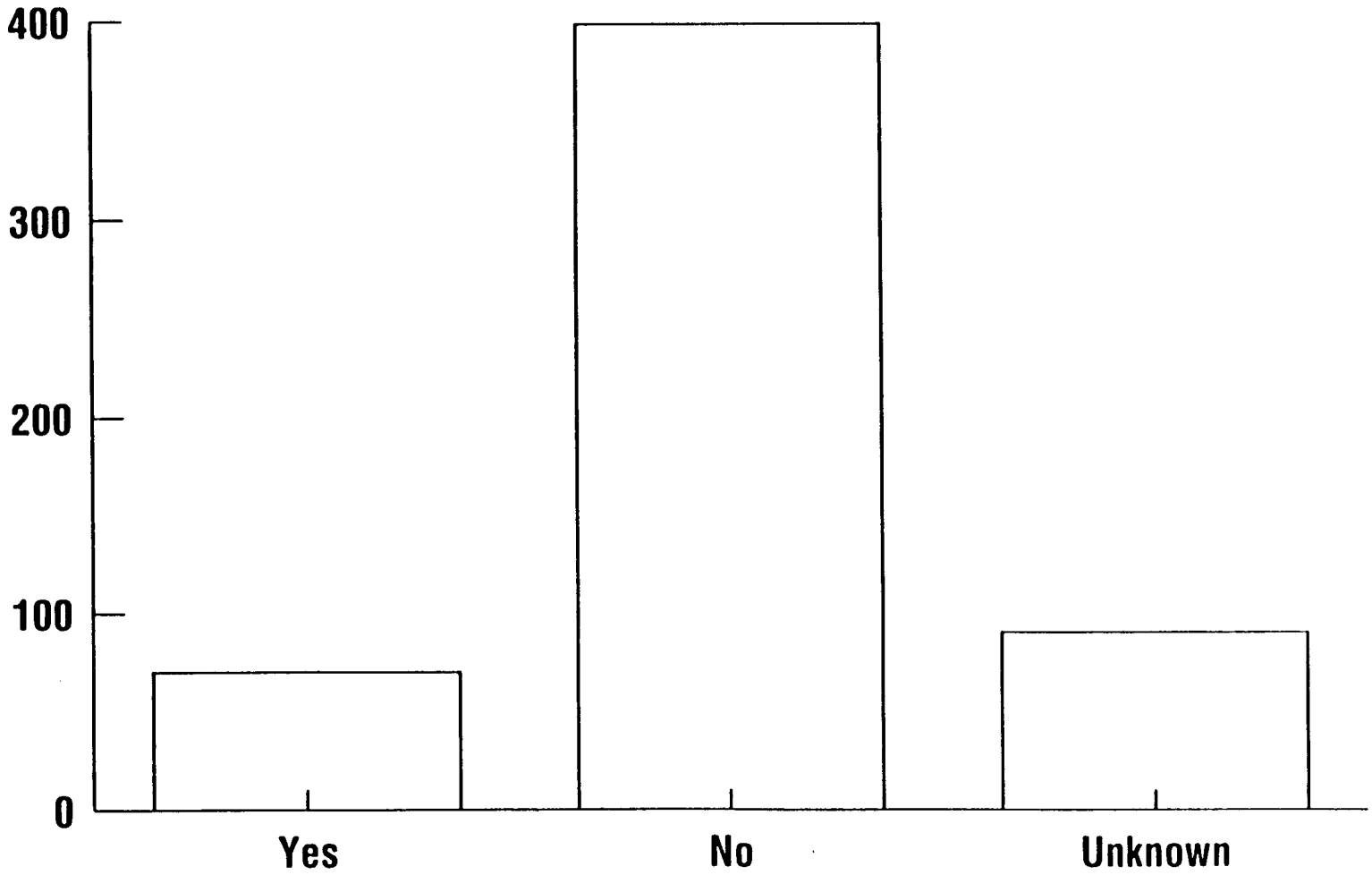

Figure 5-11: Alternate Route to PSAP

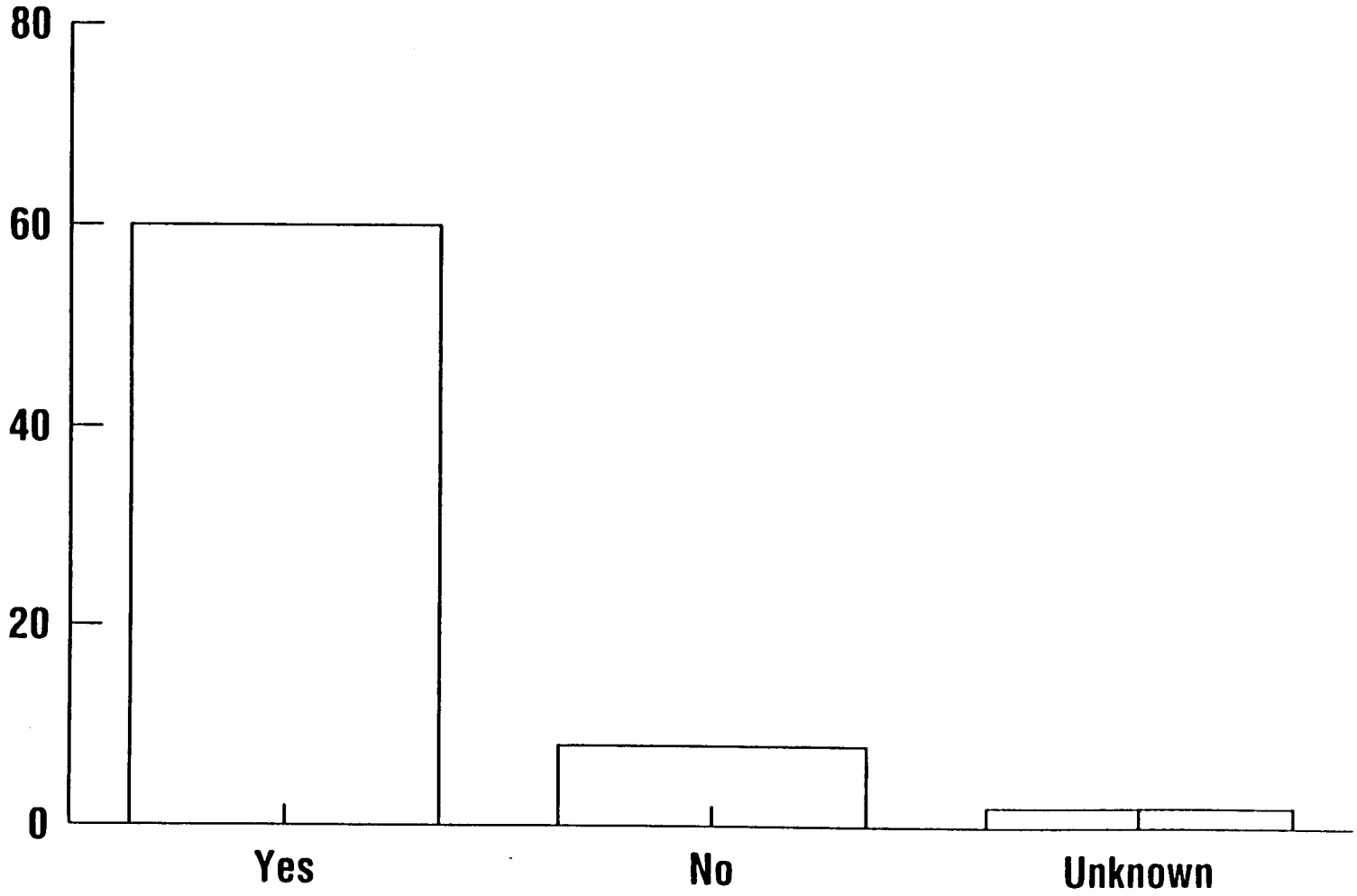

Figure 5-12: Diverse Route to PSAP

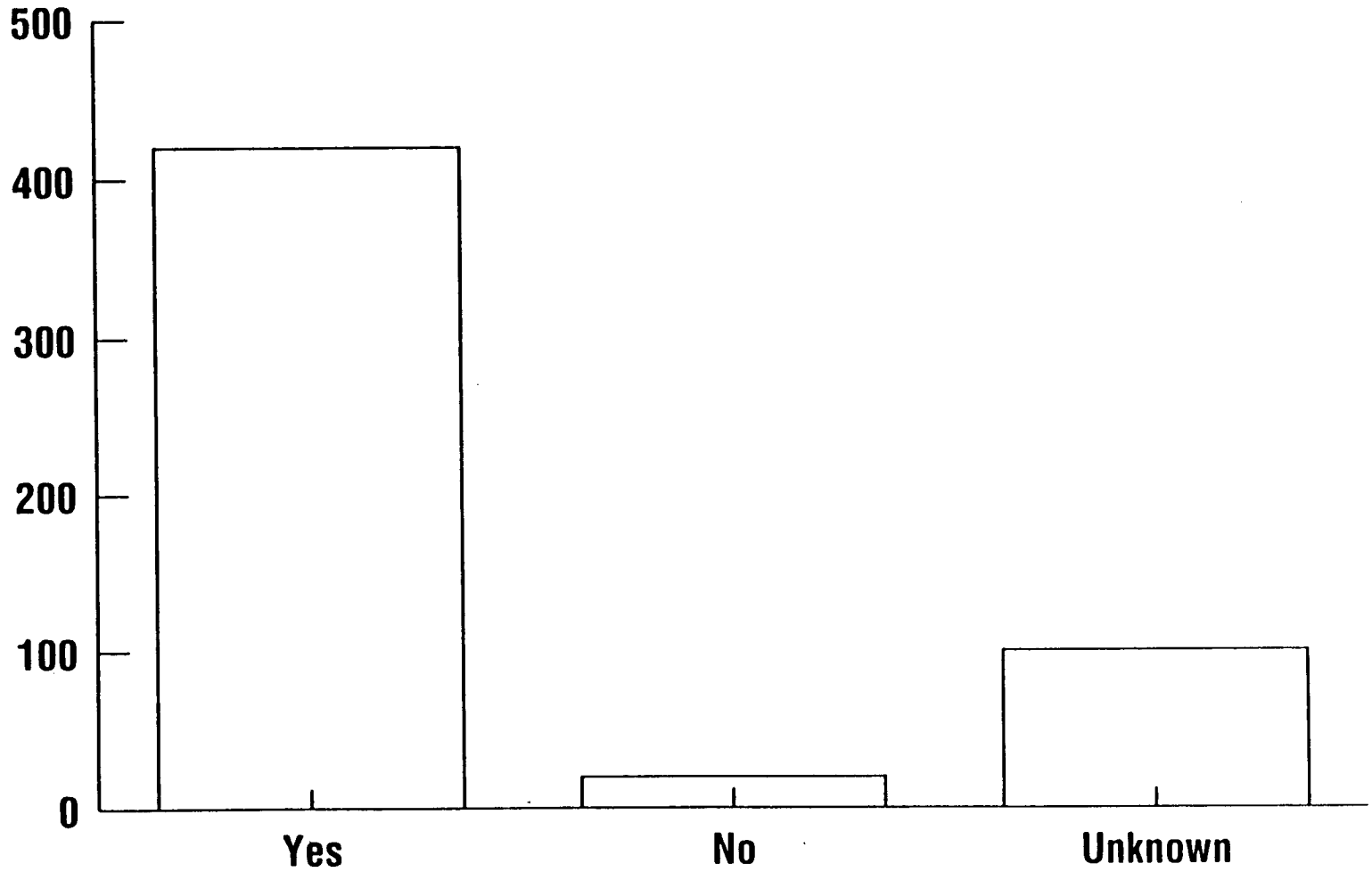

Figure 5-13: Back-Up Power Supply at PSAP

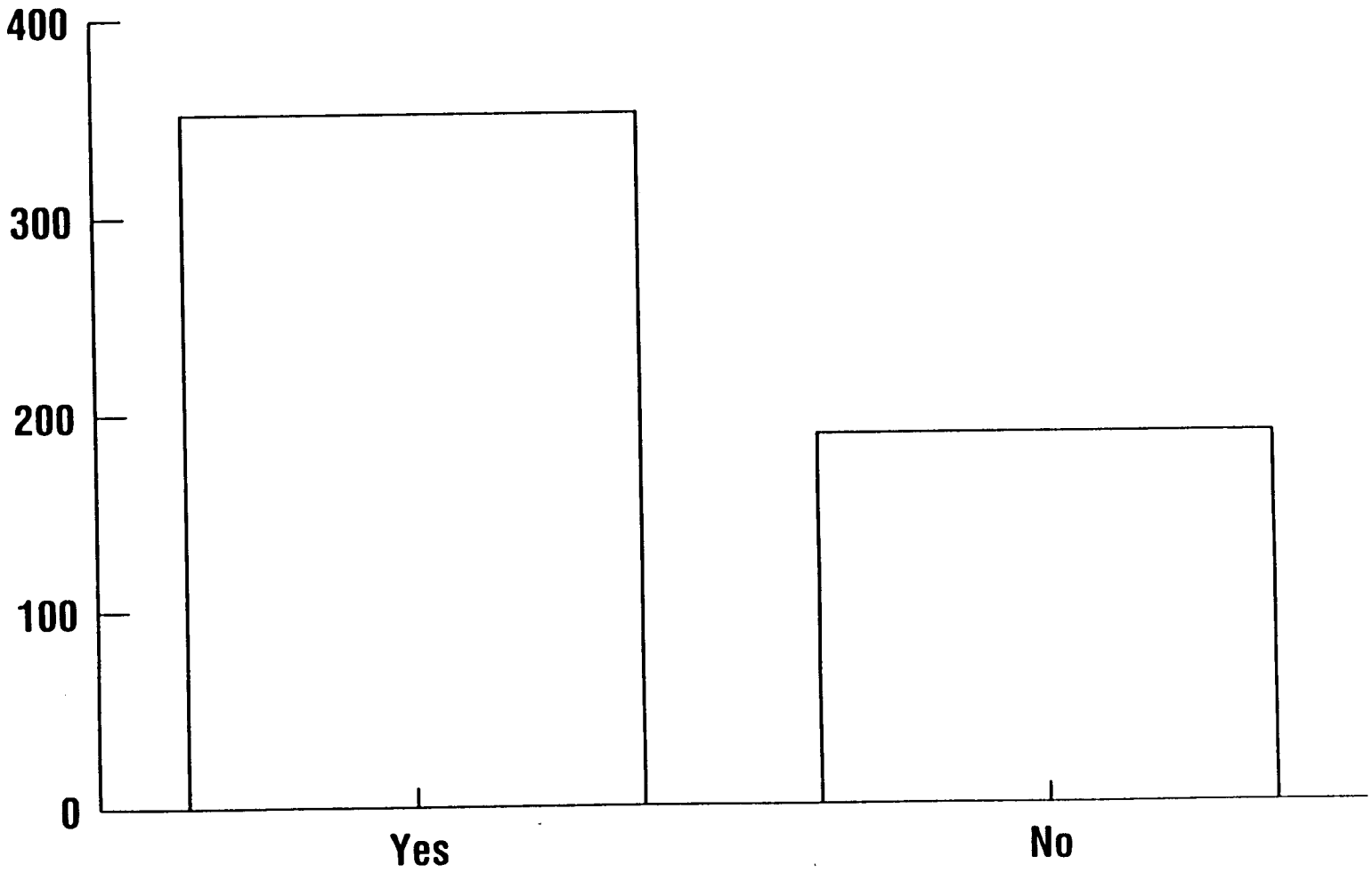

Figure 5-14: PSAP Backed Up

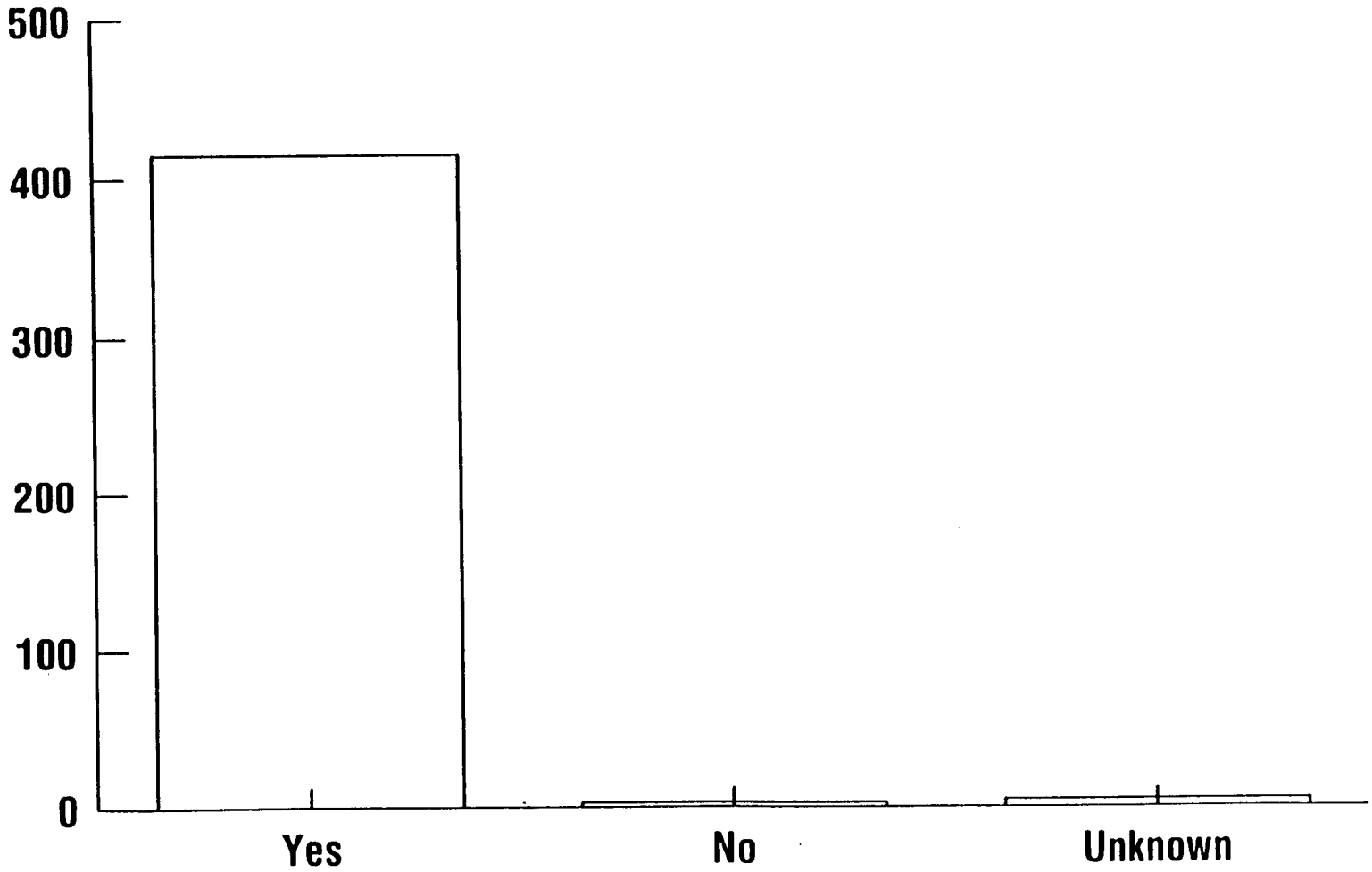

Figure 5-15: Duplicate ALI Data Base

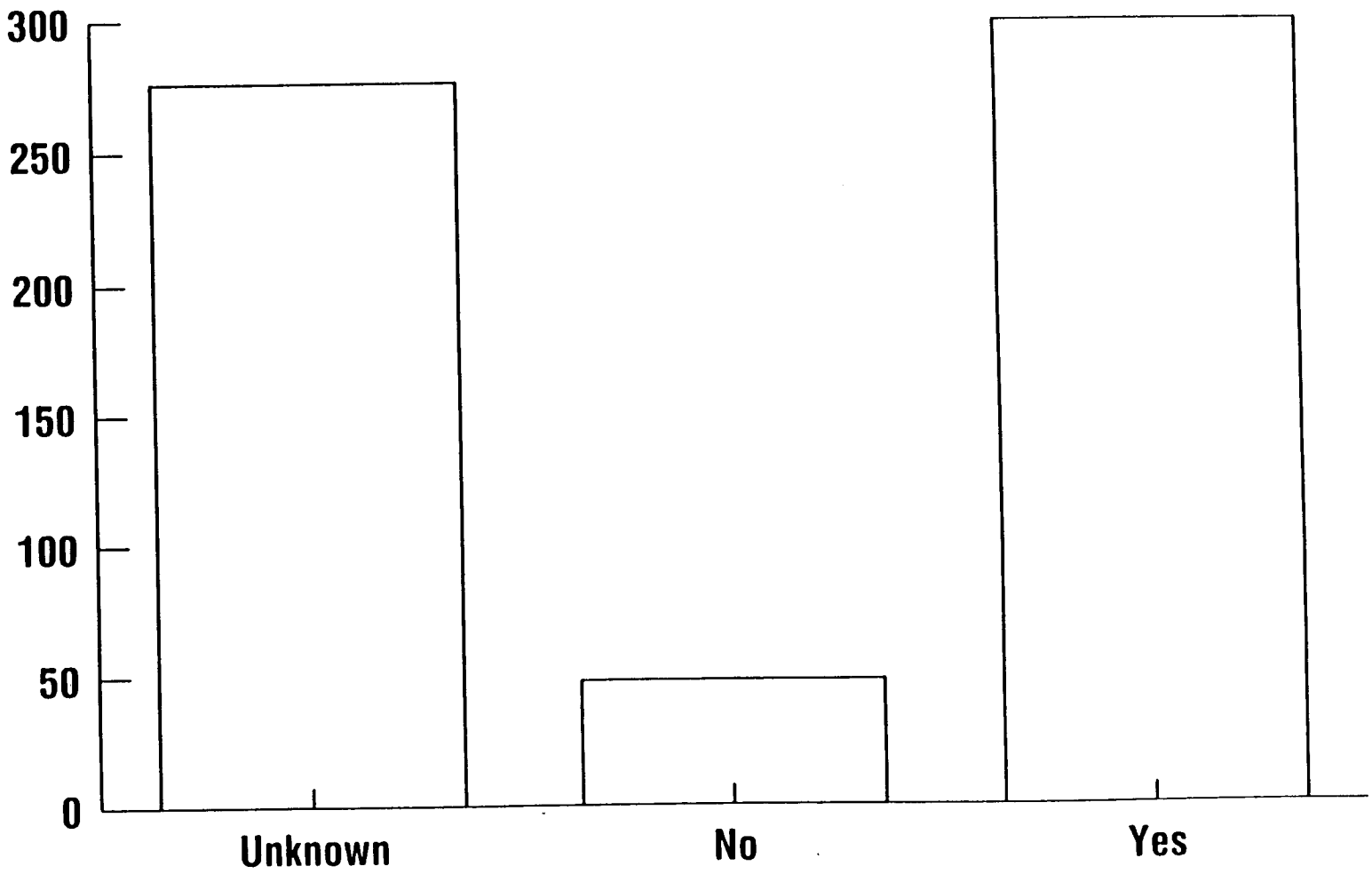

Figure 5-16: PSAP Link Diverse

Location	Number	% Total
Interoffice Facility (FAC)	59	48
LEC Tandem Office (TDM)	17	13
LEC End Office (EO)	14	11
PSAP Equipment (PSAP)	11	9
Other	9	7
FAC & EO	5	4
FAC & PSAP	2	2
FAC & Other	2	2
EO & Other	2	2
EO & PSAP	1	1
TDM & Other	1	1
Total	123	100

Figure 5-17: Location of Failure

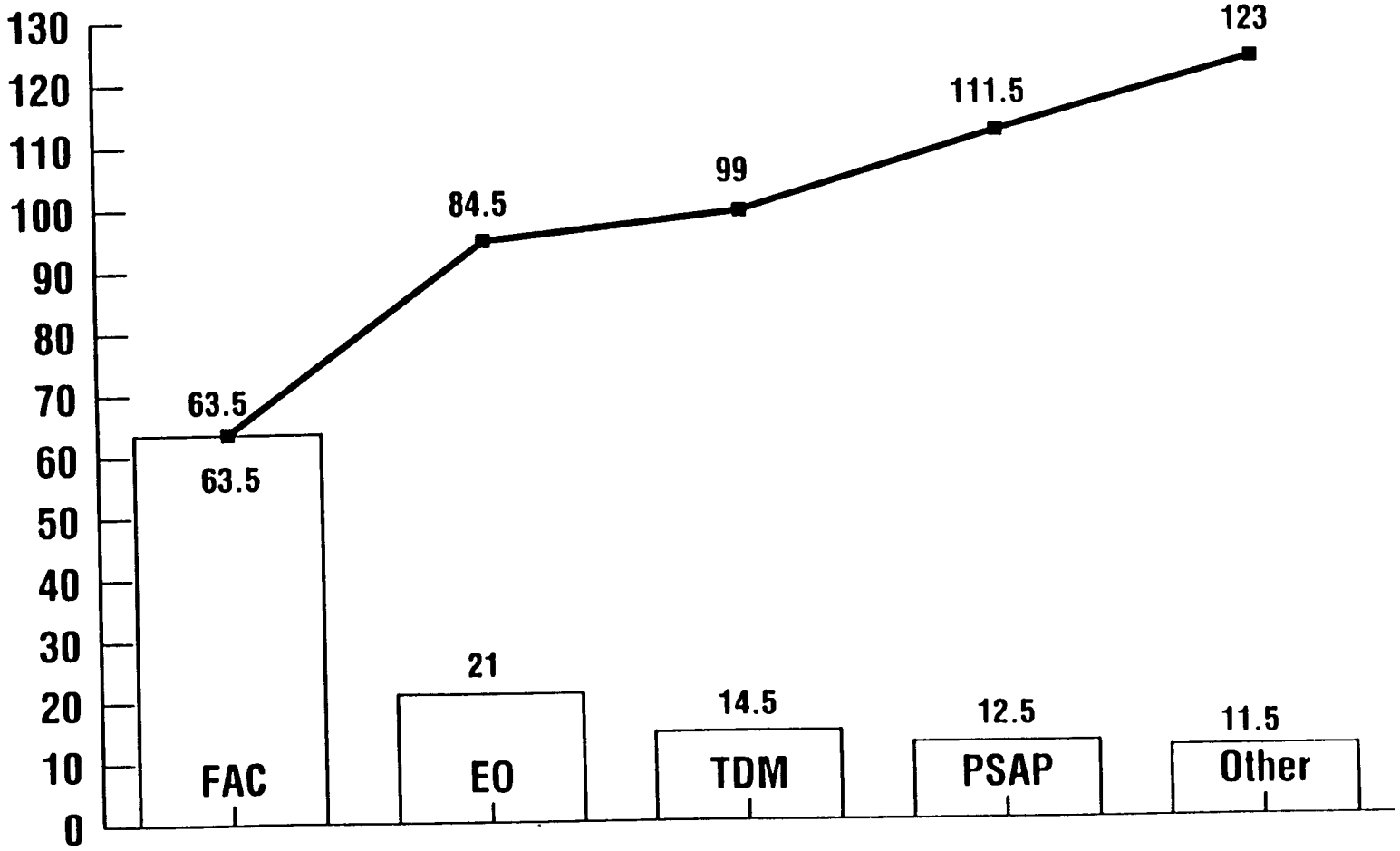

Figure 5-18: 9-1-1 Service Disruptions by Location

Cause	Number	% Total
Hardware	31	25
Cable Dig Up	30	24
Other	29	24
Craft	14	11
Software	12	10
Unknown	7	6
Traffic Load	0	0
Total	123	100

Figure 5-19: Cause of Failure

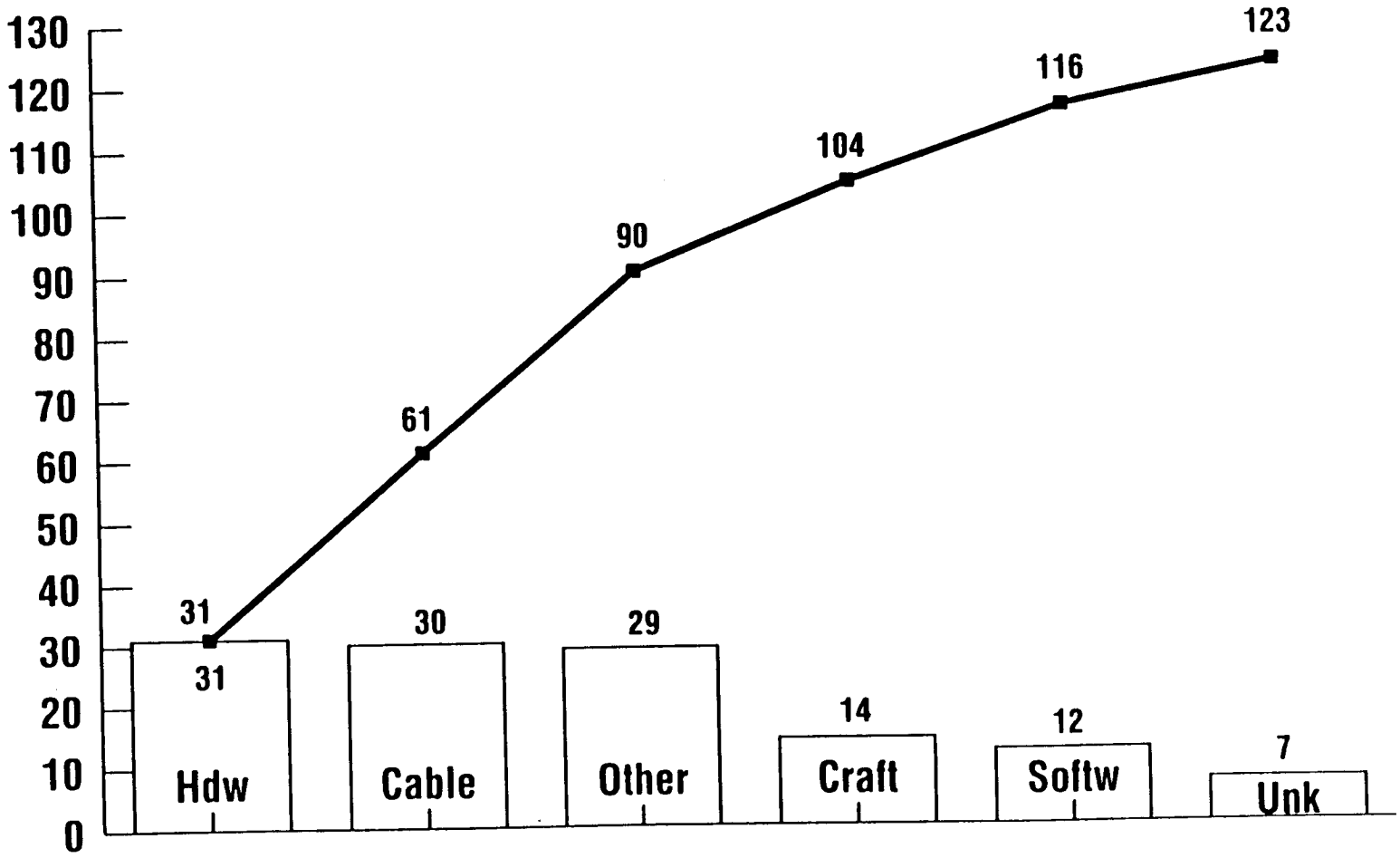

Figure 5-20: 9-1-1 Service Disruptions by Cause

	Cause						
Location	Hardw.	Softw.	Cable	Craft	Other	Unknown	Total
LEC End Ofc.	9	3	0	4	5	1	22
LEC Tandem	5	6	0	4	4	0	19
Facility	15	1	31	4	13	4	68
E911	6	2	0	0	5	2	15
Other	4	2	1	5	5	0	17
Total	39	14	32	17	32	7	141

Figure 5-21: Location by Cause of Failure

Location	Cause	# Failures	% Failures
Facility	Cable	31	22
Facility	Hardware	15	11
Facility	Other	13	9
LEC End Office	Hardware	9	6
Remaining	Remaining	73	52
	Total	141	100

Figure 5-22: Location by Cause

	Hours To Restore				
Location	End Of.	Tandem	IO FAC	911	Other
Upper 25%	1.88	2.33	5.33	5.9	4.3
Median	1.17	2.0	3.5	1.7	2.2
Lower 25%	.90	1.38	2.5	.83	1.0

Figure 5-23: Duration by Location of Failure

% Of Facility Failures	Restoral Time
Top 25%	5.33 Hours or Longer
Next 25%	3.5 To 5.33 Hours
Next 25%	2.5 To 3.49 Hours
Bottom 25%	0.5 To 2.49 Hours

Figure 5-24: Interoffice Facility Failure Restoral Time

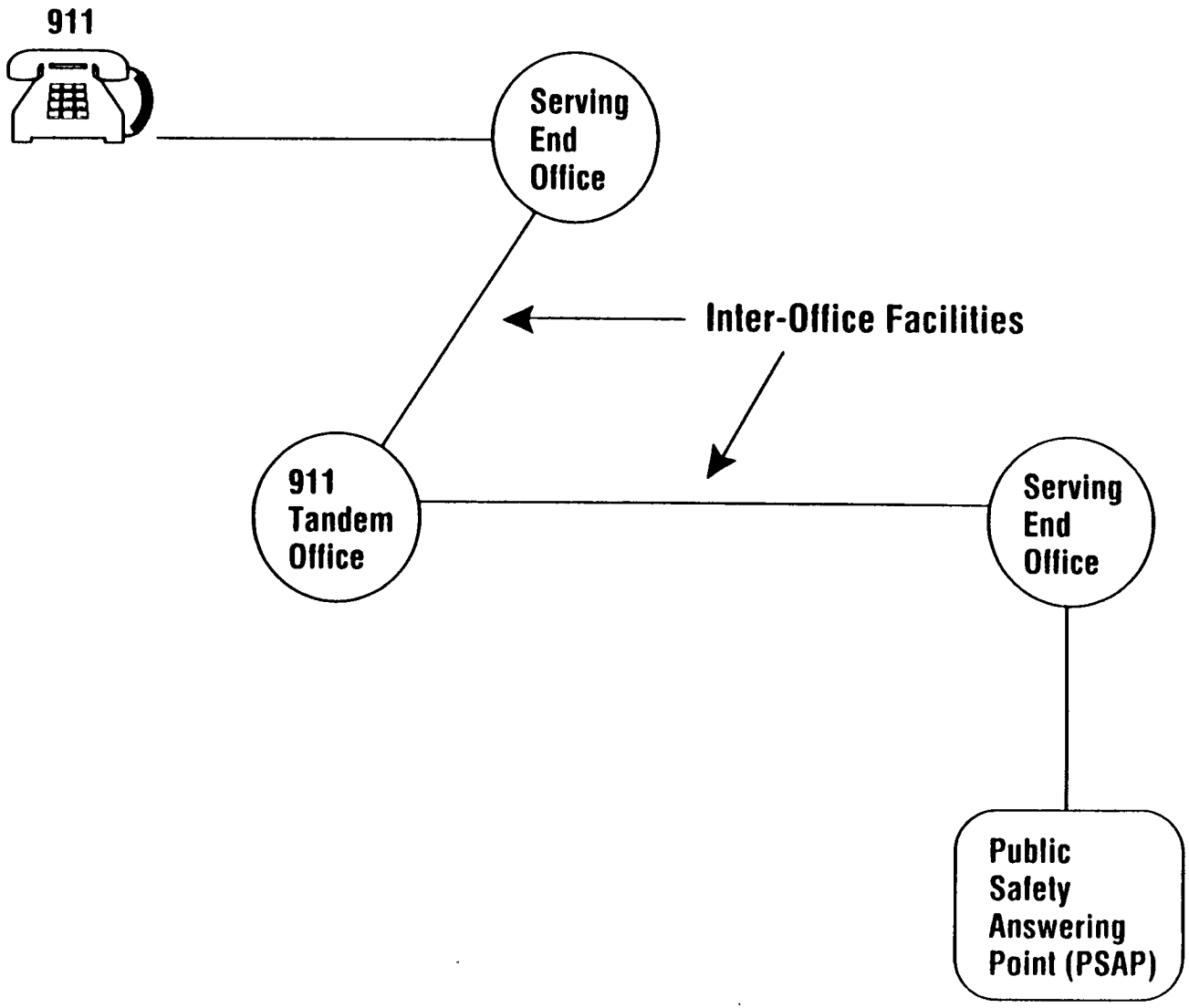

Figure 6-1: Standard 911 Serving Architecture

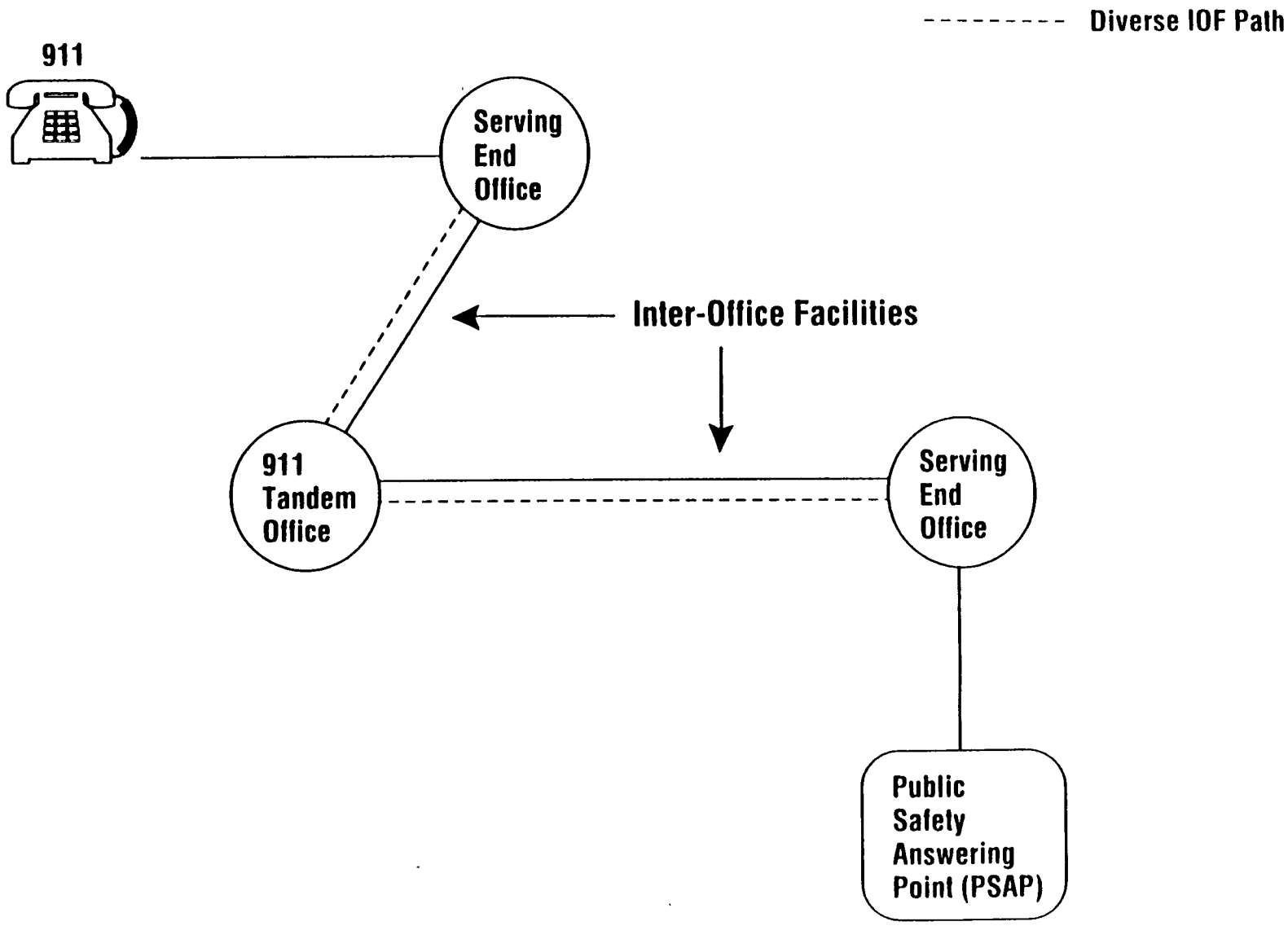

Figure 6-2: Inter-Office Facility Architecture/Diversity

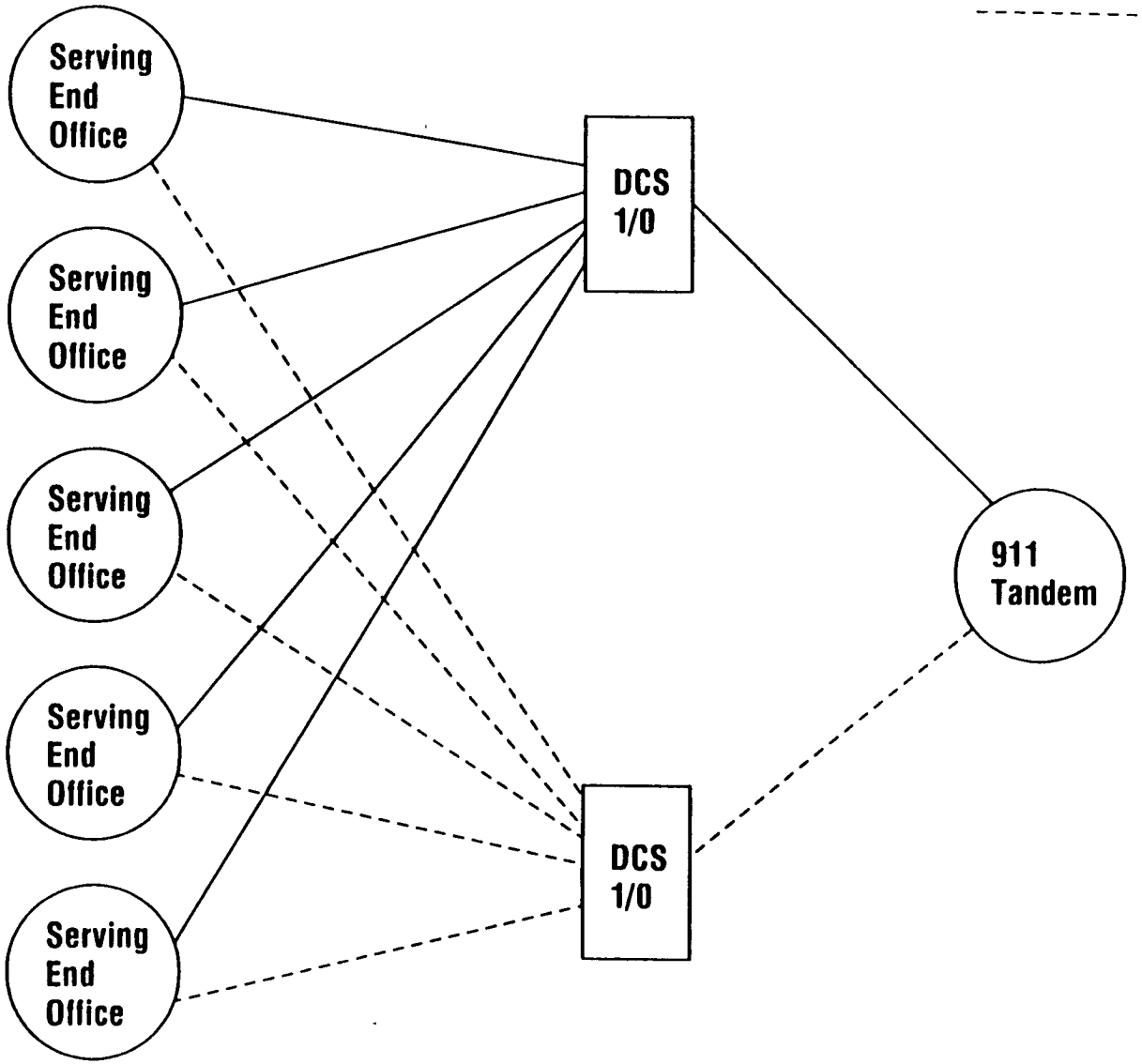

Figure 6-3: Inter-Office Facility Architecture/ DCS Diversity

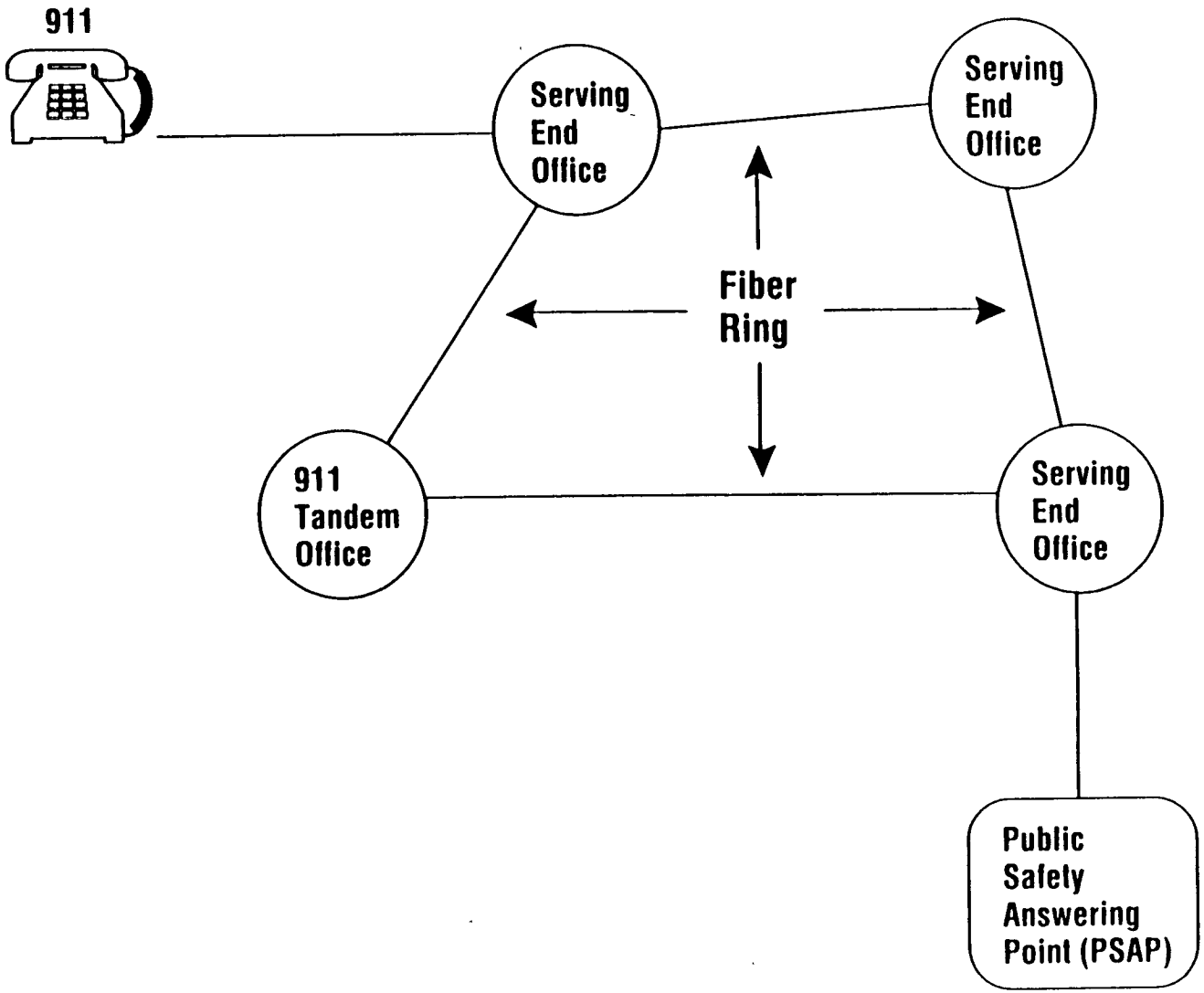

Figure 6-4: Inter-Office Facility Architecture/Ring Diversity

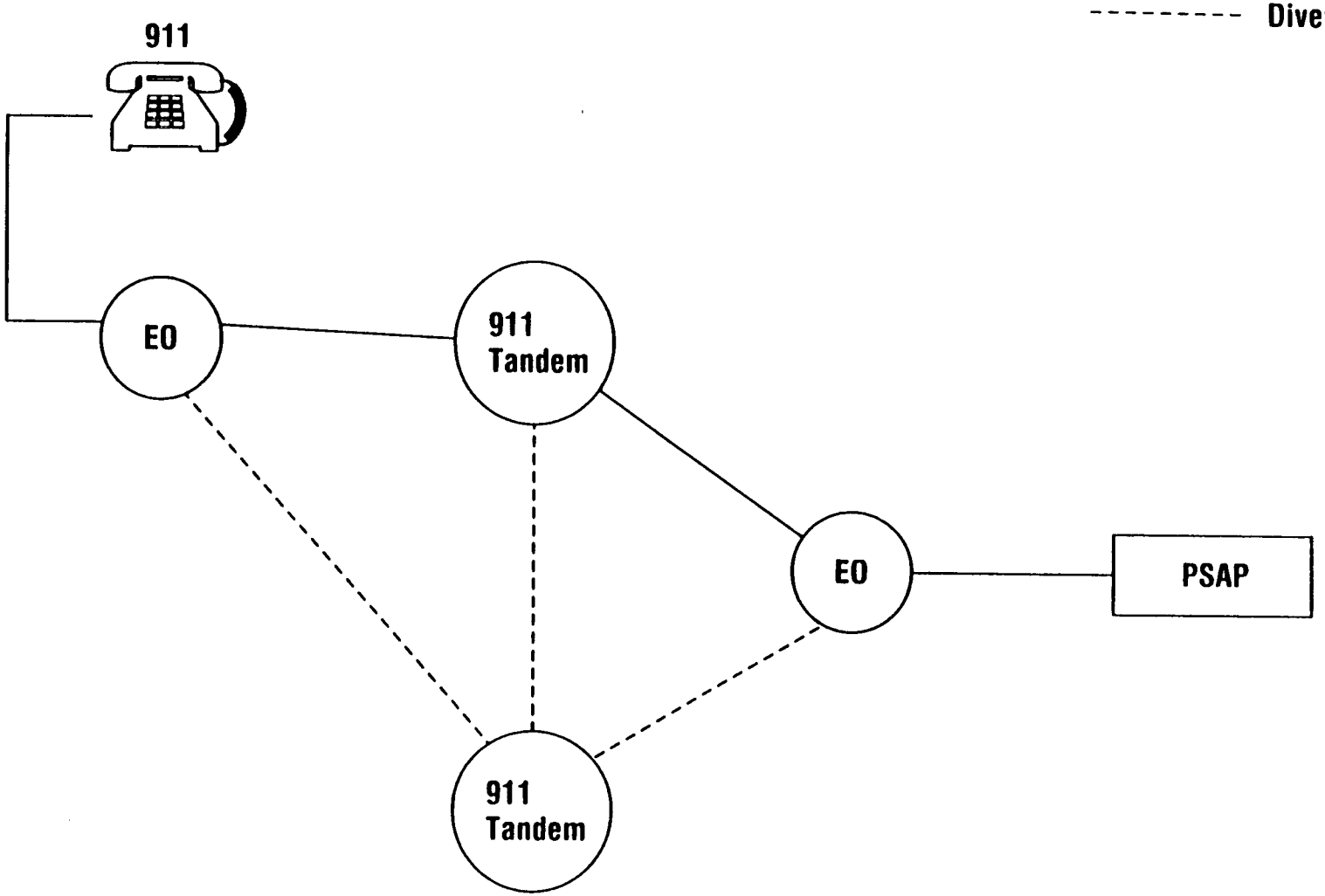

Figure 6-5: Inter-Office Facility Architecture/Tandem Diversity

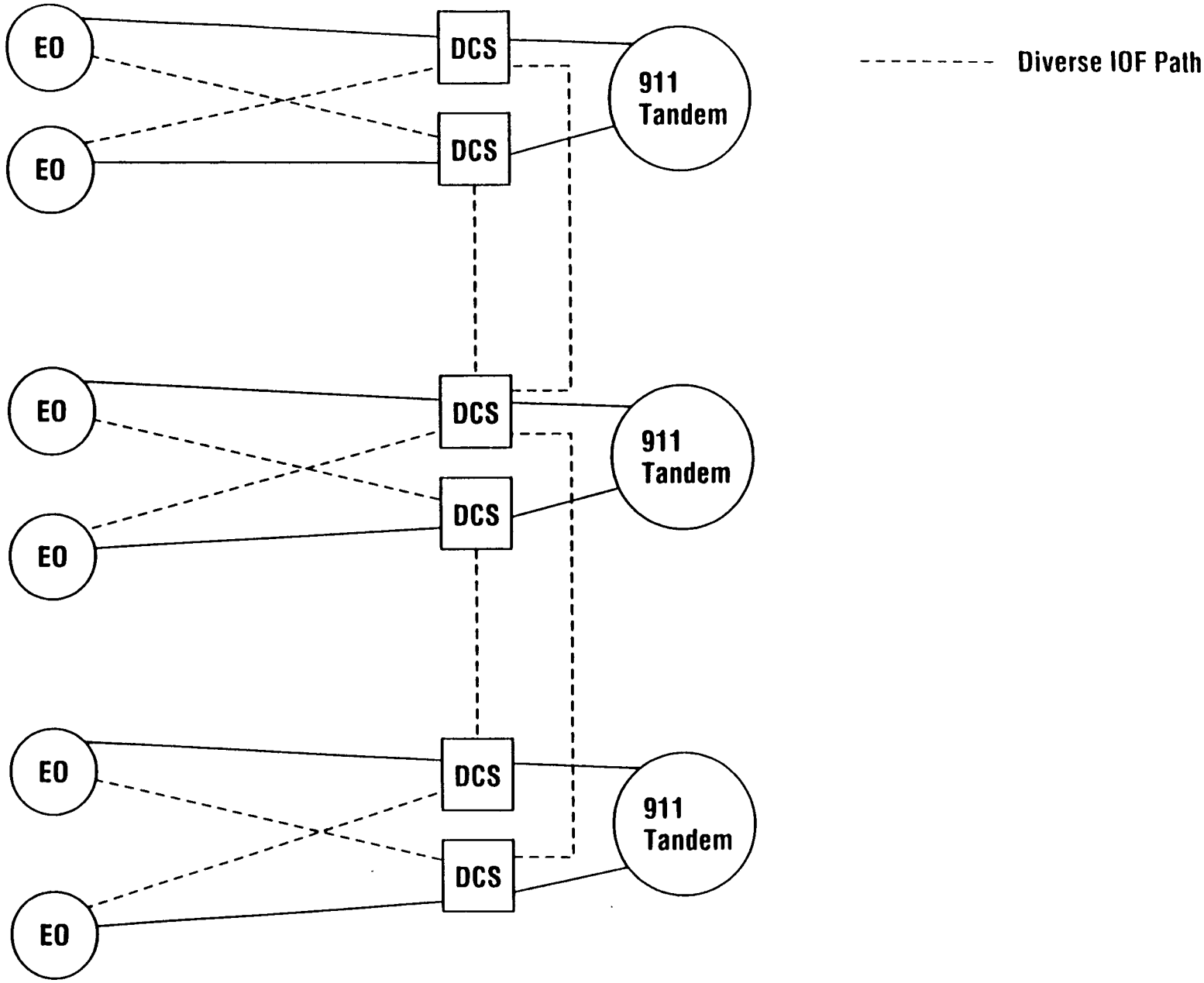

Figure 6-6: Inter-Office Facility Architecture/Multiple Tandem Diversity

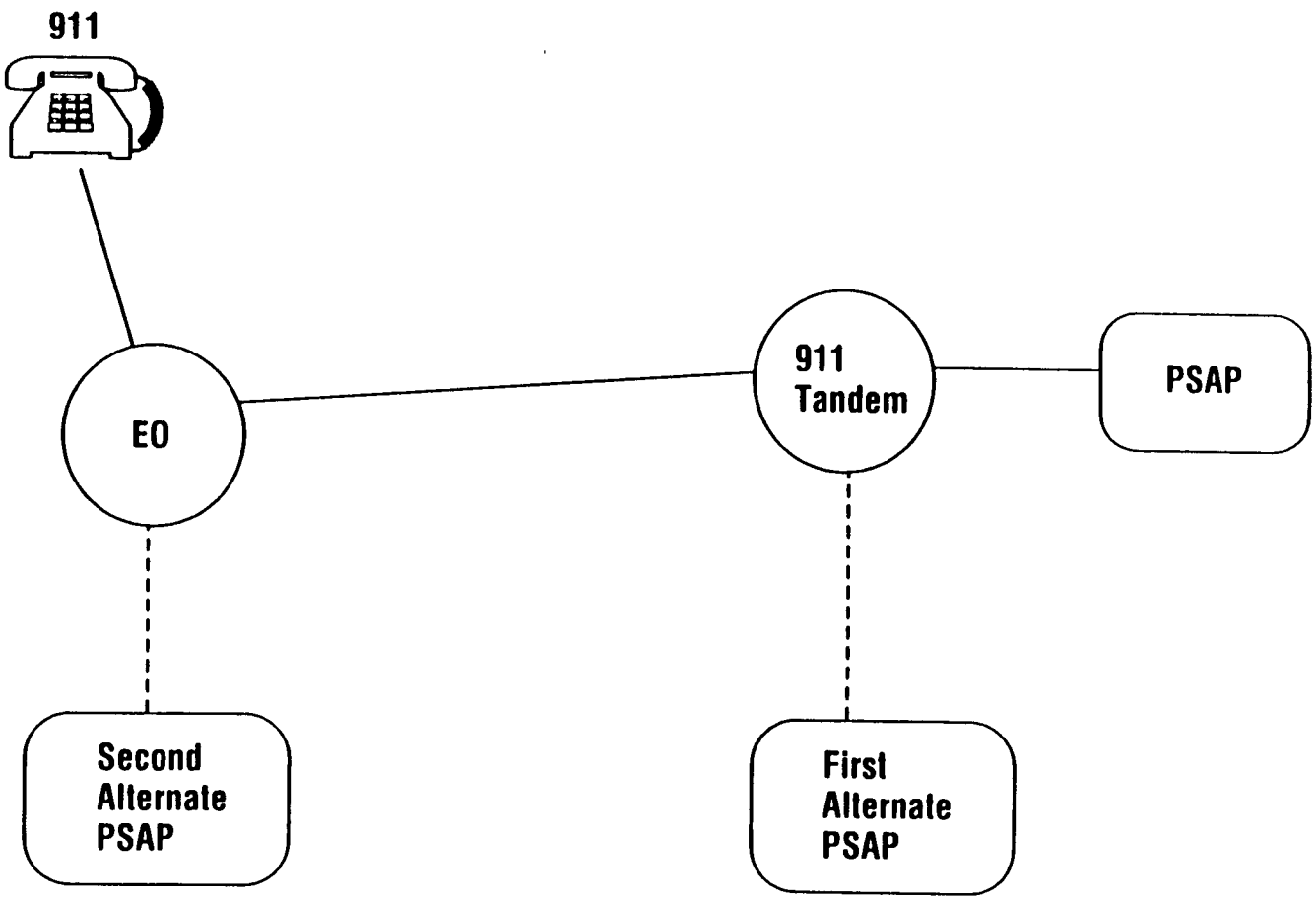

Figure 6-7: Alternative PSAP for Backup/Overflow

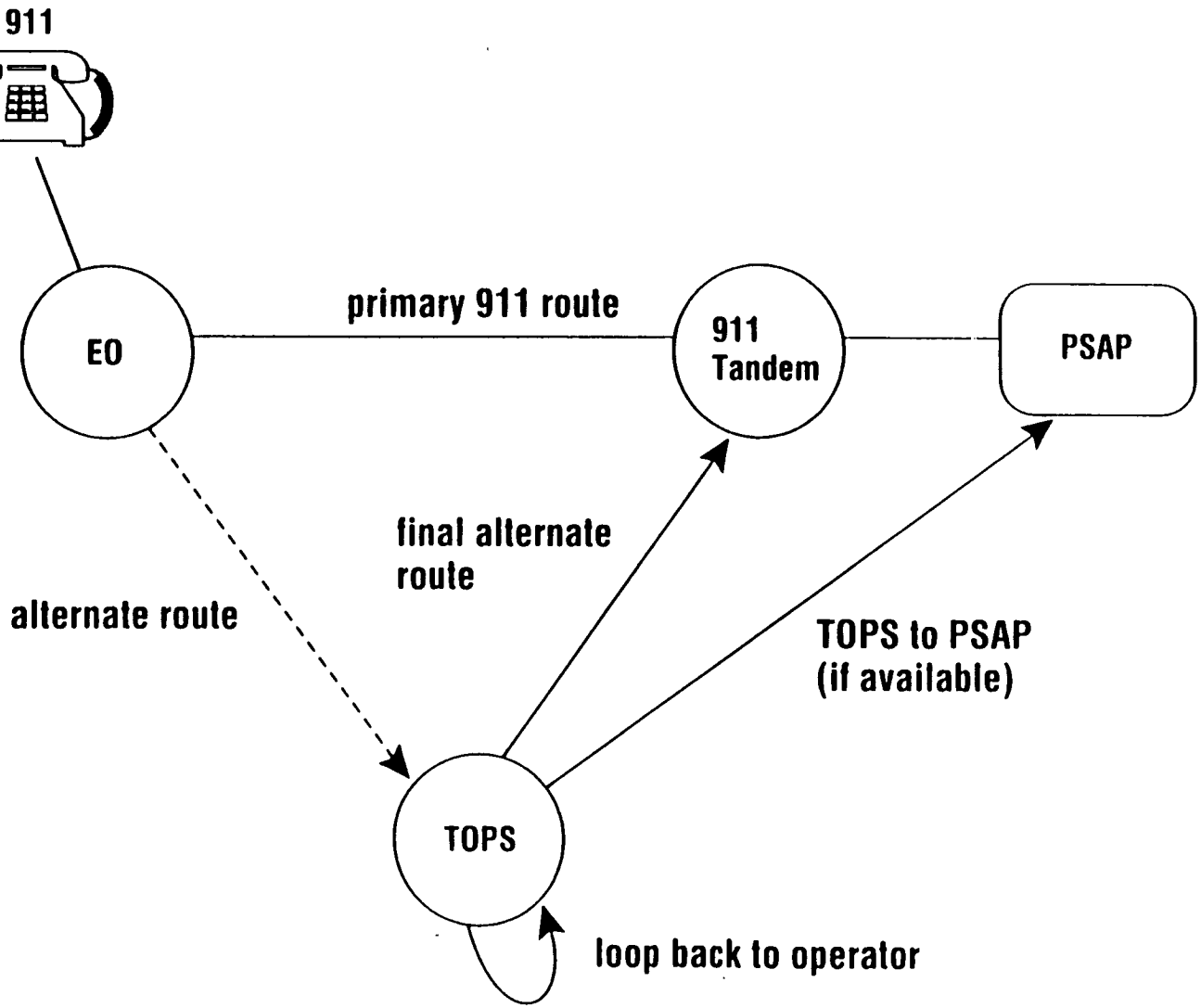

Figure 6-8: TOPS for Overflow/Backup

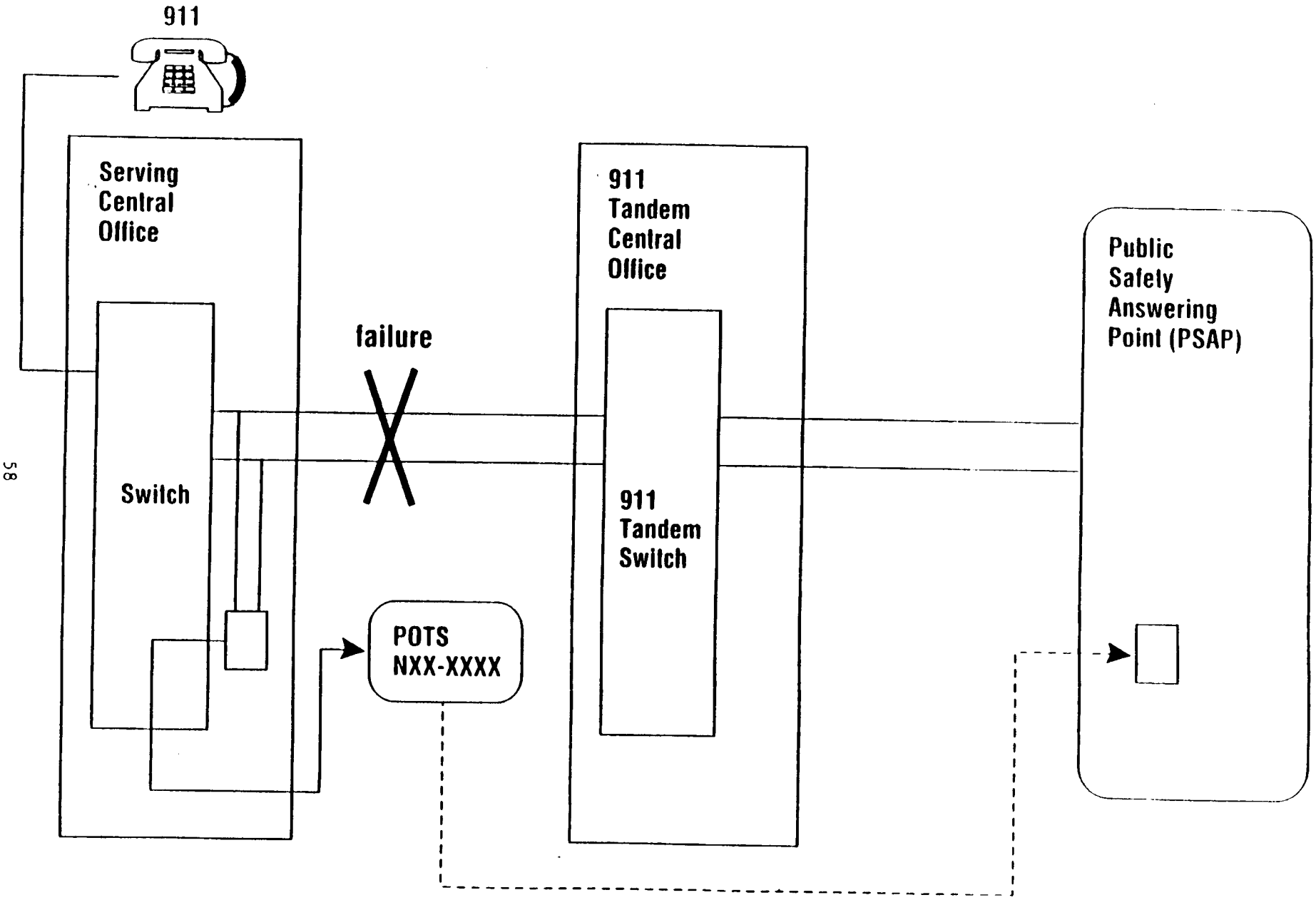

Figure 6-9: Diversity Through the Public Switch Telephone Network

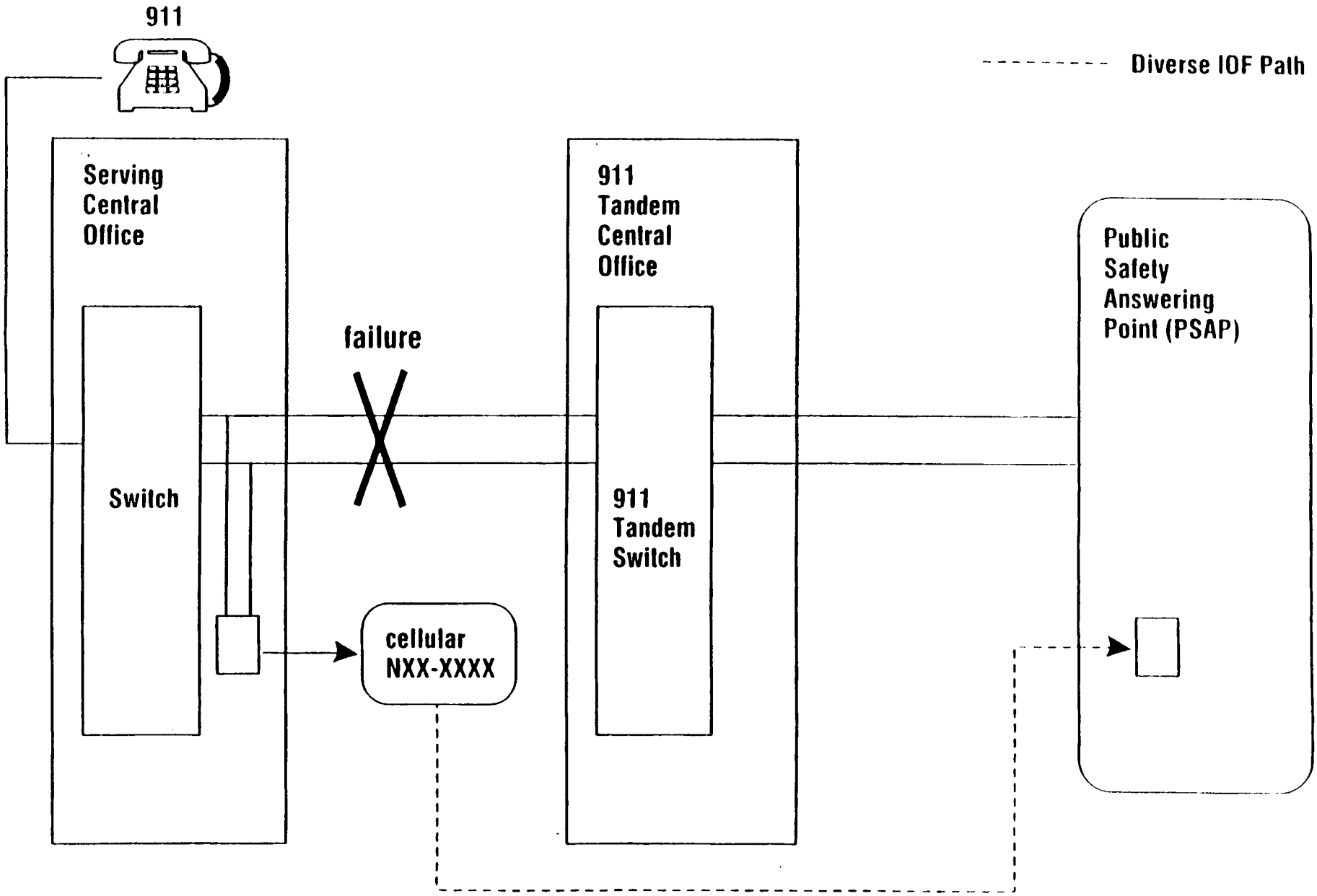

Figure 6-10: Diversity Through the Cellular Network

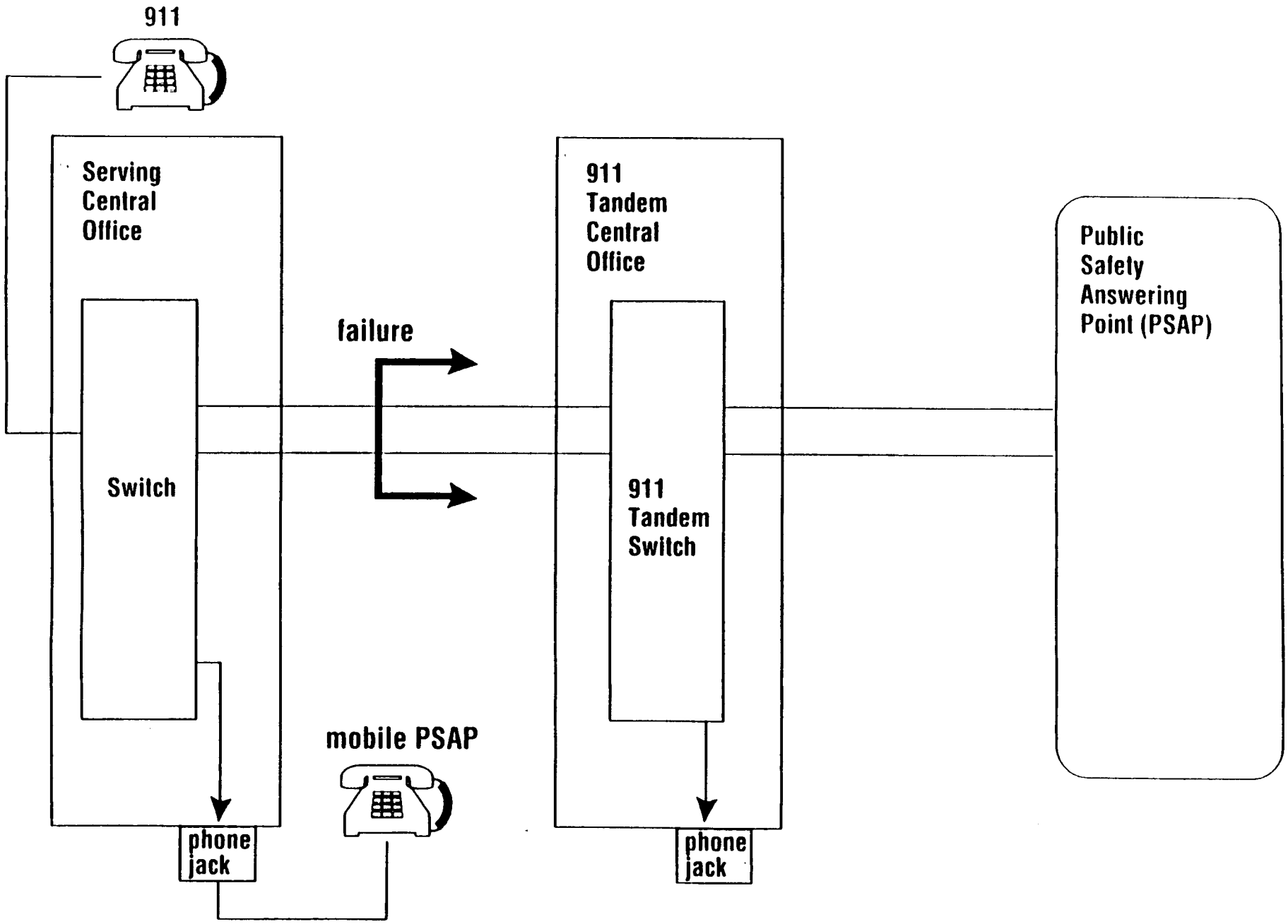

Figure 6-11: Diversity Through an Intra-Office Call Termination

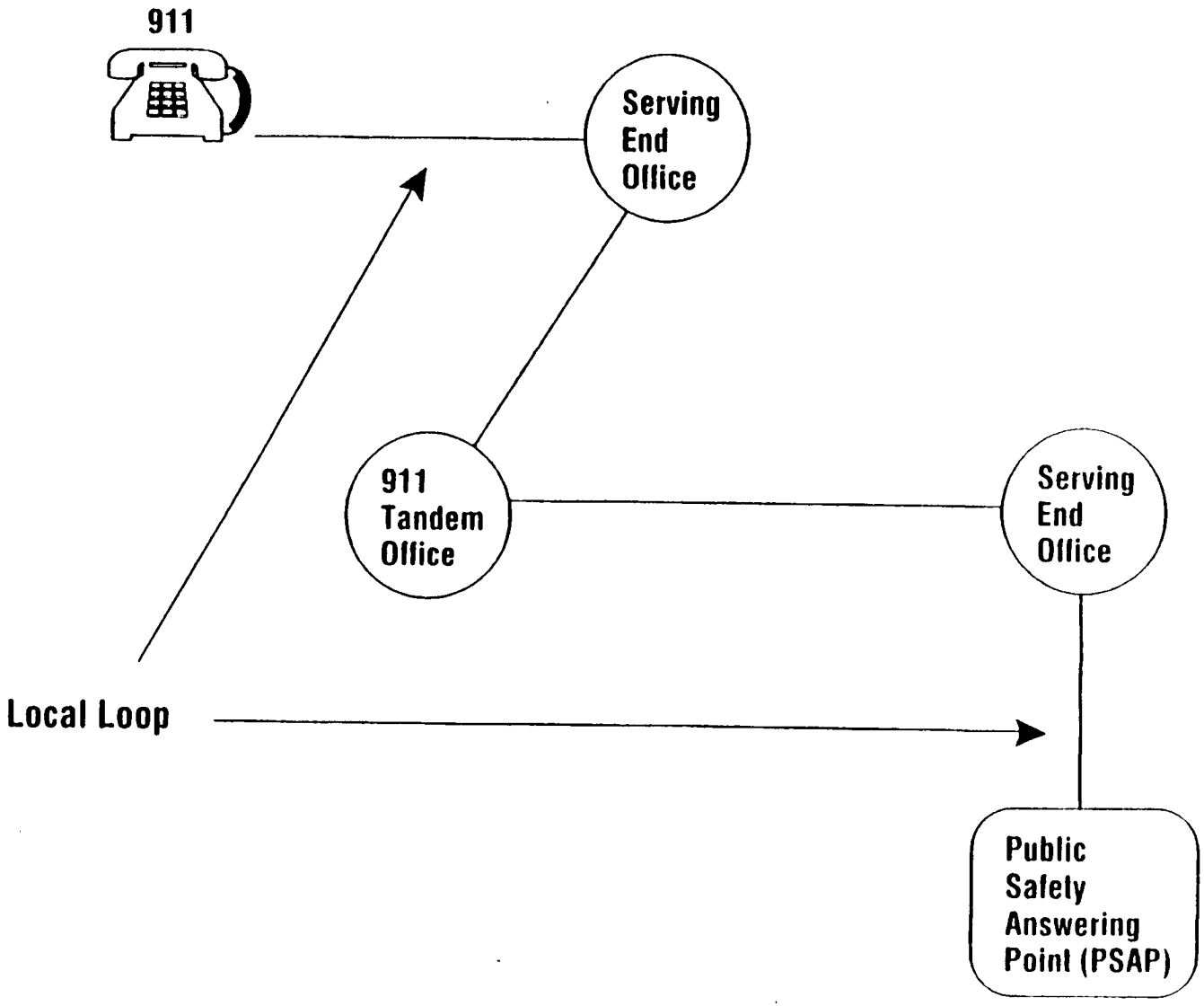

Figure 6-12: 911 Serving Architecture

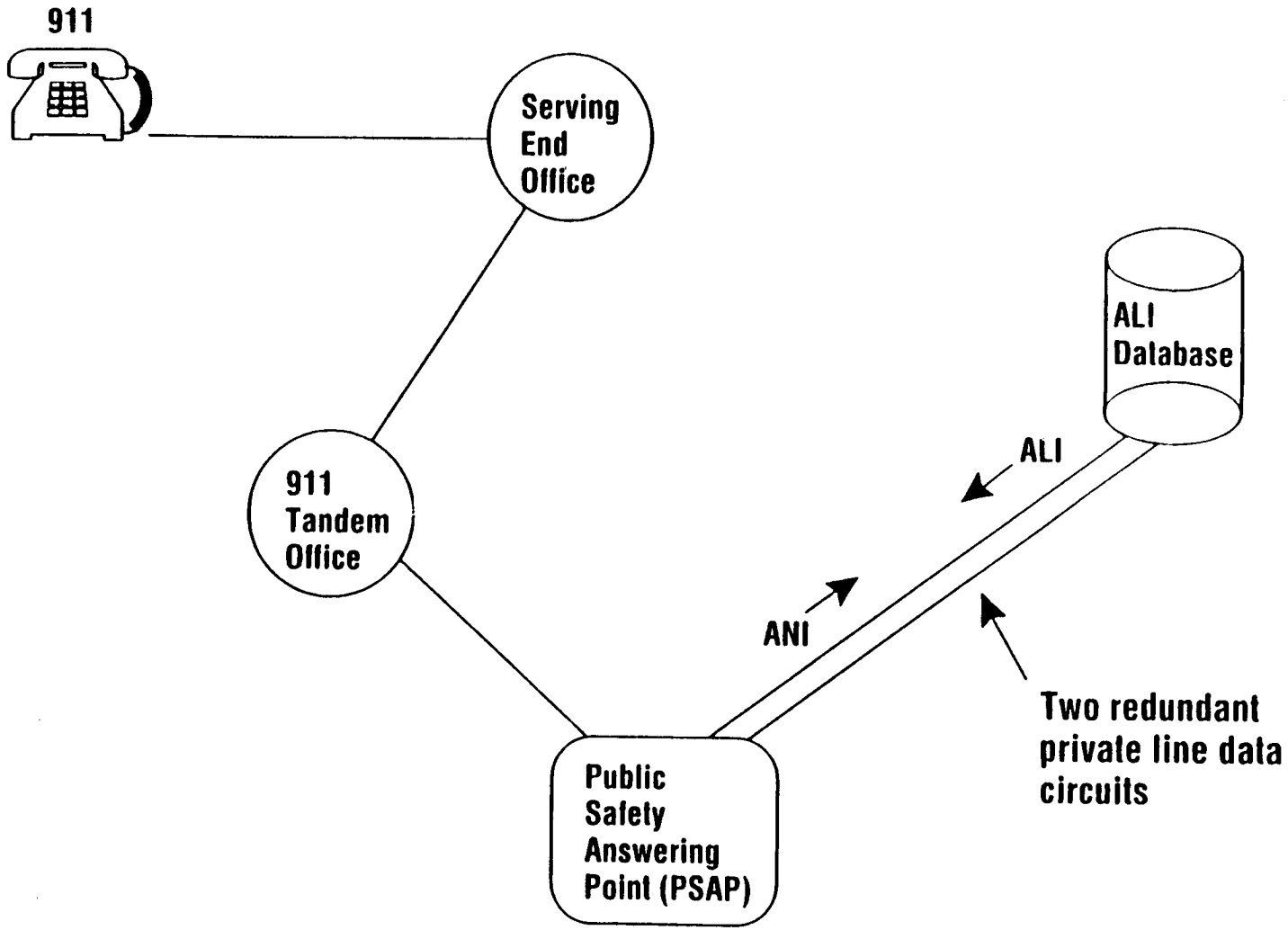

Figure 6-13: Standard ALI Retrieval Architecture

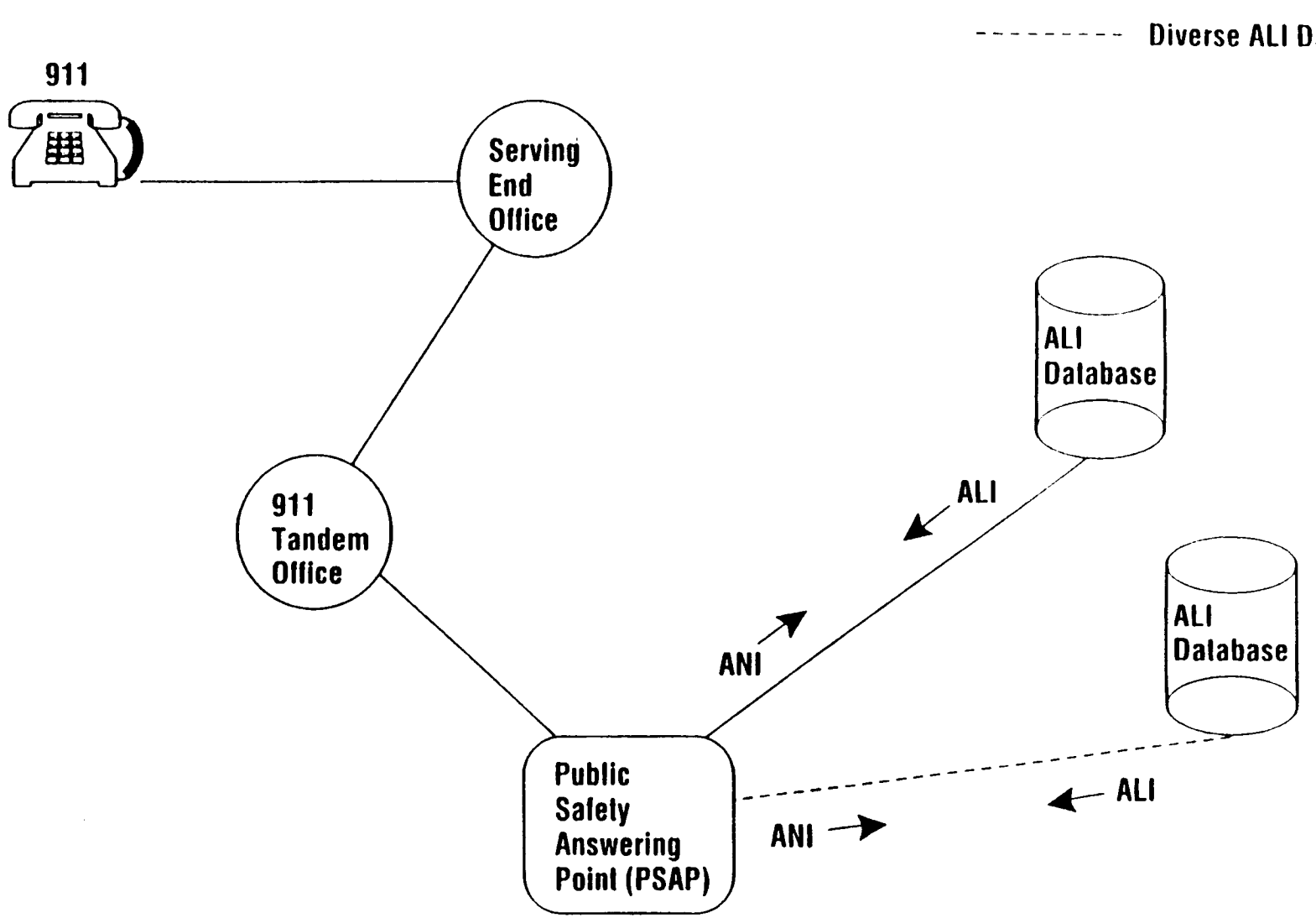

Figure 6-14: ALI Retrieval Architecture/ALI Diversity

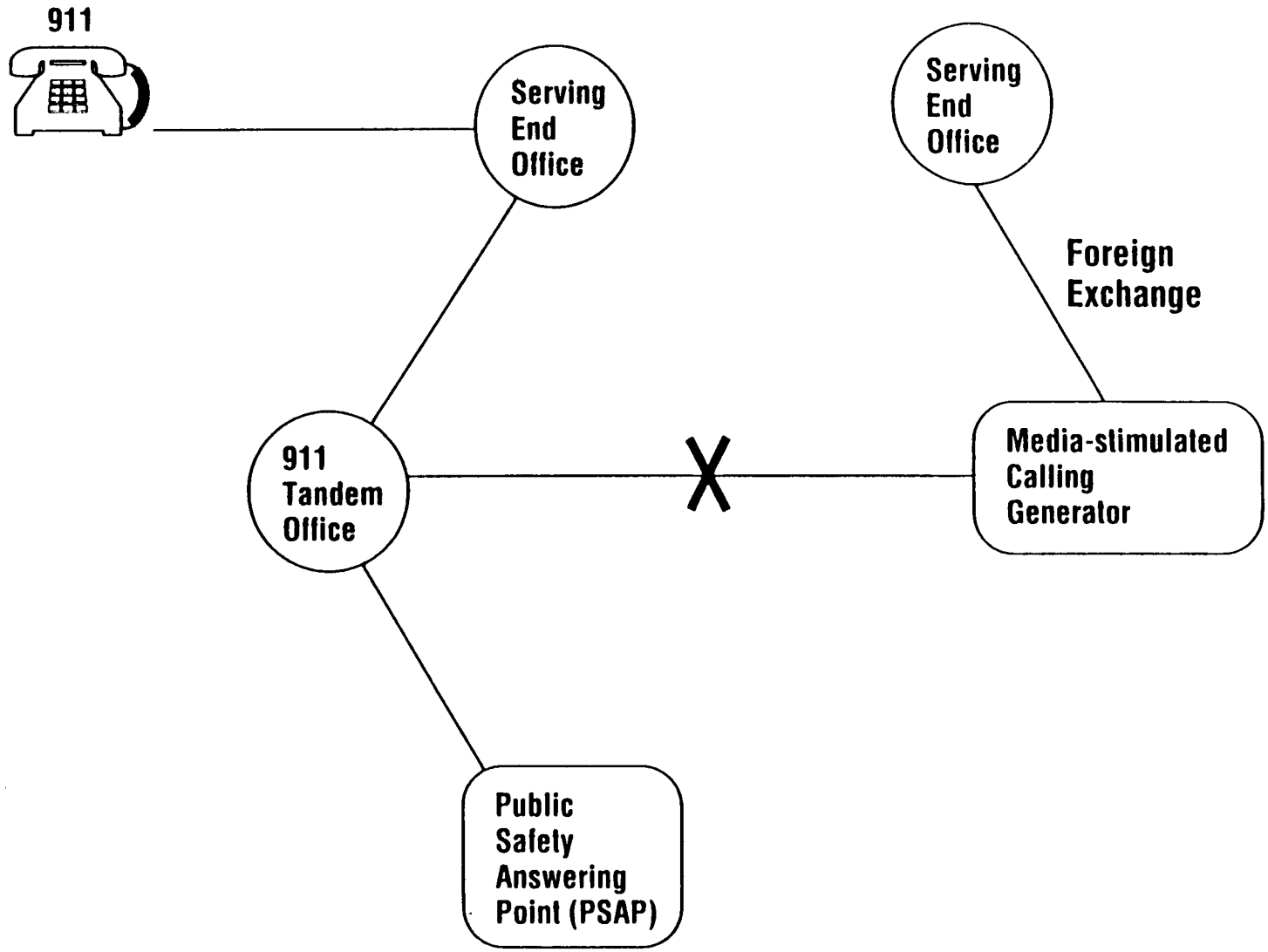

Figure 6-15: Media-Stimulated Calling Architecture

Wednesday, April 29, 1992

- 15,214 E9-1-1 Calls
- 1,881 Spanish calls
- 7,404 Secondary calls
- 11,059 Abandoned prior to completion
- 35,558 Total

Thursday, April 30, 1992

- 30,294 E9-1-1 Calls
- 3,711 Spanish calls
- 10,460 Secondary calls
- 18,284 Abandoned prior to completion
- 62,749 Total (previous call load record 20,810)

Friday, May 1, 1992

- 16,868 E-9-1-1 Calls
- 3,065 Spanish calls
- 8,512 Secondary calls
- 4,586 Abandoned prior to completion
- 33,031 Total

Saturday, May 2, 1992

- 10,025 E9-1-1 Calls
- 1,787 Spanish calls
- 7,502 Secondary calls
- 1,995 Abandoned prior to completion
- 21,700 Total

Figure 6-16: E9-1-1 Call volume
City of Los Angeles, April 29, 1992–May 2, 1992

F

- One primary PSAP serving LA
- 60 Position PSAP, largest Enhanced 9-1-1 public safety answering point in nation
- Two Telephone Companies serve E9-1-1 needs for LA area
- Normal PSAP call volume is less than 8,000 calls per 24-hours
- 62,000 call volume in 24-hour period during civil unrest. Previous record 21,000.

Figure 6-17: E9-1-1 City of Los Angeles

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- Contingency planning is important, they must also be tested periodically
- Educate public to limit 9-1-1 use during disasters

Figure 6-18: E9-1-1 City of Los Angeles Recommendations

F

National Emergency
Number Association

Tarrant County 9-1-1 District
500 Throckmorton, Suite 2700
Fort Worth, TX 76102
(817) 334-0911
Fax (817) 338-1013

Beth Ozanich
President

March 16, 1993

Mr. Bob Powers
Chairman
9-1-1 Focus Group
Network Reliability Council

Dear Mr. Powers:

The National Emergency Number Association (NENA) is a group of more than 2500 Communications professionals primarily concerned with the provisioning of 9-1-1 emergency communications services to the public. The organization's purpose is to lead in the technological advancement, availability and implementation of universal emergency telephone number systems. In carrying out these purposes, NENA promotes research, planning, training and educational opportunities for the public safety communications industry. NENA members are acutely aware of the importance of network integrity and survivability.

Through our National Issues Committee Chairman, Dr. J. William Munn, we have learned that the Network Reliability Council is seeking a permanent affiliation with a national organization who would fill a sponsorship role for the Council's forums and its recommendations. We would be honored to fulfill this need for you and to work in concert with your organization to promote system reliability.

We are also pleased to invite you to hold your annual meetings in conjunction with NENA's Annual Conferences. The 1993 conference will be held in Montreal, Quebec, Canada, from June 27 through July 1. Having checked with our conference manager, there is space available for your meetings. I am enclosing a brochure that describes NENA's 1993 Annual Conference. Network Reliability Council members and 9-1-1 Focus Subgroup members are welcome to register for the conference and participate in the meetings. Please let me know of your plans during the next month.

Sincerely,

Beth Ozanich
President

FIGURE 8-1: NENA Request