A Network Management Solution for Pre-Alarm Detection in EPU Telecommunications Network

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Abstract: The pre-alarm detection is a novel method for ensuring high availability of operational traffic in corporate telephone network of Electric Power Utility, beside usage of redundant elements and alternate routing. In this paper, is examined software solution for pre-alarm detection in network management domain. After the analysis of the domain characteristics was proposed solution based on analysis of traffic on direct links between telephone exchanges. In order to find when high priority Integrated Service Digital Network (ISDN) or Internet Protocol (IP) links are faulty, calls over high voltage power lines are analysed in two step process, using data retrieved from Call Detail Records of telephone exchanges. Increased accuracy of detection characterizes this solution compared with the previously proposed, because there are no false negatives in the detection process. In this research was verified that proposed solution can be implemented as an additional layer in network management hierarchy without change of existing network management system software or infrastructure.

Keywords: Electric power utility; High availability; Network management; Telephone network; Call detail record

1 Introduction

Telecommunications network in Electric Power Utility (EPU) is used to enable communication between its employees [1]. The role of telephone network in telecommunications network of EPU is to enable communication between Power Grid operators, and even in some countries its design is required by the government regulations, as explained in [2]. Frequency bands and power levels for communications over power line systems are defined in international recommendations [3]. The main objective of building separate network is achieving high availability because on emergency on power facility information

exchange between operators must be possible. The reliable and prolonged life is the subject of analysis for each implemented network type. For example, the same problem as in the case of telecommunications network in EPU may be also found in wireless sensor network implementation [4].

The telephone network in EPU differs from the public telephone network by introduction of prioritized traffic (operator traffic is with priority), usage of high voltage power lines like communications resources and solutions for maintaining high availability. It is demonstrated [5] that these methods can be improved, by using so-called pre-alarm detection, which is based on telephone traffic statistics. In the previous research was analyzed call statistics, defined efficiency parameters and proposed hardware implementation of detector as solution. In this paper, we are examining software solution in network management domain, as an extension of our research presented in [5-7].

After this introduction, in the Section 2 are summarized known methods for achieving high availability in telephone network of EPU, and process of occurrence of pre-alarm state. In the Section 3 is presented previous research on parameters used to measure detection efficiency.

In the Section 4 are analysed required characteristics of solution in network management domain, as well as their influence on detection process. In the Section 5 is provided detailed proposal of the pre-alarm detection software using information stored in Call Detail Record (CDR) of telephone exchange. The proposed algorithm is described, as well as its Impact on efficiency parameters. In Section 6 is described verification of the proposal. Behaviour of implemented pre-alarm detection software is described together with symbolic presentation of the traffic process. At the end, the conclusion is in the Section 7.

2 Known Methods for Achieving High Availability in the Telephone Network of EPU

Availability of telephone network of EPU represents the portion of time when it is working correctly. By high availability is considered availability of at least 99.999%.

Methods for increasing availability of the telephone network in EPU are alternate routing and redundant elements usage. In contrast to public telephone network, which is hierarchically organized, telephone network of EPU is built in one layer to enable usage of alternate routing. This procedure enables usage of another path when the first order route is not available. Alternate routing is used in two occasions: link failure (when the link is not available) and congestion on priority link. When the network operates without failures, calls are established according to the routing plan, using direct or shortest paths, and best quality links.

Redundant resources are used to improve the system availability, and emphasis is on redundant links.

Telephone network of EPU may be represented by nodes (telephone exchanges) and links. Despite electrical grid is built for electrical energy delivery, its complex interconnected structure can be used in communication network [1], [8]. Power Line Carrier Communication (PLCC) is a technology used for voice and data communication over high voltage power lines (over 50 kV) [9]. This technology operates using modulated carrier signals on the power lines [10], and it is used in the design of telephone network in EPU. Priority of links between two nodes is based on their characteristics (connection set-up time, speech quality. etc.) and therefore PLCC link is with the lowest priority. Since existing power lines make alternative networking infrastructure [10-11], PLCC links are widely used as telephone network of EPU.

The nodes, which are telephone exchanges when considering EPU telephone network, are in fact huge transformer stations with its engaged personnel. The primary personnel duty is to keep reliable electric power delivery and high telephone network availability. In order to achieve it, the personnel presence in network nodes is mandatory, which allows prompt reaction to each incident situation related to telephone network operation. The solution presented in this paper is based on software analysis. It is relatively simple procedure used to detect locally, on each node, system behaviour for traffic sources seizure and release. Since it is performed locally, the local personnel can provide immediate reaction in order to repair the network. Summary information if the pre-alarm exists on local link can be transferred to the network operations center. This can be achieved in different ways, of which one is explained in [12].

Since it is performed locally, time for network repair is shorter or same as if centralized management system is applied as the one presented in [13] for mobile operator networks supervision. Besides the possibility for faster reaction, the advantages of such a concept of local supervision are that there is no need for complex data mining over the numerous often non-useful alarms to detect root cause using specifically developed algorithms as in [14]. High accuracy of detection and quick response of local personnel are reason why it is also not necessary to use build complex software systems based on machine learning for analysis of data in order to enhance responsiveness in managing a large set of alarms [15].

Simplified model of links between two nodes in the network of EPU is presented in Figure 1. It was demonstrated [5], [7] that detection on one direct connection between two nodes is possible, without the need for information of call routing in the network. Since pre-alarm detection is performed locally, detection is not affected neither by network topology nor number of nodes in the network.

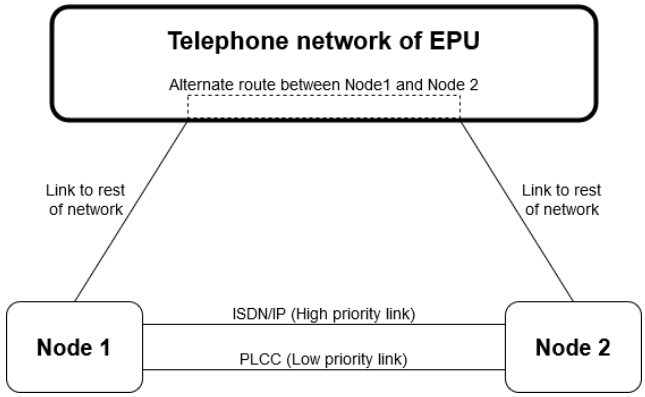

Figure 1
Model with two network nodes connected with one ISDN or IP link, and one PLCC link between two nodes

In this model, there are two direct links between nodes. Link of high priority may be Internet Protocol (IP) or Integrated Service Digital Network (ISDN) realized on optical cables, and PLCC link is of low priority.

The low priority link can be used in two cases [16]:

1) traffic is increased over the capacity of the other direct link (traffic overflow);

2) there is a failure on high priority link, therefore, the only direct link without failure between two nodes is low priority link.

The pre-alarm state means that high priority link is with failure and that lower priority link is used [5-7]. Direct traffic between two nodes still exist during pre-alarm state because decreased amount of traffic is carried over lower priority link, and availability is not affected. Such unwanted situation, which may precede alarm situation and complete link failure, is possible to be detected during initiated call by using statistically determined time duration of its dialing phase. There is a difference in the called party number selection on the old PLCC links and on more modern ISDN or IP links: the slowest pulse dialing is applied on PLCC link, while faster address messages are used in two other cases. This difference is used in the solution presented in [6] to implement test calls generation from a central point and to measure the time to ring-back tone. The problem solved in [7] is the same as in this paper, but in this paper are used different specific parameters of telephone call. As a conclusion, it may be said that detection is localized on single link in [7] and in this paper, i.e., test is performed separately for each link.

Since telephone traffic is still carried during pre-alarm state between two nodes, pre-alarm state is not detected in telephone network of EPU, nor it can be recognized by degradation of telephone service [5]. If the pre-alarm is not recognized, the failure might affect low priority link, and alarm state might become.

Alarm state in the network occurs when all links between two nodes are with failure, and there is no direct traffic between them. If the alternate routes are used for direct traffic, there is no traffic between two nodes which is not acceptable. It means that during alarm state the availability is affected.

3 Detector Efficiency Parameters

This chapter summarize results on research on efficiency parameters definition and provides formulas for multiple steps detection [5], [7].

It is demonstrated [5] that in telephone network of an EPU the analysis of telephone traffic can be used for pre-alarm detection using so-called detector. The detector is hardware system that locally monitors state of PLCC link. In detection is used characteristic of PLCC link that its state can be found using simple algorithms based on short seizures that are undetected by the detector [5]. It is more complex to determine state of high priority link, especially if the problem is in the switching systems (for example, in the signalization protocol). The principles of faulty link detection, presented in this paper, are universal and may be implemented in various types of networks [17].

The detection process can be performed in multiple steps. In the first step of detection, it is recognized that PLCC is seized (start of the call). After its release (end of the call), the timer is turned and it ticks during so-called detection interval. If the PLCC is used during that interval (the next call starts), the system goes to the next step. In the last step, upon the seizure of PLCC, pre-alarm is declared.

Possible detection results and their corresponding probabilities are presented in Table 1 for detector with K steps. As indicated, detection can be wrong in two cases: when non-existent pre-alarm is detected (false pre-alarm, false positive) and when the existent pre-alarm is not detected (miss in detection, false negative).

The state of traffic in whole network can affect the behaviour of the monitored link, which is still operational, if serious accident happens in distant part of the network. It would be the case when multiple links are not functional (or PLCC is used for traffic) and it is not possible to use alternate routing. In this hypothetical situation the observed link will be used to transit large number of connections and then it would be possible that pre-alarm or alarm state occurs on this link, although the locally generated traffic is not increased. As in normal operation false pre-alarm state is extremely rare, practically impossible, experimental verification of the developed solution in praxis is only possible by the test procedure which would include artificially stopping the data flow over the great number of carefully selected links in the network and thus causing the great traffic over the observed link.

Table 1
Detection results and their probabilities

link state (*ISDN/IP* link)	pre-alarm state (*ISDN/IP* link)	pre-alarm state (Detector)	result	characte-ristic	probability
Correct	Inactive	Inactive	Correct	-	-
		Active	*Wrong*	*False pre-alarm*	P_{fpaK}
Failure	Active	Inactive	*Wrong*	*Miss in detection*	P_{mK}
		Active	Correct	-	-

The probability of false pre-alarm P_{fpaK} is the product of two probabilities:

1) For first step probability that call arrives on PLCC (P_{onPLCC}) due to the overflow traffic;

2) From steps 2 to K probability that at least one new call arrives on PLCC during timer interval T_K . This implies that call from previous step must be finished, in order that PLCC can accept new call. The value of this probability for single step is $P_{call}(T_K)$, so for *K-1* steps it is $P_{call}^{K-1}(T_K)$. The probability $P_{call}(T_K)$ presents excluded probability of interval without call arrivals from probability of all possible call arrivals:

$$P_{fpaK} = P_{onPLCC} \cdot P_{call}{}^{K-1}(T_K) \approx E_{n+1}(A) \cdot \left(1 - e^{-\left(\frac{T_K}{T_{ia}} \cdot E_n(A)\right)}\right)^{K-1} \tag{1}$$

where $E_n(A)$ is Erlang formula - the blocking probability (call congestion) in the group with n channels on ISDN or IP link with offered traffic A, $E_{n+1}(A)$ is the blocking probability in the group with n channels on ISDN or IP link and one channel that exists on the PLCC, T_{ia} is the mean inter-arrival time between calls, and T_K is detection interval. This is our original equation and it follows from [7].

The probability of miss in detection P_{m2} is calculated in system with failure on link with priority. It is the probability that after the end of call, during the timer interval next call doesn't arrive on PLCC:

$$P_{mK} = P_{m2} \cdot \sum_{i=0}^{K-2} (1 - P_{m2})^i \tag{2}$$

where P_{m2} is probability of miss in detection for two steps detector and it is:

$$P_{m2} \approx e^{-\frac{T_2}{T_{ia}}} \tag{3}$$

The third important parameter is meantime from failure to detection of pre-alarm state, T_{dpaK}. It is the sum of mean inter-arrival time after the failure occurs and mean call duration t_m and mean inter-arrival time before next call arrives for each step:

$$T_{dpaK} = T_{ia} + (t_m + T_{ia}) \cdot (K - 1) = K \cdot T_{ia} + (K - 1) \cdot t_m \quad (4)$$

It is concluded [5] that in most cases two steps detector can be used because the increased number of test steps provide small improvement of detection miss and false pre-alarm probability, but gradually degrades detection time.

4 Analysis of Network Management Domain for Pre-Alarm Detection

The network management is used for the establishment of services in the telecommunication network of EPU. The operation includes interaction of software system used for network management with software systems on the network element. Full specification of those management systems doesn't exist, and their implementations can be proprietary or based on various standards [18].

Management of telephone network of EPU is complex due to the diversification of vendors and adding new generation of equipment without discarding existing one. When the equipment of various vendors is used, various information models and even various communication protocols are used, which are mostly proprietary in the older generations of equipment. Previously telephone exchanges were designed specifically for EPU, but now the equipment used in Public Switched Telephone Network (PSTN) is the first choice for network upgrade. There are two reasons for this change: increased availability compared with the previous generations of devices [19] and economic benefit of using solutions from PSTN.

As mentioned in Section 2, there is no specification of pre-alarm detection, but using management systems some of its side-effects can be recognized. In the network management systems single link is not treated as network element. Its monitoring is performed by collecting information from network elements on both sides of the link. These network elements can be transmission systems or switching systems. Failures on the transmission system can be detected, but not all the failures on the switching system.

The objective of this paper is the design of a solution for pre-alarm detection using management information from one network element. To apply the proposed solution necessary information must exist on the network element, and management system must have access to that information, which shall include:

1) identification of used link for the call, and

2) start of the call time
3) end of the call time

One example of a record which contains call parameters may be found in [20]. In this example is necessary to include source ("channel") or destination channel ("dstchannel") to determine the used calling party or called party link (channel), "start" or "answer" to determine the time of the call beginning and "end" to determine the time of call end.

In the case when described necessary information does not exist on the network element, the modification of the software system on element is needed, which is unwanted consequence. Reason for this is that usually vendors don't deliver programming code of software systems, so only they can make modifications on existed systems, which makes price of this operation higher. There are further problems: various hardware and software versions make maintenance difficult, sometime vendor doesn't exist anymore, etc. Principally, adding non-existing features on the delivered network elements shouldn't be considered.

Another important consideration is the organisation of data access to necessary information. Instead of direct access to network element, this paper proposes use of Northbound (integration) interface of the network management systems. This can localize the knowledge of information models and network protocols on the existing network management systems. Further, this proposal leads to one more important characteristic: it can be implemented as the additional layer in the network management hierarchy.

5 Pre-Alarm Detection Software Solution Proposal

Recently there were various efforts for usage of data stored in CDR for analysis of users behaviour in mobile communications network [21-22] and in this paper is accepted the same approach. In mentioned papers are analysed systems with generated large amount of data, which is collected during long period. In this system, the small portions of data should be collected in short intervals.

In classic telephony, CDR information is used for accounting, and it is produced by telephone exchanges. Since the objective of the telephone network of EPU is to provide telephone calls between dispatchers, presence of accounting information is not mandatory in telephone exchanges. Therefore, major of telephone exchanges specialized for telephone network of EPU is not storing accounting data. When telephone exchanges from PSTN are used, accounting information is stored on them, including CDR.

Format and structure of CDR are not standardized, and therefore their implementation is vendor specific. This paper uses assumption that information

that should be stored in CDR contains information on used channels and of the start of the call, because it is mandatory for determining rates between operators. It is also considered that this information can be accessed immediately after the start of the call.

Collecting information from any network element can be performed in two possible ways: by sending events or by polling. Call arrival is not treated as event in the existing system specification. Changes on software system of network element would be needed for the event-based mechanism, which is not an acceptable option (Section 4). Therefore, polling principle was selected.

The system performs in two steps, presented in Figure 2. The solution is based on the concept of two step detector [5]. The principal difference from the solution in [5] is that in this solution is used timer that is active during the whole program execution and that system behaviour is initiated by timer ticks. The pre-alarm is detected if the second call arrives on PLCC during the detection interval. Step 1 begins after the system is initialized and timer is started. After timer tick, information from CDR between two successive polls is processed. If the information of the start of the call on PLCC is found in processed data, system goes to step 2. Otherwise, system waits next timer tick to repeat the same steps.

Step 2 starts with the timer tick, and the end of call (started in step 1) is awaited. After this event information about calls between two consequent timer ticks is polled from CDR and processed. The arrival of the first call is awaited. When the call arrives, the route of the call is analysed. If no call arrived on PLCC, it is assumed that the first call arrived due to the increased traffic, and the detector returns to the first step. If the call arrived on PLCC, pre-alarm state is detected.

System presents pre-alarm detection until the user's action (acknowledgement of pre-alarm), and then returns to step 1.

It is enough to have single detection software on any of two nodes to detect pre-alarm in the model with two directly connected nodes, presented in Figure 1. The traffic doesn't stop during pre-alarm, therefore, it can be detected on any node.

There are changes in the efficiency parameters of this solution, compared to those of two steps detector [5]. Software timer interval T_T is used as detection interval length.

The probability of the occurrence of false pre-alarm upon (1) is:

$$P_{fpa} = E_{n+1}(A) \cdot \left(1 - e^{-\left(\frac{T_T}{T_{ia}} \cdot E_n(A) \right)} \right) \tag{5}$$

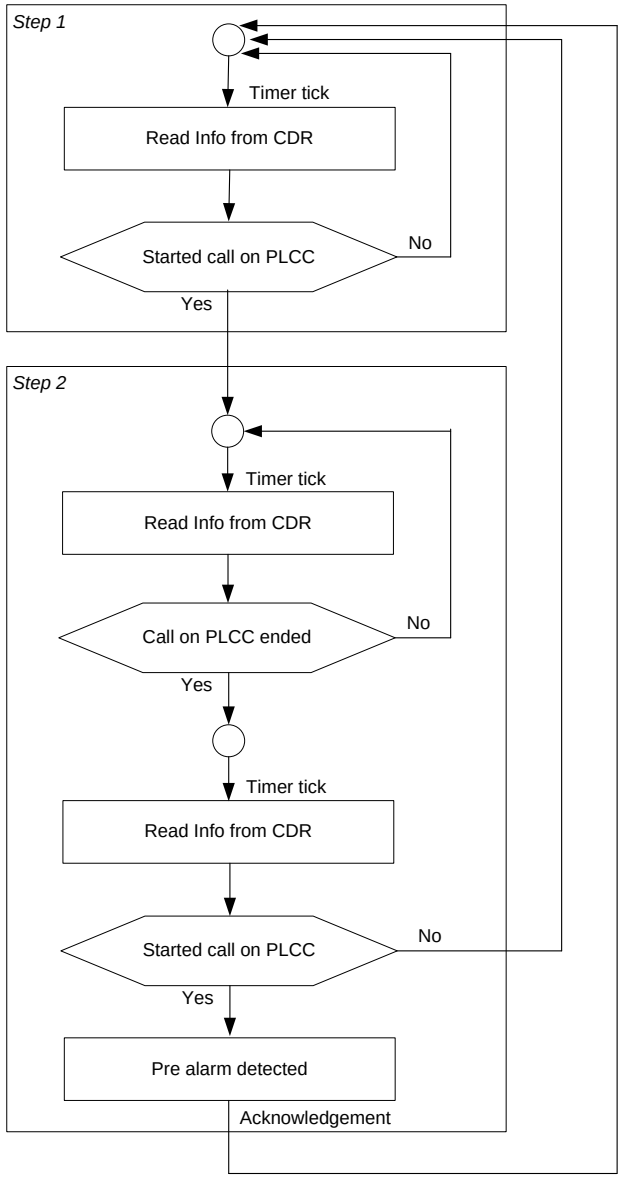

Figure 2
Algorithm of system behavior

The important improvement is that described solution cannot create the miss in detection because the second step is extended until the call arrives, and its probability P_m is:

$$P_m = 0 \tag{6}$$

Since detection is executed in discrete intervals of the length T_T, mean detection time T_{dpa} can be presented as integer number of those intervals. It is assumed that length of timer interval is at least equal to inter-arrival time between two calls (T_{ia}). The mean call duration t_m can be presented as the integer number of timer intervals increased by one. The resulting formula is:

$$T_{dpa} = 2 \cdot T_T + t_m = 2 \cdot T_T + \left(\left[\frac{t_m}{T_T} \right] + 1 \right) \cdot T_T = \left(\left[\frac{t_m}{T_T} \right] + 3 \right) \cdot T_T \tag{7}$$

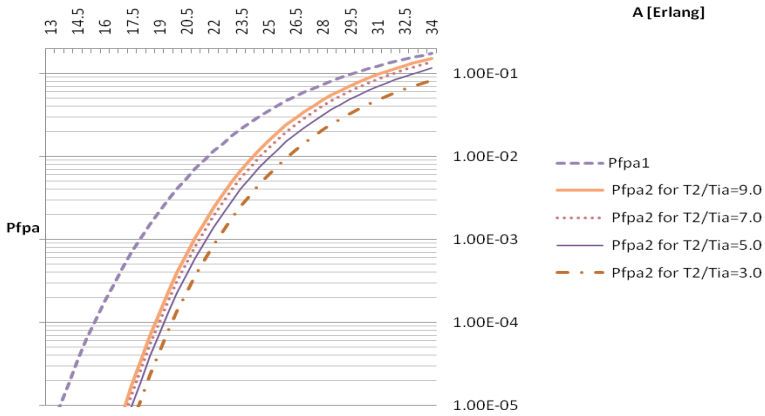

Figure 3

Probability of false pre-alarm (P_{fpa}) as the function of offered traffic (A) for two-step detector in the system with 30-channel ISDN link [23]

Figure 3 presents the values of false pre-alarm probability (P_{fpa}) as the function of offered traffic (A) calculated according to formula (1). These values are presented for two-step detector (K=2 in (1)) and for the 30-channel ISDN system (primary ISDN interface) as the link of the first choice. The graphs are presented for 4 various ratios of detection time and mean calls inter-arrival time (T_2/T_{ia}). The fifth graph for probability of false pre-alarm for one-step detector (P_{fpa1}) is presented for the comparison. It is important to emphasize which traffic values are real in EPU network. As transformer station personnel is not huge (surely not more than 10 people), it is not possible to have more than 10 simultaneous local connections. This means that the locally generated traffic may not be over 10E. It is possible to have also several transit connections due to the specific structure of EPU telephone network which is not hierarchical, but the number of these connections is not more than 5. Therefore, the total traffic in EPU network nodes is less than 15E. It means that the typical values of P_{fpa} are lower than 10^{-5} according to the graph from the Figure 3, or in other words practical values of P_{fpa} are very small. Even more important is that detection algorithm is adjusted to reach the probability of detection miss equal to 0 according to (6).

The improvement in detector performances compared with other solutions is related first to [7]. In [7] P_{fpa} has been determined in the same way as in this paper, but the second step in the detection period has not been spread until the next call arrival. This is the significant improvement because P_m according to the detection procedure in [7] has a low value, but typically higher than it is the value of P_{fpa}.

The second comparison is made to the solution from [6]. When considering the values of P_{fpa} and P_m obtained according to the algorithm presented in this paper and the solution from [6], it can be concluded that the presented results are better. It is possible to reach the value P_m=0 according to [6], but the corresponding P_{fpa} may be higher than 10^{-5}. It is possible to decrease P_{fpa}, but then it becomes P_{fpa}>0. The other difference is that it is necessary to generate test calls to realize the analysis according to [6]. For the procedure realization according to this paper it is enough to keep track of the existing traffic flow.

6 Proposal Verification

Verification of the proposed solution is made by implementing a Java application as the pre-alarm detection software. The diagram on Figure 4 presents the organization of the implemented system.

Existing system includes Telephone exchange and its Network Management System. Both systems were developed by IRITEL [24].

Pre-alarm detection software creates new layer in the system. It was added on top of the existing system (Figure 4), without influence on Telephone Exchange, and without modification in network management system software organization or in its infrastructure. In order to detect the pre-alarm, information from CDR of network management system was analysed. The application was accessing it in eXtensible Markup Language (XML) data format, which can encapsulate any other format - including proprietary one.

List of events from CDR are analysed in each timer tick. Timer tick initiates collection of events list between two successive ticks. Events in the list are analysed, and detection is made upon information on: time of occurrence, is this call on PLCC, and if this is start or end of the call.

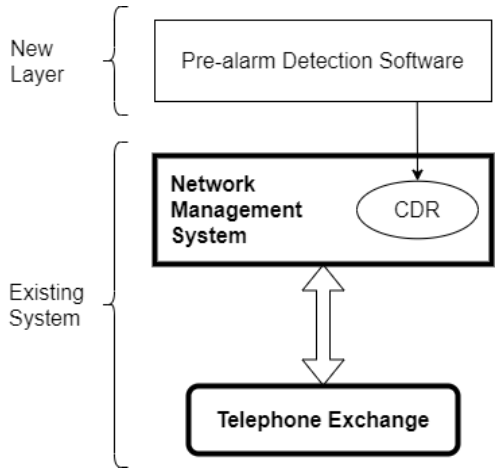

Figure 4
Organization of the implemented system

The state transition diagram of the detector is presented in the Figure 5:

1) Detector is in the inactive state in the start.

   On each timer tick is collected data from CDR generated between last two ticks.

2) Detector remains in this state until the call arrives on PLCC, when it starts waiting the end of this call.

   Pre-alarm detection software needs to discover which new calls arrived in the collected events list, and to recognize link where the call is routed. When the call is routed on PLCC, its end is awaited.

3) After the call ended, detector waits start of the next call.

   On timer tick, data generated between last two ticks is collected from CDR, and then analysed if new call arrives.

4) If the call arrived, but not on PLCC, the system goes to Inactive state,

   This means that in collected data between last two ticks from CDR call is recognized on high priority link. Detector concluded that previous call on PLCC was due to the overflow traffic.

5) If the call arrived on PLCC, the system goes to the pre-alarm detected state, where it remains until the user acknowledges pre-alarm.

   This means that pre-alarm is detected by finding next call on PLCC, in data collected from CDR between last two ticks.

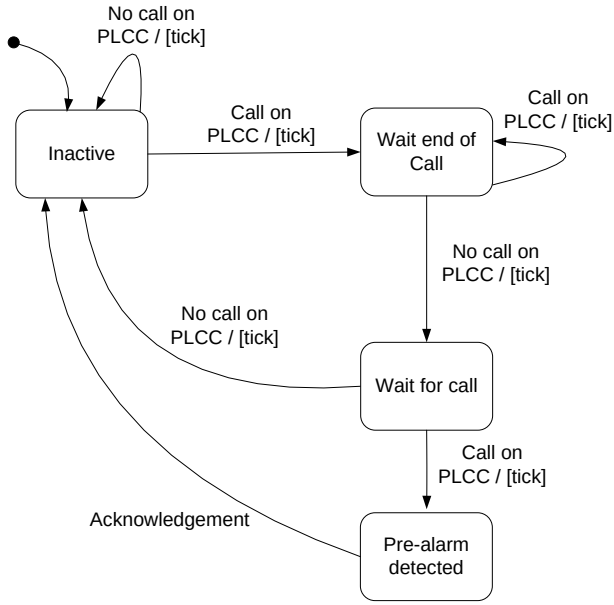

Figure 5
Pre-alarm detector state transition

Correct system behaviour is illustrated in Figure 6. Symbolic presentation of the traffic process on PLCC is based on detection diagrams introduced for two step detector [5] which consist of: *a)* carried traffic of the system, *b)* call arrival in the system, *c)* call arrivals on ISDN or IP link, *d)* call arrivals on PLCC link and *e)* traffic process on PLCC. Timer ticks are presented using dashed lines, and each timer interval is numbered. Moments of the occurrence of failure t_0 and detection t_d are presented.

In illustrative example in Figure 6, during interval 1, calls arrive only on priority link, and system resides in the step one. In interval 2 there is a call on PLCC, which will cause end of step 1 of detection. During interval 3, detector is in step two, but there are calls on priority link, and therefore system returns to step one. Interval 4 is analogue to interval 1, and system resides in step 1. During the interval 5, failure on priority links occurs. The next call arrives on PLCC, and step 1 of the detection ends. Since there are no calls in the system in the interval 6, system resides in step two, waiting for next call arrival. In the interval 7 calls arrive on PLCC, and pre-alarm is detected.

It is interesting to consider what pre-alarm detector efficiency depends on. According to the Figure 6, the time between a failure on ISDN/IP link and failure detection depends on the time between successive calls on PLCC link. This time is shorter with the increase of the offered traffic.

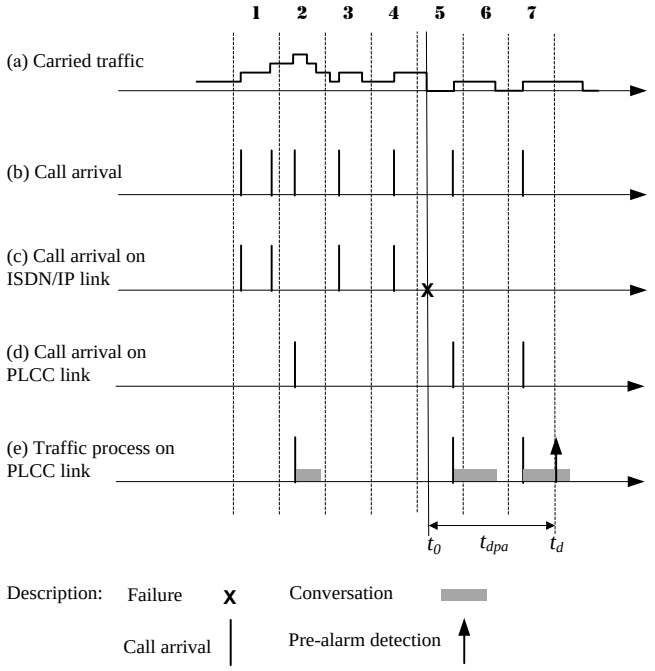

Figure 6
Detection diagrams for pre-alarm

Therefore, it may be concluded that detection rate is as higher when the offered traffic is greater. Unfortunately, too large increasement of the offered traffic also leads to the false alarm probability increase. Let us consider one correct ISDN link in the intervals of great offered traffic. Let us, further, suppose that higher priority ISDN link is completely busy in time intervals tB. There is a (low) probability that two successive calls are generated on PLCC link during this time interval tB. These two calls may cause the state of detected pre-alarm, i.e. faulty ISDN link, which is incorrect information. The probability that all ISDN links are busy is very low. That's why the probability of false pre-alarm may be neglected.

Generally, there is a small number of solutions dealing with supervision of telecommunication network of EPU and these solutions are cited throughout this paper. Especially there are no solutions satisfying two important advantages over usual solutions: 1) only software based solution without need of additional specific hardware and 2) solution where software management is realized completely independently, without need to change existing software. That's why it would be hard to perform some additional efficiency parameters comparison besides the ones presented in this paper.

Conclusions

Telephone network of EPU primary objective is to provide high availability. Two standard methods for achieving high availability are: adding redundant elements and usage of alternate routing. In this paper, is proposed software solution for usage of network management in pre-alarm detection, a novel method for achieving high availability in telephone network of EPU. The solution is realized in two steps for collection and analysis of data stored in CDR. Steps in the process are invoked on timer tick. In the first step is awaited call on PLCC. In the second step, after the end of the call started in the first step, pre-alarm is detected if a call arrives on PLCC during the detection interval.

Description of the system behaviour is provided, and an example of call arrival process is demonstrated. Efficiency parameters of the proposed solution are compared with those previously defined in the literature. It is concluded that there is no miss in detection in the proposed solution. The probability of false pre-alarm is not changed compared with the solution in [5]. The exact values of the probability of false alarm in the EPU network are significantly lower than 10^{-5} due to low offered traffic. That's why it is difficult to test the solution in real conditions. It is necessary for testing purposes to artificially stop the traffic over the ISDN (IP) part of the considered link to verify detector behaviour in pre-alarm conditions. The character of discrete domain influences that the meantime to detection is slightly longer in the existing solution.

Solution can be implemented without changes in existing network infrastructure if existing management systems have stored data in CDR and if they have integration (Northbound) interface. The detection procedure is performed locally, and local personel can make necessary equipment repairment. If the telecommunications network management is centralized, only the summary information about pre-alarm should be transferred, and there is no need to transfer large amount of data for analysis, nor is required complex root cause analysis software in network operations center.

In literature is described pre-alarm detector usage to locally monitor PLCC link between two telephone exchanges. Additional hardware system for each link was required in detector implementation. In this paper, is proposed solution based on network management, and which implementation doesn't require additional hardware. It was demonstrated during verification that the described solution can be implemented as additional network management layer in the system, without change in existing network management system software or infrastructure.

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