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# Intelligent Microcontroller Based Battery Management System for BLDC Electric Vehicles with Regenerative Braking

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**ABSTRACT:** Fault localization is one of the most expensive, tedious and time consuming activities in network. Fault localization is the process of finding the exact source of failure from a set of failure indications with minimal human intervention. This demand has led to the proposal and development of various methods each of which seeks to make the fault localization process more effective in its own unique and creative way. In this paper we provide an overview of several such methods and discuss some of the key issues and concerns that are relevant to fault localization.

**KEYWORDS:** Fault localization, Probing, Monitoring, Probe station selection, Problem detection, Problem determination.

## I. INTRODUCTION

The rapid growth in size and complexity of computer networks requires performance management using fault diagnosis poses an increasingly important and difficult task. Since faults are unavoidable in communication system, they require quick detection and isolation.

The basic concepts in the field of fault management.
Event, defined as exceptional condition occurring in the operation of hardware or software of a managed network, it is a central concept pertaining to fault diagnosis [10,12].

Faults (also referred to as problems or root cause) constitute a class of network events that can cause other events but or not themselves caused by other events [22,23].

Error is defined as a discrepancy between a computed, observed, or measured value or condition and a true, specified, or theoretically correct value or condition [10]. Faults may or may not cause one or more errors.

Failure is used to denote network errors. Errors do not need to be directly corrected, and in many cases they are not visible externally. Errors may propagate within the network causing failures of faultless hardware or software [10].

The process of fault diagnosis usually involves two steps:

- Fault detection—a process of capturing on-line indications of network disorder provided by manufacturing devices in the form of alarms.
- Fault localization (also referred as fault isolation, alarm/ even correlation and root cause analysis)—a set of observed fault indications is analysed to find an explanation of the alarms.

A fault localization process should try to find the optimal solution according to some accepted optimal criteria. In large networks fault localization should be performed in distributed fashion.

Fault management in network environment can also provide certain auxiliary information for accomplishing resource reallocation and topology reconstruction of network. Probing tool (e.g. Skitter, Net Timer) as an effective approach for fault management, monitors network status by collecting end-to-end substrate network disorders.
This survey paper mainly focuses on monitoring and probing techniques. Monitoring involves collecting system metrics. Various tools and techniques have been proposed for monitoring the operations in system. These techniques can be broadly classified into two:

- Component level passive monitoring techniques
- End-to-end probing based techniques

In probing technique, probes are sent to localize faults in networks. Probes are usually set of transactions (e.g. pings, trace route, http request). There are two techniques in probing. They are:

- Preplanned probing
- Active probing

Finally, we would like to highlight probing and monitoring techniques in the area of fault localization and try to discuss them in as much detail as possible.

## II. NEED FOR FAULT LOCALIZATION

Today's enterprise systems are increasing in scale and complexity and are being used for serving various performance critical applications. For smooth operations of these systems there is an increasing demand to monitor the system performance and localize any component failure in minimal time [7].

It appears to be a fact of life that network defects are introduced and removed continuously to improve the quality of the network for that we have to remove as many defect in the network as possible without introducing new fault at the same time.

Fault localization increases the speed of the network, utilization of the network, availability. Performance-sensitive services, such as cloud computing, and mission-critical networks, such as the military and ISP networks, require high assurance of network data delivery. However, real-world incidents and studies reveal the existence of compromised routers in ISP and enterprise networks, and demonstrate that current networks are surprisingly vulnerable to data-plane attacks[50]. Also, in a 2010 worldwide security survey, 61% network operators ranked infrastructure outages due to misconfigured network equipment such as routers as the No. 2 security threat [3]. A compromised router or a dishonest transit ISP can easily drop, delay, inject or modify packets on the forwarding path to mount Denial-of-Service, surveillance, man-in-the-middle attacks, etc [3].

## III. FAULT LOCALIZATION TECHNIQUES

### a) Probing

A probe is a program that executes on a particular machine (called a probe station) by sending a command or transaction to a server or network element and measuring the response. The ping program is probably the most popular probing tool that can be used to detect network availability.

Other probing tools, such as IBM's EPP technology, provide more sophisticated, application-level probes. For example, probes can be sent in the form of test e-mail messages, web-access requests, and so on. Generally a distributed system (as well as many other applications) can be represented by a logical "dependency graph", where nodes are either hardware elements (e.g., workstations, servers, routers, links) or software components and services, and links can represent both physical and logical connections between the elements. Probes are issued from machines, called probe-stations, where probing software is installed, and traverse the network, testing the availability and performance of the various objects. Probes can be low-level ping probes, or higher level test transactions such as web access, e-mail, etc. Each probe may depend on, and thus tests the functioning of, a wide variety of different objects in the network.

### i). Probe types

Various types of probes have been used in the past for monitoring different network characteristics.
**1-packet:** V. Jacobson in his 'pathchar' tool used 1-packet method, to estimate link bandwidth from round trip delays of different sized packets from successive routers along the path [38]. One packet methods are based on the assumption that the transmission delay grows linearly with the packet size.

**Packet pair:** These methods are based on spacing effect of the bottleneck link. They use the minimum inter-departure time of consecutive packets sent back to back on a link to estimate the bottleneck bandwidth. Some methods estimate available band width based on the observation of inter-departure time of consecutive probe packets [39,40].

**Packet train:** A sequence of packet pairs is called packet train. Different methods vary in their use of packet trains based on how the packet pair gaps are controlled by the sender, Methods like path load [41], IGI, PTR use packet trains with uniform intervals. In contrast in Path Chirp [42] and Spruce [43], packet intervals are statistically constructed, forming a nonuniform packet train.

**Packet tailgating:** This method uses packet trains consisting of large packets interleaved with small tailgating packets. Large packets exit midway due to limited TTL but small packets travel to the destination while capturing important timing information. Many packet dispersion based bandwidth tools have been developed in the past [41]. They are based on self induced congestion. Probe packets temporarily induce network congestion if and only if the probing bit rate exceeds the available bandwidth on the path, thus increasing queuing delay significantly. The minimum probing bit rate that causes network congestion hence gives an estimate of available bandwidth.

**Hybrid methods:** These methods exploit both the 1- packet and packet-pair effects, e.g., Packet Quartet [44] uses packet quartet probe class where probes are replaced by probe and pacesetter pair. Different estimation methods are built on this framework based on delay variation and peak detection.

**ii). Probing techniques:**

Probing has been used in network monitoring applications broadly in two ways:

**Preplanned probing:** It involves offline selection of a set of probes [45]. These probes are periodically sent out in the network. This is followed by a passive data mining approach to infer the network state by analyzing the probe results. This approach generates a large amount of management traffic, a large part of which might be wasteful. Another significant drawback in this approach is the involved difficulty in envisaging all possible problems and generating a probe set for it. Also as the probes are sent at periodic intervals of time, the inference procedure can involve a delay. The involved delay can cause a certain degree of inaccuracy in the network state inferred from the probe results. Preplanned probing, however, imposes less overhead on the manager for selecting probes.

**Active probing:** It adapts the probing strategy to the observed network state. Instead of sending probes for locating all potential problems in the network, it sends a minimal number of probes initially and then adapts the probe set to the observed network state [45,46]. The probe stations then send probes that provide most information gain. This approach can greatly reduce management traffic and provide more accurate and timely diagnosis. Key goal of active probing based network measurement is to be able to obtain accurate, reliable estimates using only a small number of probes and using probe streams of low average traffic. Fig 1. The significant drawback in this system is probes should be selected carefully because sending a large number of probes will increase the already existing system traffic so probes should be selected such that it should cover the whole network. It fails to give a node level view of the network and also increases the localization time. With increasing size of the network, the number of available probes also increases. This increases the search space to select the minimal set of probes. Probe analysis becomes more challenging in presence of incomplete and inaccurate dependency information. Issues like transient failures, spurious symptoms, dynamic routing, load balancers, node mobility further aggravate the problem [8].

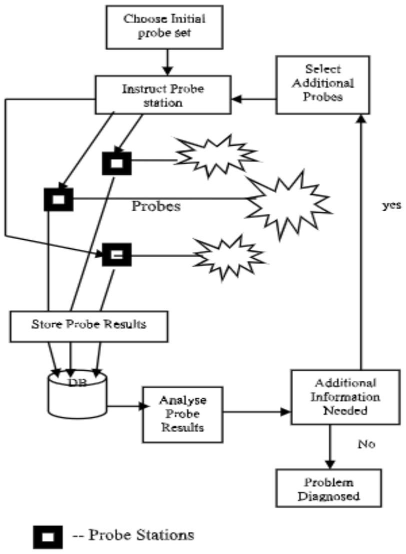

Figure 1: Active probing system

**b) Monitoring**

Monitoring techniques are used in computer networks to support a wide range of activities involving network design and operation. A network monitoring can be divided into two broad categories: Passive and Active monitoring[6] .

**i) Passive monitoring**

The passive monitoring techniques typically involve deployments of agents (e.g. Tivoli, nagios) at each machine to periodically collect various performance metrics such as CPU utilization, page fault, etc. The tools based on passive monitoring focus on individual component, the probing-based tools compute the end-to-end metrics such as latency, throughput, etc[47,48,49]. The passive approach uses devices to watch the traffic as it passes by. The passive monitoring devices are polled periodically and information is collected (in the case of SNMP devices the data is extract from Management Information Bases (MIB)) to assess network performance and status.

The passive approach does not increase the traffic on the network for the measurements. It also measures real traffic. However, the polling required to collect the data and the traps and alarms all generate network traffic, which can be substantial. Further the amount of data gathered can be substantial especially if one is doing flow analysis or trying to capture information on all packets. The passive approach is extremely valuable in network trouble-shooting, however they are limited in their ability emulate error scenarios or isolating the exact fault location. Since the passive approach may require viewing all packets on the network, there can be privacy or security issues about how to access/protect the data gathered.

**ii) Active monitoring**

Active monitoring involves sending traffic onto a network to sample its behaviour. This traffic is sent in the form of probes which can vary from simple probes such as pings to complex test transactions.

Active monitoring techniques use probing for a variety of network monitoring applications. As discussed above probing can be used broadly in two ways: active and preplanned probing. Active probing has the potential to develop effective solutions for network monitoring applications due to its fundamental end-to-end nature and flexibility. One such application is fault localization. Fault localization identifies the fault that can best explain the observed network disorders. Active probing can be used to perform efficient fault localization where probes can be selected in real time and sent to diagnose the root cause of a failure. The active approach relies on the capability to inject test packets into the network or send packets to servers and applications, following them and measuring service obtained from the network. As such it does create extra traffic, and the traffic or its parameters are artificial. The volume and other parameters of the introduced traffic is fully adjustable and small traffic volumes are enough to obtain meaningful measurements [1].

One of the biggest problems faced by the data centre operators is making a decision on what metrics to monitor at what time? Monitoring all the metrics at a very high frequency (e.g. every second) produces enormous amount of monitoring logs. Storing as well as analyzing such logs pose several challenges. Furthermore, interesting data tends to get buried in such large data-sets and may possibly escape careful analysis. On the other hand, monitoring very few metrics at a low frequency incurs the risk of losing important information and events of interest.

**c) Hybrid Approach**

Effective fault localization can be designed by using the information captured by both probing and monitoring agents.

**i)Adaptive Probing**

The Adaptive probing is a twostep approach

1. A small set of probes are sent periodically to detect the presence of failure in the network. The probes only detect the presence of a failure but do not localize the failed nodes. The selection of probes and their probing frequency should be such that (a) probe traffic is minimized and (b) detection time is minimized [7,12].
2. On detection of a failure, additional probes are sent to localize the exact failure. The selection of probes should be such that (a) fault localization accuracy is high, and (b) localization-time is minimized [7].

The above steps of detection and localization can be improved using the information collected by monitors. The metrics collected by the monitoring agent at each node can be used to estimate potential failure or change in steady state of a node. Monitoring information can then be used to adapt the probing policies for detection and localization of failure in order to improve probe-traffic, localization time, and localization accuracy.

**ii) Adaptive monitoring**

Adaptive monitoring algorithm that uses end-to-end probe for deriving monitoring levels of individual components. An experimental evaluation to demonstrate that the generated monitoring data (through the above adaptive monitoring algorithm) successfully captures all interesting properties while retaining a significantly low volume monitoring data.

Adaptive monitoring involves following four major steps:
1) Selection of probes: An important initial problem to address is the selection of right set of probes. Probes can be ongoing system transactions or customized synthetic traffic. The probes should be selected such that the monitoring recommendations can be provided to all components of interest by analyzing the probe results. A lot of earlier work on probing can be useful in addressing this problem.
2) Analysis of probe performance: An important step of adaptive monitoring is the analysis of the probe performance metrics. Adaptive monitoring requires analysis of these end to-end metrics to infer the health of various components serving the probe. The analysis needs to capture various events such as sudden changes, gradual changes, and deviation from the normal behaviour.
3) Deriving monitoring recommendations from probe
Performance: The analysis of end-to-end metrics provides insights into component health. This analysis thus provides enough indication on criticality of monitoring a specific component. These insights need to be translated to monitoring levels.
4) Setting monitoring levels: Once the monitoring recommendations are derived, the monitoring agents at the component need to be re-tuned to the new monitoring level. The solution for this step makes various decisions such as: how frequently should the monitoring levels be changed? Monitoring levels of which set of components should be changed together? etc [6].
However, the problems faced in hybrid approach are selecting minimal nodes to deploy monitoring agents, selecting minimal nodes to deploy monitoring agents and giving user to choose probes, etc.

**d) Other Techniques**

Numerous fault localization techniques were proposed in past they are derived in different areas of computer science including artificial intelligence, graph theory and neural networks. The common approaches are as follows

- model-based reasoning tools
- fault propagation models
- model traversing techniques
- case-based reasoning tools

**Artificial Intelligence techniques for Fault Localization**

Expert systems are most widely used in artificial intelligence techniques for fault diagnosis and localization [24]. Expert systems try to reflect actions of a human expert when solving problems in a particular domain. Their knowledge base imitates knowledge of a human, which may be either surface – resulting from experience, or deep – resulting from understanding the system behaviour from its principles. Expert systems applied to the fault localization problem differ with respect to the structure of the knowledge they use.

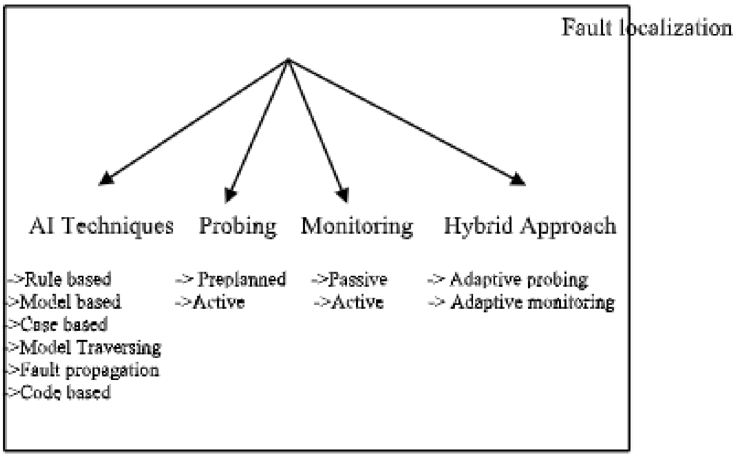

Figure 2: classification of fault localization techniques.

In this section some of the approaches presented in figure2 will be described and compared.

**Rule-based systems**

Approaches that rely solely on surface knowledge are referred to as rule-based reasoning systems [8,12]. It exploits a forward-chaining inference mechanism. Rule-based systems do not require profound understanding of the architectural and operational principles of the underlying system. The problems faced here are inability to learn from experience, inability to deal with unseen problems, difficulty in updating the system [25] knowledge and difficult to maintain because the rules frequently contain hard-coded network configuration information [26].

**Model-based approaches**

This approach incorporates deep knowledge in the form of a model of the underlying system [27,28,29,30]. They constitute a class of expert systems that are the most widely used for fault diagnosis. The system model provides information on network topology [31] and on how a failure condition or alarm in one component is related to failure conditions or alarms in other components. It has the potential to solve novel problems and their knowledge may be organized in an expandable, upgradeable and modular fashion. The main problem in this approach is difficult to obtain and keep up-to-date and manipulation is computationally complex.

**Case-based system**

These systems make their decisions based on experience and past situations [32]. They try to acquire relevant knowledge of past cases and previously used solutions to propose solutions for new problems. If a direct match for an open problem is found in the database, the solution from the matching case is returned. Otherwise, the case is chosen that most closely matches the open problem. Then, the solution applied to the chosen past case is adapted for the open problem. Case-based systems are well suited for learning correlation patterns. They are resilient to changes in network configuration [8].However it requires an application-specific model for the resolution process and also computationally complex.

**Model traversing techniques**

This technique uses a formal representation of a communication system with clearly marked relationships between network entities [33,34,35,36]. Failures in the communication system propagate along relationships between network entities. are robust against frequent network configuration changes [36]. They are particularly attractive when automatic testing of a managed object may be done as a part of the fault localization process. Model traversing techniques seem natural when relationships between objects are graph-like and easy to obtain. The downside of this technique is it is unable to model situations in which the failure of a device may depend on a logical combination of other device failures.

**Fault propagation models**

Fault propagation models require a-priori specification of how a failure condition or alarm in one component is related to failure conditions or alarms in other components [34]. Based on this information, the fault localization algorithm tries to isolate the root cause of the observed set of symptoms. Given a set of observed symptoms, the algorithm solving the correlation problem should return a number of fault hypotheses along with some measure of their correctness. It has been shown that the correlation problem is NP-hard. However, independent multiple faults happen simultaneously with a probability that may not be ignored. In these cases the appropriate heuristics is to find the explanation that offers the greatest level of confidence. As a measure of confidence, the probability of fault occurrence or information cost associated with fault occurrence are used.

**Code-based techniques**

This technique uses information-theory to facilitate the process of fault localization. Fault propagation patterns in code-based techniques are represented by a codebook [31,37]. For every problem, a code is generated that makes it possible to distinguish this problem from other problems. In the deterministic code-based technique, a code is a sequence of values from {0, 1}. Problem codes are generated based on the available system model and a fault information model. The drawback of this technique is accuracy is hard to predict when more than one fault occurs, regenerating the code book is time consuming and not suitable for dynamically changing dependencies.

## IV. CHALLENGES IN FAULT LOCALIZATION

In addition to provide security fault localization also faces the following challenges (i) low detection delay(i.e., the time required to accurately localize a faulty link), (ii) low computational overhead, (iii) low communication overhead, and (iv) low storage overhead.

- **Security and efficiency:** Sophisticated attacks such as framing and collusion attacks and natural packet loss tend to break fault localization protocols or lead to heavy-weight protocols (to prevent sophisticated attacks) [3].
- **Agility:** In addition, current secure and relatively light-weight protocols leverage coarse grained flow fingerprinting along end-to-end paths to prevent packet modification attacks while reducing communication overhead. However, in addition to having high storage overhead, these techniques result in long detection delays and require monitored paths to be long-lived which is impractical for networks with short-lived flows and agile routing paths [3].

## V. CONCLUSION

Fault localization, a central aspect of network fault management, is a process of deducing the exact source of a failure from a set of observed failure indications .It has been a focus of research activity since the advent of modern communication systems, which produced numerous fault localization techniques. Fault localization is subject to complications resulting from complexity, unreliability, and non-determinism of communication systems.

This paper presents a comprehensive survey of fault localization techniques in communication systems. These techniques derive from different areas of networks, including Graph theory, probing, monitoring, etc

Even with the presence of so many different fault localization methods, fault localization is far from perfect. While these methods are constantly advancing, network too is becoming increasingly more complex which means the challenges posed by fault localization are also growing. Thus, there is a significant amount of research still to be done, and a large number of breakthroughs yet to be made.

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