Impacts and Cost of Faults on Services in Cellular Networks

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Abstract

In this paper faults are processed and models of faults in telecommunications networks are proposed in relation to services and revenues. The probability of faults occurring is estimated. Cost models are presented predicting the amount of revenue loss. We relate faults to services with detailed relationship between them being shown.

Index Terms: OSS, services, faults, models, ESPs, QoS, UML, ERDs, Databases, Level of Service Agreement (SLA) and costs.

1. Introduction

The rapid changes in telecommunications technology come with a lot of challenges in faults management. Most telecommunication companies and Enhanced Service Providers (ESPs) today put a lot of resources in ensuring a fault free system. The impact of this cost cannot be ignored, as it continues to eat into the service providers' revenue and it contributes to the rising cost of services.

In this paper we propose mathematical models, which can be used to estimate the impact of telecommunications network faults. In our publication [1] we gave the models that relate to voice service. There are a number of cost models in this area. For example, a cost model of an ISP is proposed in [2], which only focused on expenses in providing service to enable ISPs fix their consumer prices; Cost impact of poor quality switch software is presented in [3], which does not consider planned outages in its formula. A behavioural model and a model for monitoring faults are presented in [4][5], which do consider the impact of such faults on services. Faults are related to cells in [6] but we relate faults to services to uncover the impact of faults on services.

This paper proposes more fault models in relation to services describing the impacts of faults on cellular network services. We cluster faults and services and establish relationships.

This paper is organized as follows. In section 2, we give a brief overview of faults in cellular networks. We present services model in section 3 and faults model in section 4. We relate faults to services in section 5 and draw conclusion in the subsequent section.

2. Overview of faults

In this section we define faults and give an overview of faults in cellular networks. A telecommunications fault is an abnormal operation that significantly degrades networks' active performance. It may disrupt communications. An abnormally high error rate generally indicates faults but all errors are not faults as protocols can mostly handle them.

Faults can be classified as hardware and software faults. These faults cause malfunctions and outages. When the active network elements may be working with some errors in some sense but not well it is said to malfunction, while for outages, the active network elements are completely knocked out and do not work at all. Planned outages may be undertaken for the network maintenance to provide high quality of services. In our previous work [1], we classified faults further as shown in Figure 1.

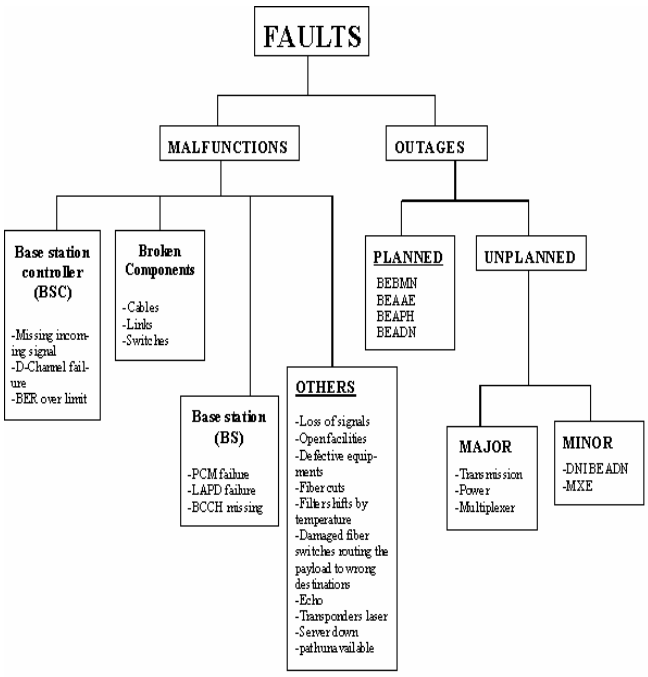

Figure 1: Faults classes [1]

3. Service modelling

A services model is proposed in this section. The model is generic in nature. It consists of Faults Reporting components, Service Agent, Service User (Client/Consumer), Database and ATM Switches. These components are split further into elements.

The model is divided into Architecture and Services. The architecture is further divided into Connection Management and Control Logic. The services model is based on the classification of services in terms of characteristics as *basic* and *user-defined* services in [7]. The services model is shown in Figure 2.

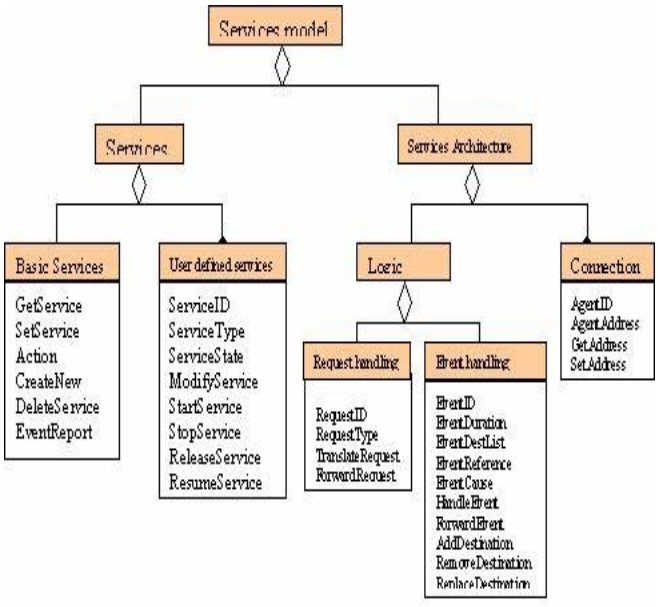

Figure 2: Services model

The Architectural model of services above is divided into Connection and the Logic of operations or transactions. The connection deals with different agents that connect different elements that are responsible for a particular service. Its main role is to maintain the address of each internal component. Logic handles the internal and external requests and forwards them to an appropriate destination, which may be an external component or a sub-component of the Network.

We model a service as a composition of features. The examples of features are address translation (for call routing services such as call screening or call forwarding), call control (call-on-hold, admission or removal of a new medium or user), security (authentication, confidentiality, data integrity), user interaction, charging, and connectivity. We model each feature using the Unified Modeling Language (UML) [8], which is a technique for representing the object classes of a system as well as the relationships among them. UML uses both graphical and textual notations to describe classes. Every class or relationship is mapped to a Java class by adding its properties (called attributes) and methods (i.e., operations that can be invoked on instances of the class).

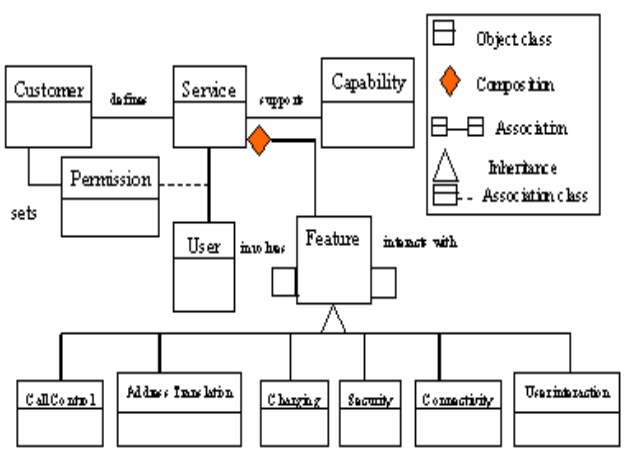

Figure 3: Service modelling

The customer defines a service as shown in Figure 3 and allows users to access this service by setting appropriate permissions. A service offers a number of actionable capabilities for instance; capabilities of electronic banking are funds transfer, account lookup, and funds withdrawal and are composed of features. A feature can interfere with another feature in a troublesome relationship called *feature interaction*, which is not addressed here because of brevity. Moreover, a feature can involve other features. For instance, some call control operations, such as admission of new users, involve the connectivity features. For the sake of brevity, we model only address translation.

3.1 Address translation

Considering that an end system can embed several devices for example, many network interface cards, we associate an address with each device rather than the end-system as shown in Figure 4. End-system is a generic concept that embraces all equipment, other than network elements, that is involved in communication services. Examples of end-systems are user terminals (e.g., telephones and computers), gateways, gatekeepers, information transcoding equipment, and multi-point control units. A network element implements only the lower three layers of the International Standards Organization (ISO) Open Systems Interconnection (OSI) seven-layer reference model.

The term *device* is used here in its broader sense to mean any entity that holds and/or processes information. It might be any piece of software or hardware board, or a combination of both. Examples are storages, processors, protocol suites, networking devices, information converters, and smart cards. The user employs devices to communicate, and can also have an address for example, e-mail

address that basically does not relate to the device he/she is using.

An important class in Figure 4 is address binding, which is used to bind address objects with one another. This class is defined and managed by the user or an authorized individual. It can be used to provide services such as abbreviated dialing, call screening and call forwarding. For abbreviated dialing, an address is bound to another one with fewer digits. Screening a call means associating it with a null address.

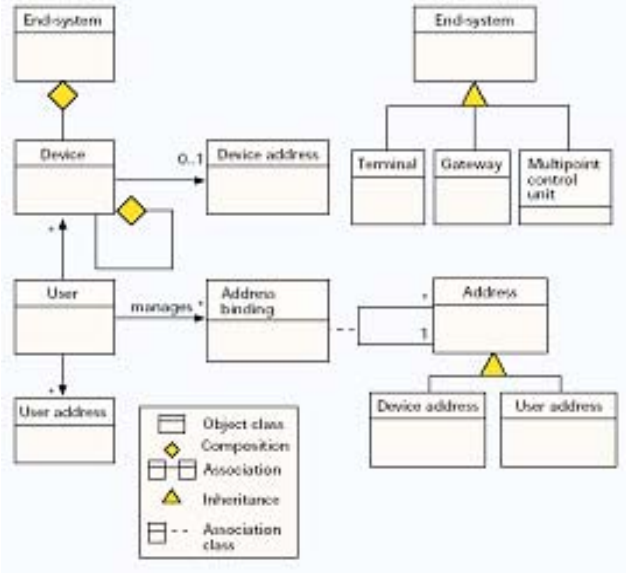

Figure 4: Modelling of the address translation feature

4. Faults modelling

In this section we propose fault models. Faults can be classified into hardware and software faults. As presented in our findings in Figure 1[1], we classified faults further as malfunctions and outages. With the data from a certain telecommunications network, the model gives an overview of what kinds of faults commonly occur over their network.

4.1. Benefits of Cost Models

Some of the benefits of cost models to operators are:

1) A suitable cost model serves the network operators with respect to its internal cost management as it helps to understand its own costs, which may have crucial influence on marketing decisions as well as operational processes.

2) A cost model provides a solid basis for calculating prices and charges for value-added services.

3) The cost model may be viewed as being the starting point for building a tool that allows operators to decide on the cost of additional Quality-of-Service (QoS) and the cost of service in general. Hence, the cost model design is concerned with the clear identification of faults and its associated costs in addition to formalized description of its relationships.

4.2. Faults probability

We derived mathematical models for assessing the impact ratio (IR) and probability of a fault occurring [1]. The most common faults that occurred within a certain network service provider are grouped as: i) Multiplexer (M), ii) Transmission (T), iii) Cell (C), and vi) Power (P) failures. In our previous work [1], we determined the independence of each fault to another and the probability of each fault occurrence. However, here we combined the faults in bundles of twos to see which faults are likely to occur at once. This will enable the network service providers to successfully prepare for the disaster.

Using the Product Rule (PR) of probability for independent events (for example, equation 1), we related these faults (M, T, C, and P) to one another and found out that transmission and multiplexer faults have high probability (95%) of occurring together. This we call combined faults probability as shown in Figure 5.

We estimated (using equation 1) that power and cell failures are the least likely faults to occur together. The combined probability is less than 0.05 (5%). This means these two faults are independent of each other. They are least likely to occur together at any given time. The large amount of data collected over a period of six months and the vast area covered by the network service provider may have contributed to this independence.

$$p(PC) = p(P) * p(C) \qquad (1)$$

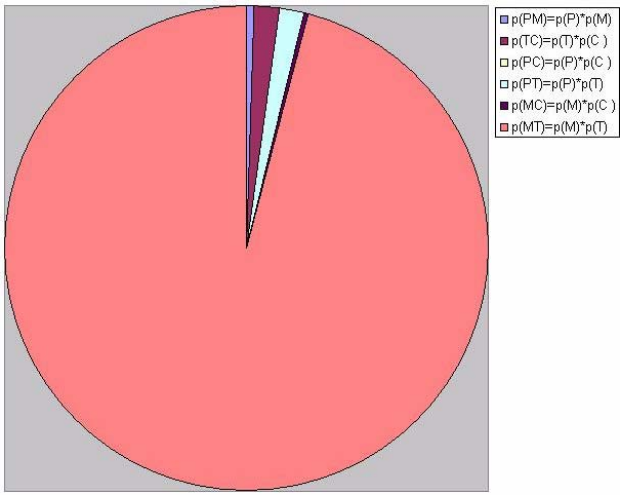

Figure 5: Combined faults probability

An average of 1027 SMSs were transacted every minute over the network of this service provider. Transmission has the greatest effect on the service [Figure 6].

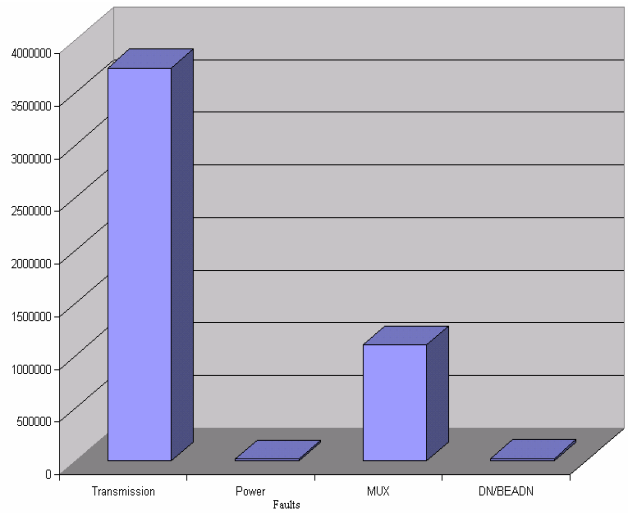

Figure 6: Undelivered SMSs caused by faults

4.3. Cost Of Faults Models

A lot of resources are put in maintenance of the network system (hardware and software) by most network service providers. Whenever a fault occurs network operators incur some cost associated with: customer churn due to loss of confidence in network, lost revenue for each minute of outage and recovery cost associated with such outages. The outage can be long, short or partial. Software and hardware diagnosis time, technical support time, effort to install, test and activate a temporary working network. It is harder to quantify a loss of confidence in the services an operator provides, but it can be estimated in terms of the churn rate.

With real faults data from a network operator, we have estimated the accumulated cost of faults based on a period of one-year average taken from November 2001 up to February 2002 as the first quarter. Let the duration of outage in minutes be D, total number of cells affected be N, and missed calls per hour per cell estimated to be S based on the average number of incoming and outgoing calls from a cell. To compute the missed calls caused by a particular fault, MC_F we use the following formula:

$$MC_F = \frac{D * N * S}{60} \qquad (2)$$

If the cost of a minute call is R2, then, the cost of an hour call will be R120. We represent this cost as C_H. Therefore the revenue loss caused by a particular fault denoted by R_L can be computed as:

$$R_L = (MC_F * C_H) \qquad (3)$$

The cost of Short Message Service (SMS) is R 0.75 per message. Suppose we dealt with an average of 10,356,372 SMSs transacted per week. Let the duration of outage in minutes be D, the total number of cells affected be N and SMSs undelivered per hour per cell is estimated to be S based on average number of SMSs transacted under normal circumstances, and total number of cells estimated to be Q. To compute undelivered SMSs caused by a particular fault, MS_F we use the following formula:

$$MS_F = \frac{D * N * S}{60 * Q} \qquad (4)$$

Let the cost of undelivered SMSs per minute be S_H, and undelivered SMSs caused by a particular fault be MS_F. Therefore the revenue loss caused by a particular fault denoted by R_L can be computed as:

$$R_L = (MS_F * S_H) \qquad (5)$$

We would like to note that we were unable to access data on other services offered by the network service provider under study.

5. Relate faults to services

We give the detailed relationship between faults and services in this section. The major faults that occur within this network service provider under study can be related to services as:

5.1. Transmission

The fault frequency of occurrence is high (75%). It occurs as a result of Mobile Switching Center (MSC) failure, switch failure, software failure, etc. If for example, transmission fault occurs at the MSC, the whole area covered by this MSC will not offer any service. SMS, VoIP, Voice message, and many other services will be affected. Hence transmission fault may affect all services that emanate from the area affected. It might not only affect services at this area but also cause more problems to the whole network i.e., congestion, loss of packets, etc. The location-based services at this area will definitely be affected.

5.2. Power

This fault causes more impact than any other. It causes an unplanned outage. This outage must be reversed in the quickest time possible either by restoring the power supply or by using the alternative power sources, i.e., generator. During this period, the network will be unusable by customers. It will totally affect all services that originate from

that particular area, the services terminating at that point (though some can be retrieved later once the power is restored if the MSC is not affected i.e., voice mail, SMS, etc).

5.3. Multiplexer

Network links normally employ equipments like repeaters, bridges, gateways, and multiplexers. Multiplexer is a device for taking several separate digital data streams and combining them together into one data stream of a higher data rate. This allows multiple data streams to be carried from one place to another over one physical link, which saves cost. This cost may not be saved if this device malfunctions or totally fails to work. Real-time services are the most affected. Path blockage and routing problems will occur as a result of links being ineffective to function. Packets will have to find an alternative routes leading to congestion of the network. In the long run the fault will have an impact on the whole network.

6. Conclusion

The definition of faults was presented with fault models that classify faults as malfunctions and outages. We presented service models that classify services as basic and user-defined services. The probability and cost of faults can be computed using the fault models presented. The benefits of cost models and relationship between faults and services are presented in this work.

7. Acknowledgement

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