SICAEN: A NEW METHOD TO DETERMINE THE IMPACT OF SEVERE NETWORK FAULTS ON BASIC TELECOMMUNICATION SERVICES

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Abstract: Despite the effort that has been carried out in the last two decades, there is still a huge gap between the information that network management systems can provide to identify and solve network problems, and the information they offer to determine the actual impact of these problems on basic telecommunication services. This paper presents a new method (called SICAEN) to identify and characterize service impact incidents using network resource unavailability information as an input. Most of the previously done work tries to identify the root cause of a failure, while SICAEN is concerned with the actual impact of the failure, from a user (service) perspective. The method performs impact evaluation in a per-service basis and has been successfully applied in real world in the context of Telefonica's IMPACTA project, whose goal is to determine the impact of severe network faults on mobile basic services for the Spanish biggest mobile operator.

1 INTRODUCTION

A big effort has been carried out in the last two decades in order to define the structure of telecommunication network faults and their treatment by a network fault management system. In fact, during these last two decades telecommunication service providers, network equipment providers, software vendors and system integrators have tried to define and standardize the structure and the management of network faults. Some of the most widely accepted proposals in this area are:

- ITU-T X733 Alarm Reporting Function (ISO/IEC 10164-4).
- 3GPP Alarm Integration Reference Point (3GPP) .
- OSS/J Quality of Service API (Åberg, 2002) and Fault Management API (Raymer and Flauw, 2007).
- Multi-Technology Operation System Interface (MTOSI) Release 1.0 (TMFORUM-MTOSI).

These proposals define management solution sets, but each of them has a different background since they evolve from working groups related to specific network technologies. This is the case of 3GPP, focused on mobile networks, and MTOSI, on transport technologies, while others evolve from solutions for fixed networks from the 90's as is the case of ITU-T, the former CCITT, and OSS/J who tries to define a J2EE standard for network management. All of these proposals are roughly equivalent and recently some efforts have been made to integrate them (Raymer, 2004).

Nowadays, there is a wide range of commercial operation support systems that implement, to a certain extent, some of the aforementioned proposals. This adoption has made it easy to achieve system interoperability and, what is more, to improve network oriented management processes whose goal is to identify and solve network issues and events.

Nevertheless, there is still a wide gap between the information operation support systems provide to identify and solve network problems, and the information they can offer to determine the actual impact of these problems on basic telecommunication services. In fact most of service impact analysis is done manually, based on the knowledge of the network topology provided by the maintenance experts. It must be also noticed that,

although the information related to a service impact is based on network data, it has an independent life-cycle and scope, so the raw network data must be processed to obtain service impact information. This detailed service impact knowledge is essential to prioritize repairing actions on severe network faults, to take new network planning decisions and, more generally, to achieve higher levels of service and, by extent, of customer satisfaction. It must be noted that the TeleManagement Forum (TM Forum) clearly states (see TMFORUM-eTOM and TMFORUM-TAM) that the billing/invoice service must be feed with information about service impacts in order to trigger the appropriate customer care actions if appropriated (v.g. SLA violation treatment). This is also enforced by law in some EU countries, like Spain (see Real Decreto 424/2005).

In order to fill this gap, the first issue to be dealt with is the lack of a clear and widely accepted definition for service impact incidents. These incidents have a complete life-cycle with a well defined start and end point but, in opposition to standard network faults, their nature and their scope can vary meaningfully over time, presenting different intermediate states. Therefore, to be able to capture all the data needed to track and to record the service impact incident life-cycle, a more complex definition and structure for service faults is needed. The TeleManagement Forum has recently launched a working group (TMFORUM-NGOSS) to define all these items.

This paper presents a new method that has been developed to identify and characterize service impacting incidents using network resource unavailability information as an input. The method performs impact evaluation in a per-service basis and has been identified with the name SICAEN. The method has been successfully applied in the context of Telefonica's IMPACTA project whose main goal was to determine the impact of severe network faults on mobile basic services (GMS voice, GPRS data, UMTS voice, UMTS data, etc).

The rest of the paper is organised as follows: Section 2 provides some basic definitions and architectural assumptions. Then Section 3 presents the different stages of the SICAEN method. Implementation results indicating the effectiveness of the approach are presented in Section 4, and finally future work and conclusions are drawn in Section 5.

2 PREVIOUS DEFINITIONS

Most of the concepts that are going to be used in the development of this paper are well known and their definitions can be found in the references (see for example Jakobson and Weissman, 1993), but, although SICAEN will be presented in the following sections, there are certain definitions and architectural assumptions that must be introduced in order to fully understand the scope and mechanisms employed.

The formerly mentioned proposals use a basic fault definition (see ISO/IEC 10164-4, 3GPP, Åberg 2002, Raymer and Flauw 2007 and TMFORUM-MTOSI) as a basis for their fault management processes and interfaces. As it has already been stated, this definition is clearly insufficient to handle service impact incidents, so new concepts and new structures must be defined to manage them. Along this paper, "Service Incident" stands for a telecommunication service unavailability affecting a geographical area and/or a defined group of customers. Service Incidents may evolve dynamically, featuring a complete life-cycle, during which they may change their affection scope, may disappear once the affection scope is void, may be aggregated with another Service Incident, may be divided in two or more independent parts, etc.

Regarding the architecture, SICAEN does not define and implement a complete OSS, but it complements the concept of OSS with service impact generation. Therefore SICAEN assumes the existence an OSS solution which provides network management facilities (i.e Fault and Configuration). This implies that SICAEN can be deployed as an independent module of the OSS or as a completely independent system, accessing to the underlying OSSs. This last configuration would be typical on a multivendor environment since the SICAEN method needs access to the different network events provided by the underlying network managers.

Also, SICAEN follows the recommendations of the TM Forum about data stewardships so it requires the existence of a corporate repository and unified resource identifiers. A corporate repository of the network resources is needed in order to complete the information provided by the underlying OSS. Also, since the SICAEN method will integrate different sources of events and will make use of the corporate network repository, a unified network resource identifier (UNRI) for every element must be provided to be able to correlate all these sources. This unified identifier, UNRI, will be used to retrieve information from the corporate repository.

Finally, as it will be shown in following sections, SICAEN method requires a rich detailed knowledge of the role and characteristics of each element, so it

can integrate the events originated by each element in the appropriated service impact incident.

3 SICAEN METHOD

SICAEN is an acronym formed by the initial letter of each of the five Spanish-named stages which constitute the method: SI for "Selección de Indisponibilidades" (Unavailability Selection), C for "Consolidación" (Consolidation), A for "Agregación" (Aggregation), E for "Estabilización" (Stabilization) and N for "Notificación" (Notification).

In the following sections the different stages of the method will be presented along with the concepts that emerge from them.

3.1 First Stage: Unavailability Selection

The first stage (see Figure 1), named "Unavailability Selection (SI)", collects unavailability data from network elements and network element managers and selects any alarm, state change event or operator action record representing a total unavailability of a network resource or the end of the unavailability condition. As an example, in the context of IMPACTA project, aimed to identify the impact of severe network faults on mobile basic services, the method selects and catalogues unavailability network resource conditions and restorations. Although the list is not exhaustive, some of the most relevant conditions are:

- GSM cell service unavailable.
- GSM cell service available.
- GSM cell manually locked.
- GSM cell manually unlocked.
- BSC function unavailable.
- BSC function available.
- MSC function unavailable.
- MSC function available.
- UMTS cell service unavailable.
- UMTS cell service available.
- UMTS cell manually locked.
- UMTS cell manually unlocked.
- HLR function unavailable.
- HLR function available.
- SGSN function unavailable.
- SGSN function available.

Each of these un/availability conditions can be generated by a variable range of alarms, events or manual actions extracted from log records. This

range differs from one network technology to another. SICAEN method first stage (SI) transforms (see Figure 1) alarms, state change events and records into catalogued un/availability conditions and forwards them to the next stage as a new kind of notification called Service Potential Incidents (SPI). These notifications can be firing notifications (SPI-F) or clearing ones (SPI-C) and they convey information regarding the un/availability condition such as its type, the starting and/or ending time and the affected network resource identity using the aforementioned unified network resource identifier UNRI (see Section 2).

This transformation process may be a simple mapping of the received events. That is to say, just an event acquisition from some kind of event source followed by a network resource identity resolution. This kind of schema can be implemented in a quite straight forward way, although the SPI can be defined as a complex combination of simple events and a more sophisticated approach may be needed using techniques such as correlation engines as described in (Forgy, 1979 and 1982) in order to produce the SPI.
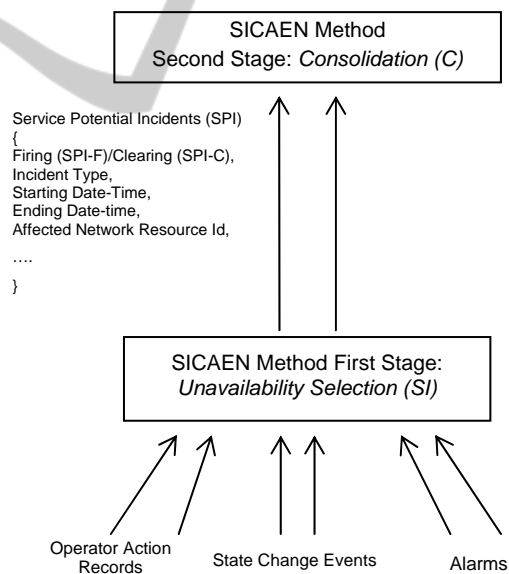

Figure 1: SICAEN First Stage: Unavailability Selection.

It must be noted that multiple "Unavailability Selectors", each of them using different sources, can be employed simultaneously to feed the next stage. This may lead to duplicated SPIs for a given network resource, but it may provide a simpler way to integrate different sources or even to provide some resilience to failures on the fault reporting functions. This event redundancy must be dealt by

the second stage "Consolidation".

3.2 Second Stage: Consolidation

In the second stage (see Figure 2), named
"Consolidation (C)", the system checks the recorded
state of the network resource referenced by the
incoming SPI against the state reported by this SPI.
If there is no change in the state of the network
resource, then the SPI may be discarded since the
received SPI will not affect the state of the network
resource. This discard process works as follows:

- If an SPI-C is received for a non faulty
  network resource, the SPI-C is discarded and
  regarded as an internal error (In fact, the error
  is: There is not an existing SPI active in the
  network resource).

- If an SPI-F is received and is not already
  attached to the network resource, then it is
  attached and the "life-count" of the network
  resource is increased. The existence of
  multiple "Unavailability Selector" from the
  previous stage can lead to multiple path
  detection for SPI.

An SPI-C can still be not treated, even when the
referenced network resource is in a faulty state, if
the "life-count" for the network resource is bigger
than one. This represents that the SPI-C is just
deleting a path, but there are still other SPI for the
network resource.

This "life-count" mechanism allows to
coordinate multiple "Unavailability Selector" in a
very simple and straightforward way, although it
should be noted that some sort of synchronising
protocols between this second Consolidation stage
and all the instances of the previous stage
(Unavailability Selection) must be implemented.

Once it has been stated that the received SPI is
relevant and that it must be treated, the method
updates the network resource state, recording the
date and the time of the state change. Then, it
searches through the Network Inventory and the
Service Inventory to identify the basic services
affected by the network resource referenced by the
SPI. As soon as these services have been identified,
this stage forwards them to the next stage
(Aggregation), generating as many Service-Specific
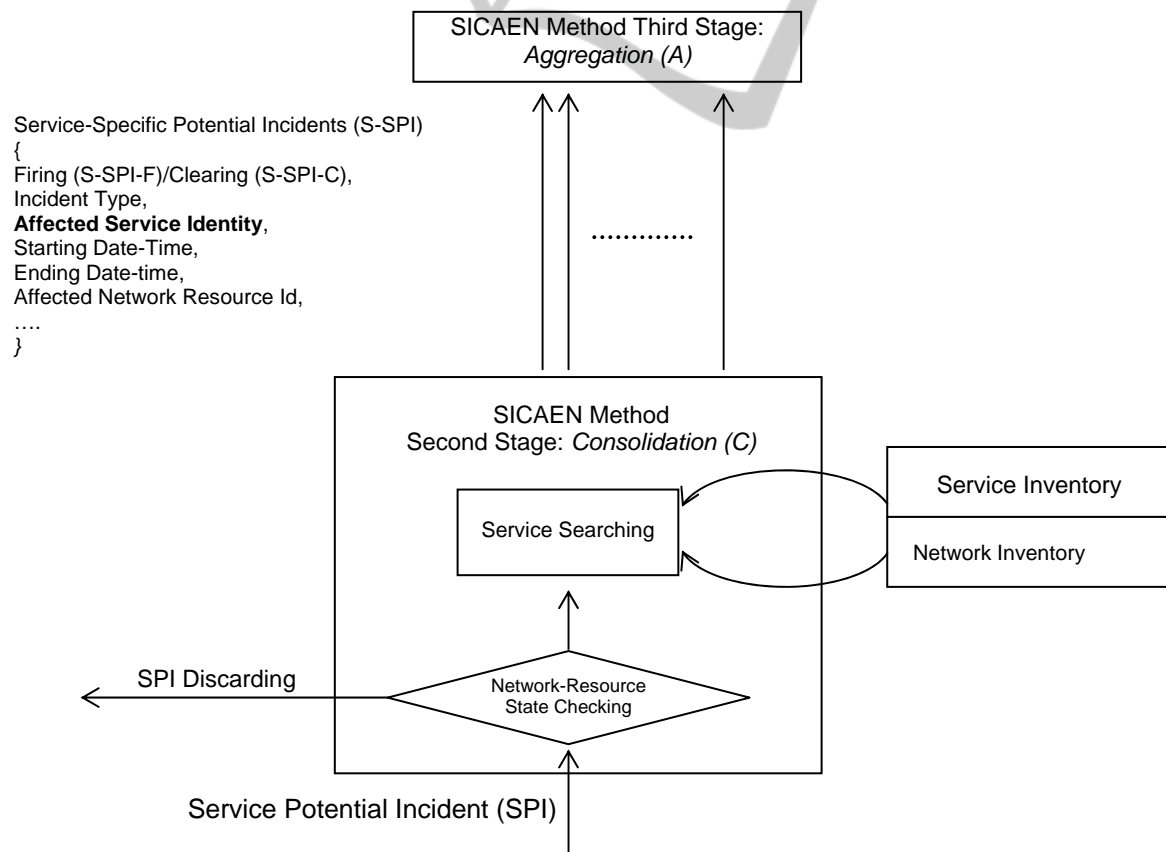Potential Incidents (S-SPI) as basic services have

Figure 2: SICAEN Second Stage: Consolidation.

been found. Together with the information conveyed by the SPI, each of the S-SPI generated by the second stage holds the affected service identity.

Therefore, this second stage performs a first unification of the network data, in a more complete approach than the pre-processing proposed in Li and Li (2011). It also provides more flexibility when the method is deployed, since the existence of several "Unavailability Selection (SI)" stages may be necessary in order to simplify their internal architecture or to provide redundancy.

3.3 Third Stage: Aggregation

The third stage, named "Aggregation (A)", is the key stage in the SICAEN Method. This stage determines whether each of the S-SPI generated by the second stage should indeed be tailored as a Service Incident (SI). This analysis is performed in a per-service basis (see Figure 3).

3.3.1 Definitions

SIs are the final output generated by the method, and, as it was stated before, they represent actual service unavailability situations affecting a geographical area and/or a defined group of customers, where each SI concerns a specific basic telecommunication service. However, SIs are not static entities: they feature a complete life-cycle, with a starting point, an ending point and an indefinite number of changes (mutations) in between. The authors have chosen the term "mutation" as the changes can be very slight or transient or lead, on some occasions, to evolutionary leaps in the SI, mimicking the mutations on life organisms. These mutations will be filtered on the consolidation phase in order to provide an ordered view of the SI evolution.

A Service Incident Mutation (SIM) may concern the incident type (for example, an incident that was originally perceived and catalogued as a "GSM cell unavailability", may be later perceived and catalogued as a "BSC function unavailability") or it may concern the incident scope, i.e. the collection of network resources affected by the incident (throughout its life cycle, the incident may involve different collections of network resources).
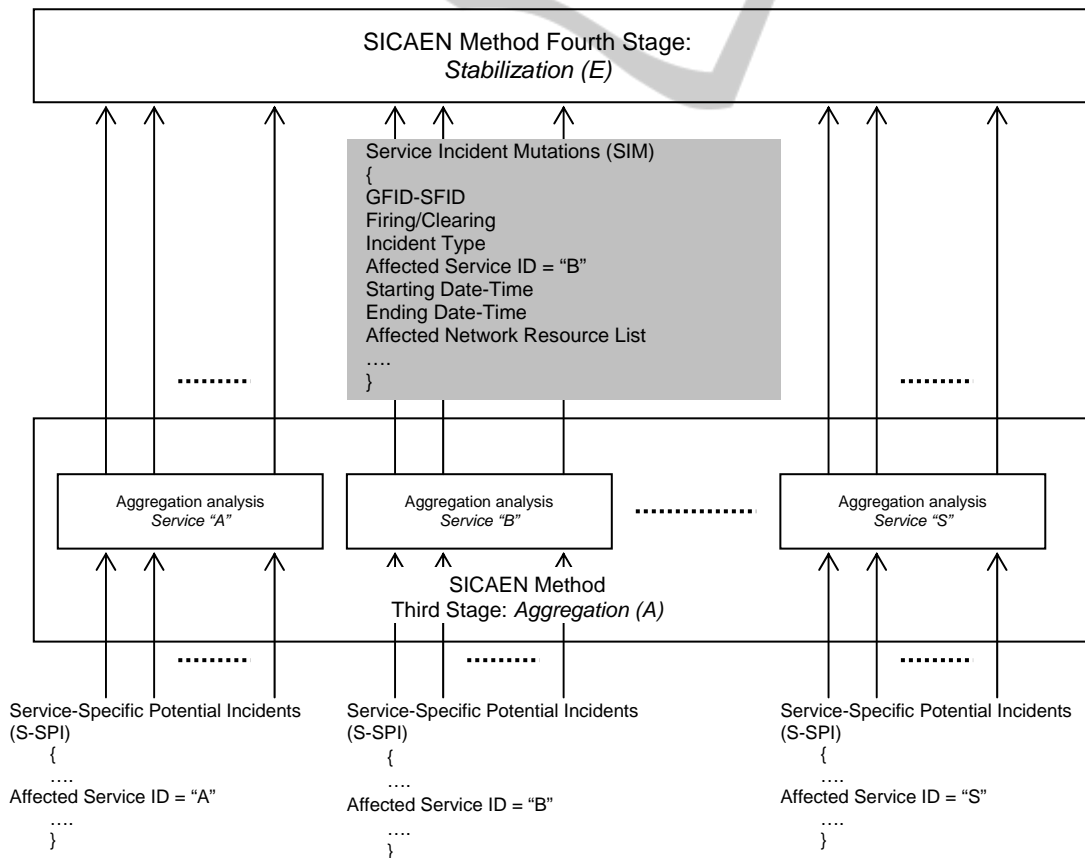
SICAEN identifies outgoing SI by a unique

Figure 3: SICAEN Third Stage: Aggregation.

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numerical identifier, named "Global Fault Identifier" (GFID), and each of the comprising SIMs by the concatenation of GFID and a second mutation-specific numerical identifier named "Specific Fault Identifier" (SFID). Like SPI and S-SPI, SIMs may be firing notification (SIM-F) or clearing ones (SIM-C). Firing notifications denote that a new SI state has been reached while clearing notifications indicate the SI is no longer at the state notified by the mutation.

Each SIM captures relevant aspects of the change suffered by the SI it belongs to. Those aspects include the type of the incident (it may be different from one mutation to the following one), the collection of network resources affected by the incident just after the mutation took place, and the time and date of the mutation. The affected service identity does not change throughout the service incident life-cycle.

The SI life-cycle is composed by the complete sequence of SIM from its rise to its demise. As an example, some of the SIMs generated by SICAEN method for a SI with GFID=214 are shown in the table below. Table 1 shows some of the thirty six mutations throughout its life-cycle, affecting service S7, where R1, R2, R3…, Rn are network resources.

As it can be seen in Table 1, SIM with SFID = 0 is a special mutation: it flags the start and the end of the whole SI.

3.3.2 Functional Behaviour

To compute the net effect of each incoming S-SPI on an ongoing SI, SICAEN Aggregation stage uses correlation techniques based on network topology, i.e. based on functional dependencies between network resources, or, failing these (when network topology information is not enough, inaccurate or non-existent), based on spatial-temporal proximity criteria. Liu et al. (2008) presents a similar proposal.

An incoming firing Service-Specific Potential Incident (S-SPI-F) may produce different results after being processed by the Aggregation stage:

- A new SI is generated.
- A new SIM for ongoing SI is created.
- Two or more SIs are aggregated into only one SI encompassing all of the network resources from the aggregated SI.
  In this case, the resultant SI retains the identity (GFID) of the oldest one being aggregated. The remaining aggregated SIs are closed.
- No effect on ongoing SIs.

Similarly, an incoming clearing Service-Specific Potential Incident (S-SPI-C) may also produce different results:

Table 1: Service Incident life-cycle example.

Time Stamp	Mutation Type	Service Incident Mutation

T0	Firing
	
	Firing
		`[GFID=214; SFID=0; {R7, R19, R24}; Firing:`
		`17:45:03 04/04/2008; Clearing: -]`
		`[GFID=214; SFID=1; {R7, R19, R24}; Firing:`
		`17:45:03 04/04/2008; Clearing: -]`

T1	Clearing
	
	Firing
		`[GFID=214; SFID=1; {R7, R19, R24}; Firing:`
		`17:45:03 04/04/2008; Clearing: 17:46:07 04/04/08]`
		`[GFID=214; SFID=2; {R7, R19, R24; R51}; Firing:`
		`17:46:07 04/04/08; Clearing: -]`

T2	Clearing
	
	Firing
		`[GFID=214; SFID=2; {R7, R19, R24; R51}; Firing:`
		`17:46:07 04/04/08; Clearing: 17:46:46 04/04/08]`
		`[GFID=214; SFID=3; {R7, R19, R24; R51; R55};`
		`Firing: 17:46:46 04/04/08; Clearing: -]`

…	…	…

T34	Clearing
	
	Firing
		`[GFID=214; SFID=34; {R19, R51; R63}; Firing:`
		`18:06:41 04/04/08; Clearing: 18:07:39 04/04/08]`
		`[GFID=214; SFID=35; { R19, R51}; Firing: 18:07:39`
		`04/04/08; Clearing: -]`

T35	Clearing
	
	Firing
		`[GFID=214; SFID=35; { R19, R51}; Firing: 18:07:39`
		`04/04/08; Clearing: 18:08:22 04/04/08]`
		`[GFID=214; SFID=36; { R19}; Firing: 18:08:22`
		`04/04/08; Clearing: -]`

T36	Clearing
	
	Clearing
		`[GFID=214; SFID=36; {R19}; Firing: 18:08:22`
		`04/04/08; Clearing: 18:10:11 04/04/08]`
		`[GFID=214; SFID=0; {}; Firing: 18:10:11 04/04/08;`
		`Clearing: 18:10:11 04/04/08]`

- ▪ An ongoing SI is closed.
- ▪ A new SIM for an ongoing SI is created.
- ▪ A new SI is created after a SIM has been emitted for an ongoing SI.
- ▪ No effect on ongoing SIs.

The process to determine the effect of each incoming Service-Specific Potential Incident (S-SPI) on ongoing SIs is named "Aggregation Analysis" and, as it has been noted before, it is performed in a "per-service" basis. Therefore, both the incoming S-SPI and the ongoing SI taken into consideration in this analysis must reference the same basic service.

3.3.3 Details of the Aggregation Analysis

The Aggregation Analysis is based on a correlation process that uses inference techniques as the basic tool, and network topology (functional dependencies between network resources for the service concerned) as the main source of knowledge. In short, the behaviour of this analysis for incoming firing Service-Specific Potential Incident (S-SPI) is as follows:

1. If the network resource referenced by the incoming S-SPI-F is functionally dependent on some of the network resources encompassed by one of the ongoing SIs, then that resource, and any other that is functionally dependent on it, is aggregated to the concerned SI.

2. If any of the network resources included in the ongoing SIs are related to the network resource referenced by the incoming S-SPI-F, then these Incidents are changed to accommodate the network resource included in the S-SPI-F. It has to be noted that functional dependency is one type of relation but not the only one, spatial-temporal relations can also be defined.

Should there be more than one SI, they will be unified. In this unification process the oldest SI will prevail, while the rest will be closed if all of theirs resources have been subsumed in the prevailing SI. Not all the relations must be of type functional dependent and although the relations are symmetric they may be not transitive
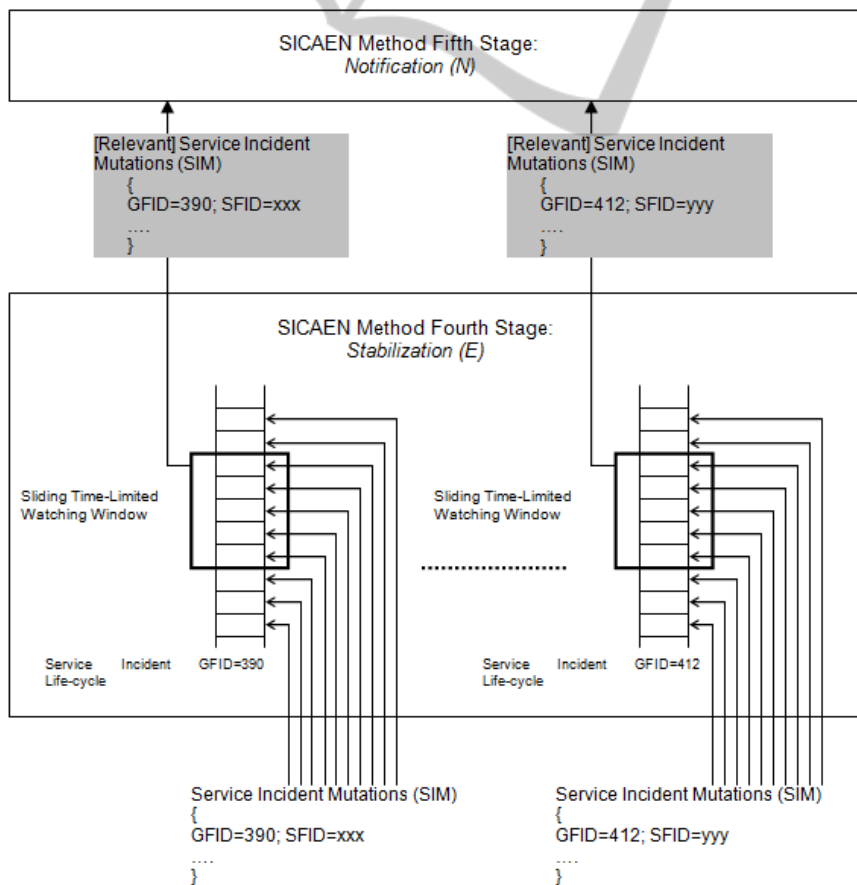

Figure 4: SICAEN Fourth Stage: Stabilization.

3. If the network resource referenced by the incoming S-SPI-F is not functionally dependent on any of the network resources encompassed by the ongoing SIs, then a new SI, encompassing that resource and any other that is functional dependent on it, is created.

There is an analogous correlation process for S-SPI-C.

In all the cases, the type of the resultant SI is re-evaluated. Every change on any ongoing SIs or the rise of a SI is notified to the next stage (Stabilization) by means of the corresponding SIMs.

As it has been formerly stated, network topology information for the concerned service may be detailed enough, inaccurate or, even, non-existent. In any of these cases, the "Aggregation Analysis" uses the concept of "spatial-temporal proximity" as a basic mechanism for its correlation process.

The spatial proximity relationship between network resources is defined as a function of both network resource typology and network resource location. As an example, in the context of IMPACTA project, aimed to identify the impact of severe network faults on mobile basic services, the method uses as spatial proximity criteria the distance between cells defined as a function of cell location (rural, urban, sub-urban, etc) and cell type (macro-cell, micro-cell, pico-cell, etc).

The temporal proximity relationship between events is simply defined as a function of elapsed time between events.

3.4 Fourth Stage: Stabilization

The fourth stage, named "Stabilization (E)", is aimed at reducing the amount of information the method delivers, in line with the proposal in Sterritt and Bustard 2002. This stage forwards to the next one only those SIMs which convey relevant information.

A severe network incident can cause hundreds, or even thousands, of alarms and events to be raised and to be cleared throughout its life-cycle. Each of them may provoke several SIMs to be issued by the Aggregation Stage. Most of those mutations report only very small changes regarding the collection of network resources affected by the incident concerned and do not alter by any means the type of the incident.

In order to select the incident mutations that must be forwarded to the following stage, Stabilization Stage makes use of a sliding time-limited watching window in a per-incident basis (see Figure 4). For each incident, this technique allows only relevant mutations to be relayed to final stage. The mutations are evaluated and since each of them represents a particular state associated to the Service Incident, the mutation located at the end of the window summarizes the previous mutations.

3.5 Fifth Stage: Notification

The fifth and last stage, named "Notification (N)", is responsible for issuing SIMs for those clients wishing to receive them. These clients can be part of any assurance process that needs to know the impact of severe network faults on basic telecommunication services.

This stage shows the typical behaviour of a standard notification service, such as OMG Notification Service (OMG, 2004) or OASIS Web Service Notification (Graham et al. 2006), although any other type of notification schema may be used.

4 IMPLEMENTATION RESULTS

The SICAEN method has been implemented on top of the proprietary OSS used by Telefónica (Spanish biggest mobile operator) to manage its mobile network which consists of several thousands of cells. It also takes on account the full network topology, BSC/RNC, MSC, SGSN, GSSN, HLR... It has provided for the last few years and still does, impact analysis on the two basic telecommunications services, voice and data over GSM and UMTS networks. It manages over a hundred thousand different event origins, compromising cells, BSC/RNCs, MSCs... It generates, on a daily basis, over thirty thousand service mutation incidents which in turn generate after the Stabilization Stage about five thousands unique Service Specific Identifiers grouped in four thousand Global Fault Identifiers, for the four basic telecommunication services managed. This information is used to prioritise network faults and evaluate their actual impact.

SICAEN is implemented and is coded in C++ and Java as a multiagent system making use of a Rete correlation engine in the Unavailability Selection stage and OASIS Web Service Notification in the Notification Stage.

The method is integrated in a wider multiagent architecture (IMPACTA) with specialised agents complementing SICAEN to provide real time maps of Service Unavailability zones to the Network Operator Centre and the Customer Care Personnel. These maps take in account the fact that in a mobile

network there is a certain degree of overlap between cells so the scope of the failure reported by SICAEN is lessened using this overlap information.

5 CONCLUSIONS AND FUTURE WORK

A complete description of the SICAEN method has been presented in the previous sections. Stages SI and C provide a normalised annotated input to the Aggregation phase. These first two stages make a heavy use of the facilities provided by the underlying OSS and corporate repositories to obtain normalised Service-Specific Potential Incidents, taking into account not only network faults, but also operator actions. The later are not usually analyzed by other methods since its root cause is already known, but nevertheless they create a measurable Service Impact to the user.

The Aggregation stage computes, using topological and functional relationships among the network elements, the net effect for each Service Specific Potential Incidence (S-SPI). The last two stages, E and N, provide the means to reduce the volume of information generated by the Aggregation stage and to relay the information to external clients.

SICAEN method has proven to be a powerful tool to determine the impact of severe network faults on mobile basic services in the context of Telefonica's IMPACTA project, which is used to provide automated reports, textual and graphical, on severe network failures as requested by the Spanish Law (Real Decreto 424/2005). Nevertheless, some enhancements have been identified during its daily use.

The first enhancement regards the ability to disaggregate a long life Service Incident into several separate Service Incidents when it is suspected to have been wrongly aggregated. In this situation, a re-evaluation of correlation criteria for every concerned Service-Specific Potential Incident (S-SPI) should be performed.

Another enhancement concerns the use of network resource partial unavailability information as input. A network resource may be only partially affected by a fault and, as a result, it may be only able to preserve part of the services it usually supports operating under regular conditions. Additionally, the effect of the fault over each individual service may vary meaningfully. To handle this kind of partial unavailability information the use of fuzzy logic and fuzzy reasoning techniques (Zadeh, 1988 and Baldwin, 1981)) shall be explored.

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APPENDIX

Patent pending. Reference number: P200803548