ICT Degradation Modelling

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Abstract. With the advent of Cyber-Physical Energy Systems (CPES) and their application on Smart Grids (SG), the integration of Communication Technologies (ICT) and Power Systems (PS) have been rooted deeply. ICTs and PS in such environments have heavy mutual interdependencies on one another. Failures in ICT can disrupt PS, while failures in PS could disrupt ICTs due to lack of energy, thus leading into cascading system failures. While the ENTSO-ESSC provides classification systems for classifying PS operation states to determine PS degradation, such comparable systems are not available for ICTs. In this paper, we attempt to understand various components of an ICT system, and understand the various operation states of the ICT components. We attempt to survey the distribution network technologies as a part of the SG paradigm, and isolate components of interest. The essential properties such as availability and reliability are determined and used to map the states of components. Since distribution networks can be treated as Markov models, we attempt to design degradation models of the distribution networks using Markov chain analysis.

Keywords: Cyber-Physical Energy Systems · Information and Communication Technology · Degradation Modelling · Degradation Detection · PKIs · Markov Time Chains

1 Introduction

The ENTSO-ESSC is a system state classification that is implemented to determine the operational state of a Power System. ESSC however does not regard for the impact that the ICT system has on determining the operational state of a PS. ENSTO-E PS state classification defines five various states - Normal, Alert, Emergency, Blackout a Restoration. There is a change in the system state each time a failure may occur. For example, a certain failure may escalate the PS from a Normal state to an Alert state. In this paper, we shall attempt to understand if such a classification can be implemented on an ICT systems, and what components can be understood to achieve such a classification.

2 Background Work

In [1], there is an attempt to understand the bridge between the PS and ICT state classifications, and to isolate the elements, which could be used as properties to define system states. The study adopts from the ResiliNets project with the difference being a slight deviation in the definition of what an operation state is. While the ResiliNets project only considers the network and the service that it provides, the paper accounts for both the network infrastructure and the various services that it provides while defining the operational state. The three Key Performance Indicators (KPIs) considered are those of Availability, Accuracy and Latency. As such three states were defined as follows - Normal State, Limited State and Failed State.

In a similar study [3] on modelling communication technologies to find the Distribution Grid's reliability, the ICT components are considered to have some network states. The states range from an in-service state, observable state and an IED (intelligent Electronic Device) state. The KPIs in this particular study were component availability and latency requirements. The study, similar to previous study emphasised on both the network infrastructure and the services provided to define operational states.

3 Network Degradation Modelling

3.1 Cellular Networks

As we focus on the ICT segment rather than the PS segment, we find that extensive work has been made on degradation detection in cellular network, there is currently not much work available for degradation modelling. However, we can study the degradation detection techniques and adopt from the same to formulate degradation models.

With the advent of 3G and newer generation cellular networks, SONs (Self-Organising Networks) have been integrated as a part of the 3GPP standard. SONs provide for easy network management and maintenance amidst the growing complexity of these newer generation networks, and can automate some functions such as network configurations, healing and also optimization. This ability is of certain interest to us as it enables a network to recover from a so defined degraded state to a normal state.

Research shown in [4] and [5] have detailed study on degradation detection in SON based networks. Both the researches work on understanding the degradation patterns in cells using various methods such as analysing cell metrics over a time period or by observing the interaction between two cells to determine a potentially degraded cell.

LTE Network Structure and KPIs Identification

The three main parts of a LTE network are:

- UE (User Equipment)
- E-UTRAN (Evolved UMTS Terrestrial Radio Access Network)
- EPC(Evolved Packet Core)

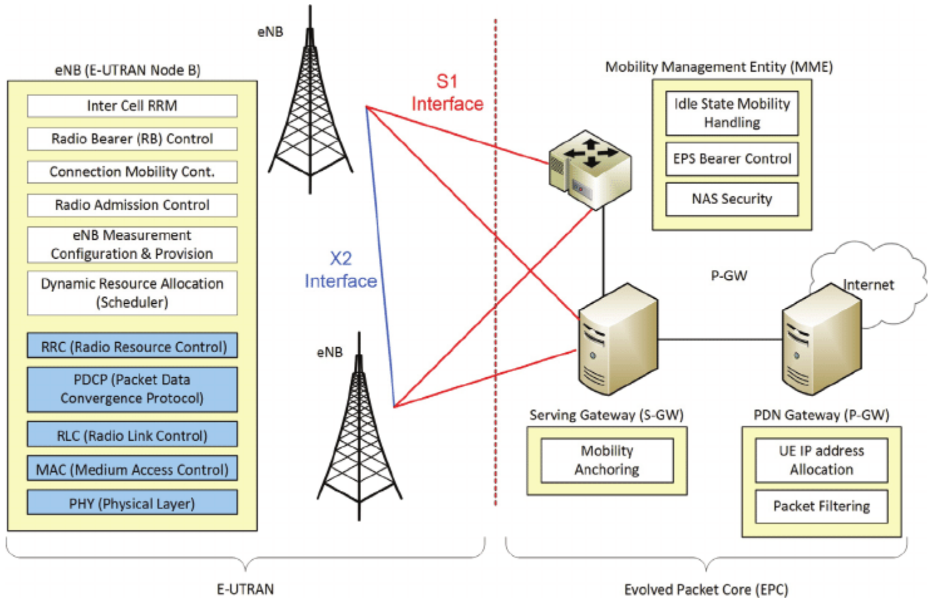

Fig. 1. LTE Network Structure (Image source :[6])

The user equipment is similar to the Mobile Equipment that is used in 2G-GSM networks. The E-UTRAN is responsible for managing the communication between the mobile (UE) and the evolved packet core (EPC). The EPC consists of the evolved base stations, called eNodeB, which is simply a base station that controls mobile devices in a given cell(s). EPC is analogous to the Core Network (CN) of the LTE system.

LTE cellular networks have 5 KPIs that are defined to monitor, optimise the network performance while detecting any performance problems. The KPIs are listed below with some possible test cases (see Table 1):

Hendrawi et al. [2] has demonstrated Accessibility based degradation prediction using the KPIs of RRC Setup Success Rate, ERAB Setup Success Rate and Connection Signaling Success Rate. The paper proposes three accessibility conditions that a SON system will have, namely high, acceptable or low. Hourly data from an eNodeB (Evolved Node B) consisting of three cells deployed over a LTE network was collected over a month, and the system state for each hour mapped against being high, acceptable or low. The collected data was used to calculate a representative value spanning over a larger period of time, such as a day. The system state was then found by evaluating the representative value against a predetermined threshold value. They also determined that it was necessary to calculate a cumulative representative value that would represent all three KPIs considered. This value was said to be the representative system value.

Table 1. KPI index in LTE Networks

KPIs	Test Cases
Accessibility	RRC setup success rate ERAB setup success rate Call Setup Success Rate
Retain-ability	Call drop rate Service Call drop rate
Mobilty	Intra-Frequency Handover Out Success Rate Inter-Frequency Handover Out Success Rate
Integrity	E-UTRAN IP Throughput E-UTRAN IP Latency
Availability	E-UTRAN Cell Availability Partial cell availability

There were a total of 739 sequences that were used to form a state transition probability matrix. This probability matrix can be then used for modelling a Discrete Time Markov Chain for predicting the long-run accessibility conditions of the system.

4 Work in progress

4.1 formulating Dicrete Markov Time Chain

The Markov process is said to be a stochastic process for $X_t : t \epsilon T$ such that for a point of observation $0 = t_0 < t_1 < .... < t_n < t_{n-1}$ for every state $s_i \epsilon S$, we have that the conditional probability distribution of $X(t_{n-1})$ depends only on $X(t_n)$ and not any previous values.

As such the Markov property will hold if:

$$P(X_{n+1} = S_{n+} + 1 | X_n = S_n, X_{n-1}, ..., X_0 = S_0) = P(X_{n+1} = S_{n+1} | X_n = S_n) \quad (1)$$

Thus given an initial state of s_0 and some initial probability, we can easily find the state that the system will be in after 'n' steps.

4.2 Notes

- safe to assume we can consider ICT systems to have three states, and show the transition between them
- Using DMTC as opposed to CMTC
- Availablity KPIs that can be considered: reference - [7]

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