Assessment of Interdependencies between Mobile Communication and Electricity Distribution Networks in Storm Fault Scenarios

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Abstract

The reciprocity between mobile communication and electricity distribution networks has increased with the introduction of automation and digitalisation of modern smart grids. Modernization of grids has prompted energy companies to seek the new cost effective and reliable wireless technologies to enable real-time remote control and monitoring of electricity distribution grids covering vast area. Traditionally, dedicated and private wireless communication network have been used for the automation purpose. But, with the advent of robust, ubiquitous and cost effective cellular networks, they can prove themselves as the best candidate for the remote control of the smart grids.

1 Introduction

Until now, there has been little research on the interdependency of mobile communications and electricity distribution networks for different types of fault scenario. We have implemented a simulation tool that enables a detail modelling of two networks and assessment of outages caused by failures if distribution entities and storms on communication network. The assessments were carried out in two different areas in Finland, Raasepori and Koillismaa. Based on the fault simulations, we tried to find answers to the following questions:

- Are GSM-900 and UMTS-900 networks sufficient for smart grid communication in a sparsely populated area?
- How vulnerable are commercial communication networks to different sized failures?
- How should smart grid and mobile communication networks be enhanced in order to make them more resilient and robust?

This paper also discusses the simulation results showing effect of power outages to the mobile communication networks and consequently to the remote control and monitoring of electricity distribution networks.

2 Coverage-redundancy calculation

In simulation tool, electrical distribution networks, 2G/3G mobile networks and 3D propagation environment are modelled in detail in order to make realistic simulations. Moreover, terrain height and vegetation information are used to compute the shadowing of large obstacles. Coverage prediction for all 2G and 3G base stations is computed. Several field trials were performed in order to fine tune and validate the coverage predictions. To affirm the reliability of the study, coverage raster weren't enough; therefore we computed redundancy rasters indicating numbers of the base station available at the given location for both networks. This value is termed as "cell count". Figure 1 and Figure 2 show coverage as well as redundancy rasters calculated in Raasepori, Finland for downlink direction. Redundancy rasters shows that both GSM-900 and UMTS-900 have good coverage and high redundancy near cities and along roads. Moreover, GSM-900 offers more redundancy level than UMTS-900. GSM-900 is primarily dedicated to provide coverage to rural areas while UMTS-900 provides additional capacity. The redundancy level of GSM networks was 5-12 while of UMTS networks 3-5.

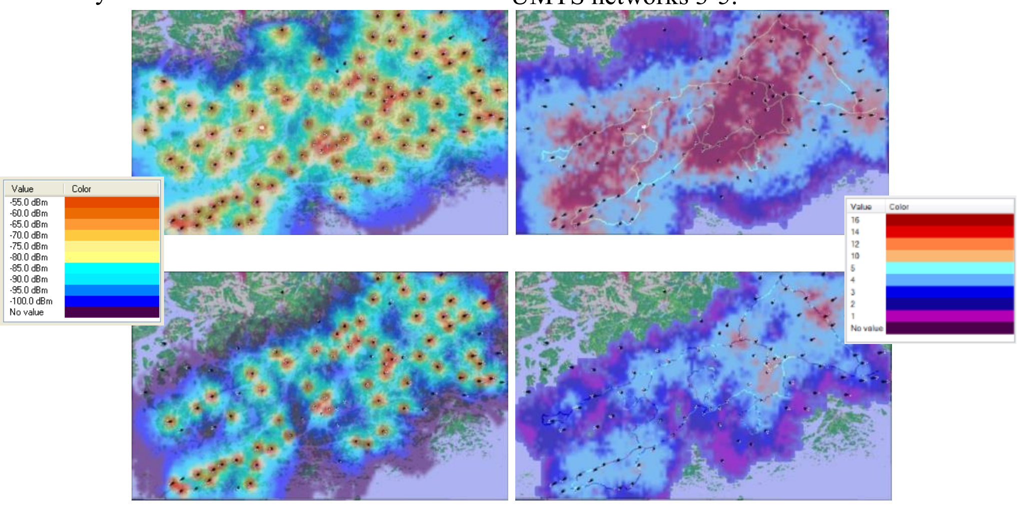

Figure 1 Predicted GSM 900 (Top) and UMTS 900 (bottom) DL coverage (left) and cell count rasters (Right) in Raasepori area

3 Storm Fault Analysis

For fault analysis, base station masts are connected to the electricity distribution network. Information pertaining to structure of electricity distribution network was obtained from energy companies. Fig 2 shows the electricity distribution entities including primary substation, disconnectors and secondary substation where entities are colored according to their feeder lines. Storm fault reports contain secondary substation specific information about when the outages started and ended. This information was very essential for modelling the failure and recovery of electricity distribution and telecommunication networks during a storm. Fault scenarios were simulated with and without battery backup on telecommunication masts. The battery backup prolonged the usage of communication links after the electricity was cut off from a communication mast.

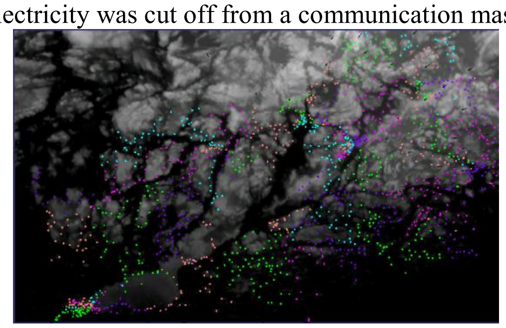

Figure 2 Secondary substations in Raasepori area

Storm analysis concentrates on storm Patrick that occurred in Raasepori, Finland in 2011.The Patrick storm case in Raasepori area is depicted in Figure 3. Red symbols indicate snapshot locations during the failure phase and green ones during the recovery phase. The red line shows the percentage of operational secondary substations, the light blue line operational masts and the dark blue the estimated area without coverage. In Figure 3, we can observe that the storm had two stages. In the middle of the first one, approximately 40 % of secondary substations were down. A significant number of those secondary substations were recovered within a few hours with the aid of electricity distribution network automation. As a result, over 75 % of secondary substations remained operational after the first stage of the storm. The second stage was more severe and over 75 % of the secondary substations went down. Clearance and repair work was started instantly after the storm and within 12 hours approximately 20 % of the de-energized secondary substations were repaired. The number of operational secondary substations increased approximately 15–20 % each day. After a while, the clearance work gradually got slower as the distances to the fault locations got longer. The light blue line shows the percentage of operational masts. It goes down at the same pace as the percentage of secondary substations. Approximately 65 % of the GSM-900 masts got de-energized at the peak of the storm. Since the clearance work began at primary substations located in populated areas with high base station density, the percentage of operational masts grew faster than the percentage of operational secondary substations. The growth starts to slow down as the clearance work moves further away from towns and main roads. As a result, the coverage loss was not as extensive as the power loss.

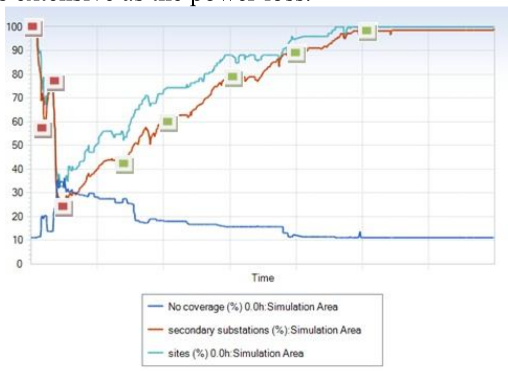

Figure 3 Percentages of operational secondary substations, active masts and the area without coverage based on the fault reports of the Patrick storm

Figure 4 shows the simulation run with 12 hours of battery backup on each mast. We can observe that those 12 extra hours would have helped the recovery. Approximately 25 % of the masts would have got their power back before the batteries would have run out. Consequently, the coverage loss would have decreased by 10–15 %. What makes this significant is the fact that the mobile network will remain operational and ease the clearance and repair work, and the remote control of electricity distribution network entities. As we can observe in the figure, the advantage of exploiting longer battery backup time decreases over the time as the clearance work gradually slows down.

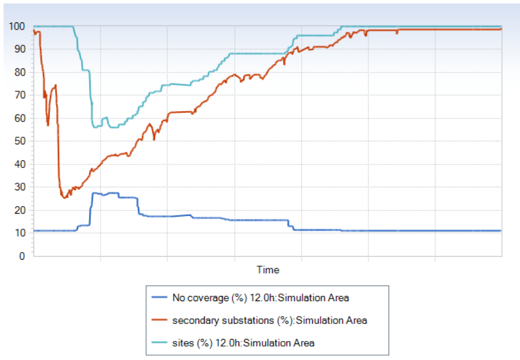

Figure 4 Percentages of operational secondary substations, active masts and the area without coverage based on the fault reports with 12 h battery backup.

4 Conclusion

The simulations indicated that ensuring power supply to critical base stations will improve the resiliency of telecommunication networks, which in turn will have a significant effect on clearance and repair work and wireless remote control of electricity distribution entities. The key factors of telecommunication networks' resiliency are the speed of the clearance work, the duration of battery backups, and coverage redundancy and base station radius.