DATA STORAGE SYSTEM FOR LS7001/LS8000 LIGHTNING DETECTION NETWORKS

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Abstract
In this paper a new improvement for lightning detection networks (LDNs), based on Vaisala LS7001/LS8000 sensors, is presented. The sensors of a LDN send the registered data online to a central processor (CP) to be stored. The percent of detected events and the level of accuracy in the positioning are dependent on the absence of failures in the communication network and on the guarantee of having no lack of data in the communications, mainly in regional and local networks, which are composed of a small number of sensors. That is because any data that are not gathered by the CP in real-time operation affect the final performance of the network.

The paper is structured as follows. First, this work analyzes the effects of the potential communication faults in the data quality. Then, a solution that allows the LS7001 and LS8000 sensors storing their data locally for further processing in the CP is described. The recorded data are organized in a non real-time total lightning database. Last, the improvement in the location accuracy and the upgraded integrity of the system are outlined.

This cost-effective solution can be applied to LS7001 or LS8000 (Vaisala, 2007) sensors in any lightning detection network. The benefits obtained from its implementation will lead to a better performance of the networks when analyzing historical data that will contribute to a better understanding of past meteorological episodes.

1. Architecture and normal operation of a lightning detection network

The lightning detection networks under study are based on the real-time operation of several sensors that perform lightning detections in different frequency bands (LF and VHF). Depending on the frequency, different techniques are used for calculating the detections. In the case of the LF subsystem, two different techniques are used: Time-of-Arrival (TOA) and magnetic direction finding (MDF). The LF subsystem performs, mainly, cloud-to-ground event detection. On the other hand, the VHF subsystem uses the interferometry technique for calculating the locations of the intra-cloud sources.

These two subsystems send real-time information to a central processor (CP) (Vaisala, 2004) that calculates lightning solutions with the data gathered from all the sensors participating in the detection of each discharge.

The CP stores the basic measurements provided by each sensor in daily raw files and the solutions in daily product files. It also sends the solutions to a real-time database and to the on-line monitoring system used for surveillance purposes. The architecture of the network and its on-line operation can be seen in Figures 1 and 2.

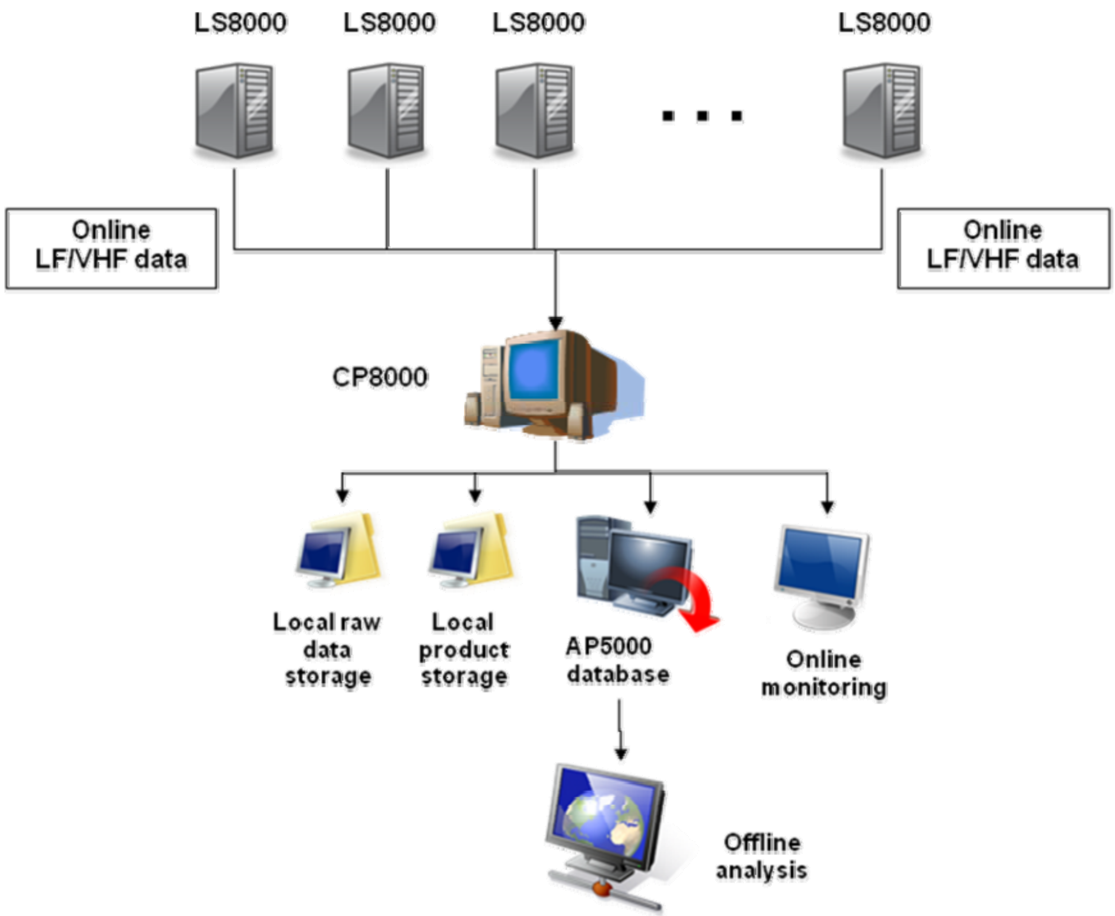


Fig. 1. Architecture of a LS8000 lightning detection network

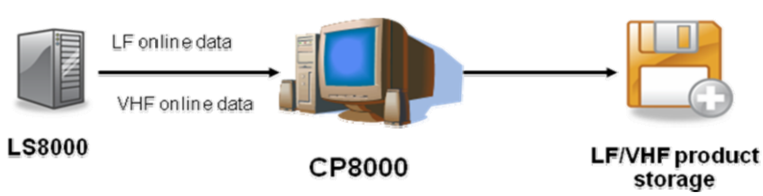


Fig 2. On-line storage of the data detected by the LS8000 sensors.

1.1. The effect of failures in the communication links

When the communication link fails, the sensor continues its normal operation. The data from the sensor do not reach the CP due to the communication failure, however, and consequently, the data are lost. The loss of data from one or more sensors in a network will lead to both higher uncertainties in the final solutions calculated by the CP and fewer solutions overall due to reduced probability of detection. Therefore, the quality of the data will be degraded, as they rely on the information retrieved only by a part of the network in real-time and the historic database would be incomplete.

In large networks, the normal operation is assured because of the higher number of sensors contributing to the final solutions. That is, there is some redundancy that avoids performance problems due to failures in the communications with one or more sensors in the network. This redundancy makes a temporary data loss from a sensor less critical and the location accuracy of the detected events is not degraded.

However, in regional and local networks the number of sensors is lower and it is fitted to the coverage area. Consequently, a failure in the data links is decisive, because it will cause a considerable loss of accuracy, as well as non-detection of some episodes.

The communication failures cannot be avoided in the normal operation of a lightning detection network. Nowadays, lightning data analysis is carried out using only the available data in the real-time database. Therefore, only the products calculated with the contribution of the on-line sensors during the storm episode can be taken into consideration. Furthermore, even in an off-line mode, if the raw sensor data were not present to begin with, reprocessing does not improve either location accuracy or detection efficiency. The main goal of this work is to assure the data quality at least for off-line analysis.

Some improvements and additional equipment must be incorporated to those networks with a limited number of sensors, so that it can be guaranteed that there will be no loss of data although there might be communication cuts. In this paper, the necessary algorithms and equipment for implementing the data storage and recovery system and its implementations in a regional network based on the operation of four sensors are described.

2. Description of the Data Storage System

Total lightning (Demetriades, 2004) sensors work with two different subsystems (LF and VHF) for the different technologies in use. As these subsystems work independently, it is necessary to control both data flows for an optimal in-situ storage of raw data. In this section, the necessary equipment and the algorithms developed for both subsystems are described.

2.1. LF subsystem

The LF subsystem of the lightning detection sensors is responsible for generating cloud-to-ground products. This subsystem is configured for sending real-time data to the CP.

The Data Storage System developed in the Basque Country is based on a script written for this purpose that redirects the data flow to a local file. The procedure uses the combined capabilities of the LF software modules of the LS7001/LS8000 and the operating system of the sensor.

The proposed process allows the redirection to a local storage without disturbing the normal operation of the LF subsystem, as it sends data from the LS8000 sensor to the CP via the normal communication link.

In case this link goes down, the data sending to the CP would stop. However, the developed script would keep on redirecting data to the local file and the LF products would not be lost. Figure 3 shows the operation of the improved LF subsystem. With the Data Storage System, the detected data are sent from each sensor to the CP in real time as long as the communication channel is available, while these data are also redirected to a local file. In the event of a communications outage, the file containing stored data can be reprocessed with all the on-line data from the rest of the sensors, for generating a reprocessed dataset different from the on-line products obtained during the communications failure.

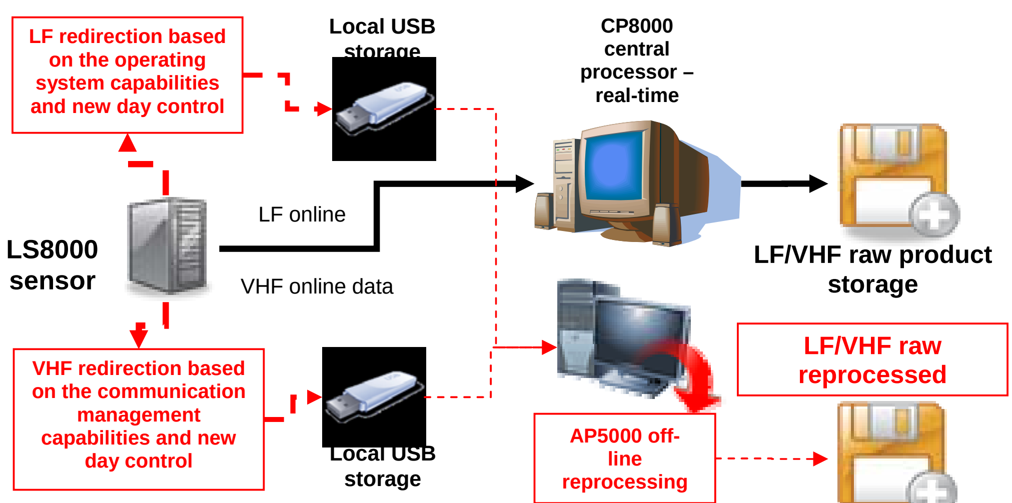


Fig. 3. Improved operation of the LF and VHF subsystems (improvements marked in red)

2.2. VHF subsystem

The VHF subsystem in the sensor provides the necessary information for product calculation based on the interferometry technique.

In this case, it is not possible to develop a process based on the VHF data acquisition module in the sensor, as has been carried out in the LF subsystem. In the normal operation, the VHF subsystem sends the data to the CP using a permanent channel with a defined port. The internal process that generates the data packets automatically sends these data to the CP, without possibilities for a parallel redirection.

For this reason, the solution adopted in this case consists of the redirection of the on-line data flow to a local file. Therefore, the developed procedure is based on the network connection management capabilities.

Prior to the redirection of the data flow, the system connections are checked. Once the data connection is identified, the data flow can be redirected to the local file. In this case the data flow redirection requires a previous knowledge of how the communication ports are managed in the sensor and in the CP. With this purpose, a study of how the communications are managed in the sensors and in the central processor must be carried out. The operating system allows a direct access to this information.

Figure 3 shows the operation of the improved VHF subsystem in a sensor. The proposed system allows the obtaining of a dataset with locally stored files. These files may be combined with the data retrieved on-line from the other sensors in order to a proper and accurate off-line analysis.

2.3. Data redirection and management of the stored data

The redirection of the data flow to local files stored in an external USB drive requires an automatic management of the generation of these files.

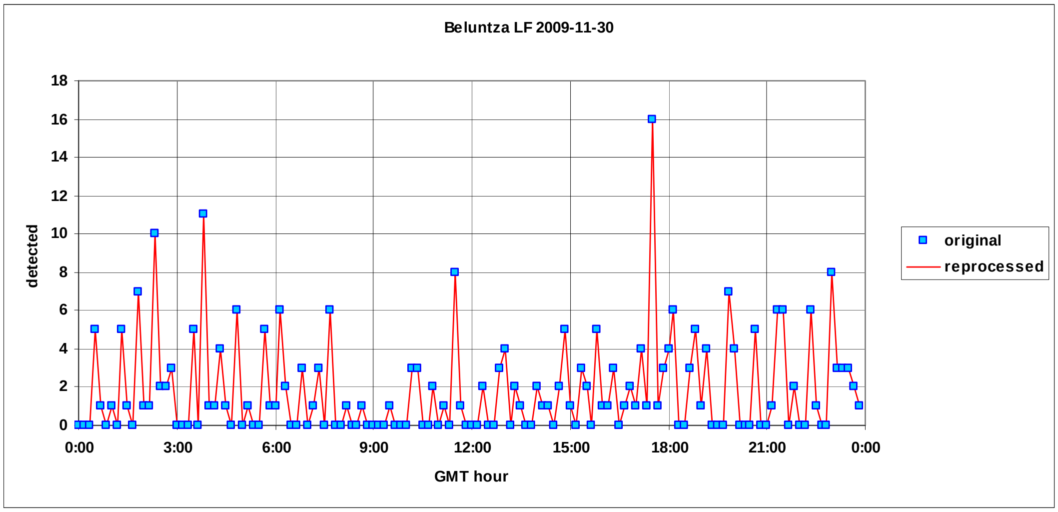
The data stored are structured in files with daily data. Moreover, the data from the two subsystems, LF and VHF, are differentiated and identified with different tags. The proposed solution brings redundancy to the entire system. The operating system in the sensors does not have a synchronization tool for synchronizing the execution of the redirections, and it is necessary to control the opening and closing of the files for maintaining the daily creation of the data backup. Two different scripts have been developed for redirecting both the LF and the VHF data flows. The scripts have been programmed as shell scripts, using the available features of the operating system.

The scripts redirect the data flow to be stored in a local file in the external USB drive at the beginning of the operation, and it is closed at the end of each day, opening a new one for the new day’s data.

2.4. Reprocessing procedure of the recovered data in the CP

The daily data files stored in the USB drives can be retrieved manually from the CP when the communication link is recovered. The reprocessing of these data is carried out by using the same processes that operate in real-time. This reprocessing generates new information in the raw data files in the CP. This may corrupt the real-time generated raw files, appending the new information to the files. Therefore, the reprocessing must be carried out in a different machine. In the network architecture presented in Fig. 1, the AP5000 is the machine storing the real-time database. The purpose of this machine is the management of the real-time database. However, it also incorporates the data processing procedures that exist in the CP. They can be invoked in order to locally generate raw files apart from the CP. With this action, the generation of new raw files is ensured, and they can be directly compared to those generated in the CP during the real-time operation.

The following picture shows a comparison between the data retrieved in real-time and the data stored in the local USB drive for the LF and the VHF subsystems in one of the sensors in the Basque Country during a period when no communications failure occurred.



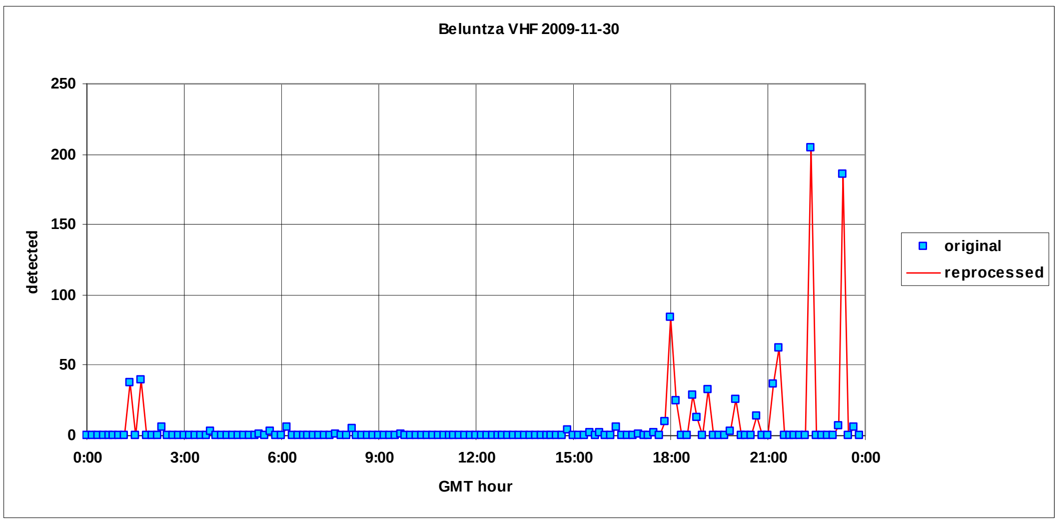


Fig. 4. Comparison between the original data and the reprocessed data for the LF and VHF subsystems in the Beluntza sensor

Fig. 4. shows a direct match between the original information received in real-time in the central processor and the data saved locally in the sensor, thereby confirming the proper operation of the local storage capability developed for the sensor. These data were recovered and reprocessed in a different CP for generating this comparison.

3. Implementation of the Data Storage System in the Euskalmet LDN

The network in use in the Basque Country is composed of four sensors that are permanently connected to a CP located at the central offices of the Basque

Meteorology Agency (Euskalmet). The network is designed with the purpose that at least three sensors be always available for an optimal location of lightning events.

This regional LDN consists of four LS8000 sensors performing total lightning detections in the Basque Country (Gaztelumendi, 2009), covering a territory of, approximately, 7000 km^2. The reduced number of sensors compromises the overall performance when one of the sensors is off. This problem also happens if one of the network links used for communicating a site with the CP is down. In some situations, relying only on three sensors for accurate detections is not enough. If two of the network links are down, the on-line data quality cannot be relied upon at all.

An improved operation of a lightning detection network is under study in the Basque Country, consisting of local data storage in the sensors. This requires an exhaustive knowledge of the data retrieval processes running on the operating system of the sensors.

The proposed data storage system has been implemented in the sensors of the Basque Country LDN. The operation of the data storage system has been reviewed in the last months and further improvements regarding the opening and closing of the daily files, and the management of the space in the USB drive, are being carried out.

4. Conclusions

In this paper, a complementary system for local data storage in lightning detection sensors has been presented. This improvement to the sensors in a LDN allows a better performance in those cases when the communication links with one or some of the stations fail.

The proposed solution is especially useful for regional or local detection networks, where the number of sensors is limited and the redundancy is not feasible. The proposed storage system allows a further reprocessing of local data together with the lightning information retrieved on-line by the sensors that remained connected to the network. Therefore, although the on-line performance is reduced in case the communications fail, a reprocessing of the complete dataset once the files have been retrieved allows a better understanding of past events.

The proposed complementary data storage system is cost-effective, and it can be easily implemented in all LS7001 and LS8000 networks, achieving a better overall performance for the analysis of past lightning data. This system provides redundancy in the data detected by the sensors. It is being implemented in the lightning detection network in the Basque Country.

5. References

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