

Press the Button: Online/Offline Mobile Applications in an Agricultural Context

GI_Forum 2016, Vol.1

Page: 106-116

Full Paper

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DOI: 10.1553/giscience2016_01_s106

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Abstract

In many developing countries, smartphone and internet usage has become a revolution for the population and has opened up many possibilities to use new services for communication purposes. For researchers and development organizations, it is now possible to engage more directly with beneficiaries during the implementation phase of a project. However, many regions still face the problem of a non-existent or unreliable internet connection, which is why mobile applications have to be able to work offline as well as online. In order to achieve this, the new OGC standard Geopackage was used to create an offline mobile application. Geopackage can be integrated with a native Android mobile application and is especially useful for connecting with different GIS tools, since it is interoperable with various important platforms.

Keywords:

geopackage, mobile application, offline, open

1 Introduction

Within the last few years, mobile phones and smart applications, often referred to as Internet Communication Tools (ICT), have become part of our everyday lives, indispensable for how we communicate at work and for our modern lifestyles. In contrast to wired internet services, the mobile internet offers an efficient way to reach and communicate with people in remote parts of the world and enables feedback in almost real time. In fact, for the community of researchers and development organizations it has triggered a minor revolution in closing any remaining gap cost-effectively and allowing more direct engagement with many beneficiaries, such as smallholder farmers, during the project-implementation phase (Rao, 2007).

Urban areas of developing countries are still mostly better-connected to mobile and internet services (Kasusse, 2005) than rural areas, where a lack of access to these services is evident. Nevertheless, mobile phone and internet coverage is now reaching many remote areas of the

world which before were isolated (May, Diga, 2015). In Africa especially, mobile phones have proved revolutionary for rural populations, opening up many possibilities to use new services that make daily life easier. Two examples of these new services are the mobile payment system, and the information services for farming (Agricultural and Rural Development (ARD), 2011). Mobile phone penetration in Africa has grown exponentially in recent years. However, while most people (65%) in Sub-Saharan Africa use mobile phones, only the minority use smartphones (15%). Comparing these figures to those for the U.S., where 64% of the population uses a smartphone and 25% uses a mobile phone, highlights the great differences in the use of ICT between different areas of the world (Poushter & Oates, 2015). Furthermore, in Sub-Saharan Africa the lack of access to ICT is often correlated with poverty (May, 2012).

Research into agricultural smallholder systems in developing countries requires socio-ecological data in order to understand the experiences of farmers within agricultural and cultural contexts. Some researchers are integrating the farmers in field experiments following a citizen science approach and are collecting huge amounts of data through crowd-sourcing using ICT (van Etten, 2011; Bonney et al., 2016). In the era of Big Data, the demand for and the process of collecting data have changed; researchers are now looking for large quantities of massive data in order to find patterns to better understand, for example, agricultural systems. As a consequence of the better availability of georeferenced data, tools and applications are emerging rapidly in the development sector, bringing many new opportunities to analyse data in order to better understand site-specific constraints and determine possible best-fit solutions (ARD, 2011).

One example for establishing information-exchange between scientists and farmers using ICT is the Climate-Smart Agriculture Implementer (CSA Implementer). The aims of this project, carried out as a pilot in rural areas of Tanzania, were to support local implementers of climate-smart agricultural practices with useful scientific research outputs and to establish a two-way communication loop during the implementation process in order to monitor and evaluate the success or failure of agricultural practices. The project's objective was to combine research results with the farmers' knowledge and use an interactive platform for realizing the communications. The platform is based on an existing framework, the Geocitizen approach (Resl et al., 2012). The Geocitizen framework provides a platform where citizens and communities can communicate with each other in order to enhance the spatial planning process (Atzmanstorfer et al., 2014). The CSA Implementer uses the concept of the Geocitizen approach but extends its functionalities and database with a monitoring and evaluation component for implementing proposed solutions. The CSA Implementer also constructed a mobile application, based on the existing framework, for use in the field (Eitzinger et al., 2015).

Establishing mobile applications in addition to desktop applications has become a necessity, since GIS and the mobile internet have developed rapidly and are now widely used. A Mobile Geographic Information System (Mobile GIS) provides geospatial information to the user of a mobile phone and thus extends the desktop GIS with a mobile GIS in order to help collect data in the field. This development also allows the addition of a spatial component to information collected via GPS, or simply allows access to, and visualization of, spatial data in the field (Fangxiong & Zhizong, 2004). Mobile GIS enhances and facilitates the reviewing of

existing data and the acquisition of field data, thanks to the existing technologies of GPS and mobile internet, and therefore plays a significant role in the data collection process. Subsequently, updating existing data while in the field can be accomplished via an internet connection (ibid.). One issue to note is that a Mobile GIS requires a small computer, which is the main difference from the desktop GIS. Other things to be taken into account when using a Mobile GIS are that a mobile device has a limited storage capacity, lower screen resolution, and slower CPU (Tsou, 2004). Hence, the infrastructure of an application for use on a mobile device has to be built in a light-weight way, and the data format has to be addressed because of the limited storage capacity.

The use of a SQLite database is common on many popular mobile applications because it stores the data in a single local file and allows the user full database and SQL functionalities (Mahmoud et al., 2012). SQLite is also popular because it allows the light-weight storage of a big dataset which can easily be transferred onto other platforms. The newly-formulated OGC standard Geopackage is based on a SQLite database. The standard was introduced in early 2014 and was created with the purposes of (a) providing a light-weight format for use on mobile devices with limited internet connection and (b) creating an interoperable and cross-platform format which would overcome the limitations of proprietary geospatial data storages and formats. Vector and raster data as well as metadata can be stored in a Geopackage (Open Geospatial Consortium, 2015). For tile storage, however, there is a well-established alternative format to Geopackage, namely MBTiles, introduced by Mapbox. Like Geopackage, it is based on SQLite and used for the light-weight storage of a large quantity of tiles. It is used for mobile as well as for desktop applications and the visualization of map tiles (Mapbox, 2015).

These formats allow data to be stored on a mobile device and therefore to be used in the absence of a stable internet connection. This is especially essential in rural areas of developing countries where scientific projects may be conducted and where the application is a useful tool for project implementation. These areas of the world still face the problem of a non-existent or unreliable internet connection. The need to create the application in such a way that it does not have to rely on a functional internet connection for the user to access the data is therefore evident. Hence, it is important to create an application which works well with an internet connection but is independent of it. Instead of adopting two different Mobile GIS architectures which work either offline (stand-alone) or online (distributed architecture), Bogossian et al. (2014) suggest the creation of a single architecture which works offline as well as online, depending on the availability of an internet connection.

In this paper, we provide a framework that uses open standards for visualizing and accessing spatial data in ICT mobile applications embedded in an agricultural development context. The overall aim is to support online access to data, and the ability to access and modify the data while functioning in offline mode. Furthermore, the use of open source software is a necessity because commercial products are less readily available in developing countries. Another requirement is the use of interoperable data formats, following standards recommended by the Open Geospatial Consortium (OGC). For this reason, Geopackage was selected as a format for data storage. Since this is a fairly new format, the ease of integrating it, as well as its performance and interoperability were tested and evaluated.

First, the methodology for extending the existing application framework as well as the challenges of integrating an online/offline function into the mobile application are addressed. The results are then presented for the suitability of Geopackage as a means of accessing data in an offline mode. The results are then discussed, and suggestions for future work are given concerning possible improvements and extensions of the mobile application.

2 Methodology

Extension of the Geocitizen Framework

The Climate-Smart Agricultural Implementer (CSA Implementer) was set up in 2014 and uses the framework provided by the Geocitizen approach. The first extension of the Geocitizen approach was to apply the framework to the CSA Implementer, with adjustments made based on the characteristics of the CSA Implementer. The two main adjustments were: (a) to generate a sub-version for use as a mobile and web application in the context of agricultural development; (b) to establish monitoring and feedback functionalities for use during the implementation of agricultural practices by local farmers and agricultural experts. The mobile application helps connect local farmers with scientists in order to facilitate communication and interaction during project development, and to create a feedback loop of acquired knowledge and learning experience. The application is used in the field in rural areas for accessing information about climate-smart agricultural practices and for collecting, updating and modifying existing data. However, there are often issues with the internet connection in rural areas of countries such as Tanzania. It therefore became evident that, in order to improve the framework and introduce it to other developing countries, an offline version of the application was highly desirable. Introducing an online/offline function for mobile applications can be seen as the second step in extending the existing framework of the Geocitizen approach.

Challenges for Integrating an Offline Function

By extending the mobile application with an offline function, the user is enabled to switch from an online mode to an offline mode (Figure 1), depending on whether a connection to the internet can be established. The ideal way to work with the application is to use the online mode of the application when the full set of data can be made available. Sets of data held by external servers can be requested and the desired data sent to the user. What data is required depends on specific interests and can vary from region to region, the spatial extent or the variables. Because the mobile device has a limited storage capacity, only a reduced version of the data is available in the offline mode. The inclusion of an offline mode in an application requires the prior definition of which data will be of interest for potential users. This is an important step because the data has to be downloaded and stored on the application before using it in the offline mode.



Figure 1: Online/Offline Mode of Mobile Application

Two sets of data are of importance for the application: (a) vector data with point information regarding farmers' activities, questions raised, and information regarding agricultural issues generated within the project of the CSA Implementer; (b) raster data, which is used as a basemap and provides background information on the region. Both types of data can be easily connected to Map APIs via internet services. In contrast to this, visualizing the data in an offline mode brings up a different set of challenges.

The first challenge is the data size. Reducing the data size as much as possible is a relevant objective for the creation of mobile applications. The bigger the dataset, the more mobile storage is required, which is a problem since the data storage capacity of mobile devices is limited. Raster data, compared to vector data, could produce very large datasets for the same information and therefore may occupy more storage space. Consequently, reducing the size of raster datasets especially, which function as basemaps, needs to be addressed. Making available a basemap for every area of the world and for every zoom level would produce an enormous dataset which could not be handled by a mobile device. Therefore, before creating the tiles, consideration needs to be given to which regions or countries need to be visualized on the map.

A second challenge is to understand the best way to store the data. Data format can have crucial impacts on the data size, performance, and data quality. Two data formats are highlighted in the context of this paper, because they allow light-weight storage: Geopackage and MBTiles. While MBTiles is used only for creating offline basemaps, Geopackage can be used for both vector and raster data. The challenge here is to evaluate how well Geopackage can be integrated into the application, and whether Geopackage is suitable for the storage of both data types. Therefore, it is important to evaluate its integrability into the structure of the application, but also its interoperability with tools which surround the application – the PostGIS database where the vector data is currently stored, and GIS tools.

A third challenge is to integrate Geopackage, and with it the offline function, into the application. The concept is to use Geopackage for both data types but to reduce the size of the raster data by pre-selecting regions to be displayed. For the online mode, however, external services for visualizing the basemap can be accessed. Both ways of accessing the data have to be integrated into the application in an efficient manner and with a smooth transition between the modes (Figure 2).

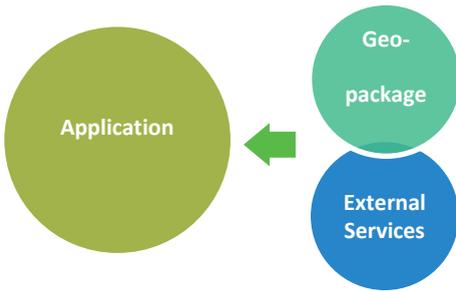


Figure 2: Concept for Integrating Geopackage

3 Results

One of the main objectives of this work was to test the integrability of Geopackage into the mobile application. Therefore, the application was created in such a way that the components of Geopackage worked smoothly with the other components of the application. As illustrated in Figure 3, the program Maperitive was used for the creation of tiles and for generating the Raster Geopackage. OpenStreetMap data was chosen to provide the basemap information, since it offers geographic data without any restrictions. Maperitive downloads the OpenStreetMap data for a user-defined region and produces tiles as a Portable Network Graphic (PNG). These images are then converted into Geopackage using a Python Module for Geopackage Conversion.¹ The tiles in the Raster Geopackage are stored as Binary Large Objects (BLOBS).

In contrast to that, the Vector Geopackage stores vector data with point information for, for example, different agricultural activities. This point information is stored in a PostGIS database and can be converted into Geopackage using the GDAL library. Both Geopackage databases (Raster and Vector Geopackage) were subsequently imported into the application framework.

The application works in two modes: an offline and an online mode. If an internet connection is available, the application works in online mode and accesses the basemap information via a URL to, for example, OpenStreetMap or GoogleMaps. The JavaScript library Leaflet is used for creating the maps on the mobile device and was chosen because the code is open-source and restriction-free. The coordinates and attributes of the point data are then sent to Leaflet via an interface connecting the native Android application with the Leaflet library. Leaflet takes the stored coordinates of the Vector Geopackage and draws them as markers on the basemap.

If no internet connection can be established, the application can be switched to offline mode. This means that the basemap, accessed via a URL, can no longer be accessed. Therefore, Leaflet has to request the tiles which are stored in the Raster Geopackage and located in the mobile application framework. The application then asks for the coordinates (x and y) and the zoom level (z) of the tiles. The tiles are converted from BLOBS to bytes,

¹ <https://github.com/GitHubRGI/geopackage-python>

and subsequently to String Base 64 format in order to visualize them on the map. The string values of the tiles and the coordinates and attributes of the point data are then sent to Leaflet.

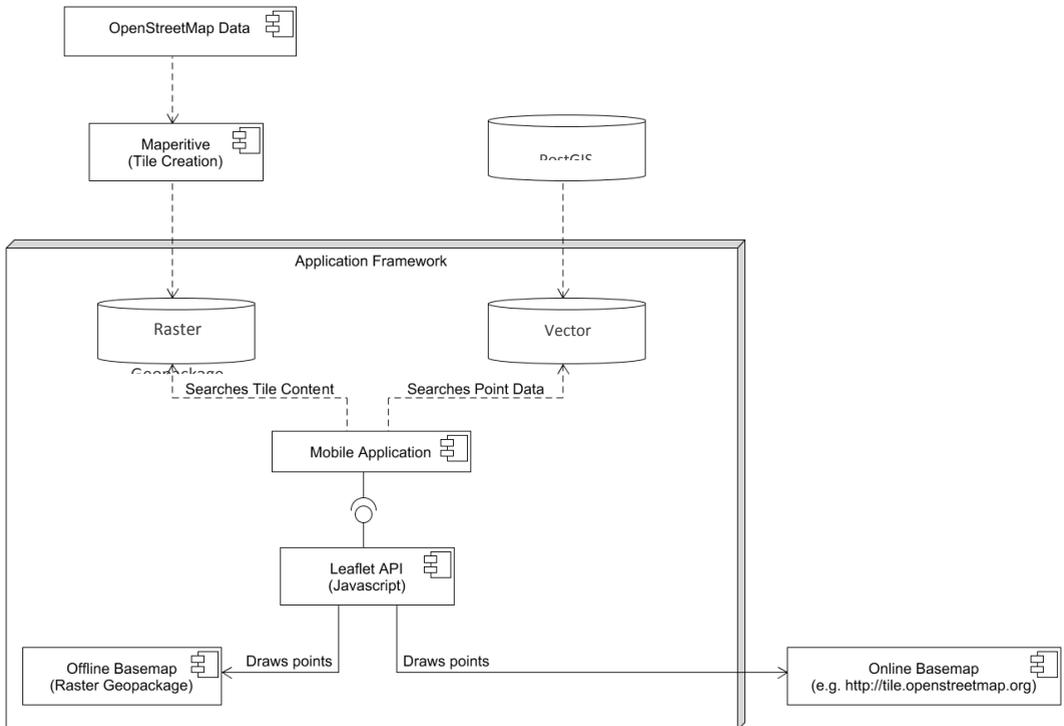


Figure 3: Components of the Mobile Application

The mobile application is a native Android application developed using Android SDK 16, which supports mobile devices with an Android version of 4.1 (Jelly Bean) or higher. It integrates all components of the application framework with the aim of visualizing the data on a map (Figure 4a).² In the settings section, the user can switch from online to offline mode, define the online basemap, and download the previously-created tiles which serve as a basemap in the offline mode (Figure 4b).

² Source code available at: https://github.com/CIAT-DAPA/cs_online_offline_map_application

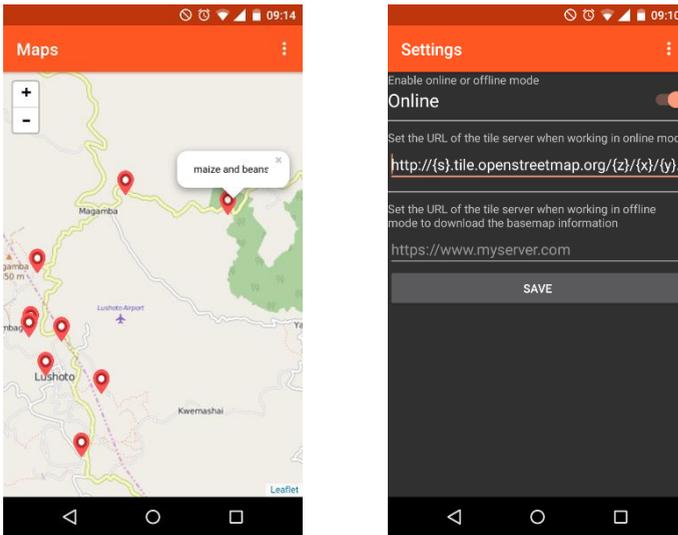


Figure 4: Final Mobile Application: (a) Screenshot of Map; (b) Settings Section

Vector data from previous projects is stored in a PostGIS database and can be converted via the GDAL library to the Geopackage format without intermediate steps. It can subsequently be stored in the mobile application (Figure 5). Additionally, Geopackage can be imported into PostGIS (via GDAL), which is useful if changes are made in the Vector Geopackage of the mobile application that then have to be stored in the PostGIS database. Geopackage can also be directly imported into QGIS for GIS analyses. Geopackage proves to be very useful and interoperable with other GIS tools, and can be easily converted with GDAL into other formats if necessary.

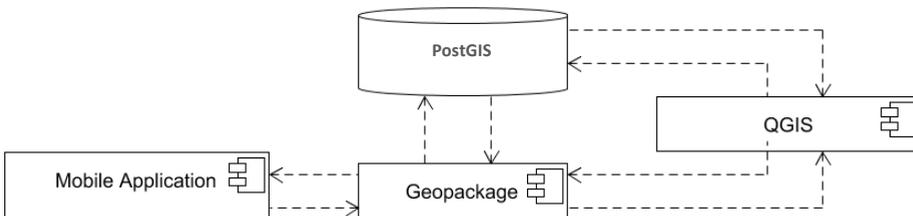


Figure 5: Interoperability of Geopackage

4 Discussion/Outlook

Various issues emerged during the development of the application and the integration of Geopackage. The problems were primarily in using the Raster Geopackage, which stores the tile data for the basemap. The format stores the data as BLOBS. These, however, are not compatible with older versions of Android. Therefore, the BLOBS have first to be converted

into String Base 64 format; subsequently, Leaflet converts this format into PNG for creating an image. This conversion procedure requires more processing time (the same problem is posed by the MBTiles format) and decreases the performance of the application in the offline mode.

The advantage of working with Geopackage is that it is an open standard formulated by OGC and is integrable with other GIS tools without too many difficulties. The work with the Vector Geopackage and its integration into the mobile application went smoothly. By contrast, the integration of the Raster Geopackage into the application required some intermediate steps, and loading the offline tiles into the map took longer than loading the online basemap. It may therefore be interesting to compare the performance of the Raster Geopackage with other possibilities for storing tiles. As mentioned above, MBTiles is an alternative to Geopackage, which, however, presents the same problems of conversion into a Leaflet-compatible format as BLOBS. Another alternative would be to load the generated tiles as compressed files into the mobile application. The tiles could then be requested by Leaflet and displayed on the map.

It is also interesting to compare the data size of the Vector Geopackage with the data size of the formats Shapefile, CSV, GeoJSON and KML. For the comparison, 2,600 points with different agricultural information relating to an Indian province were stored in these different formats (Figure 6). It can be noted that Geopackage, with 500 KB, is very small, and therefore has a similar size to CSV (488 KB). GeoJSON with 1,140 KB and KML with 972 KB are nearly double the size of Geopackage. Shapefile, with 6,590 KB, is by far the largest format.

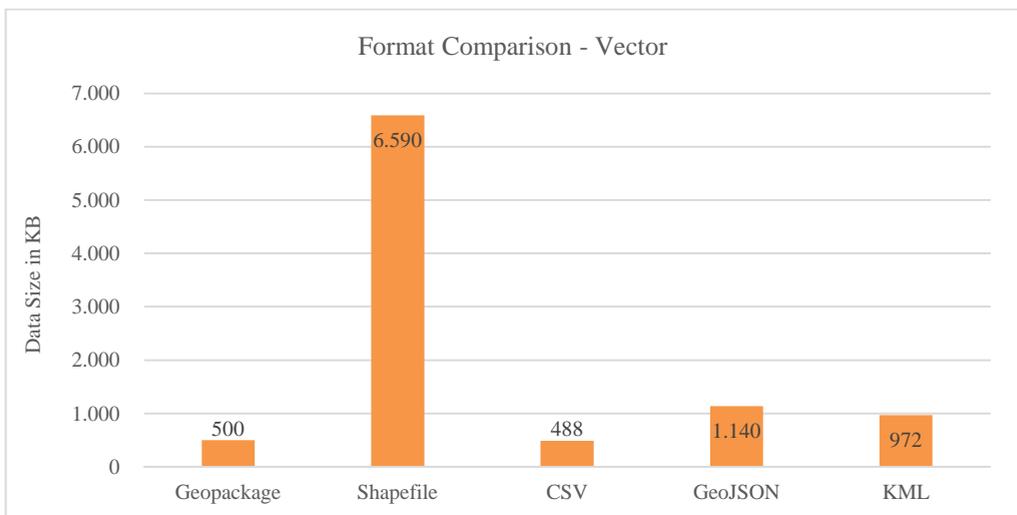


Figure 6: Comparison of Data Size of Geopackage, Shapefile, CSV, GeoJSON and KML

For future work, it would be useful to carry out a more sophisticated comparison of Geopackage and other formats, and to include a comparison of their respective

performances. The execution time for visualizing the data as well as the process of integration into the application of the different formats could also be compared.

Additionally, the performance of the Raster Geopackage within the mobile application should be observed in greater detail; the causes of the slow loading of tiles and the solutions for this could also be examined further. This also applies to the Vector Geopackage, which was slow in loading a higher quantity of point data (2,000 points). To tackle this problem, a hierarchy for loading points depending on their attributes and zoom level could be devised, and points could be grouped as marker clusters.

Another issue to be addressed in future work is the automatic synchronization of the point data once the mobile device has established an internet connection (Figure 7). The mobile application would be connected to a web service and send or receive data for updating purposes. This would be useful if the mobile device was used in the offline mode and changes were made to the point database. Once an internet connection is established, newly-generated data can be synchronized with the central database via web services. The central database could then be used as the central storage point of the tiles generated offline as well as of the vector data containing the point data.

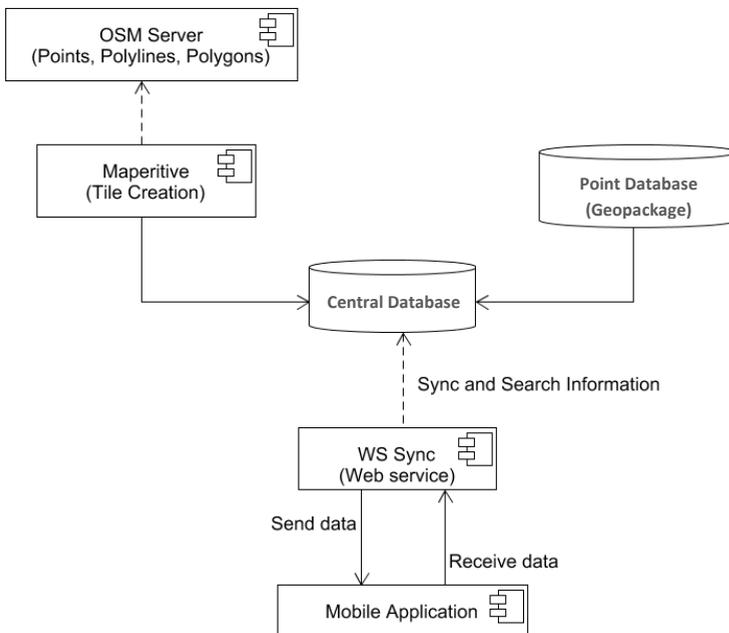


Figure 7: Extension of Mobile Application for Synchronization of Data

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