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Smart Energy Utilities based on Real-Time GIS Web Services and Internet of Things

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Abstract

Problem: The power & electric outages cause business disruptions that result in economic impacts to cities. A web map service (WMS), as a RESTful API with URL, that makes real-time information of power outage and economic loss estimation accessible and available across the web would be valuable and important for decision makers in smart cities and smart energy utility.

Objective: This paper presents a web-based system that is capable of creating real-time WMS. Our system enables geo-enabled applications (such as web mapping, mobile GIS app, operations dashboard) to access, query, and display a web map of real-time outage status and economic loss information associated with outages in the county scale.

Method: Our method is based on the Internet of Things (IoT), web services, GIS web services, web mapping, and web GIS (Geographic Information Systems). To implement our system, we used esri ArcGIS for Server, SQL Server Spatial, Amazon Web Services, and C#.NET. The system architecture consists of autonomous computer program, spatial database, GIS Server, cloud computing platform, a WMS, web feature service (WFS). Our insight is in real-time by continuously 1) connecting to web sensors and collecting outage data, 2) connecting to web services for calculating economics loss associated with outages, 4) manipulating (modify, insert, delete) our spatial database over the Internet, 4) publishing a real-time WMS.

Result: The system implementation resulted in a back-end server that includes /serves a real-time WMS. A data record includes: name of county, name of state that contains this county, total number of costumers located within the county, total number of costumers without electricity who are located into the county, and total economic losses (modeled as total jobs loss, total GDP loss, and total cost in $) caused by outages for the county.

Findings: Real-time WMS created by our system can be used by applications to display and query a web map of electric outage status and their macroeconomic loss in real-time. They provide a decision support tool for disaster emergency management in the energy sector by aiding in prioritization of restoration operations and recovery phase in electric utilities in order to reduce the economic impact of outages. Our system provides an important platform for smart cities, real-time GIS, Internet on Things, map-based crowdsourcing applications, real-time intelligent systems, and for real-time monitoring and analytical applications.

Peer-review under responsibility of the Conference Program Chairs.

Keywords: cloud; Internet of Things; sensor network; power outage; economic loss; electric utilities; spatial web service; smart cities; real-time GIS; web GIS

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1. Introduction

Problem: Electric & power outage in power & electric utilities is a short-term or long-term loss of electric power in an area. In a macro-geographic scale, an outage record is a set of information: name of county for which the outage is reported, name of a state that contains this county, number of costumers who are served by and located within this county, number of customers (business and commercial units) without electricity, and time of last update in which these data are observed. These data are open and free and are accessible in power & electric companies' web sites.

A web sensor reports a number of outage records in real-time. Indeed, a web sensor makes outage data publicly available through web services API (URL) with web data formats such as JSON across the web. For example, we are able to access and collect outage data sensed by the Dominion power company through an API (please see footnote[1]). These outage data are updated every 15 minutes to show the real-time status of power outages (please see footnote[2]). It is assumed to dedicate a web sensor to a power company. Therefore, a sensor network indicates a set of web sensors.

Outages cause economic loss (E.L. in short) due to business disruptions. Outages can impact electricity consumers primarily through property loss and business disruption. The Electric Power Research Institute estimated that the annual cost of outages across all U.S. business sectors was $104 billion to $164 billion in 2001. With the estimating the average number of power outages in a year over five minutes, a reasonable estimate for the annual economic cost yields a possible $20 billion to $31 billion as a lower range [1]. The 2003 blackout in the northern and eastern U.S. and Canada which caused a $6 billion loss in economic revenue is one of many indicators that the current electrical grid is outdated [2].

Economic models are used to assess E.L. associated with outages in counties. Losses are usually presented by the total GDP loss in USD$, total jobs loss, and total cost in USD$ in each county. Our focus is on the county level since the web sensors reports outages in counties. These models should be executed in real-time as soon as a county experiences an outage situation relative to the anticipated duration of the outage.

Outages become a crisis when an unpredictable event such as a hurricane or flood causes a widespread outages. Consequently, outages generate vast negative economic outcomes over an extended period of time. Specially, when an affected county contains many business and commercial units.

Motivation: Imagine a catastrophic hurricane Matthew hit the Florida State on October 2016 and caused widespread outages in 67 counties. An efficient action plan for restoration operations results in reducing the economic impacts of outages. Thus, the disaster emergency management department are faced with some main questions: 1) what is current (real-time) status of outages and also spatial distribution of outages in 67 counties? 2) what is current (real-time) status of E.L. associated with outages in each county? 3) which county should be considered as the first priority in restoration operations? 4) how much loss can be reduced if a certain county is restored ?

Importance of Problem: It is important to collect outage data from the sensor network in real-time, analyze the gathered data and estimate E.L., and share information (collected outages and calculated E.L.) in real-time through real-time and dynamic maps. This type of real-time map creates situational awareness.

This process is valuable for decision makers, emergency managers, industry partners, and operational decision support, as well as pre- and post-facto planning to have an accurate real-time perception (understanding) of outage crisis. Thus it enables them in a real-time mechanism to monitor outage status and their economic impacts. Moreover, it assists them a real-time mechanism to prioritize the restoration/recovery operations of critical hubs and services in order to reduce economic loss due to outages.

Research Question: Considering the fact that there is a sensor network, how can outage data be collected in real-time, E.L. be estimated in real-time, and this information as a real-time and dynamic map be shared by users through real-time web services API?

Objective: We aim to build a web-based system for smart cities. Our system is capable of 1) connecting to web sensors and collecting outage data from them, 2) connecting to web services that provide economic loss estimation (E.L.E. in short), 3) manipulating our spatial database across the web, 4) providing real-time WMS for applications

[1] http://outagemap.dom.com.s3-website-us-east-1.amazonaws.com/resources/data/external/interval_generation_data/2017_01_24_20_30_30/report_region.json?_=1485290067372

[2] http://outagemap.dom.com.s3-website-us-east-1.amazonaws.com/external/report.html?report=report-panel-county-muni